# Radium-226

## Case Narrative

---

# Tidewater, Inc.

## Phase 1 RI OU2 Great Kills Park – 2016-007

Work Order Number: 1811039

1. This report consists of the analytical results and supporting documentation for nine water samples received by ALS on 11/02/2018.

2. These samples were prepared and analyzed according to the current revision of SOP 783. The analyses were completed on 12/06/2018.

3. The analysis results for these samples are reported in units of pCi/L. Dissolved samples were field filtered prior to receipt at ALS. The other samples were not filtered prior to analysis.

4. Sample volume was insufficient to allow preparation of a duplicate. A laboratory control sample duplicate (LCSD) was prepared in lieu of a client sample duplicate.

5. ALS uses the following convention for reporting significant digits in the TPU and MDC results. The TPU value is rounded to two significant digits. The MDC value is rounded to the same decimal place as the TPU value. In practice, this could result in an MDC reported value of zero for samples with significant activity, including the batch laboratory control sample.

6. No anomalous situations were encountered during the preparation or analysis of these samples. All quality control criteria were met.

The data contained in the following report have been reviewed and approved by the personnel listed below. In addition, ALS certifies that the analyses reported herein are true, complete and correct within the limits of the methods employed.

Pik Yee Yuen — 12/12/18

Pik Yee Yuen — Date

Radiochemistry Primary Data Reviewer

12/18/18

Radiochemistry Final Data Reviewer — Date

1

Section 1

# CHAIN OF CUSTODY

# ALS -- Fort Collins

## Sample Number(s) Cross-Reference Table

**OrderNum:** 1811039
**Client Name:** Tidewater, Inc.
**Client Project Name:** Phase 1 RI OU2 Great Kills Park
**Client Project Number:** 2016-007
**Client PO Number:**

| Client Sample Number | Lab Sample Number | COC Number | Matrix | Date Collected | Time Collected |
|---|---|---|---|---|---|
| OU2-1-MW010 | 1811039-1 | | WATER | 29-Oct-18 | 15:40 |
| OU2-1-MW010-F | 1811039-2 | | WATER | 29-Oct-18 | 15:40 |
| OU2-1-MW008WT | 1811039-3 | | WATER | 31-Oct-18 | 12:10 |
| OU2-1-MW008WT-DUP | 1811039-4 | | WATER | 31-Oct-18 | 12:10 |
| OU2-1-MW008WT-F | 1811039-5 | | WATER | 31-Oct-18 | 12:10 |
| OU2-1-MW008WT-F-DUP | 1811039-6 | | WATER | 31-Oct-18 | 12:10 |
| OU2-1-MW009WT | 1811039-7 | | WATER | 31-Oct-18 | 16:55 |
| OU2-1-MW009WT-F | 1811039-8 | | WATER | 31-Oct-18 | 16:55 |
| OU2IDWSOIL110118-001 | 1811039-9 | | SOIL | 01-Nov-18 | 10:00 |
| OU2IDWWATER110118-001 | 1811039-10 | | WATER | 01-Nov-18 | 9:40 |

# ALS Environmental

225 Commerce Drive, Fort Collins, Colorado 80524
TF: (800) 443-1511 PH: (970) 490-1511 FX: (970) 490-1522

## Chain-of-Custody

Form 202r8

WORKORDER # 1811039

PAGE 1 of 1

DISPOSAL By Lab or Return to Client

| | | | |
|---|---|---|---|
| PROJECT NAME | GKP Phase I RI OU2 | SAMPLER | John C Schroeder |
| PROJECT No. | 2016-007 | SITE ID | |
| | | EDD FORMAT | contact Ryan Wensink |
| | | PURCHASE ORDER | |
| COMPANY NAME | Tidewater | BILL TO COMPANY | Tidewater |
| SEND REPORT TO | Ryan Wensink (Tidewater) | INVOICE ATTN TO | Ryan Wensink |
| ADDRESS | Devon Chicoine (AECOM) | ADDRESS | 3761 Attucks Drive |
| CITY / STATE / ZIP | devon.chicoine@aecom.com | CITY / STATE / ZIP | Powell, OH 43065 |
| PHONE | 703-966-5484 | PHONE | 614-389-6251 |
| FAX | Colleen Scott (AECOM) | FAX | |
| E-MAIL | colleen.scott@aecom.com | E-MAIL | ryan.wensink@tidah2o.net |

DATE 10/31/18

TURNAROUND

| Lab ID | Field ID | Matrix | Sample Date | Sample Time | # Bottles | Pres. | QC | Radium-226/228 (EPA 903/904) | Gross Alpha & Beta (EPA 900) | Total Uranium (EPA 200.8) | Uranium-238 | Radium-226 | Thorium-232 (EPA 901.1) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | OU2-1-MW010 | ground water | 102918 | 1540 | 5 | $HNO_3$ | | X | X | X | | | | | | | | | | | | | | | | | |
| 2 | OU2-1-MW010-F | ground water | 102918 | 1540 | 5 | $HNO_3$ | | X | X | X | | | | | | | field filtered | | | | | | | | | | |
| 3 | OU2-1-MW008WT | ground water | 103118 | 1210 | 5 | $HNO_3$ | | X | X | X | | | | | | | | | | | | | | | | | |
| 4 | OU2-1-MW008WT-DUP | ground water | 103118 | 1210 | 5 | $HNO_3$ | dupl. wtr | X | X | X | | | | | | | | | | | | | | | | | |
| 5 | OU2-1-MW008WT-F | ground water | 103118 | 1210 | 5 | $HNO_3$ | | X | X | X | | | | | | | field filtered | | | | | | | | | | |
| 6 | OU2-1-MW008WT-F-DUP | ground water | 103118 | 1210 | 5 | $HNO_3$ | dupl. wtr | X | X | X | | | | | | | field filtered | | | | | | | | | | |
| 7 | OU2-1-MW009WT | ground water | 103118 | 1655 | 5 | $HNO_3$ | | X | X | X | | | | | | | | | | | | | | | | | |
| 8 | OU2-1-MW009WT-F | ground water | 103118 | 1655 | 5 | $HNO_3$ | | X | X | X | | | | | | | field filtered | | | | | | | | | | |
| 9 | OU2IDWSOIL110118-001 | soil | 110118 | 1000 | 1 | – | | | | | X | X | X | | | | IDW sample | | | | | | | | | | |
| 10 | OU2IDWWATER110118-001 | IDW water | 110118 | 0940 | 5 | $HNO_3$ | | X | X | X | | | | | | | IDW sample | | | | | | | | | | |

*Time Zone (Circle): EST CST MST PST Matrix: O = oil S = soil NS = non-soil solid W = water L = liquid E = extract F = filter

For metals or anions, please detail analytes below.

Comments:

| QC PACKAGE (check below) | |
|---|---|
| | LEVEL II (Standard QC) |
| | LEVEL III (Std QC + forms) |
| | LEVEL IV (Std QC + forms + raw data) |
| | |

Preservative Key: 1-HCl 2-HNO3 3-H2SO4 4-NaOH 5-NaHSO4 7-Other 8-4 degrees C 9-5035

| | SIGNATURE | PRINTED NAME | DATE | TIME |
|---|---|---|---|---|
| RELINQUISHED BY | [signature] | John C Schroeder | 110118 | 1700 |
| RECEIVED BY | Fed Ex | Fed Ex | 110118 | 1700 |
| RELINQUISHED BY | FEDEX | FEDEX | 11.2.18 | 0954 |
| RECEIVED BY | [signature] | KELI-JEAN SMITH | 11.2.18 | 0954 |
| RELINQUISHED BY | | | | |
| RECEIVED BY | | | | |

**ALS Environmental - Fort Collins**
**CONDITION OF SAMPLE UPON RECEIPT FORM**

Client: TIDEWATER  Workorder No: 1811039

Project Manager: LRS  Initials: KZ  Date: 11.2.18

| | | | | |
|---|---|---|---|---|
| 1. | Are airbills / shipping documents present and/or removable? | DROP OFF | YES | NO |
| 2. | Are custody seals on **shipping** containers intact? | NONE | YES | NO |
| 3. | Are custody seals on **sample** containers intact? | NONE | YES | NO |
| 4. | Is there a COC (chain-of-custody) present? | | YES | NO |
| 5. | Is the COC in agreement with samples received? (IDs, dates, times, # of samples, # of containers, matrix, requested analyses, etc.) | | YES | NO |
| 6. | Are short-hold samples present? | | YES | NO |
| 7. | Are all samples within holding times for the requested analyses? | | YES | NO |
| 8. | Were all sample containers received intact? (not broken or leaking) | | YES | NO |
| 9. | Is there sufficient sample for the requested analyses? | | YES | NO |
| 10. | Are all samples in the proper containers for the requested analyses? | | YES | NO |
| 11. | Are all aqueous samples preserved correctly, if required? (excluding volatiles) | N/A | YES | NO |
| 12. | Are all aqueous non-preserved samples pH 4-9? | N/A | YES | NO |
| 13. | Are all samples requiring no headspace (VOC, GRO, RSK/MEE, Rx CN/S, radon) free of bubbles > 6 mm (1/4 inch) diameter? (i.e. size of green pea) | N/A | YES | NO |
| 14. | Were the samples shipped on ice? | | YES | NO |
| 15. | Were cooler temperatures measured at 0.1-6.0°C? IR gun used*: #1 #3 #4 | RAD ONLY | YES | NO |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Cooler #: | 1 | 2 | | | | | | |
| Temperature (°C): | AMB | AMB | | | | | | |
| No. of custody seals on cooler: | 2 | 2 | | | | | | |
| DOT Survey/ Acceptance Information — External µR/hr reading: | 9 | 9 | | | | | | |
| DOT Survey/ Acceptance Information — Background µR/hr reading: | 10 | | | | | | | |

Were external µR/hr readings ≤ two times background and within DOT acceptance criteria? YES / NO / NA (If no, see Form 008.)

**Additional Information:** **Please provide details here for any NO responses to gray-shaded boxes above, or any other issues noted:**

11) Sample 4 bottle 5 initial pH 6 - added 1ml
Sample 5 all 3 bottles initial pH 4 - added 0.5ml
Sample 6 bottle 5 initial pH 5 - added 0.5ml
} HNO3 lot 193289 to acheive pH<2.

All client bottle ID's vs ALS lab ID's double-checked by: KZ

If applicable, was the client contacted? YES / NO / NA Contact: Ryan W. Date/Time: 11/2

**Project Manager Signature / Date:** 11/2/18

Form 201r26.xls
(06/29/2018)

*IR Gun #1, VWR SN 170560549
*IR Gun #3, VWR SN 170647571
*IR Gun #4, Oakton, SN 2372220101-0002

1811039

# Do Not Lift Using This Tag

ORIGIN ID:LDJA (614) 389-6251
RYAN WENSINK
TIDEWATER
6625 SELNICK DR
STE A
ELKRIDGE, MD 21075
UNITED STATES US

SHIP DATE: 01NOV18
ACTWGT: 58.10 LB
CAD: 6991560/SSF01922
DIMS: 23x13x13 IN

BILL THIRD PARTY

TO SAMPLE RECIEVING
ALS ENVIRONMENTAL
225 COMMERCE DRIVE

9-2

FORT COLLINS CO 80524
(800) 443-1511
INV:
PO: REF:
DEPT:

FedEx Express

TRK# 0201 7835 5379 7932

FRI - 02 NOV 10:30A
PRIORITY OVERNIGHT
AHS
80524
CO-US DEN

NA FTCA

RI 617
ST 12
5
10:30 A
7932
11.02

# Do Not Lift Using This Tag

ORIGIN ID:LDJA (614) 389-6251
RYAN WENSINK
TIDEWATER
6625 SELNICK DR
STE A
ELKRIDGE, MD 21075
UNITED STATES US

RI 617
ST 12
5
10:30 A
4470
11.02

TO SAMPLE RECIEVING
ALS ENVIRONMENTAL
225 COMMERCE DRIVE

9-2

FORT COLLINS CO 80524
(800) 443-1511
INV:
PO: REF:
DEPT:

FedEx Express

TRK# 0201 7835 5383 4470

FRI - 02 NOV 10:30A
PRIORITY OVERNIGHT
AHS
80524
CO-US DEN

NA FTCA

Section 2

# SAMPLE RESULTS SUMMARY

# Radium-226 by Radon Emanation - Method 903.1 Sample Results Summary

**Client Name:** Tidewater, Inc.
**Client Project Name:** Phase 1 RI OU2 Great Kills Park
**Client Project Number:** 2016-007
**Laboratory Name:** **ALS -- Fort Collins**
**PAI Work Order:** 1811039


**Reported on:** Monday, December 17, 2018
1:40:26 PM

| Lab Sample ID | Client Sample ID | Sample Type | Nuclide | Result +/- 2 s TPU | MDC | DL | Units | Matrix | Prep Batch | Date Analyze | Flags |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1811039-1 | OU2-1-MW010 | Sample | Ra-226 | 0.71 +/- 0.36 | 0.24 | NA | pCi/l | WATER | RE181126-1 | 12/6/2018 | LT |
| 1811039-2 | OU2-1-MW010-F | Sample | Ra-226 | 1.62 +/- 0.63 | 0.26 | NA | pCi/l | WATER | RE181126-1 | 12/6/2018 | |
| 1811039-3 | OU2-1-MW008WT | Sample | Ra-226 | 3.3 +/- 1.1 | 0.3 | NA | pCi/l | WATER | RE181126-1 | 12/6/2018 | |
| 1811039-4 | OU2-1-MW008WT-DUP | Sample | Ra-226 | 3.4 +/- 1.0 | 0.2 | NA | pCi/l | WATER | RE181126-1 | 12/6/2018 | |
| 1811039-5 | OU2-1-MW008WT-F | Sample | Ra-226 | 4.9 +/- 1.4 | 0.4 | NA | pCi/l | WATER | RE181126-1 | 12/6/2018 | |
| 1811039-6 | OU2-1-MW008WT-F-DUP | Sample | Ra-226 | 3.6 +/- 1.1 | 0.4 | NA | pCi/l | WATER | RE181126-1 | 12/6/2018 | |
| 1811039-7 | OU2-1-MW009WT | Sample | Ra-226 | 1.04 +/- 0.49 | 0.40 | NA | pCi/l | WATER | RE181126-1 | 12/6/2018 | |
| 1811039-8 | OU2-1-MW009WT-F | Sample | Ra-226 | 0.03 +/- 0.19 | 0.38 | NA | pCi/l | WATER | RE181126-1 | 12/6/2018 | U |
| 1811039-10 | OU2IDWWATER110118-001 | Sample | Ra-226 | 4.5 +/- 1.3 | 0.3 | NA | pCi/l | WATER | RE181126-1 | 12/6/2018 | |

**Comments:**

**Data Package ID:** *RE1811039-1*

**Qualifiers/Flags:**

U - Result is less than the sample specific MDC.

LT - Result is less than Requested MDC, greater than sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

M - The requested MDC was not met.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Sample specific Minimum Detectable Concentration

BDL - Below Detection Limit

Section 3

# QC RESULTS SUMMARY ❸

# Radium-226 by Radon Emanation - Method 903.1

## PAI 783 Rev 13

## Method Blank Results

**Lab Name:** **ALS -- Fort Collins**
**Work Order Number:** 1811039
**Client Name:** Tidewater, Inc.
**ClientProject ID:** Phase 1 RI OU2 Great Kills Park 2016-007

**Lab ID:** RE181126-1MB

**Sample Matrix:** WATER
**Prep SOP:** PAI 783 Rev 13
**Date Collected:** 26-Nov-18
**Date Prepared:** 26-Nov-18
**Date Analyzed:** 06-Dec-18

**Prep Batch:** RE181126-1
**QCBatchID:** RE181126-1-2
**Run ID:** RE181126-1A
**Count Time:** 15 minutes

**Final Aliquot:** 995 ml
**Result Units:** pCi/l
**File Name:** Manual Entry

| CASNO | Target Nuclide | Result +/- 2 s TPU | MDC | Requested MDC | DL | Lab Qualifier |
|---|---|---|---|---|---|---|
| 13982-63-3 | Ra-226 | 0.07 +/- 0.16 | 0.28 | 1 | NA | U |

## Chemical Yield Summary

| Carrier/Tracer | Amount Added | Result | Units | Yield | Control Limits | Flag |
|---|---|---|---|---|---|---|
| BARIUM | 18010 | 16780 | ug | 93.1 | 40 - 110 % | |

**Comments:**

**Qualifiers/Flags:**
U - Result is less than the sample specific MDC.
Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.
Y2 - Chemical Yield outside default limits.

Abbreviations:
TPU - Total Propagated Uncertainty
MDC - Sample specific Minimum Detectable Concentration
BDL - Below Detection Limit

M - Requested MDC not met.
B - Analyte concentration greater than MDC.
B3 - Analyte concentration greater than MDC but less than Requested MDC.
DL - Decision Level

**Data Package ID:** *RE1811039-1*

# Radium-226 by Radon Emanation - Method 903.1

## PAI 783 Rev 13

## Laboratory Control Sample(s)

**Lab Name:** ALS -- Fort Collins
**Work Order Number:** 1811039
**Client Name:** Tidewater, Inc.
**ClientProject ID:** Phase 1 RI OU2 Great Kills Park 2016-007

**Lab ID:** RE181126-1LCS

**Sample Matrix:** WATER
**Prep SOP:** PAI 783 Rev 13
**Date Collected:** 26-Nov-18
**Date Prepared:** 26-Nov-18
**Date Analyzed:** 06-Dec-18

**Prep Batch:** RE181126-1
**QCBatchID:** RE181126-1-2
**Run ID:** RE181126-1A
**Count Time:** 15 minutes

**Final Aliquot:** 995 ml
**Result Units:** pCi/l
**File Name:** Manual Entry

| CASNO | Target Nuclide | Results +/- 2s TPU | MDC | Spike Added | % Rec | Control Limits | Lab Qualifier |
|---|---|---|---|---|---|---|---|
| 13982-63-3 | Ra-226 | 50 +/- 13 | 0 | 47.87 | 105 | 67 - 120 | P |

## Chemical Yield Summary

| Carrier/Tracer | Amount Added | Result | Units | Yield | Control Limits | Flag |
|---|---|---|---|---|---|---|
| BARIUM | 18010 | 15710 | ug | 87.2 | 40 - 110 % | |

### Comments:

**Qualifiers/Flags:**

U - Result is less than the sample specific MDC.
Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.
Y2 - Chemical Yield outside default limits.
L - LCS Recovery below lower control limit.
H - LCS Recovery above upper control limit.
P - LCS Recovery within control limits.
M - The requested MDC was not met.
M3 - The requested MDC was not met, but thereported activity is greater than the reported MDC.

Abbreviations:

TPU - Total Propagated Uncertainty
MDC - Minimum Detectable Concentration

**Data Package ID:** *RE1811039-1*

# Radium-226 by Radon Emanation - Method 903.1

## PAI 783 Rev 13

## Laboratory Control Sample(s)

**Lab Name:** **ALS -- Fort Collins**
**Work Order Number:** 1811039
**Client Name:** Tidewater, Inc.
**ClientProject ID:** Phase 1 RI OU2 Great Kills Park 2016-007

**Lab ID:** RE181126-1LCSD

**Sample Matrix:** WATER
**Prep SOP:** PAI 783 Rev 13
**Date Collected:** 26-Nov-18
**Date Prepared:** 26-Nov-18
**Date Analyzed:** 06-Dec-18

**Prep Batch:** RE181126-1
**QCBatchID:** RE181126-1-2
**Run ID:** RE181126-1A
**Count Time:** 15 minutes

**Final Aliquot:** 995 ml
**Result Units:** pCi/l
**File Name:** Manual Entry

| CASNO | Target Nuclide | Results +/- 2s TPU | MDC | Spike Added | % Rec | Control Limits | Lab Qualifier |
|---|---|---|---|---|---|---|---|
| 13982-63-3 | Ra-226 | 53 +/- 13 | 0 | 47.87 | 110 | 67 - 120 | P |

## Chemical Yield Summary

| Carrier/Tracer | Amount Added | Result | Units | Yield | Control Limits | Flag |
|---|---|---|---|---|---|---|
| BARIUM | 18010 | 15620 | ug | 86.7 | 40 - 110 % | |

### Comments:

**Qualifiers/Flags:**

U - Result is less than the sample specific MDC.
Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.
Y2 - Chemical Yield outside default limits.
L - LCS Recovery below lower control limit.
H - LCS Recovery above upper control limit.
P - LCS Recovery within control limits.
M - The requested MDC was not met.
M3 - The requested MDC was not met, but thereported activity is greater than the reported MDC.

Abbreviations:

TPU - Total Propagated Uncertainty
MDC - Minimum Detectable Concentration

**Data Package ID:** *RE1811039-1*

# Radium-226 by Radon Emanation - Method 903.1

## PAI 783 Rev 13

## Duplicate Sample Results (DER)

**Lab Name:** **ALS -- Fort Collins**
**Work Order Number:** 1811039
**Client Name:** Tidewater, Inc.
**ClientProject ID:** Phase 1 RI OU2 Great Kills Park 2016-007

**Field ID:**
**Lab ID:** RE181126-1LCSD

**Sample Matrix:** WATER
**Prep SOP:** PAI 783 Rev 13
**Date Collected:** 26-Nov-18
**Date Prepared:** 26-Nov-18
**Date Analyzed:** 06-Dec-18

**Prep Batch:** RE181126-1
**QCBatchID:** RE181126-1-2
**Run ID:** RE181126-1A
**Count Time:** 15 minutes

**Final Aliquot:** 995 ml
**Prep Basis:** Unfiltered
**Moisture(%):** NA
**Result Units:** pCi/l
**File Name:** Manual Entry

| CASNO | Analyte | Sample | | | Duplicate | | | DER | DER Lim |
|---|---|---|---|---|---|---|---|---|---|
| | | Result +/- 2 s TPU | MDC | Flags | Result +/- 2 s TPU | MDC | Flags | | |
| 13982-63-3 | Ra-226 | 50 +/- 13 | 0 | P | 53 +/- 13 | 0 | P | 0.13 | 2.13 |

### Comments:

**Duplicate Qualifiers/Flags:**

U - Result is less than the sample specific MDC.
Y1 - Chemical Yield is in control at 100-110%. Quantitative yield is assumed.
Y2 - Chemical Yield outside default limits.
W - DER is greater than Warning Limit of 1.42
D - DER is greater than Control Limit of 2.13
LT - Result is less than Request MDC, greater than sample specific MDC
M - Requested MDC not met.
M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.
L - LCS Recovery below lower control limit.
H - LCS Recovery above upper control limit.
P - LCS, Matrix Spike Recovery within control limits.
N - Matrix Spike Recovery outside control limits

Abbreviations:

TPU - Total Propagated Uncertainty
DER - Duplicate Error Ratio
BDL - Below Detection Limit
NR - Not Reported

**Data Package ID:** *RE1811039-1*

Section 4

# INDIVIDUAL SAMPLE RESULTS

4

# Radium-226 by Radon Emanation - Method 903.1

## PAI 783 Rev 13

## Sample Results

**Lab Name:** **ALS -- Fort Collins**
**Work Order Number:** 1811039
**Client Name:** Tidewater, Inc.
**ClientProject ID:** Phase 1 RI OU2 Great Kills Park 2016-007

**Field ID:** OU2-1-MW010
**Lab ID:** 1811039-1

**Sample Matrix:** WATER
**Prep SOP:** PAI 783 Rev 13
**Date Collected:** 29-Oct-18
**Date Prepared:** 26-Nov-18
**Date Analyzed:** 06-Dec-18

**Prep Batch:** RE181126-1
**QCBatchID:** RE181126-1-2
**Run ID:** RE181126-1A
**Count Time:** 15 minutes
**Report Basis:** Unfiltered

**Final Aliquot:** 876 ml
**Prep Basis:** Unfiltered
**Moisture(%):** NA
**Result Units:** pCi/l
**File Name:** Manual Entry

| CASNO | Target Nuclide | Result +/- 2 s TPU | MDC | Requested MDC | DL | Lab Qualifier |
|---|---|---|---|---|---|---|
| 13982-63-3 | Ra-226 | 0.71 +/- 0.36 | 0.24 | 1 | NA | LT |

## Chemical Yield Summary

| Carrier/Tracer | Amount Added | Result | Units | Yield | Control Limits | Flag |
|---|---|---|---|---|---|---|
| BARIUM | 18720 | 16120 | ug | 86.1 | 40 - 110 % | |

### Comments:

**Qualifiers/Flags:**

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

M - The requested MDC was not met.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Sample specific Minimum Detectable Concentration

BDL - Below Detection Limit

DL - Decision Level

**Data Package ID:** *RE1811039-1*

# Dissolved Radium-226 by Radon Emanation - Method 903.1

## PAI 783 Rev 13

## Sample Results

**Lab Name:** ALS -- Fort Collins
**Work Order Number:** 1811039
**Client Name:** Tidewater, Inc.
**ClientProject ID:** Phase 1 RI OU2 Great Kills Park 2016-007

**Field ID:** OU2-1-MW010-F
**Lab ID:** 1811039-2

**Sample Matrix:** WATER
**Prep SOP:** PAI 783 Rev 13
**Date Collected:** 29-Oct-18
**Date Prepared:** 26-Nov-18
**Date Analyzed:** 06-Dec-18

**Prep Batch:** RE181126-1
**QCBatchID:** RE181126-1-2
**Run ID:** RE181126-1A
**Count Time:** 15 minutes
**Report Basis:** Unfiltered

**Final Aliquot:** 915 ml
**Prep Basis:** Unfiltered
**Moisture(%):** NA
**Result Units:** pCi/l
**File Name:** Manual Entry

| CASNO | Target Nuclide | Result +/- 2 s TPU | MDC | Requested MDC | DL | Lab Qualifier |
|---|---|---|---|---|---|---|
| 13982-63-3 | Ra-226 | 1.62 +/- 0.63 | 0.26 | 1 | NA | |

## Chemical Yield Summary

| Carrier/Tracer | Amount Added | Result | Units | Yield | Control Limits | Flag |
|---|---|---|---|---|---|---|
| BARIUM | 18830 | 15970 | ug | 84.8 | 40 - 110 % | |

### Comments:

**Qualifiers/Flags:**

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

M - The requested MDC was not met.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Sample specific Minimum Detectable Concentration

BDL - Below Detection Limit

DL - Decision Level

**Data Package ID:** *RE1811039-1*

# Radium-226 by Radon Emanation - Method 903.1

## PAI 783 Rev 13

## Sample Results

**Lab Name:** **ALS -- Fort Collins**
**Work Order Number:** 1811039
**Client Name:** Tidewater, Inc.
**ClientProject ID:** Phase 1 RI OU2 Great Kills Park 2016-007

**Field ID:** OU2-1-MW008WT
**Lab ID:** 1811039-3

**Sample Matrix:** WATER
**Prep SOP:** PAI 783 Rev 13
**Date Collected:** 31-Oct-18
**Date Prepared:** 26-Nov-18
**Date Analyzed:** 06-Dec-18

**Prep Batch:** RE181126-1
**QCBatchID:** RE181126-1-2
**Run ID:** RE181126-1A
**Count Time:** 15 minutes
**Report Basis:** Unfiltered

**Final Aliquot:** 935 ml
**Prep Basis:** Unfiltered
**Moisture(%):** NA
**Result Units:** pCi/l
**File Name:** Manual Entry

| CASNO | Target Nuclide | Result +/- 2 s TPU | MDC | Requested MDC | DL | Lab Qualifier |
|---|---|---|---|---|---|---|
| 13982-63-3 | Ra-226 | 3.3 +/- 1.1 | 0.3 | 1 | NA | |

## Chemical Yield Summary

| Carrier/Tracer | Amount Added | Result | Units | Yield | Control Limits | Flag |
|---|---|---|---|---|---|---|
| BARIUM | 19860 | 17220 | ug | 86.7 | 40 - 110 % | |

### Comments:

**Qualifiers/Flags:**

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

M - The requested MDC was not met.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Sample specific Minimum Detectable Concentration

BDL - Below Detection Limit

DL - Decision Level

**Data Package ID:** *RE1811039-1*

# Radium-226 by Radon Emanation - Method 903.1

## PAI 783 Rev 13

## Sample Results

**Lab Name:** **ALS -- Fort Collins**
**Work Order Number:** 1811039
**Client Name:** Tidewater, Inc.
**ClientProject ID:** Phase 1 RI OU2 Great Kills Park 2016-007

**Field ID:** OU2-1-MW008WT-DUP
**Lab ID:** 1811039-4

**Sample Matrix:** WATER
**Prep SOP:** PAI 783 Rev 13
**Date Collected:** 31-Oct-18
**Date Prepared:** 26-Nov-18
**Date Analyzed:** 06-Dec-18

**Prep Batch:** RE181126-1
**QCBatchID:** RE181126-1-2
**Run ID:** RE181126-1A
**Count Time:** 15 minutes
**Report Basis:** Unfiltered

**Final Aliquot:** 995 ml
**Prep Basis:** Unfiltered
**Moisture(%):** NA
**Result Units:** pCi/l
**File Name:** Manual Entry

| CASNO | Target Nuclide | Result +/- 2 s TPU | MDC | Requested MDC | DL | Lab Qualifier |
|---|---|---|---|---|---|---|
| 13982-63-3 | Ra-226 | 3.4 +/- 1.0 | 0.2 | 1 | NA | |

## Chemical Yield Summary

| Carrier/Tracer | Amount Added | Result | Units | Yield | Control Limits | Flag |
|---|---|---|---|---|---|---|
| BARIUM | 19730 | 16930 | ug | 85.8 | 40 - 110 % | |

### Comments:

**Qualifiers/Flags:**

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

M - The requested MDC was not met.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Sample specific Minimum Detectable Concentration

BDL - Below Detection Limit

DL - Decision Level

**Data Package ID:** *RE1811039-1*

# Dissolved Radium-226 by Radon Emanation - Method 903.1

## PAI 783 Rev 13

## Sample Results

**Lab Name:** ALS -- Fort Collins
**Work Order Number:** 1811039
**Client Name:** Tidewater, Inc.
**ClientProject ID:** Phase 1 RI OU2 Great Kills Park 2016-007

**Field ID:** OU2-1-MW008WT-F
**Lab ID:** 1811039-5

**Sample Matrix:** WATER
**Prep SOP:** PAI 783 Rev 13
**Date Collected:** 31-Oct-18
**Date Prepared:** 26-Nov-18
**Date Analyzed:** 06-Dec-18

**Prep Batch:** RE181126-1
**QCBatchID:** RE181126-1-2
**Run ID:** RE181126-1A
**Count Time:** 15 minutes
**Report Basis:** Unfiltered

**Final Aliquot:** 995 ml
**Prep Basis:** Unfiltered
**Moisture(%):** NA
**Result Units:** pCi/l
**File Name:** Manual Entry

| CASNO | Target Nuclide | Result +/- 2 s TPU | MDC | Requested MDC | DL | Lab Qualifier |
|---|---|---|---|---|---|---|
| 13982-63-3 | Ra-226 | 4.9 +/- 1.4 | 0.4 | 1 | NA | |

## Chemical Yield Summary

| Carrier/Tracer | Amount Added | Result | Units | Yield | Control Limits | Flag |
|---|---|---|---|---|---|---|
| BARIUM | 19790 | 16870 | ug | 85.3 | 40 - 110 % | |

### Comments:

**Qualifiers/Flags:**

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

M - The requested MDC was not met.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Sample specific Minimum Detectable Concentration

BDL - Below Detection Limit

DL - Decision Level

**Data Package ID:** *RE1811039-1*

# Dissolved Radium-226 by Radon Emanation - Method 903.1

## PAI 783 Rev 13

## Sample Results

**Lab Name:** ALS -- Fort Collins
**Work Order Number:** 1811039
**Client Name:** Tidewater, Inc.
**ClientProject ID:** Phase 1 RI OU2 Great Kills Park 2016-007

**Field ID:** OU2-1-MW008WT-F-DUP
**Lab ID:** 1811039-6

**Sample Matrix:** WATER
**Prep SOP:** PAI 783 Rev 13
**Date Collected:** 31-Oct-18
**Date Prepared:** 26-Nov-18
**Date Analyzed:** 06-Dec-18

**Prep Batch:** RE181126-1
**QCBatchID:** RE181126-1-2
**Run ID:** RE181126-1A
**Count Time:** 15 minutes
**Report Basis:** Unfiltered

**Final Aliquot:** 995 ml
**Prep Basis:** Unfiltered
**Moisture(%):** NA
**Result Units:** pCi/l
**File Name:** Manual Entry

| CASNO | Target Nuclide | Result +/- 2 s TPU | MDC | Requested MDC | DL | Lab Qualifier |
|---|---|---|---|---|---|---|
| 13982-63-3 | Ra-226 | 3.6 +/- 1.1 | 0.4 | 1 | NA | |

## Chemical Yield Summary

| Carrier/Tracer | Amount Added | Result | Units | Yield | Control Limits | Flag |
|---|---|---|---|---|---|---|
| BARIUM | 19850 | 17250 | ug | 86.9 | 40 - 110 % | |

### Comments:

**Qualifiers/Flags:**

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

M - The requested MDC was not met.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Sample specific Minimum Detectable Concentration

BDL - Below Detection Limit

DL - Decision Level

**Data Package ID:** *RE1811039-1*

# Radium-226 by Radon Emanation - Method 903.1

## PAI 783 Rev 13

## Sample Results

**Lab Name:** **ALS -- Fort Collins**
**Work Order Number:** 1811039
**Client Name:** Tidewater, Inc.
**ClientProject ID:** Phase 1 RI OU2 Great Kills Park 2016-007

**Field ID:** OU2-1-MW009WT
**Lab ID:** 1811039-7

**Sample Matrix:** WATER
**Prep SOP:** PAI 783 Rev 13
**Date Collected:** 31-Oct-18
**Date Prepared:** 26-Nov-18
**Date Analyzed:** 06-Dec-18

**Prep Batch:** RE181126-1
**QCBatchID:** RE181126-1-2
**Run ID:** RE181126-1A
**Count Time:** 15 minutes
**Report Basis:** Unfiltered

**Final Aliquot:** 826 ml
**Prep Basis:** Unfiltered
**Moisture(%):** NA
**Result Units:** pCi/l
**File Name:** Manual Entry

| CASNO | Target Nuclide | Result +/- 2 s TPU | MDC | Requested MDC | DL | Lab Qualifier |
|---|---|---|---|---|---|---|
| 13982-63-3 | Ra-226 | 1.04 +/- 0.49 | 0.40 | 1 | NA | |

## Chemical Yield Summary

| Carrier/Tracer | Amount Added | Result | Units | Yield | Control Limits | Flag |
|---|---|---|---|---|---|---|
| BARIUM | 18080 | 15800 | ug | 87.4 | 40 - 110 % | |

### Comments:

**Qualifiers/Flags:**

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

M - The requested MDC was not met.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Sample specific Minimum Detectable Concentration

BDL - Below Detection Limit

DL - Decision Level

**Data Package ID:** *RE1811039-1*

# Dissolved Radium-226 by Radon Emanation - Method 903.1

## PAI 783 Rev 13

## Sample Results

**Lab Name:** ALS -- Fort Collins
**Work Order Number:** 1811039
**Client Name:** Tidewater, Inc.
**ClientProject ID:** Phase 1 RI OU2 Great Kills Park 2016-007

**Field ID:** OU2-1-MW009WT-F
**Lab ID:** 1811039-8

**Sample Matrix:** WATER
**Prep SOP:** PAI 783 Rev 13
**Date Collected:** 31-Oct-18
**Date Prepared:** 26-Nov-18
**Date Analyzed:** 06-Dec-18

**Prep Batch:** RE181126-1
**QCBatchID:** RE181126-1-2
**Run ID:** RE181126-1A
**Count Time:** 15 minutes
**Report Basis:** Unfiltered

**Final Aliquot:** 995 ml
**Prep Basis:** Unfiltered
**Moisture(%):** NA
**Result Units:** pCi/l
**File Name:** Manual Entry

| CASNO | Target Nuclide | Result +/- 2 s TPU | MDC | Requested MDC | DL | Lab Qualifier |
|---|---|---|---|---|---|---|
| 13982-63-3 | Ra-226 | 0.03 +/- 0.19 | 0.38 | 1 | NA | U |

## Chemical Yield Summary

| Carrier/Tracer | Amount Added | Result | Units | Yield | Control Limits | Flag |
|---|---|---|---|---|---|---|
| BARIUM | 18180 | 15700 | ug | 86.4 | 40 - 110 % | |

### Comments:

**Qualifiers/Flags:**

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

M - The requested MDC was not met.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Sample specific Minimum Detectable Concentration

BDL - Below Detection Limit

DL - Decision Level

**Data Package ID:** *RE1811039-1*

# Radium-226 by Radon Emanation - Method 903.1

## PAI 783 Rev 13

## Sample Results

**Lab Name:** **ALS -- Fort Collins**
**Work Order Number:** 1811039
**Client Name:** Tidewater, Inc.
**ClientProject ID:** Phase 1 RI OU2 Great Kills Park 2016-007

**Field ID:** OU2IDWWATER110118-0
**Lab ID:** 1811039-10

**Sample Matrix:** WATER
**Prep SOP:** PAI 783 Rev 13
**Date Collected:** 01-Nov-18
**Date Prepared:** 26-Nov-18
**Date Analyzed:** 06-Dec-18

**Prep Batch:** RE181126-1
**QCBatchID:** RE181126-1-2
**Run ID:** RE181126-1A
**Count Time:** 15 minutes
**Report Basis:** Unfiltered

**Final Aliquot:** 995 ml
**Prep Basis:** Unfiltered
**Moisture(%):** NA
**Result Units:** pCi/l
**File Name:** Manual Entry

| CASNO | Target Nuclide | Result +/- 2 s TPU | MDC | Requested MDC | DL | Lab Qualifier |
|---|---|---|---|---|---|---|
| 13982-63-3 | Ra-226 | 4.5 +/- 1.3 | 0.3 | 1 | NA | |

## Chemical Yield Summary

| Carrier/Tracer | Amount Added | Result | Units | Yield | Control Limits | Flag |
|---|---|---|---|---|---|---|
| BARIUM | 19380 | 15670 | ug | 80.9 | 40 - 110 % | |

### Comments:

**Qualifiers/Flags:**

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

M - The requested MDC was not met.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Sample specific Minimum Detectable Concentration

BDL - Below Detection Limit

DL - Decision Level

**Data Package ID:** *RE1811039-1*

Section 5

# RAW DATA

5

# Radium-226 by Radon Emanation - Method 903.1 Raw Data Report

**Laboratory Name:** ALS -- Fort Collins
**PAI Work Order:** 1811039

**Prep SOP:** PAI 783
**Analytical SOP:** PAI 783

**Reported on:** Thursday, December 06, 2018
1:39:12 PM

| Sample ID<br>QC Type | Nuclide<br>Type | Sample<br>Date/Time | Prep Batch<br>QCBatchID | Ingrowth<br>Date /Time | Decay<br>Date/Time | Matrix<br>%Moist. | Samp Alq<br>Analy Alq | Inst ID<br>Det ID | AnRunID<br>File Name | Count<br>Date/Time | Gr Cnts<br>Bkg Cnts | BaseEff<br>ProgEff | CntDur(min)<br>Yield | Activity +/-<br>2 s TPU | MDC<br>DecLev | ReportUnits<br>ReportBasis | DER<br>RPD | %Spk. Recov<br>Flags |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1811039-1 | Ra-226 | 10/29/2018 | RE181126-1 | 11/27/2018 | 12/06/2018 | WATER | 880 ml | Alpha Scin | RE181126-1A | 12/6/2018 | 23.000 | 160.61% | 15 | 0.71 | 0.24 | pCi/l | NA | |
| SMP | Trg. Analyte | 3:40:00 PM | RE181126-1-2 | 1:03:00 PM | 7:37:00 AM | NA | 876 ml | J058 | Manual Entry | 11:37 AM | 1.000 | NA | 86.1% | 0.36 | | Unfiltered | NA | LT |
| 1811039-2 | Ra-226 | 10/29/2018 | RE181126-1 | 11/27/2018 | 12/06/2018 | WATER | 920 ml | Alpha Scin | RE181126-1A | 12/6/2018 | 47.000 | 142.46% | 15 | 1.62 | 0.26 | pCi/l | NA | |
| SMP | Trg. Analyte | 3:40:00 PM | RE181126-1-2 | 1:03:00 PM | 7:37:00 AM | NA | 915 ml | K064 | Manual Entry | 11:37 AM | 1.000 | NA | 84.8% | 0.63 | | Unfiltered | NA | |
| 1811039-3 | Ra-226 | 10/31/2018 | RE181126-1 | 11/27/2018 | 12/06/2018 | WATER | 940 ml | Alpha Scin | RE181126-1A | 12/6/2018 | 93.000 | 132.48% | 15 | 3.3 | 0.3 | pCi/l | NA | |
| SMP | Trg. Analyte | 12:10:00 PM | RE181126-1-2 | 1:03:00 PM | 7:37:00 AM | NA | 935 ml | L060 | Manual Entry | 11:37 AM | 1.000 | NA | 86.7% | 1.1 | | Unfiltered | NA | |
| 1811039-4 | Ra-226 | 10/31/2018 | RE181126-1 | 11/27/2018 | 12/06/2018 | WATER | 1000 ml | Alpha Scin | RE181126-1A | 12/6/2018 | 122.000 | 162.86% | 15 | 3.4 | 0.2 | pCi/l | NA | |
| SMP | Trg. Analyte | 12:10:00 PM | RE181126-1-2 | 1:03:00 PM | 7:55:00 AM | NA | 995 ml | B041 | Manual Entry | 11:55 AM | 1.000 | NA | 85.8% | 1.0 | | Unfiltered | NA | |
| 1811039-5 | Ra-226 | 10/31/2018 | RE181126-1 | 11/27/2018 | 12/06/2018 | WATER | 1000 ml | Alpha Scin | RE181126-1A | 12/6/2018 | 192.000 | 171.82% | 15 | 4.9 | 0.4 | pCi/l | NA | |
| SMP | Trg. Analyte | 12:10:00 PM | RE181126-1-2 | 1:03:00 PM | 7:55:00 AM | NA | 995 ml | D037 | Manual Entry | 11:55 AM | 9.000 | NA | 85.3% | 1.4 | | Unfiltered | NA | |
| 1811039-6 | Ra-226 | 10/31/2018 | RE181126-1 | 11/27/2018 | 12/06/2018 | WATER | 1000 ml | Alpha Scin | RE181126-1A | 12/6/2018 | 155.000 | 184.00% | 15 | 3.6 | 0.4 | pCi/l | NA | |
| SMP | Trg. Analyte | 12:10:00 PM | RE181126-1-2 | 1:03:00 PM | 7:55:00 AM | NA | 995 ml | A039 | Manual Entry | 11:55 AM | 7.000 | NA | 86.9% | 1.1 | | Unfiltered | NA | |
| 1811039-7 | Ra-226 | 10/31/2018 | RE181126-1 | 11/27/2018 | 12/06/2018 | WATER | 830 ml | Alpha Scin | RE181126-1A | 12/6/2018 | 35.000 | 160.06% | 15 | 1.04 | 0.40 | pCi/l | NA | |
| SMP | Trg. Analyte | 4:55:00 PM | RE181126-1-2 | 1:03:00 PM | 7:55:00 AM | NA | 826 ml | F045 | Manual Entry | 11:55 AM | 4.000 | NA | 87.4% | 0.49 | | Unfiltered | NA | |
| 1811039-8 | Ra-226 | 10/31/2018 | RE181126-1 | 11/27/2018 | 12/06/2018 | WATER | 1000 ml | Alpha Scin | RE181126-1A | 12/6/2018 | 7.000 | 170.10% | 15 | 0.03 | 0.38 | pCi/l | NA | |
| SMP | Trg. Analyte | 4:55:00 PM | RE181126-1-2 | 1:03:00 PM | 7:55:00 AM | NA | 995 ml | G061 | Manual Entry | 11:55 AM | 6.000 | NA | 86.4% | 0.19 | | Unfiltered | NA | U |
| 1811039-10 | Ra-226 | 11/1/2018 | RE181126-1 | 11/27/2018 | 12/06/2018 | WATER | 1000 ml | Alpha Scin | RE181126-1A | 12/6/2018 | 163.000 | 172.20% | 15 | 4.5 | 0.3 | pCi/l | NA | |
| SMP | Trg. Analyte | 9:40:00 AM | RE181126-1-2 | 1:03:00 PM | 7:55:00 AM | NA | 995 ml | H062 | Manual Entry | 11:55 AM | 4.000 | NA | 80.9% | 1.3 | | Unfiltered | NA | |
| RE181126-1 | Ra-226 | 11/26/2018 | RE181126-1 | 11/27/2018 | 12/06/2018 | WATER | 1000 ml | Alpha Scin | RE181126-1A | 12/6/2018 | 7.000 | 180.18% | 15 | 0.07 | 0.28 | pCi/l | NA | |
| MB | Trg. Analyte | 11:59:35 AM | RE181126-1-2 | 1:03:00 PM | 8:12:00 AM | NA | 995 ml | G066 | Manual Entry | 12:16 PM | 4.000 | NA | 93.1% | 0.16 | | Unfiltered | NA | U |
| RE181126-1 | Ra-226 | 11/26/2018 | RE181126-1 | 11/27/2018 | 12/06/2018 | WATER | 1000 ml | Alpha Scin | RE181126-1A | 12/6/2018 | 1773.000 | 157.93% | 15 | 50 | 0 | pCi/l | NA | 105 |
| LCS | Trg. Analyte | 11:59:35 AM | RE181126-1-2 | 1:03:00 PM | 8:12:00 AM | NA | 995 ml | H072 | Manual Entry | 12:16 PM | 1.000 | NA | 87.2% | 13 | | Unfiltered | NA | P |

**Comments:**

## Data Package ID: *RE1811039-1*

### Qualifiers/Flags:

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative yield is assumed.

Y2 - Chemical Yield outside default limits.

W - DER is greater than Warning Limit of 1.42

D - DER is greater than Control Limit of 2.13

+ - Duplicate RPD not within limits.

LT - Result is less than Request MDC, greater than sample specific MDC

* - Aliquot Basis is 'As Received' while the Report Basis is 'Dry Weight'

# - Aliquot Basis is 'Dry Weight' while the Report Basis is 'As Received'

M - Requested MDC not met.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

L - LCS Recovery below lower control limit.

H - LCS Recovery above upper control limit.

P - LCS, Matrix Spike Recovery within control limits.

N - Matrix Spike Recovery outside control limits

NC - Not Calculated for duplicate results less than 5 times MDC

B - Analyte concentration greater than MDC.

B3 - Analyte concentration greater than MDC but less than Requested MDC.

### Notes:

1) The Tracer results are not yield corrected (i.e. activity measured not activity added).

2) Where sample time is not available, 12:00 PM (Mountain) is used for decay correction.

### Abbreviations:

TR- Tracer TA - Target Analyte

TPU - Total Propagated Uncertainty

MDC - Minimum Detectable Concentration

DER - Duplicate Error Ratio

BDL - Below Detection Limit

# Radium-226 by Radon Emanation - Method 903.1 Raw Data Report

**Laboratory Name:** **ALS -- Fort Collins**
**PAI Work Order:** 1811039

**Prep SOP:** PAI 783
**Analytical SOP:** PAI 783

**Reported on:** Thursday, December 06, 2018
1:39:12 PM

| Sample ID<br>QC Type | Nuclide<br>Type | Sample<br>Date/Time | Prep Batch<br>QCBatchID | Ingrowth<br>Date /Time | Decay<br>Date/Time | Matrix<br>%Moist. | Samp Alq<br>Analy Alq | Inst ID<br>Det ID | AnRunID<br>File Name | Count<br>Date/Time | Gr Cnts<br>Bkg Cnts | BaseEff<br>ProgEff | CntDur(min)<br>Yield | Activity +/-<br>2 s TPU | MDC<br>DecLev | ReportUnits<br>ReportBasis | DER<br>RPD | %Spk. Recov<br>Flags |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RE181126-1 | Ra-226 | 11/26/2018 | RE181126-1 | 11/27/2018 | 12/06/2018 | WATER | 1000 ml | Alpha Scin | RE181126-1A | 12/6/2018 | 1983.000 | 169.55% | 15 | 53 | 0 | pCi/l | 0.13 | 110 |
| LCSD | Trg. Analyte | 11:59:35 AM | RE181126-1-2 | 1:03:00 PM | 8:12:00 AM | NA | 995 ml | J068 | Manual Entry | 12:16 PM | 2.000 | NA | 86.7% | 13 | | Unfiltered | NA | P |

**Comments:**

## Data Package ID: *RE1811039-1*

Qualifiers/Flags:

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative yield is assumed.

Y2 - Chemical Yield outside default limits.

W - DER is greater than Warning Limit of 1.42

D - DER is greater than Control Limit of 2.13

+ - Duplicate RPD not within limits.

LT - Result is less than Request MDC, greater than sample specific MDC

* - Aliquot Basis is 'As Received' while the Report Basis is 'Dry Weight'

# - Aliquot Basis is 'Dry Weight' while the Report Basis is 'As Received'

M - Requested MDC not met.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

L - LCS Recovery below lower control limit.

H - LCS Recovery above upper control limit.

P - LCS, Matrix Spike Recovery within control limits.

N - Matrix Spike Recovery outside control limits

NC - Not Calculated for duplicate results less than 5 times MDC

B - Analyte concentration greater than MDC.

B3 - Analyte concentration greater than MDC but less than Requested MDC.

Notes:

1) The Tracer results are not yield corrected (i.e. activity measured not activity added).

2) Where sample time is not available, 12:00 PM (Mountain) is used for decay correction.

Abbreviations:

TR- Tracer TA - Target Analyte

TPU - Total Propagated Uncertainty

MDC - Minimum Detectable Concentration

DER - Duplicate Error Ratio

BDL - Below Detection Limit

# RA226 Run Log

Logbook No./Page 480758

**ALS Laboratory Group**

| Sample ID | Batch ID | Scalar / Detector ID | Flask ID | Run # of 20 | Background Count- Start Date | Background Count- Start Time | Background Count- Counts | Background Count- Dur. (min.) | Background Count- Pos. Chk. | Sample Count Start Date | Sample Count Start Time | Sample Count Counts | Sample Count Dur. (min.) | Sample Count Pos. Chk. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1809293-29 | RE181115-12 | G | 066 | NA | 12/5/18 | 8:27 | 3 | 15 | ✓ | 12/5/18 | 13:05 | 68 | 15 | ✓ |
| -30 | | H | 072 | | | | 3 | | | | | 12 | | |
| -31 | | J | 068 | | | | 3 | | | | | 23 | | |
| -32 | | L | 070 | | | | 4 | | | | | 20 | | |
| Check Source | — | B-L | Th | NA | — | — | — | — | — | 12/5/18 | | NA | 1 | ✓ |
| Check Source | — | B-L | Th | NA | — | — | — | — | — | 12/6/18 | 6:34 | NA | 1 | ✓ |
| 1809293-33 | RE181115-12 | B | 031 | NA | 12/6/18 | 6:44 | 1 | 15 | ✓ | 12/6/18 | 11:18 | 70 | 15 | ✓ |
| -34 | | D | 027 | | | | 2 | | | | | 42 | | |
| -35 | | A | 029 | | | | 7 | | | | | 18 | | |
| -36 | | F | 035 | | | | 1 | | | | | 8 | | |
| -37 | | G | 051 | | | | 2 | | | | | 17 | | |
| 420-1 | | H | 052 | | | | 2 | | | | | 8 | | |
| RE181115-12MB | | J | 053 | | | | 4 | | | | | 1 | | |
| -12LCS | | K | 059 | | | | 2 | | | | | 1301 | | |
| -12LCSD | | L | 055 | 12/6 | | | 1 | 12/6 | | | | 1428 | | |
| 1811459-1 | RE181129-3 | B | 0386 | | | 7:00 | ~~5~~ ~~+5~~ 1 | | | | 11:37 | 20 | | |
| -1Dup | | D | 032 | | | | 5 | | | | | 34 | | |
| -2 | | A | 034 | | | | 9 | | | | | 20 | | |
| -2MS | | F | 040 | | | | 4 | | | | | 813 | | |
| RE181129-3MB | | G | 056 | | | | 2 | | | | | 4 | | |
| -3LCS | | H | 057 | | | | 1 | | | | | 1835 | | |
| 1811039-1 | RE181126-1 | J | 058 | | | ~~11:37~~ 7:00 12/12/17 | 1 | | | | | 23 | | |

Comments: CHECK SOURCE FILE: I:\Oprtns\RAD\INST\ALPHSCNT\Daily Checks

Analyst / Date ✓ 12/6/18

Form 795r5.xls (11/9/2012)

Note: Each page is copied as completed and included with the workorder/run documentation: reviewed subsequent

# RA226 Run Log

Logbook No./Page 480759

**ALS Laboratory Group**

| Sample ID | Batch ID | Scalar / Detector ID | Flask ID | Run # of 20 | Background Count Start Date | Background Count Start Time | Background Count Counts | Background Count Dur. (min.) | Background Count Pos. Chk. | Sample Count Start Date | Sample Count Start Time | Sample Count Counts | Sample Count Dur. (min.) | Sample Count Pos. Chk. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1811031-2 | RE181126-1 | K | 064 | NA | 12/6/18 | 7:00 | 1 | 15 | ✓ | 12/6/18 | 11:37 | 97 | 15 | ✓ |
| -3 | | L | 060 | | | ↓ | 1 | | | | ↓ | 93 | | |
| -4 | | B | 041 | | | 7:14 | 1 | | | | 11:55 | 122 | | |
| -5 | | D | 037 | | | | 9 | | | | | 192 | | |
| -6 | | A | 039 | | | | 7 | | | | | 155 | | |
| -7 | | F | 045 | | | | 4 | | | | | 35 | | |
| -8 | | G | 061 | | | | 6 | | | | | 7 | | |
| -10 | | H | 062 | | | | 4 | | | | | 163 | | |
| 149-5 | | J | 063 | | | | 3 | | | | | 3 | | |
| 150-14 | | K | 069 | | | | 5 | | | | | 7 | | |
| 155-4 | | L | 065 | | | | 3 | | | | | 10 | | |
| 155-21 | | B | 046 | | | 7:37 | 1 | | | | 12:16 | 9 | | |
| 156-22 | | D | 042 | | | | 2 | | | | | 6 | | |
| 230-4 | | A | 044 | | | | 7 | | | | | 20 | | |
| -10 | | F | 050 | | | | 4 | | | | | 12 | | |
| RE181126-1MB | | G | 066 | | | | 4 | | | | | 7 | | |
| -1LCS | | H | 072 | | | | 1 | | | | | 1773 | | |
| -1LCSD | | J | 068 | | | | 2 | | | | | 1983 | | |
| Check Source | — | BL | 14 | NA | | | | | | 12/6/18 | | NA | ✓ | ✓ |

**Comments:** CHECK SOURCE FILE: I:\Oprtns\RAD\INST\ALPHSCNT\Daily Checks

Analyst / Date ✓ 12/6

Form 7556.xls (11/9/2012)

Note: Each page is copied as completed and included with the workorder/run documentation; reviewed subsequently

# Radiochemistry ICP Worksheet

**ALS -- Fort Collins**

**Prep Batch: RE181126-1**

Prep Procedure: **Ra226_RnE**

Reviewed By: asz

Review Date: **12/6/2018**

## BARIUM Recovery Results

### Reference Carrier

| LabID | QC Type | Carr Vol | Ref Carr Dil Vol | Ref Carr ICP Alq | Ref Carr ICP Dil Vol | Ref Carr ICP Run | Ref Carr ICP Conc |
|---|---|---|---|---|---|---|---|
| RE181126-1 | CAR | 1 | 26 | 0.1 | 10 | IR181127-2A1 | 6.927434 |

### Samples

| Prep Num | LabID | QC Type | Init Samp Alq (ml) | Car Vol (ml) | Samp Dil Vol (ml) | Init ICP Alq (ml) | Init ICP Dil Vol (ml) | Pre-Con Vol (ml) | Post Con Vol (ml) | Pre-Sep Vol (ml) | Post Sep Vol (ml) | Fin ICP Alq (ml) | Fin ICP Dil Vol (ml) | Initial ICP Run | Final ICP Run | Init ICP Conc (ug/ml) | Fin ICP Conc (ug/ml) | Init Samp Mass (ug) | Ref Mass (ug) | Flag | Fin Samp Mass (ug) | % Yield | Final Sample Alq |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1811039-1 | SMP | 880 | 1 | 1000 | 1 | 10 | 999 | 999 | 999 | 25 | 0.1 | 10 | IR181127-2A1 | IR181127-2A1 | 0.07062 | 6.448452 | 705.4824 | 18011.33 | | 16121.13 | 86.13% | 875.6 |
| 1 | 1811039-2 | SMP | 920 | 1 | 1000 | 1 | 10 | 999 | 999 | 999 | 25 | 0.1 | 10 | IR181127-2A1 | IR181127-2A1 | 0.08161 | 6.388442 | 815.2759 | 18011.33 | | 15971.1 | 84.83% | 915.4 |
| 1 | 1811039-3 | SMP | 940 | 1 | 1000 | 1 | 10 | 999 | 999 | 999 | 25 | 0.1 | 10 | IR181127-2A1 | IR181127-2A1 | 0.18494 | 6.889288 | 1847.568 | 18011.33 | | 17223.22 | 86.73% | 935.3 |
| 1 | 1811039-4 | SMP | 1000 | 1 | 1000 | 1 | 10 | 999 | 999 | 999 | 25 | 0.1 | 10 | IR181127-2A1 | IR181127-2A1 | 0.1718 | 6.772813 | 1716.281 | 18011.33 | | 16932.03 | 85.83% | 995.0 |
| 1 | 1811039-5 | SMP | 1000 | 1 | 1000 | 1 | 10 | 999 | 999 | 999 | 25 | 0.1 | 10 | IR181127-2A1 | IR181127-2A1 | 0.17808 | 6.74967 | 1779.02 | 18011.33 | | 16874.17 | 85.26% | 995.0 |
| 1 | 1811039-6 | SMP | 1000 | 1 | 1000 | 1 | 10 | 999 | 999 | 999 | 25 | 0.1 | 10 | IR181127-2A1 | IR181127-2A1 | 0.18360 | 6.898068 | 1834.207 | 18011.33 | | 17245.17 | 86.90% | 995.0 |
| 1 | 1811039-7 | SMP | 830 | 1 | 1000 | 1 | 10 | 999 | 999 | 999 | 25 | 0.1 | 10 | IR181127-2A1 | IR181127-2A1 | 0.0066 | 6.321453 | 65.89107 | 18011.33 | | 15803.63 | 87.42% | 825.9 |
| 1 | 1811039-8 | SMP | 1000 | 1 | 1000 | 1 | 10 | 999 | 999 | 999 | 25 | 0.1 | 10 | IR181127-2A1 | IR181127-2A1 | 0.0166 | 6.280748 | 165.8091 | 18011.33 | | 15701.87 | 86.38% | 995.0 |
| 1 | 1811039-10 | SMP | 1000 | 1 | 1000 | 1 | 10 | 999 | 999 | 999 | 25 | 0.1 | 10 | IR181127-2A1 | IR181127-2A1 | 0.13685 | 6.268246 | 1367.148 | 18011.33 | | 15670.61 | 80.87% | 995.0 |
| 1 | 1811149-5 | SMP | 1000 | 1 | 1000 | 1 | 10 | 999 | 999 | 999 | 25 | 0.1 | 10 | IR181127-2A1 | IR181127-2A1 | 0.00601 | 6.435136 | 60.08188 | 18011.33 | | 16087.84 | 89.02% | 995.0 |
| 1 | 1811150-14 | SMP | 1000 | 1 | 1000 | 1 | 10 | 999 | 999 | 999 | 25 | 0.1 | 10 | IR181127-2A1 | IR181127-2A1 | -9E-05 | 6.41333 | 0 | 18011.33 | Z | 16033.33 | 89.02% | 995.0 |
| 1 | 1811155-4 | SMP | 1000 | 1 | 1000 | 1 | 10 | 999 | 999 | 999 | 25 | 0.1 | 10 | IR181127-2A1 | IR181127-2A1 | 0.00299 | 6.212829 | 29.87412 | 18011.33 | | 15532.07 | 86.09% | 995.0 |
| 1 | 1811155-21 | SMP | 1000 | 1 | 1000 | 1 | 10 | 999 | 999 | 999 | 25 | 0.1 | 10 | IR181127-2A1 | IR181127-2A1 | 0.00101 | 6.555856 | 10.12289 | 18011.33 | | 16389.64 | 90.95% | 995.0 |
| 1 | 1811156-22 | SMP | 1000 | 1 | 1000 | 1 | 10 | 999 | 999 | 999 | 25 | 0.1 | 10 | IR181127-2A1 | IR181127-2A1 | 0.00427 | 6.448511 | 42.65433 | 18011.33 | | 16121.28 | 89.29% | 995.0 |
| 1 | 1811230-4 | SMP | 1000 | 1 | 1000 | 1 | 10 | 999 | 999 | 999 | 25 | 0.1 | 10 | IR181127-2A1 | IR181127-2A1 | 0.00072 | 6.481715 | 7.218297 | 18011.33 | | 16204.29 | 89.93% | 995.0 |
| 1 | 1811230-10 | SMP | 1000 | 1 | 1000 | 1 | 10 | 999 | 999 | 999 | 25 | 0.1 | 10 | IR181127-2A1 | IR181127-2A1 | 0.00055 | 6.33791 | 5.475543 | 18011.33 | | 15844.77 | 87.94% | 995.0 |
| 1 | RE181126-1 | MB | 1000 | 1 | 1000 | 1 | 10 | 999 | 999 | 999 | 25 | 0.1 | 10 | IR181127-2A1 | IR181127-2A1 | 0.00032 | 6.712047 | 3.151868 | 18011.33 | | 16780.12 | 93.15% | 995.0 |
| 1 | RE181126-1 | LCS | 1000 | 1 | 1000 | 1 | 10 | 999 | 999 | 999 | 25 | 0.1 | 10 | IR181127-2A1 | IR181127-2A1 | 0.00026 | 6.282784 | 2.57095 | 18011.33 | | 15706.96 | 87.19% | 995.0 |
| 1 | RE181126-1 | LCSD | 1000 | 1 | 1000 | 1 | 10 | 999 | 999 | 999 | 25 | 0.1 | 10 | IR181127-2A1 | IR181127-2A1 | 0.00026 | 6.249231 | 2.57095 | 18011.33 | | 15623.08 | 86.73% | 995.0 |



**FLAG -** LB: low bias (<= 15%) 15%: low bias (>15%)

Z: Negative init. conc. treated as zer

Supersedes:

1R181127-2A1



| Sample Id1 | Ca | Fe | K | Mg | Na | Sr | Mn | Al | Ba | Pb | U | Ni |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CCV | 50.2153 | 19.8394 | 51.2167 | 50.6898 | 49.8982 | 0.5155 | 0.9918 | 49.8152 | 1.0211 | 1.0077 | 5.0864 | 1.0278 |
| CCB | 0.0052 | 0.0092 | -0.0158 | -0.0016 | 0.0626 | 0.0000 | 0.0000 | 0.0310 | 0.0005 | 0.0047 | 0.0051 | 0.0007 |
| I 1811039-1 | 20.5456 | 0.9515 | 2.0013 | 2.7565 | 4.5007 | 0.1202 | 0.0436 | 0.0801 | 0.0706 | 0.0545 | -0.0217 | 0.0034 |
| I 1811039-2 | 20.7007 | 0.4953 | 2.1633 | 2.8523 | 4.9136 | 0.1236 | 0.0413 | 0.0462 | 0.0816 | 0.0211 | -0.0241 | 0.0026 |
| I 1811039-3 | 25.4772 | 4.3774 | 1.4850 | 3.1043 | 3.5261 | 0.2154 | 0.0721 | 0.0282 | 0.1849 | 0.0574 | 0.0006 | 0.0008 |
| I 1811039-4 | 24.1811 | 4.1386 | 1.3793 | 2.9536 | 3.3130 | 0.2040 | 0.0674 | 0.0368 | 0.1718 | 0.0133 | 0.0091 | 0.0002 |
| I 1811039-5 | 25.2994 | 4.2434 | 1.4724 | 3.0806 | 3.4565 | 0.2124 | 0.0683 | 0.0289 | 0.1781 | 0.0216 | -0.0246 | -0.0009 |
| I 1811039-6 | 25.4506 | 4.2579 | 1.4749 | 3.1210 | 3.4785 | 0.2146 | 0.0692 | 0.0311 | 0.1836 | 0.0424 | 0.0008 | 0.0003 |
| I 1811039-7 | 7.2121 | 0.1990 | 0.2297 | 2.0274 | 1.3144 | 0.0268 | 0.0991 | 0.0310 | 0.0066 | 0.0045 | -0.0044 | -0.0005 |
| I 1811039-8 | 8.5729 | 0.2299 | 0.3126 | 2.4119 | 1.6445 | 0.0333 | 0.1174 | 0.0260 | 0.0166 | 0.0422 | -0.0074 | -0.0003 |
| I 1811039-10 | 14.3609 | 8.7127 | 1.3781 | 3.8205 | 6.2683 | 0.0995 | 0.3588 | 0.4863 | 0.1369 | 0.1730 | -0.0078 | 0.0099 |
| I 1811149-5 | 0.0748 | 0.0370 | -0.0266 | 0.0059 | 0.0327 | 0.0016 | 0.0014 | 0.0296 | 0.0060 | 0.0316 | 0.0030 | 0.0010 |
| I 1811150-14 | 0.0015 | -0.0047 | -0.0348 | -0.0135 | 0.0011 | 0.0000 | -0.0002 | 0.0318 | -0.0001 | 0.0010 | -0.0162 | -0.0006 |
| I 1811155-4 | 0.0315 | 0.0061 | -0.0120 | -0.0113 | 0.0097 | 0.0017 | 0.0001 | 0.0289 | 0.0030 | 0.0147 | 0.0020 | -0.0002 |
| I 1811155-21 | 0.0043 | -0.0018 | -0.0639 | -0.0075 | 0.0001 | 0.0002 | -0.0002 | 0.0289 | 0.0010 | 0.0065 | -0.0102 | -0.0001 |
| I 181115$-22 | 0.0379 | -0.0032 | -0.0696 | -0.0022 | 0.0080 | 0.0002 | 0.0002 | 0.0368 | 0.0043 | 0.0394 | -0.0020 | 0.0003 |
| I 1811230-4 | 0.0366 | 0.1005 | -0.0361 | -0.0005 | 0.0098 | 0.0002 | 0.0008 | 0.0310 | 0.0007 | 0.0159 | -0.0012 | 0.0008 |
| I 1811230-10 | 0.0067 | -0.0028 | -0.0607 | -0.0075 | -0.0056 | 0.0002 | -0.0002 | 0.0274 | 0.0005 | 0.0128 | 0.0091 | 0.0002 |
| I RE181126-1MB | 0.0049 | -0.0045 | -0.0392 | -0.0140 | -0.0028 | 0.0000 | -0.0002 | 0.0274 | 0.0003 | 0.0038 | -0.0183 | -0.0007 |
| I RE181126-1LCS | 0.0018 | 0.0040 | -0.0291 | -0.0086 | -0.0079 | 0.0001 | -0.0002 | 0.0346 | 0.0003 | 0.0002 | 0.0081 | -0.0016 |
| I RE181126-1LCSD | 0.0006 | -0.0016 | -0.0057 | -0.0102 | -0.0052 | 0.0001 | -0.0002 | 0.0303 | 0.0003 | 0.0028 | 0.0000 | -0.0004 |
| CCV | 49.9783 | 19.7538 | 51.1041 | 50.4981 | 50.9147 | 0.5141 | 0.9855 | 49.7466 | 1.0248 | 0.9943 | 5.0723 | 1.0294 |
| CCB | 0.0067 | 0.0108 | -0.0468 | 0.0048 | 0.0223 | 0.0000 | 0.0001 | 0.0462 | 0.0009 | 0.0005 | -0.0020 | 0.0002 |
| F 1811039-1 | 0.3677 | 0.1261 | 0.1538 | 0.0145 | 157.2542 | 0.2282 | 0.0004 | 0.3234 | 6.4485 | 52.1960 | 0.0008 | 0.0007 |
| F 1811039-2 | 0.3967 | 0.1133 | 0.2056 | 0.0199 | 152.7331 | 0.2342 | 0.0004 | 0.2620 | 6.3884 | 57.6767 | 0.0313 | 0.0008 |
| F 1811039-3 | 0.5384 | -0.0057 | 0.0810 | -0.0140 | 152.6862 | 0.4434 | -0.0003 | 0.0318 | 6.8893 | 57.4975 | -0.0081 | -0.0008 |
| F 1811039-4 | 0.4715 | -0.0044 | 0.1152 | 0.0043 | 153.0931 | 0.4101 | -0.0002 | 0.0476 | 6.7728 | 59.8610 | 0.0254 | 0.0010 |
| F 1811039-5 | 0.4798 | -0.0045 | 0.1044 | -0.0016 | 151.1826 | 0.4060 | 0.0001 | 0.0397 | 6.7497 | 57.7413 | 0.0203 | 0.0010 |
| F 1811039-6 | 0.4865 | -0.0067 | 0.0943 | -0.0086 | 153.3905 | 0.4079 | -0.0003 | 0.0361 | 6.8981 | 58.7132 | -0.0203 | 0.0002 |
| F 1811039-7 | 0.1481 | -0.0069 | 0.0418 | -0.0113 | 153.6443 | 0.0435 | -0.0002 | 0.0332 | 6.3215 | 58.1092 | -0.0142 | -0.0006 |
| F 1811039-8 | 0.1429 | -0.0066 | 0.0443 | -0.0140 | 151.5247 | 0.0531 | -0.0003 | 0.0469 | 6.2807 | 57.8582 | -0.0233 | 0.0000 |
| F 1811039-10 | 0.4147 | 1.0912 | 0.5821 | 0.1729 | 146.6722 | 0.1750 | 0.0056 | 1.2855 | 6.2682 | 55.2890 | 0.0136 | 0.0038 |
| F 1811149-5 | -0.0015 | -0.0046 | 0.0462 | -0.0102 | 153.1989 | 0.0017 | -0.0002 | 0.0433 | 6.4351 | 59.3275 | -0.0091 | 0.0012 |
| F 1811150-14 | 0.0067 | 0.0247 | 0.0032 | -0.0113 | 152.7296 | 0.0008 | 0.0000 | 0.0368 | 6.4133 | 58.7784 | -0.0153 | -0.0006 |
| F 1811155-4 | -0.0021 | 0.0062 | -0.0133 | -0.0135 | 151.7661 | 0.0005 | -0.0002 | 0.0455 | 6.2128 | 58.3305 | -0.0071 | -0.0008 |
| F 1811155-21 | -0.0015 | 0.0099 | -0.0449 | -0.0167 | 154.9500 | 0.0002 | -0.0003 | 0.0426 | 6.5559 | 58.4237 | -0.0193 | -0.0014 |
| F 181115$-22 | -0.0021 | 0.0132 | 0.0240 | -0.0054 | 152.9222 | 0.0009 | 0.0000 | 0.0433 | 6.4485 | 58.5971 | -0.0112 | 0.0004 |
| F 1811230-4 | -0.0006 | -0.0060 | -0.0082 | -0.0135 | 154.7421 | 0.0014 | -0.0004 | 0.0354 | 6.4817 | 59.5732 | -0.0233 | -0.0006 |
| F 1811230-10 | -0.0018 | -0.0068 | 0.0335 | -0.0032 | 153.3877 | 0.0010 | -0.0002 | 0.0411 | 6.3379 | 59.0821 | 0.0051 | -0.0004 |
| F RE181126-1MB | 0.0049 | -0.0048 | -0.0544 | -0.0178 | 157.6730 | 0.0006 | -0.0004 | 0.0397 | 6.7120 | 60.0524 | -0.0213 | -0.0014 |
| F RE181126-1LCS | -0.0003 | -0.0045 | 0.0082 | -0.0016 | 152.6476 | 0.0003 | -0.0002 | 0.0469 | 6.2828 | 48.3738 | 0.0163 | 0.0015 |
| F RE181126-1LCSD | -0.0031 | -0.0067 | 0.0057 | -0.0038 | 151.5975 | 0.0002 | -0.0003 | 0.0419 | 6.2492 | 57.5178 | 0.0122 | -0.0002 |
| RE181126-1RC | -0.0012 | -0.0088 | -0.0797 | -0.0162 | 158.9613 | 0.0001 | -0.0003 | 0.0440 | 6.9274 | 0.0815 | -0.0193 | -0.0017 |
| CCV | 50.3085 | 19.7565 | 50.6859 | 50.5702 | 49.5937 | 0.5115 | 0.9849 | 49.4312 | 1.0144 | 1.0067 | 5.0601 | 1.0402 |
| CCB | 0.0067 | 0.0018 | -0.0133 | 0.0113 | 0.0390 | 0.0001 | 0.0000 | 0.0556 | 0.0011 | 0.0056 | 0.0213 | 0.0011 |

Section 6

# QUALITY ASSURANCE SUMMARY REPORTS

6

**No *NON-CONFORMANCE REPORTS* or *QUALITY ASSURANCE SUMMARY SHEETS* are included in this data package.**

Section 7

# LABORATORY BENCH SHEETS

7

# Radiochemistry Instrument Worksheet

**ALS -- Fort Collins**

**Prep Batch:** RE181126-1

**Prep Procedure:** Ra226_RnE

Analytical QASS / NCR? Y / N NA

| Prep Num | LabID | QC Type | Init Alq | Fin Alq | Units | Report Units | Cnt Date Time | Detector ID | Flask ID | Total Bkg Counts | Efficiency | Count Duration | Gross Counts | | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1811039-1 | SMP | 880 | 875.60 | ml | pCi/l | 12/6/18 11:37 | J | 058 | 1 | 1.6061 | 15 | 23 | | |
| 1 | 1811039-2 | SMP | 920 | 915.40 | ml | pCi/l | | K | 064 | 1 | 1.4246 | | 47 | | |
| 1 | 1811039-3 | SMP | 940 | 935.30 | ml | pCi/l | | L | 060 | 1 | 1.3248 | | 93 | | |
| 1 | 1811039-4 | SMP | 1000 | 995.00 | ml | pCi/l | 11:55 | B | 041 | 1 | 1.6286 | | 122 | | |
| 1 | 1811039-5 | SMP | 1000 | 995.00 | ml | pCi/l | | D | 037 | 9 | 1.7182 | | 192 | | |
| 1 | 1811039-6 | SMP | 1000 | 995.00 | ml | pCi/l | | A | 039 | 7 | 1.8400 | | 155 | | |
| 1 | 1811039-7 | SMP | 830 | 825.85 | ml | pCi/l | | F | 045 | 4 | 1.6006 | | 35 | | |
| 1 | 1811039-8 | SMP | 1000 | 995.00 | ml | pCi/l | | G | 061 | 6 | 1.7010 | | 7 | | |
| 1 | 1811039-10 | SMP | 1000 | 995.00 | ml | pCi/l | | H | 062 | 4 | 1.7220 | | 163 | | |
| 1 | 1811149-5 | SMP | 1000 | 995.00 | ml | pCi/l | | J | 063 | 3 | 1.6915 | | 3 | | |
| 1 | 1811150-14 | SMP | 1000 | 995.00 | ml | pCi/l | | K | 069 | 5 | 1.3781 | | 7 | | |
| 1 | 1811155-4 | SMP | 1000 | 995.00 | ml | pCi/l | | L | 065 | 3 | 1.3981 | | 10 | | |
| 1 | 1811155-21 | SMP | 1000 | 995.00 | ml | pCi/l | 12:16 | B | 046 | 1 | 1.6606 | | 9 | | |
| 1 | 1811156-22 | SMP | 1000 | 995.00 | ml | pCi/l | | D | 042 | 2 | 1.6699 | | 6 | | |
| 1 | 1811230-4 | SMP | 1000 | 995.00 | ml | pCi/l | | A | 044 | 7 | 1.7887 | | 20 | | |
| 1 | 1811230-10 | SMP | 1000 | 995.00 | ml | pCi/l | | F | 050 | 4 | 1.5635 | | 12 | | |
| 1 | RE181126-1 | MB | 1000 | 995.00 | ml | pCi/l | | G | 066 | 4 | 1.8018 | | 7 | | |
| 1 | RE181126-1 | LCS | 1000 | 995.00 | ml | pCi/l | | H | 072 | 1 | 1.5793 | | 1773 | | |
| 1 | RE181126-1 | LCSD | 1000 | 995.00 | ml | pCi/l | | J | 068 | 2 | 1.6955 | | 1983 | | |

**Tracer/Carrier Solution Information**

| Soln # | Nuclide | SolnID | Exp Date | Prep Conc | Units | Prep Date | Aliquot | Units | Pipet ID |
|---|---|---|---|---|---|---|---|---|---|
| T1 | BARIUM | 418244 | 8/23/19 | 16,012.690 | pCi/ml | NA | 1 | ml | RS037 |

**Spike Solution Information**

| Soln # | Nuclide | SolnID | Exp Date | Prep Conc | Units | Prep Date | Aliquot | Units | Pipet ID |
|---|---|---|---|---|---|---|---|---|---|
| S1 | Ra-226 | 916.4243.15 | 4/2/19 | 106.275 | DPM/ml | 11/26/18 | 1 | ml | RS037 |
| S1 | Rn-222 | 916.4243.15 | | 106.275 | DPM/ml | 11/26/18 | 1 | ml | RS037 |

## Sample Barcodes

1811039-1
RE181126-1PS1

1811039-2
RE181126-1PS2

1811039-3
RE181126-1PS3

1811039-4
RE181126-1PS4

1811039-5
RE181126-1PS5

1811039-6
RE181126-1PS6

# Radiochemistry Instrument Worksheet

**ALS -- Fort Collins**

**Prep Batch:** RE181126-1

**Prep Procedure:** Ra226_RnE

**Analytical QASS / NCR? Y / N** NO

| Prep Num | LabID | QC Type | Init Alq | Fin Alq | Units | Report Units | Cnt Date Time | Detector ID | Flask ID | Total Bkg Counts | Efficiency | Count Duration | Gross Counts | | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1811039-7 RE181126-1PS7 | | | | | | | | 1811039-8 RE181126-1PS8 | | | | | | 1811039-10 RE181126-1PS9 | |
| 1811149-5 RE181126-1PS10 | | | | | | | | 1811150-14 RE181126-1PS11 | | | | | | 1811155-4 RE181126-1PS12 | |
| 1811155-21 RE181126-1PS13 | | | | | | | | 1811156-22 RE181126-1PS14 | | | | | | 1811230-4 RE181126-1PS15 | |
| 1811230-10 RE181126-1PS16 | | | | | | | | RE181126-1MB RE181126-1PS17 | | | | | | RE181126-1LCS RE181126-1PS18 | |
| RE181126-1LCSD RE181126-1PS19 | | | | | | | | RE181126-1CAR RE181126-1PS20 | | | | | | | |

## Reporting Units

| LabID: | TstGrpName: | RptUnits: |
|---|---|---|
| 1811039-1 | Ra226_903.1 | pCi/l |
| 1811039-2 | Ra226_903.1 | pCi/l |
| 1811039-3 | Ra226_903.1 | pCi/l |
| 1811155-4 | Ra226_903.1 | pCi/l |
| 1811039-4 | Ra226_903.1 | pCi/l |
| 1811230-4 | Ra226_903.1 | pCi/l |
| 1811039-5 | Ra226_903.1 | pCi/l |
| 1811149-5 | Ra226_903.1 | pCi/l |
| 1811039-6 | Ra226_903.1 | pCi/l |
| 1811039-7 | Ra226_903.1 | pCi/l |
| 1811039-8 | Ra226_903.1 | pCi/l |
| 1811230-10 | Ra226_903.1 | pCi/l |
| 1811039-10 | Ra226_903.1 | pCi/l |
| 1811150-14 | Ra226_903.1 | pCi/l |
| 1811155-21 | Ra226_903.1 | pCi/l |
| 1811156-22 | Ra226_903.1 | pCi/l |



**Supersedes:** NA

# Radiochemistry Prep Worksheet

**ALS -- Fort Collins**

**Prep Batch:** RE181126-1

**Prep Procedure:** Ra226_RnE

**Reviewed By:** asz **Review Date:** 12/6/2018

**Non-Routine Pre-Treatment? Y N** **Batch:** Na **Re-Prep? Y N** **Batch:** Na **Prep QASS / NCR? Y N** Na

**Prep SOP:** PAI 783 **Rev:** 13
**Prep SOP:** NONE
**Matrix Class:** liquid

**Prep Analyst:** Jirushaya Hantula for JH
**Prep Date:** 11/26/2018
**Prep Dept:** RS

**Balance:**
**Balance:**

| Samp Num | Prep Num | LabID | QC Type | Dish No. | Init Alq ml | Fin Alq ml | Prep Basis | Ingrowth Date/Time | Decay Date/Time | Standards | Prep Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1811039-1 | SMP | Na | 880 | 875.6035 | Unfiltered | 11/27/18 13:03 | 12/06/18 07:37 | T1 | |
| 2 | 1 | 1811039-2 | SMP | | 920 | 915.4037 | Unfiltered | 11/27/18 13:03 | 12/06/18 07:37 | T1 | |
| 3 | 1 | 1811039-3 | SMP | | 940 | 935.3038 | Unfiltered | 11/27/18 13:03 | 12/06/18 07:37 | T1 | |
| 4 | 1 | 1811039-4 | SMP | | 1000 | 995.004 | Unfiltered | 11/27/18 13:03 | 12/06/18 07:55 | T1 | |
| 5 | 1 | 1811039-5 | SMP | | 1000 | 995.004 | Unfiltered | 11/27/18 13:03 | 12/06/18 07:55 | T1 | |
| 6 | 1 | 1811039-6 | SMP | | 1000 | 995.004 | Unfiltered | 11/27/18 13:03 | 12/06/18 07:55 | T1 | |
| 7 | 1 | 1811039-7 | SMP | | 830 | 825.8533 | Unfiltered | 11/27/18 13:03 | 12/06/18 07:55 | T1 | |
| 8 | 1 | 1811039-8 | SMP | | 1000 | 995.004 | Unfiltered | 11/27/18 13:03 | 12/06/18 07:55 | T1 | |
| 9 | 1 | 1811039-10 | SMP | | 1000 | 995.004 | Unfiltered | 11/27/18 13:03 | 12/06/18 07:55 | T1 | |
| 10 | 1 | 1811149-5 | SMP | | 1000 | 995.004 | Unfiltered | 11/27/18 13:03 | 12/06/18 07:55 | T1 | |
| 11 | 1 | 1811150-14 | SMP | | 1000 | 995.004 | Unfiltered | 11/27/18 13:03 | 12/06/18 07:55 | T1 | |
| 12 | 1 | 1811155-4 | SMP | | 1000 | 995.004 | Unfiltered | 11/27/18 13:03 | 12/06/18 07:55 | T1 | |
| 13 | 1 | 1811155-21 | SMP | | 1000 | 995.004 | Unfiltered | 11/27/18 13:03 | 12/06/18 08:12 | T1 | |
| 14 | 1 | 1811156-22 | SMP | | 1000 | 995.004 | Unfiltered | 11/27/18 13:03 | 12/06/18 08:12 | T1 | |
| 15 | 1 | 1811230-4 | SMP | | 1000 | 995.004 | Unfiltered | 11/27/18 13:03 | 12/06/18 08:12 | T1 | |
| 16 | 1 | 1811230-10 | SMP | | 1000 | 995.004 | Unfiltered | 11/27/18 13:03 | 12/06/18 08:12 | T1 | |
| 17 | 1 | RE181126-1 | MB | | 1000 | 995.004 | Unfiltered | 11/27/18 13:03 | 12/06/18 08:12 | T1 | |
| 18 | 1 | RE181126-1 | LCS | | 1000 | 995.004 | Unfiltered | 11/27/18 13:03 | 12/06/18 08:12 | T1,S1 | |
| 19 | 1 | RE181126-1 | LCSD | | 1000 | 995.004 | Unfiltered | 11/27/18 13:03 | 12/06/18 08:12 | T1,S1 | |

Comments

**Spiked By:** Jirushaya Hantula **Date:** 11/26/2018

**Witnessed By:** Michael L. Braun **Date:** 11/26/2018

**Tracer/Carrier Solution Information**

| Soln # | Nuclide | SolnID | Exp Date | Prep Conc | Units | Prep Date | Aliquot | Units | Pipet ID |
|---|---|---|---|---|---|---|---|---|---|
| T1 | BARIUM | 418244 | 8/23/19 | 16,012.690 | pCi/ml | NA | 1 | ml | RS037 |

**Spike Solution Information**

| Soln # | Nuclide | SolnID | Exp Date | Prep Conc | Units | Prep Date | Aliquot | Units | Pipet ID |
|---|---|---|---|---|---|---|---|---|---|
| S1 | Ra-226 | 916.4243.15 | 4/2/19 | 106.275 | DPM/ml | 11/26/18 | 1 | ml | RS037 |
| S1 | Rn-222 | 916.4243.15 | | 106.275 | DPM/ml | 11/26/18 | 1 | ml | RS037 |

# Radiochemistry Prep Worksheet

**ALS -- Fort Collins**

**Prep Batch:** RE181126-1

**Prep Procedure:** Ra226_RnE

## Prep Batch Not Validated!!!

**Reviewed By:** JXH **Review Date:** 11/27/2018

**Non-Routine Pre-Treatment?** Y / (N) **Batch:** N/A **Re-Prep?** Y / (N) **Batch:** N/A **Prep QASS / NCR?** Y / (N) N/A

**Prep SOP:** PAI 783 **Rev:** 13
**Prep SOP:** NONE
**Matrix Class:** liquid

**Prep Analyst:** Jirushaya Hantula
**Prep Date:** 11/26/2018
**Prep Dept:** RS

**Balance:**
**Balance:**

| Samp Num | Prep Num | LabID | QC Type | Dish No. | Init Alq ml | Fin Alq ml | Prep Basis | Ingrowth Date/Time | Decay Date/Time | Standards | Prep Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1811039-1 | SMP | | 880 | 880 | Unfiltered | 11/27/18 13:03 | 12/6/18 7:37 | T1 | |
| 2 | 1 | 1811039-2 | SMP | | 920 | 920 | Unfiltered | 11/27/18 13:03 | | T1 | |
| 3 | 1 | 1811039-3 | SMP | | 940 | 940 | Unfiltered | 11/27/18 13:03 | | T1 | |
| 4 | 1 | 1811039-4 | SMP | | 1000 | 1000 | Unfiltered | 11/27/18 13:03 | 7:55 | T1 | |
| 5 | 1 | 1811039-5 | SMP | | 1000 | 1000 | Unfiltered | 11/27/18 13:03 | | T1 | |
| 6 | 1 | 1811039-6 | SMP | | 1000 | 1000 | Unfiltered | 11/27/18 13:03 | | T1 | |
| 7 | 1 | 1811039-7 | SMP | | 830 | 830 | Unfiltered | 11/27/18 13:03 | | T1 | |
| 8 | 1 | 1811039-8 | SMP | | 1000 | 1000 | Unfiltered | 11/27/18 13:03 | | T1 | JXH 11/27/2018 |
| 9 | 1 | 1811039-10 | SMP | | 1000 | 1000 | Unfiltered | 11/27/18 13:03 | | T1 | |
| 10 | 1 | 1811149-5 | SMP | | 1000 | 1000 | Unfiltered | 11/27/18 13:03 | | T1 | |
| 11 | 1 | 1811150-14 | SMP | | 1000 | 1000 | Unfiltered | 11/27/18 13:03 | | T1 | |
| 12 | 1 | 1811155-4 | SMP | | 1000 | 1000 | Unfiltered | 11/27/18 13:03 | | T1 | |
| 13 | 1 | 1811155-21 | SMP | | 1000 | 1000 | Unfiltered | 11/27/18 13:03 | 812 | T1 | |
| 14 | 1 | 1811156-22 | SMP | | 1000 | 1000 | Unfiltered | 11/27/18 13:03 | | T1 | |
| 15 | 1 | 1811230-4 | SMP | | 1000 | 1000 | Unfiltered | 11/27/18 13:03 | | T1 | |
| 16 | 1 | 1811230-10 | SMP | | 1000 | 1000 | Unfiltered | 11/27/18 13:03 | | T1 | |
| 17 | 1 | RE181126-1 | MB | | 1000 | 1000 | Unfiltered | 11/27/18 13:03 | | T1 | |
| 18 | 1 | RE181126-1 | LCS | | 1000 | 1000 | Unfiltered | 11/27/18 13:03 | | T1,S1 | |
| 19 | 1 | RE181126-1 | LCSD | | 1000 | 1000 | Unfiltered | 11/27/18 13:03 | | T1,S1 | |

Comments

**Spiked By:** Jirushaya Hantula **Date:** 11/26/2018

**Witnessed By:** Michael L. Braun **Date:** 11/26/2018

**Tracer/Carrier Solution Information**

| Soln # | Nuclide | SolnID | Exp Date | Prep Conc | Units | Prep Date | Aliquot | Units | Pipet ID |
|---|---|---|---|---|---|---|---|---|---|
| T1 | BARIUM | 418244 | 8/23/2019 | 16,012.690 | pCi/ml | NA | 1 | ml | RS037 |

**Spike Solution Information**

| Soln # | Nuclide | SolnID | Exp Date | Prep Conc | Units | Prep Date | Aliquot | Units | Pipet ID |
|---|---|---|---|---|---|---|---|---|---|
| S1 | Ra-226 | 916.4243.15 | 4/2/2019 | 106.275 | DPM/ml | 11/26/18 | 1 | ml | RS037 |
| S1 | Rn-222 | 916.4243.15 | | 106.275 | DPM/ml | 11/26/18 | 1 | ml | RS037 |





**Supersedes:** N/A

# Sample Condition Form (Liquid)

Analyst: Jirushaya Hantula (JXH)

Analysis Date: 11/26/2018

Method: Ra226 em for water

| | | Sample Condition (Visual Appearance of Analysis Aliquot at Time of Prep) | | |
|---|---|---|---|---|
| Work Order | Sample ID | pH | Color | Remarks |
| 1811039 | 1 | <2 | brown | none |
| | 2 | | | |
| | 3 | | yellow | |
| | 4 | | | |
| | 5 | | | |
| | 6 | | | |
| | 7 | | clear | |
| | 8 | | | |
| | 10 | | brown | |
| 1811149 | 5 | | clear | |
| 1811150 | 14 | | | |
| 1811155 | 4 | | | |
| | 21 | | | |
| 1811156 | 22 | | | |
| 1811230 | 4 | | | |
| | 10 | | | |

JXH
11/27/2018

Section 8

# STANDARDS TRACEABILITY DOCUMENTS

8

# Radiochemistry Solution Report

| | | | | | |
|---|---|---|---|---|---|
| **Solution Id:** | 418244 | **Name:** | Ba carrier | **Type:** | IS |
| | | **Lot:** | | **Vendor Name:** | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Final Vol:** | 4000 | **Dept:** | RD | **Prep By** | RGS | **on** | 8/23/2018 | **Reviewed By** | tde | **on** | 9/24/2018 |
| **Units:** | mL | **Location:** | SR/RA | **Opened By** | | **on** | | **Verified By** | TDE | **on** | 9/24/2018 |
| **Matrix:** | LIQUID | **ExpireDate:** | 9/24/2019 | **Received By** | | **on** | | **Deactivated By** | | **on** | |

**Comment:**

| Component Name | Component ID | Volume Added | Units |
|---|---|---|---|
| Barium Stable Carrier Source<1> | 3756 B07592 | 113.9301 | g |

| CompName | Calibrated Primary Act/Conc | Calibration Date | Reference Date | 1/2 Life (Yrs) | Final Act/Conc | Summed Conc | Units |
|---|---|---|---|---|---|---|---|
| BARIUM | 562193.5 | | 10/22/2018 | | 16012.69 | | pCi/ml |

## Associated Parent IDs

3756 B07592

**Abbreviations: NC = Not Calculated for reagents when the volume added is not entered.**
**NE = Not Entered**

**(Prnt) = Secular equilibrium; parent half life used to calculate concentration.**



**Date Printed:** Monday, October 22, 2018

*ALS Environmental -- FC*

Standards DB Version: 1.111

Continued from Page

TE 1/17/17

Prepare a working dilution of 916.3610.76

1. Density of 0.1M HCl, lot # 0000132881
   Mass of 100mL vol. flask: 68.5633g Balance # 12
   Mass of flask & 100mL acid: 168.3994 g Balance# 12
   Net Mass: 99.8361 g
   Density: 0.9984 g/mL

2. Mass of 916.3610.76 transferred: TE 1/17/17
   Mass of open empty nalgene: 73.7098g Balance# 12
   Mass of nalgene & standard: 77.1515g Balance# 12
   Net mass of standard transferred: 3.4417g

3. Dilute to final volume:
   Mass of nalgene, standard, & diluent: 1045.2g Balance# 26
   Mass of empty nalgene (from above): 73.7098g Balance# 12
   Net mass of new dilution: 971.4902g

4. Final activity calculation:

$$30{,}156\,dpm/g\,(0.9984\,g/mL)\left(\frac{3.4417\,g}{971.4902\,g}\right)=106.66\,dpm/gmL$$ TE 1/17/17

TE 1/17/17

JP 4/16/18

Stnd ID: 916.4243.15

| | | |
|---|---|---|
| Description: | Ra-226 | |
| Expiration: | 4/2/2019 | |
| Activity: | 106.66 | dpm/ml |
| | ~~0.00~~ | ~~dpm/gram~~ JP 4/16/18 |
| 2s Uncertainty: | 5.23 | dpm/ml |
| Ref. Date: | 7/1/2010 | |
| Ref Time: | N/A | |
| Prep Date: | 1/17/2017 | Prep by: TE |
| Matrix/Comp. | 0.1 M HCl | |
| Half Life (y): | 1.60E+03 | |

| Reverification Log | | |
|---|---|---|
| Analysis Date | Initials | Expiration Date |
| | | |
| | | |
| | | |
| | | |
| | | |

JP 4/16/18

Continued on Page

TE 1/17/17 — Signed — Date

Read and Understood by — Signed — 4/16/18 — Date

Eckert & Ziegler
Analytics

1380 Seaboard Industrial Blvd.
Atlanta, Georgia 30318
Tel 404•352•8677
Fax 404•352•2837
www.analyticsinc.com

rec 7-6-10 RSO# 916

# CERTIFICATE OF CALIBRATION
## Standard Radionuclide Source

82563-307
Ra-226 5 mL Liquid in Flame Sealed Vial

**Customer:** ALS Laboratory Group / Fort Collins
**P.O. No.:** 73625 06-10-10, Item 1

This standard radionuclide source was prepared gravimetrically from a master solution calibrated by Eckert & Ziegler Analytics, using a germanium gamma spectrometer system. Radionuclide purity and calibration were checked with a germanium gamma spectrometer system. The nuclear decay rate and reference date for this source are given below. Eckert & Ziegler Analytics (EZA) maintains traceability to the National Institute of Standards and Technology through a Measurements Assurance Program as described in USNRC Regulatory Guide 4.15, Revision 1, February, 1979, and compliance with ANSI N42.22-1995, "Traceability of Radioactive Sources to NIST." EZA is accredited by the Health Physics Society (HPS) for the production of NIST-traceable sources, and this source was produced in accordance with the HPS accreditation requirements. Customers may report any concerns with the accreditation program to the HPS Secretariat, 1313 Dolley Madison Blvd., Ste. 402, McLean, VA 22101.

| Isotope | Half-Life, Days | Activity (Bq) | Uncertainty* , % Type $u_A$ | $u_B$ | U | Reference Date (12:00 PM EST) |
|---|---|---|---|---|---|---|
| Ra-226 | 5.844E+05 | 1.860E+04 | 0.5 | 2.4 | 4.9 | 07/01/2010 |

***Uncertainty:** U - Relative expanded uncertainty, k = 2. See NIST Technical Note 1297, "Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results."

**Comments:**
Impurities: γ-impurities <0.1%. 5.05176 g 0.1M HCl solution with approximately 30 μg/g Ba carrier.

Source Prepared by: _____
W. Mao, Radiochemist

QA Approved: _____ Date: 6/30/10
J. D. McCorvey, QA Manager Alternate

ANA Form005 Rev. —

Single Isotope Certificate, Rev 1 9/28/2009

ACCREDITED SOURCE CALIBRATION LABORATORY HEALTH PHYSICS SOCIETY FOUNDED 1986

Prepare a intermediate dilution of RSO # 916.

0.1 M HCl diluent lot # H45A12

Density of diluent

| | | balance # |
|---|---|---|
| Mass of 100 ml Vol flask | 68.2982 g | 12 |
| Flask + Acid | 168.0565 g | 2 |
| Net | 99.7583 g | |

$\rho$ = 0.9976 g/ml

Mass of percent transferred

| | | |
|---|---|---|
| Mass of Open full Ampule + Beaker | 38.2082 g | 12 |
| Mass of Open Empty Ampule + Beaker | 33.2251 g | 6 |
| Net | 4.9831 g | |

Dilute to final Vol./Mass

| | | |
|---|---|---|
| Mass of Open Empty 40 ml Vial | 21.397 g | 12 |
| Mass of Vial, Std, + diluent | 57.9016 g | 6 |
| Net | 36.5045 g | |

Activity Calc.

JON 9/27/10

$\frac{1}{4}$ (1860 Bq) $\left(\frac{60 \text{ dpm}}{1 \text{ Bq}}\right) \frac{4.9831 \text{ g}}{5.05176 \text{ g}} \frac{1}{36.5045 \text{ g}}$ = ~~30156~~ dpm/g

30,156.

JON 9/27/10

Continued on Page

Read and Understood By

Signed 9/27/10 Date Signed 9/27/10

Section 9

# ADDITIONAL SUPPORTING DOCUMENTATION

# Ra226 by Radon Emanation Calibration For Detectors B, D, C, A, F, G, H, J, K, L

Performed by: AZ
Date: 2/16/17

Reviewed by: JP
Date: 2/20/17

# Voltage Plateau Data

# PHOTOMULTIPLIER/SCALAR OPERATING VOLTAGE

**$^{230}$Th SOURCE (18000 dpm) COUNTED FOR 1 MINUTE AT SPECIFIED OPERATING VOLATGES**

DATE: 2/10/2017 ANALYST: AZ

SCALER/DETECTOR: 2B

| VOLTS | COUNTS | Slope/200V | OK? (Slope <+/-5%) | **Selected Voltage** |
|---|---|---|---|---|
| 500 | | NA | | |
| 600 | 0 | NA | | |
| 700 | 26 | 8434.6% | | |
| 800 | 2924 | 240.0% | | |
| 900 | 9047 | 58.9% | | |
| 1000 | 9586 | 3.4% | OK | |
| 1100 | 9448 | 0.4% | OK | **1100** |
| 1200 | 9631 | 1.9% | OK | |
| 1300 | 9663 | -85.4% | | |
| 1400 | | NA | | |
| 1500 | | NA | | |

**BACKGROUND (NO SOURCE) COUNTED MULTIPLE TIMES FOR 1 MINUTE AT SPECIFIED OPERATING VOLATGES**

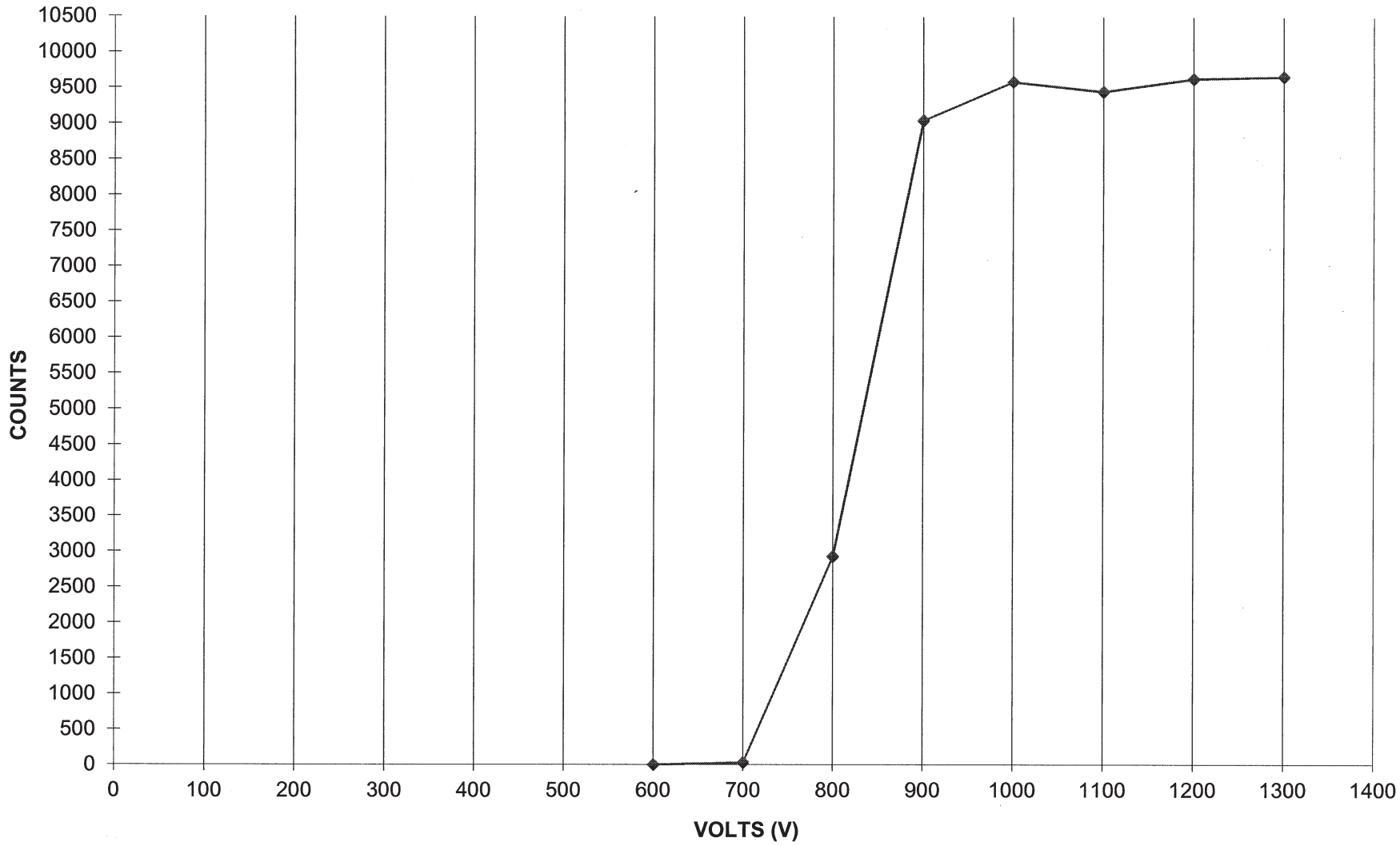
| VOLTS | COUNTS (1) | COUNTS (2) | COUNTS (3) | COUNTS (4) | COUNTS (5) | AVERAGE |
|---|---|---|---|---|---|---|
| 500 | | | | | | |
| 600 | | | | | | |
| 700 | 0 | 0 | 0 | 0 | 0 | 0.00 |
| 800 | 0 | 0 | 0 | 0 | 0 | 0.00 |
| 900 | 0 | 0 | 0 | 0 | 0 | 0.00 |
| 1000 | 0 | 0 | 0 | 0 | 0 | 0.00 |
| 1100 | 0 | 0 | 0 | 0 | 0 | 0.00 |
| 1200 | 0 | 0 | 0 | 1 | 0 | 0.20 |
| 1300 | 2 | 1 | 4 | 0 | 0 | 1.40 |
| 1400 | | | | | | |
| 1500 | | | | | | |

The operating voltage chosen should be the point on the plateau that also gives the lowest possible background counts. Therefore, it is the analyst's opinion that the operating voltage for scaler/detector 2B be set at 1100 V.

Scalar 2 will always be paired with detector B.

REVIEWED BY: John Petrovic

## OPERATING VOLTAGE FOR DETECTOR/SCALAR



# PHOTOMULTIPLIER/SCALAR OPERATING VOLTAGE

**$^{230}$Th SOURCE (18000 dpm) COUNTED FOR 1 MINUTE AT SPECIFIED OPERATING VOLATGES**

DATE: 2/10/2017 ANALYST: AZ

SCALER/DETECTOR: 5D

| VOLTS | COUNTS | Slope/200V | OK? (Slope <+/-5%) | **Selected Voltage** |
|---|---|---|---|---|
| 500 | | NA | | |
| 600 | 578 | 991.2% | | |
| 700 | 8021 | 82.1% | | |
| 800 | 9358 | 11.9% | | |
| 900 | 9450 | 2.8% | OK | **900** |
| 1000 | 9690 | 3.1% | OK | |
| 1100 | 9813 | 0.2% | OK | |
| 1200 | 9710 | 5.2% | | |
| 1300 | 10412 | -79.9% | | |
| 1400 | | NA | | |
| 1500 | | NA | | |

**BACKGROUND (NO SOURCE) COUNTED MULTIPLE TIMES FOR 1 MINUTE AT SPECIFIED OPERATING VOL**

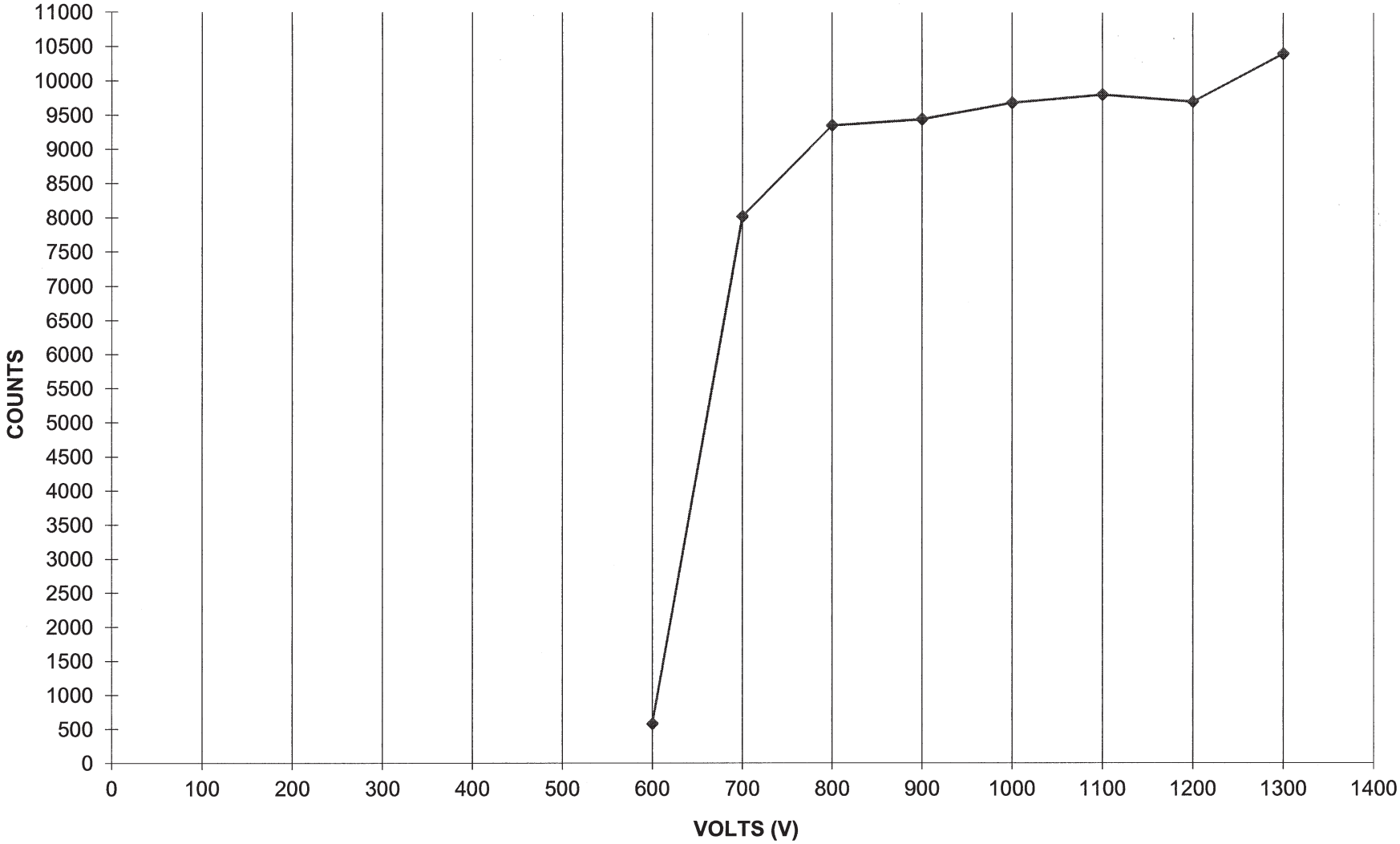
| VOLTS | COUNTS (1) | COUNTS (2) | COUNTS (3) | COUNTS (4) | COUNTS (5) | AVERAGE |
|---|---|---|---|---|---|---|
| 500 | | | | | | |
| 600 | 0 | 0 | 0 | 0 | 0 | 0.00 |
| 700 | 0 | 0 | 0 | 0 | 0 | 0.00 |
| 800 | 0 | 0 | 0 | 0 | 0 | 0.00 |
| 900 | 0 | 0 | 1 | 1 | 0 | 0.40 |
| 1000 | 1 | 1 | 1 | 1 | 2 | 1.20 |
| 1100 | 2 | 2 | 11 | 16 | 16 | 9.40 |
| 1200 | | | | | | |
| 1300 | | | | | | |
| 1400 | | | | | | |
| 1500 | | | | | | |

The operating voltage chosen should be the point on the plateau that also gives the lowest possible background counts. Therefore, it is the analyst's opinion that the operating voltage for scaler/detector 5D be set at 900 V.

Scalar 5 will always be paired with detector D.

REVIEWED BY: John Petrovic

## OPERATING VOLTAGE FOR DETECTOR/SCALAR



# PHOTOMULTIPLIER/SCALAR OPERATING VOLTAGE

**$^{230}$Th SOURCE (18000 dpm) COUNTED FOR 1 MINUTE AT SPECIFIED OPERATING VOLATGES**

| | | | | | | |
|---|---|---|---|---|---|---|
| DATE: | 2/10/2017 | ANALYST: | AZ | | | |
| SCALER/DETECTOR: | | 6C | | | | |
| VOLTS | COUNTS | Slope/200V | OK? (Slope <+/-5%) | **Selected Voltage** | | |
| 500 | | NA | | | | |
| 600 | 611 | 662.8% | | | | |
| 700 | 5670 | 115.5% | | | | |
| 800 | 9341 | 33.0% | | | | |
| 900 | 9631 | 2.1% | OK | **900** | | |
| 1000 | 9590 | -0.1% | OK | | | |
| 1100 | 9623 | 0.9% | OK | | | |
| 1200 | 9689 | -84.0% | | | | |
| 1300 | | NA | | | | |
| 1400 | | NA | | | | |
| 1500 | | NA | | | | |

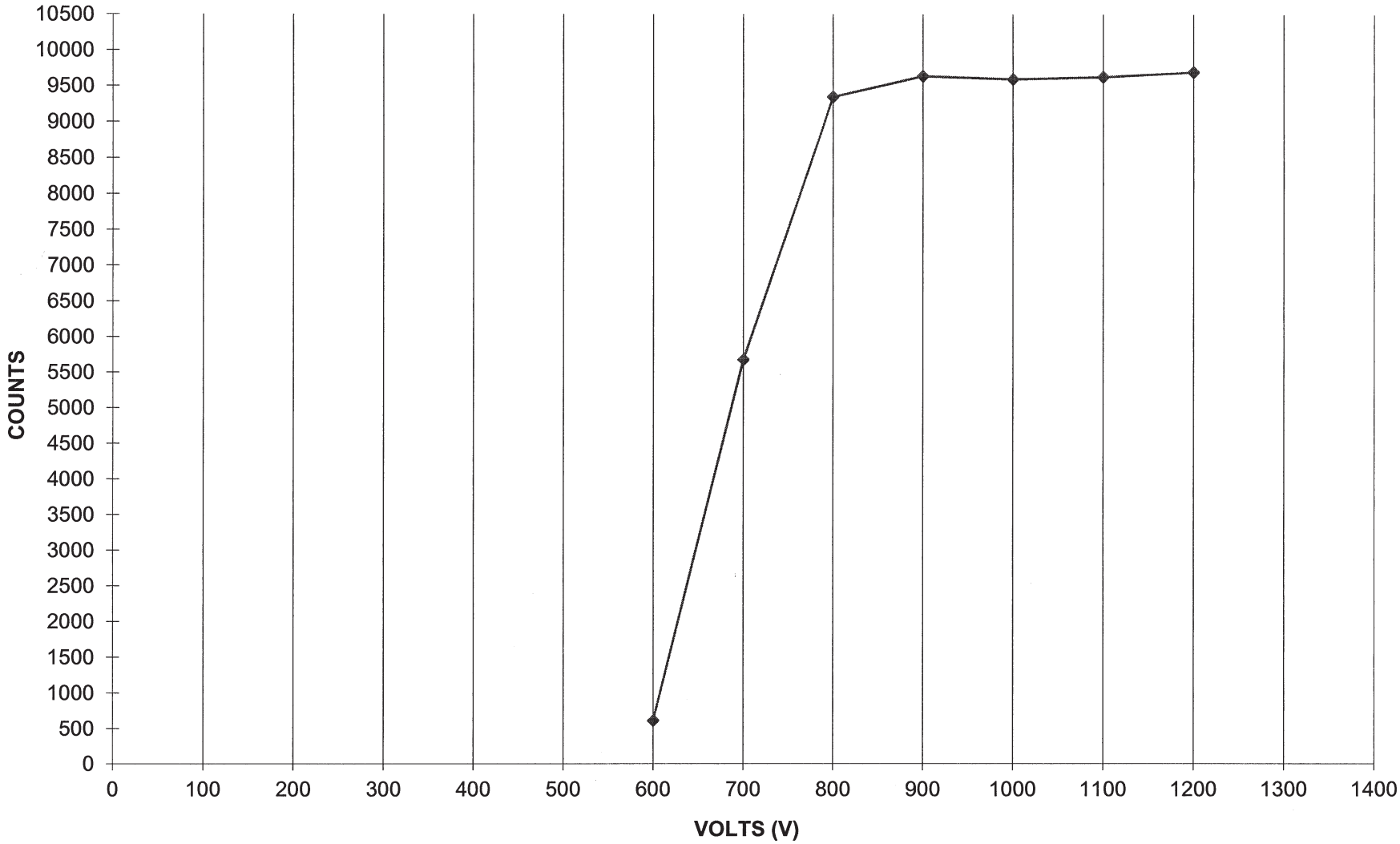
**BACKGROUND (NO SOURCE) COUNTED MULTIPLE TIMES FOR 1 MINUTE AT SPECIFIED OPERATING VOLATGES**

| VOLTS | COUNTS (1) | COUNTS (2) | COUNTS (3) | COUNTS (4) | COUNTS (5) | AVERAGE |
|---|---|---|---|---|---|---|
| 500 | | | | | | |
| 600 | 0 | 0 | 0 | 0 | 0 | 0.00 |
| 700 | 0 | 0 | 0 | 0 | 0 | 0.00 |
| 800 | 0 | 0 | 0 | 0 | 0 | 0.00 |
| 900 | 0 | 0 | 0 | 0 | 0 | 0.00 |
| 1000 | 0 | 0 | 1 | 0 | 0 | 0.20 |
| 1100 | 0 | 0 | 0 | 2 | 1 | 0.60 |
| 1200 | 12 | 63 | 14 | 7 | 16 | 22.40 |
| 1300 | | | | | | |
| 1400 | | | | | | |
| 1500 | | | | | | |

The operating voltage chosen should be the point on the plateau that also gives the lowest possible background counts. Therefore, it is the analyst's opinion that the operating voltage for scaler/detector 6C be set at 900 V.

REVIEWED BY: John Petrovic

## OPERATING VOLTAGE FOR DETECTOR/SCALAR



# PHOTOMULTIPLIER/SCALAR OPERATING VOLTAGE

**$^{230}$Th SOURCE (18000 dpm) COUNTED FOR 1 MINUTE AT SPECIFIED OPERATING VOLATGES**

DATE: 2/13/2017 ANALYST: AZ

DETECTOR/SCALER: 7A

| VOLTS | COUNTS | Slope/200V | OK? (Slope <+/-5%) | **Selected Voltage** |
|---|---|---|---|---|
| 500 | | NA | | |
| 600 | 143 | 2739.3% | | |
| 700 | 5484 | 123.2% | | |
| 800 | 9149 | 34.6% | | |
| 900 | 9555 | 3.0% | OK | |
| 1000 | 9505 | 0.6% | OK | **1000** |
| 1100 | 9626 | 2.2% | OK | |
| 1200 | 9762 | 0.1% | OK | |
| 1300 | 9634 | -86.9% | | |
| 1400 | | NA | | |
| 1500 | | NA | | |

**BACKGROUND (NO SOURCE) COUNTED MULTIPLE TIMES FOR 1 MINUTE AT SPECIFIED OPERATING VOLATGES**

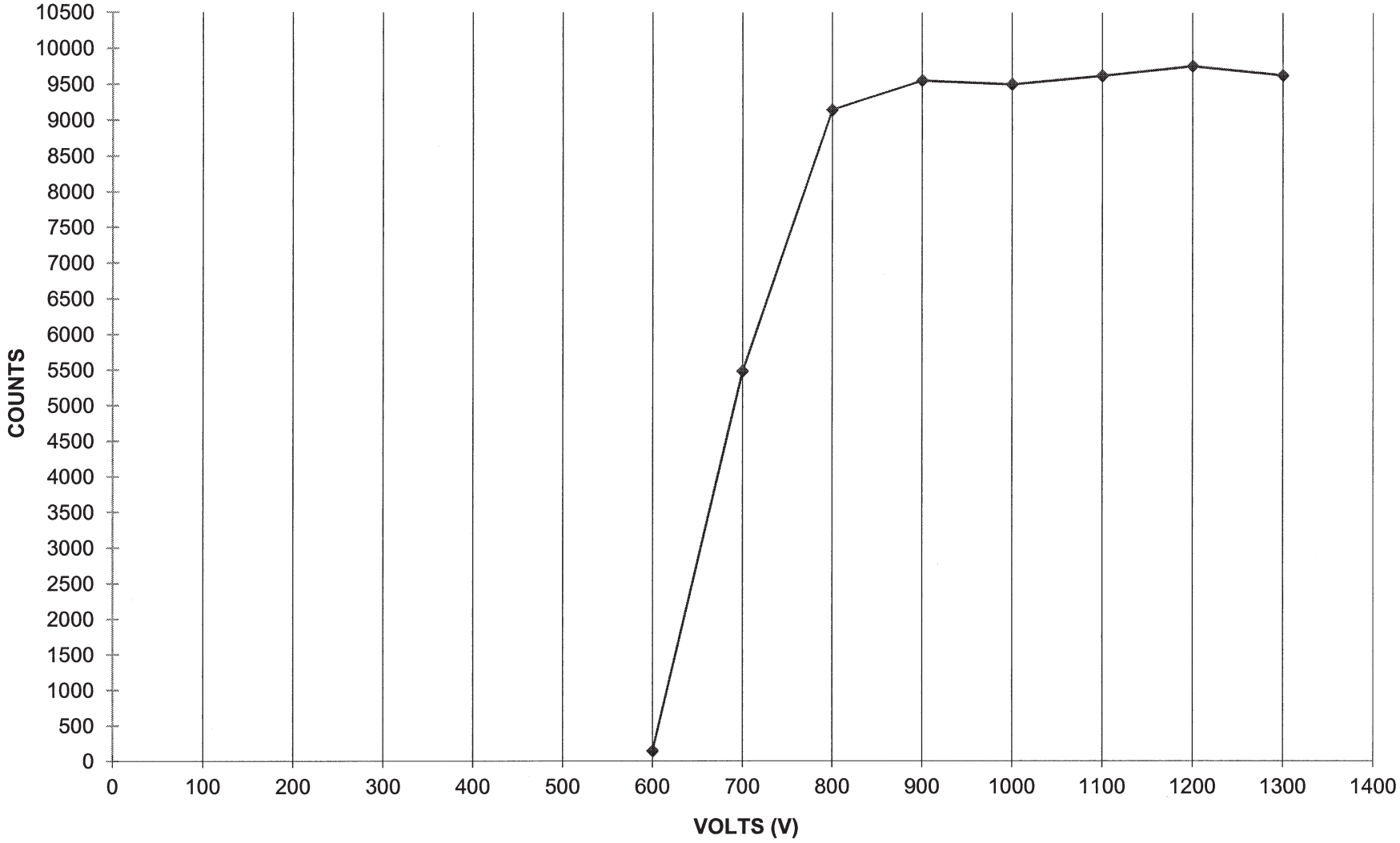
| VOLTS | COUNTS (1) | COUNTS (2) | COUNTS (3) | COUNTS (4) | COUNTS (5) | AVERAGE |
|---|---|---|---|---|---|---|
| 500 | | | | | | |
| 600 | 0 | 0 | 0 | 0 | 0 | 0.00 |
| 700 | 9 | 0 | 0 | 0 | 0 | 1.80 |
| 800 | 0 | 0 | 0 | 0 | 0 | 0.00 |
| 900 | 0 | 0 | 0 | 0 | 0 | 0.00 |
| 1000 | 0 | 0 | 0 | 0 | 0 | 0.00 |
| 1100 | 0 | 1 | 0 | 0 | 0 | 0.20 |
| 1200 | 6 | 4 | 1 | 3 | 4 | 3.60 |
| 1300 | | | | | | |
| 1400 | | | | | | |
| 1500 | | | | | | |

The operating voltage chosen should be the point on the plateau that also gives the lowest possible background counts. Therefore, it is the analyst's opinion that the operating voltage for DETECTOR/SCALER 7A be set at 1000 V.

Scaler 7 will always be paired with detector A.

REVIEWED BY: John Petrovic

## OPERATING VOLTAGE FOR DETECTOR/SCALAR



# PHOTOMULTIPLIER/SCALAR OPERATING VOLTAGE

**$^{230}$Th SOURCE (18000 dpm) COUNTED FOR 1 MINUTE AT SPECIFIED OPERATING VOLATGES**

DATE: 2/10/2017 ANALYST: AZ

SCALER/DETECTOR: 1F

| VOLTS | COUNTS | Slope/200V | OK? (Slope <+/-5%) | **Selected Voltage** |
|---|---|---|---|---|
| 500 | | NA | | |
| 600 | 0 | NA | | |
| 700 | 13 | 14480.8% | | |
| 800 | 2510 | 264.8% | | |
| 900 | 8558 | 64.9% | | |
| 1000 | 9458 | 7.7% | | |
| 1100 | 9447 | -0.3% | OK | **1100** |
| 1200 | 9428 | 2.9% | OK | |
| 1300 | 9767 | -82.7% | | |
| 1400 | | NA | | |
| 1500 | | NA | | |

**BACKGROUND (NO SOURCE) COUNTED MULTIPLE TIMES FOR 1 MINUTE AT SPECIFIED OPERATING VOL**

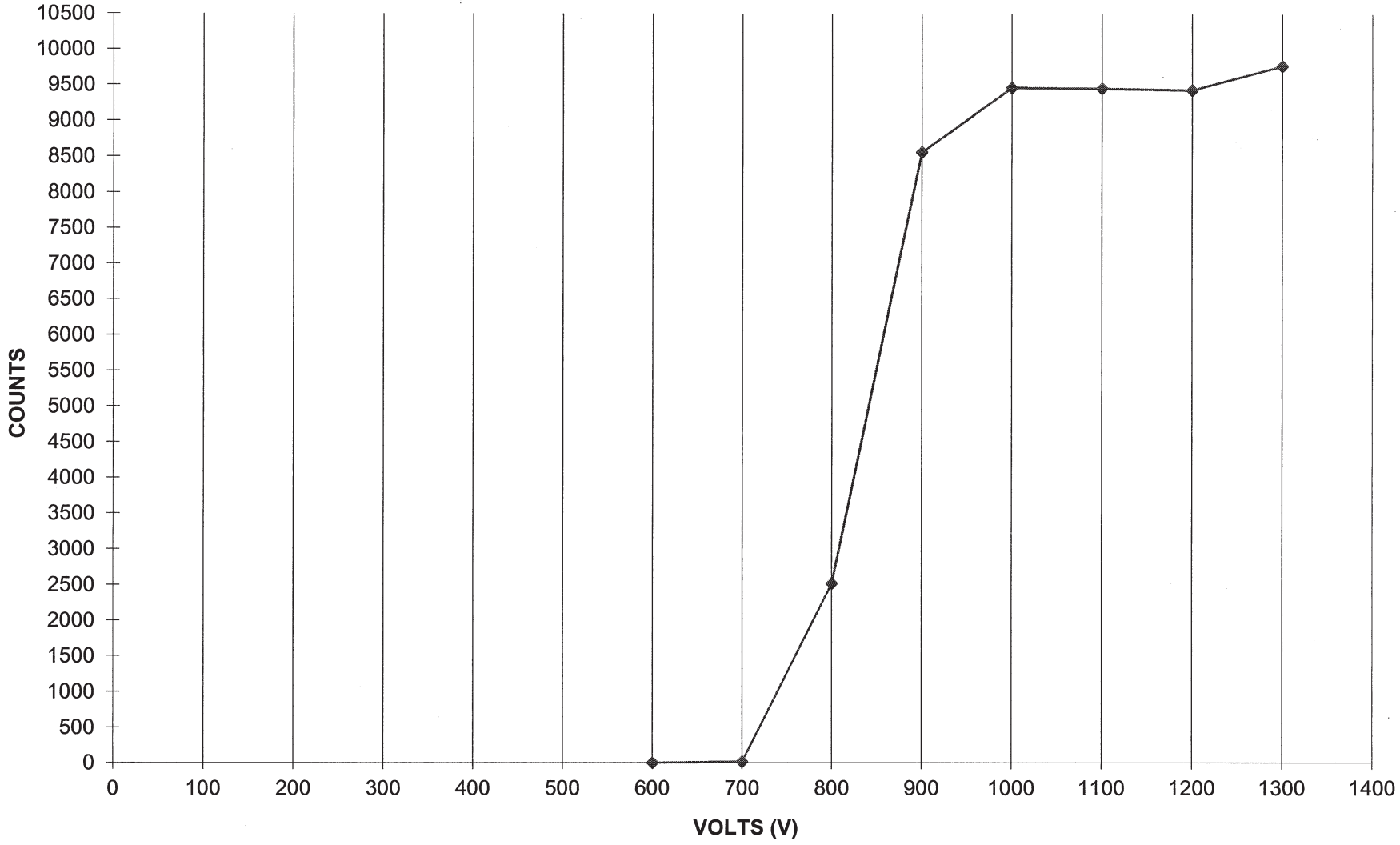
| VOLTS | COUNTS (1) | COUNTS (2) | COUNTS (3) | COUNTS (4) | COUNTS (5) | AVERAGE |
|---|---|---|---|---|---|---|
| 500 | | | | | | |
| 600 | 0 | 0 | 0 | 0 | 0 | 0.00 |
| 700 | 0 | 0 | 0 | 0 | 0 | 0.00 |
| 800 | 0 | 0 | 0 | 0 | 0 | 0.00 |
| 900 | 0 | 0 | 0 | 0 | 0 | 0.00 |
| 1000 | 0 | 0 | 0 | 0 | 0 | 0.00 |
| 1100 | 0 | 0 | 0 | 0 | 0 | 0.00 |
| 1200 | 0 | 0 | 1 | 1 | 1 | 0.60 |
| 1300 | 4 | 3 | 3 | 3 | 5 | 3.60 |
| 1400 | | | | | | |
| 1500 | | | | | | |

The operating voltage chosen should be the point on the plateau that also gives the lowest possible background counts. Therefore, it is the analyst's opinion that the operating voltage for scalar/detector 1F be set at 1100 V.

Scalar 1 will always be paired with detector F.

REVIEWED BY: John Petrovic

## OPERATING VOLTAGE FOR DETECTOR/SCALAR



# PHOTOMULTIPLIER/SCALAR OPERATING VOLTAGE

**$^{230}$Th SOURCE (18000 dpm) COUNTED FOR 1 MINUTE AT SPECIFIED OPERATING VOLATGES**

| | | | | |
|---|---|---|---|---|
| DATE: | 2/10/2017 | ANALYST: | AZ | |
| SCALER/DETECTOR: | | 8G | | |
| VOLTS | COUNTS | Slope/200V | OK? (Slope <+/-5%) | **Selected Voltage** |
| 500 | | NA | | |
| 600 | 7902 | 86.5% | | |
| 700 | 9573 | 13.0% | | |
| 800 | 9559 | 1.4% | OK | **800** |
| 900 | 9741 | 2.8% | OK | |
| 1000 | 9901 | 28.5% | | |
| 1100 | 13186 | -62.6% | | |
| 1200 | | NA | | |
| 1300 | | NA | | |
| 1400 | | NA | | |
| 1500 | | NA | | |

**BACKGROUND (NO SOURCE) COUNTED MULTIPLE TIMES FOR 1 MINUTE AT SPECIFIED OPERATING VOLATGES**

| VOLTS | COUNTS (1) | COUNTS (2) | COUNTS (3) | COUNTS (4) | COUNTS (5) | AVERAGE |
|---|---|---|---|---|---|---|
| 500 | | | | | | |
| 600 | 0 | 0 | 0 | 0 | 0 | 0.00 |
| 700 | 0 | 0 | 0 | 0 | 0 | 0.00 |
| 800 | 0 | 1 | 0 | 0 | 0 | 0.20 |
| 900 | 0 | 2 | 1 | 1 | 1 | 1.00 |
| 1000 | | | | | | |
| 1100 | | | | | | |
| 1200 | | | | | | |
| 1300 | | | | | | |
| 1400 | | | | | | |
| 1500 | | | | | | |

The operating voltage chosen should be the point on the plateau that also gives the lowest possible background counts. Therefore, it is the analyst's opinion that the operating voltage for scaler/detector 8G be set at 800 V.
Scalar 8 will always be paired with detector G.

REVIEWED BY: John Petrovic

# PHOTOMULTIPLIER/SCALAR OPERATING VOLTAGE

**$^{230}$Th SOURCE (18000 dpm) COUNTED FOR 1 MINUTE AT SPECIFIED OPERATING VOLATGES**

| | | | | |
|---|---|---|---|---|
| DATE: | 2/10/2017 | ANALYST: | AZ | |
| SCALER/DETECTOR: | | 9H | | |
| VOLTS | COUNTS | Slope/200V | OK? (Slope <+/-5%) | **Selected Voltage** |
| 500 | | NA | | |
| 600 | 7071 | 96.5% | | |
| 700 | 9548 | 19.7% | | |
| 800 | 9574 | 1.2% | OK | **800** |
| 900 | 9697 | 1.1% | OK | |
| 1000 | 9710 | 23.9% | | |
| 1100 | 12534 | -64.6% | | |
| 1200 | | NA | | |
| 1300 | | NA | | |
| 1400 | | NA | | |
| 1500 | | NA | | |

**BACKGROUND (NO SOURCE) COUNTED MULTIPLE TIMES FOR 1 MINUTE AT SPECIFIED OPERATING VOLATGES**

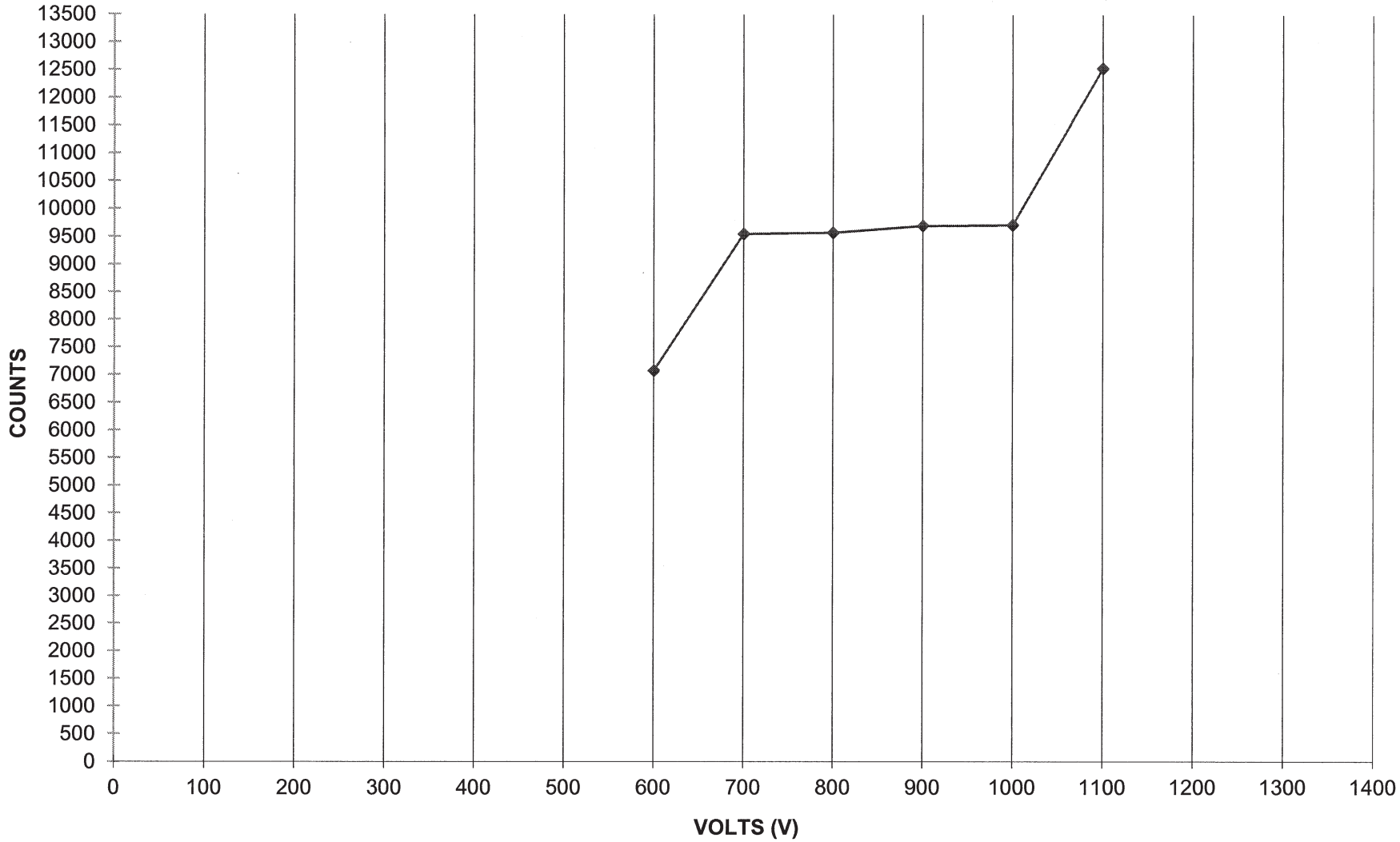
| VOLTS | COUNTS (1) | COUNTS (2) | COUNTS (3) | COUNTS (4) | COUNTS (5) | AVERAGE |
|---|---|---|---|---|---|---|
| 500 | | | | | | |
| 600 | 0 | 0 | 0 | 0 | 0 | 0.00 |
| 700 | 0 | 0 | 0 | 0 | 0 | 0.00 |
| 800 | 0 | 0 | 0 | 0 | 0 | 0.00 |
| 900 | 0 | 1 | 0 | 2 | 0 | 0.60 |
| 1000 | | | | | | |
| 1100 | | | | | | |
| 1200 | | | | | | |
| 1300 | | | | | | |
| 1400 | | | | | | |
| 1500 | | | | | | |

The operating voltage chosen should be the point on the plateau that also gives the lowest possible background counts. Therefore, it is the analyst's opinion that the operating voltage for scaler/detector 9H be set at 800 V.

Scalar 9 will always be paired with detector H.

REVIEWED BY: John Petrovic

## OPERATING VOLTAGE FOR DETECTOR/SCALAR



# PHOTOMULTIPLIER/SCALAR OPERATING VOLTAGE

**$^{230}$Th SOURCE (18000 dpm) COUNTED FOR 1 MINUTE AT SPECIFIED OPERATING VOLATGES**

| | | | | |
|---|---|---|---|---|
| DATE: | 2/10/2017 | ANALYST: | AZ | |
| SCALER/DETECTOR: | | 10J | | |
| VOLTS | COUNTS | Slope/200V | OK? (Slope <+/-5%) | **Selected Voltage** |
| 500 | | NA | | |
| 600 | 7732 | 88.7% | | |
| 700 | 9606 | 14.0% | | |
| 800 | 9529 | 0.6% | OK | **800** |
| 900 | 9682 | 1.7% | OK | |
| 1000 | 9732 | 10.2% | | |
| 1100 | 10899 | -74.4% | | |
| 1200 | | NA | | |
| 1300 | | NA | | |
| 1400 | | NA | | |
| 1500 | | NA | | |

**BACKGROUND (NO SOURCE) COUNTED MULTIPLE TIMES FOR 1 MINUTE AT SPECIFIED OPERATING VOLATGES**

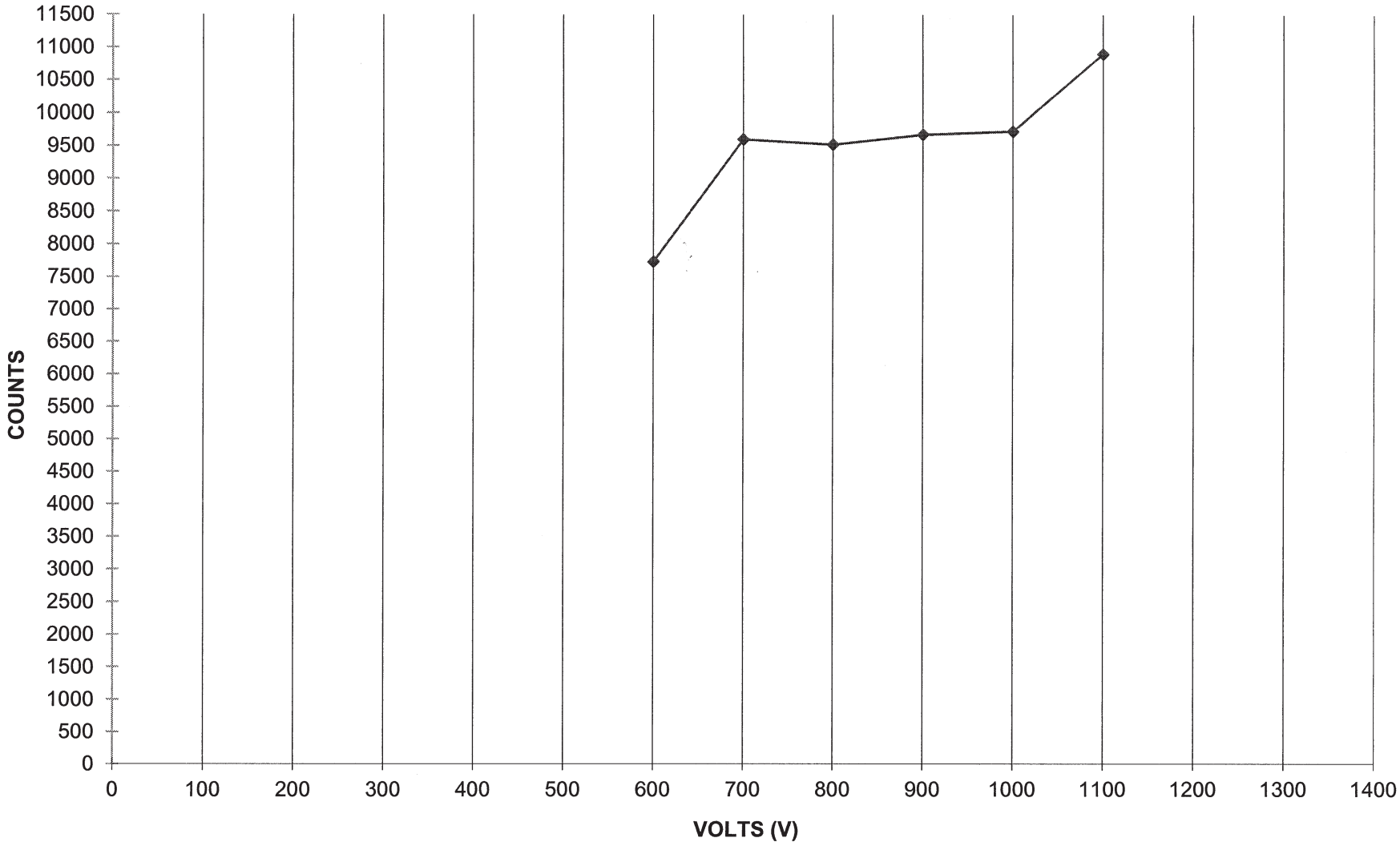
| VOLTS | COUNTS (1) | COUNTS (2) | COUNTS (3) | COUNTS (4) | COUNTS (5) | AVERAGE |
|---|---|---|---|---|---|---|
| 500 | | | | | | |
| 600 | 0 | 0 | 0 | 0 | 0 | 0.00 |
| 700 | 0 | 0 | 0 | 0 | 0 | 0.00 |
| 800 | 0 | 0 | 0 | 0 | 0 | 0.00 |
| 900 | 0 | 1 | 0 | 1 | 0 | 0.40 |
| 1000 | | | | | | |
| 1100 | | | | | | |
| 1200 | | | | | | |
| 1300 | | | | | | |
| 1400 | | | | | | |
| 1500 | | | | | | |

The operating voltage chosen should be the point on the plateau that also gives the lowest possible background counts. Therefore, it is the analyst's opinion that the operating voltage for scalar/detector 10J be set at 800 V.

Scalar 10 will always be paired with detector J.

REVIEWED BY: John Petrovic

## OPERATING VOLTAGE FOR DETECTOR/SCALAR



# PHOTOMULTIPLIER/SCALAR OPERATING VOLTAGE

**$^{230}$Th SOURCE (18000 dpm) COUNTED FOR 1 MINUTE AT SPECIFIED OPERATING VOLATGES**

DATE: 2/10/2017 ANALYST: AZ

SCALER/DETECTOR: 11K

| VOLTS | COUNTS | Slope/200V | OK? (Slope <+/-5%) | **Selected Voltage** |
|---|---|---|---|---|
| 500 | | NA | | |
| 600 | 4525 | 146.8% | | |
| 700 | 9297 | 40.4% | | |
| 800 | 9529 | 3.1% | OK | **800** |
| 900 | 9676 | 1.4% | OK | |
| 1000 | 9695 | 1.1% | OK | |
| 1100 | 9810 | 19.2% | | |
| 1200 | 11959 | -69.4% | | |
| 1300 | | NA | | |
| 1400 | | NA | | |
| 1500 | | NA | | |

**BACKGROUND (NO SOURCE) COUNTED MULTIPLE TIMES FOR 1 MINUTE AT SPECIFIED OPERATING VOLATGES**

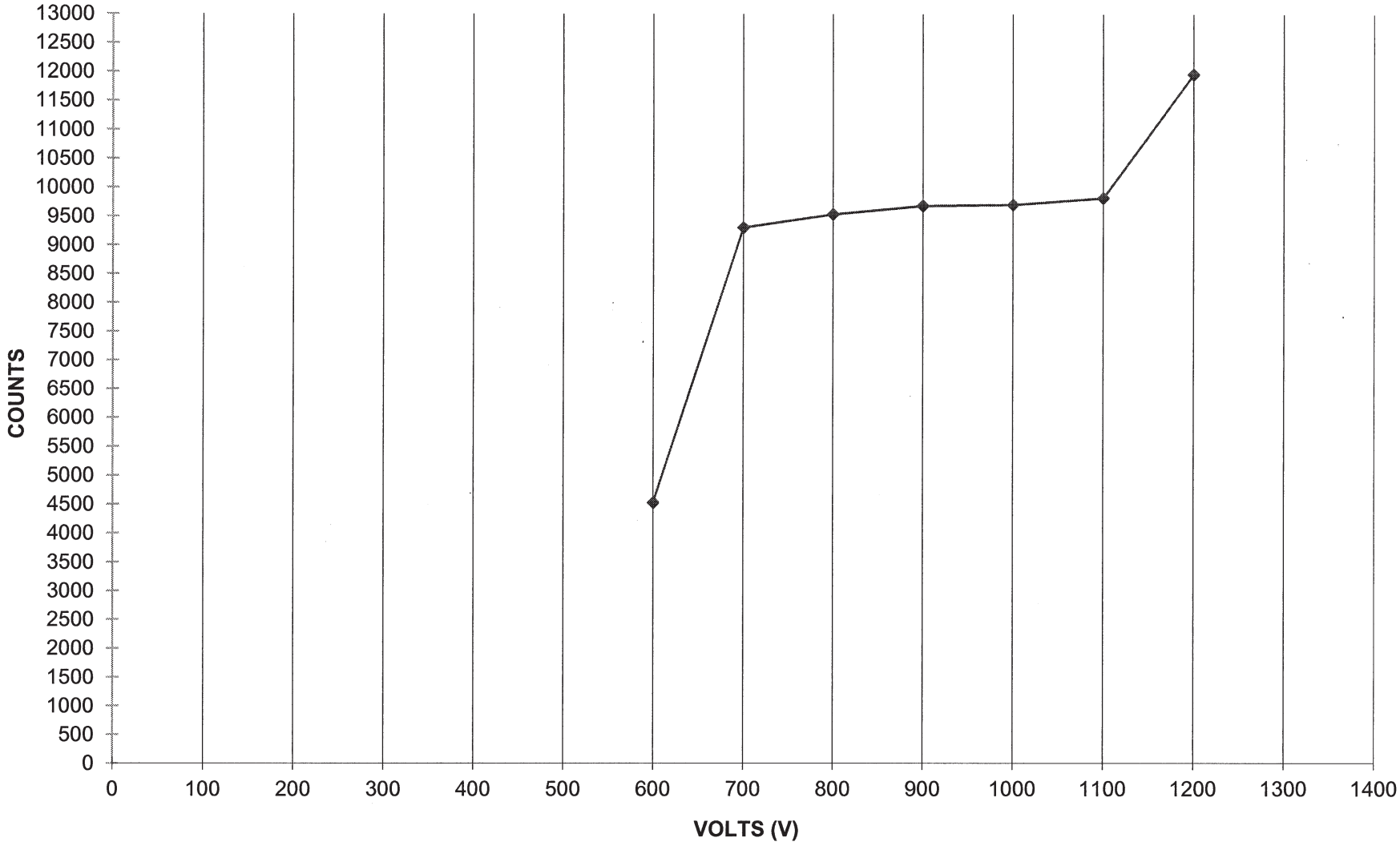
| VOLTS | COUNTS (1) | COUNTS (2) | COUNTS (3) | COUNTS (4) | COUNTS (5) | AVERAGE |
|---|---|---|---|---|---|---|
| 500 | | | | | | |
| 600 | 0 | 0 | 0 | 0 | 0 | 0.00 |
| 700 | 0 | 0 | 0 | 0 | 0 | 0.00 |
| 800 | 0 | 0 | 0 | 0 | 0 | 0.00 |
| 900 | 0 | 1 | 0 | 0 | 0 | 0.20 |
| 1000 | 1 | 0 | 1 | 0 | 0 | 0.40 |
| 1100 | | | | | | |
| 1200 | | | | | | |
| 1300 | | | | | | |
| 1400 | | | | | | |
| 1500 | | | | | | |

The operating voltage chosen should be the point on the plateau that also gives the lowest possible background counts. Therefore, it is the analyst's opinion that the operating voltage for scalar/detector 11K be set at 800 V.

Scalar 11 will always be paired with detector K.

REVIEWED BY: John Petrovic

## OPERATING VOLTAGE FOR DETECTOR/SCALAR



# PHOTOMULTIPLIER/SCALAR OPERATING VOLTAGE

**$^{230}$Th SOURCE (18000 dpm) COUNTED FOR 1 MINUTE AT SPECIFIED OPERATING VOLATGES**

DATE: 2/10/2017 ANALYST: AZ

SCALER/DETECTOR: 12L

| VOLTS | COUNTS | Slope/200V | OK? (Slope <+/-5%) | **Selected Voltage** |
|---|---|---|---|---|
| 500 | | NA | | |
| 600 | 4332 | 156.0% | | |
| 700 | 9460 | 41.1% | | |
| 800 | 9522 | 0.2% | OK | **800** |
| 900 | 9488 | 2.3% | OK | |
| 1000 | 9791 | 17.6% | | |
| 1100 | 11590 | -70.4% | | |
| 1200 | | NA | | |
| 1300 | | NA | | |
| 1400 | | NA | | |
| 1500 | | NA | | |

**BACKGROUND (NO SOURCE) COUNTED MULTIPLE TIMES FOR 1 MINUTE AT SPECIFIED OPERATING VOLATGES**

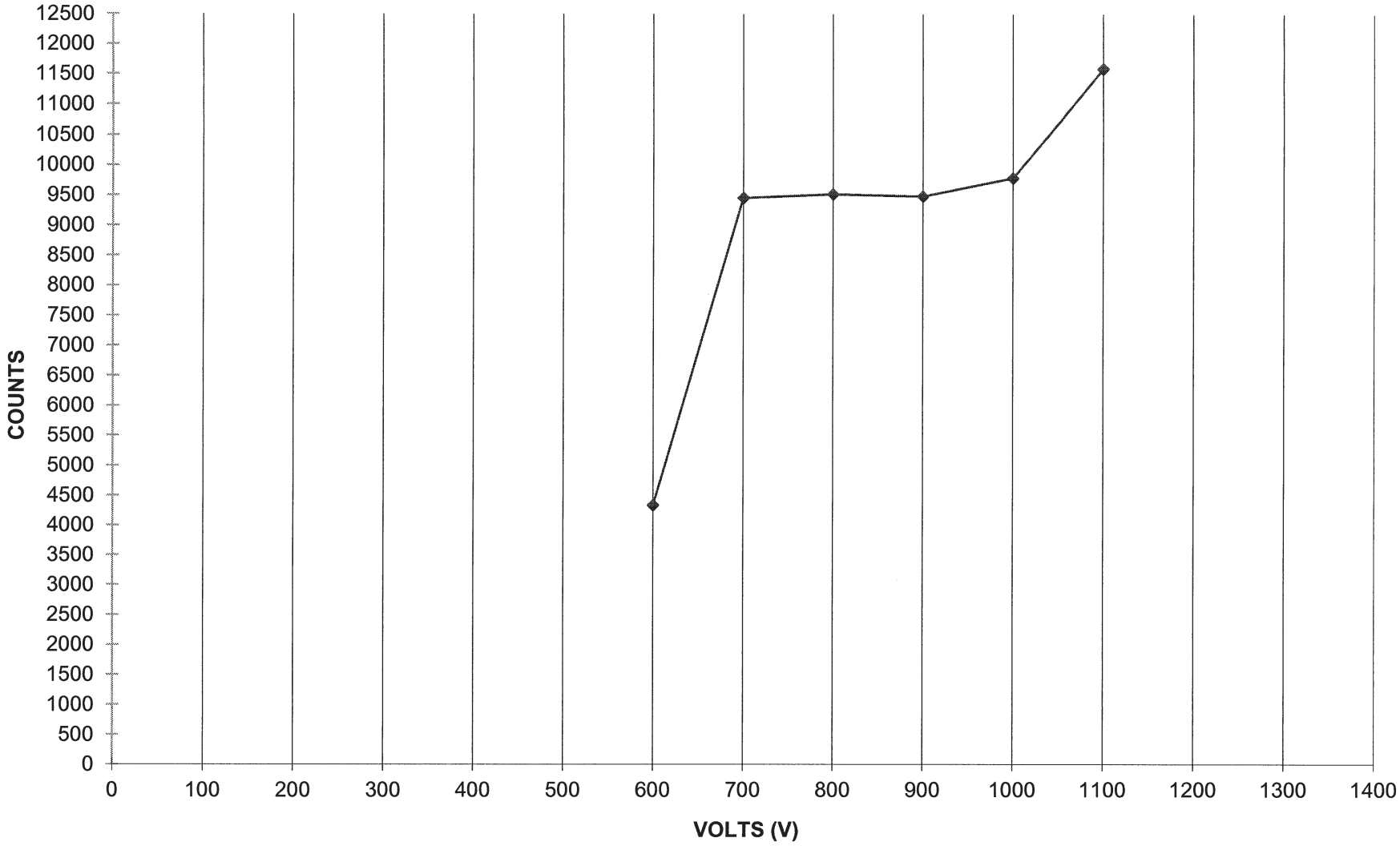
| VOLTS | COUNTS (1) | COUNTS (2) | COUNTS (3) | COUNTS (4) | COUNTS (5) | AVERAGE |
|---|---|---|---|---|---|---|
| 500 | | | | | | |
| 600 | 0 | 0 | 0 | 0 | 0 | 0.00 |
| 700 | 0 | 0 | 0 | 0 | 0 | 0.00 |
| 800 | 0 | 0 | 0 | 0 | 0 | 0.00 |
| 900 | 0 | 1 | 0 | 0 | 0 | 0.20 |
| 1000 | 11 | 8 | 7 | 4 | 4 | 6.80 |
| 1100 | | | | | | |
| 1200 | | | | | | |
| 1300 | | | | | | |
| 1400 | | | | | | |
| 1500 | | | | | | |

The operating voltage chosen should be the point on the plateau that also gives the lowest possible background counts. Therefore, it is the analyst's opinion that the operating voltage for scalar/detector 12L be set at 800 V.

Scalar 12 will always be paired with detector L.

REVIEWED BY: John Petrovic

## OPERATING VOLTAGE FOR DETECTOR/SCALAR



Voltage Plateaus For Counters 2B, 5D, 6C, 7A, 1F, 8G, 9H, 10J, 11K, + 12L
(Th source for one minute at each voltage)

| Voltage(kV) | 2B | 5D | 6C | 7A | 1F | 8G | 9H | 10J | 11K | 12L |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.6 | 0 | 578 | 611 | 469 | 0 | ~~8274~~ 7902 | ~~4836~~ 7076 | 7732 | 4525 | 4332 |
| 0.7 | 26 | 8021 | 5670 | 4774 | 13 | 9573 | 9548 | 9606 | 9297 | 9460 |
| 0.8 | 2924 | 9358 | 9341 | 8918 | 2510 | 9559 | 9574 | 9529 | 9529 | 9522 |
| 0.9 | 9047 | 9450 | 9631 | 9819 | 8558 | 9741 | 9697 | 9682 | 9676 | 9488 |
| 1.0 | 9586 | 9690 | 9590 | 9674 | 9458 | 9901 | 9710 | 9732 | 9695 | 9791 |
| 1.1 | 9448 | 9813 | 9623 | 11879 | 9447 | — | 12554 | 10899 | 9810 | 11590 |
| 1.2 | 9631 | 9710 | 9689 | 11885 | 9428 | 13186 — | — | 216785 | 11959 | — |
| 1.3 | 9663 | 10,412 | 36881 | 11838 | 9767 | — | — | — | — | — |

BKg Counts (no source) at Plateau Energies (1 min)

| Voltage | 2B | 5D | 6C | 7A | 1F | 8G | 9H | 10J | 11K | 12L |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.6 | — | 0,0,0,0,0 | 0,0,0,0 | 00000 | 00000 | 00000 | 00000 | 00000 | 00000 | 00000 |
| 0.7 | 0,0,0,0,0 | 0,0,0,0,0 | 0,0,0,0 | 10000 | 00000 | 00000 | 0,0000 | 00000 | 00000 | 00000 |
| 0.8 | 0,0,0,0,0 | 0,0,0,0,0 | 00000 | 00000 | 00000 | 01000 | 00000 | 00000 | 00000 | 00000 |
| 0.9 | 0,0,0,0,0 | 0,0000 | 00000 | 00000 | 00000 | 02111 | 01020 | 01010 | 00000 | 01000 |
| 1.0 | 0,0,0,0,0 | 11112 | 00100 | 00000 | 00000 | — | 65886 | 12,9,11,12,11 | 10100 | 11,8,7,4,4 |
| 1.1 | 0,0,0,0,0 | 25,21,16,16 | 00021 | 01000 | 00000 | — | — | — | — | — |
| 1.2 | 00000 | — | 12,15,14,7,16 | 6,4,13,4 | 00111 | — | — | — | — | — |
| 1.3 | 21400 | — | — | — | 43335 | — | — | — | — | — |

2/13/17 → Voltage Plateau For 7A re-run

| Voltage | 7A | Voltage | 7A | Voltage | 7A | Voltage | 7A |
|---|---|---|---|---|---|---|---|
| 0.6 | 143 | 0.8 | 9149 | 1.0 | 9505 | 1.2 | 9762 |
| 0.7 | 5484 | 0.9 | 9555 | 1.1 | 9626 | 1.3 | 9634 |

Continued on Page

Read and Understood By

Signed 2/13/17 Date

Signed 2/10/17 Date

# Efficiency Data

# Lucas Cell + PMT Calibration Control Summary

r:\inst\alphscnt\cell_cal.xls

Acceptance criteria: Passing ICV (control limits = 67-120%)

| Detector + Flask ID | B026 | | B031 | | B036 | | B041 | | B046 | |
|---|---|---|---|---|---|---|---|---|---|---|
| 2/14/2017 | 0.9660 | PASS | 1.5127 | PASS | 1.5186 | PASS | 1.6286 | PASS | 1.6606 | PASS |
| | | | | | | | | | | |

**DNU** = DO NOT USE

AZ 4/24/2018
Reviewed By/Date

# Lucas Cell + PMT Calibration Control Summary

r:\inst\alphscnt\cell_cal.xls

Acceptance criteria: Passing ICV (control limits = 67-120%)

| Detector + Flask ID | D027 | | D032 | | D037 | | D042 | | D047 | |
|---|---|---|---|---|---|---|---|---|---|---|
| 2/14/2017 | 1.4668 | PASS | 1.7047 | PASS | 1.7182 | PASS | 1.6699 | PASS | 1.7066 | PASS |
| | | | | | | | | | | |

**DNU** = DO NOT USE

AZ 4/24/2018
Reviewed By/Date

# Lucas Cell + PMT Calibration Control Summary

r:\inst\alphscnt\cell_cal.xls

Acceptance criteria: Passing ICV (control limits = 67-120%)

| Detector + Flask ID | C028 | | C033 | | C038 | | C043 | | C048 | |
|---|---|---|---|---|---|---|---|---|---|---|
| 2/14/2017 | 0.9561 | PASS | 1.3419 | PASS | 1.4563 | PASS | 1.4769 | PASS | 0.8362 | PASS |
| | | | | | | | | | | |

**DNU** = DO NOT USE AZ 4/24/2018
Reviewed By/Date

## Lucas Cell + PMT Calibration Control Summary

r:\inst\alphscnt\cell_cal.xls

Acceptance criteria: Passing ICV (control limits = 67-120%)

| Detector + Flask ID | A029 | | A034 | | A039 | | A044 | | A049 | |
|---|---|---|---|---|---|---|---|---|---|---|
| 2/14/2017 | 1.6235 | PASS | 1.8384 | PASS | 1.8400 | PASS | 1.7887 | PASS | 1.8394 | PASS |
| | | | | | | | | | | |

**DNU** = DO NOT USE AZ 4/24/2018
Reviewed By/Date

## Lucas Cell + PMT Calibration Control Summary

r:\inst\alphscnt\cell_cal.xls

Acceptance criteria: Passing ICV (control limits = 67-120%)

| Detector + Flask ID | F030 | | F035 | | F040 | | F045 | | F050 | |
|---|---|---|---|---|---|---|---|---|---|---|
| 2/14/2017 | 1.2014 | PASS | 1.2123 | PASS | 1.3949 | PASS | 1.6006 | PASS | 1.5635 | PASS |
| | | | | | | | | | | |

**DNU** = DO NOT USE AZ 4/24/2018
Reviewed By/Date

## Lucas Cell + PMT Calibration Control Summary

r:\inst\alphscnt\cell_cal.xls

Acceptance criteria: Passing ICV (control limits = 67-120%)

| Detector + Flask ID | G051 | | G056 | | G061 | | G066 | | G071 | |
|---|---|---|---|---|---|---|---|---|---|---|
| 2/14/2017 | 1.6048 | PASS | 1.6142 | PASS | 1.7010 | PASS | 1.8018 | PASS | 1.7588 | PASS |

AZ 4/24/2018

Reviewed By/Date

# Lucas Cell + PMT Calibration Control Summary

r:\inst\alphscnt\cell_cal.xls

Acceptance criteria: Passing ICV (control limits = 67-120%)

| Detector + Flask ID | H052 | | H057 | | H062 | | H067 | | H072 | |
|---|---|---|---|---|---|---|---|---|---|---|
| 2/14/2017 | 1.6508 | PASS | 1.5502 | PASS | 1.7220 | PASS | 1.6920 | PASS | 1.5793 | PASS |

AZ 4/24/2018

Reviewed By/Date

## Lucas Cell + PMT Calibration Control Summary

r:\inst\alphscnt\cell_cal.xls

Acceptance criteria: Passing ICV (control limits = 67-120%)

| Detector + Flask ID | J053 | | J058 | | J063 | | J068 | | J073 | |
|---|---|---|---|---|---|---|---|---|---|---|
| 2/14/2017 | 1.6430 | PASS | 1.6061 | PASS | 1.6915 | PASS | 1.6955 | PASS | 1.4067 | PASS |

AZ 4/24/2018

Reviewed By/Date

## Lucas Cell + PMT Calibration Control Summary

r:\inst\alphscnt\cell_cal.xls

Acceptance criteria: Passing ICV (control limits = 67-120%)

| Detector + Flask ID | K054 | | K059 | | K064 | | K069 | | K074 | |
|---|---|---|---|---|---|---|---|---|---|---|
| 2/14/2017 | 1.0500 | PASS | 1.3904 | PASS | 1.4246 | PASS | 1.3781 | PASS | 0.9742 | PASS |

AZ 4/24/2018

Reviewed By/Date

# Lucas Cell + PMT Calibration Control Summary

r:\inst\alphscnt\cell_cal.xls

Acceptance criteria: Passing ICV (control limits = 67-120%)

| Detector + Flask ID | L055 | | L060 | | L065 | | L070 | | L075 | |
|---|---|---|---|---|---|---|---|---|---|---|
| 2/14/2017 | 1.4297 | PASS | 1.3248 | PASS | 1.3981 | PASS | 1.3941 | PASS | 0.8161 | PASS |

AZ 4/24/2018

Reviewed By/Date

# Radium-226 in Water by Radon Emanation Technique for Calibration--Method 903.1

Analyst: pjw
Prep. Date S: 12/6/2011
Prep. Date C: 12/6/2011
SOP Used: 783R12

| | | S | Purge (end) | | | | | | | Deeman. (end) | | Count Start | | Count | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | S | V | Date | Time | Flask | Counter | Scaler | CBKG | CBKG | Date | Time | Date | Time | Duration | COUNT | REMARKS |
| W.O.# | ID | (L) | D1 | T1 | No. | No. | No. | # | (CORR.) | D2 | T2 | D3 | T3 | (min.) | # | |
| CS2662 | S1 | 1 | 2/13/2017 | 16:45 | 026 | B | 2 | 2 | 5 | 4/19/2018 | 8:13 | 4/19/2018 | 12:21 | 35 | 6709 | |
| CS2662 | S2 | 1 | 2/13/2017 | 16:45 | 027 | D | 5 | 9 | 21 | 4/19/2018 | 8:13 | 4/19/2018 | 12:21 | 35 | 10200 | |
| CS2662 | S3 | 1 | 2/13/2017 | 16:45 | 028 | C | 6 | 1 | 2 | 4/19/2018 | 8:13 | 4/19/2018 | 12:21 | 35 | 6638 | |
| CS2662 | S4 | 1 | 2/13/2017 | 16:45 | 029 | A | 7 | 7 | 16 | 4/19/2018 | 8:13 | 4/19/2018 | 12:21 | 35 | 11283 | |
| CS2662 | S5 | 1 | 2/13/2017 | 16:45 | 030 | F | 1 | 3 | 7 | 4/19/2018 | 8:13 | 4/19/2018 | 12:21 | 35 | 8344 | |
| CS2662 | S6 | 1 | 10/14/2013 | 9:30 | 051 | G | 8 | 5 | 12 | 2/14/2017 | 7:26 | 2/14/2017 | 11:32 | 35 | 11151 | |
| CS2662 | S7 | 1 | 10/14/2013 | 9:30 | 052 | H | 9 | 4 | 9 | 2/14/2017 | 7:26 | 2/14/2017 | 11:32 | 35 | 11468 | |
| CS2662 | S8 | 1 | 10/14/2013 | 9:30 | 053 | J | 10 | 1 | 2 | 2/14/2017 | 7:26 | 2/14/2017 | 11:32 | 35 | 11407 | |
| CS2662 | S9 | 1 | 2/13/2017 | 16:45 | 054 | K | 11 | 5 | 12 | 4/20/2018 | 7:46 | 4/20/2018 | 11:50 | 35 | 7305 | |
| CS2662 | S10 | 1 | 10/14/2013 | 9:30 | 055 | L | 12 | 2 | 5 | 2/14/2017 | 7:26 | 2/14/2017 | 11:32 | 35 | 9929 | |
| CS2662 | S11 | 1 | 10/14/2013 | 9:45 | 031 | B | 2 | 1 | 2 | 2/14/2017 | 7:55 | 2/14/2017 | 12:12 | 35 | 10488 | |
| CS2662 | S12 | 1 | 10/14/2013 | 9:45 | 032 | D | 5 | 4 | 9 | 2/14/2017 | 7:55 | 2/14/2017 | 12:12 | 35 | 11826 | |
| CS2662 | S13 | 1 | 10/14/2013 | 9:45 | 033 | C | 6 | 0 | 0 | 2/14/2017 | 7:55 | 2/14/2017 | 12:12 | 35 | 9302 | |
| CS2662 | S14 | 1 | 10/14/2013 | 9:45 | 034 | A | 7 | 4 | 9 | 2/14/2017 | 7:55 | 2/14/2017 | 12:12 | 35 | 12753 | |
| CS2662 | S8 | 1 | 2/13/2017 | 16:45 | 035 | F | 1 | 8 | 19 | 4/20/2018 | 7:46 | 4/20/2018 | 11:50 | 35 | 8436 | |
| CS2662 | S16 | 1 | 10/14/2013 | 9:45 | 056 | G | 8 | 4 | 9 | 2/14/2017 | 7:55 | 2/14/2017 | 12:12 | 35 | 11199 | |
| CS2662 | S17 | 1 | 10/14/2013 | 9:45 | 057 | H | 9 | 4 | 9 | 2/14/2017 | 7:55 | 2/14/2017 | 12:12 | 35 | 10755 | |
| CS2662 | S18 | 1 | 10/14/2013 | 9:45 | 058 | J | 10 | 2 | 5 | 2/14/2017 | 7:55 | 2/14/2017 | 12:12 | 35 | 11138 | |
| CS2662 | S19 | 1 | 10/14/2013 | 9:45 | 059 | K | 11 | 1 | 2 | 2/14/2017 | 7:55 | 2/14/2017 | 12:12 | 35 | 9640 | |
| CS2662 | S20 | 1 | 10/14/2013 | 9:45 | 060 | L | 12 | 2 | 5 | 2/14/2017 | 7:55 | 2/14/2017 | 12:12 | 35 | 9188 | |
| CS2662 | S21 | 1 | 10/14/2013 | 10:00 | 036 | B | 2 | 4 | 9 | 2/14/2017 | 8:25 | 2/14/2017 | 12:55 | 35 | 10519 | |
| CS2662 | S22 | 1 | 10/14/2013 | 10:00 | 037 | D | 5 | 1 | 2 | 2/14/2017 | 8:25 | 2/14/2017 | 12:55 | 35 | 11893 | |
| CS2662 | S23 | 1 | 10/14/2013 | 10:00 | 038 | C | 6 | 3 | 7 | 2/14/2017 | 8:25 | 2/14/2017 | 12:55 | 35 | 10085 | |
| CS2662 | S24 | 1 | 10/14/2013 | 10:00 | 039 | A | 7 | 1 | 2 | 2/14/2017 | 8:25 | 2/14/2017 | 12:55 | 35 | 12736 | |
| CS2662 | S25 | 1 | 10/14/2013 | 10:00 | 040 | F | 1 | 4 | 9 | 2/14/2017 | 8:25 | 2/14/2017 | 12:55 | 35 | 9663 | |
| CS2662 | S26 | 1 | 10/14/2013 | 10:00 | 061 | G | 8 | 1 | 1 | 2/14/2017 | 8:25 | 2/14/2017 | 12:55 | 35 | 11773 | |
| CS2662 | S27 | 1 | 10/14/2013 | 10:00 | 062 | H | 9 | 1 | 1 | 2/14/2017 | 8:25 | 2/14/2017 | 12:55 | 35 | 11918 | |
| CS2662 | S28 | 1 | 10/14/2013 | 10:00 | 063 | J | 10 | 1 | 1 | 2/14/2017 | 8:25 | 2/14/2017 | 12:55 | 35 | 11707 | |
| CS2662 | S29 | 1 | 10/14/2013 | 10:00 | 064 | K | 11 | 1 | 1 | 2/14/2017 | 8:25 | 2/14/2017 | 12:55 | 35 | 9860 | |
| CS2662 | S30 | 1 | 10/14/2013 | 10:00 | 065 | L | 12 | 1 | 1 | 2/14/2017 | 8:25 | 2/14/2017 | 12:55 | 35 | 9677 | |
| CS2662 | S31 | 1 | 10/14/2013 | 10:15 | 041 | B | 2 | 4 | 5 | 2/14/2017 | 8:55 | 2/14/2017 | 13:33 | 35 | 11264 | |
| CS2662 | S32 | 1 | 10/14/2013 | 10:15 | 042 | D | 5 | 2 | 2 | 2/14/2017 | 8:55 | 2/14/2017 | 13:33 | 35 | 11547 | |
| CS2662 | S33 | 1 | 10/14/2013 | 10:15 | 043 | C | 6 | 2 | 2 | 2/14/2017 | 8:55 | 2/14/2017 | 13:33 | 35 | 10213 | |
| CS2662 | S34 | 1 | 10/14/2013 | 10:15 | 044 | A | 7 | 3 | 4 | 2/14/2017 | 8:55 | 2/14/2017 | 13:33 | 35 | 12370 | |
| CS2662 | S35 | 1 | 10/14/2013 | 10:15 | 045 | F | 1 | 9 | 11 | 2/14/2017 | 8:55 | 2/14/2017 | 13:33 | 35 | 11076 | |
| CS2662 | S36 | 1 | 10/14/2013 | 10:15 | 066 | G | 8 | 3 | 4 | 2/14/2017 | 8:55 | 2/14/2017 | 13:33 | 35 | 12460 | |
| CS2662 | S37 | 1 | 10/14/2013 | 10:15 | 067 | H | 9 | 1 | 1 | 2/14/2017 | 8:55 | 2/14/2017 | 13:33 | 35 | 11699 | |
| CS2662 | S38 | 1 | 10/14/2013 | 10:15 | 068 | J | 10 | 2 | 2 | 2/14/2017 | 8:55 | 2/14/2017 | 13:33 | 35 | 11724 | |
| CS2662 | S39 | 1 | 10/14/2013 | 10:15 | 069 | K | 11 | 1 | 1 | 2/14/2017 | 8:55 | 2/14/2017 | 13:33 | 35 | 9529 | |
| CS2662 | S40 | 1 | 10/14/2013 | 10:15 | 070 | L | 12 | 1 | 1 | 2/14/2017 | 8:55 | 2/14/2017 | 13:33 | 35 | 9639 | |



4/26/18

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CS2662 | S41 | 1 | 10/14/2013 | 10:30 | 046 | B | 2 | 4 | 5 | 2/14/2017 | 9:20 | 2/14/2017 | 14:12 | 35 | 11465 | no |
| CS2662 | S42 | 1 | 10/14/2013 | 10:30 | 047 | D | 5 | 9 | 11 | 2/14/2017 | 9:20 | 2/14/2017 | 14:12 | 35 | 11788 | |
| CS2662 | S7 | 1 | 2/13/2017 | 16:45 | 048 | C | 6 | 1 | 1 | 4/20/2018 | 7:46 | 4/20/2018 | 11:50 | 35 | 5807 | |
| CS2662 | S44 | 1 | 10/14/2013 | 10:30 | 049 | A | 7 | 2 | 2 | 2/14/2017 | 9:20 | 2/14/2017 | 14:12 | 35 | 12697 | |
| CS2662 | S45 | 1 | 10/14/2013 | 10:30 | 050 | F | 1 | 4 | 5 | 2/14/2017 | 9:20 | 2/14/2017 | 14:12 | 35 | 10795 | |
| CS2662 | S46 | 1 | 10/14/2013 | 10:30 | 071 | G | 8 | 1 | 1 | 2/14/2017 | 9:20 | 2/14/2017 | 14:12 | 35 | 12139 | |
| CS2662 | S47 | 1 | 10/14/2013 | 10:30 | 072 | H | 9 | 3 | 4 | 2/14/2017 | 9:20 | 2/14/2017 | 14:12 | 35 | 10903 | |
| CS2662 | S48 | 1 | 10/14/2013 | 10:30 | 073 | J | 10 | 0 | 0 | 2/14/2017 | 9:20 | 2/14/2017 | 14:12 | 35 | 9708 | |
| CS2662 | S49 | 2 | 10/14/2013 | 10:30 | 074 | K | 11 | 0 | 0 | 2/14/2017 | 9:20 | 2/14/2017 | 14:12 | 35 | 6723 | |
| CS2662 | S6 | 1 | 2/13/2017 | 16:45 | 075 | L | 12 | 9 | 11 | 4/19/2018 | 8:13 | 4/19/2018 | 12:21 | 35 | 5674 | |

| Std./Ba Carrier ID | 'Std./ 'Carrier Type | Spike Vol. (ml) | pipet No. | Activity added (dpm) | Ref. date |
|---|---|---|---|---|---|
| 907.3610.53 | Ra 226 | 0.2 | rs015 | 205 | 2/24/2010 |

Spiked by: PJW 12/6/2011
Spike Witness: GDW 12/6/2011
Reviewed by:







4/26/18

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 272.2571 | 0.028571 | 1218.9444 | 4.633333 | 35 | 0.181286 | 0.007554 | 0.000126 | 1.3781 | CS2662 S39 |
| 275.4 | 0.028571 | 1218.9444 | 4.633333 | 35 | 0.181286 | 0.007554 | 0.000126 | 1.3941 | CS2662 S40 |
| 327.5714 | 0.114286 | 1218.9514 | 4.866667 | 35 | 0.181286 | 0.007554 | 0.000126 | 1.6606 | CS2662 S41 |
| 336.8 | 0.257143 | 1218.9514 | 4.866667 | 35 | 0.181286 | 0.007554 | 0.000126 | 1.7066 | CS2662 S42 |
| 165.9143 | 0.028571 | 430.6257 | 4.066667 | 35 | 0.181286 | 0.007554 | 0.000126 | 0.8362 | CS2662 S7 |
| 362.7714 | 0.057143 | 1218.9514 | 4.866667 | 35 | 0.181286 | 0.007554 | 0.000126 | 1.8394 | CS2662 S44 |
| 308.4286 | 0.114286 | 1218.9514 | 4.866667 | 35 | 0.181286 | 0.007554 | 0.000126 | 1.5635 | CS2662 S45 |
| 346.8286 | 0.028571 | 1218.9514 | 4.866667 | 35 | 0.181286 | 0.007554 | 0.000126 | 1.7588 | CS2662 S46 |
| 311.5143 | 0.085714 | 1218.9514 | 4.866667 | 35 | 0.181286 | 0.007554 | 0.000126 | 1.5793 | CS2662 S47 |
| 277.3714 | 0 | 1218.9514 | 4.866667 | 35 | 0.181286 | 0.007554 | 0.000126 | 1.4067 | CS2662 S48 |
| 192.0857 | 0 | 1218.9514 | 4.866667 | 35 | 0.181286 | 0.007554 | 0.000126 | 0.9742 | CS2662 S49 |
| 162.1143 | 0.257143 | 429.6444 | 4.133333 | 35 | 0.181286 | 0.007554 | 0.000126 | 0.8161 | CS2662 S6 |



4/24/18

# Radium-226 in Water by Radon Emanation Technique for Calibration--Method 903.1

Calibration results

Analyst: AZ
Prep. Date S:
Prep. Date C:
SOP Used: 783R12

Count Date: 4/24/2018

| W.O.# | S ID | Flask No. | Counter No. | Scaler No. | Ra-226 Standard (dpm) | Efficiency | |
|---|---|---|---|---|---|---|---|
| CS2662 | S1 | 026 | B | 2 | 205.0155499 | 0.966087641 | 0.9660 |
| CS2662 | S2 | 027 | D | 5 | 205.0155499 | 1.466783587 | 1.4668 |
| CS2662 | S3 | 028 | C | 6 | 205.0155499 | 0.956192844 | 0.9561 |
| CS2662 | S4 | 029 | A | 7 | 205.0155499 | 1.623515252 | 1.6235 |
| CS2662 | S5 | 030 | F | 1 | 205.0155499 | 1.201353253 | 1.2014 |
| CS2662 | S6 | 051 | G | 8 | 205.0155499 | 1.60476254 | 1.6048 |
| CS2662 | S7 | 052 | H | 9 | 205.0155499 | 1.650766565 | 1.6508 |
| CS2662 | S8 | 053 | J | 10 | 205.0155499 | 1.642987179 | 1.6430 |
| CS2662 | S9 | 054 | K | 11 | 205.0155499 | 1.050432842 | 1.0500 |
| CS2662 | S10 | 055 | L | 12 | 205.0155499 | 1.429726348 | 1.4297 |
| CS2662 | S11 | 031 | B | 2 | 205.0155499 | 1.512686904 | 1.5127 |
| CS2662 | S12 | 032 | D | 5 | 205.0155499 | 1.70470009 | 1.7047 |
| CS2662 | S13 | 033 | C | 6 | 205.0155499 | 1.34192837 | 1.3419 |
| CS2662 | S14 | 034 | A | 7 | 205.0155499 | 1.838431288 | 1.8384 |
| CS2662 | S8 | 035 | F | 1 | 205.0155499 | 1.212318562 | 1.2123 |
| CS2662 | S16 | 056 | G | 8 | 205.0155499 | 1.614247598 | 1.6142 |
| CS2662 | S17 | 057 | H | 9 | 205.0155499 | 1.550195115 | 1.5502 |
| CS2662 | S18 | 058 | J | 10 | 205.0155499 | 1.606120819 | 1.6061 |
| CS2662 | S19 | 059 | K | 11 | 205.0155499 | 1.390352432 | 1.3904 |
| CS2662 | S20 | 060 | L | 12 | 205.0155499 | 1.324809238 | 1.3248 |
| CS2662 | S21 | 036 | B | 2 | 205.0155499 | 1.518632577 | 1.5186 |
| CS2662 | S22 | 037 | D | 5 | 205.0155499 | 1.718185204 | 1.7182 |
| CS2662 | S23 | 038 | C | 6 | 205.0155499 | 1.456257329 | 1.4563 |
| CS2662 | S24 | 039 | A | 7 | 205.0155499 | 1.83999756 | 1.8400 |
| CS2662 | S25 | 040 | F | 1 | 205.0155499 | 1.394941738 | 1.3949 |
| CS2662 | S26 | 061 | G | 8 | 205.0155499 | 1.701013948 | 1.7010 |
| CS2662 | S27 | 062 | H | 9 | 205.0155499 | 1.721966252 | 1.7220 |
| CS2662 | S28 | 063 | J | 10 | 205.0155499 | 1.691477038 | 1.6915 |
| CS2662 | S29 | 064 | K | 11 | 205.0155499 | 1.424588043 | 1.4246 |
| CS2662 | S30 | 065 | L | 12 | 205.0155499 | 1.398144791 | 1.3981 |
| CS2662 | S31 | 041 | B | 2 | 205.0155499 | 1.628597801 | 1.6286 |
| CS2662 | S32 | 042 | D | 5 | 205.0155499 | 1.669869627 | 1.6699 |
| CS2662 | S33 | 043 | C | 6 | 205.0155499 | 1.4769142 | 1.4769 |
| CS2662 | S34 | 044 | A | 7 | 205.0155499 | 1.788743091 | 1.7887 |
| CS2662 | S35 | 045 | F | 1 | 205.0155499 | 1.600560925 | 1.6006 |
| CS2662 | S36 | 066 | G | 8 | 205.0155499 | 1.801761073 | 1.8018 |
| CS2662 | S37 | 067 | H | 9 | 205.0155499 | 1.692024304 | 1.6920 |
| CS2662 | S38 | 068 | J | 10 | 205.0155499 | 1.695471659 | 1.6955 |
| CS2662 | S39 | 069 | K | 11 | 205.0155499 | 1.378146286 | 1.3781 |
| CS2662 | S40 | 070 | L | 12 | 205.0155499 | 1.394057153 | 1.3941 |
| CS2662 | S41 | 046 | B | 2 | 205.0155499 | 1.660595522 | 1.6606 |
| CS2662 | S42 | 047 | D | 5 | 205.0155499 | 1.706552785 | 1.7066 |
| CS2662 | S7 | 048 | C | 6 | 205.0155499 | 0.836193511 | 0.8362 |
| CS2662 | S44 | 049 | A | 7 | 205.0155499 | 1.839449692 | 1.8394 |
| CS2662 | S45 | 050 | F | 1 | 205.0155499 | 1.563512919 | 1.5635 |
| CS2662 | S46 | 071 | G | 8 | 205.0155499 | 1.758764872 | 1.7588 |
| CS2662 | S47 | 072 | H | 9 | 205.0155499 | 1.579331104 | 1.5793 |
| CS2662 | S48 | 073 | J | 10 | 205.0155499 | 1.406683459 | 1.4067 |
| CS2662 | S49 | 074 | K | 11 | 205.0155499 | 0.974158724 | 0.9742 |
| CS2662 | S6 | 075 | L | 12 | 205.0155499 | 0.816104612 | 0.8161 |





4/24/18

# RA226 Run Log

Logbook No./Page 475190

**ALS Laboratory Group**

| Sample ID | Batch ID | Scalar / Detector ID | Flask ID | Run # of 20 | Background Count Start Date | Background Count Start Time | Background Count Counts | Background Count Dur. (min.) | Background Count Pos. Chk. | Sample Count Start Date | Sample Count Start Time | Sample Count Counts | Sample Count Dur. (min.) | Sample Count Pos. Chk. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ICV2662-66 | Monthly CCV | B | 046 | NA | 4/17/18 | 9:12 | 7 | 15 | [illegible] | 4/17/18 | 13:52 | 1714 | 15 | [illegible] |
| -67 | | D | 047 | | | | 7 | | | | | 2238 | | |
| -68 | | C | 048 | | | | 4 | | | | | 1478 | | |
| -69 | | A | 049 | | | | 3 | | | | | 2438 | | |
| -70 | | F | 050 | | | | 2 | | | | | ~~2111~~ 2057 2411 | | [illegible] 4/17/18 |
| -71 | | G | 071 | | | | 5 | | | | | ~~1627~~ 627 | | |
| -72 | | H | 072 | | | | 6 | | | | | ~~1428~~ 1458 | | |
| -73 | | J | 073 | | | | 4 | | | | | ~~8~~ 882 | | |
| -74 | | K | 074 | | | | 1 | | | | | — | | |
| Check Source | — | B-L | Th | | | — | | | | | 14:09 | NA | 1 | [illegible] |
| Check Source | — | B-F, L | Th | NA | — | | | | | 4/19/18 | 7:00 | NA | 1 | [illegible] |
| CS2662-1 | Cell Calibration | B | 026 | | 4/19/18 | 7:15 | 2 | 35 | [illegible] | | 12:21 | 6709 | 35 | [illegible] |
| -2 | | D | 027 | | | | 9 | | | | | 10200 | | |
| -3 | | C | 028 | | | | 1 | | | | | 6638 | | |
| -4 | | A | 029 | | | | 7 | | | | | 11283 | | |
| -5 | | F | 070 | | | | 3 | | | | | 8344 | | |
| -6 | | L | ~~05075~~ | | | | 9 | | | | | 5674 | | |
| Check Source | — | B-L | Th | NA | — | | | | | 4/20/18 | 6:46 | NA | 1 | [illegible] |
| CS6226-7 | Cell Calibration | C | 048 | | 4/20/18 | 6:54 | 1 | 35 | [illegible] | 4/20/18 | 11:50 | 3807 | 35 | [illegible] |
| -8 | | F | 035 | | | | 8 | | | | | 8436 | | |
| -9 | | K | 054 | | | | 5 | | | | | 7305 | | |
| Check Source | — | B-L | Th | NA | — | | | | | 4/20/18 | 13:31 | NA | 1 | [illegible] |

Comments: CHECK SOURCE FILE: I:\Oprtns\RAD\INST\ALPHSCNT\Daily Checks

Analyst / Date [illegible] 4/20/18

Form 795r5.xls (11/9/2012)

Note: Each page is copied as completed and included with the workorder/run documentation; reviewed subsequently

# RA226 Run Log

Logbook No./Page 475191

**ALS Laboratory Group**

| Sample ID | Batch ID | Scalar / Detector ID | Flask ID | Run # of 20 | Background Count Start Date | Background Count Start Time | Background Count Counts | Background Count Dur. (min.) | Background Count Pos. Chk. | Sample Count Start Date | Sample Count Start Time | Sample Count Counts | Sample Count Dur. (min.) | Sample Count Pos. Chk. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Check Source | — | B-L | Th | NA | → | | | | | 4/23/18 | 8:05 | NA | 1 | [illegible] |
| 1803387-1 | RE180404-1 | B | 031 | | 4/23/18 | 8:23 | 6 | 30 | [illegible] | 4/23/18 | 13:13 | 11 | 30 | [illegible] |
| -4 | | D | 032 | | | | 9 | | | | | 17 | | |
| -5 | | C | 033 | | | | 7 | | | | | 12 | | |
| 395-1 | | A | 034 | | | | 8 | | | | | 100 | | |
| -2 | | F | 040 | | | | 7 | | | | | 75 | | |
| 260-1 | RE180411-1 | G | 051 | | | | 9 | | | | | 20 | | |
| 434-21 | | H | 052 | | | | 2 | | | | | 11 | | |
| -22 | | J | 053 | | | | 6 | | | | | 100 | | |
| -23 | | K | 054 | | | | 6 | | | | | 21 | | |
| -24 | | L | 055 | | | | 6 | | | | | 40 | | |
| Check Source | — | B-L | Th | NA | → | | | | | 4/23/18 | 14:00 | NA | 1 | [illegible] |
| ~~IDV 2662~~ | ~~Monthly ICV~~ | ~~D~~ | ~~027~~ | | | | | | | | | | | |
| | | A | 029 | | | | | | | | | | | |
| | | K | 064 | | | | | | | | | | | |

[illegible] 5/2/18

Comments: CHECK SOURCE FILE: I:\Oprtns\RAD\INST\ALPHSCNT\Daily Checks

Analyst / Date [illegible] 4/24/18

Note: Each page is copied as completed and included with the workorder/run documentation; reviewed subsequently



Form [illegible]

# RA226 Run Log

Logbook No./Page 475192

**ALS Laboratory Group**

| Sample ID | Batch ID | Scalar / Detector ID | Flask ID | Run # of 20 | Background Count Start Date | Background Count Start Time | Background Count Counts | Background Count Dur. (min.) | Background Count Pos. Chk. | Sample Count Start Date | Sample Count Start Time | Sample Count Counts | Sample Count Dur. (min.) | Sample Count Pos. Chk. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Check Source | — | D,A,K | Th | NA | | | | | | 4/24/18 | 6:13 | NA | 1 | [illegible] |
| ICV-2662-76 | monthly ICV | D | 027 | | 4/24/18 | 6:16 | 8 | 15 | [illegible] | 4/24/18 | | | 15 | [illegible] |
| -77 | | A | 021 | | | | 21 | | | | | | | |
| -78 | | K | 064 | | | | 2 | | | | | | | |
| -79 | | F | 030 | | | | 4 | | | | | | | |
| | | K | 054 | | | 6:37 | | | | | | | | |

[illegible] 4/24/18

**Comments: CHECK SOURCE FILE: I:\Oprtns\RAD\INST\ALPHSCNT\Daily Checks**

Analyst / Date [illegible] 4/24/18

Form 795r5.xls (11/9/2012)

Note: Each page is copied as completed and included with the workorder/run documentation; reviewed subsequently

PROJECT 907.3610.53 Ra-226 Notebook No. _____ 53

Continued From Page _____

Prepare a Calibration Source of ~1000 dpm/ml of Ra-226 from RSO # 907.

Density of 0.1 M HCl diluent lot# H42A01 Bal

Mass of Volumetric flask 68.2976 g 12

Mass of flask + Acid. 168.0675 g 4

Net mass 100 mls diluent 99.7699

$\rho = 0.9977$ g/ml

Mass of Parent transferred

Mass of Source (open) 37.7936 g 12

Mass of empty vial 32.7493 g 4

Net mass transferred 5.0043 g

Dilute to final Vol

Mass of Volume, Parent + Diluent 1151.5 g 26

Net mass of empty Volume: 74.7890 g 12

Final Mass = 1076.711 g

Activity Calculation

$$\left(1.875\times10^{4}\ \text{Bq}\right)\left(\frac{60\ \text{dpm}}{1\ \text{Bq}}\right)\left(\frac{5.0043\ \text{g}}{5.08515\ \text{g}}\right)\left(\frac{0.9977\ \text{g/ml}}{1076.711\ \text{g}}\right) = 1025.87\ \frac{\text{dpm}}{\text{ml}}$$

RG 4/6/10

Stnd ID: 907.3610.53

Description: Ra-226

Expiration: 3/10/2011

Activity: 1025.87 dpm/mL

2s Uncertainty: 50.27 dpm/mL

Ref. Date: 2/24/2010

Ref Time: N/A

Prep Date: 3/5/2010 Prep by: JD

Matrix/Comp. 0.1M HCl

Half Life (y): 1.60E+03

RG 4/6/10

| Reverification Log | | |
|---|---|---|
| Analysis Date | Initials | Expiration Date |
| 5-3-11 | DC | 5-3-12 |
| 9-23-11 | RG | 9-23-12 |
| | | |
| | | |
| | | |

RG 4/6/10

RG 4/6/10

Continued on Page

Read and Understood By

Signed 3/5/10 Date

Signed 3/10/10 Date

Eckert & Ziegler Analytics

PCL 2-26-2010

RSO# 907

1380 Seaboard Industrial Blvd.
Atlanta, Georgia 30318
Tel 404•352•8677
Fax 404•352•2837
www.analyticsinc.com

# CERTIFICATE OF CALIBRATION

## Standard Radionuclide Source

81680A-307

5 mL Liquid in Flame Sealed Vial

**Customer:** ALS Lab/Fort Collins, CO
**P.O. No.:** 73625 02-04-10, Item 1

This standard radionuclide source was prepared gravimetrically from a master solution calibrated by Eckert & Ziegler Analytics, using a germanium gamma spectrometer system. Radionuclide purity and calibration were checked with a germanium gamma spectrometer system. The nuclear decay rate and reference date for this source are given below. Eckert & Ziegler Analytics (EZA) maintains traceability to the National Institute of Standards and Technology through a Measurements Assurance Program as described in USNRC Regulatory Guide 4.15, Revision 1, February, 1979, and compliance with ANSI N42.22-1995, "Traceability of Radioactive Sources to NIST." EZA is accredited by the Health Physics Society (HPS) for the production of NIST-traceable sources, and this source was produced in accordance with the HPS accreditation requirements. Customers may report any concerns with the accreditation program to the HPS Secretariat, 1313 Dolley Madison Blvd., Ste. 402, McLean, VA 22101.

| Isotope | Half-Life, Days | Activity (Bq) | Uncertainty*, % Type $u_A$ | $u_B$ | U | Reference Date (12:00 PM EST) |
|---|---|---|---|---|---|---|
| Ra-228 | 5.844E+05 | 1.875E+04 | 0.5 | 2.4 | 4.9 | 02/24/2010 |

*Uncertainty: U - Relative expanded uncertainty, k = 2. See NIST Technical Note 1297, "Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results."

**Comments:**
Impurities: γ-impurities < 0.1 %. 5.08515 grams in 0.1M HCl solution with approximately 30 µg/g Ba carrier.

Source Prepared by: _____
W. Mao, Radiochemist

QA Approved: _____ Date: 2/24/10
J. D. McCorvey, QA Manager Alternate

Reverified: 5-3-11 DC
New Expiration Date: 5-3-12

ACCREDITED SOURCE CALIBRATION LABORATORY HEALTH PHYSICS SOCIETY FOUNDED 1958

ANA Form005 Rev. —

Single Isotope Certificate, Rev 1 9/28/2009

# Radiochemistry Solution Report

| Solution Id: | 907.3610.53 | Name: | Ra-226 Calibration source | Type: | IS |
|---|---|---|---|---|---|
| Lot: | | Vendor Name: | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Final Vol: | 1079.193 | Dept: | RD | Prep By | JDD | on | 3/5/2010 | Reviewed By | rxg | on | 4/6/2010 |
| Units: | mL | Location: | RADSTD | Opened By | | on | | Verified By | JCP | on | 9/23/2011 |
| Matrix: | LIQUID | ExpireDate: | 9/23/2012 | Received By | | on | | Deactivated By | | on | |

Comment:

| Component Name | Component ID | Volume Added | Units |
|---|---|---|---|
| Ra-226 Parent source | 907 | 5.0043 | g |

| CompName | Calibrated Primary Act/Conc | Calibration Date | Reference Date | 1/2 Life (Yrs) | Final Act/Conc | Summed Conc | Units |
|---|---|---|---|---|---|---|---|
| Rn-222 | 99654.24 | 2/24/2010 | 10/11/2011 | 1600 (Prnt) | 461.778855737817 | | pCi/ml |
| Ra-226 | 99654.24 | 2/24/2010 | 10/11/2011 | 1600 | 461.778855737817 | | pCi/ml |

## Associated Parent IDs

907

## Parent Solutions Sub Report

| Solution Id: | 907 | Name: | Ra-226 Parent source | Type: | PS |
|---|---|---|---|---|---|

| Final Vol: | 5.08515 | Units: | g | Matrix: | LIQUID |
|---|---|---|---|---|---|

| CompName | Calibration Date | Reference Date | Decay Corrected Act/Conc | Units |
|---|---|---|---|---|
| Rn-222 | 2/24/2010 | 10/11/2011 | 1.6820982248009E-42 | pCi/g |
| Ra-226 | 2/24/2010 | 10/11/2011 | 99584.0552331242 | pCi/g |

Abbreviations: NC = Not Calculated for reagents when the volume added is not entered.
NE = Not Entered

(Prnt) = Secular equilibrium; parent half life used to calculate concentration.

# ICVs

# Radium-226 in Water by Radon Emanation Technique for Calibration--Method 903.1

Analyst: CDJ
Prep. Date S: 11/19/2016
Prep. Date C: 11/19/2016
SOP Used: 783R12

| | | S | Purge (end) | | | | | | | Deeman. (end) | | Count Start | | Count | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | S | V | Date | Time | Flask | Counter | Scaler | CBKG | BKG DUR | Date | Time | Date | Time | Duration | COUNT | REMARKS |
| W.O.# | ID | (L) | D1 | T1 | No. | No. | No. | # | (min) | D2 | T2 | D3 | T3 | (min.) | # | |
| ICV2662 | ICV1 | 1 | 11/19/2016 | 14:20 | 026 | B | 2 | 8 | 15 | 2/16/2017 | 8:06 | 2/16/2017 | 12:51 | 15 | 2041 | NA |
| ICV2662 | ICV2 | 1 | 11/19/2016 | 14:20 | 027 | D | 5 | 9 | 15 | 2/16/2017 | 8:06 | 2/16/2017 | 12:51 | 15 | 2499 | |
| ICV2662 | ICV3 | 1 | 11/19/2016 | 14:20 | 028 | C | 6 | 4 | 15 | 2/16/2017 | 8:06 | 2/16/2017 | 12:51 | 15 | 2231 | |
| ICV2662 | ICV4 | 1 | 11/19/2016 | 14:20 | 029 | A | 7 | 9 | 15 | 2/16/2017 | 8:06 | 2/16/2017 | 12:51 | 15 | 2128 | |
| ICV2662 | ICV5 | 1 | 11/19/2016 | 14:20 | 030 | F | 1 | 10 | 15 | 2/16/2017 | 8:06 | 2/16/2017 | 12:51 | 15 | 2346 | |
| ICV2662 | ICV6 | 1 | 11/19/2016 | 14:20 | 051 | G | 8 | 5 | 15 | 2/16/2017 | 8:06 | 2/16/2017 | 12:51 | 15 | 2438 | |
| ICV2662 | ICV7 | 1 | 11/19/2016 | 14:20 | 052 | H | 9 | 2 | 15 | 2/16/2017 | 8:06 | 2/16/2017 | 12:51 | 15 | 2310 | |
| ICV2662 | ICV8 | 1 | 11/19/2016 | 14:20 | 053 | J | 10 | 5 | 15 | 2/16/2017 | 8:06 | 2/16/2017 | 12:51 | 15 | 2494 | |
| ICV2662 | ICV9 | 1 | 11/19/2016 | 14:20 | 054 | K | 11 | 6 | 15 | 2/16/2017 | 8:06 | 2/16/2017 | 12:51 | 15 | 2012 | |
| ICV2662 | ICV10 | 1 | 11/19/2016 | 14:20 | 055 | L | 12 | 5 | 15 | 2/16/2017 | 8:06 | 2/16/2017 | 12:51 | 15 | 1959 | |
| ICV2662 | ICV11 | 1 | 11/19/2016 | 14:20 | 031 | B | 2 | 6 | 15 | 2/16/2017 | 8:30 | 2/16/2017 | 13:18 | 15 | 2235 | |
| ICV2662 | ICV12 | 1 | 11/19/2016 | 14:20 | 032 | D | 5 | 4 | 15 | 2/16/2017 | 8:30 | 2/16/2017 | 13:18 | 15 | 2590 | |
| ICV2662 | ICV13 | 1 | 11/19/2016 | 14:20 | 033 | C | 6 | 6 | 15 | 2/16/2017 | 8:30 | 2/16/2017 | 13:18 | 15 | 2149 | |
| ICV2662 | ICV14 | 1 | 11/19/2016 | 14:20 | 034 | A | 7 | 1 | 15 | 2/16/2017 | 8:30 | 2/16/2017 | 13:18 | 15 | 2629 | |
| ICV2662 | ICV15 | 1 | 11/19/2016 | 14:20 | 035 | F | 1 | 3 | 15 | 2/16/2017 | 8:30 | 2/16/2017 | 13:18 | 15 | 1645 | |
| ICV2662 | ICV16 | 1 | 11/19/2016 | 14:20 | 056 | G | 8 | 4 | 15 | 2/16/2017 | 8:30 | 2/16/2017 | 13:18 | 15 | 2450 | |
| ICV2662 | ICV17 | 1 | 11/19/2016 | 14:20 | 057 | H | 9 | 4 | 15 | 2/16/2017 | 8:30 | 2/16/2017 | 13:18 | 15 | 2454 | |
| ICV2662 | ICV18 | 1 | 11/19/2016 | 14:20 | 058 | J | 10 | 3 | 15 | 2/16/2017 | 8:30 | 2/16/2017 | 13:18 | 15 | 2624 | |
| ICV2662 | ICV19 | 1 | 11/19/2016 | 14:20 | 059 | K | 11 | 3 | 15 | 2/16/2017 | 8:30 | 2/16/2017 | 13:18 | 15 | 2062 | |
| ICV2662 | ICV20 | 1 | 11/19/2016 | 14:20 | 060 | L | 12 | 6 | 15 | 2/16/2017 | 8:30 | 2/16/2017 | 13:18 | 15 | 1789 | |
| ICV2662 | ICV21 | 1 | 11/19/2016 | 14:20 | 036 | B | 2 | 8 | 15 | 2/16/2017 | 9:01 | 2/16/2017 | 13:38 | 15 | 2249 | |
| ICV2662 | ICV22 | 1 | 11/19/2016 | 14:20 | 037 | D | 5 | 11 | 15 | 2/16/2017 | 9:01 | 2/16/2017 | 13:38 | 15 | 2538 | |
| ICV2662 | ICV23 | 1 | 11/19/2016 | 14:20 | 038 | C | 6 | 5 | 15 | 2/16/2017 | 9:01 | 2/16/2017 | 13:38 | 15 | 2365 | |
| ICV2662 | ICV24 | 1 | 11/19/2016 | 14:20 | 039 | A | 7 | 7 | 15 | 2/16/2017 | 9:01 | 2/16/2017 | 13:38 | 15 | 2719 | |
| ICV2662 | ICV25 | 1 | 11/19/2016 | 14:20 | 040 | F | 1 | 10 | 15 | 2/16/2017 | 9:01 | 2/16/2017 | 13:38 | 15 | 2194 | |
| ICV2662 | ICV26 | 1 | 11/19/2016 | 14:20 | 061 | G | 8 | 4 | 15 | 2/16/2017 | 9:01 | 2/16/2017 | 13:38 | 15 | 2305 | |
| ICV2662 | ICV27 | 1 | 11/19/2016 | 14:20 | 062 | H | 9 | 2 | 15 | 2/16/2017 | 9:01 | 2/16/2017 | 13:38 | 15 | 2483 | |
| ICV2662 | ICV28 | 1 | 11/19/2016 | 14:20 | 063 | J | 10 | 1 | 15 | 2/16/2017 | 9:01 | 2/16/2017 | 13:38 | 15 | 2680 | |
| ICV2662 | ICV29 | 1 | 11/19/2016 | 14:20 | 064 | K | 11 | 5 | 15 | 2/16/2017 | 9:01 | 2/16/2017 | 13:38 | 15 | 2040 | |
| ICV2662 | ICV30 | 1 | 11/19/2016 | 14:20 | 065 | L | 12 | 6 | 15 | 2/16/2017 | 9:01 | 2/16/2017 | 13:38 | 15 | 1999 | |
| ICV2662 | ICV31 | 1 | 11/19/2016 | 14:20 | 041 | B | 2 | 6 | 15 | 2/16/2017 | 9:23 | 2/16/2017 | 14:01 | 15 | 2257 | |
| ICV2662 | ICV32 | 1 | 11/19/2016 | 14:20 | 042 | D | 5 | 7 | 15 | 2/16/2017 | 9:23 | 2/16/2017 | 14:01 | 15 | 2431 | |
| ICV2662 | ICV33 | 1 | 11/19/2016 | 14:20 | 043 | C | 6 | 4 | 15 | 2/16/2017 | 9:23 | 2/16/2017 | 14:01 | 15 | 2059 | |
| ICV2662 | ICV34 | 1 | 11/19/2016 | 14:20 | 044 | A | 7 | 3 | 15 | 2/16/2017 | 9:23 | 2/16/2017 | 14:01 | 15 | 2479 | |
| ICV2662 | ICV35 | 1 | 11/19/2016 | 14:20 | 045 | F | 1 | 7 | 15 | 2/16/2017 | 9:23 | 2/16/2017 | 14:01 | 15 | 2559 | |
| ICV2662 | ICV36 | 1 | 11/19/2016 | 14:20 | 066 | G | 8 | 8 | 15 | 2/16/2017 | 9:23 | 2/16/2017 | 14:01 | 15 | 2548 | |
| ICV2662 | ICV37 | 1 | 11/19/2016 | 14:20 | 067 | H | 9 | 3 | 15 | 2/16/2017 | 9:23 | 2/16/2017 | 14:01 | 15 | 2571 | |
| ICV2662 | ICV38 | 1 | 11/19/2016 | 14:20 | 068 | J | 10 | 3 | 15 | 2/16/2017 | 9:23 | 2/16/2017 | 14:01 | 15 | 2464 | |
| ICV2662 | ICV39 | 1 | 11/19/2016 | 14:20 | 069 | K | 11 | 4 | 15 | 2/16/2017 | 9:23 | 2/16/2017 | 14:01 | 15 | 2044 | |
| ICV2662 | ICV40 | 1 | 11/19/2016 | 14:20 | 070 | L | 12 | 6 | 15 | 2/16/2017 | 9:23 | 2/16/2017 | 14:01 | 15 | 1859 | |
| ICV2662 | ICV41 | 1 | 11/19/2016 | 14:20 | 046 | B | 2 | 3 | 15 | 2/16/2017 | 9:45 | 2/16/2017 | 14:22 | 15 | 2393 | |
| ICV2662 | ICV42 | 1 | 11/19/2016 | 14:20 | 047 | D | 5 | 15 | 15 | 2/16/2017 | 9:45 | 2/16/2017 | 14:22 | 15 | 2270 | |
| ICV2662 | ICV43 | 1 | 11/19/2016 | 14:20 | 048 | C | 6 | 6 | 15 | 2/16/2017 | 9:45 | 2/16/2017 | 14:22 | 15 | 1946 | |
| ICV2662 | ICV44 | 1 | 11/19/2016 | 14:20 | 049 | A | 7 | 6 | 15 | 2/16/2017 | 9:45 | 2/16/2017 | 14:22 | 15 | 2609 | |

90 01 153

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ICV2662 | ICV45 | 1 | 11/19/2016 | 14:20 | 050 | F | 1 | 2 | 15 | 2/16/2017 | 9:45 | 2/16/2017 | 14:22 | 15 | 2229 | NA |
| ICV2662 | ICV46 | 1 | 11/19/2016 | 14:20 | 071 | G | 8 | 7 | 15 | 2/16/2017 | 9:45 | 2/16/2017 | 14:22 | 15 | 2449 | |
| ICV2662 | ICV47 | 1 | 11/19/2016 | 14:20 | 072 | H | 9 | 1 | 15 | 2/16/2017 | 9:45 | 2/16/2017 | 14:22 | 15 | 2340 | |
| ICV2662 | ICV48 | 1 | 11/19/2016 | 14:20 | 073 | J | 10 | 19 | 15 | 2/16/2017 | 9:45 | 2/16/2017 | 14:22 | 15 | 1997 | |
| ICV2662 | ICV49 | 1 | 11/19/2016 | 14:20 | 074 | K | 11 | 4 | 15 | 2/16/2017 | 9:45 | 2/16/2017 | 14:22 | 15 | 1298 | |
| ICV2662 | ICV50 | 1 | 11/19/2016 | 14:20 | 075 | L | 12 | 4 | 15 | 2/16/2017 | 9:45 | 2/16/2017 | 14:22 | 15 | 519 | |

| Std./Ba Carrier ID | 'Std./ 'Carrier Type | conc dpm/ mL | Spike Vol. (ml) | pipet No. | Activity added (dpm) | Ref. date |
|---|---|---|---|---|---|---|
| 916.4095.69 | Ra 226 | 100.64 | 1.0 | RS-033 | 100.64 | 7/1/2010 |

| | Initials | Date |
|---|---|---|
| Spiked by: | CDJ | 11/19/2016 |
| Spike Witness: | JKB | 11/19/2016 |
| Reviewed by: | JP | 2/16/17 |

ICV Radiometric Recovery Summary for B, D, C, A, F, G, H, J, K and L
Acceptance Criteria: Passing CCV (control limits = 67% - 120%)

| W.O.# | S ID | Flask No. | Efficiency | Denom | Ra-226 Activity (pCi/l) | Ra-226 Cnt. Unc. | Ra-226 2 sig. TPU | Ra-226 MDC | Sample ID | Radiometric Recovery (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| ICV2662 | ICV1 | 026 | 1.3827 | 0.005587 | 45.81 | 2.00 | 4.05 | 0.36 | ICV2662 ICV1 | 101.33% |
| ICV2662 | ICV2 | 027 | 1.7051 | 0.00689 | 45.50 | 1.79 | 3.93 | 0.30 | ICV2662 ICV2 | 100.64% |
| ICV2662 | ICV3 | 028 | 1.3764 | 0.005562 | 50.41 | 2.10 | 4.40 | 0.27 | ICV2662 ICV3 | 111.51% |
| ICV2662 | ICV4 | 029 | 1.3451 | 0.005435 | 49.08 | 2.10 | 4.31 | 0.39 | ICV2662 ICV4 | 108.57% |
| ICV2662 | ICV5 | 030 | 1.4832 | 0.005993 | 49.07 | 2.00 | 4.27 | 0.37 | ICV2662 ICV5 | 108.55% |
| ICV2662 | ICV6 | 051 | 1.6048 | 0.006484 | 47.24 | 1.88 | 4.09 | 0.25 | ICV2662 ICV6 | 104.49% |
| ICV2662 | ICV7 | 052 | 1.6508 | 0.00667 | 43.56 | 1.78 | 3.79 | 0.18 | ICV2662 ICV7 | 96.36% |
| ICV2662 | ICV8 | 053 | 1.6430 | 0.006639 | 47.20 | 1.86 | 4.07 | 0.25 | ICV2662 ICV8 | 104.41% |
| ICV2662 | ICV9 | 054 | 1.2414 | 0.005016 | 50.34 | 2.21 | 4.45 | 0.35 | ICV2662 ICV9 | 111.36% |
| ICV2662 | ICV10 | 055 | 1.4297 | 0.005777 | 42.58 | 1.89 | 3.78 | 0.29 | ICV2662 ICV10 | 94.19% |
| ICV2662 | ICV11 | 031 | 1.5127 | 0.00611 | 45.93 | 1.91 | 4.01 | 0.29 | ICV2662 ICV11 | 101.59% |
| ICV2662 | ICV12 | 032 | 1.7047 | 0.006886 | 47.28 | 1.83 | 4.06 | 0.22 | ICV2662 ICV12 | 104.59% |
| ICV2662 | ICV13 | 033 | 1.3419 | 0.00542 | 49.77 | 2.11 | 4.37 | 0.33 | ICV2662 ICV13 | 110.10% |
| ICV2662 | ICV14 | 034 | 1.8384 | 0.007426 | 44.55 | 1.70 | 3.82 | 0.12 | ICV2662 ICV14 | 98.55% |
| ICV2662 | ICV15 | 035 | 1.1955 | 0.004829 | 42.81 | 2.07 | 3.89 | 0.28 | ICV2662 ICV15 | 94.69% |
| ICV2662 | ICV16 | 056 | 1.6142 | 0.00652 | 47.23 | 1.87 | 4.08 | 0.23 | ICV2662 ICV16 | 104.47% |
| ICV2662 | ICV17 | 057 | 1.5502 | 0.006261 | 49.26 | 1.95 | 4.26 | 0.24 | ICV2662 ICV17 | 108.96% |
| ICV2662 | ICV18 | 058 | 1.6061 | 0.006487 | 50.86 | 1.95 | 4.37 | 0.21 | ICV2662 ICV18 | 112.51% |
| ICV2662 | ICV19 | 059 | 1.3904 | 0.005616 | 46.16 | 2.00 | 4.07 | 0.24 | ICV2662 ICV19 | 102.10% |
| ICV2662 | ICV20 | 060 | 1.3248 | 0.005351 | 41.95 | 1.95 | 3.77 | 0.33 | ICV2662 ICV20 | 92.79% |
| ICV2662 | ICV21 | 036 | 1.5186 | 0.006142 | 45.93 | 1.91 | 4.01 | 0.33 | ICV2662 ICV21 | 101.60% |
| ICV2662 | ICV22 | 037 | 1.7182 | 0.00695 | 45.78 | 1.79 | 3.95 | 0.33 | ICV2662 ICV22 | 101.26% |
| ICV2662 | ICV23 | 038 | 1.4563 | 0.00589 | 50.44 | 2.04 | 4.38 | 0.28 | ICV2662 ICV23 | 111.58% |
| ICV2662 | ICV24 | 039 | 1.8400 | 0.007442 | 45.88 | 1.73 | 3.93 | 0.25 | ICV2662 ICV24 | 101.48% |
| ICV2662 | ICV25 | 040 | 1.3949 | 0.005642 | 48.73 | 2.05 | 4.27 | 0.39 | ICV2662 ICV25 | 107.79% |
| ICV2662 | ICV26 | 061 | 1.7010 | 0.00688 | 42.10 | 1.72 | 3.66 | 0.22 | ICV2662 ICV26 | 93.13% |
| ICV2662 | ICV27 | 062 | 1.7220 | 0.006965 | 44.84 | 1.77 | 3.87 | 0.17 | ICV2662 ICV27 | 99.20% |
| ICV2662 | ICV28 | 063 | 1.6915 | 0.006842 | 49.30 | 1.87 | 4.22 | 0.14 | ICV2662 ICV28 | 109.04% |
| ICV2662 | ICV29 | 064 | 1.4246 | 0.005762 | 44.46 | 1.94 | 3.93 | 0.29 | ICV2662 ICV29 | 98.35% |
| ICV2662 | ICV30 | 065 | 1.3981 | 0.005655 | 44.37 | 1.95 | 3.93 | 0.31 | ICV2662 ICV30 | 98.14% |
| ICV2662 | ICV31 | 041 | 1.6286 | 0.006586 | 43.03 | 1.78 | 3.75 | 0.27 | ICV2662 ICV31 | 95.17% |
| ICV2662 | ICV32 | 042 | 1.6699 | 0.006753 | 45.19 | 1.80 | 3.91 | 0.28 | ICV2662 ICV32 | 99.95% |
| ICV2662 | ICV33 | 043 | 1.4769 | 0.005973 | 43.31 | 1.88 | 3.82 | 0.25 | ICV2662 ICV33 | 95.81% |
| ICV2662 | ICV34 | 044 | 1.7887 | 0.007234 | 43.09 | 1.70 | 3.72 | 0.19 | ICV2662 ICV34 | 95.31% |
| ICV2662 | ICV35 | 045 | 1.6006 | 0.006473 | 49.63 | 1.93 | 4.27 | 0.29 | ICV2662 ICV35 | 109.79% |
| ICV2662 | ICV36 | 066 | 1.8018 | 0.007287 | 43.88 | 1.71 | 3.78 | 0.27 | ICV2662 ICV36 | 97.07% |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| ICV2662 | ICV37 | 067 | 1.6920 | 0.006843 | 47.24 | 1.83 | 4.06 | 0.20 | ICV2662 ICV37 | 104.51% |
| ICV2662 | ICV38 | 068 | 1.6955 | 0.006857 | 45.18 | 1.79 | 3.90 | 0.20 | ICV2662 ICV38 | 99.95% |
| ICV2662 | ICV39 | 069 | 1.3781 | 0.005574 | 46.08 | 2.00 | 4.07 | 0.27 | ICV2662 ICV39 | 101.93% |
| ICV2662 | ICV40 | 070 | 1.3941 | 0.005638 | 41.38 | 1.89 | 3.70 | 0.31 | ICV2662 ICV40 | 91.53% |
| ICV2662 | ICV41 | 046 | 1.6606 | 0.006717 | 44.80 | 1.80 | 3.88 | 0.20 | ICV2662 ICV41 | 99.09% |
| ICV2662 | ICV42 | 047 | 1.7066 | 0.006903 | 41.13 | 1.71 | 3.59 | 0.38 | ICV2662 ICV42 | 90.97% |
| ICV2662 | ICV43 | 048 | 1.1596 | 0.00469 | 52.07 | 2.32 | 4.63 | 0.38 | ICV2662 ICV43 | 115.18% |
| ICV2662 | ICV44 | 049 | 1.8394 | 0.00744 | 44.05 | 1.70 | 3.78 | 0.24 | ICV2662 ICV44 | 97.43% |
| ICV2662 | ICV45 | 050 | 1.5635 | 0.006324 | 44.33 | 1.84 | 3.87 | 0.18 | ICV2662 ICV45 | 98.06% |
| ICV2662 | ICV46 | 071 | 1.7588 | 0.007114 | 43.22 | 1.72 | 3.74 | 0.27 | ICV2662 ICV46 | 95.59% |
| ICV2662 | ICV47 | 072 | 1.5793 | 0.006388 | 46.10 | 1.87 | 4.00 | 0.15 | ICV2662 ICV47 | 101.97% |
| ICV2662 | ICV48 | 073 | 1.4067 | 0.00569 | 43.77 | 1.95 | 3.88 | 0.51 | ICV2662 ICV48 | 96.81% |
| ICV2662 | ICV49 | 074 | 0.9742 | 0.00394 | 41.34 | 2.26 | 3.90 | 0.38 | ICV2662 ICV49 | 91.45% |
| ICV2662 | ICV50 | 075 | 0.3813 | 0.001542 | 42.04 | 3.66 | 4.88 | 0.98 | ICV2662 ICV50 | 92.98% |

# RA226 Run Log

Logbook No./Page 469346

**ALS Laboratory Group**

| Sample ID | Batch ID | Scalar / Detector ID | Flask ID | Run # of 20 | Background Count Start Date | Background Count Start Time | Background Counts | Background Dur. (min.) | Background Pos. Chk. | Sample Count Start Date | Sample Count Start Time | Sample Counts | Sample Dur. (min.) | Sample Pos. Chk. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1112201-S 36 | NA | G | 066 | NA | 2/13/17 | 13:13 | 3 | 15 | AZ | 2/14/17 | 13:33 | 12460 | 35 | AZ |
| -37 | | H | 067 | | | | 1 | | | | | 11699 | | |
| -38 | | J | 068 | | | | 2 | | | | | 11724 | | |
| -39 | | K | 069 | | | | 1 | | | | | 9829 | | |
| -40 | | L | 070 | | | | 1 | | | | | 9639 | | |
| -41 | | B | 046 | | | 1330 | 4 | | | | 15:26 | 11465 | | |
| -42 | | D | 047 | | | | 9 | | | | 14:12 | 11783 | | |
| -43 | | C | 048 | | | | 2 | | | | | 8005 | | |
| -44 | | A | 049 | | | | 2 | | | | | 12697 | | |
| -45 | | F | 050 | | | | 4 | | | | | 10715 | | |
| -46 | | G | 071 | | | | 1 | | | | | 12139 | | |
| -47 | | H | 072 | | | | 3 | | | | | 10403 | | |
| -48 | | J | 073 | | | | 0 | | | | | 9708 | | |
| -49 | | K | 074 | | | | 0 | | | | | 6723 | | |
| -50 | | L | 075 | | | | 2 | | | | | 2634 | | |
| Check Source | NA | B-L | Th | NA | | | | | | 2/14/17 | 6:41 | NA | 1 | AZ |
| Check Source | NA | B-L | Th | NA | | ~~AZ 2/15/17~~ 13:20 ~~7:35~~ | | | | 2/15/17 | 7:00 | NA | 1 | AZ |
| ICV 2662-1 | | B | 026 | | 2/15/17 | | 138 | 15 | AZ | 2/16/17 | 12:51 | 2041 | 15 | AZ |
| -2 | | D | 027 | | | | 149 | | | | | 2499 | | |
| -3 | | C | 028 | | | | 84 | | | | | 2235 | | |
| -4 | | A | 029 | | | | 101 | | | | | 2128 | | |
| -5 | | F | 030 | | | | 810 | | | | | 2346 | | |

**Comments: CHECK SOURCE FILE: I:\Oprtns\RAD\INST\ALPHSCNT\Daily Checks**

Analyst / Date AZ 2/16/17

Form 795r5.xls (11/9/2012)

Note: Each page is copied as completed and included with the workorder/run documentation; reviewed subsequently

# RA226 Run Log

Logbook No./Page 469347

**ALS Laboratory Group**

| Sample ID | Batch ID | Scalar / Detector ID | Flask ID | Run # of 20 | Background Count Start Date | Background Count Start Time | Background Count Counts | Background Count Dur. (min.) | Background Count Pos. Chk. | Sample Count Start Date | Sample Count Start Time | Sample Count Counts | Sample Count Dur. (min.) | Sample Count Pos. Chk. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ICV 2662-6 | NA | 6 | 051 | NA | 2/16/17 | ~~7:55~~ 13:20 | ~~155~~ | 15 | AL | 2/16/17 | 12:51 | 2438 | 15 | AL |
| -7 | | H | 052 | | | | ~~82~~ | | | | | 2310 | | |
| -8 | | J | 053 | | | | ~~65~~ | | | | | 2494 | | |
| -9 | | K | 054 | | | | ~~46~~ | | | | | 2012 | | |
| -10 | | L | 055 | | | | ~~45~~ | | | | | 1959 | | |
| -11 | | B | 031 | | | 13:41 ~~7:45~~ | 6 | | | | 13:18 | 2235 | | |
| -12 | | D | 032 | | | | 4 | | | | | 2590 | | |
| -13 | | C | 033 | | | | 6 | | | | | 2149 | | |
| -14 | | A | 034 | | | | 7 | | | | | 2629 | | |
| -15 | | F | 035 | | | | 3 | | | | | 1645 | | |
| -16 | | G | 056 | | | | 4 | | | | | 2450 | | |
| -17 | | H | 057 | | | | 4 | | | | | 2454 | | |
| -18 | | J | 058 | | | | 3 | | | | | 2624 | | |
| -19 | | K | 059 | | | | 3 | | | | | 2062 | | |
| -20 | | L | 060 | | | | 6 | | | | | 1789 | | |
| -21 | | B | 036 | | | 1400 | 8 | | | | 13:38 | 2249 | | |
| -22 | | D | 037 | | | | 11 | | | | | 2538 | | |
| -23 | | C | 038 | | | | 5 | | | | | 2365 | | |
| -24 | | A | 039 | | | | 7 | | | | | 2719 | | |
| -25 | | F | 040 | | | | 10 | | | | | 2194 | | |
| -26 | | G | 061 | | | | 4 | | | | | 2305 | | |
| -27 | | H | 062 | | | | 2 | | | | | 2483 | | |

**Comments: CHECK SOURCE FILE: I:\Oprtns\RAD\INST\ALPHSCNT\Daily Checks**

Analyst / Date AL 2/16/17

Form 795r5.xls (11/9/2012)

Note: Each page is copied as completed and included with the workorder/run documentation; reviewed subsequently

# RA226 Run Log

Logbook No./Page 469348

**ALS Laboratory Group**

| Sample ID | Batch ID | Scalar / Detector ID | Flask ID | Run # of 20 | Background Count Start Date | Background Count Start Time | Background Count Counts | Background Count Dur. (min.) | Background Count Pos. Chk. | Sample Count Start Date | Sample Count Start Time | Sample Count Counts | Sample Count Dur. (min.) | Sample Count Pos. Chk. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1CU2662-28 | 20 | J | 063 | NA | 2/15/17 | 14:00 | 1 | 15 | AL | 2/16/17 | 13:38 | 2680 | 15 | AL |
| -29 | | K | 064 | | | | 5 | | | | | 2040 | | |
| -30 | | L | 065 | | | | 6 | | | | | 1999 | | |
| -31 | | B | 041 | | | 14:20 | 6 | | | | 14:01 | 2257 | | |
| -32 | | D | 042 | | | | 7 | | | | | 2436 | | |
| -33 | | C | 043 | | | | 4 | | | | | 2059 | | |
| -34 | | A | 044 | | | | 3 | | | | | 2479 | | |
| -35 | | F | 045 | | | | 7 | | | | | 2559 | | |
| -36 | | G | 066 | | | | 8 | | | | | 2548 | | |
| -37 | | H | 067 | | | | 3 | | | | | 2571 | | |
| -38 | | J | 068 | | | | 3 | | | | | 2464 | | |
| -39 | | K | 069 | | | | 4 | | | | | 2044 | | |
| -40 | | L | 070 | | | | 6 | | | | | 1859 | | |
| -41 | | B | 046 | | | 1440 | 3 | | | | 14:22 | 2313 | | |
| -42 | | D | 047 | | | | 15 | | | | | 2270 | | |
| -43 | | C | 048 | | | | 6 | | | | | 1946 | | |
| -44 | | A | 049 | | | | 6 | | | | | 2609 | | |
| -45 | | F | 050 | | | | 2 | | | | | 2229 | | |
| -46 | | G | 071 | | | | 7 | | | | | 2449 | | |
| -47 | | H | 072 | | | | 1 | | | | | 2340 | | |
| -48 | | J | 073 | | | | 19 | | | | | 1997 | | |
| -49 | | K | 074 | | | | 4 | | | | | 1278 | | |

**Comments: CHECK SOURCE FILE: I:\Oprtns\RAD\INST\ALPHSCNT\Daily Checks**

Analyst / Date AL 2/16/17



Form 795r5.xls (11/9/2012)

Note: Each page is copied as completed and included with the workorder/run documentation; reviewed subsequently

# RA226 Run Log

Logbook No./Page 469349

**ALS Laboratory Group**

| Sample ID | Batch ID | Scalar / Detector ID | Flask ID | Run # of 20 | Background Count Start Date | Background Count Start Time | Background Count Counts | Background Count Dur. (min.) | Background Count Pos. Chk. | Sample Count Start Date | Sample Count Start Time | Sample Count Counts | Sample Count Dur. (min.) | Sample Count Pos. Chk. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ICV 2662-50 | — | L | 575 | | 2/15/17 | 14:40 | 4 | 15 | AZ | 2/16/17 | 14:22 | 519 | 15 | AZ |
| Check Source | — | B-L | Th | NA | | | | | | 2/16/17 | 8:00 | — | 1 | AZ |

JP 2/16/17

**Comments: CHECK SOURCE FILE: I:\Oprtns\RAD\INST\ALPHSCNT\Daily Checks**

Analyst / Date JP 2/16/17

Form 795r5.xls (11/9/2012)

Note: Each page is copied as completed and included with the workorder/run documentation; reviewed subsequently

Project 916.4095.69 Ra226 working std

Continued from Page

Prepare a working dilution of 916.3610.76 TE 12/8/14

1. Density of 0.1M HCl, lot # 0000092116
   Mass of 100mL vol. flask: 68.3000g Balance # 12
   Mass of flask & 100mL acid: 168.0372g Balance# 12
   Net Mass: 99.7372g
   Density: 0.9974g/mL

2. Mass of 916.3610.76 transferred:
   Mass of open empty nalgene: 74.1631g Balance# 12
   Mass of nalgene & standard: 77.5202g Balance# 12
   Net mass of standard transferred: 3.3571g Balance# NA

TE 12/8/14 TE 12/8/14

3. Dilute to final volume:
   Mass of nalgene, standard, & diluent: 1077.5g Balance# 26
   Mass of empty nalgene (from above): 74.1631g Balance# 12
   Net mass of new dilution: 1003.3369g Balance# NA

4. Final activity calculation:

$$30{,}156.00\ \text{dpm/g}\ (0.9974\ \text{g/mL})\left(\frac{3.3571\ \text{g}}{1003.3369\ \text{g}}\right) = 100.64\ \text{dpm/mL}$$

TE 12/8/14

JP 1/9/15

*Stnd ID:* **916.4095.69**

*Description:* **Ra-226**
*Expiration:* **1/6/2016**
*Activity:* **100.64** **dpm/mL**

*2s Uncertainty:* **4.93** **dpm/mL**
*Ref. Date:* **7/1/2010**
*Ref Time:* **N/A**
*Prep Date:* **12/8/2014** ***Prep by:*** **TE**
*Matrix/Comp.* **0.1M HCl**
*Half Life (y):* **1.60E+03**

| Reverification Log | | |
|---|---|---|
| Analysis Date | Initials | Expiration Date |
| 1/4/2016 | JP | 1/04/2017 |
| | | |
| | | |
| | | |
| | | |

JP 1/9/15

Continued on Page

T Ellet 12/8/14
Signed Date

Read and Understood By
Sign 01/09/2015
Date

76
PROJECT 916.3610.76 Ra-226 Notebook No. _____
Continued From Page _____

Prepare a intermediate dilution of RSO #916.

0.1 M HCl diluent lot # H45A12

Density of diluent

| | | Balance |
|---|---|---|
| Mass of 100 ml Vol flask | 68.7982 g | 12 |
| Flask + Acid | 168.0565 g | 2 |
| Net | 99.1583 g | |

$\rho$ = 0.9976 g/ml

Mass of permit transferred

| | | |
|---|---|---|
| Mass of Open full Ampule + Beaker | 38.2082 g | 12 |
| Mass of Open Empty Ampule + Beaker | 33.2251 g | 6 |
| Net | 4.9831 g | |

Dilute to final Vol./Mass

| | | |
|---|---|---|
| Mass of Open Empty 40 ml Ven Vial | 21.397 g | 12 |
| Mass of Vial, std, + diluent | 57.9016 g | 1 |
| Net | 36.5045 g | |

Activity Calc.

JDO 9/27/10

$$\frac{(18600.\ Bq)\left(\frac{10\ dpm}{1\ Bq}\right)\frac{4.9831\ g}{5.65176\ g}}{36.5045\ g} = 30156\ dpm/g$$

30,156.1
JDO 9/27/10

Continued on Page

Read and Understood By

Signed _____ Date 9/27/10 Signed _____ Date 9/27/10

Eckert & Ziegler
Analytics

rec 7-6-10 RSO# 916

1380 Seaboard Industrial Blvd.
Atlanta, Georgia 30318
Tel 404•352•8677
Fax 404•352•2837
www.analyticsinc.com

# CERTIFICATE OF CALIBRATION
## Standard Radionuclide Source

**82563-307**
**Ra-226 5 mL Liquid in Flame Sealed Vial**

**Customer:** ALS Laboratory Group / Fort Collins
**P.O. No.:** 73625 06-10-10, Item 1

This standard radionuclide source was prepared gravimetrically from a master solution calibrated by Eckert & Ziegler Analytics, using a germanium gamma spectrometer system. Radionuclide purity and calibration were checked with a germanium gamma spectrometer system. The nuclear decay rate and reference date for this source are given below. Eckert & Ziegler Analytics (EZA) maintains traceability to the National Institute of Standards and Technology through a Measurements Assurance Program as described in USNRC Regulatory Guide 4.15, Revision 1, February, 1979, and compliance with ANSI N42.22-1995, "Traceability of Radioactive Sources to NIST." EZA is accredited by the Health Physics Society (HPS) for the production of NIST-traceable sources, and this source was produced in accordance with the HPS accreditation requirements. Customers may report any concerns with the accreditation program to the HPS Secretariat, 1313 Dolley Madison Blvd., Ste. 402, McLean, VA 22101.

| Isotope | Half-Life, Days | Activity (Bq) | Uncertainty*, % Type $u_A$ | $u_B$ | U | Reference Date (12:00 PM EST) |
|---|---|---|---|---|---|---|
| Ra-226 | 5.844E+05 | 1.860E+04 | 0.5 | 2.4 | 4.9 | 07/01/2010 |

*Uncertainty: U - Relative expanded uncertainty, k = 2. See NIST Technical Note 1297, "Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results."

**Comments:**
Impurities: γ-impurities <0.1%. 5.05176 g 0.1M HCl solution with approximately 30 µg/g Ba carrier.

Source Prepared by: W. Mao, Radiochemist

QA Approved: J. D. McCorvey, QA Manager Alternate  Date: 6/30/10

ANA Form005 Rev. —

ACCREDITED SOURCE CALIBRATION LABORATORY HEALTH PHYSICS SOCIETY

Single Isotope Certificate, Rev 1 9/28/2009

# Radiochemistry Solution Report

| | | | | | |
|---|---|---|---|---|---|
| **Solution Id:** | 916.4095.69 | **Name:** | Ra226 working standard | **Type:** | IS |
| | | **Lot:** | | **Vendor Name:** | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Final Vol:** | 1005.952 | **Dept:** | RD | **Prep By** | TDE | **on** | 12/8/2014 | **Reviewed By** | jcp | **on** | 1/9/2015 |
| **Units:** | mL | **Location:** | SR/RA | **Opened By** | | **on** | | **Verified By** | JCP | **on** | 1/9/2015 |
| **Matrix:** | LIQUID | **ExpireDate:** | 1/4/2017 | **Received By** | | **on** | | **Deactivated By** | | **on** | |

**Comment:** Std Re-Verified 01/04/16. New Exp Date=> 01/04/2017. JP 01/07/16.

| Component Name | Component ID | Volume Added | Units |
|---|---|---|---|
| Ra-226 Intedrmediate dilution | 916.3610.76 | 3.3571 | g |

| CompName | Calibrated Primary Act/Conc | Calibration Date | Reference Date | 1/2 Life (Yrs) | Final Act/Conc | Summed Conc | Units |
|---|---|---|---|---|---|---|---|
| Rn-222 | 99510.41 | 7/1/2010 | 1/7/2016 | 1600 (Prnt) | 45.2241306505124 | | pCi/ml |
| Ra-226 | 99510.41 | 7/1/2010 | 1/7/2016 | 1600 | 45.2241306505124 | | pCi/ml |

## Associated Parent IDs

| | |
|---|---|
| 916 | 916.3610.76 |

**Abbreviations: NC = Not Calculated for reagents when the volume added is not entered.**
**NE = Not Entered**

**(Prnt) = Secular equilibrium; parent half life used to calculate concentration.**

# Daily Checks

# Th-Source + PMT Daily Performance Check Summary - Detector B, Scalar #2

r:\inst\alphscnt\dailychk.xls
Operating Voltage: 1100kV
Historical control limits established:
Interim Control Limits established: JP 2/15/17

| Obs. # | Date | Count Dur. (m) | Gross Counts | OK? | LCL | UCL | |
|---|---|---|---|---|---|---|---|
| 1 | 2/14/2017 | 1 | 9569 | OK | 8618 | 10534 | Preliminary Control Limits Established. See Daily Checks_Initial_02.13.17.xls for limits |
| 2 | 2/15/2017 | 1 | 9547 | OK | 8618 | 10534 | |
| 3 | 2/16/2017 | 1 | 9548 | OK | 8618 | 10534 | |
| 4 | 2/17/2017 | 1 | 9706 | OK | 8618 | 10534 | |
| 5 | 2/18/2017 | 1 | 9589 | OK | 8618 | 10534 | |
| 6 | 2/19/2017 | 1 | 9549 | OK | 8618 | 10534 | |

## Th-Source + PMT Daily Performance Check Summary - Detector D, Scalar #5

r:\inst\alphscnt\dailychk.xls
Operating Voltage: 900kV
Historical control limits established:
Interim Control Limits established: JP 2/15/17

| Obs. # | Date | Count Dur. (m) | Gross Counts | OK? | LCL | UCL | |
|---|---|---|---|---|---|---|---|
| 1 | 2/14/2017 | 1 | 9382 | OK | 8652 | 10575 | Preliminary Control Limits Established. See Daily Checks_Initial_02.13.17.xls for limits |
| 2 | 2/15/2017 | 1 | 9570 | OK | 8652 | 10575 | |
| 3 | 2/16/2017 | 1 | 9523 | OK | 8652 | 10575 | |
| 4 | 2/17/2017 | 1 | 9593 | OK | 8652 | 10575 | |
| 5 | 2/18/2017 | 1 | 9671 | OK | 8652 | 10575 | |
| 6 | 2/19/2017 | 1 | 9623 | OK | 8652 | 10575 | |

## Th-Source + PMT Daily Performance Check Summary - Detector C, Scalar #6

r:\inst\alphscnt\dailychk.xls
Operating Voltage: 900 kV
Historical control limits established:
Interim Control Limits established: JP 2/15/17

| Obs. # | Date | Count Dur. (m) | Gross Counts | OK? | LCL | UCL | |
|---|---|---|---|---|---|---|---|
| 1 | 2/14/2017 | 1 | 9520 | OK | 8651 | 10573 | Preliminary Control Limits Established. See Daily Checks_Initial_02.13.17.xls for limits |
| 2 | 2/15/2017 | 1 | 9548 | OK | 8651 | 10573 | |
| 3 | 2/16/2017 | 1 | 9686 | OK | 8651 | 10573 | |
| 4 | 2/17/2017 | 1 | 9602 | OK | 8651 | 10573 | |
| 5 | 2/18/2017 | 1 | 9527 | OK | 8651 | 10573 | |
| 6 | 2/19/2017 | 1 | 9586 | OK | 8651 | 10573 | |

## Th-Source + PMT Daily Performance Check Summary - Detector A, Scalar #7

r:\inst\alphscnt\dailychk.xls
Operating Voltage: 1000 kV
Historical Control Limits Established:
Interim Control Limits established: JP 2/15/17

| Obs. # | Date | Count Dur. (m) | Gross Counts | OK? | LCL | UCL | |
|---|---|---|---|---|---|---|---|
| 1 | 2/14/2017 | 1 | 9750 | OK | 8651 | 10574 | Preliminary Control Limits Established. See Daily Checks_Initial_02.13.17.xls for limits |
| 2 | 2/15/2017 | 1 | 9775 | OK | 8651 | 10574 | |
| 3 | 2/16/2017 | 1 | 9738 | OK | 8651 | 10574 | |
| 4 | 2/17/2017 | 1 | 9651 | OK | 8651 | 10574 | |
| 5 | 2/18/2017 | 1 | 9641 | OK | 8651 | 10574 | |
| 6 | 2/19/2017 | 1 | 9574 | OK | 8651 | 10574 | |

# Th-Source + PMT Daily Performance Check Summary - Detector F, Scalar #1

r:\inst\alphscnt\dailychk.xls
Operating Voltage: 1100 kV
Historical Control Limits Established:
Interim Control Limits established: JP 2/15/17

| Obs. # | Date | Count Dur. (m) | Gross Counts | OK? | LCL | UCL | |
|---|---|---|---|---|---|---|---|
| 1 | 2/14/2017 | 1 | 9459 | OK | 8562 | 10464 | Preliminary Control Limits Established. See Daily Checks_Initial_02.13.17.xls for limits |
| 2 | 2/15/2017 | 1 | 9578 | OK | 8562 | 10464 | |
| 3 | 2/16/2017 | 1 | 9569 | OK | 8562 | 10464 | |
| 4 | 2/17/2017 | 1 | 9596 | OK | 8562 | 10464 | |
| 5 | 2/18/2017 | 1 | 9579 | OK | 8562 | 10464 | |
| 6 | 2/19/2017 | 1 | 9574 | OK | 8562 | 10464 | |
| 7 | | 1 | | | | | |

# Th-Source + PMT Daily Performance Check Summary - Detector G, Scalar #8

r:\inst\alphscnt\dailychk.xls
Operating Voltage: 800 kV
Historical control limits established:
Interim Control Limits established: JP 2/15/17

| Obs. # | Date | Count Dur. (m) | Gross Counts | OK? | LCL | UCL | |
|---|---|---|---|---|---|---|---|
| 1 | 2/14/2017 | 1 | 9558 | OK | 8670 | 10597 | Preliminary Control Limits Established. See Daily Checks_Initial_02.13.17.xls for limits |
| 2 | 2/15/2017 | 1 | 9763 | OK | 8670 | 10597 | |
| 3 | 2/16/2017 | 1 | 9657 | OK | 8670 | 10597 | |
| 4 | 2/17/2017 | 1 | 9711 | OK | 8670 | 10597 | |
| 5 | 2/18/2017 | 1 | 9539 | OK | 8670 | 10597 | |
| 6 | 2/19/2017 | 1 | 9600 | OK | 8670 | 10597 | |

# Th-Source + PMT Daily Performance Check Summary - Detector H, Scalar #9

r:\inst\alphscnt\dailychk.xls
Operating Voltage: 800 kV
Historical control limits established:
Interim Control Limits established: JP 2/15/17

| Obs. # | Date | Count Dur. (m) | Gross Counts | OK? | LCL | UCL | |
|---|---|---|---|---|---|---|---|
| 1 | 2/14/2017 | 1 | 9586 | OK | 8657 | 10581 | Preliminary Control Limits Established. See Daily Checks_Initial_02.13.17.xls for limits |
| 2 | 2/15/2017 | 1 | 9689 | OK | 8657 | 10581 | |
| 3 | 2/16/2017 | 1 | 9451 | OK | 8657 | 10581 | |
| 4 | 2/17/2017 | 1 | 9706 | OK | 8657 | 10581 | |
| 5 | 2/18/2017 | 1 | 9582 | OK | 8657 | 10581 | |
| 6 | 2/19/2017 | 1 | 9643 | OK | 8657 | 10581 | |

# Th-Source + PMT Daily Performance Check Summary - Detector J, Scalar #10

r:\inst\alphscnt\dailychk.xls
Operating Voltage: 800 kV
Historical control limits established:
Interim Control Limits established: JP 2/15/17

| Obs. # | Date | Count Dur. (m) | Gross Counts | OK? | LCL | UCL | |
|---|---|---|---|---|---|---|---|
| 1 | 2/14/2017 | 1 | 9582 | OK | 8643 | 10563 | Preliminary Control Limits Established. See Daily Checks_Initial_02.13.17.xls for limits |
| 2 | 2/15/2017 | 1 | 9743 | OK | 8643 | 10563 | |
| 3 | 2/16/2017 | 1 | 9717 | OK | 8643 | 10563 | |
| 4 | 2/17/2017 | 1 | 9571 | OK | 8643 | 10563 | |
| 5 | 2/18/2017 | 1 | 9648 | OK | 8643 | 10563 | |
| 6 | 2/19/2017 | 1 | 9757 | OK | 8643 | 10563 | |

# Th-Source + PMT Daily Performance Check Summary - Detector K, Scalar #11

r:\inst\alphscnt\dailychk.xls
Operating Voltage: 800 kV
Historical control limits established:
Interim Control Limits established: JP 2/15/17

| Obs. # | Date | Count Dur. (m) | Gross Counts | OK? | LCL | UCL | |
|---|---|---|---|---|---|---|---|
| 1 | 2/14/2017 | 1 | 9608 | OK | 8615 | 10529 | Preliminary Control Limits Established. See Daily Checks_Initial_02.13.17.xls for limits |
| 2 | 2/15/2017 | 1 | 9497 | OK | 8615 | 10529 | |
| 3 | 2/16/2017 | 1 | 9571 | OK | 8615 | 10529 | |
| 4 | 2/17/2017 | 1 | 9763 | OK | 8615 | 10529 | |
| 5 | 2/18/2017 | 1 | 9449 | OK | 8615 | 10529 | |
| 6 | 2/19/2017 | 1 | 9559 | OK | 8615 | 10529 | |

## Th-Source + PMT Daily Performance Check Summary - Detector L, Scalar #12

r:\inst\alphscnt\dailychk.xls
Operating Voltage: 800 kV
Historical control limits established:
Interim Control Limits established: JP 2/15/17

| Obs. # | Date | Count Dur. (m) | Gross Counts | OK? | LCL | UCL | |
|---|---|---|---|---|---|---|---|
| 1 | 2/14/2017 | 1 | 9608 | OK | 8658 | 10582 | Preliminary Control Limits Established. See Daily Checks_Initial_02.13.17.xls for limits |
| 2 | 2/15/2017 | 1 | 9691 | OK | 8658 | 10582 | |
| 3 | 2/16/2017 | 1 | 9627 | OK | 8658 | 10582 | |
| 4 | 2/17/2017 | 1 | 9522 | OK | 8658 | 10582 | |
| 5 | 2/18/2017 | 1 | 9654 | OK | 8658 | 10582 | |
| 6 | 2/19/2017 | 1 | 9659 | OK | 8658 | 10582 | |

# Th-Source + PMT Daily Performance Check Summary - Detector B, Scalar #2

r:\inst\alphscnt\dailychk.xls
Operating Voltage: 1100kV
Historical control limits established:AZ 4/6/2017
Interim Control Limits established: JP 2/15/17

| Obs. # | Date | Count Dur. (m) | Gross Counts | OK? | LCL | UCL |
|---|---|---|---|---|---|---|
| 144 | 4/16/2018 | 1 | 9624 | OK | 9355 | 9949 |
| 145 | 4/17/2018 | 1 | 9674 | OK | 9355 | 9949 |
| 146 | 4/17/2018 | 1 | 9870 | OK | 9355 | 9949 |
| 147 | 4/19/2018 | 1 | 9668 | OK | 9355 | 9949 |
| 148 | 4/23/2018 | 1 | 9655 | OK | 9355 | 9949 |
| 149 | 4/23/2018 | 1 | 9685 | OK | 9355 | 9949 |

4/24/18

# Th-Source + PMT Daily Performance Check Summary - Detector D, Scalar #5

r:\inst\alphscnt\dailychk.xls
Operating Voltage: 900kV
Historical control limits established: AZ 4/6/2017
Interim Control Limits established: JP 2/15/17

| Obs. # | Date | Count Dur. (m) | Gross Counts | OK? | LCL | UCL |
|---|---|---|---|---|---|---|
| 215 | 4/16/2018 | 1 | 9713 | OK | 9299 | 9941 |
| 216 | 4/17/2018 | 1 | 9773 | OK | 9299 | 9941 |
| 217 | 4/17/2018 | 1 | 9492 | OK | 9299 | 9941 |
| 218 | 4/19/2018 | 1 | 9728 | OK | 9299 | 9941 |
| 219 | 4/23/2018 | 1 | 9635 | OK | 9299 | 9941 |
| 220 | 4/23/2018 | 1 | 9682 | OK | 9299 | 9941 |

AZ 4/24/18

# Th-Source + PMT Daily Performance Check Summary - Detector C, Scalar #6

r:\inst\alphscnt\dailychk.xls
Operating Voltage: 900 kV
Historical control limits established:AZ 4/6/2017
Interim Control Limits established: JP 2/15/17

| Obs. # | Date | Count Dur. (m) | Gross Counts | OK? | LCL | UCL |
|---|---|---|---|---|---|---|
| 215 | 4/17/2018 | 1 | 9486 | OK | 9170 | 9827 |
| 216 | 4/19/2018 | 1 | 9592 | OK | 9170 | 9827 |
| 217 | 4/20/2018 | 1 | 9547 | OK | 9170 | 9827 |
| 218 | 4/20/2018 | 1 | 9645 | OK | 9170 | 9827 |
| 219 | 4/23/2018 | 1 | 9693 | OK | 9170 | 9827 |
| 220 | 4/23/2018 | 1 | 9690 | OK | 9170 | 9827 |

4/24/17

# Th-Source + PMT Daily Performance Check Summary - Detector A, Scalar #7

r:\inst\alphscnt\dailychk.xls
Operating Voltage: 1000 kV
Historical Control Limits Establishe AZ 4/6/2017
Interim Control Limits established: JP 2/15/17

| Obs. # | Date | Count Dur. (m) | Gross Counts | OK? | LCL | UCL |
|---|---|---|---|---|---|---|
| 215 | 4/16/2018 | 1 | 9741 | OK | 9418 | 9910 |
| 216 | 4/17/2018 | 1 | 9630 | OK | 9418 | 9910 |
| 217 | 4/17/2018 | 1 | 9766 | OK | 9418 | 9910 |
| 218 | 4/19/2018 | 1 | 9692 | OK | 9418 | 9910 |
| 219 | 4/23/2018 | 1 | 9618 | OK | 9418 | 9910 |
| 220 | 4/23/2018 | 1 | 9820 | OK | 9418 | 9910 |

4/24/18

# Th-Source + PMT Daily Performance Check Summary - Detector F, Scalar #1

r:\inst\alphscnt\dailychk.xls
Operating Voltage: 1100 kV
Historical Control Limits Establishe AZ 4/6/2017
Interim Control Limits established: JP 2/15/17

| Obs. # | Date | Count Dur. (m) | Gross Counts | OK? | LCL | UCL |
|---|---|---|---|---|---|---|
| 214 | 4/17/2018 | 1 | 9611 | OK | 9320 | 9843 |
| 215 | 4/19/2018 | 1 | 9656 | OK | 9320 | 9843 |
| 216 | 4/20/2018 | 1 | 9597 | OK | 9320 | 9843 |
| 217 | 4/20/2018 | 1 | 9674 | OK | 9320 | 9843 |
| 218 | 4/23/2018 | 1 | 9733 | OK | 9320 | 9843 |
| 219 | 4/23/2018 | 1 | 9663 | OK | 9320 | 9843 |

4/24/18

# Th-Source + PMT Daily Performance Check Summary - Detector G, Scalar #8

r:\inst\alphscnt\dailychk.xls
Operating Voltage: 800 kV
Historical control limits established:AZ 4/6/2017
Interim Control Limits established: JP 2/15/17

| Obs. # | Date | Count Dur. (m) | Gross Counts | OK? | LCL | UCL |
|---|---|---|---|---|---|---|
| 211 | 4/16/2018 | 1 | 9794 | OK | 9292 | 9986 |
| 212 | 4/16/2018 | 1 | 9664 | OK | 9292 | 9986 |
| 213 | 4/17/2018 | 1 | 9827 | OK | 9292 | 9986 |
| 214 | 4/17/2018 | 1 | 9514 | OK | 9292 | 9986 |
| 215 | 4/23/2018 | 1 | 9529 | OK | 9292 | 9986 |
| 216 | 4/23/2018 | 1 | 9675 | OK | 9292 | 9986 |



9/24/18

# Th-Source + PMT Daily Performance Check Summary - Detector H, Scalar #9

r:\inst\alphscnt\dailychk.xls
Operating Voltage: 800 kV
Historical control limits established: AZ 4/6/2017
Interim Control Limits established: JP 2/15/17

| Obs. # | Date | Count Dur. (m) | Gross Counts | OK? | LCL | UCL |
|---|---|---|---|---|---|---|
| 210 | 4/16/2018 | 1 | 9660 | OK | 9382 | 9879 |
| 211 | 4/16/2018 | 1 | 9458 | OK | 9382 | 9879 |
| 212 | 4/17/2018 | 1 | 9538 | OK | 9382 | 9879 |
| 213 | 4/17/2018 | 1 | 9644 | OK | 9382 | 9879 |
| 214 | 4/23/2018 | 1 | 9621 | OK | 9382 | 9879 |
| 215 | 4/23/2018 | 1 | 9675 | OK | 9382 | 9879 |

AZ
4/25/18

# Th-Source + PMT Daily Performance Check Summary - Detector J, Scalar #10

r:\inst\alphscnt\dailychk.xls
Operating Voltage: 800 kV
Historical control limits established:AZ 4/6/2017
Interim Control Limits established: JP 2/15/17

| Obs. # | Date | Count Dur. (m) | Gross Counts | OK? | LCL | UCL |
|---|---|---|---|---|---|---|
| 208 | 4/16/2018 | 1 | 9567 | OK | 9394 | 9910 |
| 209 | 4/16/2018 | 1 | 9608 | OK | 9394 | 9910 |
| 210 | 4/17/2018 | 1 | 9703 | OK | 9394 | 9910 |
| 211 | 4/17/2018 | 1 | 9732 | OK | 9394 | 9910 |
| 212 | 4/23/2018 | 1 | 9736 | OK | 9394 | 9910 |
| 213 | 4/23/2018 | 1 | 9511 | OK | 9394 | 9910 |

4/24/18

# Th-Source + PMT Daily Performance Check Summary - Detector K, Scalar #11

r:\inst\alphscnt\dailychk.xls
Operating Voltage: 800 kV
Historical control limits established:AZ 4/6/2017
Interim Control Limits established: JP 2/15/17

| Obs. # | Date | Count Dur. (m) | Gross Counts | OK? | LCL | UCL |
|---|---|---|---|---|---|---|
| 209 | 4/17/2018 | 1 | 9444 | OK | 9297 | 9771 |
| 210 | 4/17/2018 | 1 | 9494 | OK | 9297 | 9771 |
| 211 | 4/20/2018 | 1 | 9462 | OK | 9297 | 9771 |
| 212 | 4/20/2018 | 1 | 9715 | OK | 9297 | 9771 |
| 213 | 4/23/2018 | 1 | 9495 | OK | 9297 | 9771 |
| 214 | 4/23/2018 | 1 | 9475 | OK | 9297 | 9771 |



4/24/18

# Th-Source + PMT Daily Performance Check Summary - Detector L, Scalar #12

r:\inst\alphscnt\dailychk.xls
Operating Voltage: 800 kV
Historical control limits established:AZ 4/6/2017
Interim Control Limits established: JP 2/15/17

| Obs. # | Date | Count Dur. (m) | Gross Counts | OK? | LCL | UCL |
|---|---|---|---|---|---|---|
| 145 | 4/16/2018 | 1 | 9498 | OK | 9328 | 9860 |
| 146 | 4/17/2018 | 1 | 9622 | OK | 9328 | 9860 |
| 147 | 4/17/2018 | 1 | 9470 | OK | 9328 | 9860 |
| 148 | 4/19/2018 | 1 | 9599 | OK | 9328 | 9860 |
| 149 | 4/23/2018 | 1 | 9633 | OK | 9328 | 9860 |
| 150 | 4/23/2018 | 1 | 9476 | OK | 9328 | 9860 |



9/24/18

Th Source 2/13/2017

| | B | D | C | A | F | G | H | J | K | L |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 9573 | 9658 | 9666 | 9487 | 9452 | 9644 | 9704 | 9548 | 9566 | 9519 |
| 2 | 9471 | 9531 | 9771 | 9651 | 9508 | 9643 | 9613 | 9652 | 9605 | 9636 |
| 3 | 9507 | 9538 | 9552 | 9599 | 9435 | 9647 | 9504 | 9673 | 9620 | 9642 |
| 4 | 9657 | 9665 | 9553 | 9631 | 9618 | 9751 | 9582 | 9591 | 9488 | 9609 |
| 5 | 9672 | 9675 | 9518 | 9694 | 9551 | 9483 | 9691 | 9550 | 9580 | 9693 |

New Daily Control Limits

New Preliminary (Interim) Control limits established on 2/14/17 From the average of 5 counts performed on each detector/scalar ± 10%. Historical Control limits will be set after 30 Data Points are achieved.

Interim Control Limits are:

| | |
|---|---|
| B: 8618-10534 | G: 8670-10597 |
| D: 8652-10575 | H: 8657-10581 |
| C: 8651-10573 | J: 8643-10563 |
| A: 8651-10574 | K: 8615-10529 |
| F: 8652-10464 | L: 8658-10582 |

JP 2/20/17

Continued on Page

Read and Understood By

Signed 2/17/17 Date Signed Date

# Ra226 by Radon Emanation
# CCV's
# For
# Detectors B, D, C, A, F, G, H, J, K, L

Performed by:
Date: 10/8/18

Reviewed by: JP
Date: 10/9/18

Analyst: ASZ
Prep. Date S: 11/19/2016
Prep. Date C: 11/19/2016
SOP Used: 783R12

| | | S | Purge (end) | | | | | | | Deeman. (end) | | Count Start | | Count | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | S | V | Date | Time | Flask | Counter | Scaler | CBKG | BKG DUR | Date | Time | Date | Time | Duration | COUNT | REMARKS |
| W.O.# | ID | (L) | D1 | T1 | No. | No. | No. | # | (min) | D2 | T2 | D3 | T3 | (min.) | # | |
| ICV2662 | CCV26 | 1 | 8/10/2018 | 13:09 | 026 | B | 2 | 3 | 15 | 10/5/2018 | 7:43 | 10/5/2018 | 11:43 | 15 | 400 | Cell out of commission |
| ICV2662 | CCV27 | 1 | 8/10/2018 | 13:09 | 027 | D | 5 | 7 | 15 | 10/5/2018 | 7:43 | 10/5/2018 | 11:43 | 15 | 1982 | |
| ICV2662 | CCV28 | 1 | 8/10/2018 | 13:09 | 028 | C | 6 | 2 | 15 | 10/5/2018 | 7:43 | 10/5/2018 | 11:43 | 15 | 1230 | Cell out of commission |
| ICV2662 | CCV29 | 1 | 8/10/2018 | 13:09 | 029 | A | 7 | 6 | 15 | 10/5/2018 | 7:43 | 10/5/2018 | 11:43 | 15 | 2274 | |
| ICV2662 | CCV30 | 1 | 8/10/2018 | 13:09 | 030 | F | 1 | 2 | 15 | 10/5/2018 | 7:43 | 10/5/2018 | 11:43 | 15 | 1628 | |
| ICV2662 | CCV31 | 1 | 8/10/2018 | 13:09 | 051 | G | 8 | 8 | 15 | 10/5/2018 | 7:43 | 10/5/2018 | 11:43 | 15 | 2365 | |
| ICV2662 | CCV32 | 1 | 8/10/2018 | 13:09 | 052 | H | 9 | 7 | 15 | 10/5/2018 | 7:43 | 10/5/2018 | 11:43 | 15 | 1779 | |
| ICV2662 | CCV33 | 1 | 8/10/2018 | 13:09 | 053 | J | 10 | 6 | 15 | 10/5/2018 | 7:43 | 10/5/2018 | 11:43 | 15 | 2040 | |
| ICV2662 | CCV34 | 1 | 8/10/2018 | 13:09 | 054 | K | 11 | 2 | 15 | 10/5/2018 | 7:43 | 10/5/2018 | 11:43 | 15 | 1308 | Cell out of commission |
| ICV2662 | CCV35 | 1 | 8/10/2018 | 13:09 | 055 | L | 12 | 3 | 15 | 10/5/2018 | 7:43 | 10/5/2018 | 11:43 | 15 | 1812 | |
| ICV2662 | CCV36 | 1 | 8/10/2018 | 13:09 | 031 | B | 2 | 5 | 15 | 10/5/2018 | 8:04 | 10/5/2018 | 12:04 | 15 | 1550 | |
| ICV2662 | CCV37 | 1 | 8/10/2018 | 13:09 | 032 | D | 5 | 1 | 15 | 10/5/2018 | 8:04 | 10/5/2018 | 12:04 | 15 | 2404 | |
| ICV2662 | CCV38 | 1 | 8/10/2018 | 13:09 | 033 | C | 6 | 3 | 15 | 10/5/2018 | 8:04 | 10/5/2018 | 12:04 | 15 | 1606 | |
| ICV2662 | CCV39 | 1 | 8/10/2018 | 13:09 | 034 | A | 7 | 13 | 15 | 10/5/2018 | 8:04 | 10/5/2018 | 12:04 | 15 | 1889 | |
| ICV2662 | CCV40 | 1 | 8/10/2018 | 13:09 | 035 | F | 1 | 5 | 15 | 10/5/2018 | 8:04 | 10/5/2018 | 12:04 | 15 | 1398 | |
| ICV2662 | CCV41 | 1 | 8/10/2018 | 13:09 | 056 | G | 8 | 6 | 15 | 10/5/2018 | 8:04 | 10/5/2018 | 12:04 | 15 | 2298 | |
| ICV2662 | CCV42 | 1 | 8/10/2018 | 13:09 | 057 | H | 9 | 9 | 15 | 10/5/2018 | 8:04 | 10/5/2018 | 12:04 | 15 | 1778 | |
| ICV2662 | CCV43 | 1 | 8/10/2018 | 13:09 | 058 | J | 10 | 8 | 15 | 10/5/2018 | 8:04 | 10/5/2018 | 12:04 | 15 | 2036 | |
| ICV2662 | CCV44 | 1 | 8/10/2018 | 13:09 | 059 | K | 11 | 7 | 15 | 10/5/2018 | 8:04 | 10/5/2018 | 12:04 | 15 | 1736 | |
| ICV2662 | CCV45 | 1 | 8/10/2018 | 13:09 | 060 | L | 12 | 7 | 15 | 10/5/2018 | 8:04 | 10/5/2018 | 12:04 | 15 | 1798 | |
| ICV2662 | CCV46 | 1 | 8/10/2018 | 13:09 | 036 | B | 2 | 3 | 15 | 10/5/2018 | 8:24 | 10/5/2018 | 12:24 | 15 | 1723 | |
| ICV2662 | CCV47 | 1 | 8/10/2018 | 13:09 | 037 | D | 5 | 1 | 15 | 10/5/2018 | 8:24 | 10/5/2018 | 12:24 | 15 | 2392 | |
| ICV2662 | CCV48 | 1 | 8/10/2018 | 13:09 | 038 | C | 6 | 2 | 15 | 10/5/2018 | 8:24 | 10/5/2018 | 12:24 | 15 | 1761 | |
| ICV2662 | CCV49 | 1 | 8/10/2018 | 13:09 | 039 | A | 7 | 4 | 15 | 10/5/2018 | 8:24 | 10/5/2018 | 12:24 | 15 | 2633 | |
| ICV2662 | CCV50 | 1 | 8/10/2018 | 13:09 | 040 | F | 1 | 5 | 15 | 10/5/2018 | 8:24 | 10/5/2018 | 12:24 | 15 | 1959 | |
| ICV2662 | CCV51 | 1 | 8/10/2018 | 13:09 | 061 | G | 8 | 1 | 15 | 10/5/2018 | 8:24 | 10/5/2018 | 12:24 | 15 | 2300 | |
| ICV2662 | CCV52 | 1 | 8/10/2018 | 13:09 | 062 | H | 9 | 7 | 15 | 10/5/2018 | 8:24 | 10/5/2018 | 12:24 | 15 | 1889 | |
| ICV2662 | CCV53 | 1 | 8/10/2018 | 13:09 | 063 | J | 10 | 8 | 15 | 10/5/2018 | 8:24 | 10/5/2018 | 12:24 | 15 | 2295 | |
| ICV2662 | CCV54 | 1 | 8/10/2018 | 13:09 | 064 | K | 11 | 3 | 15 | 10/5/2018 | 8:24 | 10/5/2018 | 12:24 | 15 | 1684 | |
| ICV2662 | CCV55 | 1 | 8/10/2018 | 13:09 | 065 | L | 12 | 5 | 15 | 10/5/2018 | 8:24 | 10/5/2018 | 12:24 | 15 | 1871 | |
| ICV2662 | CCV56 | 1 | 8/10/2018 | 13:09 | 041 | B | 2 | 5 | 15 | 10/5/2018 | 8:42 | 10/5/2018 | 12:46 | 15 | 1903 | |
| ICV2662 | CCV57 | 1 | 8/10/2018 | 13:09 | 042 | D | 5 | 10 | 15 | 10/5/2018 | 8:42 | 10/5/2018 | 12:46 | 15 | 1895 | |
| ICV2662 | CCV58 | 1 | 8/10/2018 | 13:09 | 043 | C | 6 | 3 | 15 | 10/5/2018 | 8:42 | 10/5/2018 | 12:46 | 15 | 1694 | |
| ICV2662 | CCV59 | 1 | 8/10/2018 | 13:09 | 044 | A | 7 | 11 | 15 | 10/5/2018 | 8:42 | 10/5/2018 | 12:46 | 15 | 2541 | |
| ICV2662 | CCV60 | 1 | 8/10/2018 | 13:09 | 045 | F | 1 | 9 | 15 | 10/5/2018 | 8:42 | 10/5/2018 | 12:46 | 15 | 2236 | |
| ICV2662 | CCV61 | 1 | 8/10/2018 | 13:09 | 066 | G | 8 | 2 | 15 | 10/5/2018 | 8:42 | 10/5/2018 | 12:46 | 15 | 2431 | |
| ICV2662 | CCV62 | 1 | 8/10/2018 | 13:09 | 067 | H | 9 | 1 | 15 | 10/5/2018 | 8:42 | 10/5/2018 | 12:46 | 15 | 1589 | Did not pass, leak found |
| ICV2662 | CCV63 | 1 | 8/10/2018 | 13:09 | 068 | J | 10 | 5 | 15 | 10/5/2018 | 8:42 | 10/5/2018 | 12:46 | 15 | 2253 | |
| ICV2662 | CCV64 | 1 | 8/10/2018 | 13:09 | 069 | K | 11 | 6 | 15 | 10/5/2018 | 8:42 | 10/5/2018 | 12:46 | 15 | 1682 | |
| ICV2662 | CCV65 | 1 | 8/10/2018 | 13:09 | 070 | L | 12 | 3 | 15 | 10/5/2018 | 8:42 | 10/5/2018 | 12:46 | 15 | 1912 | |
| ICV2662 | CCV66 | 1 | 8/10/2018 | 13:09 | 046 | B | 2 | 1 | 15 | 10/5/2018 | 9:02 | 10/5/2018 | 13:06 | 15 | 1744 | |
| ICV2662 | CCV67 | 1 | 8/10/2018 | 13:09 | 047 | D | 5 | 9 | 15 | 10/5/2018 | 9:02 | 10/5/2018 | 13:06 | 15 | 2116 | |
| ICV2662 | CCV68 | 1 | 8/10/2018 | 13:09 | 048 | C | 6 | 2 | 15 | 10/5/2018 | 9:02 | 10/5/2018 | 13:06 | 15 | 1001 | Cell out of commission |
| ICV2662 | CCV69 | 1 | 8/10/2018 | 13:09 | 049 | A | 7 | 14 | 15 | 10/5/2018 | 9:02 | 10/5/2018 | 13:06 | 15 | 2555 | |
| ICV2662 | CCV70 | 1 | 8/10/2018 | 13:09 | 050 | F | 1 | 3 | 15 | 10/5/2018 | 9:02 | 10/5/2018 | 13:06 | 15 | 2060 | |
| ICV2662 | CCV71 | 1 | 8/10/2018 | 13:09 | 071 | G | 8 | 15 | 15 | 10/5/2018 | 9:02 | 10/5/2018 | 13:06 | 15 | 2502 | |
| ICV2662 | [illegible] | 1 | 8/10/2018 | 13:09 | 072 | H | 9 | 11 | 15 | 10/5/2018 | 9:02 | 10/5/2018 | 13:06 | 15 | [illegible] | |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ICV2662 | CCV73 | 1 | 8/10/2018 | 13:09 | 073 | J | 10 | 7 | 15 | 10/5/2018 | 9:02 | 10/5/2018 | 13:06 | 15 | 1805 | NA |
| ICV2662 | CCV74 | 1 | 8/10/2018 | 13:09 | 074 | K | 11 | 1 | 15 | 10/5/2018 | 9:02 | 10/5/2018 | 13:06 | 15 | 1061 | Cell out of commission |
| ICV2662 | CCV75 | 1 | 8/10/2018 | 13:09 | 075 | L | 12 | 4 | 15 | 10/5/2018 | 9:02 | 10/5/2018 | 13:06 | 15 | 1435 | Cell out of commission |

| Std./Ba Carrier ID | Std./ Carrier Type | conc dpm/ mL | Spike Vol. (ml) | pipet No. | Activity added (dpm) | Ref. date |
|---|---|---|---|---|---|---|
| 916.4095.69 | Ra 226 | 100.64 | 1.0 | RS-033 | 100.64 | 7/1/2010 |

| | Initials | Date |
|---|---|---|
| Spiked by: | CDJ | 11/19/2016 |
| Spike Witness: | JKB | 11/19/2016 |
| Reviewed by: | | |



10/18

ICV Radiometric Recovery Summary for B, D, C, A, F, G, H, J, K and L
Acceptance Criteria: Passing CCV (control limits = 67% - 120%)

| W.O.# | S ID | Flask No. | Efficiency | Denom | Ra-226 Activity (pCi/l) | Ra-226 Cnt. Unc. | Ra-226 2 sig. TPU | Ra-226 MDC | Sample ID | Radiometric Recovery (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| ICV2662 | CCV26 | 026 | 0.9660 | 0.003925 | 12.73 | 1.26 | 1.60 | 0.35 | ICV2662 CCV26 | 28.16% |
| ICV2662 | CCV27 | 027 | 1.4668 | 0.00596 | 41.72 | 1.85 | 3.70 | 0.32 | ICV2662 CCV27 | 92.28% |
| ICV2662 | CCV28 | 028 | 0.9561 | 0.003885 | 39.79 | 2.23 | 3.78 | 0.30 | ICV2662 CCV28 | 88.02% |
| ICV2662 | CCV29 | 029 | 1.6235 | 0.006597 | 43.28 | 1.79 | 3.77 | 0.27 | ICV2662 CCV29 | 95.74% |
| ICV2662 | CCV30 | 030 | 1.2014 | 0.004882 | 41.93 | 2.04 | 3.81 | 0.24 | ICV2662 CCV30 | 92.75% |
| ICV2662 | CCV31 | 051 | 1.6048 | 0.006521 | 45.50 | 1.84 | 3.95 | 0.31 | ICV2662 CCV31 | 100.66% |
| ICV2662 | CCV32 | 052 | 1.6508 | 0.006708 | 33.26 | 1.55 | 2.99 | 0.28 | ICV2662 CCV32 | 73.56% |
| ICV2662 | CCV33 | 053 | 1.6430 | 0.006676 | 38.36 | 1.67 | 3.39 | 0.27 | ICV2662 CCV33 | 84.84% |
| ICV2662 | CCV34 | 054 | 1.0500 | 0.004267 | 38.54 | 2.09 | 3.62 | 0.27 | ICV2662 CCV34 | 85.24% |
| ICV2662 | CCV35 | 055 | 1.4297 | 0.00581 | 39.20 | 1.81 | 3.51 | 0.23 | ICV2662 CCV35 | 86.71% |
| ICV2662 | CCV36 | 031 | 1.5127 | 0.006147 | 31.64 | 1.58 | 2.90 | 0.27 | ICV2662 CCV36 | 70.00% |
| ICV2662 | CCV37 | 032 | 1.7047 | 0.006927 | 43.67 | 1.75 | 3.78 | 0.13 | ICV2662 CCV37 | 96.60% |
| ICV2662 | CCV38 | 033 | 1.3419 | 0.005453 | 37.01 | 1.82 | 3.37 | 0.25 | ICV2662 CCV38 | 81.86% |
| ICV2662 | CCV39 | 034 | 1.8384 | 0.00747 | 31.61 | 1.44 | 2.82 | 0.33 | ICV2662 CCV39 | 69.93% |
| ICV2662 | CCV40 | 035 | 1.2123 | 0.004926 | 35.60 | 1.88 | 3.32 | 0.33 | ICV2662 CCV40 | 78.75% |
| ICV2662 | CCV41 | 056 | 1.6142 | 0.006559 | 43.99 | 1.81 | 3.83 | 0.27 | ICV2662 CCV41 | 97.30% |
| ICV2662 | CCV42 | 057 | 1.5502 | 0.006299 | 35.35 | 1.66 | 3.18 | 0.33 | ICV2662 CCV42 | 78.20% |
| ICV2662 | CCV43 | 058 | 1.6061 | 0.006526 | 39.12 | 1.71 | 3.46 | 0.31 | ICV2662 CCV43 | 86.53% |
| ICV2662 | CCV44 | 059 | 1.3904 | 0.00565 | 38.53 | 1.82 | 3.48 | 0.33 | ICV2662 CCV44 | 85.22% |
| ICV2662 | CCV45 | 060 | 1.3248 | 0.005383 | 41.88 | 1.95 | 3.76 | 0.35 | ICV2662 CCV45 | 92.65% |
| ICV2662 | CCV46 | 036 | 1.5186 | 0.006171 | 35.09 | 1.66 | 3.17 | 0.22 | ICV2662 CCV46 | 77.62% |
| ICV2662 | CCV47 | 037 | 1.7182 | 0.006982 | 43.11 | 1.73 | 3.74 | 0.13 | ICV2662 CCV47 | 95.37% |
| ICV2662 | CCV48 | 038 | 1.4563 | 0.005917 | 37.42 | 1.75 | 3.37 | 0.20 | ICV2662 CCV48 | 82.78% |
| ICV2662 | CCV49 | 039 | 1.8400 | 0.007477 | 44.27 | 1.69 | 3.80 | 0.20 | ICV2662 CCV49 | 97.92% |
| ICV2662 | CCV50 | 040 | 1.3949 | 0.005668 | 43.40 | 1.93 | 3.85 | 0.29 | ICV2662 CCV50 | 96.00% |
| ICV2662 | CCV51 | 061 | 1.7010 | 0.006912 | 41.87 | 1.71 | 3.64 | 0.13 | ICV2662 CCV51 | 92.62% |
| ICV2662 | CCV52 | 062 | 1.7220 | 0.006997 | 33.86 | 1.54 | 3.02 | 0.27 | ICV2662 CCV52 | 74.90% |
| ICV2662 | CCV53 | 063 | 1.6915 | 0.006873 | 41.89 | 1.72 | 3.65 | 0.29 | ICV2662 CCV53 | 92.66% |
| ICV2662 | CCV54 | 064 | 1.4246 | 0.005789 | 36.56 | 1.75 | 3.31 | 0.23 | ICV2662 CCV54 | 80.87% |
| ICV2662 | CCV55 | 065 | 1.3981 | 0.005681 | 41.35 | 1.88 | 3.69 | 0.29 | ICV2662 CCV55 | 91.46% |
| ICV2662 | CCV56 | 041 | 1.6286 | 0.006614 | 36.12 | 1.63 | 3.22 | 0.25 | ICV2662 CCV56 | 79.91% |
| ICV2662 | CCV57 | 042 | 1.6699 | 0.006782 | 34.99 | 1.59 | 3.12 | 0.32 | ICV2662 CCV57 | 77.40% |
| ICV2662 | CCV58 | 043 | 1.4769 | 0.005998 | 35.49 | 1.69 | 3.21 | 0.23 | ICV2662 CCV58 | 78.50% |
| ICV2662 | CCV59 | 044 | 1.7887 | 0.007265 | 43.84 | 1.72 | 3.78 | 0.31 | ICV2662 CCV59 | 96.98% |
| ICV2662 | CCV60 | 045 | 1.6006 | 0.006501 | 43.13 | 1.80 | 3.77 | 0.32 | ICV2662 CCV60 | 95.40% |
| ICV2662 | CCV61 | 066 | 1.8018 | 0.007318 | 41.79 | 1.66 | 3.61 | 0.16 | ICV2662 CCV61 | 92.44% |
| ICV2662 | CCV62 | 067 | 1.6920 | 0.006872 | 29.09 | 1.43 | 2.65 | 0.13 | ICV2662 CCV62 | 64.35% |
| ICV2662 | CCV63 | 068 | 1.6955 | 0.006886 | 41.10 | 1.70 | 3.59 | 0.24 | ICV2662 CCV63 | 90.91% |
| ICV2662 | CCV64 | 069 | 1.3781 | 0.005597 | 37.70 | 1.81 | 3.41 | 0.32 | ICV2662 CCV64 | 83.38% |
| ICV2662 | CCV65 | 070 | 1.3941 | 0.005662 | 42.45 | 1.91 | 3.78 | 0.24 | ICV2662 CCV65 | 93.89% |
| ICV2662 | CCV66 | 046 | 1.6606 | 0.006744 | 32.54 | 1.53 | 2.93 | 0.14 | ICV2662 CCV66 | 71.97% |
| ICV2662 | CCV67 | 047 | 1.7066 | 0.006931 | 38.27 | 1.64 | 3.37 | 0.30 | ICV2662 CCV67 | 84.66% |
| ICV2662 | CCV68 | 048 | 0.8362 | 0.003396 | 37.03 | 2.30 | 3.66 | 0.34 | ICV2662 CCV68 | 81.91% |
| ICV2662 | CCV69 | 049 | 1.8394 | 0.007471 | 42.82 | 1.67 | 3.69 | 0.34 | ICV2662 CCV69 | 94.72% |





L 10/18

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| ICV2662 | CCV70 | 050 | 1.5635 | 0.00635 | 40.78 | 1.76 | 3.60 | 0.21 | ICV2662 CCV70 | 90.21% |
| ICV2662 | CCV71 | 071 | 1.7588 | 0.007143 | 43.83 | 1.73 | 3.79 | 0.37 | ICV2662 CCV71 | 96.96% |
| ICV2662 | CCV72 | 072 | 1.5793 | 0.006414 | 37.41 | 1.69 | 3.33 | 0.36 | ICV2662 CCV72 | 82.75% |
| ICV2662 | CCV73 | 073 | 1.4067 | 0.005713 | 39.62 | 1.84 | 3.56 | 0.33 | ICV2662 CCV73 | 87.64% |
| ICV2662 | CCV74 | 074 | 0.9742 | 0.003956 | 33.73 | 2.03 | 3.29 | 0.23 | ICV2662 CCV74 | 74.61% |
| ICV2662 | CCV75 | 075 | 0.8161 | 0.003315 | 54.35 | 2.82 | 5.04 | 0.46 | ICV2662 CCV75 | 120.23% |

# RA226 Run Log

Logbook No./Page 480702

**ALS Laboratory Group**

| Sample ID | Batch ID | Scalar / Detector ID | Flask ID | Run # of 20 | Background Count Start Date | Background Count Start Time | Background Counts | Background Dur. (min.) | Background Pos. Chk. | Sample Count Start Date | Sample Count Start Time | Sample Counts | Sample Dur. (min.) | Sample Pos. Chk. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1809119-1 | RE180927-1 | F | 050 | NA | 10/4/18 | 8:30 | 7 | 45 | [illegible] | 10/4/18 | 13:45 | 96 | 45 | [illegible] |
| 121-1 | | G | 066 | | | | 10 | | | | | 14 | | |
| -2 | | H | 067 | | | | 5 | | | | | 6 | | |
| 123-1 | | J | 068 | | | | 5 | | | | | 662 | | |
| RE180927-1MB | | K | 059 | | | | 4 | | | | | 6 | | |
| -1LCS | | L | ~~055~~ 070 + 014 | | | | 1 | 15 | | | | 1918 | 15 | |
| Check Source | — | B-L | Th | NA | — | | | | | | 14:33 | NA | 1 | [illegible] |
| Check Source | — | B-L | Th | NA | — | | | | | 10/5/18 | 6:55 | NA 400 | 1 | [illegible] |
| ICV 2662-26 | monthly ICV | B | 026 | | 10/5/18 | 7:00 | 3 | 15 | [illegible] | 10/5/18 | 11:43 | ~~1482~~ | 15 | [illegible] |
| -27 | | D | 027 | | | | 7 | | | | | 1982 | | |
| -28 | | C | 028 | | | | 2 | | | | | 1230 | | |
| -29 | | A | 029 | | | | 6 | | | | | 2274 | | |
| -30 | | F | 030 | | | | 2 | | | | | 1628 | | |
| -31 | | G | 051 | | | | 8 | | | | | 2365 | | |
| -32 | | H | 052 | | | | 7 | | | | | 1779 | | |
| -33 | | J | 053 | | | | 6 | | | | | 2040 | | |
| -34 | | K | 054 | | | | 2 | | | | | 1308 | | |
| -35 | | L | 055 | | | | 3 | | | | | 1812 | | |
| -36 | | B | 031 | | | 7:28 | 5 | | | | 12:04 | 1550 | | |
| -37 | | D | 032 | | | | 1 | | | | | 2404 | | |
| -38 | | C | 033 | | | | 3 | | | | | 1606 | | |
| -39 | | A | 034 | | | | 13 | | | | | 1889 | | |

**Comments: CHECK SOURCE FILE: I:\Oprtns\RAD\INST\ALPHSCNT\Daily Checks**

Analyst / Date [illegible] 10/5/18

Form 795-5.xls (11/9/2012)

Note: Each page is copied as completed and included with the workorder/run documentation; reviewed subsequently

# RA226 Run Log

Logbook No./Page 480703

**ALS Laboratory Group**

| Sample ID | Batch ID | Scalar / Detector ID | Flask ID | Run # of 20 | Background Count Start Date | Background Count Start Time | Background Count Counts | Background Count Dur. (min.) | Background Count Pos. Chk. | Sample Count Start Date | Sample Count Start Time | Sample Count Counts | Sample Count Dur. (min.) | Sample Count Pos. Chk. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ICV 2662-40 | Monthly CCV | F | 035 | na | 10/5/18 | 7:28 | 5 | 15 | [illegible] | 10/5/18 | 12:04 | 1398 | 15 | [illegible] |
| -41 | | G | 056 | | | | 6 | | | | | 2296 | | |
| -42 | | H | 057 | | | | 9 | | | | | 1776 | | |
| -43 | | J | 058 | | | | 8 | | | | | 2036 | | |
| -44 | | K | 059 | | | | 7 | | | | | 1736 | | |
| -45 | | L | 060 | | | | 7 | | | | | 1796 | | |
| -46 | | B | 036 | | | 7:46 | 3 | | | | 12:24 | 1723 | | |
| -47 | | D | 037 | | | | 1 | | | | | 2392 | | |
| -48 | | C | 038 | | | | 2 | | | | | 1761 | | |
| -49 | | A | 039 | | | | 4 | | | | | 2633 | | |
| -50 | | F | 040 | | | | 5 | | | | | 1959 | | |
| -51 | | G | 061 | | | | 1 | | | | | 2300 | | |
| -52 | | H | 062 | | | | 7 | | | | | 1789 | | |
| -53 | | J | 063 | | | | 8 | | | | | 2295 | | |
| -54 | | K | 064 | | | | 3 | | | | | 1684 | | |
| -55 | | L | 065 | | | | 5 | | | | | 1871 | | |
| -56 | | B | 041 | | | 8:05 | 5 | | | | 12:46 | 1903 | | |
| -57 | | D | 042 | | | | 10 | | | | | 1895 | | |
| -58 | | C | 043 | | | | 3 | | | | | 1694 | | |
| -59 | | A | 044 | | | | 11 | | | | | 2541 | | |
| -60 | | F | 045 | | | | 9 | | | | | 2236 | | |
| -61 | | G | 066 | | | | 2 | | | | | 2431 | | |

**Comments:** CHECK SOURCE FILE: I:\Oprtns\RAD\INST\ALPHSCNT\Daily Checks

Analyst / Date [illegible] 10/5/18

Form 795r5.xls (11/9/2012)

Note: Each page is copied as completed and included with the workorder/run documentation; reviewed subsequently

# RA226 Run Log

Logbook No./Page 480704

**ALS Laboratory Grou**

| Sample ID | Batch ID | Scalar / Detector ID | Flask ID | Run # of 20 | Background Count Start Date | Background Count Start Time | Background Count Counts | Background Count Dur. (min.) | Background Count Pos. Chk. | Sample Count Start Date | Sample Count Start Time | Sample Count Counts | Sample Count Dur. (min.) | Sample Count Pos. Chk. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ICV2662-62 | Monthly CCV | H | 067 | NA | 10/5/18 | 8:05 | 1 | 15 | [illegible] | 10/5/18 | 12:56 | 1589 | 15 | [illegible] |
| -63 | | J | 068 | | | | 5 | | | | | 2253 | | |
| -64 | | K | 069 | | | | 6 | | | | | 1682 | | |
| -65 | | L | 070 | | | | 3 | | | | | 1912 | | |
| -66 | | B | 046 | | | 8:22 | 1 | | | | 13:06 | 1744 | | |
| -67 | | D | 047 | | | | 9 | | | | | 2116 | | |
| -68 | | C | 048 | | | | 2 | | | | | 1001 | | |
| -69 | | A | 049 | | | | 14 | | | | | 2555 | | |
| -70 | | F | 050 | | | | 3 | | | | | 2060 | | |
| -71 | | G | 071 | | | | 15 | | | | | 2502 | | |
| -72 | | H | 072 | | | | 11 | | | | | 1917 | | |
| -73 | | J | 073 | | | | 7 | | | | | 1805 | | |
| -74 | | K | 074 | | | | 1 | | | | | 1061 | | |
| -75 | | L | 075 | | | | 4 | | | | | 1435 | | |
| Check Source | — | B-L | TH | NA | — | | | | | 10/5/18 | 13:37 | NA | 1 | [illegible] |

Comments: CHECK SOURCE FILE: I:\Oprtns\RAD\INST\ALPHSCNT\Daily Checks

Analyst / Date [illegible] 10/18

# Th-Source + PMT Daily Performance Check Summary - Detector B, Scalar #2

r:\inst\alphscnt\dailychk.xls
Operating Voltage: 1100kV
Historical control limits established:AZ 4/6/2017
Interim Control Limits established: JP 2/15/17

| Obs. # | Date | Count Dur. (m) | Gross Counts | OK? | LCL | UCL |
|---|---|---|---|---|---|---|
| 325 | 10/3/2018 | 1 | 9364 | OK | 9355 | 9949 |
| 326 | 10/3/2018 | 1 | 9494 | OK | 9355 | 9949 |
| 327 | 10/4/2018 | 1 | 9721 | OK | 9355 | 9949 |
| 328 | 10/4/2018 | 1 | 9741 | OK | 9355 | 9949 |
| 329 | 10/5/2018 | 1 | 9537 | OK | 9355 | 9949 |
| 330 | 10/5/2018 | 1 | 9526 | OK | 9355 | 9949 |

10/8/18

# Th-Source + PMT Daily Performance Check Summary - Detector D, Scalar #5

r:\inst\alphscnt\dailychk.xls
Operating Voltage: 900kV
Historical control limits established: AZ 4/6/2017
Interim Control Limits established: JP 2/15/17

| Obs. # | Date | Count Dur. (m) | Gross Counts | OK? | LCL | UCL |
|---|---|---|---|---|---|---|
| 394 | 10/3/2018 | 1 | 9665 | OK | 9299 | 9941 |
| 395 | 10/3/2018 | 1 | 9697 | OK | 9299 | 9941 |
| 396 | 10/4/2018 | 1 | 9844 | OK | 9299 | 9941 |
| 397 | 10/4/2018 | 1 | 9555 | OK | 9299 | 9941 |
| 398 | 10/5/2018 | 1 | 9698 | OK | 9299 | 9941 |
| 399 | 10/5/2018 | 1 | 9647 | OK | 9299 | 9941 |

10/8/18

# Th-Source + PMT Daily Performance Check Summary - Detector C, Scalar #6

r:\inst\alphscnt\dailychk.xls
Operating Voltage: 900 kV
Historical control limits established:AZ 4/6/2017
Interim Control Limits established: JP 2/15/17

| Obs. # | Date | Count Dur. (m) | Gross Counts | OK? | LCL | UCL |
|---|---|---|---|---|---|---|
| 388 | 10/2/2018 | 1 | 9540 | OK | 9170 | 9827 |
| 389 | 10/2/2018 | 1 | 9565 | OK | 9170 | 9827 |
| 390 | 10/4/2018 | 1 | 9411 | OK | 9170 | 9827 |
| 391 | 10/4/2018 | 1 | 9449 | OK | 9170 | 9827 |
| 392 | 10/5/2018 | 1 | 9428 | OK | 9170 | 9827 |
| 393 | 10/5/2018 | 1 | 9744 | OK | 9170 | 9827 |

10/8/18

# Th-Source + PMT Daily Performance Check Summary - Detector A, Scalar #7

r:\inst\alphscnt\dailychk.xls
Operating Voltage: 1000 kV
Historical Control Limits Establishe AZ 4/6/2017
Interim Control Limits established: JP 2/15/17

| Obs. # | Date | Count Dur. (m) | Gross Counts | OK? | LCL | UCL |
|---|---|---|---|---|---|---|
| 394 | 10/3/2018 | 1 | 9775 | OK | 9418 | 9910 |
| 395 | 10/3/2018 | 1 | 9744 | OK | 9418 | 9910 |
| 396 | 10/4/2018 | 1 | 9647 | OK | 9418 | 9910 |
| 397 | 10/4/2018 | 1 | 9755 | OK | 9418 | 9910 |
| 398 | 10/5/2018 | 1 | 9528 | OK | 9418 | 9910 |
| 399 | 10/5/2018 | 1 | 9721 | OK | 9418 | 9910 |

10/8/18

# Th-Source + PMT Daily Performance Check Summary - Detector F, Scalar #1

r:\inst\alphscnt\dailychk.xls
Operating Voltage: 1100 kV
Historical Control Limits Establishe AZ 4/6/2017
Interim Control Limits established: JP 2/15/17

| Obs. # | Date | Count Dur. (m) | Gross Counts | OK? | LCL | UCL |
|---|---|---|---|---|---|---|
| 385 | 10/2/2018 | 1 | 9624 | OK | 9320 | 9843 |
| 386 | 10/2/2018 | 1 | 9519 | OK | 9320 | 9843 |
| 387 | 10/4/2018 | 1 | 9647 | OK | 9320 | 9843 |
| 388 | 10/4/2018 | 1 | 9526 | OK | 9320 | 9843 |
| 389 | 10/5/2018 | 1 | 9794 | OK | 9320 | 9843 |
| 390 | 10/5/2018 | 1 | 9364 | OK | 9320 | 9843 |

10/8/18

# Th-Source + PMT Daily Performance Check Summary - Detector G, Scalar #8

r:\inst\alphscnt\dailychk.xls
Operating Voltage: 800 kV
Historical control limits established:AZ 4/6/2017
Interim Control Limits established: JP 2/15/17

| Obs. # | Date | Count Dur. (m) | Gross Counts | OK? | LCL | UCL |
|---|---|---|---|---|---|---|
| 384 | 10/3/2018 | 1 | 9520 | OK | 9292 | 9986 |
| 385 | 10/3/2018 | 1 | 9734 | OK | 9292 | 9986 |
| 386 | 10/4/2018 | 1 | 9659 | OK | 9292 | 9986 |
| 387 | 10/4/2018 | 1 | 9586 | OK | 9292 | 9986 |
| 388 | 10/5/2018 | 1 | 9665 | OK | 9292 | 9986 |
| 389 | 10/5/2018 | 1 | 9775 | OK | 9292 | 9986 |

10/8/18

# Th-Source + PMT Daily Performance Check Summary - Detector H, Scalar #9

r:\inst\alphscnt\dailychk.xls
Operating Voltage: 800 kV
Historical control limits established: AZ 4/6/2017
Interim Control Limits established: JP 2/15/17

| Obs. # | Date | Count Dur. (m) | Gross Counts | OK? | LCL | UCL |
|---|---|---|---|---|---|---|
| 380 | 10/3/2018 | 1 | 9670 | OK | 9382 | 9879 |
| 381 | 10/3/2018 | 1 | 9760 | OK | 9382 | 9879 |
| 382 | 10/4/2018 | 1 | 9659 | OK | 9382 | 9879 |
| 383 | 10/4/2018 | 1 | 9484 | OK | 9382 | 9879 |
| 384 | 10/5/2018 | 1 | 9636 | OK | 9382 | 9879 |
| 385 | 10/5/2018 | 1 | 9670 | OK | 9382 | 9879 |

10/8/18

# Th-Source + PMT Daily Performance Check Summary - Detector J, Scalar #10

r:\inst\alphscnt\dailychk.xls
Operating Voltage: 800 kV
Historical control limits established:AZ 4/6/2017
Interim Control Limits established: JP 2/15/17

| Obs. # | Date | Count Dur. (m) | Gross Counts | OK? | LCL | UCL |
|---|---|---|---|---|---|---|
| 372 | 10/2/2018 | 1 | 9579 | OK | 9394 | 9910 |
| 373 | 10/2/2018 | 1 | 9632 | OK | 9394 | 9910 |
| 374 | 10/4/2018 | 1 | 9816 | OK | 9394 | 9910 |
| 375 | 10/4/2018 | 1 | 9811 | OK | 9394 | 9910 |
| 376 | 10/5/2018 | 1 | 9654 | OK | 9394 | 9910 |
| 377 | 10/5/2018 | 1 | 9797 | OK | 9394 | 9910 |

10/8/18

# Th-Source + PMT Daily Performance Check Summary - Detector K, Scalar #11

r:\inst\alphscnt\dailychk.xls
Operating Voltage: 800 kV
Historical control limits established:AZ 4/6/2017
Interim Control Limits established: JP 2/15/17

| Obs. # | Date | Count Dur. (m) | Gross Counts | OK? | LCL | UCL |
|---|---|---|---|---|---|---|
| 372 | 10/2/2018 | 1 | 9574 | OK | 9297 | 9771 |
| 373 | 10/2/2018 | 1 | 9485 | OK | 9297 | 9771 |
| 374 | 10/4/2018 | 1 | 9651 | OK | 9297 | 9771 |
| 375 | 10/4/2018 | 1 | 9581 | OK | 9297 | 9771 |
| 376 | 10/5/2018 | 1 | 9527 | OK | 9297 | 9771 |
| 377 | 10/5/2018 | 1 | 9670 | OK | 9297 | 9771 |

10/8/18

# Th-Source + PMT Daily Performance Check Summary - Detector L, Scalar #12

r:\inst\alphscnt\dailychk.xls
Operating Voltage: 800 kV
Historical control limits established:AZ 4/6/2017
Interim Control Limits established: JP 2/15/17

| Obs. # | Date | Count Dur. (m) | Gross Counts | OK? | LCL | UCL |
|---|---|---|---|---|---|---|
| 48 | 10/2/2018 | 1 | 9713 | OK | 9328 | 9860 |
| 49 | 10/2/2018 | 1 | 9807 | OK | 9328 | 9860 |
| 50 | 10/4/2018 | 1 | 9602 | OK | 9328 | 9860 |
| 51 | 10/4/2018 | 1 | 9547 | OK | 9328 | 9860 |
| 52 | 10/5/2018 | 1 | 9375 | OK | 9328 | 9860 |
| 53 | 10/5/2018 | 1 | 9484 | OK | 9328 | 9860 |

10/8/18

# Daily Performance Checks

THE SOURCE INC.
Radiation standards and check sources
2810 Siler Lane Santa Fe, NM 87501
(505)473-9538 FAX(505)473-5805

Paragon # 191
recd 3-21-96

REF.PO# 65-1924

# Certificate of Calibration

(Alpha Sources)

The Thorium 230 alpha source was measured in a proportional counter using P-10 as counting gas. The alpha emissions from the surface of the source were measured at its plateau voltage to determine its 2pi cpm rate. Corrections were applied for background, coincidence loss and backscatter factors when applicable. The source is referenced to NIST 90TH4704627A used in establishing traceablilty.

Active Diameter(or area) 44mm
Total Diameter(or area) 47mm
9,150 cpm
18,000 dpm
0.00812 microcurie
08/20/92 date of measurement
92TH4703015 source serial number

Mounting Material SS
Thickness 0.79mm
± 460 cpm 2pi
± 900 dpm 4pi

Michael A. Ortiz — Calibration Manager
Charles L. Gonzales — Q.A. Manager

The total uncertainty of the measurement at the 99% confidence interval is 5.0 percent.

AC005

# Th-Source + PMT Daily Performance Check Summary - Detector B, Scalar #2

r:\inst\alphscnt\dailychk.xls
Operating Voltage: 1100kV
Historical control limits established:AZ 4/6/2017
Interim Control Limits established: JP 2/15/17

| Obs. # | Date | Count Dur. (m) | Gross Counts | OK? | LCL | UCL |
|---|---|---|---|---|---|---|
| 401 | 12/4/2018 | 1 | 9575 | OK | 9355 | 9949 |
| 402 | 12/4/2018 | 1 | 9526 | OK | 9355 | 9949 |
| 403 | 12/5/2018 | 1 | 9645 | OK | 9355 | 9949 |
| 404 | 12/5/2018 | 1 | 9583 | OK | 9355 | 9949 |
| 405 | 12/6/2018 | 1 | 9515 | OK | 9355 | 9949 |
| 406 | 12/6/2018 | 1 | 9648 | OK | 9355 | 9949 |

SG 12/7
1216

# Th-Source + PMT Daily Performance Check Summary - Detector D, Scalar #5

r:\inst\alphscnt\dailychk.xls
Operating Voltage: 900kV
Historical control limits established: AZ 4/6/2017
Interim Control Limits established: JP 2/15/17

| Obs. # | Date | Count Dur. (m) | Gross Counts | OK? | LCL | UCL |
|---|---|---|---|---|---|---|
| 472 | 12/4/2018 | 1 | 9671 | OK | 9299 | 9941 |
| 473 | 12/4/2018 | 1 | 9502 | OK | 9299 | 9941 |
| 474 | 12/5/2018 | 1 | 9614 | OK | 9299 | 9941 |
| 475 | 12/5/2018 | 1 | 9621 | OK | 9299 | 9941 |
| 476 | 12/6/2018 | 1 | 9591 | OK | 9299 | 9941 |
| 477 | 12/6/2018 | 1 | 9564 | OK | 9299 | 9941 |

SG 12/7

12/6

# Th-Source + PMT Daily Performance Check Summary - Detector A, Scalar #7

r:\inst\alphscnt\dailychk.xls
Operating Voltage: 1000 kV
Historical Control Limits Establishe AZ 4/6/2017
Interim Control Limits established: JP 2/15/17

| Obs. # | Date | Count Dur. (m) | Gross Counts | OK? | LCL | UCL |
|---|---|---|---|---|---|---|
| 472 | 12/4/2018 | 1 | 9703 | OK | 9418 | 9910 |
| 473 | 12/4/2018 | 1 | 9590 | OK | 9418 | 9910 |
| 474 | 12/5/2018 | 1 | 9501 | OK | 9418 | 9910 |
| 475 | 12/5/2018 | 1 | 9639 | OK | 9418 | 9910 |
| 476 | 12/6/2018 | 1 | 9751 | OK | 9418 | 9910 |
| 477 | 12/6/2018 | 1 | 9656 | OK | 9418 | 9910 |

SG 1217

K216

# Th-Source + PMT Daily Performance Check Summary - Detector F, Scalar #1

r:\inst\alphscnt\dailychk.xls
Operating Voltage: 1100 kV
Historical Control Limits Establishe AZ 4/6/2017
Interim Control Limits established: JP 2/15/17

| Obs. # | Date | Count Dur. (m) | Gross Counts | OK? | LCL | UCL |
|---|---|---|---|---|---|---|
| 461 | 12/4/2018 | 1 | 9597 | OK | 9320 | 9843 |
| 462 | 12/4/2018 | 1 | 9786 | OK | 9320 | 9843 |
| 463 | 12/5/2018 | 1 | 9627 | OK | 9320 | 9843 |
| 464 | 12/5/2018 | 1 | 9548 | OK | 9320 | 9843 |
| 465 | 12/6/2018 | 1 | 9473 | OK | 9320 | 9843 |
| 466 | 12/6/2018 | 1 | 9717 | OK | 9320 | 9843 |

SG 12/7

# Th-Source + PMT Daily Performance Check Summary - Detector G, Scalar #8

r:\inst\alphscnt\dailychk.xls
Operating Voltage: 800 kV
Historical control limits established:AZ 4/6/2017
Interim Control Limits established: JP 2/15/17

| Obs. # | Date | Count Dur. (m) | Gross Counts | OK? | LCL | UCL |
|---|---|---|---|---|---|---|
| 460 | 12/4/2018 | 1 | 9794 | OK | 9292 | 9986 |
| 461 | 12/4/2018 | 1 | 9643 | OK | 9292 | 9986 |
| 462 | 12/5/2018 | 1 | 9753 | OK | 9292 | 9986 |
| 463 | 12/5/2018 | 1 | 9517 | OK | 9292 | 9986 |
| 464 | 12/6/2018 | 1 | 9728 | OK | 9292 | 9986 |
| 465 | 12/6/2018 | 1 | 9646 | OK | 9292 | 9986 |

SG 12/7

# Th-Source + PMT Daily Performance Check Summary - Detector H, Scalar #9

r:\inst\alphscnt\dailychk.xls
Operating Voltage: 800 kV
Historical control limits established: AZ 4/6/2017
Interim Control Limits established: JP 2/15/17

| Obs. # | Date | Count Dur. (m) | Gross Counts | OK? | LCL | UCL |
|---|---|---|---|---|---|---|
| 454 | 12/4/2018 | 1 | 9680 | OK | 9382 | 9879 |
| 455 | 12/4/2018 | 1 | 9584 | OK | 9382 | 9879 |
| 456 | 12/5/2018 | 1 | 9706 | OK | 9382 | 9879 |
| 457 | 12/5/2018 | 1 | 9669 | OK | 9382 | 9879 |
| 458 | 12/6/2018 | 1 | 9463 | OK | 9382 | 9879 |
| 459 | 12/6/2018 | 1 | 9657 | OK | 9382 | 9879 |

SG 12/7

# Th-Source + PMT Daily Performance Check Summary - Detector J, Scalar #10

r:\inst\alphscnt\dailychk.xls
Operating Voltage: 800 kV
Historical control limits established:AZ 4/6/2017
Interim Control Limits established: JP 2/15/17

| Obs. # | Date | Count Dur. (m) | Gross Counts | OK? | LCL | UCL |
|---|---|---|---|---|---|---|
| 446 | 12/4/2018 | 1 | 9631 | OK | 9394 | 9910 |
| 447 | 12/4/2018 | 1 | 9687 | OK | 9394 | 9910 |
| 448 | 12/5/2018 | 1 | 9701 | OK | 9394 | 9910 |
| 449 | 12/5/2018 | 1 | 9696 | OK | 9394 | 9910 |
| 450 | 12/6/2018 | 1 | 9508 | OK | 9394 | 9910 |
| 451 | 12/6/2018 | 1 | 9637 | OK | 9394 | 9910 |

SG 12/7

F216

# Th-Source + PMT Daily Performance Check Summary - Detector K, Scalar #11

r:\inst\alphscnt\dailychk.xls
Operating Voltage: 800 kV
Historical control limits established:AZ 4/6/2017
Interim Control Limits established: JP 2/15/17

| Obs. # | Date | Count Dur. (m) | Gross Counts | OK? | LCL | UCL |
|---|---|---|---|---|---|---|
| 446 | 12/4/2018 | 1 | 9388 | OK | 9297 | 9771 |
| 447 | 12/4/2018 | 1 | 9559 | OK | 9297 | 9771 |
| 448 | 12/5/2018 | 1 | 9546 | OK | 9297 | 9771 |
| 449 | 12/5/2018 | 1 | 9558 | OK | 9297 | 9771 |
| 450 | 12/6/2018 | 1 | 9586 | OK | 9297 | 9771 |
| 451 | 12/6/2018 | 1 | 9557 | OK | 9297 | 9771 |

SG 1217

12/6

# Th-Source + PMT Daily Performance Check Summary - Detector L, Scalar #12

r:\inst\alphscnt\dailychk.xls
Operating Voltage: 800 kV
Historical control limits established:AZ 4/6/2017
Interim Control Limits established: JP 2/15/17

| Obs. # | Date | Count Dur. (m) | Gross Counts | OK? | LCL | UCL |
|---|---|---|---|---|---|---|
| 120 | 12/4/2018 | 1 | 9517 | OK | 9328 | 9860 |
| 121 | 12/4/2018 | 1 | 9603 | OK | 9328 | 9860 |
| 122 | 12/5/2018 | 1 | 9558 | OK | 9328 | 9860 |
| 123 | 12/5/2018 | 1 | 9614 | OK | 9328 | 9860 |
| 124 | 12/6/2018 | 1 | 9706 | OK | 9328 | 9860 |
| 125 | 12/6/2018 | 1 | 9684 | OK | 9328 | 9860 |

SG 12/17

# Radium-228

## Case Narrative

---

# Tidewater, Inc.

## Phase 1 RI OU2 Great Kills Park – 2016-007

### Work Order Number: 1811039

1. This report consists of the analytical results and supporting documentation for nine water samples received by ALS on 11/02/2018.

2. These samples were prepared according to the current revision of SOP 749.

3. The samples were analyzed for the presence of $^{228}$Ra by low background gas flow proportional counting of $^{228}$Ac, which is the ingrown progeny of $^{228}$Ra, according to the current revision of SOP 724. The analyses were completed on 12/07/2018.

4. The analysis results for these samples are reported in units of pCi/L. Dissolved samples were field filtered prior to receipt at ALS. Samples 1811039-1, -2, and -10 were filtered prior to analysis. The other samples were not filtered prior to analysis.

5. Sample volume was insufficient to allow preparation of a duplicate. A laboratory control sample duplicate (LCSD) was prepared in lieu of a client sample duplicate.

6. No anomalous situations were noted during the preparation and analysis of these samples OR. All quality control criteria were met.

The data contained in the following report have been reviewed and approved by the personnel listed below. In addition, ALS certifies that the analyses reported herein are true, complete and correct within the limits of the methods employed.

Pik Yee Yuen — 12/12/18
Pik Yee Yuen — Date
Radiochemistry Primary Data Reviewer

12/18/18
Radiochemistry Final Data Reviewer — Date

1

Section 1

# CHAIN OF CUSTODY

# ALS -- Fort Collins

## Sample Number(s) Cross-Reference Table

**OrderNum:** 1811039
**Client Name:** Tidewater, Inc.
**Client Project Name:** Phase 1 RI OU2 Great Kills Park
**Client Project Number:** 2016-007
**Client PO Number:**

| Client Sample Number | Lab Sample Number | COC Number | Matrix | Date Collected | Time Collected |
|---|---|---|---|---|---|
| OU2-1-MW010 | 1811039-1 | | WATER | 29-Oct-18 | 15:40 |
| OU2-1-MW010-F | 1811039-2 | | WATER | 29-Oct-18 | 15:40 |
| OU2-1-MW008WT | 1811039-3 | | WATER | 31-Oct-18 | 12:10 |
| OU2-1-MW008WT-DUP | 1811039-4 | | WATER | 31-Oct-18 | 12:10 |
| OU2-1-MW008WT-F | 1811039-5 | | WATER | 31-Oct-18 | 12:10 |
| OU2-1-MW008WT-F-DUP | 1811039-6 | | WATER | 31-Oct-18 | 12:10 |
| OU2-1-MW009WT | 1811039-7 | | WATER | 31-Oct-18 | 16:55 |
| OU2-1-MW009WT-F | 1811039-8 | | WATER | 31-Oct-18 | 16:55 |
| OU2IDWSOIL110118-001 | 1811039-9 | | SOIL | 01-Nov-18 | 10:00 |
| OU2IDWWATER110118-001 | 1811039-10 | | WATER | 01-Nov-18 | 9:40 |

# ALS Environmental

225 Commerce Drive, Fort Collins, Colorado 80524
TF: (800) 443-1511 PH: (970) 490-1511 FX: (970) 490-1522

## Chain-of-Custody

Form 202r8

| | | | | | |
|---|---|---|---|---|---|
| WORKORDER # | 1811039 | | | | |
| SAMPLER | John C Schroeder | DATE | 10/31/18 | PAGE | 1 of 1 |
| PROJECT NAME | GKP Phase I RI OU2 | SITE ID | | TURNAROUND | DISPOSAL: By Lab or Return to Client |
| PROJECT No. | 2016-007 | EDD FORMAT | contact Ryan Wensink | | |
| | | PURCHASE ORDER | | | |
| COMPANY NAME | Tidewater | BILL TO COMPANY | Tidewater | | |
| SEND REPORT TO | Ryan Wensink (Tidewater) | INVOICE ATTN TO | Ryan Wensink | | |
| ADDRESS | Devon Chicoine (AECOM) | ADDRESS | 3761 Attucks Drive | | |
| CITY / STATE / ZIP | devon.chicoine@aecom.com | CITY / STATE / ZIP | Powell, OH 43065 | | |
| PHONE | 703-966-5484 | PHONE | 614-389-6251 | | |
| FAX | Colleen Scott (AECOM) | FAX | | | |
| E-MAIL | colleen.scott@aecom.com | E-MAIL | ryan.wensink@tidah2o.net | | |

| Lab ID | Field ID | Matrix | Sample Date | Sample Time | # Bottles | Pres. | QC | Radium 226/228 (EPA 903/904) | Gross Alpha & Beta (EPA 900) | Total Uranium (EPA 200.8) | Uranium-238 | Radium-226 | Thorium-232 | 901.1 | EPA | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | OU2-1-MW010 | ground water | 102918 | 1540 | 5 | $HNO_3$ | | X | X | X | | | | | | |
| 2 | OU2-1-MW010-F | ground water | 102918 | 1540 | 5 | $HNO_3$ | | X | X | X | | | | | | field filtered |
| 3 | OU2-1-MW008WT | ground water | 103118 | 1210 | 5 | $HNO_3$ | | X | X | X | | | | | | |
| 4 | OU2-1-MW008WT-DUP | ground water | 103118 | 1210 | 5 | $HNO_3$ | dupl. wtr | X | X | X | | | | | | |
| 5 | OU2-1-MW008WT-F | ground water | 103118 | 1210 | 5 | $HNO_3$ | | X | X | X | | | | | | field filtered |
| 6 | OU2-1-MW008WT-F-DUP | ground water | 103118 | 1210 | 5 | $HNO_3$ | dupl. wtr | X | X | X | | | | | | field filtered |
| 7 | OU2-1-MW009WT | ground water | 103118 | 1655 | 5 | $HNO_3$ | | X | X | X | | | | | | |
| 8 | OU2-1-MW009WT-F | ground water | 103118 | 1655 | 5 | $HNO_3$ | | X | X | X | | | | | | field filtered |
| 9 | OU2IDWSOIL110118-001 | soil | 110118 | 1000 | 1 | – | | | | | X | X | X | | | IDW sample |
| 10 | OU2IDWWATER110118-001 | IDW water | 110118 | 0940 | 5 | $HNO_3$ | | X | X | X | | | | | | IDW sample |

*Time Zone (Circle): EST CST MST PST Matrix: O = oil S = soil NS = non-soil solid W = water L = liquid E = extract F = filter

For metals or anions, please detail analytes below.

Comments:

| QC PACKAGE (check below) | |
|---|---|
| | LEVEL II (Standard QC) |
| | LEVEL III (Std QC + forms) |
| | LEVEL IV (Std QC + forms + raw data) |
| | |

Preservative Key: 1-HCl 2-HNO3 3-H2SO4 4-NaOH 5-NaHSO4 7-Other 8-4 degrees C 9-5035

| | SIGNATURE | PRINTED NAME | DATE | TIME |
|---|---|---|---|---|
| RELINQUISHED BY | [signature] | John C Schroeder | 110118 | 1700 |
| RECEIVED BY | Fed Ex | Fed Ex | 110118 | 1700 |
| RELINQUISHED BY | FEDEX | FEDEX | 11.2.18 | 0954 |
| RECEIVED BY | [signature] | KELI-JEAN SMITH | 11.2.18 | 0954 |
| RELINQUISHED BY | | | | |
| RECEIVED BY | | | | |

**ALS Environmental - Fort Collins**
**CONDITION OF SAMPLE UPON RECEIPT FORM**

Client: TIDEWATER  Workorder No: 1811039

Project Manager: LRS  Initials: RZ  Date: 11.2.18

| | | | | |
|---|---|---|---|---|
| 1. | Are airbills / shipping documents present and/or removable? | DROP OFF | YES | NO |
| 2. | Are custody seals on **shipping** containers intact? | NONE | YES | NO |
| 3. | Are custody seals on **sample** containers intact? | NONE | YES | NO |
| 4. | Is there a COC (chain-of-custody) present? | | YES | NO |
| 5. | Is the COC in agreement with samples received? (IDs, dates, times, # of samples, # of containers, matrix, requested analyses, etc.) | | YES | NO |
| 6. | Are short-hold samples present? | | YES | NO |
| 7. | Are all samples within holding times for the requested analyses? | | YES | NO |
| 8. | Were all sample containers received intact? (not broken or leaking) | | YES | NO |
| 9. | Is there sufficient sample for the requested analyses? | | YES | NO |
| 10. | Are all samples in the proper containers for the requested analyses? | | YES | NO |
| 11. | Are all aqueous samples preserved correctly, if required? (excluding volatiles) | N/A | YES | NO |
| 12. | Are all aqueous non-preserved samples pH 4-9? | N/A | YES | NO |
| 13. | Are all samples requiring no headspace (VOC, GRO, RSK/MEE, Rx CN/S, radon) free of bubbles > 6 mm (1/4 inch) diameter? (i.e. size of green pea) | N/A | YES | NO |
| 14. | Were the samples shipped on ice? | | YES | NO |
| 15. | Were cooler temperatures measured at 0.1-6.0°C? IR gun used*: #1 #3 #4 | RAD ONLY | YES | NO |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Cooler #: | 1 | 2 | | | | | | |
| Temperature (°C): | AMB | AMB | | | | | | |
| No. of custody seals on cooler: | 2 | 2 | | | | | | |
| DOT Survey/ Acceptance Information — External µR/hr reading: | 9 | 9 | | | | | | |
| DOT Survey/ Acceptance Information — Background µR/hr reading: | 10 | | | | | | | |

Were external µR/hr readings ≤ two times background and within DOT acceptance criteria? YES / NO / NA (If no, see Form 008.)

**Additional Information:** **Please provide details here for any NO responses to gray-shaded boxes above, or any other issues noted:**

11) Sample 4 bottle 5 initial pH 6 - added 1ml
Sample 5 all 3 bottles initial pH 4 - added 0.5ml
Sample 6 bottle 5 initial pH 5 - added 0.5ml
} HNO3 lot 193289 to acheive pH<2.

All client bottle ID's vs ALS lab ID's double-checked by: RZ

If applicable, was the client contacted? YES / NO / NA Contact: Ryan W. Date/Time: 11/2

**Project Manager Signature / Date:** 11/2/18

Form 201r26.xls
(06/29/2018)

*IR Gun #1, VWR SN 170560549
*IR Gun #3, VWR SN 170647571
*IR Gun #4, Oakton, SN 2372220101-0002

1811039

# Do Not Lift Using This Tag

ORIGIN ID:LDJA (614) 389-6251
RYAN WENSINK
TIDEWATER
6625 SELNICK DR
STE A
ELKRIDGE, MD 21075
UNITED STATES US

SHIP DATE: 01NOV18
ACTWGT: 58.10 LB
CAD: 6991560/SSF01922
DIMS: 23x13x13 IN

BILL THIRD PARTY

TO SAMPLE RECIEVING
ALS ENVIRONMENTAL
225 COMMERCE DRIVE

9-2

FORT COLLINS CO 80524
(800) 443-1511
INV:
PO: REF:
DEPT:

FedEx Express

TRK# 0201 7835 5379 7932

FRI - 02 NOV 10:30A
PRIORITY OVERNIGHT
AHS
80524
CO-US DEN

NA FTCA

R1 617
S1 12
5
10:30 A
7932
11.02

# Do Not Lift Using This Tag

ORIGIN ID:LDJA (614) 389-6251
RYAN WENSINK
TIDEWATER
6625 SELNICK DR
STE A
ELKRIDGE, MD 21075
UNITED STATES US

R1 617
5
10:30 A
470
11.02

TO SAMPLE RECIEVING
ALS ENVIRONMENTAL
225 COMMERCE DRIVE

9-2

FORT COLLINS CO 80524
(800) 443-1511
INV:
PO: REF:
DEPT:

FedEx Express

TRK# 0201 7835 5383 4470

FRI - 02 NOV 10:30A
PRIORITY OVERNIGHT
AHS
80524
CO-US DEN

NA FTCA

Section 2

2

# SAMPLE RESULTS SUMMARY

# Radium-228 Analysis by GFPC Sample Results Summary

**Client Name:** Tidewater, Inc.
**Client Project Name:** Phase 1 RI OU2 Great Kills Park
**Client Project Number:** 2016-007
**Laboratory Name:** **ALS -- Fort Collins**
**PAI Work Order:** 1811039


**Reported on:** Monday, December 17, 2018
1:34:14 PM

| Lab Sample ID | Client Sample ID | Sample Type | Nuclide | Result +/- 2 s TPU | MDC | DL | Units | Matrix | Prep Batch | Date Analyze | Flags |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1811039-1 | OU2-1-MW010 | Sample | Ra-228 | 0.48 +/- 0.42 | 0.85 | NA | pCi/l | WATER | RA181128-1 | 12/7/2018 | U |
| 1811039-2 | OU2-1-MW010-F | Sample | Ra-228 | 0.54 +/- 0.44 | 0.88 | NA | pCi/l | WATER | RA181128-1 | 12/7/2018 | U |
| 1811039-3 | OU2-1-MW008WT | Sample | Ra-228 | 0.48 +/- 0.41 | 0.83 | NA | pCi/l | WATER | RA181128-1 | 12/7/2018 | U |
| 1811039-4 | OU2-1-MW008WT-DUP | Sample | Ra-228 | 0.41 +/- 0.41 | 0.84 | NA | pCi/l | WATER | RA181128-1 | 12/7/2018 | U |
| 1811039-5 | OU2-1-MW008WT-F | Sample | Ra-228 | 0.69 +/- 0.40 | 0.74 | NA | pCi/l | WATER | RA181128-1 | 12/7/2018 | U |
| 1811039-6 | OU2-1-MW008WT-F-DUP | Sample | Ra-228 | 0.44 +/- 0.38 | 0.76 | NA | pCi/l | WATER | RA181128-1 | 12/7/2018 | U |
| 1811039-7 | OU2-1-MW009WT | Sample | Ra-228 | 0.45 +/- 0.37 | 0.74 | NA | pCi/l | WATER | RA181128-1 | 12/7/2018 | U |
| 1811039-8 | OU2-1-MW009WT-F | Sample | Ra-228 | 0.07 +/- 0.33 | 0.72 | NA | pCi/l | WATER | RA181128-1 | 12/7/2018 | U |
| 1811039-10 | OU2IDWWATER110118-001 | Sample | Ra-228 | 0.72 +/- 0.42 | 0.79 | NA | pCi/l | WATER | RA181128-1 | 12/7/2018 | U |

**Comments:**

**Data Package ID:** *RA1811039-1*

**Qualifiers/Flags:**

U - Result is less than the sample specific MDC.
LT - Result is less than Requested MDC, greater than sample specific MDC.
Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.
Y2 - Chemical Yield outside default limits.
M - The requested MDC was not met.
M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

Abbreviations:

TPU - Total Propagated Uncertainty
MDC - Sample specific Minimum Detectable Concentration

BDL - Below Detection Limit

Section 3

# QC RESULTS SUMMARY ❸

# Radium-228 Analysis by GFPC

## PAI 724 Rev 13

## Method Blank Results

**Lab Name:** **ALS -- Fort Collins**
**Work Order Number:** 1811039
**Client Name:** Tidewater, Inc.
**ClientProject ID:** Phase 1 RI OU2 Great Kills Park 2016-007

**Lab ID:** RA181128-1MB

**Sample Matrix:** WATER
**Prep SOP:** SOP749 Rev 5
**Date Collected:** 28-Nov-18
**Date Prepared:** 28-Nov-18
**Date Analyzed:** 07-Dec-18

**Prep Batch:** RA181128-1
**QCBatchID:** RA181128-1-3
**Run ID:** RA181128-1A
**Count Time:** 150 minutes

**Final Aliquot:** 997 ml
**Result Units:** pCi/l
**File Name:** RAC1207B

| CASNO | Target Nuclide | Result +/- 2 s TPU | MDC | Requested MDC | DL | Lab Qualifier |
|---|---|---|---|---|---|---|
| 15262-20-1 | Ra-228 | 0.03 +/- 0.33 | 0.73 | 1 | NA | U |

## Chemical Yield Summary

| Carrier/Tracer | Amount Added | Result | Units | Yield | Control Limits | Flag |
|---|---|---|---|---|---|---|
| BARIUM | 31840 | 30070 | ug | 94.5 | 40 - 110 % | |

**Comments:** This sample was filtered prior to analysis.

**Qualifiers/Flags:**
U - Result is less than the sample specific MDC.
Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.
Y2 - Chemical Yield outside default limits.

Abbreviations:
TPU - Total Propagated Uncertainty
MDC - Sample specific Minimum Detectable Concentration
BDL - Below Detection Limit

M - Requested MDC not met.
B - Analyte concentration greater than MDC.
B3 - Analyte concentration greater than MDC but less than Requested MDC.
DL - Decision Level

**Data Package ID:** *RA1811039-1*

# Radium-228 Analysis by GFPC

## PAI 724 Rev 13

## Laboratory Control Sample(s)

**Lab Name:** **ALS -- Fort Collins**
**Work Order Number:** 1811039
**Client Name:** Tidewater, Inc.
**ClientProject ID:** Phase 1 RI OU2 Great Kills Park 2016-007

**Lab ID:** RA181128-1LCS

**Sample Matrix:** WATER
**Prep SOP:** SOP749 Rev 5
**Date Collected:** 28-Nov-18
**Date Prepared:** 28-Nov-18
**Date Analyzed:** 07-Dec-18

**Prep Batch:** RA181128-1
**QCBatchID:** RA181128-1-3
**Run ID:** RA181128-1A
**Count Time:** 30 minutes

**Final Aliquot:** 997 ml
**Result Units:** pCi/l
**File Name:** RAC1207C

| CASNO | Target Nuclide | Results +/- 2s TPU | MDC | Spike Added | % Rec | Control Limits | Lab Qualifier |
|---|---|---|---|---|---|---|---|
| 15262-20-1 | Ra-228 | 9.4 +/- 2.6 | 1.4 | 8.595 | 110 | 70 - 130 | P,M3 |

## Chemical Yield Summary

| Carrier/Tracer | Amount Added | Result | Units | Yield | Control Limits | Flag |
|---|---|---|---|---|---|---|
| BARIUM | 31840 | 30610 | ug | 96.1 | 40 - 110 % | |

**Comments:** This sample was filtered prior to analysis.

**Qualifiers/Flags:**

U - Result is less than the sample specific MDC.
Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.
Y2 - Chemical Yield outside default limits.
L - LCS Recovery below lower control limit.
H - LCS Recovery above upper control limit.
P - LCS Recovery within control limits.
M - The requested MDC was not met.
M3 - The requested MDC was not met, but thereported activity is greater than the reported MDC.

Abbreviations:

TPU - Total Propagated Uncertainty
MDC - Minimum Detectable Concentration

**Data Package ID:** *RA1811039-1*

# Radium-228 Analysis by GFPC

## PAI 724 Rev 13

## Laboratory Control Sample(s)

**Lab Name:** **ALS -- Fort Collins**
**Work Order Number:** 1811039
**Client Name:** Tidewater, Inc.
**ClientProject ID:** Phase 1 RI OU2 Great Kills Park 2016-007

**Lab ID:** RA181128-1LCSD

**Sample Matrix:** WATER
**Prep SOP:** SOP749 Rev 5
**Date Collected:** 28-Nov-18
**Date Prepared:** 28-Nov-18
**Date Analyzed:** 07-Dec-18

**Prep Batch:** RA181128-1
**QCBatchID:** RA181128-1-3
**Run ID:** RA181128-1A
**Count Time:** 30 minutes

**Final Aliquot:** 997 ml
**Result Units:** pCi/l
**File Name:** RAC1207C

| CASNO | Target Nuclide | Results +/- 2s TPU | MDC | Spike Added | % Rec | Control Limits | Lab Qualifier |
|---|---|---|---|---|---|---|---|
| 15262-20-1 | Ra-228 | 8.3 +/- 2.3 | 1.5 | 8.595 | 96.8 | 70 - 130 | P,M3 |

## Chemical Yield Summary

| Carrier/Tracer | Amount Added | Result | Units | Yield | Control Limits | Flag |
|---|---|---|---|---|---|---|
| BARIUM | 31840 | 30660 | ug | 96.3 | 40 - 110 % | |

**Comments:** This sample was filtered prior to analysis.

**Qualifiers/Flags:**

U - Result is less than the sample specific MDC.
Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.
Y2 - Chemical Yield outside default limits.
L - LCS Recovery below lower control limit.
H - LCS Recovery above upper control limit.
P - LCS Recovery within control limits.
M - The requested MDC was not met.
M3 - The requested MDC was not met, but thereported activity is greater than the reported MDC.

Abbreviations:

TPU - Total Propagated Uncertainty
MDC - Minimum Detectable Concentration

**Data Package ID:** *RA1811039-1*

# Radium-228 Analysis by GFPC

## PAI 724 Rev 13

## Duplicate Sample Results (DER)

**Lab Name:** **ALS -- Fort Collins**
**Work Order Number:** 1811039
**Client Name:** Tidewater, Inc.
**ClientProject ID:** Phase 1 RI OU2 Great Kills Park 2016-007

**Field ID:**
**Lab ID:** RA181128-1LCSD

**Sample Matrix:** WATER
**Prep SOP:** SOP749 Rev 5
**Date Collected:** 28-Nov-18
**Date Prepared:** 28-Nov-18
**Date Analyzed:** 07-Dec-18

**Prep Batch:** RA181128-1
**QCBatchID:** RA181128-1-3
**Run ID:** RA181128-1A
**Count Time:** 30 minutes

**Final Aliquot:** 997 ml
**Prep Basis:** Filtered
**Moisture(%):** NA
**Result Units:** pCi/l
**File Name:** RAC1207C

| CASNO | Analyte | Sample | | | Duplicate | | | DER | DER Lim |
|---|---|---|---|---|---|---|---|---|---|
| | | Result +/- 2 s TPU | MDC | Flags | Result +/- 2 s TPU | MDC | Flags | | |
| 15262-20-1 | Ra-228 | 9.4 +/- 2.6 | 1.4 | P,M3 | 8.3 +/- 2.3 | 1.5 | P,M3 | 0.326 | 2.13 |

**Comments:** This sample was filtered prior to analysis.

**Duplicate Qualifiers/Flags:**

U - Result is less than the sample specific MDC.
Y1 - Chemical Yield is in control at 100-110%. Quantitative yield is assumed.
Y2 - Chemical Yield outside default limits.
W - DER is greater than Warning Limit of 1.42
D - DER is greater than Control Limit of 2.13
LT - Result is less than Request MDC, greater than sample specific MDC
M - Requested MDC not met.
M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.
L - LCS Recovery below lower control limit.
H - LCS Recovery above upper control limit.
P - LCS, Matrix Spike Recovery within control limits.
N - Matrix Spike Recovery outside control limits

Abbreviations:

TPU - Total Propagated Uncertainty
DER - Duplicate Error Ratio
BDL - Below Detection Limit
NR - Not Reported

**Data Package ID:** *RA1811039-1*

Section 4

# INDIVIDUAL SAMPLE RESULTS

4

# Radium-228 Analysis by GFPC

## PAI 724 Rev 13

## Sample Results

**Lab Name:** **ALS -- Fort Collins**
**Work Order Number:** 1811039
**Client Name:** Tidewater, Inc.
**ClientProject ID:** Phase 1 RI OU2 Great Kills Park 2016-007

**Field ID:** OU2-1-MW010
**Lab ID:** 1811039-1

**Sample Matrix:** WATER
**Prep SOP:** SOP749 Rev 5
**Date Collected:** 29-Oct-18
**Date Prepared:** 28-Nov-18
**Date Analyzed:** 07-Dec-18

**Prep Batch:** RA181128-1
**QCBatchID:** RA181128-1-3
**Run ID:** RA181128-1A
**Count Time:** 150 minutes
**Report Basis:** Filtered

**Final Aliquot:** 997 ml
**Prep Basis:** Filtered
**Moisture(%):** NA
**Result Units:** pCi/l
**File Name:** RAA1207A

| CASNO | Target Nuclide | Result +/- 2 s TPU | MDC | Requested MDC | DL | Lab Qualifier |
|---|---|---|---|---|---|---|
| 15262-20-1 | Ra-228 | 0.48 +/- 0.42 | 0.85 | 1 | NA | U |

## Chemical Yield Summary

| Carrier/Tracer | Amount Added | Result | Units | Yield | Control Limits | Flag |
|---|---|---|---|---|---|---|
| BARIUM | 32530 | 30030 | ug | 92.3 | 40 - 110 % | |

**Comments:** This sample was filtered prior to analysis.

**Qualifiers/Flags:**

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

M - The requested MDC was not met.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Sample specific Minimum Detectable Concentration

BDL - Below Detection Limit

DL - Decision Level

**Data Package ID:** *RA1811039-1*

# Dissolved Radium-228 Analysis by GFPC

## PAI 724 Rev 13

## Sample Results

**Lab Name:** **ALS -- Fort Collins**
**Work Order Number:** 1811039
**Client Name:** Tidewater, Inc.
**ClientProject ID:** Phase 1 RI OU2 Great Kills Park 2016-007

**Field ID:** OU2-1-MW010-F
**Lab ID:** 1811039-2

**Sample Matrix:** WATER
**Prep SOP:** SOP749 Rev 5
**Date Collected:** 29-Oct-18
**Date Prepared:** 28-Nov-18
**Date Analyzed:** 07-Dec-18

**Prep Batch:** RA181128-1
**QCBatchID:** RA181128-1-3
**Run ID:** RA181128-1A
**Count Time:** 150 minutes
**Report Basis:** Filtered

**Final Aliquot:** 997 ml
**Prep Basis:** Filtered
**Moisture(%):** NA
**Result Units:** pCi/l
**File Name:** RAA1207A

| CASNO | Target Nuclide | Result +/- 2 s TPU | MDC | Requested MDC | DL | Lab Qualifier |
|---|---|---|---|---|---|---|
| 15262-20-1 | Ra-228 | 0.54 +/- 0.44 | 0.88 | 1 | NA | U |

## Chemical Yield Summary

| Carrier/Tracer | Amount Added | Result | Units | Yield | Control Limits | Flag |
|---|---|---|---|---|---|---|
| BARIUM | 32580 | 30000 | ug | 92.1 | 40 - 110 % | |

**Comments:** This sample was filtered prior to analysis.

**Qualifiers/Flags:**

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

M - The requested MDC was not met.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Sample specific Minimum Detectable Concentration

BDL - Below Detection Limit

DL - Decision Level

**Data Package ID:** *RA1811039-1*

# Radium-228 Analysis by GFPC

## PAI 724 Rev 13

## Sample Results

**Lab Name:** **ALS -- Fort Collins**
**Work Order Number:** 1811039
**Client Name:** Tidewater, Inc.
**ClientProject ID:** Phase 1 RI OU2 Great Kills Park 2016-007

**Field ID:** OU2-1-MW008WT
**Lab ID:** 1811039-3

**Sample Matrix:** WATER
**Prep SOP:** SOP749 Rev 5
**Date Collected:** 31-Oct-18
**Date Prepared:** 28-Nov-18
**Date Analyzed:** 07-Dec-18

**Prep Batch:** RA181128-1
**QCBatchID:** RA181128-1-3
**Run ID:** RA181128-1A
**Count Time:** 150 minutes
**Report Basis:** Unfiltered

**Final Aliquot:** 997 ml
**Prep Basis:** Unfiltered
**Moisture(%):** NA
**Result Units:** pCi/l
**File Name:** RAA1207A

| CASNO | Target Nuclide | Result +/- 2 s TPU | MDC | Requested MDC | DL | Lab Qualifier |
|---|---|---|---|---|---|---|
| 15262-20-1 | Ra-228 | 0.48 +/- 0.41 | 0.83 | 1 | NA | U |

## Chemical Yield Summary

| Carrier/Tracer | Amount Added | Result | Units | Yield | Control Limits | Flag |
|---|---|---|---|---|---|---|
| BARIUM | 33530 | 31150 | ug | 92.9 | 40 - 110 % | |

### Comments:

**Qualifiers/Flags:**

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

M - The requested MDC was not met.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Sample specific Minimum Detectable Concentration

BDL - Below Detection Limit

DL - Decision Level

**Data Package ID:** *RA1811039-1*

# Radium-228 Analysis by GFPC

## PAI 724 Rev 13

## Sample Results

**Lab Name:** **ALS -- Fort Collins**
**Work Order Number:** 1811039
**Client Name:** Tidewater, Inc.
**ClientProject ID:** Phase 1 RI OU2 Great Kills Park 2016-007

**Field ID:** OU2-1-MW008WT-DUP
**Lab ID:** 1811039-4

**Sample Matrix:** WATER
**Prep SOP:** SOP749 Rev 5
**Date Collected:** 31-Oct-18
**Date Prepared:** 28-Nov-18
**Date Analyzed:** 07-Dec-18

**Prep Batch:** RA181128-1
**QCBatchID:** RA181128-1-3
**Run ID:** RA181128-1A
**Count Time:** 150 minutes
**Report Basis:** Unfiltered

**Final Aliquot:** 997 ml
**Prep Basis:** Unfiltered
**Moisture(%):** NA
**Result Units:** pCi/l
**File Name:** RAA1207A

| CASNO | Target Nuclide | Result +/- 2 s TPU | MDC | Requested MDC | DL | Lab Qualifier |
|---|---|---|---|---|---|---|
| 15262-20-1 | Ra-228 | 0.41 +/- 0.41 | 0.84 | 1 | NA | U |

## Chemical Yield Summary

| Carrier/Tracer | Amount Added | Result | Units | Yield | Control Limits | Flag |
|---|---|---|---|---|---|---|
| BARIUM | 33510 | 30270 | ug | 90.3 | 40 - 110 % | |

### Comments:

**Qualifiers/Flags:**

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

M - The requested MDC was not met.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Sample specific Minimum Detectable Concentration

BDL - Below Detection Limit

DL - Decision Level

**Data Package ID:** *RA1811039-1*

# Dissolved Radium-228 Analysis by GFPC

## PAI 724 Rev 13

## Sample Results

**Lab Name:** **ALS -- Fort Collins**
**Work Order Number:** 1811039
**Client Name:** Tidewater, Inc.
**ClientProject ID:** Phase 1 RI OU2 Great Kills Park 2016-007

**Field ID:** OU2-1-MW008WT-F
**Lab ID:** 1811039-5

**Sample Matrix:** WATER
**Prep SOP:** SOP749 Rev 5
**Date Collected:** 31-Oct-18
**Date Prepared:** 28-Nov-18
**Date Analyzed:** 07-Dec-18

**Prep Batch:** RA181128-1
**QCBatchID:** RA181128-1-3
**Run ID:** RA181128-1A
**Count Time:** 150 minutes
**Report Basis:** Unfiltered

**Final Aliquot:** 997 ml
**Prep Basis:** Unfiltered
**Moisture(%):** NA
**Result Units:** pCi/l
**File Name:** RAA1207A

| CASNO | Target Nuclide | Result +/- 2 s TPU | MDC | Requested MDC | DL | Lab Qualifier |
|---|---|---|---|---|---|---|
| 15262-20-1 | Ra-228 | 0.69 +/- 0.40 | 0.74 | 1 | NA | U |

## Chemical Yield Summary

| Carrier/Tracer | Amount Added | Result | Units | Yield | Control Limits | Flag |
|---|---|---|---|---|---|---|
| BARIUM | 33500 | 31790 | ug | 94.9 | 40 - 110 % | |

### Comments:

**Qualifiers/Flags:**

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

M - The requested MDC was not met.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Sample specific Minimum Detectable Concentration

BDL - Below Detection Limit

DL - Decision Level

**Data Package ID:** *RA1811039-1*

# Dissolved Radium-228 Analysis by GFPC

## PAI 724 Rev 13

## Sample Results

**Lab Name:** **ALS -- Fort Collins**
**Work Order Number:** 1811039
**Client Name:** Tidewater, Inc.
**ClientProject ID:** Phase 1 RI OU2 Great Kills Park 2016-007

**Field ID:** OU2-1-MW008WT-F-DUP
**Lab ID:** 1811039-6

**Sample Matrix:** WATER
**Prep SOP:** SOP749 Rev 5
**Date Collected:** 31-Oct-18
**Date Prepared:** 28-Nov-18
**Date Analyzed:** 07-Dec-18

**Prep Batch:** RA181128-1
**QCBatchID:** RA181128-1-3
**Run ID:** RA181128-1A
**Count Time:** 150 minutes
**Report Basis:** Unfiltered

**Final Aliquot:** 997 ml
**Prep Basis:** Unfiltered
**Moisture(%):** NA
**Result Units:** pCi/l
**File Name:** RAA1207A

| CASNO | Target Nuclide | Result +/- 2 s TPU | MDC | Requested MDC | DL | Lab Qualifier |
|---|---|---|---|---|---|---|
| 15262-20-1 | Ra-228 | 0.44 +/- 0.38 | 0.76 | 1 | NA | U |

## Chemical Yield Summary

| Carrier/Tracer | Amount Added | Result | Units | Yield | Control Limits | Flag |
|---|---|---|---|---|---|---|
| BARIUM | 33520 | 31570 | ug | 94.2 | 40 - 110 % | |

### Comments:

**Qualifiers/Flags:**

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

M - The requested MDC was not met.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Sample specific Minimum Detectable Concentration

BDL - Below Detection Limit

DL - Decision Level

**Data Package ID:** *RA1811039-1*

# Radium-228 Analysis by GFPC

## PAI 724 Rev 13

## Sample Results

**Lab Name:** **ALS -- Fort Collins**
**Work Order Number:** 1811039
**Client Name:** Tidewater, Inc.
**ClientProject ID:** Phase 1 RI OU2 Great Kills Park 2016-007

**Field ID:** OU2-1-MW009WT
**Lab ID:** 1811039-7

**Sample Matrix:** WATER
**Prep SOP:** SOP749 Rev 5
**Date Collected:** 31-Oct-18
**Date Prepared:** 28-Nov-18
**Date Analyzed:** 07-Dec-18

**Prep Batch:** RA181128-1
**QCBatchID:** RA181128-1-3
**Run ID:** RA181128-1A
**Count Time:** 150 minutes
**Report Basis:** Unfiltered

**Final Aliquot:** 997 ml
**Prep Basis:** Unfiltered
**Moisture(%):** NA
**Result Units:** pCi/l
**File Name:** RAA1207A

| CASNO | Target Nuclide | Result +/- 2 s TPU | MDC | Requested MDC | DL | Lab Qualifier |
|---|---|---|---|---|---|---|
| 15262-20-1 | Ra-228 | 0.45 +/- 0.37 | 0.74 | 1 | NA | U |

## Chemical Yield Summary

| Carrier/Tracer | Amount Added | Result | Units | Yield | Control Limits | Flag |
|---|---|---|---|---|---|---|
| BARIUM | 31910 | 29450 | ug | 92.3 | 40 - 110 % | |

### Comments:

**Qualifiers/Flags:**

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

M - The requested MDC was not met.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Sample specific Minimum Detectable Concentration

BDL - Below Detection Limit

DL - Decision Level

**Data Package ID:** *RA1811039-1*

# Dissolved Radium-228 Analysis by GFPC

## PAI 724 Rev 13

## Sample Results

**Lab Name:** **ALS -- Fort Collins**
**Work Order Number:** 1811039
**Client Name:** Tidewater, Inc.
**ClientProject ID:** Phase 1 RI OU2 Great Kills Park 2016-007

**Field ID:** OU2-1-MW009WT-F
**Lab ID:** 1811039-8

**Sample Matrix:** WATER
**Prep SOP:** SOP749 Rev 5
**Date Collected:** 31-Oct-18
**Date Prepared:** 28-Nov-18
**Date Analyzed:** 07-Dec-18

**Prep Batch:** RA181128-1
**QCBatchID:** RA181128-1-3
**Run ID:** RA181128-1A
**Count Time:** 150 minutes
**Report Basis:** Unfiltered

**Final Aliquot:** 997 ml
**Prep Basis:** Unfiltered
**Moisture(%):** NA
**Result Units:** pCi/l
**File Name:** RAA1207A

| CASNO | Target Nuclide | Result +/- 2 s TPU | MDC | Requested MDC | DL | Lab Qualifier |
|---|---|---|---|---|---|---|
| 15262-20-1 | Ra-228 | 0.07 +/- 0.33 | 0.72 | 1 | NA | U |

## Chemical Yield Summary

| Carrier/Tracer | Amount Added | Result | Units | Yield | Control Limits | Flag |
|---|---|---|---|---|---|---|
| BARIUM | 31910 | 29840 | ug | 93.5 | 40 - 110 % | |

### Comments:

**Qualifiers/Flags:**

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

M - The requested MDC was not met.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Sample specific Minimum Detectable Concentration

BDL - Below Detection Limit

DL - Decision Level

**Data Package ID:** *RA1811039-1*

# Radium-228 Analysis by GFPC

## PAI 724 Rev 13

## Sample Results

**Lab Name:** **ALS -- Fort Collins**
**Work Order Number:** 1811039
**Client Name:** Tidewater, Inc.
**ClientProject ID:** Phase 1 RI OU2 Great Kills Park 2016-007

**Field ID:** OU2IDWWATER110118-0
**Lab ID:** 1811039-10

**Sample Matrix:** WATER
**Prep SOP:** SOP749 Rev 5
**Date Collected:** 01-Nov-18
**Date Prepared:** 28-Nov-18
**Date Analyzed:** 07-Dec-18

**Prep Batch:** RA181128-1
**QCBatchID:** RA181128-1-3
**Run ID:** RA181128-1A
**Count Time:** 150 minutes
**Report Basis:** Filtered

**Final Aliquot:** 997 ml
**Prep Basis:** Filtered
**Moisture(%):** NA
**Result Units:** pCi/l
**File Name:** RAA1207A

| CASNO | Target Nuclide | Result +/- 2 s TPU | MDC | Requested MDC | DL | Lab Qualifier |
|---|---|---|---|---|---|---|
| 15262-20-1 | Ra-228 | 0.72 +/- 0.42 | 0.79 | 1 | NA | U |

## Chemical Yield Summary

| Carrier/Tracer | Amount Added | Result | Units | Yield | Control Limits | Flag |
|---|---|---|---|---|---|---|
| BARIUM | 32990 | 31250 | ug | 94.7 | 40 - 110 % | |

**Comments:** This sample was filtered prior to analysis.

**Qualifiers/Flags:**

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

M - The requested MDC was not met.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Sample specific Minimum Detectable Concentration

BDL - Below Detection Limit

DL - Decision Level

**Data Package ID:** *RA1811039-1*

Section 5

# RAW DATA

5

# Radium-228 Analysis by GFPC Raw Data Report

**Laboratory Name:** ALS -- Fort Collins
**PAI Work Order:** 1811039

**Prep SOP:** SOP749
**Analytical SOP:** PAI 724

**Reported on:** Monday, December 10, 2018
9:08:32 AM

| Sample ID<br>QC Type | Nuclide<br>Type | Sample<br>Date/Time | Prep Batch<br>QCBatchID | Ingrowth<br>Date /Time | Decay<br>Date/Time | Matrix<br>%Moist. | Samp Alq<br>Analy Alq | Inst ID<br>Det ID | AnRunID<br>File Name | Count<br>Date/Time | GrossCPM<br>BkgCPM | BaseEff<br>ProgEff | CntDur(min)<br>Yield | Activity +/-<br>2 s TPU | MDC<br>DecLev | ReportUnits<br>ReportBasis | DER<br>RPD | %Spk. Recov<br>Flags |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1811039-1 | Ra-228 | 10/29/2018 | RA181128-1 | 12/05/2018 | 12/07/2018 | WATER | 1000 ml | LB4100-A | RA181128-1A | 12/7/2018 | 2.273 | 43.43% | 150 | 0.48 | 0.85 | pCi/l | NA | |
| SMP | Trg. Analyte | 3:40:00 PM | RA181128-1-3 | 1:48:00 PM | 9:22:00 AM | NA | 997 ml | A1 | RAA1207A | 10:43 AM | 1.962 | NA | 92.3% | 0.42 | | Filtered | NA | U |
| 1811039-2 | Ra-228 | 10/29/2018 | RA181128-1 | 12/05/2018 | 12/07/2018 | WATER | 1000 ml | LB4100-A | RA181128-1A | 12/7/2018 | 2.440 | 43.08% | 150 | 0.54 | 0.88 | pCi/l | NA | |
| SMP | Trg. Analyte | 3:40:00 PM | RA181128-1-3 | 1:48:00 PM | 9:22:00 AM | NA | 997 ml | A2 | RAA1207A | 10:43 AM | 2.090 | NA | 92.1% | 0.44 | | Filtered | NA | U |
| 1811039-3 | Ra-228 | 10/31/2018 | RA181128-1 | 12/05/2018 | 12/07/2018 | WATER | 1000 ml | LB4100-A | RA181128-1A | 12/7/2018 | 2.320 | 44.49% | 150 | 0.48 | 0.83 | pCi/l | NA | |
| SMP | Trg. Analyte | 12:10:00 PM | RA181128-1-3 | 1:48:00 PM | 9:22:00 AM | NA | 997 ml | A3 | RAA1207A | 10:43 AM | 2.001 | NA | 92.9% | 0.41 | | Unfiltered | NA | U |
| 1811039-4 | Ra-228 | 10/31/2018 | RA181128-1 | 12/05/2018 | 12/07/2018 | WATER | 1000 ml | LB4100-A | RA181128-1A | 12/7/2018 | 2.287 | 45.06% | 150 | 0.41 | 0.84 | pCi/l | NA | |
| SMP | Trg. Analyte | 12:10:00 PM | RA181128-1-3 | 1:48:00 PM | 9:22:00 AM | NA | 997 ml | A4 | RAA1207A | 10:43 AM | 2.017 | NA | 90.3% | 0.41 | | Unfiltered | NA | U |
| 1811039-5 | Ra-228 | 10/31/2018 | RA181128-1 | 12/05/2018 | 12/07/2018 | WATER | 1000 ml | LB4100-A | RA181128-1A | 12/7/2018 | 2.340 | 46.52% | 150 | 0.69 | 0.74 | pCi/l | NA | |
| SMP | Trg. Analyte | 12:10:00 PM | RA181128-1-3 | 1:48:00 PM | 9:22:00 AM | NA | 997 ml | C2 | RAA1207A | 10:43 AM | 1.843 | NA | 94.9% | 0.40 | | Unfiltered | NA | U |
| 1811039-6 | Ra-228 | 10/31/2018 | RA181128-1 | 12/05/2018 | 12/07/2018 | WATER | 1000 ml | LB4100-A | RA181128-1A | 12/7/2018 | 2.200 | 46.48% | 150 | 0.44 | 0.76 | pCi/l | NA | |
| SMP | Trg. Analyte | 12:10:00 PM | RA181128-1-3 | 1:48:00 PM | 9:22:00 AM | NA | 997 ml | C4 | RAA1207A | 10:43 AM | 1.887 | NA | 94.2% | 0.38 | | Unfiltered | NA | U |
| 1811039-7 | Ra-228 | 10/31/2018 | RA181128-1 | 12/05/2018 | 12/07/2018 | WATER | 1000 ml | LB4100-A | RA181128-1A | 12/7/2018 | 1.907 | 44.90% | 150 | 0.45 | 0.74 | pCi/l | NA | |
| SMP | Trg. Analyte | 4:55:00 PM | RA181128-1-3 | 1:48:00 PM | 9:22:00 AM | NA | 997 ml | D1 | RAA1207A | 10:43 AM | 1.603 | NA | 92.3% | 0.37 | | Unfiltered | NA | U |
| 1811039-8 | Ra-228 | 10/31/2018 | RA181128-1 | 12/05/2018 | 12/07/2018 | WATER | 1000 ml | LB4100-A | RA181128-1A | 12/7/2018 | 1.653 | 45.40% | 150 | 0.07 | 0.72 | pCi/l | NA | |
| SMP | Trg. Analyte | 4:55:00 PM | RA181128-1-3 | 1:48:00 PM | 9:22:00 AM | NA | 997 ml | D3 | RAA1207A | 10:43 AM | 1.608 | NA | 93.5% | 0.33 | | Unfiltered | NA | U |
| 1811039-10 | Ra-228 | 11/1/2018 | RA181128-1 | 12/05/2018 | 12/07/2018 | WATER | 1000 ml | LB4100-A | RA181128-1A | 12/7/2018 | 2.560 | 45.92% | 150 | 0.72 | 0.79 | pCi/l | NA | |
| SMP | Trg. Analyte | 9:40:00 AM | RA181128-1-3 | 1:48:00 PM | 9:22:00 AM | NA | 997 ml | D4 | RAA1207A | 10:43 AM | 2.049 | NA | 94.7% | 0.42 | | Filtered | NA | U |
| RA181128-1 | Ra-228 | 11/28/2018 | RA181128-1 | 12/05/2018 | 12/07/2018 | WATER | 1000 ml | LB4100-C | RA181128-1A | 12/7/2018 | 1.833 | 47.03% | 150 | 0.03 | 0.73 | pCi/l | NA | |
| MB | Trg. Analyte | 1:37:39 PM | RA181128-1-3 | 1:48:00 PM | 9:22:00 AM | NA | 997 ml | C2 | RAC1207B | 10:43 AM | 1.810 | NA | 94.5% | 0.33 | | Filtered | NA | U |
| RA181128-1 | Ra-228 | 11/28/2018 | RA181128-1 | 12/05/2018 | 12/07/2018 | WATER | 1000 ml | LB4100-C | RA181128-1A | 12/7/2018 | 9.667 | 48.03% | 30 | 9.4 | 1.4 | pCi/l | NA | 110 |
| LCS | Trg. Analyte | 1:37:39 PM | RA181128-1-3 | 1:48:00 PM | 9:22:00 AM | NA | 997 ml | C3 | RAC1207C | 10:45 AM | 1.694 | NA | 96.1% | 2.6 | | Filtered | NA | P,M3 |

**Comments:**

## Data Package ID: *RA1811039-1*

### Qualifiers/Flags:

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative yield is assumed.

Y2 - Chemical Yield outside default limits.

W - DER is greater than Warning Limit of 1.42

D - DER is greater than Control Limit of 2.13

+ - Duplicate RPD not within limits.

LT - Result is less than Request MDC, greater than sample specific MDC

* - Aliquot Basis is 'As Received' while the Report Basis is 'Dry Weight'

# - Aliquot Basis is 'Dry Weight' while the Report Basis is 'As Received'

M - Requested MDC not met.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

L - LCS Recovery below lower control limit.

H - LCS Recovery above upper control limit.

P - LCS, Matrix Spike Recovery within control limits.

N - Matrix Spike Recovery outside control limits

NC - Not Calculated for duplicate results less than 5 times MDC

B - Analyte concentration greater than MDC.

B3 - Analyte concentration greater than MDC but less than Requested MDC.

### Notes:

1) The Tracer results are not yield corrected (i.e. activity measured not activity added).

2) Where sample time is not available, 12:00 PM (Mountain) is used for decay correction.

### Abbreviations:

TR- Tracer TA - Target Analyte

TPU - Total Propagated Uncertainty

MDC - Minimum Detectable Concentration

DER - Duplicate Error Ratio

BDL - Below Detection Limit

# Radium-228 Analysis by GFPC Raw Data Report

**Laboratory Name:** **ALS -- Fort Collins**
**PAI Work Order:** 1811039

**Prep SOP:** SOP749
**Analytical SOP:** PAI 724

**Reported on:** Monday, December 10, 2018
9:08:32 AM

| Sample ID<br>QC Type | Nuclide<br>Type | Sample<br>Date/Time | Prep Batch<br>QCBatchID | Ingrowth<br>Date /Time | Decay<br>Date/Time | Matrix<br>%Moist. | Samp Alq<br>Analy Alq | Inst ID<br>Det ID | AnRunID<br>File Name | Count<br>Date/Time | GrossCPM<br>BkgCPM | BaseEff<br>ProgEff | CntDur(min)<br>Yield | Activity +/-<br>2 s TPU | MDC<br>DecLev | ReportUnits<br>ReportBasis | DER<br>RPD | %Spk. Recov<br>Flags |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RA181128-1 | Ra-228 | 11/28/2018 | RA181128-1 | 12/05/2018 | 12/07/2018 | WATER | 1000 ml | LB4100-C | RA181128-1A | 12/7/2018 | 8.567 | 45.96% | 30 | 8.3 | 1.5 | pCi/l | 0.33 | 96.8 |
| LCSD | Trg. Analyte | 1:37:39 PM | RA181128-1-3 | 1:48:00 PM | 9:22:00 AM | NA | 997 ml | D1 | RAC1207C | 10:45 AM | 1.835 | NA | 96.3% | 2.3 | | Filtered | NA | P,M3 |

**Comments:**

**Data Package ID:** *RA1811039-1*

Qualifiers/Flags:

U - Result is less than the sample specific MDC.
Y1 - Chemical Yield is in control at 100-110%. Quantitative yield is assumed.
Y2 - Chemical Yield outside default limits.
W - DER is greater than Warning Limit of 1.42
D - DER is greater than Control Limit of 2.13
+ - Duplicate RPD not within limits.
LT - Result is less than Request MDC, greater than sample specific MDC
* - Aliquot Basis is 'As Received' while the Report Basis is 'Dry Weight'
# - Aliquot Basis is 'Dry Weight' while the Report Basis is 'As Received'

M - Requested MDC not met.
M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.
L - LCS Recovery below lower control limit.
H - LCS Recovery above upper control limit.
P - LCS, Matrix Spike Recovery within control limits.
N - Matrix Spike Recovery outside control limits
NC - Not Calculated for duplicate results less than 5 times MDC
B - Analyte concentration greater than MDC.
B3 - Analyte concentration greater than MDC but less than Requested MDC.

Notes:

1) The Tracer results are not yield corrected (i.e. activity measured not activity added).
2) Where sample time is not available, 12:00 PM (Mountain) is used for decay correction.

Abbreviations:

TR- Tracer TA - Target Analyte
TPU - Total Propagated Uncertainty
MDC - Minimum Detectable Concentration
DER - Duplicate Error Ratio
BDL - Below Detection Limit

# ALS - Gas Flow Proportional Sample Analysis LB4100-A

Unit Type: LB4100-A/W
Counting Unit ID: Orange
High Voltage Mode: Simultaneous
Application Revision: C
Application Version: PA
Rev.05/09/13 JP

Data file name: RAA1207A
Batch ID: RA181128-1
Count Preset (m): 150
Batch Ended: 12/7/18 13:07

Background logfile: BKGABW
Date of Bkg. Cal: 12/5/18
Alpha efficiency logfile: Am241R-07/18
Alpha attenuation calibration: AAM119
Beta efficiency logfile: Ra228-08/18
Beta attenuation calibration: ASR1115

Alpha prog. logfile: n/a
Alpha prog. attenuation: n/a
Beta prog. logfile: n/a
Beta prog. attenuation: n/a

| Alpha Attenuation Calibration y = b*m^(a*(mass-x0)) | | Beta Attenuation Calibration y = b*m^(a*(mass-x0)) | |
|---|---|---|---|
| Alpha b= | 0.92510 | Beta b= | 1.0213 |
| m= | 0.99230 | m= | 0.9990 |
| a= | 0.9429 | a= | 0.7203 |
| x0= | 21.4875 | x0= | 0.0000 |
| Alpha to Beta X-talk y = b*m^-x | | Beta to Alpha X-talk y = b*mass + m | |
| a ->b xtalk b= | 0.2621 | b ->a xtalk b= | -2.250E-06 |
| a ->b xtalk m= | 0.9993 | b ->a xtalk m= | 0.0008 |

| Det. ID | Sample ID | Count End Date & Time | Count Dur. (min) | Resid. Mass (mg) | Alpha Activity Gross CPM | Alpha Bkg. CPM | Alpha b>a xtlk CPM | Alpha Base Eff | Alpha Base Cor.Fact. | Alpha Progeny Eff | Alpha Progeny Cor.Fact. | Beta Activity Gross CPM | Beta Bkg. CPM | Beta a>b xtlk CPM | Beta Base Eff | Beta Base Cor.Fact. | Beta Progeny Eff | Beta Progeny Cor.Fact. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 | 1811039-1 | 12/7/18 13:07 | 150.00 | 0.0 | 0.113 | 0.126 | 0.000 | 0.2091 | 1.082 | n/a | n/a | 2.273 | 1.962 | 0.0000 | 0.4343 | 1.021 | n/a | n/a |
| A2 | 1811039-2 | 12/7/18 13:07 | 150.00 | 0.0 | 0.173 | 0.124 | 0.000 | 0.2135 | 1.082 | n/a | n/a | 2.440 | 2.090 | 0.0129 | 0.4308 | 1.021 | n/a | n/a |
| C2 | 1811039-5 | 12/7/18 13:07 | 150.00 | 0.0 | 0.207 | 0.183 | 0.000 | 0.2315 | 1.082 | n/a | n/a | 2.340 | 1.843 | 0.0062 | 0.4652 | 1.021 | n/a | n/a |
| A3 | 1811039-3 | 12/7/18 13:07 | 150.00 | 0.0 | 0.220 | 0.098 | 0.000 | 0.2208 | 1.082 | n/a | n/a | 2.320 | 2.001 | 0.0320 | 0.4449 | 1.021 | n/a | n/a |
| A4 | 1811039-4 | 12/7/18 13:07 | 150.00 | 0.0 | 0.180 | 0.117 | 0.000 | 0.2100 | 1.082 | n/a | n/a | 2.287 | 2.017 | 0.0165 | 0.4506 | 1.021 | n/a | n/a |
| C4 | 1811039-6 | 12/7/18 13:07 | 150.00 | 0.0 | 0.247 | 0.139 | 0.000 | 0.2180 | 1.082 | n/a | n/a | 2.200 | 1.887 | 0.0282 | 0.4648 | 1.021 | n/a | n/a |
| D1 | 1811039-7 | 12/7/18 13:07 | 150.00 | 0.0 | 0.213 | 0.112 | 0.000 | 0.2299 | 1.082 | n/a | n/a | 1.907 | 1.603 | 0.0266 | 0.4490 | 1.021 | n/a | n/a |
| D3 | 1811039-8 | 12/7/18 13:07 | 150.00 | 0.0 | 0.247 | 0.124 | 0.000 | 0.2366 | 1.082 | n/a | n/a | 1.653 | 1.608 | 0.0322 | 0.4540 | 1.021 | n/a | n/a |
| D4 | 1811039-10 | 12/7/18 13:07 | 150.00 | 0.0 | 0.100 | 0.119 | 0.000 | 0.2240 | 1.082 | n/a | n/a | 2.560 | 2.049 | 0.0000 | 0.4592 | 1.021 | n/a | n/a |

MM 12-11-18

NP 12/09/18

Date 12/07/18

SOP 724r 12

# ALS

## Low Background Gas Flow Proportional Counter Log

**Instrument: LB4100A**

*Instrument Daily Response and Background Checks*

| Det. | Daily Response Check Start 1 | Status | Start 2 | Status | Background Check Start 1 | Status | Start 2 | Status | Det. Status |
|---|---|---|---|---|---|---|---|---|---|
| 1 | NP | P | | | NP | P | | | P |
| 2 | | | | | | (H/α) | NP | P | |
| 3 | | | | | | P | | | |
| 4 | | | | | | | | | |
| 5 | | | | | | P | | | OL |
| 6 | | | | | | (H/α) | | | |
| 7 | | | | | | P | | | P |
| 8 | | | | | | | | | |
| 9 | | | | | | | | | OL |
| 10 | | | | | | | | | P |
| 11 | | | | | | | | | OL |
| 12 | | | | | | | | | P |
| 13 | | | | | | | | | P |
| 14 | | | | | | | | | |
| 15 | | | | | | | | | |
| 16 | | | | | | | | | |

Det = Detector; α = Alpha; β = Beta; P = Pass; H = High; L = Low; OL = Offline; R = Recount; W = Weekly; NP = Not Processed

*Weekly Background Calibration*

| | Current Calib. File ID | Weekly Calib. Started | Status | File ID |
|---|---|---|---|---|
| Dr A | BKA1204W | | | |
| Dr B | | | | |
| Dr C | | | | |
| Dr D | | | | |

Dr = Drawer

*Gas Supply*

| P-10 Supply | | P-10 Flow | |
|---|---|---|---|
| Tank 1 | 2200 | Dr A | 10 |
| | | Dr B | |
| Tank 2 | 800 | Dr C | |
| | | Dr D | |

Comments:

Page No.: 481057 A

Form 780r8.doc (6/23/06)

Reviewed By / Date NP 12/07/18

Date 12/07/18

SOP 724r 12

**ALS**

Low Background Gas Flow Proportional Counter Log

**Instrument: LB4100A**

| Det. | Sample ID | Batch | Test | Count Dur. (min) | Start Time | Analyst Initials | File ID | Output Initials |
|---|---|---|---|---|---|---|---|---|
| 1-16 | Daily Eff | — | — | 10 | 06:26 | NP | EFA1207 | NP |
| 1-16 | Daily BKg | — | — | 60 | 06:39 | | BKA1207 | |
| 2 | | — | — | 1 | 07:44 | | BKA1207A | |
| 1 | 1811163-1 | RA181203-1 | Ra228 | 15.0 | 07:56 | NP | RAA1207 | NP |
| 3 | -2 | | | | | | | |
| 4 | -3 | | | | | | | |
| 10 | -4 | | | | | | | |
| 12 | -5 | | | | | | | |
| 13 | 1811200-1 | | | | | | | |
| 15 | -2 | | | | | | | |
| 16 | -3 | | | | | | | |
| 1 | 1811039-1 | RA181128-1 | Ra228 | | 10:36 | | RAA1207A | |
| 2 | -2 | | | | | | | |
| 3 | -3 | | | | | | | |
| 4 | -4 | | | | | | | |
| 10 | -5 | | | | | | | |
| 12 | -6 | | | | | | | |
| 13 | -7 | | | | | | | |
| 15 | -8 | | | | | | | |
| 16 | -10 | | | | | | | |
| 1 | 1812063-1 | AB181206-4 | αβ | 480 | 17:14 | | ABA1207 | |
| 2 | -10 | | | | | | | |
| 3 | -2 | | | | | | | |
| 4 | -3 | | | | | | | |
| 10 | AB181206-4MB | | | | | | | |
| 12 | -4LCS | | | | | | | |

NP 12/09/18

Comments:

Page No.: 481057 B

(cont. from page N/A B)

Form 780r8.doc (6 23 06)

Reviewed By / Date NP 12/09/18

# ALS - Gas Flow Proportional Sample Analysis LB4100-C

Unit Type: LB4100 -C
Counting Unit ID: Magenta
High Voltage Mode: Simultaneous
Application Revision: 2
Application Version: Standard
Rev.12/01/08 JCP

Data file name: RAC1207B
Batch ID: RA181128-1
Count Preset (m): 150
Batch Ended: 12/7/2018 13:10

Background logfile: BKGABW
Date of Bkg. Cal: 11/29/2018
Alpha efficiency logfile: Am_WIPE-06/17 Alpha prog. logfile: n/a
Alpha attenuation calibration: AAM0606, 0607 Alpha prog. attenuation: n/a
Beta efficiency logfile: RA228-06/17 Beta prog. logfile: n/a
Beta attenuation calibration: ASR0607 Beta prog. attenuation: n/a

| Alpha Attenuation Calibration | | Beta Attenuation Calibration | |
|---|---|---|---|
| y = b*m^(a*(mass-x0)) | | y = b*m^(a*(mass-x0)) | |
| Alpha b= | 0.90300 | Beta b= | 0.9681 |
| m= | 0.99110 | m= | 0.9996 |
| a= | 0.8270 | a= | 0.9174 |
| x0= | 21.4875 | x0= | 0.0000 |
| Alpha to Beta X-talk | | Beta to Alpha X-talk | |
| y = b *m^-mass | | y = b*mass + m | |
| a ->b xtalk b= | 0.2511 | b ->a xtalk b= | -1.69E-05 |
| a ->b xtalk m= | 0.9984 | b ->a xtalk m= | 0.0036 |

| Det. ID | Sample ID | Count End Date & Time | Count Dur. (min) | Resid. Mass (mg) | Alpha Activity Gross CPM | Alpha Bkg. CPM | Alpha b>a xtlk CPM | Alpha Base Eff | Alpha Base Cor.Fact. | Alpha Progeny Eff | Alpha Progeny Cor.Fact. | Beta Activity Gross CPM | Beta Bkg. CPM | Beta a>b xtlk CPM | Beta Base Eff | Beta Base Cor.Fact. | Beta Progeny Eff | Beta Progeny Cor.Fact. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A2 | 1811043-2 | 12/7/2018 13:09 | 150.00 | 0.0 | 0.173 | 0.123 | 0.001 | 0.2663 | 1.058 | n/a | n/a | 1.687 | 1.524 | 0.0126 | 0.4708 | 0.968 | n/a | n/a |
| A3 | 1811043-3 | 12/7/2018 13:09 | 150.00 | 0.0 | 0.213 | 0.147 | 0.002 | 0.2667 | 1.058 | n/a | n/a | 2.100 | 1.608 | 0.0167 | 0.4851 | 0.968 | n/a | n/a |
| A4 | 1811057-1 | 12/7/2018 13:09 | 150.00 | 0.0 | 0.167 | 0.123 | 0.000 | 0.2682 | 1.058 | n/a | n/a | 1.700 | 1.573 | 0.0110 | 0.4835 | 0.968 | n/a | n/a |
| C1 | 1811105-1 | 12/7/2018 13:09 | 150.00 | 0.0 | 0.173 | 0.142 | 0.000 | 0.2660 | 1.058 | n/a | n/a | 1.847 | 1.751 | 0.0079 | 0.4843 | 0.968 | n/a | n/a |
| C2 | RA181128-1MB | 12/7/2018 13:09 | 150.00 | 0.0 | 0.220 | 0.147 | 0.000 | 0.2618 | 1.058 | n/a | n/a | 1.833 | 1.810 | 0.0183 | 0.4703 | 0.968 | n/a | n/a |
| B1 | 1811058-1 | 12/7/2018 13:10 | 150.00 | 0.0 | 0.327 | 0.123 | 0.066 | 0.2653 | 1.058 | n/a | n/a | 19.853 | 1.645 | 0.0511 | 0.4803 | 0.968 | n/a | n/a |
| B2 | 1811059-1 | 12/7/2018 13:10 | 150.00 | 0.0 | 0.340 | 0.129 | 0.031 | 0.2570 | 1.058 | n/a | n/a | 10.387 | 1.721 | 0.0530 | 0.4584 | 0.968 | n/a | n/a |
| B4 | 1811082-1 | 12/7/2018 13:10 | 150.00 | 0.0 | 0.140 | 0.152 | 0.002 | 0.2603 | 1.058 | n/a | n/a | 2.347 | 1.791 | 0.0000 | 0.4828 | 0.968 | n/a | n/a |



mc 12-11-18

NP 12/04/18

# ALS - Gas Flow Proportional Sample Analysis LB4100-C

Unit Type: LB4100 -C
Counting Unit ID: Magenta
High Voltage Mode: Simultaneous
Application Revision: 2
Application Version: Standard
Rev.12/01/08 JCP

Data file name: RAC1207C
Batch ID: RA181128-1
Count Preset (m): 30
Batch Ended: 12/7/2018 11:10

Background logfile: BKGABW
Date of Bkg. Cal: 11/29/2018
Alpha efficiency logfile: Am_WIPE-06/17 Alpha prog. logfile: n/a
Alpha attenuation calibration: AAM0606, 0607 Alpha prog. attenuation: n/a
Beta efficiency logfile: RA228-06/17 Beta prog. logfile: n/a
Beta attenuation calibration: ASR0607 Beta prog. attenuation: n/a

| Alpha Attenuation Calibration | | Beta Attenuation Calibration | |
|---|---|---|---|
| y = b*m^(a*(mass-x0)) | | y = b*m^(a*(mass-x0)) | |
| Alpha b= | 0.90300 | Beta b= | 0.9681 |
| m= | 0.99110 | m= | 0.9996 |
| a= | 0.8270 | a= | 0.9174 |
| x0= | 21.4875 | x0= | 0.0000 |
| Alpha to Beta X-talk | | Beta to Alpha X-talk | |
| y = b *m^-mass | | y = b*mass + m | |
| a ->b xtalk b= | 0.2511 | b ->a xtalk b= | -1.69E-05 |
| a ->b xtalk m= | 0.9984 | b ->a xtalk m= | 0.0036 |

| Det. ID | Sample ID | Count End Date & Time | Count Dur. (min) | Resid. Mass (mg) | Alpha Activity Gross CPM | Alpha Bkg. CPM | Alpha b>a xtlk CPM | Alpha Base Eff | Alpha Base Cor.Fact. | Alpha Progeny Eff | Alpha Progeny Cor.Fact. | Beta Activity Gross CPM | Beta Bkg. CPM | Beta a>b xtlk CPM | Beta Base Eff | Beta Base Cor.Fact. | Beta Progeny Eff | Beta Progeny Cor.Fact. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C3 | RA181128-1LCS | 12/7/2018 11:10 | 30.00 | 0.0 | 0.167 | 0.114 | 0.029 | 0.2629 | 1.058 | n/a | n/a | 9.667 | 1.694 | 0.0132 | 0.4803 | 0.968 | n/a | n/a |
| D1 | RA181128-1LCSD | 12/7/2018 11:10 | 30.00 | 0.0 | 0.367 | 0.163 | 0.024 | 0.2582 | 1.058 | n/a | n/a | 8.567 | 1.835 | 0.0511 | 0.4596 | 0.968 | n/a | n/a |

MK 12-11-18



NP 12/09/18

Date 12/07/18

SOP 724r 12

# ALS

## Low Background Gas Flow Proportional Counter Log

**Instrument: LB4100C**

*Instrument Daily Response and Background Checks*

| Det. | Daily Response Check Start 1 | Status | Start 2 | Status | Background Check Start 1 | Status | Start 2 | Status | Det. Status |
|---|---|---|---|---|---|---|---|---|---|
| 1 | NP | P | | | NP | (LB) | | | OL |
| 2 | | | | | | P | | | P |
| 3 | | | | | | | | | |
| 4 | | | | | | | | | |
| 5 | | | | | | | | | |
| 6 | | | | | | | | | |
| 7 | | | | | | (Hα) | NP | (Hα) | OL |
| 8 | | | | | | P | | | P |
| 9 | | | | | | | | | |
| 10 | | | | | | | | | |
| 11 | | | | | | | | | |
| 12 | | | | | | | | | |
| 13 | | | | | | | | | |
| 14 | | (Lα, β) | | | | | | | OL |
| 15 | | P | | | | | | | P |
| 16 | | | | | | | | | |

Det = Detector; α = Alpha; β = Beta; P = Pass; H = High; L = Low; OL = Offline; R = Recount; W = Weekly; NP = Not Processed

*Weekly Background Calibration*

| | Current Calib. File ID | Weekly Calib. Started | Status | File ID |
|---|---|---|---|---|
| Dr A | BKC1128W | | | |
| Dr B | | | | |
| Dr C | | | | |
| Dr D | 1129W | | | |

Dr = Drawer

*Gas Supply*

| P-10 Supply | | P-10 Flow | |
|---|---|---|---|
| Tank 1 | 2200 | Dr A | 10 |
| | | Dr B | |
| Tank 2 | 800 | Dr C | |
| | | Dr D | |

Comments:

Page No.: 480872 A

Form 780r8.doc (6/23/06)

Reviewed By / Date NP 12/07/18

Date 12/07/18

SOP 724r 12

**ALS**

Low Background Gas Flow Proportional Counter Log

**Instrument: LB4100C**

| Det. | Sample ID | Batch | Test | Count Dur. (min) | Start Time | Analyst Initials | File ID | Output Initials |
|---|---|---|---|---|---|---|---|---|
| 1-16 | Daily EFF | — | — | 10 | 06:30 | NP | EFC1207 | NP |
| 1-16 | Daily Bkg | — | — | 60 | 07:31 | | BKC1207 | NP 12/07/18 |
| 7 | ↓ | — | — | 1 | 08:40 | | BKC1207A | |
| 2 | 1811219-1 | RA181203-1 | Ra228 | 150 | 07:57 | NP | RAC1207 | NP |
| 3 | -2 | | | | | | | |
| 4 | -3 | | | | | | | |
| 5 | -4 | | | | | | | |
| 6 | -5 | | | | | | | |
| 8 | 1811277-1 | | | | | | | |
| 9 | -2 | | | | | | | |
| 10 | 1811299-1 | | | | | | | |
| 11 | 1811335-1 | | | | | | | |
| 13 | RA181203-1MB | | | | | | | |
| 15 | -1LCS | | | 30 | | | RAC1207A | |
| 16 | -1LCSD | | | 1 | | | | |
| 2 | 1811043-2 | RA181128-1 | | 150 | 10:40 | | RAC1207B | |
| 3 | -3 | | | | | | | |
| 4 | 1811057-1 | | | | | | | |
| 5 | 8-1 | | | | | | | |
| 6 | 9-1 | | | | | | | |
| 8 | 1811082-1 | | | | | | | |
| 9 | 1811105-1 | | | | | | | |
| 10 | RA181128-1MB | | | | | | | |
| 11 | -1LCS | | | 30 | | | RAC1207C | |
| 13 | -1LCSD | | | 1 | | | | |
| 16 | 1811483-4 | AB181203-1 | αβ | 90 | 10:54 | | ABC1207 | |
| 2 | 1811190-1 | AB181108-1 | | 180 | 13:56 | | ABC1207A | |
| 3 | -1D | | | | | | | |
| 4 | AB181108-1MB | | | | | | | |
| 5 | -1LCS | | | | | | | |
| 6 | 1811114-1 | AB181107-2 | | | | | | |
| 8 | -1D | | | | | | | |
| 9 | AB181107-2MB | | | | | | | |
| 10 | -2LCS | | | | | | | |

NP 12/09/18

Comments:

Page No.: 480872 **B**

(cont. from page N/A B)

Form 780r8.doc (6 23 06)

Reviewed By / Date NP 12/09/18

# Radiochemistry ICP Worksheet

**ALS -- Fort Collins**

**Prep Batch: RA181128-1**

Prep Procedure: **Ra228**

Reviewed By: **rgs** Review Date: **12/8/2018**

## BARIUM Recovery Results

### Reference Carrier

| LabID | QC Type | Carr Vol | Ref Carr Dil Vol | Ref Carr ICP Alq | Ref Carr ICP Dil Vol | Ref Carr ICP Run | Ref Carr ICP Conc |
|---|---|---|---|---|---|---|---|
| RA181128-1 | CAR | 2 | 27 | 0.05 | 10.05 | IR181207-2A1 | 5.86619 |

### Samples

| Prep Num | LabID | QC Type | Init Samp Alq (ml) | Car Vol (ml) | Samp Dil Vol (ml) | Init ICP Alq (ml) | Init ICP Dil Vol (ml) | Pre-Con Vol (ml) | Post Con Vol (ml) | Pre-Sep Vol (ml) | Post Sep Vol (ml) | Fin ICP Alq (ml) | Fin ICP Dil Vol (ml) | Initial ICP Run | Final ICP Run | Init ICP Conc (ug/ml) | Fin ICP Conc (ug/ml) | Init Samp Mass (ug) | Ref Mass (ug) | Flag | Fin Samp Mass (ug) | % Yield | Final Sample Alq |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1811039-1 | SMP | 1000 | 2 | 1000 | 1 | 10 | 999 | 999 | 999 | 25 | 0.05 | 10.05 | IR181207-2A1 | IR181207-2A1 | 0.06960 | 5.97579 | 695.3395 | 31835.82 | | 30028.34 | 92.31% | 997.0 |
| 1 | 1811039-2 | SMP | 1000 | 2 | 1000 | 1 | 10 | 999 | 999 | 999 | 25 | 0.05 | 10.05 | IR181207-2A1 | IR181207-2A1 | 0.07435 | 5.969604 | 742.7587 | 31835.82 | | 29997.26 | 92.08% | 997.0 |
| 1 | 1811039-3 | SMP | 1000 | 2 | 1000 | 1 | 10 | 999 | 999 | 999 | 25 | 0.05 | 10.05 | IR181207-2A1 | IR181207-2A1 | 0.16955 | 6.198777 | 1693.807 | 31835.82 | | 31148.85 | 92.90% | 997.0 |
| 1 | 1811039-4 | SMP | 1000 | 2 | 1000 | 1 | 10 | 999 | 999 | 999 | 25 | 0.05 | 10.05 | IR181207-2A1 | IR181207-2A1 | 0.16763 | 6.024804 | 1674.626 | 31835.82 | | 30274.64 | 90.34% | 997.0 |
| 1 | 1811039-5 | SMP | 1000 | 2 | 1000 | 1 | 10 | 999 | 999 | 999 | 25 | 0.05 | 10.05 | IR181207-2A1 | IR181207-2A1 | 0.16640 | 6.326563 | 1662.372 | 31835.82 | | 31790.98 | 94.90% | 997.0 |
| 1 | 1811039-6 | SMP | 1000 | 2 | 1000 | 1 | 10 | 999 | 999 | 999 | 25 | 0.05 | 10.05 | IR181207-2A1 | IR181207-2A1 | 0.16864 | 6.283257 | 1684.749 | 31835.82 | | 31573.37 | 94.19% | 997.0 |
| 1 | 1811039-7 | SMP | 1000 | 2 | 1000 | 1 | 10 | 999 | 999 | 999 | 25 | 0.05 | 10.05 | IR181207-2A1 | IR181207-2A1 | 0.00747 | 5.861497 | 74.62755 | 31835.82 | | 29454.02 | 92.30% | 997.0 |
| 1 | 1811039-8 | SMP | 1000 | 2 | 1000 | 1 | 10 | 999 | 999 | 999 | 25 | 0.05 | 10.05 | IR181207-2A1 | IR181207-2A1 | 0.00742 | 5.93755 | 74.09474 | 31835.82 | | 29836.19 | 93.50% | 997.0 |
| 1 | 1811039-10 | SMP | 1000 | 2 | 1000 | 1 | 10 | 999 | 999 | 999 | 25 | 0.05 | 10.05 | IR181207-2A1 | IR181207-2A1 | 0.1151 | 6.219097 | 1149.818 | 31835.82 | | 31250.96 | 94.74% | 997.0 |
| 1 | 1811043-2 | SMP | 1000 | 2 | 1000 | 1 | 10 | 999 | 999 | 999 | 25 | 0.05 | 10.05 | IR181207-2A1 | IR181207-2A1 | 0.00342 | 5.829337 | 34.13475 | 31835.82 | | 29292.42 | 91.91% | 997.0 |
| 1 | 1811043-3 | SMP | 1000 | 2 | 1000 | 1 | 10 | 999 | 999 | 999 | 25 | 0.05 | 10.05 | IR181207-2A1 | IR181207-2A1 | 0.00432 | 6.020004 | 43.19234 | 31835.82 | | 30250.52 | 94.89% | 997.0 |
| 1 | 1811057-1 | SMP | 1000 | 2 | 1000 | 1 | 10 | 999 | 999 | 999 | 25 | 0.05 | 10.05 | IR181207-2A1 | IR181207-2A1 | 0.00422 | 6.098937 | 42.12674 | 31835.82 | | 30647.16 | 96.14% | 997.0 |
| 1 | 1811058-1 | SMP | 250 | 2 | 1000 | 1 | 10 | 999 | 999 | 999 | 25 | 0.05 | 10.05 | IR181207-2A1 | IR181207-2A1 | 0.98614 | 7.979043 | 9851.508 | 31835.82 | | 40094.69 | 96.18% | 249.3 |
| 1 | 1811059-1 | SMP | 250 | 2 | 1000 | 1 | 10 | 999 | 999 | 999 | 25 | 0.05 | 10.05 | IR181207-2A1 | IR181207-2A1 | 0.40464 | 6.666937 | 4042.389 | 31835.82 | | 33501.36 | 93.38% | 249.3 |
| 1 | 1811082-1 | SMP | 1000 | 2 | 1000 | 1 | 10 | 999 | 999 | 999 | 25 | 0.05 | 10.05 | IR181207-2A1 | IR181207-2A1 | 0.00347 | 6.002297 | 34.66754 | 31835.82 | | 30161.54 | 94.64% | 997.0 |
| 1 | 1811105-1 | SMP | 250 | 2 | 1000 | 1 | 10 | 999 | 999 | 999 | 25 | 0.05 | 10.05 | IR181207-2A1 | IR181207-2A1 | 0.00016 | 6.147203 | 1.633944 | 31835.82 | | 30889.7 | 97.02% | 249.3 |
| 1 | RA181128-1 | MB | 1000 | 2 | 1000 | 1 | 10 | 999 | 999 | 999 | 25 | 0.05 | 10.05 | IR181207-2A1 | IR181207-2A1 | 0.00011 | 5.984217 | 1.101144 | 31835.82 | | 30070.69 | 94.45% | 997.0 |
| 1 | RA181128-1 | LCS | 1000 | 2 | 1000 | 1 | 10 | 999 | 999 | 999 | 25 | 0.05 | 10.05 | IR181207-2A1 | IR181207-2A1 | 0.00048 | 6.092164 | 4.830744 | 31835.82 | | 30613.12 | 96.14% | 997.0 |
| 1 | RA181128-1 | LCSD | 1000 | 2 | 1000 | 1 | 10 | 999 | 999 | 999 | 25 | 0.05 | 10.05 | IR181207-2A1 | IR181207-2A1 | 0.00075 | 6.101817 | 7.494744 | 31835.82 | | 30661.63 | 96.29% | 997.0 |





**ALS -- Fort Collins**
LIMS Version: 6.886

**FLAG -** LB: low bias (<= 15%) 15%: low bias (>15%)
Z: Negative init. conc. treated as zer

**Supersedes:**

1R181207-2A1



| Sample Id1 | Ca | Fe | K | Mg | Na | Sr | Mn | Al | Ba | Pb | Ni | S |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CCV | 49.2526 | 19.1475 | 46.8382 | 49.8001 | 48.4043 | 0.4639 | 0.9638 | 48.7528 | 0.9618 | 0.9430 | 0.9685 | 5.0141 |
| CCB | 0.0062 | 0.0099 | -0.0547 | -0.0010 | 0.0086 | 0.0000 | 0.0003 | 0.0041 | 0.0000 | 0.0010 | 0.0018 | -0.0094 |
| I 1811039-1 | 23.0093 | 1.0555 | 2.1165 | 3.1123 | 5.1438 | 0.1228 | 0.0498 | 0.0513 | 0.0696 | 0.0198 | 0.0044 | 2.6341 |
| I 1811039-2 | 22.6585 | 0.5922 | 2.2644 | 3.1287 | 5.3242 | 0.1215 | 0.0461 | 0.0226 | 0.0744 | 0.0069 | 0.0029 | 2.5447 |
| I 1811039-3 | 25.6912 | 4.2947 | 1.3780 | 3.1329 | 3.3638 | 0.1961 | 0.0717 | 0.0000 | 0.1695 | 0.0067 | 0.0008 | 0.0706 |
| I 1811039-4 | 25.1519 | 4.2464 | 1.3521 | 3.0560 | 3.3348 | 0.1925 | 0.0721 | 0.0192 | 0.1676 | 0.0250 | 0.0007 | 0.0753 |
| I 1811039-5 | 25.0559 | 4.1244 | 1.3296 | 3.0560 | 3.2968 | 0.1918 | 0.0673 | 0.0103 | 0.1664 | 0.0051 | 0.0004 | 0.0470 |
| I 1811039-6 | 25.1883 | 4.1388 | 1.3509 | 3.0841 | 3.3389 | 0.1936 | 0.0674 | 0.0137 | 0.1686 | 0.0137 | 0.0017 | 0.0564 |
| I 1811039-7 | 8.4498 | 0.2427 | 0.2274 | 2.3690 | 1.5080 | 0.0288 | 0.1145 | 0.0082 | 0.0075 | 0.0055 | 0.0013 | 2.6811 |
| I 1811039-8 | 8.4731 | 0.2768 | 0.2285 | 2.4074 | 1.5856 | 0.0293 | 0.1195 | 0.0321 | 0.0074 | 0.0063 | 0.0014 | 2.7611 |
| I 1811039-10 | 14.5962 | 8.3358 | 1.2329 | 3.8716 | 6.2943 | 0.0928 | 0.3699 | 0.4165 | 0.1151 | 0.1260 | 0.0090 | 1.0207 |
| I 1811043-2 | 1.4700 | 0.0165 | 0.0604 | 0.4901 | 7.4285 | 0.0417 | 0.0009 | 0.0294 | 0.0034 | 0.0208 | 0.0009 | 1.7639 |
| I 1811043-3 | 21.9634 | 0.0077 | 0.8076 | 6.7225 | 31.4278 | 2.3837 | 0.1208 | 0.0232 | 0.0043 | 0.0079 | 0.0008 | 14.0405 |
| I 1811057-1 | 0.7078 | 0.0123 | 0.0000 | 0.1061 | 0.4239 | 0.0080 | 0.0004 | 0.0239 | 0.0042 | 0.0102 | -0.0008 | 0.0282 |
| I 1811058-1 | 62.7991 | 0.5215 | 15.2892 | 32.8439 | 288.1720 | 6.7996 | 0.0124 | 0.0273 | 0.9861 | 0.0083 | 0.0010 | 0.4892 |
| I 1811059-1 | 45.0608 | 0.4901 | 10.9342 | 24.8695 | 248.4198 | 4.8093 | 0.0154 | 0.0588 | 0.4046 | 0.0113 | 0.0303 | 1.9567 |
| I 1811082-1 | 50.3529 | 0.0252 | 0.5359 | 133.8795 | 19.1769 | 0.3142 | 0.0010 | 0.0369 | 0.0035 | 0.0069 | 0.0019 | 198.2596 |
| I 1811105-1 | 13.7900 | 16.7121 | -0.1410 | 111.9183 | 2.7377 | 0.0026 | 31.8968 | 166.8643 | 0.0002 | 0.0096 | 0.4659 | 427.6576 |
| I RA181128-1MB | 0.0585 | 0.0431 | -0.0881 | 0.1697 | 0.1505 | 0.0017 | 0.0469 | 0.2275 | 0.0001 | 0.0025 | 0.0014 | 0.7338 |
| I RA181128-1LCS | 0.0219 | 0.0131 | -0.1197 | 0.0302 | 0.0943 | 0.0007 | 0.0079 | 0.0656 | 0.0005 | 0.0013 | 0.0010 | 0.1411 |
| I RA181128-1LCSD | 0.0151 | 0.0048 | -0.1013 | 0.0185 | 0.0325 | 0.0003 | 0.0039 | 0.0512 | 0.0008 | 0.0030 | 0.0010 | 0.0564 |
| CCV | 49.6483 | 19.2542 | 47.5042 | 50.0620 | 48.9271 | 0.4749 | 0.9662 | 49.2549 | 0.9833 | 0.9367 | 1.0011 | 5.0847 |
| CCB | 0.0115 | 0.0127 | -0.1099 | 0.0026 | 0.0218 | 0.0001 | 0.0005 | 0.0458 | 0.0001 | 0.0021 | 0.0006 | 0.0141 |
| F 1811039-1 | 0.0281 | 0.0073 | -0.0599 | -0.0036 | 87.0335 | 0.0802 | 0.0005 | 0.0492 | 5.9758 | 0.2300 | 0.0006 | 1.7733 |
| F 1811039-2 | 0.0219 | 0.0031 | -0.0956 | -0.0046 | 87.2507 | 0.0818 | 0.0003 | 0.0451 | 5.9696 | 0.3353 | -0.0004 | 1.8250 |
| F 1811039-3 | 0.0281 | 0.0020 | -0.0656 | 0.0021 | 85.7301 | 0.1712 | 0.0003 | 0.0506 | 6.1988 | 0.3968 | 0.0015 | 1.9473 |
| F 1811039-4 | 0.0222 | -0.0001 | -0.0817 | -0.0062 | 86.6531 | 0.1833 | 0.0001 | 0.0444 | 6.0248 | 0.4863 | -0.0005 | 1.9567 |
| F 1811039-5 | 0.0213 | -0.0008 | -0.0570 | -0.0087 | 86.2007 | 0.1648 | 0.0001 | 0.0417 | 6.3266 | 0.4192 | 0.0010 | 1.9755 |
| F 1811039-6 | 0.0183 | -0.0013 | -0.1013 | -0.0077 | 86.4171 | 0.2443 | 0.0000 | 0.0492 | 6.2833 | 0.4381 | 0.0013 | 2.0132 |
| F 1811039-7 | 0.0157 | 0.0112 | -0.0869 | -0.0077 | 86.6168 | 0.0238 | 0.0002 | 0.0458 | 5.8615 | 0.3912 | 0.0006 | 1.7827 |
| F 1811039-8 | 0.0136 | -0.0002 | -0.1025 | -0.0036 | 86.2786 | 0.0198 | 0.0002 | 0.0444 | 5.9376 | 0.3784 | 0.0007 | 1.7639 |
| F 1811039-10 | 0.0195 | 0.0078 | -0.0840 | 0.0036 | 86.2775 | 0.0971 | 0.0004 | 0.0656 | 6.2191 | 0.4206 | 0.0005 | 1.9285 |
| F 1811043-2 | 0.0106 | -0.0007 | -0.0817 | -0.0031 | 86.5736 | 0.0248 | 0.0001 | 0.0478 | 5.8293 | 0.3927 | 0.0009 | 1.7498 |
| F 1811043-3 | 0.0112 | -0.0015 | -0.0973 | -0.0021 | 87.0279 | 1.2770 | 0.0000 | 0.0492 | 6.0200 | 0.4222 | 0.0008 | 2.3283 |
| F 1811057-1 | 0.0086 | -0.0012 | -0.1111 | -0.0041 | 86.7226 | 0.0130 | -0.0001 | 0.0396 | 6.0989 | 0.3765 | 0.0008 | 1.8344 |
| F 1811058-1 | 0.0201 | -0.0016 | -0.1341 | -0.0118 | 87.5194 | 4.1440 | -0.0002 | 0.0492 | 7.9790 | 0.4815 | -0.0006 | 4.1204 |
| F 1811059-1 | 0.0248 | 0.0017 | -0.0714 | 0.0005 | 83.4834 | 2.1772 | 0.0000 | 0.0492 | 6.6669 | 0.5302 | 0.0019 | 3.0151 |
| F 1811082-1 | 0.0213 | 0.0067 | -0.0858 | -0.0041 | 86.9561 | 0.3094 | 0.0001 | 0.0581 | 6.0023 | 0.4526 | 0.0009 | 1.9332 |
| F 1811105-1 | 0.0384 | 0.0007 | -0.0794 | -0.0056 | 87.1815 | 0.0028 | 0.0014 | 0.0492 | 6.1472 | 11.2640 | -0.0003 | 3.6689 |
| F RA181128-1MB | 0.0124 | -0.0016 | -0.1002 | -0.0051 | 86.8847 | 0.0005 | 0.0003 | 0.0574 | 5.9842 | 0.3999 | 0.0012 | 1.7921 |
| F RA181128-1LCS | 0.0065 | 0.0268 | -0.1232 | -0.0097 | 86.9379 | 0.0003 | 0.0000 | 0.0506 | 6.0922 | 0.3192 | 0.0004 | 1.7874 |
| F RA181128-1LCSD | 0.0109 | -0.0017 | -0.0829 | -0.0072 | 86.5560 | 0.0005 | -0.0001 | 0.0567 | 6.1018 | 0.3362 | 0.0005 | 1.7733 |
| RA181128-1RC | 0.0112 | -0.0024 | -0.0760 | -0.0046 | 83.0144 | 0.0001 | -0.0001 | 0.0451 | 5.8662 | 0.0026 | 0.0008 | 0.0094 |
| CCV | 50.0482 | 19.3667 | 47.9842 | 50.2963 | 48.8132 | 0.4801 | 0.9679 | 49.4632 | 0.9927 | 0.9464 | 1.0140 | 5.0423 |
| CCB | 0.0174 | 0.0139 | -0.0766 | 0.0154 | 0.0483 | 0.0002 | 0.0007 | 0.0676 | 0.0004 | 0.0027 | 0.0013 | 0.0000 |

Section 6

# QUALITY ASSURANCE SUMMARY REPORTS

6

**No *NON-CONFORMANCE REPORTS* or *QUALITY ASSURANCE SUMMARY SHEETS* are included in this data package.**

Section 7

# LABORATORY BENCH SHEETS

7

# Radiochemistry Instrument Worksheet

**ALS -- Fort Collins**

**Prep Batch:** RA181128-1

**Prep Procedure:** Ra228

**Analytical QASS / NCR? Y / N** N/A

| Prep Num | LabID | QC Type | Init Alq | Fin Alq | Units | Report Units | Residual Mass (mg) | Cnt 1 File | Cnt 1 Inst/Det | Cnt 1 Pos Chk By | Cnt 2 File | Cnt 2 Inst/Det | Cnt 2 Pos Chk By | Cnt 3 File | Cnt 3 Inst/Det | Cnt 3 Pos Chk By | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1811039-1 | SMP | 1000 | 997.00 | ml | pCi/l | | RAA1207A | 1 | NP | | | | | | | |
| 1 | 1811039-2 | SMP | 1000 | 997.00 | ml | pCi/l | | | 2 | | | | | | | | |
| 1 | 1811039-3 | SMP | 1000 | 997.00 | ml | pCi/l | | | 3 | | | | | | | | |
| 1 | 1811039-4 | SMP | 1000 | 997.00 | ml | pCi/l | | | 4 | | | | | | | | |
| 1 | 1811039-5 | SMP | 1000 | 997.00 | ml | pCi/l | | | 10 | | | | | | | | |
| 1 | 1811039-6 | SMP | 1000 | 997.00 | ml | pCi/l | | | 12 | | | | | | | | |
| 1 | 1811039-7 | SMP | 1000 | 997.00 | ml | pCi/l | | | 13 | | | | | | | | |
| 1 | 1811039-8 | SMP | 1000 | 997.00 | ml | pCi/l | | | 15 | | | | | | | | |
| 1 | 1811039-10 | SMP | 1000 | 997.00 | ml | pCi/l | | | 16 | | | | | | | | |
| 1 | 1811043-2 | SMP | 1000 | 997.00 | ml | pCi/l | | RAC1207B | 2 | NP | | | | | | | |
| 1 | 1811043-3 | SMP | 1000 | 997.00 | ml | pCi/l | | | 3 | | | | | | | | |
| 1 | 1811057-1 | SMP | 1000 | 997.00 | ml | BQ/L | | | 4 | | | | | | | | |
| 1 | 1811058-1 | SMP | 250 | 249.25 | ml | BQ/L | | | 5 | | | | | | | | |
| 1 | 1811059-1 | SMP | 250 | 249.25 | ml | BQ/L | | | 6 | | | | | | | | |
| 1 | 1811082-1 | SMP | 1000 | 997.00 | ml | pCi/l | | | 8 | | | | | | | | |
| 1 | 1811105-1 | SMP | 250 | 249.25 | ml | pCi/l | | | 9 | | | | | | | | |
| 1 | RA181128-1 | MB | 1000 | 997.00 | ml | BQ/L | | | 10 | | | | | | | | |
| 1 | RA181128-1 | MB | 1000 | 997.00 | ml | pCi/l | | | 1 | | | | | | | | |
| 1 | RA181128-1 | LCS | 1000 | 997.00 | ml | BQ/L | | RAC1207C | 11 | NP | | | | | | | |
| 1 | RA181128-1 | LCS | 1000 | 997.00 | ml | pCi/l | | | 1 | | | | | | | | |
| 1 | RA181128-1 | LCSD | 1000 | 997.00 | ml | pCi/l | | | 13 | | | | | | | | |
| 1 | RA181128-1 | LCSD | 1000 | 997.00 | ml | BQ/L | | | 1 | | | | | | | | NP 12/10/18 |

**Tracer/Carrier Solution Information**

| Soln # | Nuclide | SolnID | Exp Date | Prep Conc | Units | Prep Date | Aliquot | Units | Pipet ID |
|---|---|---|---|---|---|---|---|---|---|
| T1 | BARIUM | 418244 | 8/23/19 | 16,012.690 | pCi/ml | NA | 2 | ml | RS031 |

**Spike Solution Information**

| Soln # | Nuclide | SolnID | Exp Date | Prep Conc | Units | Prep Date | Aliquot | Units | Pipet ID |
|---|---|---|---|---|---|---|---|---|---|
| S1 | Ra-228 | 1014.4095.79 | 3/20/19 | 76.547 | DPM/ml | 11/28/18 | 0.25 | ml | RS019 |

**Sample Barcodes**

1811039-1
RA181128-1PS21

1811039-2
RA181128-1PS22

1811039-3
RA181128-1PS23



**Date Printed:** 12/7/2018 10:31

**ALS -- Fort Collins**

LIMS Version: 6.886

**Supersedes:** N/A

# Radiochemistry Instrument Worksheet

**ALS -- Fort Collins**

**Prep Batch:** RA181128-1

**Prep Procedure:** Ra228

**Analytical QASS / NCR? Y / N** N/A

| Prep Num | LabID | QC Type | Init Alq | Fin Alq | Units | Report Units | Residual Mass (mg) | Cnt 1 File | Cnt 1 Inst/Det | Cnt 1 Pos Chk By | Cnt 2 File | Cnt 2 Inst/Det | Cnt 2 Pos Chk By | Cnt 3 File | Cnt 3 Inst/Det | Cnt 3 Pos Chk By | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1811039-4 RA181128-1PS24 | | | | | | | | 1811039-5 RA181128-1PS25 | | | | | | 1811039-6 RA181128-1PS26 | | | |
| 1811039-7 RA181128-1PS27 | | | | | | | | 1811039-8 RA181128-1PS28 | | | | | | 1811039-10 RA181128-1PS29 | | | |
| 1811043-2 RA181128-1PS31 | | | | | | | | 1811043-3 RA181128-1PS32 | | | | | | 1811057-1 RA181128-1PS33 | | | |
| 1811058-1 RA181128-1PS34 | | | | | | | | 1811059-1 RA181128-1PS35 | | | | | | 1811082-1 RA181128-1PS36 | | | |
| 1811105-1 RA181128-1PS37 | | | | | | | | RA181128-1MB RA181128-1PS38 | | | | | | RA181128-1LCS RA181128-1PS39 | | | |
| RA181128-1LCSD RA181128-1PS40 | | | | | | | | RA181128-1CAR RA181128-1PS41 | | | | | | | | | |

## Reporting Units

| LabID: | TstGrpName: | RptUnits: |
|---|---|---|
| 1811082-1 | Ra228Combined226 | pCi/l |
| 1811059-1 | Ra228_2012 | BQ/L |
| 1811058-1 | Ra228_2012 | BQ/L |
| 1811057-1 | Ra228_2012 | BQ/L |
| 1811105-1 | Ra228_2012 | pCi/l |
| 1811039-1 | Ra228_2012 | pCi/l |
| 1811043-2 | Ra228_2012 | pCi/l |
| 1811039-2 | Ra228_2012 | pCi/l |
| 1811043-3 | Ra228_2012 | pCi/l |
| 1811039-3 | Ra228_2012 | pCi/l |
| 1811039-4 | Ra228_2012 | pCi/l |
| 1811039-5 | Ra228_2012 | pCi/l |
| 1811039-6 | Ra228_2012 | pCi/l |
| 1811039-7 | Ra228_2012 | pCi/l |
| 1811039-8 | Ra228_2012 | pCi/l |
| 1811039-10 | Ra228_2012 | pCi/l |

# Radiochemistry Prep Worksheet

**ALS -- Fort Collins**

**Prep Batch:** RA181128-1

**Prep Procedure:** Ra228

**Reviewed By:** rgs RGS **Review Date:** 12/10/2018

**Non-Routine Pre-Treatment?** Y / N **Batch:** **Re-Prep?** Y / N **Batch:** **Prep QASS / NCR?** Y / N

**Prep SOP:** SOP749 **Rev:** 5
**Prep SOP:** NONE
**Matrix Class:** liquid

**Prep Analyst:** Reilly G. Stockton RGS
**Prep Date:** 11/28/2018
**Prep Dept:** RS

**Balance:** N/A
**Balance:** N/A

| Samp Num | Prep Num | LabID | QC Type | Dish No. | Init Alq ml | Fin Alq ml | Prep Basis | Ingrowth Date/Time | Decay Date/Time | Standards | Prep Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1811039-1 | SMP | | 1000 | 997.002 | Filtered | 12/05/18 13:48 | 12/07/18 09:22 | T1 | |
| 2 | 1 | 1811039-2 | SMP | | 1000 | 997.002 | Filtered | 12/05/18 13:48 | 12/07/18 09:22 | T1 | |
| 3 | 1 | 1811039-3 | SMP | | 1000 | 997.002 | Unfiltered | 12/05/18 13:48 | 12/07/18 09:22 | T1 | |
| 4 | 1 | 1811039-4 | SMP | | 1000 | 997.002 | Unfiltered | 12/05/18 13:48 | 12/07/18 09:22 | T1 | |
| 5 | 1 | 1811039-5 | SMP | | 1000 | 997.002 | Unfiltered | 12/05/18 13:48 | 12/07/18 09:22 | T1 | |
| 6 | 1 | 1811039-6 | SMP | | 1000 | 997.002 | Unfiltered | 12/05/18 13:48 | 12/07/18 09:22 | T1 | |
| 7 | 1 | 1811039-7 | SMP | | 1000 | 997.002 | Unfiltered | 12/05/18 13:48 | 12/07/18 09:22 | T1 | |
| 8 | 1 | 1811039-8 | SMP | | 1000 | 997.002 | Unfiltered | 12/05/18 13:48 | 12/07/18 09:22 | T1 | |
| 9 | 1 | 1811039-10 | SMP | | 1000 | 997.002 | Filtered | 12/05/18 13:48 | 12/07/18 09:22 | T1 | |
| 10 | 1 | 1811043-2 | SMP | | 1000 | 997.002 | Unfiltered | 12/05/18 13:48 | 12/07/18 09:22 | T1 | |
| 11 | 1 | 1811043-3 | SMP | | 1000 | 997.002 | Unfiltered | 12/05/18 13:48 | 12/07/18 09:22 | T1 | |
| 12 | 1 | 1811057-1 | SMP | | 1000 | 997.002 | Unfiltered | 12/05/18 13:48 | 12/07/18 09:22 | T1 | |
| 13 | 1 | 1811058-1 | SMP | | 250 | 249.2505 | Unfiltered | 12/05/18 13:48 | 12/07/18 09:22 | T1 | |
| 14 | 1 | 1811059-1 | SMP | | 250 | 249.2505 | Unfiltered | 12/05/18 13:48 | 12/07/18 09:22 | T1 | |
| 15 | 1 | 1811082-1 | SMP | | 1000 | 997.002 | Unfiltered | 12/05/18 13:48 | 12/07/18 09:22 | T1 | |
| 16 | 1 | 1811105-1 | SMP | | 250 | 249.2505 | Unfiltered | 12/05/18 13:48 | 12/07/18 09:22 | T1 | |
| 17 | 1 | RA181128-1 | MB | | 1000 | 997.002 | Filtered | 12/05/18 13:48 | 12/07/18 09:22 | T1 | |
| 18 | 1 | RA181128-1 | MB | | 1000 | 997.002 | Unfiltered | 12/05/18 13:48 | 12/07/18 09:22 | T1 | |
| 19 | 1 | RA181128-1 | LCS | | 1000 | 997.002 | Filtered | 12/05/18 13:48 | 12/07/18 09:22 | S1,T1 | |
| 20 | 1 | RA181128-1 | LCS | | 1000 | 997.002 | Unfiltered | 12/05/18 13:48 | 12/07/18 09:22 | S1,T1 | |
| 21 | 1 | RA181128-1 | LCSD | | 1000 | 997.002 | Filtered | 12/05/18 13:48 | 12/07/18 09:22 | S1,T1 | |
| 22 | 1 | RA181128-1 | LCSD | | 1000 | 997.002 | Unfiltered | 12/05/18 13:48 | 12/07/18 09:22 | S1,T1 | |

RGS 12/10/18

# Radiochemistry Prep Worksheet

**ALS -- Fort Collins**

**Prep Batch:** RA181128-1

**Prep Procedure:** Ra228

**Reviewed By:** rgs **Review Date:** 12/10/2018

**Non-Routine Pre-Treatment?** Y (N) **Batch:** **Re-Prep?** Y (N) **Batch:** **Prep QASS / NCR?** Y (N)

**Prep SOP:** SOP749 **Rev:** 5
**Prep SOP:** NONE
**Matrix Class:** liquid

**Prep Analyst:** Reilly G. Stockton
**Prep Date:** 11/28/2018
**Prep Dept:** RS

**Balance:** N/A
**Balance:** N/A

| Samp Num | Prep Num | LabID | QC Type | Dish No. | Init Alq ml | Fin Alq ml | Prep Basis | Ingrowth Date/Time | Decay Date/Time | Standards | Prep Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|

Comments
**Samples 1811058-1, 1811059-1, and 1811105-1 all had reduced aliquots due to matrix interferences.**

**Spiked By:** Reilly G. Stockton **Date:** 11/29/2018 **Yttrium Added By:** **Date:**

**Witnessed By:** Steven D. White **Date:** 11/29/2018 **Witnessed By:** **Date:**

**Tracer/Carrier Solution Information**

| Soln # | Nuclide | SolnID | Exp Date | Prep Conc | Units | Prep Date | Aliquot | Units | Pipet ID |
|---|---|---|---|---|---|---|---|---|---|
| T1 | BARIUM | 418244 | 8/23/19 | 16,012.690 | pCi/ml | NA | 2 | ml | RS031 |

**Spike Solution Information**

| Soln # | Nuclide | SolnID | Exp Date | Prep Conc | Units | Prep Date | Aliquot | Units | Pipet ID |
|---|---|---|---|---|---|---|---|---|---|
| S1 | Ra-228 | 1014.4095.79 | 3/20/19 | 76.547 | DPM/ml | 11/28/18 | 0.25 | ml | RS019 |

# Radiochemistry Prep Worksheet

**ALS -- Fort Collins**

**Prep Batch:** RA181128-1

**Prep Procedure:** Ra228

## Prep Batch Not Validated!!!

**Reviewed By:**

**Review Date:**

**Non-Routine Pre-Treatment? Y / N** **Batch:** _____ **Re-Prep? Y / N** **Batch:** _____ **Prep QASS / NCR? Y / N** _____

**Prep SOP:** SOP749 **Rev:** 5
**Prep SOP:** NONE
**Matrix Class:** liquid

**Prep Analyst:** Reilly G. Stockton RGS
**Prep Date:** 11/28/2018
**Prep Dept:** RS

**Balance:**
**Balance:**

| Samp Num | Prep Num | LabID | QC Type | Dish No. | Init Alq ml | Fin Alq ml | Prep Basis | Ingrowth Date/Time | Decay Date/Time | Standards | Prep Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1811039-1 | SMP | | 1000 | 1000 | ~~Unfiltered~~ | D/S 13:48 | 9:22 | T1 | |
| 2 | 1 | 1811039-2 | SMP | | 1000 | 1000 | ~~Unfiltered~~ | | 12/7 | T1 | |
| 3 | 1 | 1811039-3 | SMP | | 1000 | 1000 | Unfiltered | | | T1 | |
| 4 | 1 | 1811039-4 | SMP | | 1000 | 1000 | Unfiltered | | | T1 | |
| 5 | 1 | 1811039-5 | SMP | | 1000 | 1000 | Unfiltered | | | T1 | |
| 6 | 1 | 1811039-6 | SMP | | 1000 | 1000 | Unfiltered | | | T1 | |
| 7 | 1 | 1811039-7 | SMP | | 1000 | 1000 | Unfiltered | | | T1 | |
| 8 | 1 | 1811039-8 | SMP | | 1000 | 1000 | Unfiltered | | | T1 | |
| 9 | 1 | 1811039-10 | SMP | | 1000 | 1000 | ~~Unfiltered~~ | | | T1 | |
| 10 | 1 | 1811043-1 | SMP | | 1000 | 1000 | Unfiltered | | | T1 | |
| 11 | 1 | 1811043-2 | SMP | | 1000 | 1000 | Unfiltered | | | T1 | |
| 12 | 1 | 1811043-3 | SMP | | 1000 | 1000 | Unfiltered | | | T1 | |
| 13 | 1 | 1811057-1 | SMP | | 1000 | 1000 | Unfiltered | | | T1 | |
| 14 | 1 | 1811058-1 | SMP | 250 | ~~1000~~ | 1000 | Unfiltered | | | T1 | |
| 15 | 1 | 1811059-1 | SMP | 250 | ~~1000~~ | 1000 | Unfiltered | | | T1 | |
| 16 | 1 | 1811082-1 | SMP | | 1000 | 1000 | Unfiltered | | | T1 | |
| 17 | 1 | 1811105-1 | SMP | 250 | ~~1000~~ | 1000 | Unfiltered | | | T1 | |
| 18 | 1 | RA181128-1 | MB | | 1000 | 1000 | Unfiltered | | | T1 | |
| 19 | 1 | RA181128-1 | LCS | | 1000 | 1000 | Unfiltered | | | S1,T1 | |
| 20 | 1 | RA181128-1 | LCSD | | 1000 | 1000 | Unfiltered | | | S1,T1 | |

Comments

**Spiked By:** Reilly Stockton **Date:** 11/29/18
**Witnessed By:** [illegible] **Date:** 11-29-18

**Yttrium Added By:** _____ **Date:** _____
**Witnessed By:** _____ **Date:** _____

**Tracer/Carrier Solution Information**

| Soln # | Nuclide | SolnID | Exp Date | Prep Conc | Units | Prep Date | Aliquot | Units | Pipet ID |
|---|---|---|---|---|---|---|---|---|---|
| T1 | BARIUM | 418244 | 8/23/19 | 16,012.690 | pCi/ml | NA | 2 | ml | RS031 |

**Spike Solution Information**

| Soln # | Nuclide | SolnID | Exp Date | Prep Conc | Units | Prep Date | Aliquot | Units | Pipet ID |
|---|---|---|---|---|---|---|---|---|---|
| S1 | Ra-228 | 1014.4095.79 | 3/20/19 | 76.547 | DPM/ml | 11/28/18 | 0.25 | ml | RS019 |

# Sample Condition Form (Liquid)

Analyst: Reilly Stockton

Analysis Date: 11/28/18 | Method: Radium 228

| | | Sample Condition (Visual Appearance of Analysis Aliquot at Time of Prep) | | |
|---|---|---|---|---|
| Work Order | Sample ID | pH | Color | Remarks |
| 1811039 | 1 | <2 | brown | thick sediment, filtered |
| | 2 | | ↓ | ↓ |
| | 3 | | ~~clear~~ light yellow | none |
| | 4 | | | |
| | 5 | | | |
| | 6 | | ↓ | |
| | 7 | | clear | |
| | 8 | | ↓ | |
| | 10 | | brown | thick sediment, filtered |
| 1811043 | 1 | | clear | none |
| | 2 | | | |
| | 3 | | | |
| 1811057 | 1 | | | |
| 1811058 | 1 | | | RAS 11/28/18 ~~brown~~ none |
| 1811059 | 1 | | tan | |
| 1811082 | 1 | | | |
| 1811105 | 1 | | blue green | |
| | | | | |
| | | | | |
| | | | | RAS 11/28/18 |
| | | | | |

Section 8

# STANDARDS TRACEABILITY DOCUMENTS

8

# Radiochemistry Solution Report

| | | | | | |
|---|---|---|---|---|---|
| **Solution Id:** | 418244 | **Name:** | Ba carrier | **Type:** | IS |
| | | **Lot:** | | **Vendor Name:** | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Final Vol:** | 4000 | **Dept:** | RD | **Prep By** | RGS | **on** | 8/23/2018 | **Reviewed By** | tde | **on** | 9/24/2018 |
| **Units:** | mL | **Location:** | SR/RA | **Opened By** | | **on** | | **Verified By** | TDE | **on** | 9/24/2018 |
| **Matrix:** | LIQUID | **ExpireDate:** | 9/24/2019 | **Received By** | | **on** | | **Deactivated By** | | **on** | |

**Comment:**

| Component Name | Component ID | Volume Added | Units |
|---|---|---|---|
| Barium Stable Carrier Source<1> | 3756 B07592 | 113.9301 | g |

| CompName | Calibrated Primary Act/Conc | Calibration Date | Reference Date | 1/2 Life (Yrs) | Final Act/Conc | Summed Conc | Units |
|---|---|---|---|---|---|---|---|
| BARIUM | 562193.5 | | 10/22/2018 | | 16012.69 | | pCi/ml |

## Associated Parent IDs

3756 B07592

**Abbreviations: NC = Not Calculated for reagents when the volume added is not entered.**
**NE = Not Entered**

**(Prnt) = Secular equilibrium; parent half life used to calculate concentration.**



**Date Printed:** Monday, October 22, 2018

*ALS Environmental -- FC*

Standards DB Version: 1.111

Prepare a working dilution of RSO# 1014 TE 1/16/15

1. Density of 8% HNO3, lot # 000008417G
   Mass of 100mL vol. flask: 68.3149g Balance # 12
   Mass of flask & 100mL acid: 172.2758g Balance# 12
   Net Mass: 103.9609g
   Density: 1.0396 g/mL

2. Mass of RSO# 1014 transferred:
   Mass of open empty nalgene: 48.3028g Balance# 12
   Mass of nalgene & standard: 53.2851g Balance# 12
   Net mass of standard transferred: 4.9823g Balance# N/A

   TE 1/16/15 TE 1/16/15

3. Dilute to final volume:
   Mass of nalgene, standard, & diluent: 344.91g Balance# 26
   Mass of empty nalgene (from above): 48.3028g Balance# 12
   Net mass of new dilution: 296.6072g Balance# N/A

4. Final activity calculation:

$$195\ Bq/g \left(\frac{60\ dpm}{1\ Bq}\right)\left(\frac{4.9823g}{296.6072g}\right)(1.0396\ g/mL) = 204.32\ dpm/mL$$

TE 1/16/15

JP 4/15/15

*Std ID:* 1014.4095.79

*Description:* Ra-228
*Expiration:* 4/9/2016
*Activity:* 204.32 dpm/mL

*2s Uncertainty:* 14.71 dpm/mL
*Ref. Date:* 10/7/2010
*Ref Time:* N/A
*Prep Date:* 1/16/2015 *Prep by:* TE
*Matrix/Comp.* 8% HNO3
*Half Life (y):* 5.75E+00

| Reverification Log | | |
|---|---|---|
| Analysis Date | Initials | Expiration Date |
| 4/2/2016 | JP | 4/02/2017 |
| 3/23/2017 | JP | 3/23/2018 |
| 3/20/2018 | JP | 3/20/2019 |
| | | |
| | | |

JP 4/15/15

Continued on Page

T Ellis 1/16/15
Signed Date

Read and Understood By 4/15/15
Signed Date

K50 F
1014

# National Institute of Standards & Technology

# Certificate

## Standard Reference Material® 4339b

### Radium-228 Radioactivity Standard

This Standard Reference Material (SRM) consists of a solution of a standardized and certified quantity of radioactive radium-228 in a suitably stable and homogeneous matrix. It is intended primarily for the calibration of instruments that are used to measure radioactivity and for the monitoring of radiochemical procedures. A unit of SRM 4339b consists of approximately 5 mL of a solution, whose composition is specified in Tables 1 and 2, contained in a flame-sealed borosilicate-glass ampoule [1].

**The certified radium-228 massic activity value, at a Reference Time of 1200 EST, 07 October 2010, is:**

$$(195 \pm 14)\ \mathrm{Bq \cdot g^{-1}}$$

A NIST certified value, as used within the context of this certificate, is a value for which NIST has the highest confidence in its uncertainty assessment. It is a "measurement result" [2] obtained directly or indirectly from a "primary reference measurement procedure" [3]. The certified value is traceable to the derived SI unit, Becquerel (Bq).

Additional physical, chemical, and radiological properties for this SRM, as well as details on the standardization method, are given in Tables 1 and 2. Uncertainties for the certified quantities are expanded ($k = 2$). The uncertainties are calculated according to the ISO and NIST Guides [4,5]. Table 3 contains a specification of the components that comprise the uncertainty analyses.

**Expiration of Certification:** The certification of SRM 4339b is valid indefinitely, within the measurement uncertainty specified, provided that the SRM is handled and stored properly and that no evaporation or change in composition has occurred. The solution matrix, in an unopened ampoule, is homogeneous and stable within its half-life-dependent useful lifetime provided the SRM is handled in accordance with instructions given in this certificate (see "Instructions for Handling and Storage"). Periodic recertification of this SRM is not required. The certification is nullified if the SRM is damaged, contaminated, or otherwise modified.

**Maintenance of SRM Certification:** NIST will monitor this SRM over the period of its certification. If substantive technical changes occur that affect the certification, NIST will notify the purchaser. Registration (see attached sheet) will facilitate notification.

**Radiological and Chemical Hazard:** Consult the Safety Data Sheet (SDS), enclosed with the SRM shipment, for radiological and chemical hazard information.

This SRM was prepared in the Physical Measurement Laboratory, Radiation and Biomolecular Physics Division, Radioactivity Group, M.P. Unterweger, Group Leader. The overall technical direction and physical measurement leading to certification and photon-emitting impurity analyses were provided by L. Pibida of the NIST Radioactivity Group, with production assistance by J. LaRosa, R. Collé, and L. Laureano-Pérez. Alpha-emitting impurity analyses were provided by J. LaRosa.

Support aspects involved in the issuance of this SRM were coordinated through the NIST Office of Reference Materials.

Lisa R. Karam, Chief
Radiation and Biomolecular Physics Division

Gaithersburg, Maryland 20899

Robert L. Watters, Jr., Director
Office of Reference Materials

Certificate Issue Date: 14 November 2012

Table 1. Certified Massic Activity of SRM 4339b

| | |
|---|---|
| Radionuclide | Radium-228[a] |
| Reference time | 1200 EST, 07 October 2010 |
| Massic activity of the solution | 195 $Bq \cdot g^{-1}$ |
| Relative expanded uncertainty ($k = 2$) | 7.2 %[b] |

[a] The final $^{228}Ra$ purification from the $^{232}Th$ mother solution was performed on 02 September 2010 0920 EST.
[b] The uncertainties on certified values are expanded uncertainties, $U = ku_c$. The quantity $u_c$ is the combined standard uncertainty calculated according to the ISO and NIST Guides [4,5]. The combined standard uncertainty is multiplied by a coverage factor of $k = 2$ and was chosen to obtain what is assumed to be an approximate 95 % level of confidence.

Table 2. Uncertified Information of SRM 4339b

| | |
|---|---|
| Source description | Liquid in a flame-sealed 5 mL borosilicate-glass ampoule [1] |
| Solution composition | 1.3 $mol \cdot L^{-1}$ $HNO_3$ with 19.8 $\mu g \cdot g^{-1}$ $Ba^{+2}$ |
| Solution density | $(1.034 \pm 0.002)$ $g \cdot mL^{-1}$ at 20.8 °C[a] |
| Solution mass | $(5.180 \pm 0.003)$ g[a] |
| Photon-emitting impurities | $^{226}Ra$: < 0.5 $Bq \cdot g^{-1}$[b] |
| Alpha-emitting impurities | $^{232}Th$: < 0.08 $Bq \cdot g^{-1}$[c] |
| Half-lives used | $^{228}Ra$: $(5.75 \pm 0.04)$ a[d] [6]<br>$^{228}Ac$: $(6.15 \pm 0.02)$ h [7]<br>$^{226}Ra$: $(1600 \pm 7)$ a [8]<br>$^{232}Th$: $(14.02 \pm 0.06) \times 10^9$ a [9] |
| Calibration methods (and instruments) | The certified massic activity for $^{228}Ra$ was obtained by high-resolution gamma-ray spectrometry of three master solution ampoules (eleven separate determinations), as measured on three to five different spectrometers and geometries on each ampoule, and used assumed nuclear data for probabilities per decay for 16 gamma-ray transitions. Confirmatory measurements were performed by $2\pi\alpha$ spectrometry of ingrown $^{228}Th$ with a planar, ion-implanted Si detector. |

[a] The stated uncertainty is two times the standard uncertainty. See reference 5.
[b] Based on gamma-ray spectrometry of forced-fitted peak at 186.2 keV and assuming a probability per decay of 0.0355 [6].
[c] The maximum $^{232}Th$ activity concentration in $^{228}Ra$.
[d] The stated uncertainty is the standard uncertainty. See reference 5.

Table 3. Uncertainty Evaluation for the Massic Activity of SRM 4339b

| | Uncertainty component | Assessment Type[a] | Relative standard uncertainty contribution on massic activity of $^{228}$Ra (%) |
|---|---|---|---|
| 1 | Gamma-ray spectrometry precision; relative standard deviation of the grand mean on the average massic gamma-ray emission rates for 16 measured $^{228}$Ac gamma-ray transitions. Each mean in the grand mean is based on 11 determinations with three sources in three to five different detectors. The uncertainty in the determination of the massic gamma-ray emission rate for any one transition in a given determination ranged from typically 0.5 % to 1.5 %. The relative standard deviation of the mean for the average of the 16 lines, for any one determination, was typically 1 %; whereas the relative standard deviation of the grand mean for the average of the 16 lines across all 11 determinations is 0.34 %[b]. Data passes normality test. | A | 0.84 |
| 2 | Uncertainty due to assumed gamma-ray probabilities per decay for the measured $^{228}$Ac transitions [7]. The uncertainty on each transition has a shared (correlated) component of 2.5 % (see comments in [7]). | B | 3.5 |
| 3 | Detection efficiencies not embodied within component 1 | B | 0.4 |
| 4 | Mass determinations for dilution factors and counting source preparations | B | 0.1 |
| 5 | Decay corrections for $^{228}$Ra half-life uncertainty of 0.7 % [6] | B | 0.003 |
| 6 | Effect of $^{228}$Ra and $^{228}$Ac half-life uncertainties on secular equilibrium ratio | B | 0.02 |
| **Relative combined standard uncertainty** | | | **3.6** |
| **Relative expanded uncertainty ($k = 2$)** | | | **7.2** |

[a] Letter A denotes evaluation by statistical methods; B denotes evaluation by other methods.
[b] Average massic gamma-ray emission rates of 11 geometries ($R_\gamma$) for 16 measured $^{228}$Ac gamma-ray transitions with their respective energy ($E_\gamma$); assumed gamma-ray probabilities per decay ($I_\gamma$) and standard deviation of the mean ($S_m$).

| $E_\gamma$ (keV) | Assumed $I_\gamma$ (%) [1] | Mean $R_\gamma$ ($s^{-1} \cdot g^{-1}$)[i] | $S_m$ (%)[ii] |
|---|---|---|---|
| 129.065 | 2.50 | 1347 | 0.38 |
| 153.967 | 0.754 | 421.6 | 0.40 |
| 209.249 | 3.97 | 2264 | 0.55 |
| 270.245 | 3.55 | 2014 | 0.33 |
| 328.004 | 3.04 | 1822 | 0.43 |
| 338.32 | 11.4 | 6712 | 0.43 |
| 409.46 | 2.02 | 1185 | 0.29 |
| 463.002 | 4.45 | 2645 | 0.33 |
| 755.313 | 1.03 | 593.3 | 0.46 |
| 772.291 | 1.52 | 899.2 | 0.53 |
| 794.942 | 4.31 | 2588 | 0.35 |
| 835.704 | 1.7 | 995.3 | 0.42 |
| 911.196 | 26.2 | 15609 | 0.29 |
| 964.786 | 4.99 | 3007 | 0.35 |
| 968.96 | 15.9 | 9582 | 0.30 |
| 1588.2 | 3.06 | 1889 | 0.28 |

(i) Grand mean for $n = 11$ determinations with three sources in three to five different detectors.
(ii) Relative standard deviation of the grand mean on $R_\gamma$ for $n = 11$.

## INSTRUCTIONS FOR HANDLING AND STORAGE

**Handling:** If the ampoule is transported, it should be packed, marked, labeled, and shipped in accordance with the applicable national, international, and carrier regulations. The solution in the ampoule is a dangerous good (hazardous material) because of both the radioactivity and the strong acid. The ampoule should be opened only by persons qualified to handle both radioactive material and alkaline and/or acidic solutions. Appropriate shielding and/or distance should be used to minimize personnel exposure. Refer to SDS for further information.

**Storage:** SRM 4339b should be stored and used at a temperature between 5 °C and 65 °C. The ampoule (or any subsequent container) should always be clearly marked as containing radioactive material.

## REFERENCES


[1] NIST Physical Measurement Laboratory; *Storage and Handling of Radioactive Standard Reference Materials, Ampoule Specifications and Opening Procedure*, available at http://www.nist.gov/pml/div682/grp04/srm.cfm (accessed Nov 2012). Note: This SRM is contained in a generic borosilicate-glass ampoule and not in the standard NIST ampoule.

[2] JCGM 200:2012; *International Vocabulary of Metrology - Basic and General Concepts and Associated Terms (VIM)* (2008 version with Minor Corrections), 3rd edition; Joint Committee for Guides in Metrology: BIPM, Sevres Cedex, France; p. 19 (2012); available at http://www.bipm.org/utils/common/documents/jcgm/JCGM_200_2012.pdf (accessed Nov 2012).

[3] JCGM 200:2012; *International Vocabulary of Metrology - Basic and General Concepts and Associated Terms (VIM)* (2008 version with Minor Corrections), 3rd edition; Joint Committee for Guides in Metrology: BIPM, Sevres Cedex, France; p. 18 (2012); available at http://www.bipm.org/utils/common/documents/jcgm/JCGM_200_2012.pdf (accessed Nov 2012).

[4] JCGM 100:2008; *Guide to the Expression of Uncertainty in Measurement;* (ISO GUM 1995 with Minor Corrections), Joint Committee for Guides in Metrology: BIPM, Sevres Cedex, France (2008); available at http://www.bipm.org/utils/common/documents/jcgm/JCGM_100_2008_E.pdf (accessed Nov 2012).

[5] Taylor, B.N.; Kuyatt, C.E.; *Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results*; NIST Technical Note 1297, U.S. Government Printing Office: Washington, DC (1994); available at http://physics.nist.gov/Pubs/ (accessed Nov 2012).

[6] Luca, A.; June 2009, $^{228}$Ra. LNE-LNHB/CEA Table of Radionuclides, available at http://www.nucleide.org/DDEP_WG/Nuclides/Ra-228_tables.pdf (accessed Nov 2012).

[7] Pearce, A.; January 2010, $^{228}$Ac. LNE-LNHB/CEA Table of Radionuclides, available at http://www.nucleide.org/DDEP_WG/Nuclides/Ac-228_tables.pdf (accessed Nov 2012).

[8] Christé, V. and M.M. Bé; December 2006, $^{226}$Ra. LNE-LNHB/CEA Table of Radionuclides, available at http://www.nucleide.org/DDEP_WG/Nuclides/Ra-226_tables.pdf (accessed Nov 2012).

[9] Arinc, A.; September 2008, $^{232}$Th. LNE-LNHB/CEA Table of Radionuclides, available at http://www.nucleide.org/DDEP_WG/Nuclides/Th-232_tables.pdf (accessed Nov 2012).


*Users of this SRM should ensure that the Certificate in their possession is current. This can be accomplished by contacting the SRM Program: telephone (301) 975-2200; fax (301) 948-3730; e-mail srminfo@nist.gov; or via the Internet at http://www.nist.gov/srm.*

Section 9

# ADDITIONAL SUPPORTING DOCUMENTATION

**Gas Proportional Counter**

# Instrument Calibration

# Background Calibration

**LB4100-A Long Background Instrument Calibration**
**Background Determinations**

| Detector ID | Alpha CPM | Alpha LCL | Alpha UCL | Alpha Flag | Beta CPM | Beta LCL | Beta UCL | Beta Flag | Detector ID |
|---|---|---|---|---|---|---|---|---|---|
| A1 (01) | 0.126 | 0.0011 | 0.2149 | PASS | 1.962 | 1.143 | 3.429 | PASS | A1 (01) |
| A2 (02) | 0.124 | 0.0010 | 0.1990 | PASS | 2.090 | 0.984 | 2.951 | PASS | A2 (02) |
| A3 (03) | 0.098 | 0.0009 | 0.1811 | PASS | 2.001 | 0.970 | 2.909 | PASS | A3 (03) |
| A4 (04) | 0.117 | 0.0008 | 0.1493 | PASS | 2.017 | 0.957 | 2.870 | PASS | A4 (04) |
| B1 (05) | 0.147 | 0.0012 | 0.2308 | PASS | 1.905 | 1.857 | 5.570 | PASS | B1 (05) |
| B2 (06) | 0.164 | 0.0011 | 0.2249 | PASS | 1.861 | 0.900 | 2.699 | PASS | B2 (06) |
| B3 (07) | 0.183 | 0.0011 | 0.2090 | PASS | 1.896 | 0.961 | 2.882 | PASS | B3 (07) |
| B4 (08) | 0.178 | 0.0013 | 0.2567 | PASS | 1.832 | 0.832 | 2.495 | PASS | B4 (08) |
| C1 (09) | 0.118 | 0.0010 | 0.1910 | PASS | 1.770 | 0.884 | 2.651 | PASS | C1 (09) |
| C2 (10) | 0.183 | 0.0011 | 0.2149 | PASS | 1.843 | 0.837 | 2.510 | PASS | C2 (10) |
| C3 (11) | 0.132 | 0.0008 | 0.1592 | PASS | 1.665 | 0.763 | 2.289 | PASS | C3 (11) |
| C4 (12) | 0.139 | 0.0010 | 0.1990 | PASS | 1.887 | 0.905 | 2.714 | PASS | C4 (12) |
| D1 (13) | 0.112 | 0.0006 | 0.1234 | PASS | 1.603 | 0.719 | 2.157 | PASS | D1 (13) |
| D2 (14) | 0.143 | 0.0007 | 0.1433 | PASS | 1.997 | 0.943 | 2.828 | PASS | D2 (14) |
| D3 (15) | 0.124 | 0.0008 | 0.1493 | PASS | 1.608 | 0.737 | 2.210 | PASS | D3 (15) |
| D4 (16) | 0.119 | 0.0010 | 0.2030 | PASS | 2.049 | 1.026 | 3.078 | PASS | D4 (16) |

Reviewed by: _____ Date: 12/05/18

Interim Control Limits set to Alpha +- 99%,Beta +-50% JP 07/12/2018



BKA1204W.XLD

Printed 12/5/18 7:14 AM

**LB4100-C**
**Long Instrument Background Calibration**
**Background Determination**

| Detector ID | Alpha CPM | Alpha LCL | Alpha UCL | Alpha Flag | Beta CPM | Beta LCL | Beta UCL | Beta Flag | Detector ID | |
|---|---|---|---|---|---|---|---|---|---|---|
| A1 (01) | 0.116 | 0.0538 | 0.1713 | PASS | 3.395 | 0.717 | 2.732 | FLAG-HIGH | A1 (01) | * |
| A2 (02) | 0.123 | 0.0500 | 0.1751 | PASS | 1.524 | 1.255 | 1.718 | PASS | A2 (02) | |
| A3 (03) | 0.147 | 0.0237 | 0.2204 | PASS | 1.608 | 1.374 | 1.711 | PASS | A3 (03) | |
| A4 (04) | 0.123 | 0.0640 | 0.1738 | PASS | 1.573 | 1.378 | 1.635 | PASS | A4 (04) | |
| B1 (05) | 0.123 | 0.0868 | 0.1681 | PASS | 1.645 | 1.429 | 1.742 | PASS | B1 (05) | |
| B2 (06) | 0.129 | 0.0532 | 0.1998 | PASS | 1.721 | 1.538 | 1.811 | PASS | B2 (06) | |
| B3 (07) | 0.116 | 0.0424 | 0.2040 | PASS | 1.659 | 1.473 | 1.931 | PASS | B3 (07) | |
| B4 (08) | 0.152 | 0.0528 | 0.2226 | PASS | 1.791 | 1.439 | 1.904 | PASS | B4 (08) | |
| C1 (09) | 0.142 | 0.0759 | 0.1706 | PASS | 1.751 | 1.025 | 2.424 | PASS | C1 (09) | |
| C2 (10) | 0.147 | 0.0800 | 0.2190 | PASS | 1.810 | 1.596 | 1.913 | PASS | C2 (10) | |
| C3 (11) | 0.114 | 0.0515 | 0.1805 | PASS | 1.694 | 1.526 | 1.723 | PASS | C3 (11) | |
| C4 (12) | 0.173 | 0.0785 | 0.2262 | PASS | 2.507 | 1.349 | 3.194 | PASS | C4 (12) | |
| D1 (13) | 0.109 | 0.0608 | 0.1655 | PASS | 1.872 | 1.530 | 1.841 | FLAG-HIGH | D1 (13) | Δ |
| D2 (14) | 0.073 | 0.0054 | 0.1582 | PASS | 1.464 | 1.223 | 1.767 | PASS | D2 (14) | |
| D3 (15) | 0.163 | 0.0413 | 0.2190 | PASS | 1.700 | 1.411 | 1.714 | PASS | D3 (15) | |
| D4 (16) | 0.117 | 0.0797 | 0.1625 | PASS | 1.732 | 1.029 | 2.545 | PASS | D4 (16) | |

*: Detector offline

Reviewed by: _____ Date: 11/29/18

Historical Control Limits set to be +/- 3 Std Dev Of 15 Data Points (07/04/17-->01/24/18)
JP 01/25/18

Δ: Recount to BKC1129W

**LB4100-C**
**Long Instrument Background Calibration**
**Background Determination**

| Detector ID | Alpha CPM | Alpha LCL | Alpha UCL | Alpha Flag | Beta CPM | Beta LCL | Beta UCL | Beta Flag | Detector ID |
|---|---|---|---|---|---|---|---|---|---|
| A1 (01) | #REF! | 0.0538 | 0.1713 | #REF! | #REF! | 0.717 | 2.732 | #REF! | A1 (01) |
| A2 (02) | #REF! | 0.0500 | 0.1751 | #REF! | #REF! | 1.255 | 1.718 | #REF! | A2 (02) |
| A3 (03) | #REF! | 0.0237 | 0.2204 | #REF! | #REF! | 1.374 | 1.711 | #REF! | A3 (03) |
| A4 (04) | #REF! | 0.0640 | 0.1738 | #REF! | #REF! | 1.378 | 1.635 | #REF! | A4 (04) |
| B1 (05) | #REF! | 0.0868 | 0.1681 | #REF! | #REF! | 1.429 | 1.742 | #REF! | B1 (05) |
| B2 (06) | #REF! | 0.0532 | 0.1998 | #REF! | #REF! | 1.538 | 1.811 | #REF! | B2 (06) |
| B3 (07) | #REF! | 0.0424 | 0.2040 | #REF! | #REF! | 1.473 | 1.931 | #REF! | B3 (07) |
| B4 (08) | #REF! | 0.0528 | 0.2226 | #REF! | #REF! | 1.439 | 1.904 | #REF! | B4 (08) |
| C1 (09) | #REF! | 0.0759 | 0.1706 | #REF! | #REF! | 1.025 | 2.424 | #REF! | C1 (09) |
| C2 (10) | #REF! | 0.0800 | 0.2190 | #REF! | #REF! | 1.596 | 1.913 | #REF! | C2 (10) |
| C3 (11) | #REF! | 0.0515 | 0.1805 | #REF! | #REF! | 1.526 | 1.723 | #REF! | C3 (11) |
| C4 (12) | #REF! | 0.0785 | 0.2262 | #REF! | #REF! | 1.349 | 3.194 | #REF! | C4 (12) |
| D1 (13) | 0.163 | 0.0608 | 0.1655 | PASS | 1.835 | 1.530 | 1.841 | PASS | D1 (13) |
| D2 (14) | #REF! | 0.0054 | 0.1582 | #REF! | #REF! | 1.223 | 1.767 | #REF! | D2 (14) |
| D3 (15) | #REF! | 0.0413 | 0.2190 | #REF! | #REF! | 1.411 | 1.714 | #REF! | D3 (15) |
| D4 (16) | #REF! | 0.0797 | 0.1625 | #REF! | #REF! | 1.029 | 2.545 | #REF! | D4 (16) |

Reviewed by: _____ Date: 11/30/18

Historical Control Limits set to be +/- 3 Std Dev Of 15 Data Points (07/04/17-->01/24/18)
JP 01/25/18

**Gas Proportional Counter**

# Quality Control Data

# Daily Instrument Performance Checks

## LB4100-A Daily Instrument Performance Check
## Efficiency Determinations

| Detector ID | Alpha Eff. | Alpha LCL | Alpha UCL | Alpha Flag | Beta Eff. | Beta LCL | Beta UCL | Beta Flag | Detector ID |
|---|---|---|---|---|---|---|---|---|---|
| A1 (01) | 0.2095 | 0.1869 | 0.2284 | PASS | 0.2056 | 0.1818 | 0.2222 | PASS | A1 (01) |
| A2 (02) | 0.2056 | 0.1832 | 0.2240 | PASS | 0.2201 | 0.1949 | 0.2382 | PASS | A2 (02) |
| A3 (03) | 0.2270 | 0.1983 | 0.2423 | PASS | 0.2116 | 0.1881 | 0.2299 | PASS | A3 (03) |
| A4 (04) | 0.2258 | 0.2005 | 0.2451 | PASS | 0.2270 | 0.2006 | 0.2452 | PASS | A4 (04) |
| B1 (05) | 0.2160 | 0.1958 | 0.2393 | PASS | 0.2312 | 0.2079 | 0.2541 | PASS | B1 (05) |
| B2 (06) | 0.2208 | 0.1975 | 0.2414 | PASS | 0.2362 | 0.2101 | 0.2567 | PASS | B2 (06) |
| B3 (07) | 0.2253 | 0.2055 | 0.2512 | PASS | 0.2257 | 0.1999 | 0.2443 | PASS | B3 (07) |
| B4 (08) | 0.2197 | 0.1975 | 0.2414 | PASS | 0.2220 | 0.1979 | 0.2418 | PASS | B4 (08) |
| C1 (09) | 0.2146 | 0.1903 | 0.2326 | PASS | 0.2122 | 0.1904 | 0.2327 | PASS | C1 (09) |
| C2 (10) | 0.2107 | 0.1946 | 0.2379 | PASS | 0.2265 | 0.2061 | 0.2519 | PASS | C2 (10) |
| C3 (11) | 0.2248 | 0.2053 | 0.2509 | PASS | 0.2142 | 0.1948 | 0.2381 | PASS | C3 (11) |
| C4 (12) | 0.2279 | 0.2052 | 0.2508 | PASS | 0.2333 | 0.2070 | 0.2530 | PASS | C4 (12) |
| D1 (13) | 0.2591 | 0.2313 | 0.2827 | PASS | 0.2447 | 0.2203 | 0.2693 | PASS | D1 (13) |
| D2 (14) | 0.2506 | 0.2208 | 0.2698 | PASS | 0.2464 | 0.2262 | 0.2765 | PASS | D2 (14) |
| D3 (15) | 0.2305 | 0.2074 | 0.2535 | PASS | 0.2360 | 0.2110 | 0.2579 | PASS | D3 (15) |
| D4 (16) | 0.2363 | 0.2087 | 0.2551 | PASS | 0.2405 | 0.2147 | 0.2624 | PASS | D4 (16) |

Reviewed by: _____ Date: 12/07/18

Interim Control Limits -- +/-10% of Average of 5 Data Points. JP 07/12/18

## LB4100-A Daily Instrument Calibration and Check
## Background Determinations

| Detector ID | Alpha CPM | Alpha LCL | Alpha UCL | Alpha Flag | Beta CPM | Beta LCL | Beta UCL | Beta Flag | Detector ID | |
|---|---|---|---|---|---|---|---|---|---|---|
| A1 (01) | 0.067 | -0.0115 | 0.2635 | PASS | 1.967 | 1.420 | 2.504 | PASS | A1 (01) | |
| A2 (02) | 0.300 | -0.0124 | 0.2604 | FLAG-HIGH | 1.983 | 1.530 | 2.650 | PASS | A2 (02) | Δ |
| A3 (03) | 0.067 | -0.0232 | 0.2192 | PASS | 1.817 | 1.453 | 2.549 | PASS | A3 (03) | |
| A4 (04) | 0.033 | -0.0155 | 0.2495 | PASS | 1.817 | 1.467 | 2.567 | PASS | A4 (04) | |
| B1 (05) | 0.267 | -0.0015 | 0.2955 | PASS | 1.833 | 1.370 | 2.440 | PASS | B1 (05) | |
| B2 (06) | 0.367 | 0.0072 | 0.3208 | FLAG-HIGH | 1.867 | 1.333 | 2.389 | PASS | B2 (06) | * |
| B3 (07) | 0.283 | 0.0173 | 0.3487 | PASS | 2.300 | 1.363 | 2.429 | PASS | B3 (07) | |
| B4 (08) | 0.133 | 0.0146 | 0.3414 | PASS | 1.817 | 1.308 | 2.356 | PASS | B4 (08) | |
| C1 (09) | 0.167 | -0.0150 | 0.2510 | PASS | 1.867 | 1.255 | 2.285 | PASS | C1 (09) | |
| C2 (10) | 0.233 | 0.0173 | 0.3487 | PASS | 1.833 | 1.317 | 2.369 | PASS | C2 (10) | |
| C3 (11) | 0.167 | -0.0087 | 0.2727 | PASS | 1.750 | 1.165 | 2.165 | PASS | C3 (11) | |
| C4 (12) | 0.150 | -0.0054 | 0.2834 | PASS | 1.950 | 1.355 | 2.419 | PASS | C4 (12) | |
| D1 (13) | 0.150 | -0.0176 | 0.2416 | PASS | 1.417 | 1.113 | 2.093 | PASS | D1 (13) | |
| D2 (14) | 0.167 | -0.0035 | 0.2895 | PASS | 2.083 | 1.450 | 2.544 | PASS | D2 (14) | |
| D3 (15) | 0.150 | -0.0124 | 0.2604 | PASS | 1.683 | 1.117 | 2.099 | PASS | D3 (15) | |
| D4 (16) | 0.183 | -0.0146 | 0.2526 | PASS | 2.100 | 1.495 | 2.603 | PASS | D4 (16) | |

*: Detector offline

Reviewed by: _____ Date: 12/07/18

Control Limits established from previousweekly background determinations

| Weekly Bkg File: | BKA1204W | Date: | 12/4/18 | Analyst: | JP |
|---|---|---|---|---|---|
| | 0 | | 1/0/00 | | 0 |

Δ: Recount to BKA1207A



BKA1207.XLD

Printed 12/18/18 6:56 AM

## LB4100-A Daily Instrument Calibration and Check
## Background Determinations

| Detector ID | Alpha CPM | Alpha LCL | Alpha UCL | Alpha Flag | Beta CPM | Beta LCL | Beta UCL | Beta Flag | Detector ID |
|---|---|---|---|---|---|---|---|---|---|
| A1 (01) | #REF! | #REF! | #REF! | **#REF!** | #REF! | #REF! | #REF! | **#REF!** | A1 (01) |
| A2 (02) | 0.083 | -0.0124 | 0.2604 | **PASS** | 2.067 | 1.530 | 2.650 | **PASS** | A2 (02) |
| A3 (03) | #REF! | #REF! | #REF! | **#REF!** | #REF! | #REF! | #REF! | **#REF!** | A3 (03) |
| A4 (04) | #REF! | #REF! | #REF! | **#REF!** | #REF! | #REF! | #REF! | **#REF!** | A4 (04) |
| B1 (05) | #REF! | #REF! | #REF! | **#REF!** | #REF! | #REF! | #REF! | **#REF!** | B1 (05) |
| B2 (06) | #REF! | #REF! | #REF! | **#REF!** | #REF! | #REF! | #REF! | **#REF!** | B2 (06) |
| B3 (07) | #REF! | #REF! | #REF! | **#REF!** | #REF! | #REF! | #REF! | **#REF!** | B3 (07) |
| B4 (08) | #REF! | #REF! | #REF! | **#REF!** | #REF! | #REF! | #REF! | **#REF!** | B4 (08) |
| C1 (09) | #REF! | #REF! | #REF! | **#REF!** | #REF! | #REF! | #REF! | **#REF!** | C1 (09) |
| C2 (10) | #REF! | #REF! | #REF! | **#REF!** | #REF! | #REF! | #REF! | **#REF!** | C2 (10) |
| C3 (11) | #REF! | #REF! | #REF! | **#REF!** | #REF! | #REF! | #REF! | **#REF!** | C3 (11) |
| C4 (12) | #REF! | #REF! | #REF! | **#REF!** | #REF! | #REF! | #REF! | **#REF!** | C4 (12) |
| D1 (13) | #REF! | #REF! | #REF! | **#REF!** | #REF! | #REF! | #REF! | **#REF!** | D1 (13) |
| D2 (14) | #REF! | #REF! | #REF! | **#REF!** | #REF! | #REF! | #REF! | **#REF!** | D2 (14) |
| D3 (15) | #REF! | #REF! | #REF! | **#REF!** | #REF! | #REF! | #REF! | **#REF!** | D3 (15) |
| D4 (16) | #REF! | #REF! | #REF! | **#REF!** | #REF! | #REF! | #REF! | **#REF!** | D4 (16) |

Reviewed by: _____ Date: 12/07/18

Control Limits established from previousweekly background determinations

| | | | | | |
|---|---|---|---|---|---|
| Weekly Bkg File: | BKA1204W | Date: | 12/4/18 | Analyst: | JP |
| | 0 | | 1/0/00 | | 0 |

## LB4100-A Daily Instrument Performance Check
## Efficiency Determinations

| Detector ID | Alpha Eff. | Alpha LCL | Alpha UCL | Alpha Flag | Beta Eff. | Beta LCL | Beta UCL | Beta Flag | Detector ID |
|---|---|---|---|---|---|---|---|---|---|
| A1 (01) | 0.2080 | 0.1869 | 0.2284 | PASS | 0.2052 | 0.1818 | 0.2222 | PASS | A1 (01) |
| A2 (02) | 0.2004 | 0.1832 | 0.2240 | PASS | 0.2176 | 0.1949 | 0.2382 | PASS | A2 (02) |
| A3 (03) | 0.2243 | 0.1983 | 0.2423 | PASS | 0.2112 | 0.1881 | 0.2299 | PASS | A3 (03) |
| A4 (04) | 0.2233 | 0.2005 | 0.2451 | PASS | 0.2219 | 0.2006 | 0.2452 | PASS | A4 (04) |
| B1 (05) | 0.2204 | 0.1958 | 0.2393 | PASS | 0.2368 | 0.2079 | 0.2541 | PASS | B1 (05) |
| B2 (06) | 0.2232 | 0.1975 | 0.2414 | PASS | 0.2353 | 0.2101 | 0.2567 | PASS | B2 (06) |
| B3 (07) | 0.2312 | 0.2055 | 0.2512 | PASS | 0.2287 | 0.1999 | 0.2443 | PASS | B3 (07) |
| B4 (08) | 0.2202 | 0.1975 | 0.2414 | PASS | 0.2220 | 0.1979 | 0.2418 | PASS | B4 (08) |
| C1 (09) | 0.2164 | 0.1903 | 0.2326 | PASS | 0.2117 | 0.1904 | 0.2327 | PASS | C1 (09) |
| C2 (10) | 0.2108 | 0.1946 | 0.2379 | PASS | 0.2240 | 0.2061 | 0.2519 | PASS | C2 (10) |
| C3 (11) | 0.2223 | 0.2053 | 0.2509 | PASS | 0.2130 | 0.1948 | 0.2381 | PASS | C3 (11) |
| C4 (12) | 0.2323 | 0.2052 | 0.2508 | PASS | 0.2320 | 0.2070 | 0.2530 | PASS | C4 (12) |
| D1 (13) | 0.2607 | 0.2313 | 0.2827 | PASS | 0.2404 | 0.2203 | 0.2693 | PASS | D1 (13) |
| D2 (14) | 0.2411 | 0.2208 | 0.2698 | PASS | 0.2425 | 0.2262 | 0.2765 | PASS | D2 (14) |
| D3 (15) | 0.2344 | 0.2074 | 0.2535 | PASS | 0.2376 | 0.2110 | 0.2579 | PASS | D3 (15) |
| D4 (16) | 0.2415 | 0.2087 | 0.2551 | PASS | 0.2414 | 0.2147 | 0.2624 | PASS | D4 (16) |

Reviewed by: _____ Date: 12/09/18

Interim Control Limits -- +/-10% of Average of 5 Data Points. JP 07/12/18


Printed 12/18/187:07 AM

## LB4100-A Daily Instrument Calibration and Check
## Background Determinations

| Detector ID | Alpha CPM | Alpha LCL | Alpha UCL | Alpha Flag | Beta CPM | Beta LCL | Beta UCL | Beta Flag | Detector ID |
|---|---|---|---|---|---|---|---|---|---|
| A1 (01) | 0.167 | -0.0115 | 0.2635 | PASS | 1.800 | 1.420 | 2.504 | PASS | A1 (01) |
| A2 (02) | 0.117 | -0.0124 | 0.2604 | PASS | 2.117 | 1.530 | 2.650 | PASS | A2 (02) |
| A3 (03) | 0.117 | -0.0232 | 0.2192 | PASS | 1.983 | 1.453 | 2.549 | PASS | A3 (03) |
| A4 (04) | 0.167 | -0.0155 | 0.2495 | PASS | 1.933 | 1.467 | 2.567 | PASS | A4 (04) |
| B1 (05) | 0.233 | -0.0015 | 0.2955 | PASS | 2.183 | 1.370 | 2.440 | PASS | B1 (05) |
| B2 (06) | 0.317 | 0.0072 | 0.3208 | PASS | 2.050 | 1.333 | 2.389 | PASS | B2 (06) |
| B3 (07) | 0.167 | 0.0173 | 0.3487 | PASS | 2.000 | 1.363 | 2.429 | PASS | B3 (07) |
| B4 (08) | 0.250 | 0.0146 | 0.3414 | PASS | 1.883 | 1.308 | 2.356 | PASS | B4 (08) |
| C1 (09) | 0.217 | -0.0150 | 0.2510 | PASS | 1.833 | 1.255 | 2.285 | PASS | C1 (09) |
| C2 (10) | 0.300 | 0.0173 | 0.3487 | PASS | 2.117 | 1.317 | 2.369 | PASS | C2 (10) |
| C3 (11) | 0.183 | -0.0087 | 0.2727 | PASS | 1.817 | 1.165 | 2.165 | PASS | C3 (11) |
| C4 (12) | 0.133 | -0.0054 | 0.2834 | PASS | 1.783 | 1.355 | 2.419 | PASS | C4 (12) |
| D1 (13) | 0.150 | -0.0176 | 0.2416 | PASS | 1.533 | 1.113 | 2.093 | PASS | D1 (13) |
| D2 (14) | 0.167 | -0.0035 | 0.2895 | PASS | 1.900 | 1.450 | 2.544 | PASS | D2 (14) |
| D3 (15) | 0.067 | -0.0124 | 0.2604 | PASS | 1.667 | 1.117 | 2.099 | PASS | D3 (15) |
| D4 (16) | 0.100 | -0.0146 | 0.2526 | PASS | 2.317 | 1.495 | 2.603 | PASS | D4 (16) |

Reviewed by: _____ Date: 12/09/18

Control Limits established from previousweekly background determinations

| | | | | | |
|---|---|---|---|---|---|
| Weekly Bkg File: | BKA1204W | Date: | 12/4/18 | Analyst: | JP |
| | 0 | | 1/0/00 | | 0 |

## LB4100-C
### Daily Instrument Performance Check-Efficiency Determination

| Detector ID | Alpha Eff. | Alpha LCL | Alpha UCL | Alpha Flag | Beta Eff. | Beta LCL | Beta UCL | Beta Flag | Detector ID |
|---|---|---|---|---|---|---|---|---|---|
| A1 (01) | 0.1921 | 0.1843 | 0.2142 | PASS | 0.3729 | 0.3620 | 0.4207 | PASS | A1 (01) |
| A2 (02) | 0.2053 | 0.1938 | 0.2252 | PASS | 0.3751 | 0.3690 | 0.4288 | PASS | A2 (02) |
| A3 (03) | 0.2097 | 0.1992 | 0.2315 | PASS | 0.3748 | 0.3711 | 0.4313 | PASS | A3 (03) |
| A4 (04) | 0.2065 | 0.1947 | 0.2262 | PASS | 0.3881 | 0.3719 | 0.4323 | PASS | A4 (04) |
| B1 (05) | 0.2266 | 0.2145 | 0.2493 | PASS | 0.4176 | 0.3869 | 0.4496 | PASS | B1 (05) |
| B2 (06) | 0.1982 | 0.1855 | 0.2156 | PASS | 0.3588 | 0.3499 | 0.4067 | PASS | B2 (06) |
| B3 (07) | 0.2177 | 0.2036 | 0.2367 | PASS | 0.3810 | 0.3710 | 0.4312 | PASS | B3 (07) |
| B4 (08) | 0.2181 | 0.2010 | 0.2336 | PASS | 0.3848 | 0.3728 | 0.4332 | PASS | B4 (08) |
| C1 (09) | 0.2065 | 0.1947 | 0.2263 | PASS | 0.3758 | 0.3723 | 0.4327 | PASS | C1 (09) |
| C2 (10) | 0.2167 | 0.2037 | 0.2367 | PASS | 0.3923 | 0.3806 | 0.4423 | PASS | C2 (10) |
| C3 (11) | 0.2148 | 0.1949 | 0.2265 | PASS | 0.3906 | 0.3700 | 0.4300 | PASS | C3 (11) |
| C4 (12) | 0.2244 | 0.2051 | 0.2384 | PASS | 0.3972 | 0.3832 | 0.4453 | PASS | C4 (12) |
| D1 (13) | 0.2144 | 0.2002 | 0.2327 | PASS | 0.3805 | 0.3656 | 0.4249 | PASS | D1 (13) |
| D2 (14) | 0.1706 | 0.1786 | 0.2076 | FLAG-LOW | 0.3227 | 0.3369 | 0.3916 | FLAG-LOW | D2 (14) * |
| D3 (15) | 0.2189 | 0.2045 | 0.2377 | PASS | 0.3672 | 0.3550 | 0.4126 | PASS | D3 (15) |
| D4 (16) | 0.2213 | 0.2069 | 0.2405 | PASS | 0.3818 | 0.3591 | 0.4174 | PASS | D4 (16) |

*: Detector offline

Reviewed by: _____ Date: 12/07/18

Historical Control Limits Established based on 30 Data Points
Established 01/22/18 JP

**LB4100-C**
**Daily Instrument Performance Checks**
**Background Checks**

| Detector ID | Alpha CPM | Alpha LCL | Alpha UCL | Alpha Flag | Beta CPM | Beta LCL | Beta UCL | Beta Flag | Detector ID |
|---|---|---|---|---|---|---|---|---|---|
| A1 (01) | 0.133 | -0.016 | 0.248 | PASS | 1.800 | 2.681 | 4.109 | FLAG-LOW | A1 (01) * |
| A2 (02) | 0.167 | -0.013 | 0.259 | PASS | 1.667 | 1.046 | 2.002 | PASS | A2 (02) |
| A3 (03) | 0.117 | -0.001 | 0.295 | PASS | 1.317 | 1.117 | 2.099 | PASS | A3 (03) |
| A4 (04) | 0.117 | -0.013 | 0.259 | PASS | 1.650 | 1.087 | 2.059 | PASS | A4 (04) |
| B1 (05) | 0.183 | -0.013 | 0.259 | PASS | 1.550 | 1.148 | 2.142 | PASS | B1 (05) |
| B2 (06) | 0.133 | -0.010 | 0.268 | PASS | 1.783 | 1.213 | 2.229 | PASS | B2 (06) |
| B3 (07) | 0.350 | -0.016 | 0.248 | FLAG-HIGH | 1.867 | 1.160 | 2.158 | PASS | B3 (07) Δ |
| B4 (08) | 0.200 | 0.001 | 0.303 | PASS | 2.050 | 1.273 | 2.309 | PASS | B4 (08) |
| C1 (09) | 0.283 | -0.004 | 0.288 | PASS | 1.883 | 1.239 | 2.263 | PASS | C1 (09) |
| C2 (10) | 0.283 | -0.001 | 0.295 | PASS | 1.550 | 1.289 | 2.331 | PASS | C2 (10) |
| C3 (11) | 0.100 | -0.017 | 0.245 | PASS | 1.550 | 1.190 | 2.198 | PASS | C3 (11) |
| C4 (12) | 0.300 | 0.012 | 0.334 | PASS | 2.000 | 1.894 | 3.120 | PASS | C4 (12) |
| D1 (13) | 0.183 | 0.007 | 0.319 | PASS | 1.400 | 1.310 | 2.360 | PASS | D1 (13) |
| D2 (14) | 0.117 | -0.032 | 0.178 | PASS | 1.500 | 0.995 | 1.933 | PASS | D2 (14) |
| D3 (15) | 0.150 | 0.007 | 0.319 | PASS | 1.867 | 1.195 | 2.205 | PASS | D3 (15) |
| D4 (16) | 0.067 | -0.015 | 0.249 | PASS | 1.917 | 1.222 | 2.242 | PASS | D4 (16) |

*: detector offline

Reviewed by: _____ Date: 12/07/18

Control Limits established from previous weekly background determinations.

| | | | |
|---|---|---|---|
| Weekly Background File: | BKC1128W | Date: 11/28/2018 | Analyst: JP |
| | BKC1129W | 11/29/2018 | JP |
| | | | JP |

Δ: Recount to BKC1207A

BKC1207.XLD

Printed 12/18/2018 9:37 AM

**LB4100-C**
**Daily Instrument Performance Checks**
**Background Checks**

| Detector ID | Alpha CPM | Alpha LCL | Alpha UCL | Alpha Flag | Beta CPM | Beta LCL | Beta UCL | Beta Flag | Detector ID |
|---|---|---|---|---|---|---|---|---|---|
| A1 (01) | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | A1 (01) |
| A2 (02) | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | A2 (02) |
| A3 (03) | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | A3 (03) |
| A4 (04) | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | A4 (04) |
| B1 (05) | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | B1 (05) |
| B2 (06) | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | B2 (06) |
| B3 (07) | 0.317 | -0.016 | 0.248 | FLAG-HIGH | 2.117 | 1.160 | 2.158 | PASS | B3 (07) * |
| B4 (08) | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | B4 (08) |
| C1 (09) | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | C1 (09) |
| C2 (10) | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | C2 (10) |
| C3 (11) | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | C3 (11) |
| C4 (12) | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | C4 (12) |
| D1 (13) | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | D1 (13) |
| D2 (14) | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | D2 (14) |
| D3 (15) | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | D3 (15) |
| D4 (16) | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | #REF! | D4 (16) |

*: detector offline

Reviewed by: _____ Date: 12/07/18

Control Limits established from previous weekly background determinations.

| | | | |
|---|---|---|---|
| Weekly Background File: | BKC1128W | Date: 11/28/2018 | Analyst: JP |
| | BKC1129W | 11/29/2018 | JP |
| | | | JP |



BKC1207A.XLD

Printed 12/18/2018 9:37 AM

**LB4100-C**
**Daily Instrument Performance Check-Efficiency Determination**

| Detector ID | Alpha Eff. | Alpha LCL | Alpha UCL | Alpha Flag | Beta Eff. | Beta LCL | Beta UCL | Beta Flag | Detector ID |
|---|---|---|---|---|---|---|---|---|---|
| A1 (01) | 0.1951 | 0.1843 | 0.2142 | PASS | 0.3680 | 0.3620 | 0.4207 | PASS | A1 (01) |
| A2 (02) | 0.2059 | 0.1938 | 0.2252 | PASS | 0.3738 | 0.3690 | 0.4288 | PASS | A2 (02) |
| A3 (03) | 0.2102 | 0.1992 | 0.2315 | PASS | 0.3751 | 0.3711 | 0.4313 | PASS | A3 (03) |
| A4 (04) | 0.2052 | 0.1947 | 0.2262 | PASS | 0.3745 | 0.3719 | 0.4323 | PASS | A4 (04) |
| B1 (05) | 0.2274 | 0.2145 | 0.2493 | PASS | 0.4044 | 0.3869 | 0.4496 | PASS | B1 (05) |
| B2 (06) | 0.1948 | 0.1855 | 0.2156 | PASS | 0.3618 | 0.3499 | 0.4067 | PASS | B2 (06) |
| B3 (07) | 0.2087 | 0.2036 | 0.2367 | PASS | 0.3867 | 0.3710 | 0.4312 | PASS | B3 (07) |
| B4 (08) | 0.2204 | 0.2010 | 0.2336 | PASS | 0.3860 | 0.3728 | 0.4332 | PASS | B4 (08) |
| C1 (09) | 0.2069 | 0.1947 | 0.2263 | PASS | 0.3836 | 0.3723 | 0.4327 | PASS | C1 (09) |
| C2 (10) | 0.2152 | 0.2037 | 0.2367 | PASS | 0.4055 | 0.3806 | 0.4423 | PASS | C2 (10) |
| C3 (11) | 0.2116 | 0.1949 | 0.2265 | PASS | 0.3836 | 0.3700 | 0.4300 | PASS | C3 (11) |
| C4 (12) | 0.2212 | 0.2051 | 0.2384 | PASS | 0.4002 | 0.3832 | 0.4453 | PASS | C4 (12) |
| D1 (13) | 0.2103 | 0.2002 | 0.2327 | PASS | 0.3785 | 0.3656 | 0.4249 | PASS | D1 (13) |
| D2 (14) | 0.1697 | 0.1786 | 0.2076 | FLAG-LOW | 0.3205 | 0.3369 | 0.3916 | FLAG-LOW | D2 (14) * |
| D3 (15) | 0.2154 | 0.2045 | 0.2377 | PASS | 0.3552 | 0.3550 | 0.4126 | PASS | D3 (15) |
| D4 (16) | 0.2218 | 0.2069 | 0.2405 | PASS | 0.3774 | 0.3591 | 0.4174 | PASS | D4 (16) |

*: Detector offline

Reviewed by: _____ Date: 12/09/18

Historical Control Limits Established based on 30 Data Points
Established 01/22/18 JP

**LB4100-C**
**Daily Instrument Performance Checks**
**Background Checks**

| Detector ID | Alpha CPM | Alpha LCL | Alpha UCL | Alpha Flag | Beta CPM | Beta LCL | Beta UCL | Beta Flag | Detector ID |
|---|---|---|---|---|---|---|---|---|---|
| A1 (01) | 0.150 | -0.016 | 0.248 | PASS | 2.250 | 2.681 | 4.109 | FLAG-LOW | A1 (01) * |
| A2 (02) | 0.183 | -0.013 | 0.259 | PASS | 1.433 | 1.046 | 2.002 | PASS | A2 (02) |
| A3 (03) | 0.217 | -0.001 | 0.295 | PASS | 1.383 | 1.117 | 2.099 | PASS | A3 (03) |
| A4 (04) | 0.117 | -0.013 | 0.259 | PASS | 1.400 | 1.087 | 2.059 | PASS | A4 (04) |
| B1 (05) | 0.217 | -0.013 | 0.259 | PASS | 1.567 | 1.148 | 2.142 | PASS | B1 (05) |
| B2 (06) | 0.250 | -0.010 | 0.268 | PASS | 1.933 | 1.213 | 2.229 | PASS | B2 (06) |
| B3 (07) | 0.167 | -0.016 | 0.248 | PASS | 1.650 | 1.160 | 2.158 | PASS | B3 (07) |
| B4 (08) | 0.267 | 0.001 | 0.303 | PASS | 2.017 | 1.273 | 2.309 | PASS | B4 (08) |
| C1 (09) | 0.200 | -0.004 | 0.288 | PASS | 1.600 | 1.239 | 2.263 | PASS | C1 (09) |
| C2 (10) | 0.133 | -0.001 | 0.295 | PASS | 1.350 | 1.289 | 2.331 | PASS | C2 (10) |
| C3 (11) | 0.200 | -0.017 | 0.245 | PASS | 1.850 | 1.190 | 2.198 | PASS | C3 (11) |
| C4 (12) | 0.367 | 0.012 | 0.334 | FLAG-HIGH | 2.067 | 1.894 | 3.120 | PASS | C4 (12) * |
| D1 (13) | 0.033 | 0.007 | 0.319 | PASS | 1.650 | 1.310 | 2.360 | PASS | D1 (13) |
| D2 (14) | 0.083 | -0.032 | 0.178 | PASS | 1.483 | 0.995 | 1.933 | PASS | D2 (14) |
| D3 (15) | 0.233 | 0.007 | 0.319 | PASS | 1.550 | 1.195 | 2.205 | PASS | D3 (15) |
| D4 (16) | 0.067 | -0.015 | 0.249 | PASS | 1.750 | 1.222 | 2.242 | PASS | D4 (16) |

*: Detector offline

Reviewed by: _____ Date: 12/09/18

Control Limits established from previous weekly background determinations.

| Weekly Background File: | Date: | Analyst: |
|---|---|---|
| BKC1128W | 11/28/2018 | JP |
| BKC1129W | 11/29/2018 | JP |
| | | JP |

**Gas Proportional Counter**

# Instrument Calibration

# Initial Efficiency Calibration Standards Traceability

Instrument: LB4100-A

Calibration: Ra-228

Date of Calibration: 08/03/18

Efficiency Log Files: **Ra228-08/18**

Efficiency Instrument Files: ERA0803, A, and B

Source ID's: Efficiency (Ra-228 1083.4243.30)
ICV/ICB'S (Ra-228 1014.4095.79)

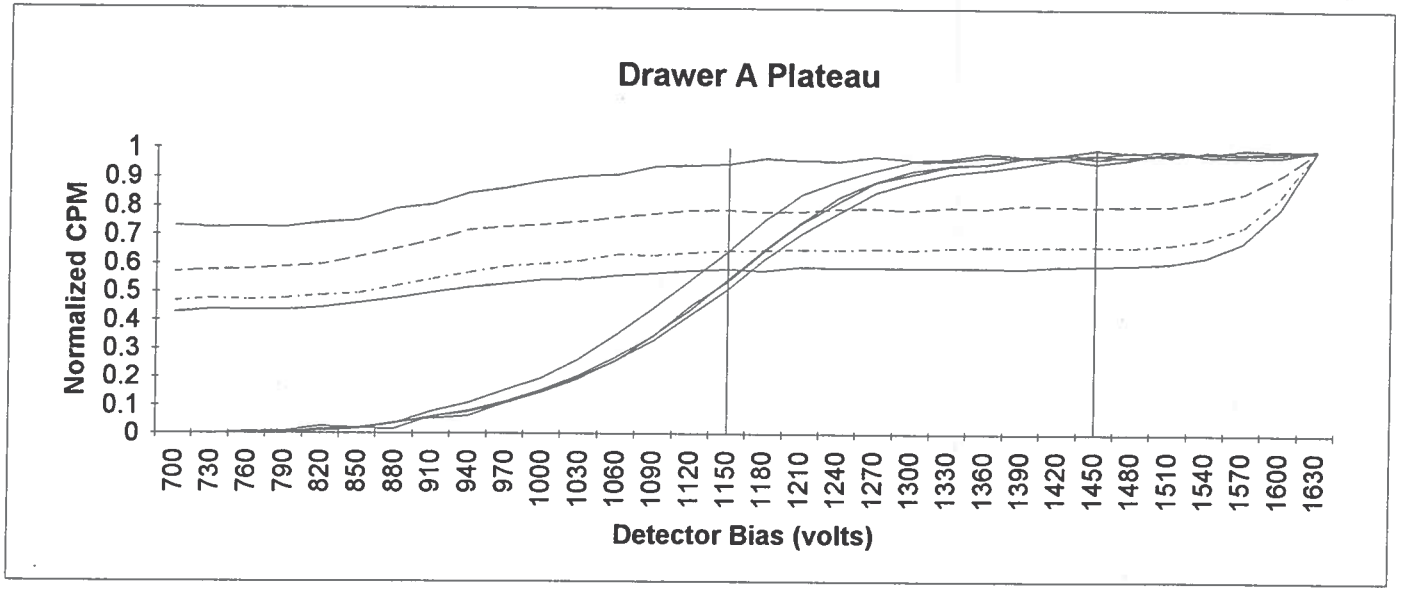
**Detectors B1, B2, C1 and C3 Offline**

OK JP 8/15/2018
Expires 07/07/2019

# Instrument Plateaus

Unit Type: LB4100/W
Date Performed: 7/7/18 07:19
FileName: PTA0707A
Batch ID: DRAWER A PLATEAU

Unit Id: Orange
Application Revision: B
Application Version: Standard




Optimum alpha beta simultaneous operating voltage: 1447.5

Optimum alpha only operating voltage: 1150

| | A1 | A2 | A3 | A4 |
|---|---|---|---|---|
| Beta slope at beta voltage | 2.88% | 1.84% | 0.68% | 1.55% |
| Alpha slope at beta voltage | 0.45% | -0.18% | 2.56% | 1.25% |
| Alpha slope at alpha voltage | 2.42% | 0.63% | 2.82% | 2.73% |

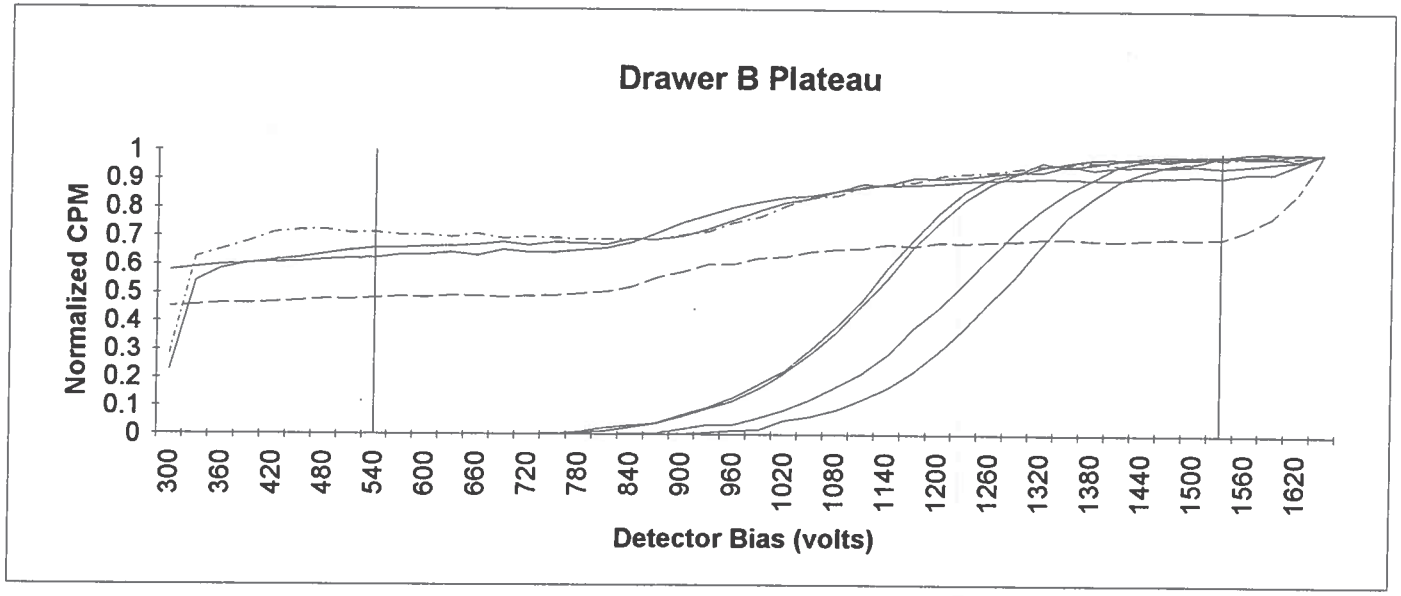
Ok JP 7/11/18



Printed 7/11/18 7:05 AM

Unit Type: LB4100/W
Date Performed: 7/10/18 07:07
FileName: PTA0710B
Batch ID: DRTAWER B PLATEAU

Unit Id: Orange
Application Revision: B
Application Version: Standard




Optimum alpha beta simultaneous operating voltage: 1522.5

Optimum alpha only operating voltage: 540

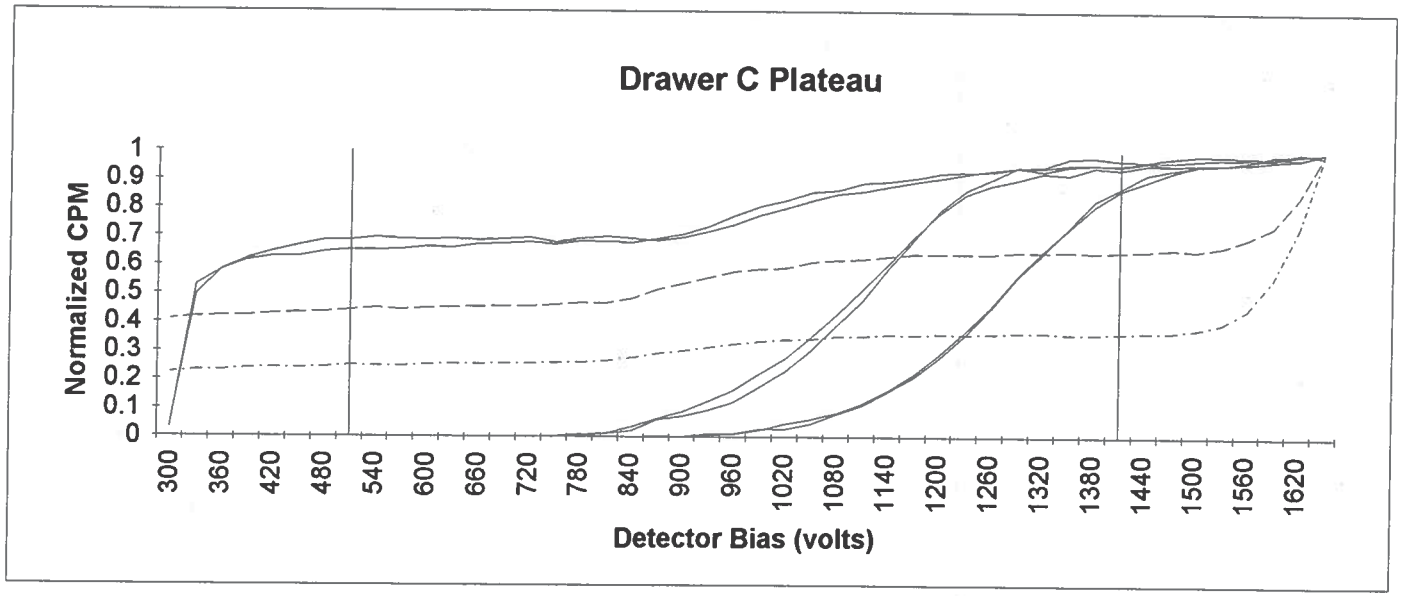
| | B1 | B2 | B3 | B4 |
|---|---|---|---|---|
| Beta slope at beta voltage | 0.46% | 0.82% | 2.36% | 2.33% |
| Alpha slope at beta voltage | 1.58% | 8.54% | 1.18% | 0.28% |
| Alpha slope at alpha voltage | 2.76% | 1.57% | 3.25% | -2.02% |

OK JP 7/11/18

Printed 7/11/18 7:06 AM

Unit Type: LB4100/W
Date Performed: 7/10/18 07:02
FileName: PTA0710C
Batch ID: DRAWER C PLATEAU

Unit Id: Orange
Application Revision: B
Application Version: Standard




Optimum alpha beta simultaneous operating voltage: 1402.5

Optimum alpha only operating voltage: 510

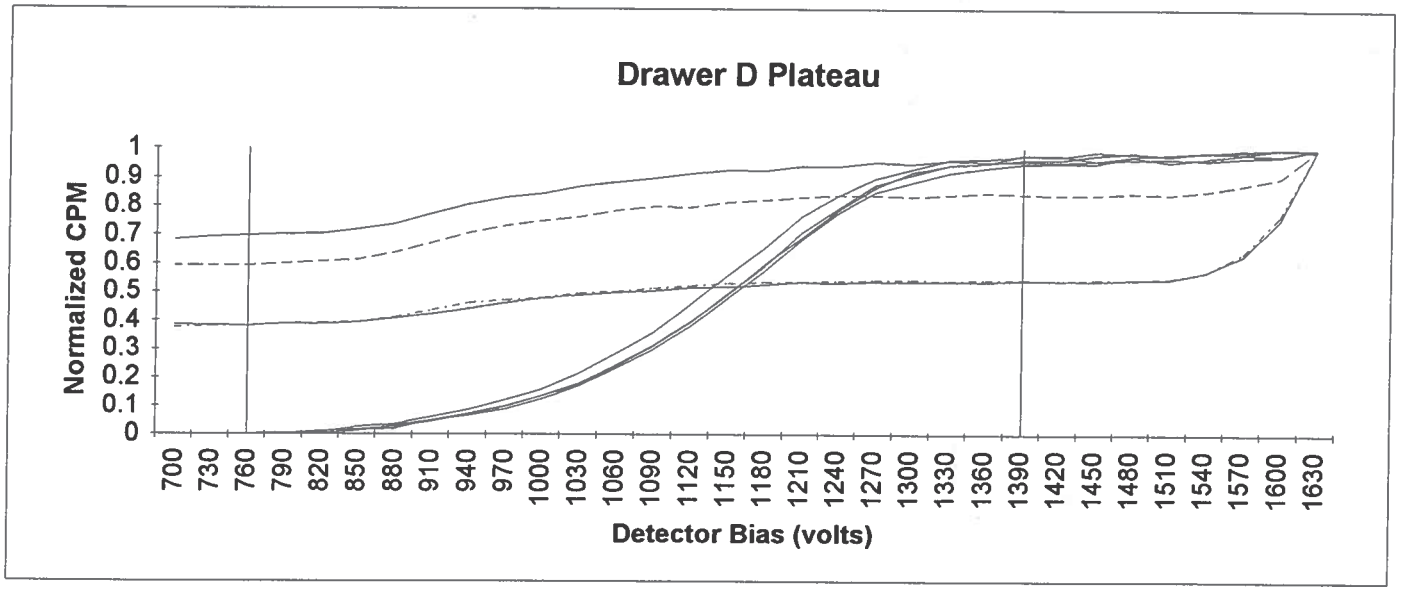
| | C1 | C2 | C3 | C4 |
|---|---|---|---|---|
| Beta slope at beta voltage | 19.48% | -0.18% | 19.74% | 2.73% |
| Alpha slope at beta voltage | 1.52% | 1.14% | 0.38% | 1.90% |
| Alpha slope at alpha voltage | 2.46% | 2.85% | 2.86% | 2.20% |

OWOP 7/11/18

Printed 7/11/18 7:07 AM

Unit Type: LB4100/W
Date Performed: 7/7/18 12:57
FileName: PTA0707D
Batch ID: DRAWER D PLATEAU

Unit Id: Orange
Application Revision: B
Application Version: Standard




Optimum alpha beta simultaneous operating voltage: 1390

Optimum alpha only operating voltage: 760

| | D1 | D2 | D3 | D4 |
|---|---|---|---|---|
| Beta slope at beta voltage | 2.17% | 2.19% | 2.90% | 2.80% |
| Alpha slope at beta voltage | -0.06% | -0.34% | 0.51% | -0.05% |
| Alpha slope at alpha voltage | 2.39% | 1.74% | 1.29% | 3.42% |

OWJP 7/11/18

Printed 7/11/18 7:07 AM

Date 7/7/18

SOP 724r 12

# ALS

## Low Background Gas Flow Proportional Counter Log

**Instrument: LB4100A**

*Instrument Daily Response and Background Checks*

| Det. | Daily Response Check Start 1 | Status | Start 2 | Status | Background Check Start 1 | Status | Start 2 | Status | Det. Status |
|---|---|---|---|---|---|---|---|---|---|
| 1 | JV | P | | | | | | | P |
| 2 | | | | | | | | | |
| 3 | | | | | | | | | |
| 4 | | | | | | | | | |
| 5 | | | | | | | | | |
| 6 | | | | | | | | | |
| 7 | | | | | | | | | OL |
| 8 | | | | | | | | | P |
| 9 | | | | | | | | | |
| 10 | | | | | | | | | |
| 11 | | | | | | | | | OL |
| 12 | | (Hα, Hβ) | | | | | | | P |
| 13 | OL | | | | | | | | OL |
| 14 | | | | | | | | | |
| 15 | | | | | | | | | |
| 16 | | | | | | | | | |

Det = Detector; α = Alpha; β = Beta; P = Pass; H = High; L = Low; OL = Offline; R = Recount; W = Weekly; NP = Not Processed

*Weekly Background Calibration*

| | Current Calib. File ID | Weekly Calib. Started | Status | File ID |
|---|---|---|---|---|
| Dr A | BKA051460 | | | |
| Dr B | | | | |
| Dr C | | | | |
| Dr D | | | | |

Dr = Drawer

*Gas Supply*

| P-10 Supply | | P-10 Flow | |
|---|---|---|---|
| Tank 1 | 1900 | Dr A | 10 |
| | | Dr B | |
| Tank 2 | 600 | Dr C | |
| | | Dr D | |

Comments:

Page No.: 478604 A

Form 780r8.doc (6/23/06)

Reviewed By / Date 7/7/18

Date 7/7/18

SOP 724r 12

**ALS**

Low Background Gas Flow Proportional Counter Log

**Instrument: LB4100A**

| Det. | Sample ID | Batch | Test | Count Dur. (min) | Start Time | Analyst Initials | File ID | Output Initials |
|---|---|---|---|---|---|---|---|---|
| 1-12 | Daily EF | | | 30 | 6:50 | JP | EFA0707 | JP |
| 1-4 | Alpha/Beta | Drawer A Platen | Platego | 5Min/STEP | 7:14 | JP | PTA0707A | JP |
| 5-8 | Beta/Alpha | Drawer B Platen | | | | | PTA0707B | |
| 9-12 | Alpha/Beta | Drawer C Platen | | | 12:56 | JP | PTA0707C | |
| 13-16 | Beta/Alpha | Drawer D Platen | | | | | PTA0707D | |

Comments:

Page No.: 478604 B

(cont. from page NA B)

Form 780r8.doc (6/23/06)

Reviewed By / Date JP 7/8/18

Date 7/10/18

SOP 724

# ALS

## Low Background Gas Flow Proportional Counter Log

**Instrument: LB4100A**

*Instrument Daily Response and Background Checks*

| Det. | Daily Response Check Start 1 | Status | Start 2 | Status | Background Check Start 1 | Status | Start 2 | Status |
|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | |
| 2 | | | | | | | | |
| 3 | | | | | | | | |
| 4 | | | | | | | | |
| 5 | | | | | | | | |
| 6 | | | | | | | | |
| 7 | | | | | | | | |
| 8 | | | | | | | | |
| 9 | | | | | | | | |
| 10 | | | | | | | | |
| 11 | | | | | | | | |
| 12 | | | | | | | | |
| 13 | | | | | | | | |
| 14 | | | | | | | | |
| 15 | | | | | | | | |
| 16 | | | | | | | | |

Det = Detector; α = Alpha; β = Beta; P = Pass; H = High; L = Low; OL = Offline; R = Recount; W = Weekly; NP = Not Processed

*Weekly Background Calibration*

| | Current Calib. File ID | Weekly Calib. Started | Status | File ID |
|---|---|---|---|---|
| Dr A | | | | |
| Dr B | | | | |
| Dr C | | | | |
| Dr D | | | | |

Dr = Drawer

*Gas Supply*

| P-10 Supply | | P-10 Flow | |
|---|---|---|---|
| Tank 1 | | Dr A | |
| | | Dr B | |
| Tank 2 | | Dr C | |
| | | Dr D | |

Comments:

Page No.: 478606 A

Form 780r8.doc (6/23/06)

Reviewed By / Date

Date 7/10/18

SOP 724r 12

**ALS**

Low Background Gas Flow Proportional Counter Log

**Instrument: LB4100A**

| Det. | Sample ID | Batch | Test | Count Dur. (min) | Start Time | Analyst Initials | File ID | Output Initials |
|---|---|---|---|---|---|---|---|---|
| 5-8 | Alpha / Beta | Drawer B Plateau | Plateau | 5 Min/Step | 7:02 | JP | PTA0710B | JP |
| 9-12 | Beta / Alpha | Drawer C Plateau | | | 7:02 | JP | PTA0710C | JP |

JP 7/11/18

Comments:

Page No.: 478606 **B**

(cont. from page NA B)

Form 780r8.doc (6/23/06)

Reviewed By / Date JP 7/11/18

Date 7/11/18

SOP 724r 12

# ALS

## Low Background Gas Flow Proportional Counter Log

**Instrument: LB4100A**

*Instrument Daily Response and Background Checks*

| Det. | Daily Response Check Start 1 | Status | Start 2 | Status | Background Check Start 1 | Status | Start 2 | Status | Det. Status |
|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | |
| 2 | | | | | | | | | |
| 3 | | | | | | | | | |
| 4 | | | | | | | | | |
| 5 | | | | | | | | | |
| 6 | | | | | | | | | |
| 7 | | | | | | | | | |
| 8 | | | | | | | | | |
| 9 | | | | | | | | | |
| 10 | | | | | | | | | |
| 11 | | | | | | | | | |
| 12 | | | | | | | | | |
| 13 | | | | | | | | | |
| 14 | | | | | | | | | |
| 15 | | | | | | | | | |
| 16 | | | | | | | | | |

Det = Detector; α = Alpha; β = Beta; P = Pass; H = High; L = Low; OL = Offline; R = Recount; W = Weekly; NP = Not Processed

*Weekly Background Calibration*

| | Current Calib. File ID | Weekly Calib. Started | Status | File ID |
|---|---|---|---|---|
| Dr A | | JP | P | BKA0711W |
| Dr B | | ↓ | ↓ | ↓ |
| Dr C | | | | |
| Dr D | | | | |

Dr = Drawer

*Gas Supply*

| P-10 Supply | | P-10 Flow | |
|---|---|---|---|
| Tank 1 | 900 | Dr A | 10 |
| | ↓ | Dr B | ↓ |
| Tank 2 | 2050 | Dr C | |
| | ↓ | Dr D | |

Comments:

Page No.: 478607 A

Form 780r8.doc (6/23/06)

Reviewed By / Date JP 7/12/18

7/7/18

Voltage Plateau Calibration → All Drawers

| α Sources | | β Sources | | Detector | | | | Filenames |
|---|---|---|---|---|---|---|---|---|
| 410 | Am241 | 406 | Sr90/Y90 | A1 | B1 | C1 | D1 | PTA0707A |
| 411 | 17,800 DPM | 407 | 29,600 DPM | A2 | B2 | C2 | D2 | PTA0707B |
| 412 | 2-6-1995 | 408 | 9-15-1992 | A3 | B3 | C3 | D3 | PTA0707C |
| 413 | | 409 | | A4 | B4 | C4 | D4 | PTA0707D |

Parameters
Starting Voltage 700
Ending Voltage 1650
Volts/Step 30
Count Time/Step 5.0
Time Between Steps 0.1

Count Preset 40,000
Weak Check Time s → 0.1
Weak Count Limit → 35

Outcome
Drawer A+D → Met All Criteria
Rerun Drawers B, C → Some Detector did not meet Slope < 3.5% Criteria

7/10/18 JT/Rolle

Voltage ~~Plateau~~ Plateau Calibration → Drawers B & C

| α Sources | | β Sources | | Detectors | | Filenames |
|---|---|---|---|---|---|---|
| 410 | Am241 | 406 | Sr90/Y90 | B1 | C1 | PTA0710B |
| 411 | 17,800 DPM | 407 | 29,600 DPM | B2 | C2 | PTA0710C |
| 412 | 2-6-1995 | 408 | 9-15-1992 | B3 | C3 | |
| 413 | | 409 | | B4 | C4 | |

Parameters
Starting Voltage 300
Ending Voltage 1650
Volts/Step → 30
Count Time/Step 5.0
Time Between Steps 0.1

Count Preset 40,000
Weak Check Time s → 0.1
Weak Count Limits → 35

Outcome
Drawer B → Det B2(6) → Did not meet < 3.5% Criteria
Drawer C → Dets C1(9), C3(11) → Did Not meet < 3.5% Criteria

7/11/18

ROIs Set For Drawers A, B, C, D using Sr90/Y90 Sources (406, 407, 408, 409)
Over 40,000 counts aquired per Detector
α Lower Limit, β Upper Limit set to 50%
Both α Lower Limit & β Upper Limit moved to achieved β → α X Talk of 2.5%
α lower Limit moved to achieve β → α X Talk of 0.1%
Detector B1(5), B2(6), C1(9), C3(11) → Did not meet β → α X-Talk of 0.1%.

Continued on Page

Signed 7/13/18 Date

Read and Understood By
Signed Date

# Instrument ROIs

# LB4100-A/W Sample Counting Parameters for LIMS

| | |
|---|---|
| Certainty requirement for MDA and flags | 95% |
| Maximum count time (min) | 10.00 |
| Typical Residual Mass (mg) | 80.00 |
| Typical Sample Volume (l) | 1.00 |

| | α |
|---|---|
| Action level for flags (pCi/l) | 1.000E+00 |
| Activity Multiplier | 1.000E+00 |
| Mass Error (%) | 1.00% |
| Volume Error (%) | 1.00% |

| | Alpha | | | Beta | | |
|---|---|---|---|---|---|---|
| | eff. | bkg. | MDA (pCi/l) | eff. | bkg. | MDA (pCi/l) |
| A1 | 19.49% | 0.108 | 1.431E+00 | 35.69% | 2.286 | 2.378E+00 |
| A2 | 23.65% | 0.1 | 1.204E+00 | 39.09% | 1.967 | 2.041E+00 |
| A3 | 26.47% | 0.091 | 1.063E+00 | 38.56% | 1.939 | 2.057E+00 |
| A4 | 23.86% | 0.075 | 1.103E+00 | 37.47% | 1.913 | 2.102E+00 |

Batch Specific:

| | Event | Recycle |
|---|---|---|
| Orange | 1 | 0 |

Drawer Specific:

| | Date/Time | Official | Bias | Step |
|---|---|---|---|---|
| A | 7/7/18 7:19 | TRUE | 1447.5 | 0 |
| B | 7/10/18 7:07 | TRUE | 1522.5 | 0 |
| C | 7/10/18 7:02 | TRUE | 1402.5 | 0 |
| D | 7/7/18 12:57 | TRUE | 1390 | 0 |

Detector Specific:

| | Date/Time | Official | Threshold | bLL | bUL | aLL | aUL |
|---|---|---|---|---|---|---|---|
| A1 | 7/11/18 0:00 | TRUE | 0.1 | 0 | 27.59 | 58.16 | 100 |
| A2 | 7/11/18 0:00 | TRUE | 0.1 | 0 | 37.19 | 74.4 | 100 |
| A3 | 7/11/18 0:00 | TRUE | 0.1 | 0 | 27.13 | 59.24 | 100 |
| A4 | 7/11/18 0:00 | TRUE | 0.1 | 0 | 29.25 | 62.1 | 100 |
| B1 | 7/11/18 0:00 | TRUE | 0.1 | 0 | 59.29 | 99.34 | 100 |
| B2 | 7/11/18 0:00 | TRUE | 0.1 | 0 | 60.68 | 100 | 100 |
| B3 | 7/11/18 0:00 | TRUE | 0.1 | 0 | 16.38 | 39.73 | 100 |
| B4 | 7/11/18 0:00 | TRUE | 0.1 | 0 | 15.26 | 37.43 | 100 |
| C1 | 7/11/18 0:00 | TRUE | 0.1 | 0 | 6.66 | 15.43 | 100 |
| C2 | 7/11/18 0:00 | TRUE | 0.1 | 0 | 20.73 | 41.58 | 100 |
| C3 | 7/11/18 0:00 | TRUE | 0.1 | 0 | 6.59 | 15.38 | 100 |
| C4 | 7/11/18 0:00 | TRUE | 0.1 | 0 | 22.12 | 46.91 | 100 |
| D1 | 7/11/18 0:00 | TRUE | 0.1 | 0 | 13.6 | 28.1 | 100 |
| D2 | 7/11/18 0:00 | TRUE | 0.1 | 0 | 13.96 | 27.93 | 100 |
| D3 | 7/11/18 0:00 | TRUE | 0.1 | 0 | 12.67 | 27.37 | 100 |
| D4 | 7/11/18 0:00 | TRUE | 0.1 | 0 | 14.26 | 30.23 | 100 |

OK JP 7/11/18

Project LB4100A #3974

Continued from Page

7/7/18

Voltage Plateau Calibration → All Drawers

| α Sources | | β Sources | | Detector | | | | Filenames |
|---|---|---|---|---|---|---|---|---|
| 410 | Am241 | 406 | Sr90/490 | A1 | B1 | C1 | D1 | PTA0707A |
| 411 | 17,800 DPM | 407 | 29,600 DPM | A2 | B2 | C2 | D2 | PTA0707B |
| 412 | 2-6-1995 | 408 | 9-15-1992 | A3 | B3 | C3 | D3 | PTA0707C |
| 413 | | 409 | | A4 | B4 | C4 | D4 | PTA0707D |

Parameters

Starting Voltage 700
Ending Voltage 1650
Volts/Step 30
Count Time/Step 5.0
Time Between Steps 0.1

Count Preset 40,000
Weak Check Times → 0.1
Weak Count Limit → 35

Outcome

Drawer A+D → Met All Criteria
Rerun Drawers B, C → Some Detector did not meet Slope < 3.5% Criteria

7/10/18 JT/Rolle

Voltage ~~Plateau~~ Plateau Calibration → Drawers B & C

| α Sources | | β Sources | | Detectors | | Filenames |
|---|---|---|---|---|---|---|
| 410 | Am241 | 406 | Sr90/490 | B1 | C1 | PTA0710B |
| 411 | 17,800 DPM | 407 | 29,600 DPM | B2 | C2 | PTA0710C |
| 412 | 2-6-1995 | 408 | 9-15-1992 | B3 | C3 | |
| 413 | | 409 | | B4 | C4 | |

Parameters

Starting Voltage 300
Ending Voltage 1650
Volts/Step → 30
Count Time/Step 5.0
Time Between Steps 0.1

Count Preset 40,000
Weak Check Times → 0.1
Weak Count Limits → 35

Outcome

Drawer B → Det B2(6) → Did not meet < 3.5% Criteria
Drawer C → Dets C1(9), C3(11) → Did Not meet < 3.5% Criteria

7/11/18

ROIs Set For Drawers A, B, C, D using Sr90/490 Sources (406, 407, 408, 409)
Over 40,000 counts aquired per Detector
α Lower Limit, β Upper Limit set to 50%
Both α Lower Limit & β Upper Limit moved to achieve β → α X Talk of 2.5%
α Lower Limit moved to achieve β → α X Talk of 0.1%

Detector B1(5), B2(6), C1(9), C3(11) → Did not meet β → α X-Talk of 0.1%.

Continued on Page

Signed 7/13/18 Date

Read and Understood By

Signed Date

# Calibration Efficiencies

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 640 | Ra-228 | Beta | 2100.1875 | 3379.8 | 111.5 | 1-Dec-17 | ALS | Ra228-08/18 |

| | | A1 | A2 | A3 | A4 | B3 | B4 | C2 | C4 | D1 | D2 | D3 | D4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 | 6 | 7 | 9 | 11 | 12 | 13 | 14 | 15 |
| | offset | 0 | 1 | 2 | 3 | 0 | 1 | 2 | 3 | 0 | 1 | 2 | 3 |
| | NumRecs | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | total time | 9.34 | 9.42 | 9.12 | 9.01 | 9.29 | 10.29 | 8.96 | 8.97 | 9.5 | 9.99 | 9.4 | 9.29 |
| Alpha | total count | 92 | 63 | 73 | 70 | 110 | 155 | 109 | 86 | 142 | 108 | 88 | 84 |
| | reduced chi | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! |
| | chi-square | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! |
| | CPM | 9.734107 | 6.596898 | 7.884386 | 7.652145 | 11.71169 | 14.89817 | 12.01118 | 9.482514 | 14.85337 | 10.72581 | 9.289702 | 8.942981 |
| | CPM var | 1.064434 | 0.714532 | 0.884201 | 0.868433 | 1.288712 | 1.48672 | 1.372674 | 1.078139 | 1.595844 | 1.093936 | 1.004762 | 0.981577 |
| | Efficiency | 0.003123 | 0.002117 | 0.00253 | 0.002455 | 0.003758 | 0.00478 | 0.003854 | 0.003042 | 0.004766 | 0.003441 | 0.002981 | 0.002869 |
| | archived S | 0.000347 | 0.00028 | 0.000313 | 0.00031 | 0.000385 | 0.000422 | 0.000397 | 0.000348 | 0.000435 | 0.000354 | 0.000336 | 0.000332 |
| | predicted S | 0.000328 | 0.000268 | 0.000298 | 0.000296 | 0.00036 | 0.000386 | 0.000371 | 0.00033 | 0.000401 | 0.000332 | 0.000319 | 0.000315 |
| | actual STD | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! |
| Beta | total count | 10008 | 10005 | 10005 | 10010 | 10004 | 10005 | 10007 | 10009 | 10004 | 10011 | 10009 | 10014 |
| | reduced chi | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! |
| | chi-square | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! |
| | CPM | 1069.066 | 1059.99 | 1094.973 | 1109.012 | 1074.966 | 970.4462 | 1115.045 | 1114.014 | 1051.413 | 1000.218 | 1063.219 | 1075.949 |
| | CPM var | 229.5418 | 225.5578 | 240.641 | 246.7374 | 231.8797 | 189.0293 | 249.3865 | 248.9054 | 221.7413 | 200.7333 | 226.654 | 232.2276 |
| | Efficiency | 0.343005 | 0.340093 | 0.351317 | 0.355821 | 0.344899 | 0.311364 | 0.357758 | 0.357427 | 0.337343 | 0.320917 | 0.341131 | 0.345216 |
| | archived S | 0.012316 | 0.012211 | 0.012613 | 0.012775 | 0.012383 | 0.011179 | 0.012844 | 0.012832 | 0.012111 | 0.011522 | 0.012247 | 0.012394 |
| | predicted S | 0.003433 | 0.003403 | 0.003516 | 0.00356 | 0.003451 | 0.003116 | 0.003579 | 0.003576 | 0.003375 | 0.00321 | 0.003412 | 0.003453 |
| | actual STD | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! |

| Standard Information Ra-228 | | | Instrument: LB4100A | |
|---|---|---|---|---|
| ID 1083.4243.30 | | | | |
| Activity concentration: | 337.98 | dpm/mL | | |
| Reference Date: | 12/1/2017 | | | |
| Spike volume: | 10 | mL | | |

| | A1 | A2 | A3 | A4 |
|---|---|---|---|---|
| Source | 1820002-1 | 1820002-2 | 1820002-3 | 1820002-5 |
| Ac-228 Ingrowth Date: | 7/31/2018 | 7/31/2018 | 7/31/2018 | 7/31/2018 |
| Ac-228 Ingrowth Time: | 5:00 PM | 5:00 PM | 5:00 PM | 5:00 PM |
| Ac-228 Decay Date: | 8/3/2018 | 8/3/2018 | 8/3/2018 | 8/3/2018 |
| Ac-228 Decay Time: | 9:28 AM | 9:28 AM | 9:28 AM | 9:28 AM |
| Count Start Date: | 8/3/2018 | 8/3/2018 | 8/3/2018 | 8/3/2018 |
| Count End Time: | 11:39 AM | 11:39 AM | 11:39 AM | 11:39 AM |
| Count Duration(min.): | 9.34 | 9.42 | 9.12 | 9.01 |
| Count Start Time: | 11:30:00 AM | 11:30:00 AM | 11:30:00 AM | 11:30:00 AM |
| Count Duration(hrs): | 0.2 | 0.2 | 0.2 | 0.2 |
| Elapsed Time reference date to analysis (days): | 242 | 242 | 242 | 242 |
| Ac-228 Ingrowth time (hrs): | 64.5 | 64.5 | 64.5 | 64.5 |
| Elapsed Time, sep. to ct.start., (hrs): | 2.03 | 2.03 | 2.03 | 2.03 |
| Gross CPM | 1069.066 | 1059.99 | 1094.973 | 1109.012 |
| Bkg CPM | 2.454 | 2.112 | 2.066 | 1.976 |
| Ra-228 decay: | 0.9232 | 0.9232 | 0.9232 | 0.9232 |
| Ac-228 ingrowth: | 0.9993 | 0.9993 | 0.9993 | 0.9993 |
| Ac-228 decay: | 0.7946 | 0.7946 | 0.7946 | 0.7946 |
| Count Ingrowth: | 0.0174 | 0.0176 | 0.0170 | 0.0168 |
| Count Decay: | 0.0176 | 0.0178 | 0.0172 | 0.0170 |
| Known dpm on ref date: | 3379.8 | 3379.8 | 3379.8 | 3379.8 |
| Efficiency: | 0.4343 | 0.4308 | 0.4449 | 0.4506 |

| Standard Information Ra-228 | | | Instrument: LB4100A | | |
|---|---|---|---|---|---|
| ID 1083.4243.30 | | | | | |
| Activity concentration: | 337.98 | dpm/mL | | | |
| Reference Date: | 12/1/2017 | | | | |
| Spike volume: | 10 | mL | | | |
| | **B3** | **B4** | **C2** | **C4** | |
| Source | 1820002-1 | 1820002-2 | 1820002-3 | 1820002-5 | |
| Ac-228 Ingrowth Date: | 7/31/2018 | 7/31/2018 | 7/31/2018 | 7/31/2018 | |
| Ac-228 Ingrowth Time: | 5:00 PM | 5:00 PM | 5:00 PM | 5:00 PM | |
| Ac-228 Decay Date: | 8/3/2018 | 8/3/2018 | 8/3/2018 | 8/3/2018 | |
| Ac-228 Decay Time: | 9:28 AM | 9:28 AM | 9:28 AM | 9:28 AM | |
| Count Start Date: | 8/3/2018 | 8/3/2018 | 8/3/2018 | 8/3/2018 | |
| Count End Time: | 11:53 AM | 11:54 AM | 11:52 AM | 11:52 AM | |
| Count Duration(min.): | 9.29 | 10.29 | 8.96 | 8.97 | |
| Count Start Time: | 11:44:00 AM | 11:44:00 AM | 11:44:00 AM | 11:44:00 AM | |
| Count Duration(hrs): | 0.2 | 0.2 | 0.1 | 0.1 | |
| Elapsed Time reference date to analysis (days): | 242 | 242 | 242 | 242 | |
| Ac-228 Ingrowth time (hrs): | 64.5 | 64.5 | 64.5 | 64.5 | |
| Elapsed Time, sep. to ct.start., (hrs): | 2.27 | 2.27 | 2.27 | 2.27 | |
| Gross CPM | 1074.966 | 970.4462 | 1115.045 | 1114.014 | |
| Bkg CPM | 1.891 | 1.857 | 1.808 | 1.817 | |
| Ra-228 decay: | 0.9232 | 0.9232 | 0.9232 | 0.9232 | |
| Ac-228 ingrowth: | 0.9993 | 0.9993 | 0.9993 | 0.9993 | |
| Ac-228 decay: | 0.7739 | 0.7739 | 0.7739 | 0.7739 | |
| Count Ingrowth: | 0.0174 | 0.0192 | 0.0167 | 0.0168 | |
| Count Decay: | 0.0175 | 0.0194 | 0.0169 | 0.0169 | |
| Known dpm on ref date: | 3379.8 | 3379.8 | 3379.8 | 3379.8 | |
| Efficiency: | 0.4486 | 0.4053 | 0.4652 | 0.4648 | |

| Standard Information Ra-228 | | | Instrument: LB4100A | | |
|---|---|---|---|---|---|
| ID 1083.4243.30 | | | | | |
| Activity concentration: | 337.98 | dpm/mL | | | |
| Reference Date: | 12/1/2017 | | | | |
| Spike volume: | 10 | mL | | | |

| | D1 | D2 | D3 | D4 |
|---|---|---|---|---|
| Source | 1820002-1 | 1820002-2 | 1820002-3 | 1820002-5 |
| Ac-228 Ingrowth Date: | 7/31/2018 | 7/31/2018 | 7/31/2018 | 7/31/2018 |
| Ac-228 Ingrowth Time: | 5:00 PM | 5:00 PM | 5:00 PM | 5:00 PM |
| Ac-228 Decay Date: | 8/3/2018 | 8/3/2018 | 8/3/2018 | 8/3/2018 |
| Ac-228 Decay Time: | 9:28 AM | 9:28 AM | 9:28 AM | 9:28 AM |
| Count Start Date: | 8/3/2018 | 8/3/2018 | 8/3/2018 | 8/3/2018 |
| Count End Time: | 12:05 PM | 12:05 PM | 12:05 PM | 12:05 PM |
| Count Duration(min.): | 9.5 | 9.99 | 9.4 | 9.29 |
| Count Start Time: | 11:56:00 AM | 11:56:00 AM | 11:56:00 AM | 11:56:00 AM |
| Count Duration(hrs): | 0.2 | 0.2 | 0.2 | 0.2 |
| Elapsed Time reference date to analysis (days): | 242 | 242 | 242 | 242 |
| Ac-228 Ingrowth time (hrs): | 64.5 | 64.5 | 64.5 | 64.5 |
| Elapsed Time, sep. to ct.start., (hrs): | 2.47 | 2.47 | 2.47 | 2.47 |
| Gross CPM | 1051.413 | 1000.218 | 1063.219 | 1075.949 |
| Bkg CPM | 1.64 | 1.884 | 1.568 | 1.984 |
| Ra-228 decay: | 0.9232 | 0.9232 | 0.9232 | 0.9232 |
| Ac-228 ingrowth: | 0.9993 | 0.9993 | 0.9993 | 0.9993 |
| Ac-228 decay: | 0.7566 | 0.7566 | 0.7566 | 0.7566 |
| Count Ingrowth: | 0.0177 | 0.0187 | 0.0176 | 0.0174 |
| Count Decay: | 0.0179 | 0.0188 | 0.0177 | 0.0175 |
| Known dpm on ref date: | 3379.8 | 3379.8 | 3379.8 | 3379.8 |
| Efficiency: | 0.4490 | 0.4272 | 0.4540 | 0.4592 |

7/18/18
Gross Beta (Sr90) Mass Attenuation Curve Filename: AGR0718
Benchsheet: AB180619-4 Sources: 1118007-1→16

| Det | 10:49 | 11:00 | 11:14 | 11:25 | 11:34 | 11:46 | 11:57 | 12:07 | 12:15 | 12:27 | 12:36 | 12:43 | 12:52 | 13:10 | 13:22 | 13:43 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 | 1 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 |
| A2 | 2 | 1 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 |
| A3 | 3 | 2 | 1 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 |
| A4 | 4 | 3 | 2 | 1 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 |
| B3 | 5 | 4 | 3 | 2 | 1 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 |
| B4 | 6 | 5 | 4 | 3 | 2 | 1 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 |
| C2 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| C4 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 |
| D1 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 16 | 15 | 14 | 13 | 12 | 11 | 10 |
| D2 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 16 | 15 | 14 | 13 | 12 | 11 |
| D3 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 16 | 15 | 14 | 13 | 12 |
| D4 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 16 | 15 | 14 | 13 |

7/23/18
Gross Alpha (Am-241) Efficiency Calibration
Benchsheet: AB180718-1 Source ID: 7639
Log File: Am-241R-07/18

| Sources | Detectors | Filenames |
|---|---|---|
| 1819010-1 | A1 A2 A3 A4 | EAM0723 |
| -2 | B3 B4 C2 C4 | EAM0723A |
| -4 | D1 D2 D3 D4 | EAM0723B |
| -5 | | |

8/3/2018
Ra228 Efficiency Calibration
Benchsheet: RA180803-1 Source ID: 640 Log File: Ra228-08/18

| Sources | Detectors | Filenames |
|---|---|---|
| 1820002-1 | A1 A2 A3 A4 | ERA0803 |
| -2 | B3 B4 C2 C4 | ERA0803A |
| -3 | D1 D2 D3 D4 | ERA0803B |
| -5 | | |

Continued on Page

Signed 8/4/18 Date

Read and Understood By
Signed Date

Date 8/03/18

SOP 724r 12

# ALS
## Low Background Gas Flow Proportional Counter Log
## Instrument: LB4100A

*Instrument Daily Response and Background Checks*

| Det. | Daily Response Check Start 1 | Status | Start 2 | Status | Background Check Start 1 | Status | Start 2 | Status | Det. Status |
|---|---|---|---|---|---|---|---|---|---|
| 1 | NP | P | | | NP | P | | | P |
| 2 | | | | | | | | | |
| 3 | | | | | | | | | |
| 4 | | | | | | | | | |
| 5 | | | | | | | | | OL |
| 6 | | | | | | | | | |
| 7 | | | | | | | | | P |
| 8 | | | | | | | | | |
| 9 | | | | | | | | | OL |
| 10 | | | | | | (Hα) | NP | P | P |
| 11 | | | | | | P | | | OL |
| 12 | | | | | | | | | P |
| 13 | | | | | | | | | |
| 14 | | | | | | | | | |
| 15 | | | | | | | | | |
| 16 | | | | | | | | | |

Det = Detector; α = Alpha; β = Beta; P = Pass; H = High; L = Low; OL = Offline; R = Recount; W = Weekly; NP = Not Processed

*Weekly Background Calibration*

| | Current Calib. File ID | Weekly Calib. Started | Status | File ID |
|---|---|---|---|---|
| Dr A | BKA0731W | | | |
| Dr B | | | | |
| Dr C | | | | |
| Dr D | 0801W | | | |

Dr = Drawer

*Gas Supply*

| P-10 Supply | | P-10 Flow | |
|---|---|---|---|
| Tank 1 | 1900 | Dr A | 10 |
| | | Dr B | |
| Tank 2 | 2100 | Dr C | |
| | | Dr D | |

Comments:

Page No.: 478629 A

Form 780r8.doc (6/23/06)

Reviewed By / Date NP 8/03/18

Date 8/03/18

SOP 724r 12

**ALS**

Low Background Gas Flow Proportional Counter Log

**Instrument: LB4100A**

| Det. | Sample ID | Batch | Test | Count Dur. (min) | Start Time | Analyst Initials | File ID | Output Initials |
|---|---|---|---|---|---|---|---|---|
| ~~15~~ | ~~ABK 180801-13~~ | ~~AB180801-13~~ | ~~αβ~~ | ~~10~~ | ~~09:53~~ | ~~NP~~ | ~~ABA080310~~ | |
| 15 | AB180801-13MB | AB180801-13 | αβ | 10 | 09:53 | NP | ABA080310 | NP 8/03/18 |
| 4 | 1820102-1 | RA180803-1 | Ra226 | 8 | 10:27 | JP | RAA0803 | JP |
| 4 | -2 | | Other | | 10:36 | JP | RAA0803A | JP |
| 4 | -3 | | | | 10:52 | JP | RAA0803B | |
| 4 | -4 | | | | 11:06 | JP | RAA0803C | |
| 4 | -5 | | | | 11:17 | | RAA0803D | |
| 1-4 | 640 | RA180803-1 | Ra226 | 10 | 11:29 | JP | ERA0803 | |
| 7,8,11,12 | | | Eff | | 11:44 | | ERA0803A | |
| 13-16 | | | Cal | | 11:56 | | ERA0803B | |
| 1 | 1807153-1 | SR180801-1 | Sr90 | 60 | 12:12 | JP | SRA0803 | JP |
| 2 | -2 | | | | | | | |
| 3 | -3 | | | | | | | |
| 4 | -4 | | | | | | | |
| 7 | -5 | | | | | | | |
| 8 | -6 | | | | | | | |
| 10 | -7 | | | | | | | |
| 12 | -8 | | | | | | | |
| 13 | -9 | | | | | | | |
| 14 | -10 | | | | | | | |
| 15 | -11 | | | | | | | |
| 16 | -12 | | | | | | | |
| 1 | -13 | | | | 13:32 | JP | SRA0803A | |
| 2 | SR180801-1MB | | | | | | | |
| 3 | 1807153-14 | SR180801-2 | | | | | | |
| 4 | -15 | | | | | | | |
| 7 | -16 | | | | | | | |
| 8 | -17 | | | | | | | |
| 10 | -18 | | | | | | | |
| 12 | -19 | | | | | | | |
| 13 | -20 | | | | | | | |
| 14 | -21 | | | | | | | |
| 15 | -22 | | | | | | | |
| 16 | -23 | | | | | | | |
| 2 | -24 | | | | 15:06 | JP | SRA0803B | |
| 3 | -25 | | | | | | | |
| 4 | SR180801-2MB | | | | | | | |

JP 8/4/18

Comments:

Page No.: 478630 B

(cont. from page 478629 B)

Form 780r8.doc (6/23/06)

Reviewed By / Date JP 8/4/18

Date 8/4/18

SOP 724r 12

# ALS
## Low Background Gas Flow Proportional Counter Log
**Instrument: LB4100A**

*Instrument Daily Response and Background Checks*

| Det. | Daily Response Check Start 1 | Status | Start 2 | Status | Background Check Start 1 | Status | Start 2 | Status | Det. Status |
|---|---|---|---|---|---|---|---|---|---|
| 1 | JP | P | | | JP | (HB) | JP | P | P |
| 2 | | | | | | P | | | |
| 3 | | | | | | | | | |
| 4 | | | | | | | | | |
| 5 | | | | | | (LB) | | | OL |
| 6 | | | | | | P | | | P |
| 7 | | | | | | | | | |
| 8 | | | | | | | | | |
| 9 | | | | | | | | | OL |
| 10 | | | | | | | | | P |
| 11 | | | | | | | | | OL |
| 12 | | | | | | (HL) | JP | P | P |
| 13 | | | | | | P | | | P |
| 14 | | | | | | | | | |
| 15 | | | | | | | | | |
| 16 | | | | | | | | | |

Det = Detector; α = Alpha; β = Beta; P = Pass; H = High; L = Low; OL = Offline; R = Recount; W = Weekly; NP = Not Processed

*Weekly Background Calibration*

| | Current Calib. File ID | Weekly Calib. Started | Status | File ID |
|---|---|---|---|---|
| Dr A | BKA0731W | | | |
| Dr B | | | | |
| Dr C | | | | |
| Dr D | 0801W | | | |

Dr = Drawer

*Gas Supply*

| P-10 Supply | | P-10 Flow | |
|---|---|---|---|
| Tank 1 | 1500 | Dr A | 10 |
| | | Dr B | |
| Tank 2 | 2100 | Dr C | |
| | | Dr D | |

Comments:

Page No.: 478631 A

Form 780r8.doc (6/23/06)

Reviewed By / Date JP 8/4/18

# Radiochemistry Instrument Worksheet

**ALS -- Fort Collins**

**Prep Batch:** RA180803-1

**Prep Procedure:** Ra228

Analytical QASS / NCR? Y / N

| Prep Num | LabID | QC Type | Init Alq | Fin Alq | Units | Report Units | Residual Mass (mg) | Cnt 1 File | Cnt 1 Inst/Det | Cnt 1 Pos Chk By | Cnt 2 File | Cnt 2 Inst/Det | Cnt 2 Pos Chk By | Cnt 3 File | Cnt 3 Inst/Det | Cnt 3 Pos Chk By | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1820002-1 | SMP | 25 | 25 | ml | pCi/l | See Maintenance Log #3974 pg 47 | | | | | | | | | | |
| 1 | 1820002-2 | SMP | 25 | 25 | ml | pCi/l | | | | | | | | | | | JP 8/16/18 |
| 1 | 1820002-3 | SMP | 25 | 25 | ml | pCi/l | | | | | | | | | | | |
| 1 | 1820002-4 | SMP | 25 | 25 | ml | pCi/l | | | | | | | | | | | Outlier |
| 1 | 1820002-5 | SMP | 25 | 25 | ml | pCi/l | | | | | | | | | | | |

**Tracer/Carrier Solution Information**

| Soln # | Nuclide | SolnID | Exp Date | Prep Conc | Units | Prep Date | Aliquot | Units | Pipet ID |
|---|---|---|---|---|---|---|---|---|---|
| T1 | BARIUM | 418241 | 10/12/18 | 16,024.834 | pCi/ml | NA | 2 | ml | RS031 |

**Spike Solution Information**

| Soln # | Nuclide | SolnID | Exp Date | Prep Conc | Units | Prep Date | Aliquot | Units | Pipet ID |
|---|---|---|---|---|---|---|---|---|---|
| S1 | Ra-228 | 1083.4243.30 | 5/22/19 | 311.680 | DPM/ml | 08/03/18 | 10 | ml | RS041 |

## Sample Barcodes

1820002-1
RA180803-1PS1

1820002-2
RA180803-1PS2

1820002-3
RA180803-1PS3

1820002-4
RA180803-1PS4

1820002-5
RA180803-1PS5

## Reporting Units

| LabID: | TstGrpName: | RptUnits: |
|---|---|---|
| 1820002-1 | Ra228_2012 | pCi/l |
| 1820002-2 | Ra228_2012 | pCi/l |
| 1820002-3 | Ra228_2012 | pCi/l |
| 1820002-4 | Ra228_2012 | pCi/l |
| 1820002-5 | Ra228_2012 | pCi/l |

# Radiochemistry Prep Worksheet

**ALS -- Fort Collins**

**Prep Batch:** RA180803-1

**Prep Procedure:** Ra228

**Reviewed By:** rgs RGS **Review Date:** 8/3/2018

**Non-Routine Pre-Treatment? Y / N** **Batch:** MS **Re-Prep? Y / N** **Batch:** MS **Prep QASS / NCR? Y / N** MS

**Prep SOP:** SOP749 **Rev:** 5
**Prep SOP:** NONE
**Matrix Class:** liquid

**Prep Analyst:** Reilly G. Stockton RGS
**Prep Date:** 8/3/2018
**Prep Dept:** RS

**Balance:** N/A
**Balance:** N/A

| Samp Num | Prep Num | LabID | QC Type | Dish No. | Init Alq ml | Fin Alq ml | Prep Basis | Ingrowth Date/Time | Decay Date/Time | Standards | Prep Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1820002-1 | SMP | MS | 25 | 25 | As Received | 07/31/18 17:00 | 08/03/18 09:28 | S1,T1 | |
| 2 | 1 | 1820002-2 | SMP | | 25 | 25 | As Received | 07/31/18 17:00 | 08/03/18 09:28 | S1,T1 | |
| 3 | 1 | 1820002-3 | SMP | | 25 | 25 | As Received | 07/31/18 17:00 | 08/03/18 09:28 | S1,T1 | |
| 4 | 1 | 1820002-4 | SMP | | 25 | 25 | As Received | 07/31/18 17:00 | 08/03/18 09:28 | S1,T1 | |
| 5 | 1 | 1820002-5 | SMP | | 25 | 25 | As Received | 07/31/18 17:00 | 08/03/18 09:28 | S1,T1 | |

RGS 8/3

Comments
Ra228 calibration

**Spiked By:** Steve Workman **Date:** 8/2/2018 **Yttrium Added By:** **Date:**

**Witnessed By:** Reilly G. Stockton **Date:** 8/2/2018 **Witnessed By:** **Date:**

**Tracer/Carrier Solution Information**

| Soln # | Nuclide | SolnID | Exp Date | Prep Conc | Units | Prep Date | Aliquot | Units | Pipet ID |
|---|---|---|---|---|---|---|---|---|---|
| T1 | BARIUM | 418241 | 10/12/18 | 16,024.834 | pCi/ml | NA | 2 | ml | RS031 |

**Spike Solution Information**

| Soln # | Nuclide | SolnID | Exp Date | Prep Conc | Units | Prep Date | Aliquot | Units | Pipet ID |
|---|---|---|---|---|---|---|---|---|---|
| S1 | Ra-228 | 1083.4243.30 | 5/22/19 | 311.680 | DPM/ml | 08/03/18 | 10 | ml | RS041 |

# Radiochemistry Prep Worksheet

**ALS -- Fort Collins**

**Prep Batch:** RA180803-1

**Prep Procedure:** Ra228

## Prep Batch Not Validated!!!

**Reviewed By:**

**Review Date:**

**Non-Routine Pre-Treatment? Y / N** **Batch:** _____ **Re-Prep? Y / N** **Batch:** _____ **Prep QASS / NCR? Y / N** _____

**Prep SOP:** SOP749 **Rev:** 5
**Prep SOP:** NONE
**Matrix Class:** liquid

**Prep Analyst:** Reilly G. Stockton RGS
**Prep Date:** 8/3/2018
**Prep Dept:** RS

**Balance:** N/A
**Balance:** N/A

| Samp Num | Prep Num | LabID | QC Type | Dish No. | Init Alq ml | Fin Alq ml | Prep Basis | Ingrowth Date/Time | Decay Date/Time | Standards | Prep Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1820002-1 | SMP | MS | 25 | 25 | As Received | 07/31/18 17:00 | 08/03/18 09:28 | S1,T1 | |
| 2 | 1 | 1820002-2 | SMP | | 25 | 25 | As Received | 07/31/18 17:00 | 08/03/18 09:28 | S1,T1 | |
| 3 | 1 | 1820002-3 | SMP | | 25 | 25 | As Received | 07/31/18 17:00 | 08/03/18 09:28 | S1,T1 | |
| 4 | 1 | 1820002-4 | SMP | | 25 | 25 | As Received | 07/31/18 17:00 | 08/03/18 09:28 | S1,T1 | |
| 5 | 1 | 1820002-5 | SMP | | 25 | 25 | As Received | 07/31/18 17:00 | 08/03/18 09:28 | S1,T1 | |

Comments
**Ra228 calibration**

**Spiked By:** Steve Workman **Date:** 8/2/2018 **Yttrium Added By:** _____ **Date:** _____

**Witnessed By:** Reilly G. Stockton **Date:** 8/2/2018 **Witnessed By:** _____ **Date:** _____

**Tracer/Carrier Solution Information**

| Soln # | Nuclide | SolnID | Exp Date | Prep Conc | Units | Prep Date | Aliquot | Units | Pipet ID |
|---|---|---|---|---|---|---|---|---|---|
| T1 | BARIUM | 418241 | 10/12/18 | 16,024.834 | pCi/ml | NA | 2 | ml | RS031 |

**Spike Solution Information**

| Soln # | Nuclide | SolnID | Exp Date | Prep Conc | Units | Prep Date | Aliquot | Units | Pipet ID |
|---|---|---|---|---|---|---|---|---|---|
| S1 | Ra-228 | 1083.4243.30 | 5/22/19 | 311.680 | DPM/ml | 08/03/18 | 10 | ml | RS041 |

# Sample Condition Form (Liquid)

Analyst: Reilly Stockton

Analysis Date: 8/3/18 | Method: Radium 228

| | | Sample Condition (Visual Appearance of Analysis Aliquot at Time of Prep) | | |
|---|---|---|---|---|
| Work Order | Sample ID | pH | Color | Remarks |
| 1820002 | 1 | 6 | clear | diluted |
| | 2 | | | |
| | 3 | | | |
| | 4 | | | |
| | 5 | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | RGS 8/3/18 |
| | | | | |
| | | | | |

Project Ra228 working Standard 1083.4243_30

Continued from Page

TE 5/21/18

Prepare a working dilution of RSO #1083

1. Density of 1M HNO3, lot # 6000191696
   Mass of 100mL vol. flask: 68.2948g Balance # 12
   Mass of flask & 100mL acid: 171.0452g Balance# 12
   Net Mass: 102.7504g
   Density: 1.0275 g/mL

2. Mass of #1083 transferred:
   Mass of open empty nalgene: 18.5431g Balance# 12
   Mass of nalgene & standard: 23.6605g Balance# 12
   Net mass of standard transferred: 5.1174g

TE 5/21/18

TE 5/21/18

3. Dilute to final volume:
   Mass of nalgene, standard, & diluent: 85.3415g Balance# 12
   Mass of empty nalgene (from above): 18.5431g Balance# 12
   Net mass of new dilution: 66.7984g

4. Final activity calculation:

$$71.56\ Bq/g \left(\frac{60\ dpm}{1\ Bq}\right)\left(\frac{1.0275\ g/mL}{66.7984\ g}\right)(5.1174\ g) = 337.98$$

TE 5/21/18

JP 6/18/18

Stnd ID: 1083.4243.30

Description: Ra-228
Expiration: 5/22/2019
Activity: 337.98 dpm/ml

2s Uncertainty: 11.15 dpm/ml
Ref. Date: 12/1/2017
Ref Time: N/A
Prep Date: 5/21/2018 Prep by: TE
Matrix/Comp. 1 M HNO3
Half Life (y): 5.75E+00

| Reverification Log | | |
|---|---|---|
| Analysis Date | Initials | Expiration Date |
| | | |
| | | |
| | | |
| | | |
| | | |

JP 6/18/18

Continued on Page

TE Ellut 5/21/18
Signed Date

Read and Understood By
Signed Date 6/18/18

Eckert & Ziegler
Isotope Products

24937 Avenue Tibbitts
Valencia, California 91355

Tel 661·309·1010
Fax 661·257·8303

RSO#
1083

# CERTIFICATE OF CALIBRATION
# BETA STANDARD SOLUTION

| | | | |
|---|---|---|---|
| **Radionuclide:** | Ra-228 | **Customer:** | ALS LABORATORY GROUP |
| **Half-life:** | 5.75 ± 0.03 years | **P.O. No.:** | FC001627 |
| **Catalog No.:** | 7328 | **Reference Date:** | 1-Dec-17 12:00 PST |
| **Source No.:** | 1984-39 | **Contained Radioactivity: (Ra-228 only)** | 0.01003 µCi 371 Bq |

**Physical Description:**

A. Mass of solution: 5.18631 g in 5 mL flame-sealed ampoule
B. Chemical form: $Ra(NO_3)_2$ in 1M $HNO_3$
C. Carrier content: Approximately 282 µg Ba/mL of solution
D. Density: 1.0318 g/mL @ 20°C

**Radioimpurities:**

None detected (Ac-228 daughter in equilibrium; Th-228 not in equilibrium)

**Radionuclide Concentration:** 0.001934 µCi/g, 71.56 Bq/g

**Method of Calibration:**

This source was prepared from a weighed aliquot of solution whose activity in µCi/g was determined using gamma ray spectrometry.

Peak energy used for integration: 338.4, 911.1 keV
Branching ratio used: 0.113, 0.266 gammas per decay

**Uncertainty of Measurement:**

A. Type A (random) uncertainty: ± 1.4 %
B. Type B (systematic) uncertainty: ± 3.0 %
C. Uncertainty in aliquot weighing: ± 0.0 %
D. Total uncertainty at the 99% confidence level: ± 3.3 %

**Notes:**

- See reverse side for leak test(s) performed on this source.
- EZIP participates in a NIST measurement assurance program to establish and maintain implicit traceability for a number of nuclides, based on the blind assay (and later NIST certification) of Standard Reference Materials (as in NRC Regulatory Guide 4.15).
- Nuclear data was taken from NCRP Report No. 58, 1985.
- This solution has a recommended working life of 5 years.

Daniel James Van Dalsem
**Quality Control**

12-NOV-17
**Date**

EZIP Ref. No.: 1984-39

# Radiochemistry Solution Report

| | | | | | |
|---|---|---|---|---|---|
| **Solution Id:** | 418241 | **Name:** | barium carrier | **Type:** | IS |
| | | **Lot:** | | **Vendor Name:** | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Final Vol:** | 4000 | **Dept:** | RD | **Prep By** | ARS | **on** | 10/12/2017 | **Reviewed By** | tde | **on** | 10/20/2017 |
| **Units:** | mL | **Location:** | SR/RA | **Opened By** | | **on** | | **Verified By** | ARS | **on** | 10/12/2017 |
| **Matrix:** | LIQUID | **ExpireDate:** | 10/12/2018 | **Received By** | | **on** | | **Deactivated By** | | **on** | |

**Comment:**

| Component Name | Component ID | Volume Added | Units |
|---|---|---|---|
| Barium Stable Carrier Source<1> | 3756 B07592 | 114.0165 | g |

| CompName | Calibrated Primary Act/Conc | Calibration Date | Reference Date | 1/2 Life (Yrs) | Final Act/Conc | Summed Conc | Units |
|---|---|---|---|---|---|---|---|
| BARIUM | 562193.5 | | 6/14/2018 | | 16024.83 | | pCi/ml |

## Associated Parent IDs

3756 B07592

**Abbreviations: NC = Not Calculated for reagents when the volume added is not entered.**
**NE = Not Entered**

**(Prnt) = Secular equilibrium; parent half life used to calculate concentration.**

# OUTLIER TEST

| FILE | DET | SAMPLE ID | Beta CPM | Relative % diff. from mean | Within acceptability range | Outlier? | Half-life (days | Separation Date & Time | Count Date & Time | Decay Factor | Chemical Yield | CPM Corrected |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RAA0803 | A4(4) | 1820002-1 | 1247.875 | 2.10% | YES | NO | 0.2554 | 8/3/2018 9:28 | 8/3/2018 10:27 | 0.8948 | 1.0000 | 1394.63 |
| RAA0803A | A4(4) | 1820002-2 | 1178.000 | 1.41% | YES | NO | 0.2554 | 8/3/2018 9:28 | 8/3/2018 10:39 | 0.8748 | 1.0000 | 1346.65 |
| RAA0803B | A4(4) | 1820002-3 | 1200.000 | 2.92% | YES | NO | 0.2554 | 8/3/2018 9:28 | 8/3/2018 10:52 | 0.8536 | 1.0000 | 1405.83 |
| RAA0803C | A4(4) | 1820002-4 | 1091.750 | 3.68% | YES | OUTLIER! | 0.2554 | 8/3/2018 9:28 | 8/3/2018 11:07 | 0.8298 | 1.0000 | 1315.68 |
| RAA0803D | A4(4) | 1820002-5 | 1113.250 | 0.08% | YES | NO | 0.2554 | 8/3/2018 9:28 | 8/3/2018 11:17 | 0.8143 | 1.0000 | 1367.11 |

| Mean of all five planchets: | | | Acceptability range | Relative range |
|---|---|---|---|---|
| Average= | 1365.98 | Upper | 1438.88 | +/- 5.34% |
| Std dev= | 36.447097 | Lower | 1293.09 | |
| 2 Std Dev= | 72.89 | | | 0.053363935 |

**Sample 1820002-4 rejected as outlier.**

Criteria: Potential outliers fall outside acceptability range; which is the mean of all five measurements +/- 2 std dev per the Grubbs statistical test.

# ALS- Gas Flow Proportional Sample Analysis LB4100-A

Unit Type: LB4100-A/W
Counting Unit ID: Orange
High Voltage Mode: Simultaneous
Application Revision: C
Application Version: PA
Rev.05/09/13 JP

Data file name: RAA0803
Batch ID: RA228 OUTLIER
Count Preset (m): 8
Batch Ended: 8/3/18 10:35

Background logfile: BKGABW
Date of Bkg. Cal: 8/1/18
Alpha efficiency logfile: Am241R-07/18
Alpha attenuation calibration: AAM1206
Beta efficiency logfile: Sr90F-07/18
Beta attenuation calibration: ASR1205

Alpha prog. logfile: n/a
Alpha prog. attenuation: n/a
Beta prog. logfile: n/a
Beta prog. attenuation: n/a

| Alpha Attenuation Calibration y = b*m^(a*(mass-x0)) | | Beta Attenuation Calibration y = b*m^(a*(mass-x0)) | |
|---|---|---|---|
| Alpha b= | 0.97970 | Beta b= | 0.9775 |
| m= | 0.99020 | m= | 0.9994 |
| a= | 0.8336 | a= | 1.0249 |
| x0= | 21.5000 | x0= | 0.0000 |
| Alpha to Beta X-talk y = b*m^-x | | Beta to Alpha X-talk y = b*mass + m | |
| a ->b xtalk b= | 0.2560 | b ->a xtalk b= | 1.950E-05 |
| a ->b xtalk m= | 0.9993 | b ->a xtalk m= | 0.0036 |

| Det. ID | Sample ID | Count End Date & Time | Count Dur. (min) | Resid. Mass (mg) | Alpha Activity Gross CPM | Alpha Bkg. CPM | Alpha b>a xtlk CPM | Alpha Base Eff | Alpha Base Cor.Fact. | Alpha Progeny Eff | Alpha Progeny Cor.Fact. | Beta Activity Gross CPM | Beta Bkg. CPM | Beta a>b xtlk CPM | Beta Base Eff | Beta Base Cor.Fact. | Beta Progeny Eff | Beta Progeny Cor.Fact. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A4 | 1820002-1 | 8/3/18 10:35 | 8.00 | 0.0 | 8.875 | 0.117 | 4.485 | 0.2100 | 1.169 | n/a | n/a | 1247.875 | 1.976 | 2.2420 | 0.3683 | 0.978 | n/a | n/a |

JT 8/3/18

# ALS- Gas Flow Proportional Sample Analysis LB4100-A

Unit Type: LB4100-A/W
Counting Unit ID: Orange
High Voltage Mode: Simultaneous
Application Revision: C
Application Version: PA
Rev.05/09/13 JP

Data file name: RAA0803A
Batch ID: RA228 OUTLIER
Count Preset (m): 8
Batch Ended: 8/3/18 10:47

Background logfile: BKGABW
Date of Bkg. Cal: 8/1/18
Alpha efficiency logfile: Am241R-07/18
Alpha attenuation calibration: AAM1206
Beta efficiency logfile: Sr90F-07/18
Beta attenuation calibration: ASR1205

Alpha prog. logfile: n/a
Alpha prog. attenuation: n/a
Beta prog. logfile: n/a
Beta prog. attenuation: n/a

| Alpha Attenuation Calibration y = b*m^(a*(mass-x0)) | | Beta Attenuation Calibration y = b*m^(a*(mass-x0)) | |
|---|---|---|---|
| Alpha b= | 0.97970 | Beta b= | 0.9775 |
| m= | 0.99020 | m= | 0.9994 |
| a= | 0.8336 | a= | 1.0249 |
| x0= | 21.5000 | x0= | 0.0000 |
| Alpha to Beta X-talk y = b*m^-x | | Beta to Alpha X-talk y = b*mass + m | |
| a ->b xtalk b= | 0.2560 | b ->a xtalk b= | 1.950E-05 |
| a ->b xtalk m= | 0.9993 | b ->a xtalk m= | 0.0036 |

| Det. ID | Sample ID | Count End Date & Time | Count Dur. (min) | Resid. Mass (mg) | Alpha Activity Gross CPM | Alpha Bkg. CPM | Alpha b>a xtlk CPM | Alpha Base Eff | Alpha Base Cor.Fact. | Alpha Progeny Eff | Alpha Progeny Cor.Fact. | Beta Activity Gross CPM | Beta Bkg. CPM | Beta a>b xtlk CPM | Beta Base Eff | Beta Base Cor.Fact. | Beta Progeny Eff | Beta Progeny Cor.Fact. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A4 | 1820002-2 | 8/3/18 10:47 | 8.00 | 0.0 | 11.875 | 0.117 | 4.234 | 0.2100 | 1.169 | n/a | n/a | 1178.000 | 1.976 | 3.0100 | 0.3683 | 0.978 | n/a | n/a |

JP 8/3/18

# ALS- Gas Flow Proportional Sample Analysis LB4100-A

Unit Type: LB4100-A/W
Counting Unit ID: Orange
High Voltage Mode: Simultaneous
Application Revision: C
Application Version: PA
Rev.05/09/13 JP

Data file name: RAA0803B
Batch ID: RA228 OUTLIER
Count Preset (m): 8
Batch Ended: 8/3/18 11:00

Background logfile: BKGABW
Date of Bkg. Cal: 8/1/18
Alpha efficiency logfile: Am241R-07/18
Alpha attenuation calibration: AAM1206
Beta efficiency logfile: Sr90F-07/18
Beta attenuation calibration: ASR1205

Alpha prog. logfile: n/a
Alpha prog. attenuation: n/a
Beta prog. logfile: n/a
Beta prog. attenuation: n/a

| Alpha Attenuation Calibration y = b*m^(a*(mass-x0)) | | Beta Attenuation Calibration y = b*m^(a*(mass-x0)) | |
|---|---|---|---|
| Alpha b= | 0.97970 | Beta b= | 0.9775 |
| m= | 0.99020 | m= | 0.9994 |
| a= | 0.8336 | a= | 1.0249 |
| x0= | 21.5000 | x0= | 0.0000 |
| **Alpha to Beta X-talk y = b*m^-x** | | **Beta to Alpha X-talk y = b*mass + m** | |
| a ->b xtalk b= | 0.2560 | b ->a xtalk b= | 1.950E-05 |
| a ->b xtalk m= | 0.9993 | b ->a xtalk m= | 0.0036 |

| Det. ID | Sample ID | Count End Date & Time | Count Dur. (min) | Resid. Mass (mg) | Alpha Activity Gross CPM | Alpha Bkg. CPM | Alpha b>a xtlk CPM | Alpha Base Eff | Alpha Base Cor.Fact. | Alpha Progeny Eff | Alpha Progeny Cor.Fact. | Beta Activity Gross CPM | Beta Bkg. CPM | Beta a>b xtlk CPM | Beta Base Eff | Beta Base Cor.Fact. | Beta Progeny Eff | Beta Progeny Cor.Fact. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A4 | 1820002-3 | 8/3/18 11:00 | 8.00 | 0.0 | 9.125 | 0.117 | 4.313 | 0.2100 | 1.169 | n/a | n/a | 1200.000 | 1.976 | 2.3060 | 0.3683 | 0.978 | n/a | n/a |

JM 8/3/18

# ALS- Gas Flow Proportional Sample Analysis LB4100-A

Unit Type: LB4100-A/W
Counting Unit ID: Orange
High Voltage Mode: Simultaneous
Application Revision: C
Application Version: PA
Rev.05/09/13 JP

Data file name: RAA0803C
Batch ID: RA228 OUTLIER
Count Preset (m): 8
Batch Ended: 8/3/18 11:15

Background logfile: BKGABW
Date of Bkg. Cal: 8/1/18
Alpha efficiency logfile: Am241R-07/18
Alpha attenuation calibration: AAM1206
Beta efficiency logfile: Sr90F-07/18
Beta attenuation calibration: ASR1205

Alpha prog. logfile: n/a
Alpha prog. attenuation: n/a
Beta prog. logfile: n/a
Beta prog. attenuation: n/a

| Alpha Attenuation Calibration y = b*m^(a*(mass-x0)) | | Beta Attenuation Calibration y = b*m^(a*(mass-x0)) | |
|---|---|---|---|
| Alpha b= | 0.97970 | Beta b= | 0.9775 |
| m= | 0.99020 | m= | 0.9994 |
| a= | 0.8336 | a= | 1.0249 |
| x0= | 21.5000 | x0= | 0.0000 |
| Alpha to Beta X-talk y = b*m^-x | | Beta to Alpha X-talk y = b*mass + m | |
| a ->b xtalk b= | 0.2560 | b ->a xtalk b= | 1.950E-05 |
| a ->b xtalk m= | 0.9993 | b ->a xtalk m= | 0.0036 |

| Det. ID | Sample ID | Count End Date & Time | Count Dur. (min) | Resid. Mass (mg) | Alpha Activity Gross CPM | Alpha Bkg. CPM | Alpha b>a xtlk CPM | Alpha Base Eff | Alpha Base Cor.Fact. | Alpha Progeny Eff | Alpha Progeny Cor.Fact. | Beta Activity Gross CPM | Beta Bkg. CPM | Beta a>b xtlk CPM | Beta Base Eff | Beta Base Cor.Fact. | Beta Progeny Eff | Beta Progeny Cor.Fact. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A4 | 1820002-4 | 8/3/18 11:15 | 8.00 | 0.0 | 9.000 | 0.117 | 3.923 | 0.2100 | 1.169 | n/a | n/a | 1091.750 | 1.976 | 2.2740 | 0.3683 | 0.978 | n/a | n/a |

JP 8/3/18

# ALS- Gas Flow Proportional Sample Analysis LB4100-A

Unit Type: LB4100-A/W
Counting Unit ID: Orange
High Voltage Mode: Simultaneous
Application Revision: C
Application Version: PA
Rev.05/09/13 JP

Data file name: RAA0803D
Batch ID: RA228 OUTLIER
Count Preset (m): 8
Batch Ended: 8/3/18 11:26

Background logfile: BKGABW
Date of Bkg. Cal: 8/1/18
Alpha efficiency logfile: Am241R-07/18
Alpha attenuation calibration: AAM1206
Beta efficiency logfile: Sr90F-07/18
Beta attenuation calibration: ASR1205

Alpha prog. logfile: n/a
Alpha prog. attenuation: n/a
Beta prog. logfile: n/a
Beta prog. attenuation: n/a

| Alpha Attenuation Calibration y = b*m^(a*(mass-x0)) | | Beta Attenuation Calibration y = b*m^(a*(mass-x0)) | |
|---|---|---|---|
| Alpha b= | 0.97970 | Beta b= | 0.9775 |
| m= | 0.99020 | m= | 0.9994 |
| a= | 0.8336 | a= | 1.0240 |
| x0= | 21.5000 | x0= | 0.0000 |
| **Alpha to Beta X-talk y = b*m^-x** | | **Beta to Alpha X-talk y = b*mass + m** | |
| a ->b xtalk b= | 0.2560 | b ->a xtalk b= | 1.950E-05 |
| a ->b xtalk m= | 0.9993 | b ->a xtalk m= | 0.0036 |

| Det. ID | Sample ID | Count End Date & Time | Count Dur. (min) | Resid. Mass (mg) | Alpha Activity Gross CPM | Alpha Bkg. CPM | Alpha b>a xtlk CPM | Alpha Base Eff | Alpha Base Cor.Fact. | Alpha Progeny Eff | Alpha Progeny Cor.Fact. | Beta Activity Gross CPM | Beta Bkg. CPM | Beta a>b xtlk CPM | Beta Base Eff | Beta Base Cor.Fact. | Beta Progeny Eff | Beta Progeny Cor.Fact. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A4 | 1820002-5 | 8/3/18 11:26 | 8.00 | 0.0 | 8.875 | 0.117 | 4.001 | 0.2100 | 1.169 | n/a | n/a | 1113.250 | 1.976 | 2.2420 | 0.3683 | 0.978 | n/a | n/a |

JM 8/3/18

Date 8/03/18

SOP 724r 12

# ALS
## Low Background Gas Flow Proportional Counter Log
## Instrument: LB4100A

*Instrument Daily Response and Background Checks*

| Det. | Daily Response Check Start 1 | Status | Start 2 | Status | Background Check Start 1 | Status | Start 2 | Status | Det. Status |
|---|---|---|---|---|---|---|---|---|---|
| 1 | NP | P | | | NP | P | | | P |
| 2 | | | | | | | | | |
| 3 | | | | | | | | | |
| 4 | | | | | | | | | |
| 5 | | | | | | | | | OL |
| 6 | | | | | | | | | |
| 7 | | | | | | | | | P |
| 8 | | | | | | | | | |
| 9 | | | | | | | | | OL |
| 10 | | | | | | (H α) | NP | P | P |
| 11 | | | | | | P | | | OL |
| 12 | | | | | | | | | P |
| 13 | | | | | | | | | |
| 14 | | | | | | | | | |
| 15 | | | | | | | | | |
| 16 | | | | | | | | | |

Det = Detector; α = Alpha; β = Beta; P = Pass; H = High; L = Low; OL = Offline; R = Recount; W = Weekly; NP = Not Processed

*Weekly Background Calibration*

| | Current Calib. File ID | Weekly Calib. Started | Status | File ID |
|---|---|---|---|---|
| Dr A | BKA0731W | | | |
| Dr B | | | | |
| Dr C | | | | |
| Dr D | 0801W | | | |

Dr = Drawer

*Gas Supply*

| P-10 Supply | | P-10 Flow | |
|---|---|---|---|
| Tank 1 | 1900 | Dr A | 10 |
| | | Dr B | |
| Tank 2 | 2100 | Dr C | |
| | | Dr D | |

Comments:

Page No.: 478629 A

Form 780r8.doc (6/23/06)

Reviewed By / Date NP 8/03/18

Date 8/03/18

SOP 724r 12

**ALS**

Low Background Gas Flow Proportional Counter Log

**Instrument: LB4100A**

| Det. | Sample ID | Batch | Test | Count Dur. (min) | Start Time | Analyst Initials | File ID | Output Initials |
|---|---|---|---|---|---|---|---|---|
| ~~15~~ | ~~ABA 180801-13~~ | ~~AB180801-13~~ | ~~αβ~~ | ~~10~~ | ~~09:53~~ | ~~NP~~ | ~~ABA0803D~~ | |
| 15 | AB180801-13MB | AB180801-13 | αβ | 10 | 09:53 | NP | ABA0803D | NP 8/03/18 |
| 4 | 1820002-1 | RA180803-1 | Ra226 | 8 | 10:27 | JP | RAA0803 | JP |
| 4 | -2 | | Outlier | | 10:36 | JP | RAA0803A | JP |
| 4 | -3 | | | | 10:52 | JP | RAA0803B | |
| 4 | -4 | | | | 11:06 | JP | RAA0803C | |
| 4 | -5 | | | | 11:19 | | RAA0803D | |
| 1-4 | 640 | RA180803-1 | Ra226 | 10 | 11:29 | JP | ERA0803 | |
| 7,8,10,12 | | | Eff | | 11:44 | | ERA0803A | |
| 13-16 | | | Cal | | 11:56 | | ERA0803B | |
| 1 | 1807153-1 | SR180801-1 | Sr90 | 60 | 12:12 | JP | SRA0803 | JP |
| 2 | -2 | | | | | | | |
| 3 | -3 | | | | | | | |
| 4 | -4 | | | | | | | |
| 7 | -5 | | | | | | | |
| 8 | -6 | | | | | | | |
| 10 | -7 | | | | | | | |
| 12 | -8 | | | | | | | |
| 13 | -9 | | | | | | | |
| 14 | -10 | | | | | | | |
| 15 | -11 | | | | | | | |
| 16 | -12 | | | | | | | |
| 1 | -13 | | | | 13:32 | JP | SRA0803A | |
| 2 | SR180801MB | | | | | | | |
| 3 | 1807153-14 | SR180801-2 | | | | | | |
| 4 | -15 | | | | | | | |
| 7 | -16 | | | | | | | |
| 8 | -17 | | | | | | | |
| 10 | -18 | | | | | | | |
| 12 | -19 | | | | | | | |
| 13 | -20 | | | | | | | |
| 14 | -21 | | | | | | | |
| 15 | -22 | | | | | | | |
| 16 | -23 | | | | | | | |
| 2 | -24 | | | | 15:06 | JP | SRA0803B | |
| 3 | -25 | | | | | | | |
| 4 | SR180801-2MB | | | | | | | |

JP 8/4/18

Comments:

Page No.: 478630 **B**

(cont. from page 478629 B)

Form 780r8.doc (6/23/06)

Reviewed By / Date JP 8/4/18

Date 8/4/18

SOP 724r 12

# ALS

## Low Background Gas Flow Proportional Counter Log

**Instrument: LB4100A**

*Instrument Daily Response and Background Checks*

| Det. | Daily Response Check Start 1 | Status | Start 2 | Status | Background Check Start 1 | Status | Start 2 | Status | Det. Status |
|---|---|---|---|---|---|---|---|---|---|
| 1 | JP | P | | | JP | (HB) | JP | P | P |
| 2 | | | | | | P | | | |
| 3 | | | | | | | | | |
| 4 | | | | | | | | | |
| 5 | | | | | | (LB) | | | OL |
| 6 | | | | | | P | | | |
| 7 | | | | | | | | | P |
| 8 | | | | | | | | | |
| 9 | | | | | | | | | OL |
| 10 | | | | | | | | | P |
| 11 | | | | | | | | | OL |
| 12 | | | | | | (HL) | JP | P | P |
| 13 | | | | | | P | | | P |
| 14 | | | | | | | | | |
| 15 | | | | | | | | | |
| 16 | | | | | | | | | |

Det = Detector; α = Alpha; β = Beta; P = Pass; H = High; L = Low; OL = Offline; R = Recount; W = Weekly; NP = Not Processed

*Weekly Background Calibration*

| | Current Calib. File ID | Weekly Calib. Started | Status | File ID |
|---|---|---|---|---|
| Dr A | BKA0731W | | | |
| Dr B | | | | |
| Dr C | | | | |
| Dr D | | 0800W | | |

Dr = Drawer

*Gas Supply*

| P-10 Supply | | P-10 Flow | |
|---|---|---|---|
| Tank 1 | 1500 | Dr A | 10 |
| | | Dr B | |
| Tank 2 | 2100 | Dr C | |
| | | Dr D | |

Comments:

Page No.: 478631 A

Form 780r8.doc (6/23/06)

Reviewed By / Date JP 8/4/18

# Radiochemistry Instrument Worksheet

**ALS -- Fort Collins**

**Prep Batch:** RA180803-1

**Prep Procedure:** Ra228 Outher

**Analytical QASS / NCR? Y / N** (N) NA

| Prep Num | LabID | QC Type | Init Alq | Fin Alq | Units | Report Units | Residual Mass (mg) | Cnt 1 File | Cnt 1 Inst/Det | Cnt 1 Pos Chk By | Cnt 2 File | Cnt 2 Inst/Det | Cnt 2 Pos Chk By | Cnt 3 File | Cnt 3 Inst/Det | Cnt 3 Pos Chk By | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1820002-1 | SMP | 25 | 25 | ml | pCi/l | | RA180803 | 4 | JP | | | | | | | |
| 1 | 1820002-2 | SMP | 25 | 25 | ml | pCi/l | | | A 4 | JP | | | | | | | |
| 1 | 1820002-3 | SMP | 25 | 25 | ml | pCi/l | | | B 4 | JP | | | | | | | |
| 1 | 1820002-4 | SMP | 25 | 25 | ml | pCi/l | | | C 4 | JP | | | | | | | |
| 1 | 1820002-5 | SMP | 25 | 25 | ml | pCi/l | | | D 4 | JM | | | | | | | |

Outher JM 8/3/18

**Tracer/Carrier Solution Information**

| Soln # | Nuclide | SolnID | Exp Date | Prep Conc | Units | Prep Date | Aliquot | Units | Pipet ID |
|---|---|---|---|---|---|---|---|---|---|
| T1 | BARIUM | 418241 | 10/12/18 | 16,024.834 | pCi/ml | NA | 2 | ml | RS031 |

**Spike Solution Information**

| Soln # | Nuclide | SolnID | Exp Date | Prep Conc | Units | Prep Date | Aliquot | Units | Pipet ID |
|---|---|---|---|---|---|---|---|---|---|
| S1 | Ra-228 | 1083.4243.30 | 5/22/19 | 311.680 | DPM/ml | 08/03/18 | 10 | ml | RS041 |

## Sample Barcodes

1820002-1
RA180803-1PS1

1820002-2
RA180803-1PS2

1820002-3
RA180803-1PS3

1820002-4
RA180803-1PS4

1820002-5
RA180803-1PS5

## Reporting Units

| LabID: | TstGrpName: | RptUnits: |
|---|---|---|
| 1820002-1 | Ra228_2012 | pCi/l |
| 1820002-2 | Ra228_2012 | pCi/l |
| 1820002-3 | Ra228_2012 | pCi/l |
| 1820002-4 | Ra228_2012 | pCi/l |
| 1820002-5 | Ra228_2012 | pCi/l |

# Radiochemistry Prep Worksheet

**ALS -- Fort Collins**

**Prep Batch:** RA180803-1

**Prep Procedure:** Ra228

**Reviewed By:** rgs RGS **Review Date:** 8/3/2018

**Non-Routine Pre-Treatment?** Y (N) **Batch:** MO **Re-Prep?** Y (N) **Batch:** MO **Prep QASS / NCR?** Y (N) MO

**Prep SOP:** SOP749 **Rev:** 5
**Prep SOP:** NONE
**Matrix Class:** liquid

**Prep Analyst:** Reilly G. Stockton RGS
**Prep Date:** 8/3/2018
**Prep Dept:** RS

**Balance:** N/A
**Balance:** N/A

| Samp Num | Prep Num | LabID | QC Type | Dish No. | Init Alq ml | Fin Alq ml | Prep Basis | Ingrowth Date/Time | Decay Date/Time | Standards | Prep Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1820002-1 | SMP | MO | 25 | 25 | As Received | 07/31/18 17:00 | 08/03/18 09:28 | S1,T1 | |
| 2 | 1 | 1820002-2 | SMP | | 25 | 25 | As Received | 07/31/18 17:00 | 08/03/18 09:28 | S1,T1 | |
| 3 | 1 | 1820002-3 | SMP | | 25 | 25 | As Received | 07/31/18 17:00 | 08/03/18 09:28 | S1,T1 | |
| 4 | 1 | 1820002-4 | SMP | | 25 | 25 | As Received | 07/31/18 17:00 | 08/03/18 09:28 | S1,T1 | |
| 5 | 1 | 1820002-5 | SMP | | 25 | 25 | As Received | 07/31/18 17:00 | 08/03/18 09:28 | S1,T1 | RGS 8/3 |

Comments
**Ra228 calibration**

**Spiked By:** Steve Workman **Date:** 8/2/2018 **Yttrium Added By:** _____ **Date:** _____

**Witnessed By:** Reilly G. Stockton **Date:** 8/2/2018 **Witnessed By:** _____ **Date:** _____

**Tracer/Carrier Solution Information**

| Soln # | Nuclide | SolnID | Exp Date | Prep Conc | Units | Prep Date | Aliquot | Units | Pipet ID |
|---|---|---|---|---|---|---|---|---|---|
| T1 | BARIUM | 418241 | 10/12/18 | 16,024.834 | pCi/ml | NA | 2 | ml | RS031 |

**Spike Solution Information**

| Soln # | Nuclide | SolnID | Exp Date | Prep Conc | Units | Prep Date | Aliquot | Units | Pipet ID |
|---|---|---|---|---|---|---|---|---|---|
| S1 | Ra-228 | 1083.4243.30 | 5/22/19 | 311.680 | DPM/ml | 08/03/18 | 10 | ml | RS041 |

# Radiochemistry Prep Worksheet

**ALS -- Fort Collins**

**Prep Batch:** RA180803-1

**Prep Procedure:** Ra228

## Prep Batch Not Validated!!!

**Reviewed By:** **Review Date:**

**Non-Routine Pre-Treatment? Y / N** **Batch:** _____ **Re-Prep? Y / N** **Batch:** _____ **Prep QASS / NCR? Y / N** _____

**Prep SOP:** SOP749 **Rev:** 5
**Prep SOP:** NONE
**Matrix Class:** liquid

**Prep Analyst:** Reilly G. Stockton RGS
**Prep Date:** 8/3/2018
**Prep Dept:** RS

**Balance:** N/A
**Balance:** N/A

| Samp Num | Prep Num | LabID | QC Type | Dish No. | Init Alq ml | Fin Alq ml | Prep Basis | Ingrowth Date/Time | Decay Date/Time | Standards | Prep Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1820002-1 | SMP | MS | 25 | 25 | As Received | 07/31/18 17:00 | 08/03/18 09:28 | S1,T1 | |
| 2 | 1 | 1820002-2 | SMP | | 25 | 25 | As Received | 07/31/18 17:00 | 08/03/18 09:28 | S1,T1 | |
| 3 | 1 | 1820002-3 | SMP | | 25 | 25 | As Received | 07/31/18 17:00 | 08/03/18 09:28 | S1,T1 | |
| 4 | 1 | 1820002-4 | SMP | | 25 | 25 | As Received | 07/31/18 17:00 | 08/03/18 09:28 | S1,T1 | |
| 5 | 1 | 1820002-5 | SMP | | 25 | 25 | As Received | 07/31/18 17:00 | 08/03/18 09:28 | S1,T1 | |

Comments
**Ra228 calibration**

**Spiked By:** Steve Workman **Date:** 8/2/2018 **Yttrium Added By:** _____ **Date:** _____

**Witnessed By:** Reilly G. Stockton **Date:** 8/2/2018 **Witnessed By:** _____ **Date:** _____

**Tracer/Carrier Solution Information**

| Soln # | Nuclide | SolnID | Exp Date | Prep Conc | Units | Prep Date | Aliquot | Units | Pipet ID |
|---|---|---|---|---|---|---|---|---|---|
| T1 | BARIUM | 418241 | 10/12/18 | 16,024.834 | pCi/ml | NA | 2 | ml | RS031 |

**Spike Solution Information**

| Soln # | Nuclide | SolnID | Exp Date | Prep Conc | Units | Prep Date | Aliquot | Units | Pipet ID |
|---|---|---|---|---|---|---|---|---|---|
| S1 | Ra-228 | 1083.4243.30 | 5/22/19 | 311.680 | DPM/ml | 08/03/18 | 10 | ml | RS041 |

# Sample Condition Form (Liquid)

Analyst: Reilly Stockton

Analysis Date: 8/3/18 | Method: Radium 228

| | | Sample Condition (Visual Appearance of Analysis Aliquot at Time of Prep) | | |
|---|---|---|---|---|
| Work Order | Sample ID | pH | Color | Remarks |
| 1820002 | 1 | 6 | clear | diluted |
| | 2 | | | |
| | 3 | | | |
| | 4 | | | |
| | 5 | | | |

RGS 8/3/18

## Internal Calculation Verifications

# ICBs

# &

# ICVs

# Rad Preliminary Data Report

**Laboratory Name:** ALS -- Fort Collins
**Analytical Run:** RA180810-2A

**Prep SOP:** SOP749
**Analytical SOP:** PAI 724

| Sample ID / QC Type | Nuclide / Type | Sample Date/Time | Prep Batch / QCBatchID | Ingrowth Date /Time | Decay Date/Time | Matrix / %Moist. | Samp Alq / Analy Alq | Inst ID / Det ID | File Name | Count Date/Time | GrossCPM / BkgCPM | BaseEff / ProgEff | CntDur(min) / Yield | Activity +/- / 2 s TPU | MDC / DecLev | ReportUnits / ReportBasis | DER / RPD | %Spk. Recov. / Flags |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1820004-1 | Ra-228 | | RA180810-2 | 8/11/2018 | 8/13/2018 | Liquid | 1000 ml | LB4100-A | | 8/13/2018 | 9.158 | 43.08% | 120 | 9.6 | 0.9 | pCi/l | NA | 108 |
| SMP | Trg. Analyte | | RA180810-2-1 | 2:30:00 PM | 8:45:00 AM | NA | 997 ml | A2 | RAA0813 | 9:43 AM | 2.112 | NA | 96.2% | 2.3 | NA | Unfiltered | NA | |
| 1820004-2 | Ra-228 | | RA180810-2 | 8/11/2018 | 8/13/2018 | Liquid | 1000 ml | LB4100-A | | 8/13/2018 | 8.675 | 44.86% | 120 | 8.8 | 0.8 | pCi/l | NA | 99.0 |
| SMP | Trg. Analyte | | RA180810-2-1 | 2:30:00 PM | 8:45:00 AM | NA | 997 ml | B3 | RAA0813 | 9:43 AM | 1.891 | NA | 97.1% | 2.1 | NA | Unfiltered | NA | |
| 1820004-3 | Ra-228 | | RA180810-2 | 8/11/2018 | 8/13/2018 | Liquid | 1000 ml | LB4100-A | | 8/13/2018 | 9.317 | 46.52% | 120 | 9.5 | 0.7 | pCi/l | NA | 106 |
| SMP | Trg. Analyte | | RA180810-2-1 | 2:30:00 PM | 8:45:00 AM | NA | 997 ml | C2 | RAA0813 | 9:43 AM | 1.808 | NA | 96.6% | 2.3 | NA | Unfiltered | NA | |
| 1820004-4 | Ra-228 | | RA180810-2 | 8/11/2018 | 8/13/2018 | Liquid | 1000 ml | LB4100-A | | 8/13/2018 | 9.133 | 44.90% | 120 | 9.8 | 0.7 | pCi/l | NA | 110 |
| SMP | Trg. Analyte | | RA180810-2-1 | 2:30:00 PM | 8:45:00 AM | NA | 997 ml | D1 | RAA0813 | 9:43 AM | 1.640 | NA | 96.7% | 2.4 | NA | Unfiltered | NA | |
| RA180810-2A | Ra-228 | 8/10/2018 | RA180810-2 | 8/11/2018 | 8/13/2018 | Liquid | 1000 ml | LB4100-A | | 8/13/2018 | 1.958 | 45.06% | 120 | -0.02 | 0.83 | pCi/l | NA | |
| MB | Trg. Analyte | 2:07:41 PM | RA180810-2-1 | 2:30:00 PM | 8:45:00 AM | NA | 997 ml | A4 | RAA0813 | 9:43 AM | 1.976 | NA | 94.1% | 0.36 | NA | Unfiltered | NA | U |
| RA180810-2B | Ra-228 | 8/10/2018 | RA180810-2 | 8/11/2018 | 8/13/2018 | Liquid | 1000 ml | LB4100-A | | 8/13/2018 | 2.083 | 40.53% | 120 | 0.33 | 0.88 | pCi/l | NA | |
| MB | Trg. Analyte | 2:07:41 PM | RA180810-2-1 | 2:30:00 PM | 8:45:00 AM | NA | 997 ml | B4 | RAA0813 | 9:43 AM | 1.857 | NA | 95.2% | 0.42 | NA | Unfiltered | NA | U |
| RA180810-2C | Ra-228 | 8/10/2018 | RA180810-2 | 8/11/2018 | 8/13/2018 | Liquid | 1000 ml | LB4100-A | | 8/13/2018 | 2.158 | 46.48% | 120 | 0.44 | 0.77 | pCi/l | NA | |
| MB | Trg. Analyte | 2:07:41 PM | RA180810-2-1 | 2:30:00 PM | 8:45:00 AM | NA | 997 ml | C4 | RAA0813 | 9:43 AM | 1.817 | NA | 94.2% | 0.38 | NA | Unfiltered | NA | U |
| RA180810-2E | Ra-228 | 8/10/2018 | RA180810-2 | 8/11/2018 | 8/13/2018 | Liquid | 1000 ml | LB4100-A | | 8/13/2018 | 2.208 | 42.72% | 120 | 0.45 | 0.84 | pCi/l | NA | |
| MB | Trg. Analyte | 2:07:41 PM | RA180810-2-1 | 2:30:00 PM | 8:45:00 AM | NA | 997 ml | D2 | RAA0813 | 9:43 AM | 1.884 | NA | 95.4% | 0.41 | NA | Unfiltered | NA | U |

Limits 70-130%

**Comments:**

## Qualifiers/Flags:

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative yield is assumed.

Y2 - Chemical Yield outside default limits.

W - DER is greater than Warning Limit of 1.42

D - DER is greater than Control Limit of 2.13

+ - Duplicate RPD not within limits.

LT - Result is less than Request MDC, greater than sample specific MDC

* - Aliquot Basis is 'As Received' while the Report Basis is 'Dry Weight'.

# - Aliquot Basis is 'Dry Weight' while the Report Basis is 'As Received'.

M - Requested MDC not met.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

L - LCS Recovery below lower control limit.

H - LCS Recovery above upper control limit.

P - LCS, Matrix Spike Recovery within control limits.

N - Matrix Spike Recovery outside control limits

NC - Not Calculated for duplicate results less than 5 times MDC

B - Analyte concentration greater than MDC.

B3 - Analyte concentration greater than MDC but less than Requested MDC.

## Notes:

1) The Tracer results are not yield corrected (i.e. activity measured not activity added).

2) Where sample time is not available, 12:00 PM (Mountain) is used for decay correction.

## Abbreviations:

TR- Tracer TA - Target Analyte

TPU - Total Propagated Uncertainty (see PAI SOP 743)

MDC - Minimum Detectable Concentration (see PAI SOP 709)

DER - Duplicate Error Ratio

BDL - Below Detection Limit

# Rad Preliminary Data Report

**Laboratory Name:** ALS -- Fort Collins

**Prep SOP:** SOP749

**Analytical Run:** RA180810-2B

**Analytical SOP:** PAI 724

| Sample ID<br>QC Type | Nuclide<br>Type | Sample<br>Date/Time | Prep Batch<br>QCBatchID | Ingrowth<br>Date /Time | Decay<br>Date/Time | Matrix<br>%Moist. | Samp Alq<br>Analy Alq | Inst ID<br>Det ID | File Name | Count<br>Date/Time | GrossCPM<br>BkgCPM | BaseEff<br>ProgEff | CntDur(min)<br>Yield | Activity +/-<br>2 s TPU | MDC<br>DecLev | ReportUnits<br>ReportBasis | DER<br>RPD | %Spk. Recov.<br>Flags |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1820004-1 | Ra-228 | | RA180810-2 | 8/11/2018 | 8/13/2018 | Liquid | 1000 ml | LB4100-A | | 8/13/2018 | 7.400 | 40.53% | 60 | 9.8 | 1.5 | pCi/l | NA | 110 |
| SMP | Trg/ Analyte | | RA180810-2-1 | 2:30:00 PM | 8:45:00 AM | NA | 997 ml | B4 | RAA0813A | 11:56 AM | 1.857 | NA | 96.2% | 2.6 | NA | Unfiltered | NA | M3 |
| 1820004-2 | Ra-228 | | RA180810-2 | 8/11/2018 | 8/13/2018 | Liquid | 1000 ml | LB4100-A | | 8/13/2018 | 7.717 | 42.72% | 60 | 9.5 | 1.4 | pCi/l | NA | 106 |
| SMP | Trg/ Analyte | | RA180810-2-1 | 2:30:00 PM | 8:45:00 AM | NA | 997 ml | D2 | RAA0813A | 11:45 AM | 1.884 | NA | 97.1% | 2.5 | NA | Unfiltered | NA | M3 |

Limits
70-130%

**Comments:**

## Qualifiers/Flags:

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative yield is assumed.

Y2 - Chemical Yield outside default limits.

W - DER is greater than Warning Limit of 1.42

D - DER is greater than Control Limit of 2.13

+ - Duplicate RPD not within limits.

LT - Result is less than Request MDC, greater than sample specific MDC

* - Aliquot Basis is 'As Received' while the Report Basis is 'Dry Weight'.

# - Aliquot Basis is 'Dry Weight' while the Report Basis is 'As Received'.

M - Requested MDC not met.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

L - LCS Recovery below lower control limit.

H - LCS Recovery above upper control limit.

P - LCS, Matrix Spike Recovery within control limits.

N - Matrix Spike Recovery outside control limits

NC - Not Calculated for duplicate results less than 5 times MDC

B - Analyte concentration greater than MDC.

B3 - Analyte concentration greater than MDC but less than Requested MDC.

## Notes:

1) The Tracer results are not yield corrected (i.e. activity measured not activity added).

2) Where sample time is not available, 12:00 PM (Mountain) is used for decay correction.

## Abbreviations:

TR- Tracer TA - Target Analyte

TPU - Total Propagated Uncertainty (see PAI SOP 743)

MDC - Minimum Detectable Concentration (see PAI SOP 709)

DER - Duplicate Error Ratio

BDL - Below Detection Limit

# ALS - Gas Flow Proportional Sample Analysis LB4100-A

Unit Type: LB4100-A/W
Counting Unit ID: Orange
High Voltage Mode: Simultaneous
Application Revision: C
Application Version: PA
Rev.05/09/13 JP

Data file name: RAA0813
Batch ID: RA180810-2
Count Preset (m): 120
Batch Ended: 8/13/18 11:46

Background logfile: BKGABW
Date of Bkg. Cal: 8/1/18
Alpha efficiency logfile: Am241R-07/18
Alpha attenuation calibration: AAM119
Beta efficiency logfile: Ra228-08/18
Beta attenuation calibration: ASR1115

Alpha prog. logfile: n/a
Alpha prog. attenuation: n/a
Beta prog. logfile: n/a
Beta prog. attenuation: n/a

| Alpha Attenuation Calibration y = b*m^(a*(mass-x0)) | | Beta Attenuation Calibration y = b*m^(a*(mass-x0)) | |
|---|---|---|---|
| Alpha b= | 0.92510 | Beta b= | 1.0213 |
| m= | 0.99230 | m= | 0.9990 |
| a= | 0.9429 | a= | 0.7203 |
| x0= | 21.4875 | x0= | 0.0000 |
| Alpha to Beta X-talk y = b*m^-x | | Beta to Alpha X-talk y = b*mass + m | |
| a ->b xtalk b= | 0.2621 | b ->a xtalk b= | -2.250E-06 |
| a ->b xtalk m= | 0.9993 | b ->a xtalk m= | 0.0008 |

| Det. ID | Sample ID | Count End Date & Time | Count Dur. (min) | Resid. Mass (mg) | Alpha Activity Gross CPM | Alpha Bkg. CPM | Alpha b>a xtlk CPM | Alpha Base Eff | Alpha Base Cor.Fact. | Alpha Progeny Eff | Alpha Progeny Cor.Fact. | Beta Activity Gross CPM | Beta Bkg. CPM | Beta a>b xtlk CPM | Beta Base Eff | Beta Base Cor.Fact. | Beta Progeny Eff | Beta Progeny Cor.Fact. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C2 | 1820004-3 | 8/13/18 11:46 | 120.00 | 0.0 | 0.267 | 0.154 | 0.006 | 0.2315 | 1.082 | n/a | n/a | 9.317 | 1.808 | 0.0295 | 0.4652 | 1.021 | n/a | n/a |
| C4 | RA180810-2CMB | 8/13/18 11:46 | 120.00 | 0.0 | 0.175 | 0.105 | 0.000 | 0.2180 | 1.082 | n/a | n/a | 2.158 | 1.817 | 0.0183 | 0.4648 | 1.021 | n/a | n/a |
| A2 | 1820004-1 | 8/13/18 11:46 | 120.00 | 0.0 | 0.242 | 0.091 | 0.006 | 0.2135 | 1.082 | n/a | n/a | 9.158 | 2.112 | 0.0395 | 0.4308 | 1.021 | n/a | n/a |
| D1 | 1820004-4 | 8/13/18 11:46 | 120.00 | 0.0 | 0.308 | 0.094 | 0.006 | 0.2299 | 1.082 | n/a | n/a | 9.133 | 1.640 | 0.0562 | 0.4490 | 1.021 | n/a | n/a |
| A4 | RA180810-2AMB | 8/13/18 11:46 | 120.00 | 0.0 | 0.200 | 0.117 | 0.000 | 0.2100 | 1.082 | n/a | n/a | 1.958 | 1.976 | 0.0218 | 0.4506 | 1.021 | n/a | n/a |
| D2 | RA180810-2EMB | 8/13/18 11:46 | 120.00 | 0.0 | 0.100 | 0.085 | 0.000 | 0.2286 | 1.082 | n/a | n/a | 2.208 | 1.884 | 0.0039 | 0.4272 | 1.021 | n/a | n/a |
| B3 | 1820004-2 | 8/13/18 11:46 | 120.00 | 0.0 | 0.333 | 0.129 | 0.005 | 0.2200 | 1.082 | n/a | n/a | 8.675 | 1.891 | 0.0536 | 0.4486 | 1.021 | n/a | n/a |
| B4 | RA180810-2BMB | 8/13/18 11:46 | 120.00 | 0.0 | 0.258 | 0.165 | 0.000 | 0.2133 | 1.082 | n/a | n/a | 2.083 | 1.857 | 0.0245 | 0.4053 | 1.021 | n/a | n/a |

JP 8/14/18

# ALS - Gas Flow Proportional Sample Analysis LB4100-A

Unit Type: LB4100-A/W
Counting Unit ID: Orange
High Voltage Mode: Simultaneous
Application Revision: C
Application Version: PA
Rev.05/09/13 JP

Data file name: RAA0813A
Batch ID: RA180810-2
Count Preset (m): 60
Batch Ended: 8/13/18 12:53

Background logfile: BKGABW
Date of Bkg. Cal: 8/1/18
Alpha efficiency logfile: Am241R-07/18
Alpha attenuation calibration: AAM119
Beta efficiency logfile: Ra228-08/18
Beta attenuation calibration: ASR1115

Alpha prog. logfile: n/a
Alpha prog. attenuation: n/a
Beta prog. logfile: n/a
Beta prog. attenuation: n/a

| Alpha Attenuation Calibration y = b*m^(a*(mass-x0)) | | Beta Attenuation Calibration y = b*m^(a*(mass-x0)) | |
|---|---|---|---|
| Alpha b= | 0.92510 | Beta b= | 1.0213 |
| m= | 0.99230 | m= | 0.9990 |
| a= | 0.9429 | a= | 0.7203 |
| x0= | 21.4875 | x0= | 0.0000 |
| **Alpha to Beta X-talk y = b*m^-x** | | **Beta to Alpha X-talk y = b*mass + m** | |
| a ->b xtalk b= | 0.2621 | b ->a xtalk b= | -2.2506-06 |
| a ->b xtalk m= | 0.9993 | b ->a xtalk m= | 0.0008 |

| Det. ID | Sample ID | Count End Date & Time | Count Dur. (min) | Resid. Mass (mg) | Alpha Activity Gross CPM | Alpha Bkg. CPM | Alpha b>a xtlk CPM | Alpha Base Eff | Alpha Base Cor.Fact. | Alpha Progeny Eff | Alpha Progeny Cor.Fact. | Beta Activity Gross CPM | Beta Bkg. CPM | Beta a>b xtlk CPM | Beta Base Eff | Beta Base Cor.Fact. | Beta Progeny Eff | Beta Progeny Cor.Fact. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| D2 | 1820004-2 | 8/13/18 12:49 | 60.00 | 0.0 | 0.183 | 0.085 | 0.005 | 0.2286 | 1.082 | n/a | n/a | 7.717 | 1.884 | 0.0258 | 0.4272 | 1.021 | n/a | n/a |
| B4 | 1820004-1 | 8/13/18 12:53 | 60.00 | 0.0 | 0.383 | 0.165 | 0.004 | 0.2133 | 1.082 | n/a | n/a | 7.400 | 1.857 | 0.0572 | 0.4053 | 1.021 | n/a | n/a |

JP 8/14/18

Date 8/13/18 SOP 724r 17

# ALS

## Low Background Gas Flow Proportional Counter Log

**Instrument: LB4100A**

*Instrument Daily Response and Background Checks*

| Det. | Daily Response Check Start 1 | Status | Start 2 | Status | Background Check Start 1 | Status | Start 2 | Status | Det. Status |
|---|---|---|---|---|---|---|---|---|---|
| 1 | NP | P | | | NP | (HB) | | | OL |
| 2 | | | | | | P | | | P |
| 3 | | | | | | | | | |
| 4 | | | | | | | | | |
| 5 | | | | | | | | | OL |
| 6 | | | | | | | | | |
| 7 | | | | | | | | | P |
| 8 | | | | | | | | | |
| 9 | | | | | | | | | OL |
| 10 | | | | | | | | | P |
| 11 | | | | | | | | | OL |
| 12 | | | | | | | | | P |
| 13 | | | | | | | | | |
| 14 | | | | | | | | | |
| 15 | | | | | | | | | |
| 16 | | | | | | | | | |

Det = Detector; α = Alpha; β = Beta; P = Pass; H = High; L = Low; OL = Offline; R = Recount; W = Weekly; NP = Not Processed

*Weekly Background Calibration*

| | Current Calib. File ID | Weekly Calib. Started | Status | File ID |
|---|---|---|---|---|
| Dr A | BKA0731W | | | |
| Dr B | | | | |
| Dr C | | | | |
| Dr D | 10801W | | | |

Dr = Drawer

*Gas Supply*

| P-10 Supply | | P-10 Flow | |
|---|---|---|---|
| Tank 1 | 1200 | Dr A | 10 |
| | | Dr B | |
| Tank 2 | 1300 | Dr C | |
| | | Dr D | |

Comments:

Page No.: 478640 A Form 780r8.doc (6/23/06) Reviewed By / Date NP 8/13/18

Date 8/13/18

SOP 724r 12

**ALS**

Low Background Gas Flow Proportional Counter Log

**Instrument: LB4100A**

| Det. | Sample ID | Batch | Test | Count Dur. (min) | Start Time | Analyst Initials | File ID | Output Initials |
|---|---|---|---|---|---|---|---|---|
| 1-16 | Daily EFF | — | — | 10 | 07:03 | NP | EFA0813 | NP |
| 1-16 | Daily BKG | — | — | 60 | 07:17 | | BKA0813 | |
| 2 | 1820004-1 | RA180810-2 | Ra228 | 120 | 9:45 | JP | RAA0813 | NP |
| 7 | -2 | | | | | | | |
| 10 | -3 | | | | | | | |
| 13 | -4 | | | | | | | |
| 4 | RA180810-2AMB | | | | | | | |
| 8 | BMB | | | | | | | |
| 12 | CMB | | | | | | | |
| 14 | EMB | | | | | | | |
| 8 | 1820004-1 | RA180810-2 | Ra226 | 60 | 11:49 | JP | RAA0813A | |
| 14 | -2 | | | | | | | |
| 2 | 1807149-10M | AB180806-1 | α β | 1000 | 13:59 | NP | ABA0813 | |
| 3 | -11 | | | | | | | |
| 4 | -12 | | | | | | | |
| 7 | -13 | | | | | | | |
| 8 | -14 | | | | | | | |
| 10 | -15 | | | | | | | |
| 12 | -16 | | | | | | | |
| 13 | -17 | | | | | | | |
| 14 | AB180806-1MB | | | | | | | |
| 15 | 1807479-14 | AB180807-2 | | | | | | |
| 16 | AB180807-2MB | | | | | | | |

NP 8/14/18

Comments:

Page No.: 478640 **B**

(cont. from page N/A B)

Form 780r8.doc (6/23/06)

Reviewed By / Date NP 8/14/18

# Radiochemistry ICP Worksheet

**ALS -- Fort Collins**

**Prep Batch: RA180810-2**

Prep Procedure: **Ra228**

Reviewed By: **rgs** Review Date: **8/13/2018**

## BARIUM Recovery Results

### Reference Carrier

| LabID | QC Type | Carr Vol | Ref Carr Dil Vol | Ref Carr ICP Alq | Ref Carr ICP Dil Vol | Ref Carr ICP Run | Ref Carr ICP Conc |
|---|---|---|---|---|---|---|---|
| RA180810-2 | CAR | 2 | 27 | 0.05 | 10.05 | IR180810-2A1 | 6.080318 |

### Samples

| Prep Num | LabID | QC Type | Init Samp Alq (ml) | Car Vol (ml) | Samp Dil Vol (ml) | Init ICP Alq (ml) | Init ICP Dil Vol (ml) | Pre-Con Vol (ml) | Post Con Vol (ml) | Pre-Sep Vol (ml) | Post Sep Vol (ml) | Fin ICP Alq (ml) | Fin ICP Dil Vol (ml) | Initial ICP Run | Final ICP Run | Init ICP Conc (ug/ml) | Fin ICP Conc (ug/ml) | Init Samp Mass (ug) | Ref Mass (ug) | Flag | Fin Samp Mass (ug) | % Yield | Final Sample Alq |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1820004-1 | SMP | 1000 | 2 | 1000 | 1 | 10 | 999 | 999 | 999 | 25 | 0.05 | 10.05 | IR180810-2A1 | IR180810-2A1 | 0.00592 | 6.330772 | 59.12623 | 32997.89 | | 31812.13 | 96.23% | 997.0 |
| 1 | 1820004-2 | SMP | 1000 | 2 | 1000 | 1 | 10 | 999 | 999 | 999 | 25 | 0.05 | 10.05 | IR180810-2A1 | IR180810-2A1 | 0.00059 | 6.375039 | 5.846232 | 32997.89 | | 32034.57 | 97.06% | 997.0 |
| 1 | 1820004-3 | SMP | 1000 | 2 | 1000 | 1 | 10 | 999 | 999 | 999 | 25 | 0.05 | 10.05 | IR180810-2A1 | IR180810-2A1 | 0.00037 | 6.347412 | 3.715033 | 32997.89 | | 31895.75 | 96.65% | 997.0 |
| 1 | 1820004-4 | SMP | 1000 | 2 | 1000 | 1 | 10 | 999 | 999 | 999 | 25 | 0.05 | 10.05 | IR180810-2A1 | IR180810-2A1 | 0.00059 | 6.351199 | 5.846232 | 32997.89 | | 31914.77 | 96.70% | 997.0 |
| 1 | RA180810-2A | MB | 1000 | 2 | 1000 | 1 | 10 | 999 | 999 | 999 | 25 | 0.05 | 10.05 | IR180810-2A1 | IR180810-2A1 | 0.00021 | 6.180852 | 2.116633 | 32997.89 | | 31058.78 | 94.12% | 997.0 |
| 1 | RA180810-2B | MB | 1000 | 2 | 1000 | 1 | 10 | 999 | 999 | 999 | 25 | 0.05 | 10.05 | IR180810-2A1 | IR180810-2A1 | 0.00027 | 6.255092 | 2.649433 | 32997.89 | | 31431.84 | 95.25% | 997.0 |
| 1 | RA180810-2C | MB | 1000 | 2 | 1000 | 1 | 10 | 999 | 999 | 999 | 25 | 0.05 | 10.05 | IR180810-2A1 | IR180810-2A1 | 0.00128 | 6.189438 | 12.77263 | 32997.89 | | 31101.93 | 94.22% | 997.0 |
| 1 | RA180810-2E | MB | 1000 | 2 | 1000 | 1 | 10 | 999 | 999 | 999 | 25 | 0.05 | 10.05 | IR180810-2A1 | IR180810-2A1 | 0.00091 | 6.263198 | 9.043033 | 32997.89 | | 31472.57 | 95.35% | 997.0 |





**ALS -- Fort Collins**
LIMS Version: 6.871

**FLAG -** LB: low bias (<= 15%) 15%: low bias (>15%)
Z: Negative init. conc. treated as zer

**Supersedes:** MS

1RI 80810-2A1

Printed 8/10/2018 16:48:54 Page 1

| Sample Id1 | Ca | Fe | K | Mg | Na | Sr | Mn | S | Al | Ba | Pb | U |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CCV | 51.3528 | 20.0363 | 47.9497 | 50.5549 | 49.2689 | 0.5001 | 0.9866 | 4.9135 | 50.1416 | 0.9746 | 0.9859 | 4.9657 |
| CCB | 0.0657 | 0.0246 | 0.1812 | 0.0618 | 0.1379 | 0.0008 | 0.0018 | 0.0000 | 0.0864 | 0.0039 | 0.0038 | 0.0084 |
| I 1820004-1 | 0.0363 | 0.0096 | 0.1634 | 0.0080 | 0.1833 | 0.0010 | 0.0001 | 0.0144 | 0.0429 | 0.0059 | 0.0198 | 0.0037 |
| I 1820004-2 | 0.0113 | 0.0051 | 0.1213 | -0.0032 | 0.0163 | 0.0001 | -0.0003 | 0.0048 | 0.0423 | 0.0006 | 0.0013 | -0.0009 |
| I 1820004-3 | 0.0110 | 0.0051 | 0.1391 | 0.0021 | 0.0098 | 0.0001 | -0.0003 | 0.0000 | 0.0442 | 0.0004 | -0.0022 | -0.0113 |
| I 1820004-4 | 0.0116 | 0.0048 | 0.1159 | 0.0011 | 0.0105 | 0.0000 | 0.0000 | 0.0000 | 0.0442 | 0.0006 | -0.0002 | -0.0038 |
| I RA180810-2AB | 0.0134 | 0.0101 | 0.1213 | 0.0016 | 0.0119 | 0.0001 | -0.0001 | -0.0096 | 0.0557 | 0.0002 | 0.0003 | 0.0094 |
| I RA180810-2BB | 0.0119 | 0.0057 | 0.1132 | 0.0080 | 0.0025 | 0.0001 | 0.0000 | -0.0048 | 0.0493 | 0.0003 | -0.0027 | 0.0262 |
| I RA180810-2CB | 0.0116 | 0.0060 | 0.1079 | -0.0021 | 0.0205 | 0.0001 | -0.0003 | 0.0048 | 0.0531 | 0.0013 | -0.0002 | -0.0028 |
| I RA180810-2~~D~~CB | 0.0220 | 0.0073 | 0.1116 | 0.0027 | 0.0192 | 0.0001 | -0.0002 | 0.0096 | 0.0506 | 0.0009 | 0.0001 | 0.0066 |
| F 1820004-1 | 0.0244 | 0.0190 | 0.1186 | -0.0043 | 93.4244 | 0.0003 | -0.0003 | 1.8204 | 0.0467 | 6.3308 | 0.3047 | -0.0057 |
| F 1820004-2 | 0.0232 | 0.0070 | 0.0890 | 0.0048 | 93.1213 | 0.0004 | 0.0001 | 1.8300 | 0.0499 | 6.3750 | 0.3036 | -0.0009 |
| F 1820004-3 | 0.0168 | 0.0059 | 0.1127 | -0.0037 | 92.6295 | 0.0003 | -0.0002 | 1.8492 | 0.0538 | 6.3474 | 0.3743 | -0.0150 |
| F 1820004-4 | 0.0144 | 0.0054 | 0.1165 | -0.0027 | 92.8730 | 0.0002 | -0.0001 | 1.8300 | 0.0474 | 6.3512 | 0.3345 | -0.0038 |
| F RA180810-2AB | 0.0192 | 0.0064 | 0.1186 | -0.0005 | 92.0312 | 0.0004 | -0.0003 | 1.7483 | 0.0500 | 6.1809 | 0.2458 | 0.0037 |
| F RA180810-2BB | 0.0107 | 0.0068 | 0.1143 | -0.0069 | 92.5009 | 0.0002 | -0.0002 | 1.7627 | 0.0576 | 6.2551 | 0.3266 | -0.0028 |
| F RA180810-2CB | 0.0156 | 0.0076 | 0.1278 | -0.0032 | 92.3052 | 0.0002 | -0.0002 | 1.7723 | 0.0416 | 6.1894 | 0.3044 | -0.0084 |
| F RA180810-2~~D~~CB | 0.0162 | 0.0086 | 0.1327 | 0.0005 | 91.8543 | 0.0003 | -0.0001 | 1.7579 | 0.0525 | 6.2632 | 0.2916 | -0.0028 |
| RA180810-2RC | 0.0205 | 0.0047 | 0.1170 | -0.0059 | 105.7172 | 0.0002 | -0.0004 | 0.0144 | 0.0474 | 6.0803 | 0.0004 | 0.0028 |
| CCV | 51.1182 | 19.8372 | 47.6099 | 50.0229 | 48.9937 | 0.5023 | 0.9737 | 4.7935 | 49.5943 | 0.9757 | 0.9756 | 4.9331 |
| CCB | 0.0660 | 0.0255 | 0.1542 | 0.0565 | 0.1404 | 0.0008 | 0.0020 | -0.0048 | 0.0979 | 0.0040 | 0.0045 | 0.0028 |

RGr
8/15

# Radiochemistry Instrument Worksheet

**ALS -- Fort Collins**

**Prep Batch:** RA180810-2

**Prep Procedure:** Ra228

Analytical QASS / NCR? Y / (N) NA

| Prep Num | LabID | QC Type | Init Alq | Fin Alq | Units | Report Units | Residual Mass (mg) | Cnt 1 File | Cnt 1 Inst/Det | Cnt 1 Pos Chk By | Cnt 2 File | Cnt 2 Inst/Det | Cnt 2 Pos Chk By | Cnt 3 File | Cnt 3 Inst/Det | Cnt 3 Pos Chk By | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1820004-1 | SMP | 1000 | 997.00 | ml | pCi/l | | RAA0813 | 2 | JP | RAA0813A | 8* | JP | | | | |
| 1 | 1820004-2 | SMP | 1000 | 997.00 | ml | pCi/l | | | 7 | | RAA0813A | 14 | | | | | |
| 1 | 1820004-3 | SMP | 1000 | 997.00 | ml | pCi/l | | | 10 | | | | | | | | |
| 1 | 1820004-4 | SMP | 1000 | 997.00 | ml | pCi/l | | | 13 | | | | | | | | |
| 1 | RA180810-2A | MB | 1000 | 997.00 | ml | pCi/l | | | 4 | | | | | | | | |
| 1 | RA180810-2B | MB | 1000 | 997.00 | ml | pCi/l | | | 8 | | | | | | | | |
| 1 | RA180810-2C | MB | 1000 | 997.00 | ml | pCi/l | | | 12 | | | | | | | | |
| 1 | RA180810-2~~A~~ E | MB | 1000 | 997.00 | ml | pCi/l | | | 14 | | | | | | | | |

JP 8/14/18

**Tracer/Carrier Solution Information**

| Soln # | Nuclide | SolnID | Exp Date | Prep Conc | Units | Prep Date | Aliquot | Units | Pipet ID |
|---|---|---|---|---|---|---|---|---|---|
| T1 | BARIUM | 418241 | 10/12/18 | 16,024.834 | pCi/ml | NA | 2 | ml | RS031 |

**Spike Solution Information**

| Soln # | Nuclide | SolnID | Exp Date | Prep Conc | Units | Prep Date | Aliquot | Units | Pipet ID |
|---|---|---|---|---|---|---|---|---|---|
| S1 | Ra-228 | 1014.4095.79 | 3/20/19 | 79.377 | DPM/ml | 08/10/18 | 0.25 | ml | RS019 |

## Sample Barcodes

| | | |
|---|---|---|
| 1820004-1<br>RA180810-2PS1 | 1820004-2<br>RA180810-2PS2 | 1820004-3<br>RA180810-2PS3 |
| 1820004-4<br>RA180810-2PS4 | RA180810-2AMB<br>RA180810-2PS5 | RA180810-2BMB<br>RA180810-2PS6 |
| RA180810-2CMB<br>RA180810-2PS7 | RA180810-2DMB<br>RA180810-2PS8 | RA180810-2CAR<br>RA180810-2PS9 |

## Reporting Units

| LabID: | TstGrpName: | RptUnits: |
|---|---|---|
| 1820004-1 | Ra228_2012 | pCi/l |
| 1820004-2 | Ra228_2012 | pCi/l |
| 1820004-3 | Ra228_2012 | pCi/l |
| 1820004-4 | Ra228_2012 | pCi/l |

*Detectors 8(B4) & 14(D2) had lower base efficiencies than other detectors (40.53% and 42.72%, respectively) An ICV was run in each of them to confirm and verify the detector is acceptable to run client samples. JP 8/14/18

# Radiochemistry Prep Worksheet

**ALS -- Fort Collins**

**Prep Batch:** RA180810-2

**Prep Procedure:** Ra228

**Reviewed By:** rgs RGS **Review Date:** 8/13/2018

**Non-Routine Pre-Treatment? Y / N** Batch: MS **Re-Prep? Y / N** Batch: MS **Prep QASS / NCR? Y / N** MS

**Prep SOP:** SOP749 **Rev:** 5
**Prep SOP:** NONE
**Matrix Class:** liquid

**Prep Analyst:** Reilly G. Stockton RGS
**Prep Date:** 8/10/2018
**Prep Dept:** RS

**Balance:** N/A
**Balance:** N/A

| Samp Num | Prep Num | LabID | QC Type | Dish No. | Init Alq ml | Fin Alq ml | Prep Basis | Ingrowth Date/Time | Decay Date/Time | Standards | Prep Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1820004-1 | SMP | MS | 1000 | 997.002 | Unfiltered | 08/11/18 14:30 | 08/13/18 08:45 | S1,T1 | |
| 2 | 1 | 1820004-2 | SMP | | 1000 | 997.002 | Unfiltered | 08/11/18 14:30 | 08/13/18 08:45 | S1,T1 | |
| 3 | 1 | 1820004-3 | SMP | | 1000 | 997.002 | Unfiltered | 08/11/18 14:30 | 08/13/18 08:45 | S1,T1 | |
| 4 | 1 | 1820004-4 | SMP | | 1000 | 997.002 | Unfiltered | 08/11/18 14:30 | 08/13/18 08:45 | S1,T1 | |
| 5 | 1 | RA180810-2A | MB | | 1000 | 997.002 | Unfiltered | 08/11/18 14:30 | 08/13/18 08:45 | T1 | |
| 6 | 1 | RA180810-2B | MB | | 1000 | 997.002 | Unfiltered | 08/11/18 14:30 | 08/13/18 08:45 | T1 | |
| 7 | 1 | RA180810-2C | MB | | 1000 | 997.002 | Unfiltered | 08/11/18 14:30 | 08/13/18 08:45 | T1 | |
| 8 | 1 | RA180810-2E | MB | | 1000 | 997.002 | Unfiltered | 08/11/18 14:30 | 08/13/18 08:45 | T1 | RGS 8/13 |

Comments
ICV/ICB Radium 228

**Spiked By:** Reilly G. Stockton **Date:** 8/8/2018 **Yttrium Added By:** **Date:**

**Witnessed By:** Nicole C. Chirban **Date:** 8/8/2018 **Witnessed By:** **Date:**

**Tracer/Carrier Solution Information**

| Soln # | Nuclide | SolnID | Exp Date | Prep Conc | Units | Prep Date | Aliquot | Units | Pipet ID |
|---|---|---|---|---|---|---|---|---|---|
| T1 | BARIUM | 418241 | 10/12/18 | 16,024.834 | pCi/ml | NA | 2 | ml | RS031 |

**Spike Solution Information**

| Soln # | Nuclide | SolnID | Exp Date | Prep Conc | Units | Prep Date | Aliquot | Units | Pipet ID |
|---|---|---|---|---|---|---|---|---|---|
| S1 | Ra-228 | 1014.4095.79 | 3/20/19 | 79.377 | DPM/ml | 08/10/18 | 0.25 | ml | RS019 |

# Radiochemistry Prep Worksheet

**ALS -- Fort Collins**

**Prep Batch:** RA180810-2

**Prep Procedure:** Ra228

## Prep Batch Not Validated!!!

**Reviewed By:**

**Review Date:**

**Non-Routine Pre-Treatment? Y / N** **Batch:** _____ **Re-Prep? Y / N** **Batch:** _____ **Prep QASS / NCR? Y / N** _____

**Prep SOP:** SOP749 **Rev:** 5
**Prep SOP:** NONE
**Matrix Class:** liquid

**Prep Analyst:** Reilly G. Stockton RGS
**Prep Date:** 8/10/2018
**Prep Dept:** RS

**Balance:** N/A
**Balance:** N/A

| Samp Num | Prep Num | LabID | QC Type | Dish No. | Init Alq ml | Fin Alq ml | Prep Basis | Ingrowth Date/Time | Decay Date/Time | Standards | Prep Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1820004-1 | SMP | | 1000 | 997.002 | | 14:30 | 8:45 | S1,T1 | |
| 2 | 1 | 1820004-2 | SMP | | 1000 | 997.002 | | 8/11 | 8/13 | S1,T1 | |
| 3 | 1 | 1820004-3 | SMP | | 1000 | 997.002 | | | | S1,T1 | |
| 4 | 1 | 1820004-4 | SMP | | 1000 | 997.002 | | | | S1,T1 | |
| 5 | 1 | RA180810-2A | MB | | 1000 | 997.002 | | | | T1 | |
| 6 | 1 | RA180810-2B | MB | | 1000 | 997.002 | | | | T1 | |
| 7 | 1 | RA180810-2C | MB | | 1000 | 997.002 | | | | T1 | |
| 8 | 1 | RA180810-2D | MB | | 1000 | 997.002 | | | | T1 | |

Comments Rev 9/13

**Spiked By:** Reilly G. Stockton RGS **Date:** 8/8/2018 **Yttrium Added By:** _____ **Date:** _____

**Witnessed By:** Nicole C. Chirban NCC **Date:** 8/8/2018 **Witnessed By:** _____ **Date:** _____

**Tracer/Carrier Solution Information**

| Soln # | Nuclide | SolnID | Exp Date | Prep Conc | Units | Prep Date | Aliquot | Units | Pipet ID |
|---|---|---|---|---|---|---|---|---|---|
| T1 | BARIUM | 418241 | 10/12/18 | 16,024.834 | pCi/ml | NA | 2 | ml | RS031 |

**Spike Solution Information**

| Soln # | Nuclide | SolnID | Exp Date | Prep Conc | Units | Prep Date | Aliquot | Units | Pipet ID |
|---|---|---|---|---|---|---|---|---|---|
| S1 | Ra-228 | 1014.4095.79 | 3/20/19 | 79.377 | DPM/ml | 08/10/18 | 0.25 | ml | RS019 |

# Sample Condition Form (Liquid)

Analyst: Reilly Stockton

Analysis Date: 8/10/18 | Method: Radium 228

| | | Sample Condition (Visual Appearance of Analysis Aliquot at Time of Prep) | | |
|---|---|---|---|---|
| Work Order | Sample ID | pH | Color | Remarks |
| 1820004 | 1 | 6 | clear | diltd |
| ↓ | 2 | ↓ | ↓ | ↓ |
| ↓ | 3 | ↓ | ↓ | ↓ |
| ↓ | 4 | ↓ | ↓ | ↓ |

RGS
8/10/18

DATA

NOT

USED

# Prep Batch: RA180810-2

**Start Date:** 8/10/2018 **End Date:** 8/10/2018
**Start Time:** 14:07 **End Time:** 14:07
**Prep Analyst:** Reilly G. Stockton

**Concentration Method:** NONE
**Extract Method:** SOP7495
**Initial Volume Units:** ml
**Final Volume Units:** ml

**Batch Created By:** rgs
**Date Created:** 8/10/2018
**Time Created:** 14:08

**Validated By:** rgs
**Date Validated:** 8/13/2018
**Time Validated:** 9:51

**Comments:**

ICV/ICB Radium 228

**QC Batch ID:** RA180810-2-1

| Prep Number | Lab ID | QC Type | Matrix | Date Collected | Test Nickname | Initial Wt/Vol | Final Wt/Vol | Cleanup Method | Cleanup DF | Misc. DF | Order Number | Leach Date | Standards | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | RA180810-2 | CAR | Liquid | | Ra228_2012 | 1000 | 1000 | NONE | 1 | 1 | 1820004 | | T1 | |
| 1 | RA180810-2A | MB | Liquid | | Ra228_2012 | 1000 | 997.00 | NONE | 1 | 1 | 1820004 | | T1 | |
| 1 | RA180810-2B | MB | Liquid | | Ra228_2012 | 1000 | 997.00 | NONE | 1 | 1 | 1820004 | | T1 | |
| 1 | RA180810-2C | MB | Liquid | | Ra228_2012 | 1000 | 997.00 | NONE | 1 | 1 | 1820004 | | T1 | |
| 1 | RA180810-2E | MB | Liquid | | Ra228_2012 | 1000 | 997.00 | NONE | 1 | 1 | 1820004 | | T1 | |
| 1 | 1820004-1 | SMP | Liquid | | Ra228_2012 | 1000 | 997.00 | NONE | 1 | 1 | 1820004 | | S1,T1 | L |
| 1 | 1820004-2 | SMP | Liquid | | Ra228_2012 | 1000 | 997.00 | NONE | 1 | 1 | 1820004 | | S1,T1 | L |
| 1 | 1820004-3 | SMP | Liquid | | Ra228_2012 | 1000 | 997.00 | NONE | 1 | 1 | 1820004 | | S1,T1 | L |
| 1 | 1820004-4 | SMP | Liquid | | Ra228_2012 | 1000 | 997.00 | NONE | 1 | 1 | 1820004 | | S1,T1 | L |

# Prep Batch: RA180810-2

**Start Date:** 8/10/2018 **End Date:** 8/10/2018
**Start Time:** 14:07 **End Time:** 14:07
**Prep Analyst:** Reilly G. Stockton

**Concentration Method:** NONE
**Extract Method:** SOP7495
**Initial Volume Units:** ml
**Final Volume Units:** ml

**Batch Created By:** rgs
**Date Created:** 8/10/2018
**Time Created:** 14:08

**Validated By:** rgs
**Date Validated:** 8/13/2018
**Time Validated:** 9:51

** = Client designated matrix qc
L = Original Nickname

## Program Spec: PAI_Standard

**Shared QC:** PAI Protocol
**BatchQCReq:** PAI Protocol
**LCS_LCSDReq:** PAI Protocol
**DUPReq:** PAI Protocol
**MS_MSDReq:** PAI Protocol
☐ Control on MS/MSD

1820004 ProjID: Calib/Blank Ver. Ra228_2012 Ra228 ICV, ICB for Instrument LB4100A

**QC Types**

| | | | |
|---|---|---|---|
| CAR | Carrier reference sample | DUP | Laboratory Duplicate |
| LCS | Laboratory Control Sample | LCSD | Laboratory Control Sample Duplicate |
| MB | Method Blank | MS | Laboratory Matrix Spike |
| MSD | Laboratory Matrix Spike Duplicate | REP | Sample replicate |
| RVS | Reporting Level Verification Standar | SMP | Field Sample |
| SYS | Sample Yield Spike | | |

**Spike Solution Information**

| Soln # | SolnID | Aliquot | Units | PiptetID |
|---|---|---|---|---|
| S1 | 1014.4095.79 | 0.25 | ml | RS019 |
| T1 | 418241 | 2 | ml | RS031 |

Project Ra228 working standard 1014.4095.79 

Continued from Page

Prepare a working dilution of RSO# 1014 TE 1/16/15

1. Density of 8% HNO3, lot # 000008417G
   Mass of 100mL vol. flask: 68.3149g Balance # 12
   Mass of flask & 100mL acid: 172.2758g Balance# 12
   Net Mass: 103.9609g
   Density: 1.0396 g/mL

2. Mass of RSO# 1014 transferred:
   Mass of open empty nalgene: 48.3028g Balance# 12
   Mass of nalgene & standard: 53.2851g Balance# 12
   Net mass of standard transferred: 4.9823g Balance# NA

   TE 1/16/15 TE 1/16/15

3. Dilute to final volume:
   Mass of nalgene, standard, & diluent: 344.9g Balance# 26
   Mass of empty nalgene (from above): 48.3028g Balance# 12
   Net mass of new dilution: 296.6072g Balance# NA

4. Final activity calculation:

$$195\ Bq/g\left(\frac{60\ dpm}{1\ Bq}\right)\left(\frac{4.9823g}{296.6072g}\right)(1.0396\ g/mL) = 204.32\ dpm/mL$$

TE 1/16/15

JP 4/15/15

Std ID: 1014.4095.79

Description: Ra-228
Expiration: 4/9/2016
Activity: 204.32 dpm/mL

2s Uncertainty: 14.71 dpm/mL
Ref. Date: 10/7/2010
Ref Time: N/A
Prep Date: 1/16/2015 Prep by: TE
Matrix/Comp. 8% HNO3
Half Life (y): 5.75E+00

| Revalidation Log | | |
|---|---|---|
| Analysis Date | Initials | Expiration Date |
| 4/2/2016 | JP | 4/02/2017 |
| 3/23/2017 | JP | 3/23/2018 |
| 3/20/2018 | JP | 3/20/2019 |
| | | |
| | | |

JP 4/15/15

Continued on Page

T Elliot 1/16/15
Signed Date

Reviewed and Understood By 4/15/15
Signed Date

KSU 1014

# National Institute of Standards & Technology

# Certificate

## Standard Reference Material® 4339b

### Radium-228 Radioactivity Standard

This Standard Reference Material (SRM) consists of a solution of a standardized and certified quantity of radioactive radium-228 in a suitably stable and homogeneous matrix. It is intended primarily for the calibration of instruments that are used to measure radioactivity and for the monitoring of radiochemical procedures. A unit of SRM 4339b consists of approximately 5 mL of a solution, whose composition is specified in Tables 1 and 2, contained in a flame-sealed borosilicate-glass ampoule [1].

The certified radium-228 massic activity value, at a Reference Time of 1200 EST, 07 October 2010, is:

$$(195 \pm 14)\ \mathrm{Bq \cdot g^{-1}}$$

A NIST certified value, as used within the context of this certificate, is a value for which NIST has the highest confidence in its uncertainty assessment. It is a "measurement result" [2] obtained directly or indirectly from a "primary reference measurement procedure" [3]. The certified value is traceable to the derived SI unit, Becquerel (Bq).

Additional physical, chemical, and radiological properties for this SRM, as well as details on the standardization method, are given in Tables 1 and 2. Uncertainties for the certified quantities are expanded ($k = 2$). The uncertainties are calculated according to the ISO and NIST Guides [4,5]. Table 3 contains a specification of the components that comprise the uncertainty analyses.

**Expiration of Certification:** The certification of SRM 4339b is valid indefinitely, within the measurement uncertainty specified, provided that the SRM is handled and stored properly and that no evaporation or change in composition has occurred. The solution matrix, in an unopened ampoule, is homogeneous and stable within its half-life-dependent useful lifetime provided the SRM is handled in accordance with instructions given in this certificate (see "Instructions for Handling and Storage"). Periodic recertification of this SRM is not required. The certification is nullified if the SRM is damaged, contaminated, or otherwise modified.

**Maintenance of SRM Certification:** NIST will monitor this SRM over the period of its certification. If substantive technical changes occur that affect the certification, NIST will notify the purchaser. Registration (see attached sheet) will facilitate notification.

**Radiological and Chemical Hazard:** Consult the Safety Data Sheet (SDS), enclosed with the SRM shipment, for radiological and chemical hazard information.

This SRM was prepared in the Physical Measurement Laboratory, Radiation and Biomolecular Physics Division, Radioactivity Group, M.P. Unterweger, Group Leader. The overall technical direction and physical measurement leading to certification and photon-emitting impurity analyses were provided by L. Pibida of the NIST Radioactivity Group, with production assistance by J. LaRosa, R. Collé, and L. Laureano-Pérez. Alpha-emitting impurity analyses were provided by J. LaRosa.

Support aspects involved in the issuance of this SRM were coordinated through the NIST Office of Reference Materials.

Lisa R. Karam, Chief
Radiation and Biomolecular Physics Division

Gaithersburg, Maryland 20899

Robert L. Watters, Jr., Director
Office of Reference Materials

Certificate Issue Date: 14 November 2012

Table 1. Certified Massic Activity of SRM 4339b

| | |
|---|---|
| **Radionuclide** | **Radium-228**[a] |
| **Reference time** | **1200 EST, 07 October 2010** |
| **Massic activity of the solution** | **195 Bq•g$^{-1}$** |
| **Relative expanded uncertainty ($k$ = 2)** | **7.2 %**[b] |

[a] The final $^{228}$Ra purification from the $^{232}$Th mother solution was performed on 02 September 2010 0920 EST.
[b] The uncertainties on certified values are expanded uncertainties, $U = ku_c$. The quantity $u_c$ is the combined standard uncertainty calculated according to the ISO and NIST Guides [4,5]. The combined standard uncertainty is multiplied by a coverage factor of $k$ = 2 and was chosen to obtain what is assumed to be an approximate 95 % level of confidence.

Table 2. Uncertified Information of SRM 4339b

| | |
|---|---|
| Source description | Liquid in a flame-sealed 5 mL borosilicate-glass ampoule [1] |
| Solution composition | 1.3 mol•L$^{-1}$ $HNO_3$ with 19.8 µg•g$^{-1}$ $Ba^{+2}$ |
| Solution density | (1.034 ± 0.002) g•mL$^{-1}$ at 20.8 °C[a] |
| Solution mass | (5.180 ± 0.003) g[a] |
| Photon-emitting impurities | $^{228}$Ra: < 0.5 Bq•g$^{-1}$[b] |
| Alpha-emitting impurities | $^{232}$Th: < 0.08 Bq•g$^{-1}$[c] |
| Half-lives used | $^{228}$Ra: (5.75 ± 0.04) a[d] [6]<br>$^{228}$Ac: (6.15 ± 0.02) h [7]<br>$^{224}$Ra: (1600 ± 7) a [8]<br>$^{232}$Th: (14.02 ± 0.06) x $10^{9}$ a [9] |
| Calibration methods (and instruments) | The certified massic activity for $^{228}$Ra was obtained by high-resolution gamma-ray spectrometry of three master solution ampoules (eleven separate determinations), as measured on three to five different spectrometers and geometries on each ampoule, and used assumed nuclear data for probabilities per decay for 16 gamma-ray transitions. Confirmatory measurements were performed by 2πα spectrometry of ingrown $^{228}$Th with a planar, ion-implanted Si detector. |

[a] The stated uncertainty is two times the standard uncertainty. See reference 5.
[b] Based on gamma-ray spectrometry of forced-fitted peak at 186.2 keV and assuming a probability per decay of 0.0355 [6].
[c] The maximum $^{232}$Th activity concentration in $^{228}$Ra.
[d] The stated uncertainty is the standard uncertainty. See reference 5.

Table 3. Uncertainty Evaluation for the Massic Activity of SRM 4339b

| | Uncertainty component | Assessment Type[a] | Relative standard uncertainty contribution on massic activity of $^{228}$Ra (%) |
|---|---|---|---|
| 1 | Gamma-ray spectrometry precision; relative standard deviation of the grand mean on the average massic gamma-ray emission rates for 16 measured $^{228}$Ac gamma-ray transitions. Each mean in the grand mean is based on 11 determinations with three sources in three to five different detectors. The uncertainty in the determination of the massic gamma-ray emission rate for any one transition in a given determination ranged from typically 0.5 % to 1.5 %. The relative standard deviation of the mean for the average of the 16 lines, for any one determination, was typically 1 %; whereas the relative standard deviation of the grand mean for the average of the 16 lines across all 11 determinations is 0.34 %[b]. Data passes normality test. | A | 0.84 |
| 2 | Uncertainty due to assumed gamma-ray probabilities per decay for the measured $^{228}$Ac transitions [7]. The uncertainty on each transition has a shared (correlated) component of 2.5 % (see comments in [7]). | B | 3.5 |
| 3 | Detection efficiencies not embodied within component 1 | B | 0.4 |
| 4 | Mass determinations for dilution factors and counting source preparations | B | 0.1 |
| 5 | Decay corrections for $^{228}$Ra half-life uncertainty of 0.7 % [6] | B | 0.003 |
| 6 | Effect of $^{228}$Ra and $^{228}$Ac half-life uncertainties on secular equilibrium ratio | B | 0.02 |
| **Relative combined standard uncertainty** | | | 3.6 |
| **Relative expanded uncertainty ($k = 2$)** | | | 7.2 |

[a] Letter A denotes evaluation by statistical methods; B denotes evaluation by other methods.
[b] Average massic gamma-ray emission rates of 11 geometries ($R_\gamma$) for 16 measured $^{228}$Ac gamma-ray transitions with their respective energy ($E_\gamma$); assumed gamma-ray probabilities per decay ($I_\gamma$) and standard deviation of the mean ($S_m$).

| $E_\gamma$ (keV) | Assumed $I_\gamma$ (%) [1] | Mean $R_\gamma$ ($s^{-1} \cdot g^{-1}$)[i] | $S_m$ (%)[ii] |
|---|---|---|---|
| 129.065 | 2.50 | 1347 | 0.38 |
| 153.967 | 0.754 | 421.6 | 0.40 |
| 209.249 | 3.97 | 2264 | 0.55 |
| 270.245 | 3.55 | 2014 | 0.33 |
| 328.004 | 3.04 | 1822 | 0.43 |
| 338.32 | 11.4 | 6712 | 0.43 |
| 409.46 | 2.02 | 1185 | 0.29 |
| 463.002 | 4.45 | 2645 | 0.33 |
| 755.313 | 1.03 | 593.3 | 0.46 |
| 772.291 | 1.52 | 899.2 | 0.53 |
| 794.942 | 4.31 | 2588 | 0.35 |
| 835.704 | 1.7 | 995.3 | 0.42 |
| 911.196 | 26.2 | 15609 | 0.29 |
| 964.786 | 4.99 | 3007 | 0.35 |
| 968.96 | 15.9 | 9582 | 0.30 |
| 1588.2 | 3.06 | 1889 | 0.28 |

(i) Grand mean for $n = 11$ determinations with three sources in three to five different detectors.
(ii) Relative standard deviation of the grand mean on $R_\gamma$ for $n = 11$.

## INSTRUCTIONS FOR HANDLING AND STORAGE

**Handling:** If the ampoule is transported, it should be packed, marked, labeled, and shipped in accordance with the applicable national, international, and carrier regulations. The solution in the ampoule is a dangerous good (hazardous material) because of both the radioactivity and the strong acid. The ampoule should be opened only by persons qualified to handle both radioactive material and alkaline and/or acidic solutions. Appropriate shielding and/or distance should be used to minimize personnel exposure. Refer to SDS for further information.

**Storage:** SRM 4339b should be stored and used at a temperature between 5 °C and 65 °C. The ampoule (or any subsequent container) should always be clearly marked as containing radioactive material.

## REFERENCES


[1] NIST Physical Measurement Laboratory; *Storage and Handling of Radioactive Standard Reference Materials, Ampoule Specifications and Opening Procedure*, available at http://www.nist.gov/pml/div682/grp04/srm.cfm (accessed Nov 2012). Note: This SRM is contained in a generic borosilicate-glass ampoule and not in the standard NIST ampoule.

[2] JCGM 200:2012; *International Vocabulary of Metrology - Basic and General Concepts and Associated Terms (VIM)* (2008 version with Minor Corrections), 3rd edition; Joint Committee for Guides in Metrology: BIPM, Sevres Cedex, France; p. 19 (2012); available at http://www.bipm.org/utils/common/documents/jcgm/JCGM_200_2012.pdf (accessed Nov 2012).

[3] JCGM 200:2012; *International Vocabulary of Metrology - Basic and General Concepts and Associated Terms (VIM)* (2008 version with Minor Corrections), 3rd edition; Joint Committee for Guides in Metrology: BIPM, Sevres Cedex, France; p. 18 (2012); available at http://www.bipm.org/utils/common/documents/jcgm/JCGM_200_2012.pdf (accessed Nov 2012).

[4] JCGM 100:2008; *Guide to the Expression of Uncertainty in Measurement;* (ISO GUM 1995 with Minor Corrections), Joint Committee for Guides in Metrology: BIPM, Sevres Cedex, France (2008); available at http://www.bipm.org/utils/common/documents/jcgm/JCGM_100_2008_E.pdf (accessed Nov 2012).

[5] Taylor, B.N.; Kuyatt, C.E.; *Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results*; NIST Technical Note 1297, U.S. Government Printing Office: Washington, DC (1994); available at http://physics.nist.gov/Pubs/ (accessed Nov 2012).

[6] Luca, A.; June 2009, $^{228}$Ra. LNE-LNHB/CEA Table of Radionuclides, available at http://www.nucleide.org/DDEP_WG/Nuclides/Ra-228_tables.pdf (accessed Nov 2012).

[7] Pearce, A.; January 2010, $^{228}$Ac. LNE-LNHB/CEA Table of Radionuclides, available at http://www.nucleide.org/DDEP_WG/Nuclides/Ac-228_tables.pdf (accessed Nov 2012).

[8] Christé, V. and M.M. Bé; December 2006, $^{226}$Ra. LNE-LNHB/CEA Table of Radionuclides, available at http://www.nucleide.org/DDEP_WG/Nuclides/Ra-226_tables.pdf (accessed Nov 2012).

[9] Arinc, A.; September 2008, $^{232}$Th. LNE-LNHB/CEA Table of Radionuclides, available at http://www.nucleide.org/DDEP_WG/Nuclides/Th-232_tables.pdf (accessed Nov 2012).


*Users of this SRM should ensure that the Certificate in their possession is current. This can be accomplished by contacting the SRM Program: telephone (301) 975-2200; fax (301) 948-3730; e-mail srminfo@nist.gov; or via the Internet at http://www.nist.gov/srm.*

# Radiochemistry Solution Report

| | | | | | |
|---|---|---|---|---|---|
| **Solution Id:** | 418241 | **Name:** | barium carrier | **Type:** | IS |
| | | **Lot:** | | **Vendor Name:** | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Final Vol:** | 4000 | **Dept:** | RD | **Prep By** | ARS | **on** | 10/12/2017 | **Reviewed By** | tde | **on** | 10/20/2017 |
| **Units:** | mL | **Location:** | SR/RA | **Opened By** | | **on** | | **Verified By** | ARS | **on** | 10/12/2017 |
| **Matrix:** | LIQUID | **ExpireDate:** | 10/12/2018 | **Received By** | | **on** | | **Deactivated By** | | **on** | |

**Comment:**

| Component Name | Component ID | Volume Added | Units |
|---|---|---|---|
| Barium Stable Carrier Source<1> | 3756 B07592 | 114.0165 | g |

| CompName | Calibrated Primary Act/Conc | Calibration Date | Reference Date | 1/2 Life (Yrs) | Final Act/Conc | Summed Conc | Units |
|---|---|---|---|---|---|---|---|
| BARIUM | 562193.5 | | 6/14/2018 | | 16024.83 | | pCi/ml |

## Associated Parent IDs

3756 B07592

**Abbreviations: NC = Not Calculated for reagents when the volume added is not entered.**
**NE = Not Entered**

**(Prnt) = Secular equilibrium; parent half life used to calculate concentration.**

Instrument: LB4100-C

Calibration: Ra-228

Date of Calibration: 06/19/2017

Efficiency Log Files: **RA228-06/17**

Efficiency Instrument Files: ERA0619A-D

Source ID's: Efficiency (Ra-228 784.3020.37)
ICV/ICB's (Ra-228 1014.4095.79)

Calibraton Re-Verified
06/07/2018
New Exp Date
06/05/2019
JP 6/7/18

ALS

# QUALITY ASSURANCE SUMMARY SHEET

ALS W.O. # / BATCH Inst C Calibration
TEST Various
METHOD GFPC
SOP/REV (PREP) Various
SOP/REV (ANAL) 724

Briefly document any QA or other problems or deviations associated with the analysis of samples. Problems could result from: log-in, color, odor, dilution, consistency, scheduling, equipment, or instrumentation, or may include documentation of minor deviations necessary due to unique DQO's or sample characteristics. JP 6/6/18

JP 6/6/18

ALS Fort Collins SOP 724 requires an efficiency calibration for each Gas Flow test to be performed annually for each instrument. Per Technical Manager, the efficiency calibrations performed in 2017 for Instrument C will be acceptable for another year providing the following acceptance criteria was met: 1) Plateau checks were performed and were within acceptance criteria (The beta slope at the beta voltage and the alpha slope at the beta voltage had a slope of less than 3.5%). 2) CCV's and CCB's were performed for each calibration and were within the acceptance criteria. These results for the plateau checks and the CCV's/CCB's can be found in the "Addendum" section in the back of the calibration.

JP 6/6/18

The instrument will be monitored with daily efficiency checks, daily background checks, and long background calibrations every two weeks, as well as quarterly plateau checks as required per SOP 724. If any detectors fail any of these checks, the specific detector will be taken offline for the day and not be used to count client samples. If a detector fails its quarterly plateau check, the detector will be taken off-line until the instrument is re-calibrated for Voltage Plateaus, ROI's, and efficiency calibrations.

JP 6/6/18

JP 6/6/18

TECHNICIAN/ANALYST _____ DATE _____

DEPARTMENT MANAGER _____ DATE 6/6/18

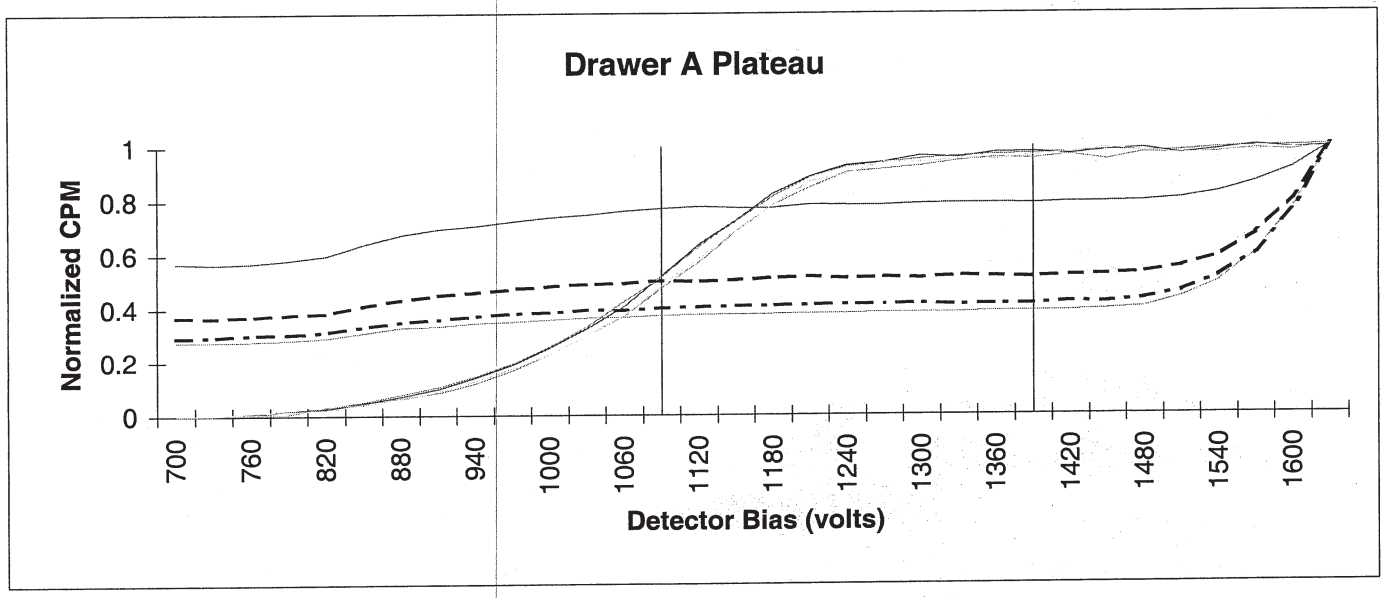
FORM 302r6.doc (4/22/04)

452915

# Instrument Plateaus

Unit Type: LB4100/W
Date Performed: 6/6/17 08:23
FileName: PTC0606A
Batch ID: DRAWER A PLATEAU

Unit Id: Magenta
Application Revision: 2
Application Version: Standard




Optimum alpha beta simultaneous operating voltage: 1402.5

Optimum alpha only operating voltage: 1087.5

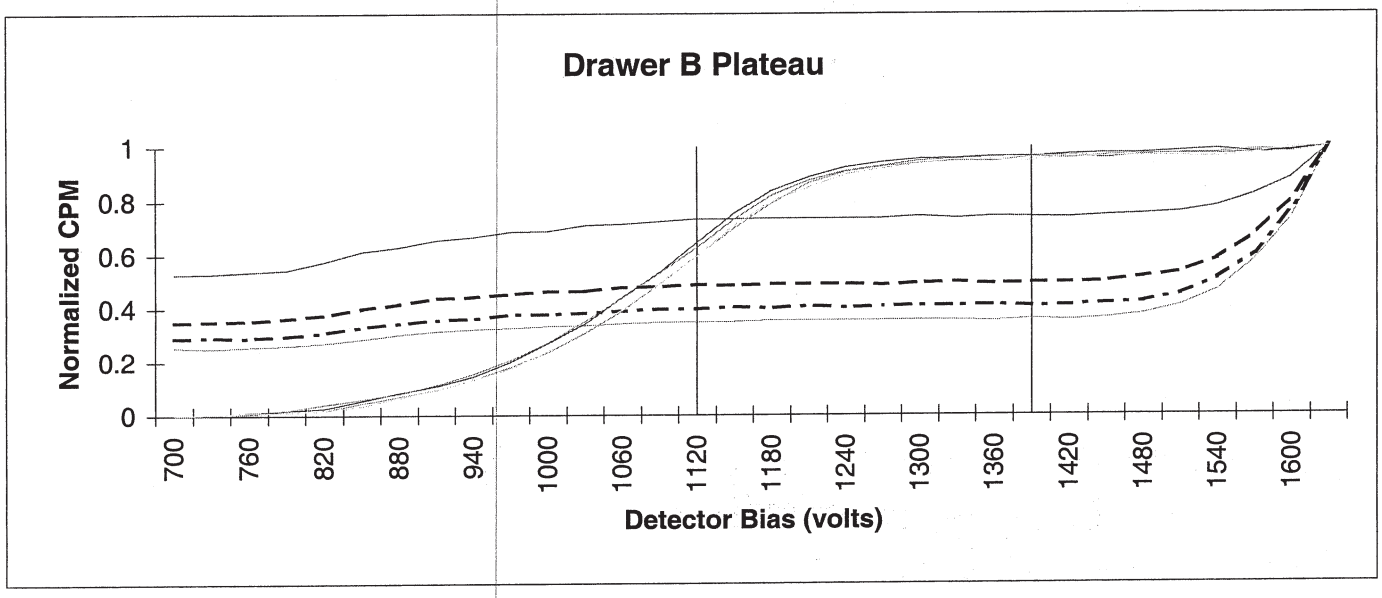
| | A1 | A2 | A3 | A4 |
|---|---|---|---|---|
| Beta slope at beta voltage | 1.47% | 1.71% | 0.53% | 3.64% |
| Alpha slope at beta voltage | 0.19% | 0.63% | 1.60% | 1.64% |
| Alpha slope at alpha voltage | 3.18% | 2.44% | 3.36% | 3.18% |

OK JP 6/9/17

Printed 6/6/2017 2:14 PM

Unit Type: LB4100/W
Date Performed: 6/6/17 08:23
FileName: PTC0606B
Batch ID: DRAWER B PLATEAU

Unit Id: Magenta
Application Revision: 2
Application Version: Standard




Optimum alpha beta simultaneous operating voltage: 1402.5

Optimum alpha only operating voltage: 1120

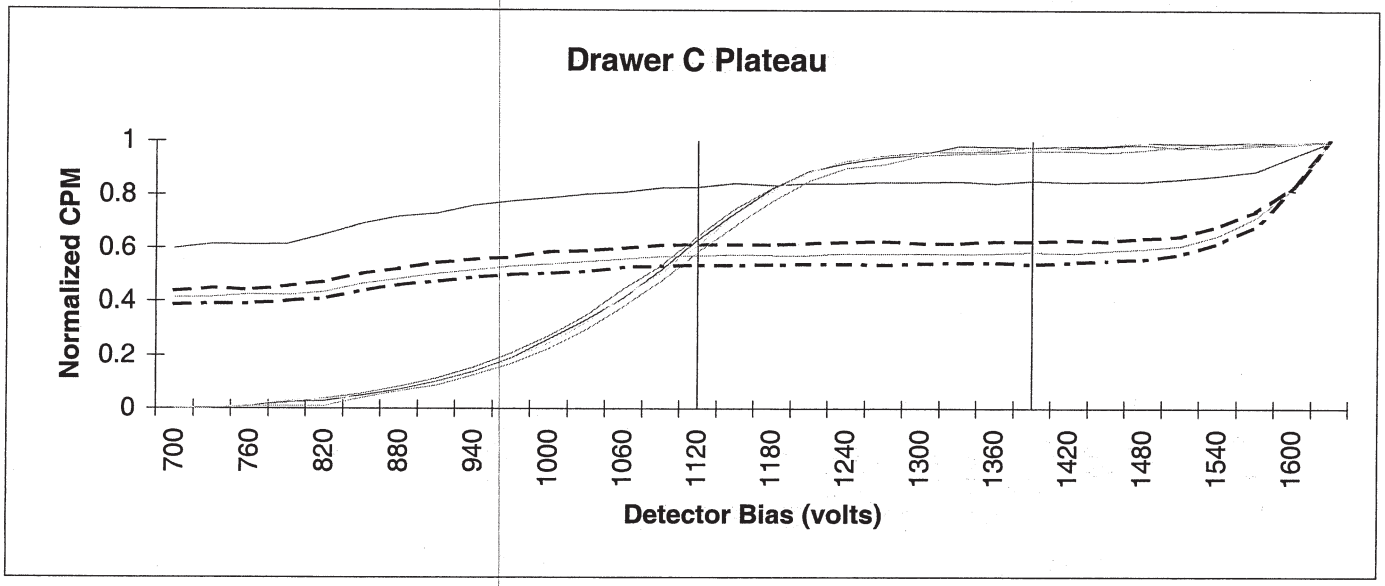
| | B1 | B2 | B3 | B4 |
|---|---|---|---|---|
| Beta slope at beta voltage | 1.46% | 0.21% | 1.67% | 1.02% |
| Alpha slope at beta voltage | 0.74% | 0.41% | 1.47% | 0.77% |
| Alpha slope at alpha voltage | 2.44% | 2.07% | 2.12% | 2.16% |

OK JP 6/9/17

Printed 6/6/2017 2:16 PM

Unit Type: LB4100/W
Date Performed: 6/5/17 16:24
FileName: PTC0605C
Batch ID: DRAWER C PLATEAU

Unit Id: Magenta
Application Revision: 2
Application Version: Standard




Optimum alpha beta simultaneous operating voltage: 1402.5

Optimum alpha only operating voltage: 1120

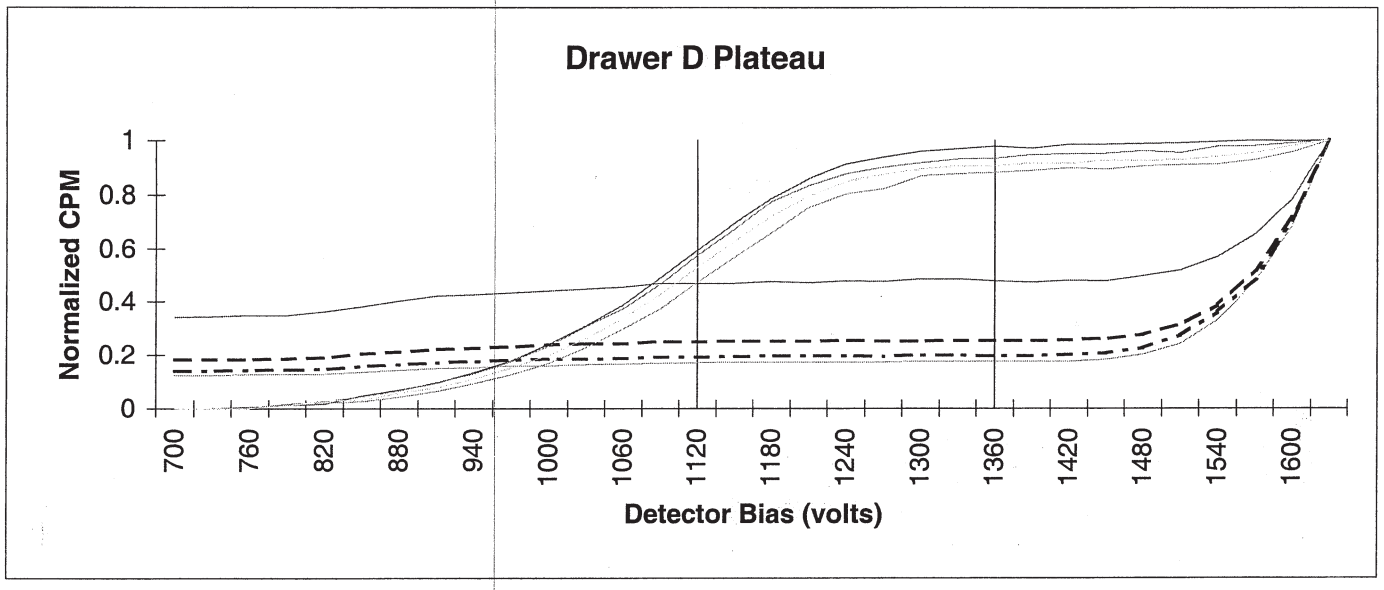
| | C1 | C2 | C3 | C4 |
|---|---|---|---|---|
| Beta slope at beta voltage | 0.01% | 1.81% | 0.66% | 1.49% |
| Alpha slope at beta voltage | 0.09% | 0.91% | 1.33% | 0.91% |
| Alpha slope at alpha voltage | 2.85% | 1.52% | 2.04% | 1.53% |

OK JR 6/9/17

Printed 6/6/2017 8:08 AM

Unit Type: LB4100/W
Date Performed: 6/5/17 16:24
FileName: PTC0605D
Batch ID: DRAWER D PLATEAU

Unit Id: Magenta
Application Revision: 2
Application Version: Standard




Optimum alpha beta simultaneous operating voltage: 1372.5

Optimum alpha only operating voltage: 1120

| | D1 | D2 | D3 | D4 |
|---|---|---|---|---|
| Beta slope at beta voltage | 1.86% | 2.83% | 2.42% | 2.14% |
| Alpha slope at beta voltage | -1.26% | 0.56% | 0.63% | 0.33% |
| Alpha slope at alpha voltage | 3.38% | 3.01% | 3.50% | 3.06% |

OK JP 6/9/17

Printed 6/9/2017 2:54 PM

Date 6/5/17

SOP 724r 12

# ALS
## Low Background Gas Flow Proportional Counter Log
## Instrument: LB4100C

*Instrument Daily Response and Background Checks*

| Det. | Daily Response Check Start 1 | Status | Start 2 | Status | Background Check Start 1 | Status | Start 2 | Status | Det. Status |
|---|---|---|---|---|---|---|---|---|---|
| 1 | JCB | P | | | JCB | P | | | P |
| 2 | | | | | | | | | |
| 3 | | | | | | | | | |
| 4 | | | | | | | | | |
| 5 | | | | | | | | | |
| 6 | | | | | | | | | |
| 7 | | | | | | | | | |
| 8 | | | | | | | | | |
| 9 | | | | | | HB | JCB | P | |
| 10 | | | | | | P | | | |
| 11 | | | | | | | | | |
| 12 | | | | | | HB | | | OL |
| 13 | | | | | | P | | | P |
| 14 | | | | | | | | | |
| 15 | | | | | | | | | |
| 16 | | | | | | | | | |

Det = Detector; α = Alpha; β = Beta; P = Pass; H = High; L = Low; OL = Offline; R = Recount; W = Weekly; NP = Not Processed

*Weekly Background Calibration*

| | Current Calib. File ID | Weekly Calib. Started | Status | File ID |
|---|---|---|---|---|
| Dr A | ~~BKC0523~~ BKC0520W | | | |
| Dr B | | | | |
| Dr C | | | | |
| Dr D | | | | |

Dr = Drawer

*Gas Supply*

| P-10 Supply | | P-10 Flow | |
|---|---|---|---|
| Tank 1 | | Dr A | 10 |
| | | Dr B | |
| Tank 2 | | Dr C | |
| | | Dr D | |

Comments:

Date 6/5/17 SOP 724r 12

**ALS**

Low Background Gas Flow Proportional Counter Log

**Instrument: LB4100C**

| Det. | Sample ID | Batch | Test | Count Dur. (min) | Start Time | Analyst Initials | File ID | Output Initials |
|---|---|---|---|---|---|---|---|---|
| 1-16 | Daily Eff | — | — | 30 | 820 | JKB | EFC0605 | JKB |
| 1-16 | Daily Bkgd | — | — | 60 | 833 | JKB | BKC0605 | |
| 9 | ↓ | — | — | 60 | 905 | JKB | BKC0605A | ↓ |
| 1-4 | Alpha/Beta | Drawer A Plat. | Plateau | 5 min/step | 1009 | ↓ | PTC0605A | ↓ |
| 5-8 | Beta/Alpha | Drawer B Plateau | ↓ | ↓ | ↓ | ↓ | PTC0605B | ↓ |
| 9-12 | Alpha/Beta | Drawer C Plateau | ↓ | ↓ | 1630 | ↓ | PTC0605C | ↓ |
| 13-16 | Beta/Alpha | Drawer D Plateau | ↓ | ↓ | ↓ | ↓ | PTC0605D | ↓ |

JKB 6/11/17

Comments:

Page No.: 471486 B

(cont. from page N/A B)

Form 780r8.doc (6/23/06)

Reviewed By / Date JKB 6/11/17

4/4/17 Drawers A+B removal from Instrument and sent back to Canberra to fix guard detector / Slide tray connection so the 3 guard pins holding the two together dont become loose over time due to opening and closing the drawers resulting in ↑ beta cpm, ↓ guard cpm

5/1/17 Drawers A+B received back from Canberra. Drawers re-installed in the instrument, daily performance check JR 5/1/17 run after allowing time for the gas to purge. ~~Weekly~~ Long Background calibration performed. Drawers A+B are now back on line.

6/5/17 Voltage Plateau
~~Plateau Check~~ run for drawers A-D

JR 6/11/17

| α sources used | | detectors | | β sources used | |
|---|---|---|---|---|---|
| 410 | Am241 | A1 B1 C1 D1 | | 406 | Sr 90/Y90 |
| 411 | 17800 dpm | A2 B2 C2 D2 | | 407 | 29600 dpm |
| 412 | 2/16/95 | A3 B3 C3 D3 | | 408 | 9/15/95 |
| 413 | | A4 B4 C4 D4 | | 409 | |

Parameters:

| | | | |
|---|---|---|---|
| Starting voltage 700 | Count preset 40000 | Filenames: | |
| Ending voltage 1650 | Time btwn steps 0.1 | PTC0605A | |
| 30V/step | Weak check times 0.1 | PTC0605B | |
| 5min/step | Weak check limits 20 | | |

6/7/17
ROIs set for all drawers using Sr/Y-90 sources
Sources → 406, 407, 408, + 409: over 40,000 counts achieved per each detector. α Lower limit + β upper limit set to 50% to start. Both lower limit + β upper limit moved to achieve β→α x talk of 2.5%. α lower limit moved to achieve α→β x talk of 0.10%
All ROIs archived

Continued on Page

Read and Understood By

Signed 6/11/17 Date

Signed 6/13/17 Date

# Instrument ROIs

# LB4100 -C Water Sample Counting Parameters

| | |
|---|---|
| Certainty requirement for MDA and flags | 95% |
| Maximum count time (min) | 360.00 |
| Typical Residual Mass (mg) | 50.00 |
| Typical Sample Volume (l) | 0.10 |

| | α |
|---|---|
| Action level for flags (pCi/l) | 1.200E+02 |
| Activity Multiplier | 1.000E+00 |
| Mass Error (%) | 1.00% |
| Volume Error (%) | 1.00% |

| | Alpha | | | Beta | | |
|---|---|---|---|---|---|---|
| | eff. | bkg. | MDA (pCi/l) | eff. | bkg. | MDA (pCi/l) |
| A1 | 15.92% | 0.078 | 1.812E+00 | 37.98% | 1.436 | 3.017E+00 |
| A2 | 16.59% | 0.094 | 1.889E+00 | 37.36% | 1.336 | 2.958E+00 |
| A3 | 16.06% | 0.096 | 1.971E+00 | 37.67% | 1.51 | 3.120E+00 |
| A4 | 16.20% | 0.083 | 1.831E+00 | 38.95% | 1.532 | 3.039E+00 |

Batch Specific:

| | Event | Recycle |
|---|---|---|
| Magenta | 1 | 0 |

Drawer Specific:

| | Date/Time | Official | Bias | Step |
|---|---|---|---|---|
| A | 6-6-17 8:23 | TRUE | 1402.5 | 0 |
| B | 6-6-17 8:23 | TRUE | 1402.5 | 0 |
| C | 6-5-17 16:24 | TRUE | 1402.5 | 0 |
| D | 6-5-17 16:24 | TRUE | 1372.5 | 0 |

Detector Specific:

| | Date/Time | Official | Threshold | bLL | bUL | aLL | aUL |
|---|---|---|---|---|---|---|---|
| A1 | 6-7-17 0:00 | TRUE | 0.1 | 0 | 40.07 | 80.17 | 100 |
| A2 | 6-7-17 0:00 | TRUE | 0.1 | 0 | 38.87 | 77.48 | 100 |
| A3 | 6-7-17 0:00 | TRUE | 0.1 | 0 | 36.33 | 74.84 | 100 |
| A4 | 6-7-17 0:00 | TRUE | 0.1 | 0 | 35.53 | 72.18 | 100 |
| B1 | 6-7-17 0:00 | TRUE | 0.1 | 0 | 39.75 | 79.58 | 100 |
| B2 | 6-7-17 0:00 | TRUE | 0.1 | 0 | 40.63 | 77.85 | 100 |
| B3 | 6-7-17 0:00 | TRUE | 0.1 | 0 | 36.99 | 75.53 | 100 |
| B4 | 6-7-17 0:00 | TRUE | 0.1 | 0 | 36.53 | 74.87 | 100 |
| C1 | 6-7-17 0:00 | TRUE | 0.1 | 0 | 36.53 | 73.52 | 100 |
| C2 | 6-7-17 0:00 | TRUE | 0.1 | 0 | 37.82 | 75.5 | 100 |
| C3 | 6-7-17 0:00 | TRUE | 0.1 | 0 | 33.33 | 70.13 | 100 |
| C4 | 6-7-17 0:00 | TRUE | 0.1 | 0 | 35.45 | 72.25 | 100 |
| D1 | 6-7-17 0:00 | TRUE | 0.1 | 0 | 25.76 | 53.3 | 100 |
| D2 | 6-7-17 0:00 | TRUE | 0.1 | 0 | 24.2 | 46.69 | 100 |
| D3 | 6-7-17 0:00 | TRUE | 0.1 | 0 | 18.87 | 40.7 | 100 |
| D4 | 6-7-17 0:00 | TRUE | 0.1 | 0 | 22.24 | 47.03 | 100 |

OK JP 6/17

4/4/17 Drawers A+B removal from Instrument and sent back to Canberra to fix guard detector / Slide tray connection so the 3 guard pins holding the two together dont become loose over time due to opening and closing the drawers resulting in ↑ beta cpm, ↓ guard cpm

5/1/17 Drawers A+B received back from Canberra. Drawers re-installed in the instrument, daily performance check run after allowing time for the gas to purge. ~~Weekly~~ Long Background calibration performed. Drawers A+B are now back on line. 5/1/17

6/5/17 Voltage Plateau
~~Plateau Check~~ run for drawers A-D

6/11/17

| α sources used | | detectors | | β sources used | |
|---|---|---|---|---|---|
| 410 | Am-241 | A1 B1 C1 D1 | | 406 | Sr 90/Y90 |
| 411 | 17800 dpm | A2 B2 C2 D2 | | 407 | 29660 dpm |
| 412 | 2/16/95 | A3 B3 C3 D3 | | 408 | 9/15/95 |
| 413 | | A4 B4 C4 D4 | | 409 | |

Parameters:
Starting voltage 700
Ending voltage 1650
30V/step
5min/step

Count preset 40000
Time btw steps 0.1
Weak check tms 0.1
Weak check limits 20

Filenames:
PTC0605A
PTC0605B

6/7/17
ROIs set for all drawers using Sr/Y-90 sources
Sources → 406, 407, 408, + 409: over 40,000 counts achieved for each detector. α Lower limit + β upper limit set to 50% to start. Both lower limit + β upper limit moved to achieve β→α xtalk of 2.5%. α lower limit moved to achieve α→β xtalk of 0.10%
All ROIs archived

Continued on Page

Read and Understood By

Signed 6/11/17 Date

Signed 6/13/17 Date

# Calibration Efficiencies

***Source Database for OSUM***

Number of sources in table: 140

Application Revision:

| Control ID | Isotope | Type | Half-Life | DPM | Std dev | Date | Status | Alpha/Beta Archive File |
|---|---|---|---|---|---|---|---|---|
| 1080 | Ra-228 | Beta | 2100.1875 | 16794.9 | 554.23 | 28-Jan-05 | ALS | RA228-06/17 |

| Standard Information Ra-228 | | | Instrument: LB4100C | |
|---|---|---|---|---|
| ID 784.3020.37 | | | | |
| Activity concentration: | 33590 | dpm/g | | |
| Reference Date: | 1/28/2005 | | | |
| Spike volume: | 0.5 | g | | |

| | A1 | A2 | A3 | A4 |
|---|---|---|---|---|
| Source | 1718016-1 | 1718016-3 | 1718016-4 | 1718016-5 |
| Ac-228 Ingrowth Date: | 6/16/2017 | 6/16/2017 | 6/16/2017 | 6/16/2017 |
| Ac-228 Ingrowth Time: | 5:00 PM | 5:00 PM | 5:00 PM | 5:00 PM |
| Ac-228 Decay Date: | 6/19/2017 | 6/19/2017 | 6/19/2017 | 6/19/2017 |
| Ac-228 Decay Time: | 7:05 AM | 7:05 AM | 7:05 AM | 7:05 AM |
| Count Start Date: | 6/19/2017 | 6/19/2017 | 6/19/2017 | 6/19/2017 |
| Count End Time: | 9:01 AM | 9:01 AM | 9:01 AM | 9:01 AM |
| Count Duration(min.): | 6.71 | 6.96 | 6.75 | 6.77 |
| Count Start Time: | 8:54:00 AM | 8:54:00 AM | 8:54:00 AM | 8:54:00 AM |
| Count Duration(hrs): | 0.1 | 0.1 | 0.1 | 0.1 |
| Elapsed Time reference date to analysis (days): | 4522 | 4522 | 4522 | 4522 |
| Ac-228 Ingrowth time (hrs): | 62.1 | 62.1 | 62.1 | 62.1 |
| Elapsed Time, sep. to ct.start., (hrs): | 1.82 | 1.82 | 1.82 | 1.82 |
| Gross CPM | 1489.622 | 1438.175 | 1482.194 | 1477.493 |
| Bkg CPM | 1.436 | 1.336 | 1.51 | 1.532 |
| Ra-228 decay: | 0.2248 | 0.2248 | 0.2248 | 0.2248 |
| Ac-228 ingrowth: | 0.9991 | 0.9991 | 0.9991 | 0.9991 |
| Ac-228 decay: | 0.8143 | 0.8143 | 0.8143 | 0.8143 |
| Count Ingrowth: | 0.0126 | 0.0130 | 0.0126 | 0.0127 |
| Count Decay: | 0.0126 | 0.0131 | 0.0127 | 0.0128 |
| Known dpm on ref date: | 16795 | 16795 | 16795 | 16795 |
| Efficiency: | 0.4875 | 0.4708 | 0.4851 | 0.4835 |

Procedure:

1 Spike 0.05ml of Ra-228 spike (ID: 784.3020.37) into a 50ml centrifuge tube.
2 Spike 32mg Ba (2ml of 16mg/ml), and bring to 25ml with EDTA.
3 Make $BaSO_4$ ppt using 1ml of 200mg/ml $(NH_4)_2SO_4$ + 2ml HOAc.
4 Centrifuge, dissolve ppt in 25ml EDTA.
5 Add 1ml of 9mg/ml Y, 16ml of 18M NaOH.
6 Shake for ~ 2hrs, centrifuge, decant supernatent into new centrifuge tube. Note beginning of Ac-228 ingrowth on benchsheet.
7 Add 1ml of 9mg/ml Y and shake gently for ~65 hours (Ac will be retained on ppt and Ra remains in solution).
8 Centrifuge, decant . Note time of beginning Ac decay on benchsheet.
9 Rinse ppt with 40ml of 1M NaOH.
10 Dissolve ppt in 20ml of 2M HCl.
11 Add 2mg of Ba (0.2ml of 10mg/ml) and mix.
12 Add ~3g $(NH_4)_2SO_4$ + 5ml of isopropanol to form Ac/$BaSO_4$ co-ppt.
13 Filter ppt onto 0.1um filters and mount filters on 2" planchets using a few drops of 50% collodion + 50% amylacetate as an adhesive (dry on hot plate at 90deg C).

| Standard Information Ra-228 | | | Instrument: LB4100C | | |
|---|---|---|---|---|---|
| ID 784.3020.37 | | | | | |
| Activity concentration: | 33590 | dpm/g | | | |
| Reference Date: | 1/28/2005 | | | | |
| Spike volume: | 0.5 | g | | | |
| | **B1** | **B2** | **B3** | **B4** | |
| Source | 1718016-1 | 1718016-3 | 1718016-4 | 1718016-5 | |
| Ac-228 Ingrowth Date: | 6/16/2017 | 6/16/2017 | 6/16/2017 | 6/16/2017 | |
| Ac-228 Ingrowth Time: | 5:00 PM | 5:00 PM | 5:00 PM | 5:00 PM | |
| Ac-228 Decay Date: | 6/19/2017 | 6/19/2017 | 6/19/2017 | 6/19/2017 | |
| Ac-228 Decay Time: | 7:05 AM | 7:05 AM | 7:05 AM | 7:05 AM | |
| Count Start Date: | 6/19/2017 | 6/19/2017 | 6/19/2017 | 6/19/2017 | |
| Count End Time: | 9:10 AM | 9:10 AM | 9:10 AM | 9:10 AM | |
| Count Duration(min.): | 6.94 | 7.26 | 6.94 | 6.9 | |
| Count Start Time: | 9:03:00 AM | 9:03:00 AM | 9:03:00 AM | 9:03:00 AM | |
| Count Duration(hrs): | 0.1 | 0.1 | 0.1 | 0.1 | |
| Elapsed Time reference date to analysis (days): | 4522 | 4522 | 4522 | 4522 | |
| Ac-228 Ingrowth time (hrs): | 62.1 | 62.1 | 62.1 | 62.1 | |
| Elapsed Time, sep. to ct.start., (hrs): | 1.97 | 1.97 | 1.97 | 1.97 | |
| Gross CPM | 1442.767 | 1376.862 | 1443.412 | 1450.438 | |
| Bkg CPM | 1.613 | 1.65 | 1.545 | 1.591 | |
| Ra-228 decay: | 0.2248 | 0.2248 | 0.2248 | 0.2248 | |
| Ac-228 ingrowth: | 0.9991 | 0.9991 | 0.9991 | 0.9991 | |
| Ac-228 decay: | 0.8006 | 0.8006 | 0.8006 | 0.8006 | |
| Count Ingrowth: | 0.0130 | 0.0136 | 0.0130 | 0.0129 | |
| Count Decay: | 0.0131 | 0.0137 | 0.0131 | 0.0130 | |
| Known dpm on ref date: | 16795 | 16795 | 16795 | 16795 | |
| Efficiency: | 0.4803 | 0.4584 | 0.4805 | 0.4828 | |

Procedure:

1 Spike 0.05ml of Ra-228 spike (ID: 784.3020.37) into a 50ml centrifuge tube.
2 Spike 32mg Ba (2ml of 16mg/ml), and bring to 25ml with EDTA.
3 Make BaSO4 ppt using 1ml of 200mg/ml (NH4)2SO4 + 2ml HOAc.
4 Centrifuge, dissolve ppt in 25ml EDTA.
5 Add 1ml of 9mg/ml Y, 16ml of 18M NaOH.
6 Shake for ~ 2hrs, centrifuge, decant supernatent into new centrifuge tube. Note beginning of Ac-228 ingrowth on benchsheet.
7 Add 1ml of 9mg/ml Y and shake gently for ~65 hours (Ac will be retained on ppt and Ra remains in solution).
8 Centrifuge, decant . Note time of beginning Ac decay on benchsheet.
9 Rinse ppt with 40ml of 1M NaOH.
10 Dissolve ppt in 20ml of 2M HCl.
11 Add 2mg of Ba (0.2ml of 10mg/ml) and mix.
12 Add ~3g (NH4)2 SO4 + 5ml of isopropanol to form Ac/BaSO4 co-ppt.
13 Filter ppt onto 0.1um filters and mount filters on 2" planchets using a few drops of 50% collodion + 50% amylacetate as an adhesive (dry on hot plate at 90deg C).

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Standard Information Ra-228 | | | Instrument: LB4100C | | | |
| | ID 784.3020.37 | | | | | | |
| | Activity concentration: | 33590 | dpm/g | | | | |
| | Reference Date: | 1/28/2005 | | | | | |
| | Spike volume: | 0.5 | g | | | | |
| | | **C1** | **C2** | **C3** | **C4** | | |
| | Source | 1718016-1 | 1718016-3 | 1718016-4 | 1718016-5 | | |
| | Ac-228 Ingrowth Date: | 6/16/2017 | 6/16/2017 | 6/16/2017 | 6/16/2017 | | |
| | Ac-228 Ingrowth Time: | 5:00 PM | 5:00 PM | 5:00 PM | 5:00 PM | | |
| | Ac-228 Decay Date: | 6/19/2017 | 6/19/2017 | 6/19/2017 | 6/19/2017 | | |
| | Ac-228 Decay Time: | 7:05 AM | 7:05 AM | 7:05 AM | 7:05 AM | | |
| | Count Start Date: | 6/19/2017 | 6/19/2017 | 6/19/2017 | 6/19/2017 | | |
| | Count End Time: | 9:18 AM | 9:18 AM | 9:18 AM | 9:18 AM | | |
| | Count Duration(min.): | 6.98 | 7.18 | 7.04 | 6.94 | | |
| | Count Start Time: | 9:11:00 AM | 9:11:00 AM | 9:11:00 AM | 9:11:00 AM | | |
| | Count Duration(hrs): | 0.1 | 0.1 | 0.1 | 0.1 | | |
| | Elapsed Time reference date to analysis (days): | 4522 | 4522 | 4522 | 4522 | | E |
| | Ac-228 Ingrowth time (hrs): | 62.1 | 62.1 | 62.1 | 62.1 | | |
| | Elapsed Time, sep. to ct.start., (hrs): | 2.10 | 2.10 | 2.10 | 2.10 | | |
| | Gross CPM | 1432.844 | 1391.377 | 1421.229 | 1441.195 | 1 | |
| | Bkg CPM | 1.54 | 1.659 | 1.64 | 2.897 | | |
| | Ra-228 decay: | 0.2248 | 0.2248 | 0.2248 | 0.2248 | | |
| | Ac-228 ingrowth: | 0.9991 | 0.9991 | 0.9991 | 0.9991 | | |
| | Ac-228 decay: | 0.7886 | 0.7886 | 0.7886 | 0.7886 | | |
| | Count Ingrowth: | 0.0131 | 0.0134 | 0.0132 | 0.0130 | | |
| | Count Decay: | 0.0132 | 0.0135 | 0.0133 | 0.0131 | | |
| | Known dpm on ref date: | 16795 | 16795 | 16795 | 16795 | | |
| | Efficiency: | 0.4843 | 0.4703 | 0.4803 | 0.4866 | | |

Procedure:

1 Spike 0.05ml of Ra-228 spike (ID: 784.3020.37) into a 50ml centrifuge tube.
2 Spike 32mg Ba (2ml of 16mg/ml), and bring to 25ml with EDTA.
3 Make $BaSO_4$ ppt using 1ml of 200mg/ml $(NH_4)_2SO_4$ + 2ml HOAc.
4 Centrifuge, dissolve ppt in 25ml EDTA.
5 Add 1ml of 9mg/ml Y, 16ml of 18M NaOH.
6 Shake for ~ 2hrs, centrifuge, decant supernatent into new centrifuge tube. Note beginning of Ac-228 ingrowth on benchsheet.
7 Add 1ml of 9mg/ml Y and shake gently for ~65 hours (Ac will be retained on ppt and Ra remains in solution).
8 Centrifuge, decant . Note time of beginning Ac decay on benchsheet.
9 Rinse ppt with 40ml of 1M NaOH.
10 Dissolve ppt in 20ml of 2M HCl.
11 Add 2mg of Ba (0.2ml of 10mg/ml) and mix.
12 Add ~3g $(NH_4)_2SO_4$ + 5ml of isopropanol to form Ac/$BaSO_4$ co-ppt.
13 Filter ppt onto 0.1um filters and mount filters on 2" planchets using a few drops of 50% collodion + 50% amylacetate as an adhesive (dry on hot plate at 90deg C).

| | | | | | |
|---|---|---|---|---|---|
| Standard Information Ra-228 | | | Instrument: LB4100C | | |
| ID 784.3020.37 | | | | | |
| Activity concentration: | 33590 | dpm/g | | | |
| Reference Date: | 1/28/2005 | | | | |
| Spike volume: | 0.5 | g | | | |
| | **D1** | **D2** | **D3** | **D4** | |
| Source | 1718016-1 | 1718016-3 | 1718016-4 | 1718016-5 | |
| Ac-228 Ingrowth Date: | 6/16/2017 | 6/16/2017 | 6/16/2017 | 6/16/2017 | |
| Ac-228 Ingrowth Time: | 5:00 PM | 5:00 PM | 5:00 PM | 5:00 PM | |
| Ac-228 Decay Date: | 6/19/2017 | 6/19/2017 | 6/19/2017 | 6/19/2017 | |
| Ac-228 Decay Time: | 7:05 AM | 7:05 AM | 7:05 AM | 7:05 AM | |
| Count Start Date: | 6/19/2017 | 6/19/2017 | 6/19/2017 | 6/19/2017 | |
| Count End Time: | 9:28 AM | 9:28 AM | 9:28 AM | 9:28 AM | |
| Count Duration(min.): | 7.48 | 7.72 | 7.31 | 7.25 | |
| Count Start Time: | 9:20:00 AM | 9:20:00 AM | 9:20:00 AM | 9:20:00 AM | |
| Count Duration(hrs): | 0.1 | 0.1 | 0.1 | 0.1 | |
| lapsed Time reference date to analysis (days): | 4522 | 4522 | 4522 | 4522 | |
| Ac-228 Ingrowth time (hrs): | 62.1 | 62.1 | 62.1 | 62.1 | |
| Elapsed Time, sep. to ct.start., (hrs): | 2.25 | 2.25 | 2.25 | 2.25 | |
| Gross CPM | 1336.621 | 1295.155 | 1367.692 | 1379.634 | |
| Bkg CPM | 1.614 | 1.607 | 1.665 | 1.607 | |
| Ra-228 decay: | 0.2248 | 0.2248 | 0.2248 | 0.2248 | |
| Ac-228 ingrowth: | 0.9991 | 0.9991 | 0.9991 | 0.9991 | |
| Ac-228 decay: | 0.7754 | 0.7754 | 0.7754 | 0.7754 | |
| Count Ingrowth: | 0.0140 | 0.0144 | 0.0137 | 0.0136 | |
| Count Decay: | 0.0141 | 0.0145 | 0.0138 | 0.0137 | |
| Known dpm on ref date: | 16795 | 16795 | 16795 | 16795 | |
| Efficiency: | 0.4596 | 0.4454 | 0.4702 | 0.4743 | |

Procedure:

1 Spike 0.05ml of Ra-228 spike (ID: 784.3020.37) into a 50ml centrifuge tube.
2 Spike 32mg Ba (2ml of 16mg/ml), and bring to 25ml with EDTA.
3 Make BaSO4 ppt using 1ml of 200mg/ml (NH4)2SO4 + 2ml HOAc.
4 Centrifuge, dissolve ppt in 25ml EDTA.
5 Add 1ml of 9mg/ml Y, 16ml of 18M NaOH.
6 Shake for ~ 2hrs, centrifuge, decant supernatent into new centrifuge tube. Note beginning of Ac-228 ingrowth on benchsheet.
7 Add 1ml of 9mg/ml Y and shake gently for ~65 hours (Ac will be retained on ppt and Ra remains in solution).
8 Centrifuge, decant . Note time of beginning Ac decay on benchsheet.
9 Rinse ppt with 40ml of 1M NaOH.
10 Dissolve ppt in 20ml of 2M HCl.
11 Add 2mg of Ba (0.2ml of 10mg/ml) and mix.
12 Add ~3g (NH4)2 SO4 + 5ml of isopropanol to form Ac/BaSO4 co-ppt.
13 Filter ppt onto 0.1um filters and mount filters on 2" planchets using a few drops of 50% collodion + 50% amylacetate as an adhesive (dry on hot plate at 90deg C).

| | | A1 | A2 | A3 | A4 | B1 | B2 | B3 | B4 | C1 | C2 | C3 | C4 | D1 | D2 | D3 | D4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| | offset | 0 | 1 | 2 | 3 | 0 | 1 | 2 | 3 | 0 | 1 | 2 | 3 | 0 | 1 | 2 | 3 |
| | NumRecs | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | total time | 6.71 | 6.96 | 6.75 | 6.77 | 6.94 | 7.26 | 6.94 | 6.9 | 6.98 | 7.18 | 7.04 | 6.94 | 7.48 | 7.72 | 7.31 | 7.25 |
| Alpha | total counts | 86 | 114 | 99 | 104 | 113 | 93 | 89 | 85 | 103 | 81 | 99 | 104 | 102 | 142 | 108 | 108 |
| | reduced ch | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! |
| | chi-square | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! |
| | CPM | 12.73869 | 16.28531 | 14.57067 | 15.27889 | 16.19142 | 12.69292 | 12.74021 | 12.21884 | 14.64645 | 11.16934 | 13.9665 | 14.84459 | 13.54136 | 18.30678 | 14.60328 | 14.79555 |
| | CPM var | 1.926593 | 2.380271 | 2.194447 | 2.292794 | 2.372773 | 1.780978 | 1.864399 | 1.800615 | 2.135989 | 1.584056 | 2.017386 | 2.181905 | 1.841733 | 2.416534 | 2.043105 | 2.076989 |
| | Efficiency | 0.003377 | 0.004318 | 0.003863 | 0.004051 | 0.004293 | 0.003365 | 0.003378 | 0.00324 | 0.003883 | 0.002961 | 0.003703 | 0.003936 | 0.00359 | 0.004854 | 0.003872 | 0.003923 |
| | archived S | 0.000385 | 0.000433 | 0.000413 | 0.000423 | 0.000432 | 0.000371 | 0.000379 | 0.000371 | 0.000408 | 0.000348 | 0.000396 | 0.000413 | 0.000379 | 0.000442 | 0.0004 | 0.000403 |
| | predicted S | 0.000365 | 0.000406 | 0.00039 | 0.000398 | 0.000405 | 0.000351 | 0.000359 | 0.000353 | 0.000384 | 0.000331 | 0.000373 | 0.000388 | 0.000357 | 0.000408 | 0.000375 | 0.000379 |
| | actual STD | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! |
| Beta | total counts | 10005 | 10019 | 10015 | 10013 | 10024 | 10008 | 10028 | 10019 | 10012 | 10002 | 10017 | 10022 | 10010 | 10011 | 10010 | 10014 |
| | reduced ch | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! |
| | chi-square | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! |
| | CPM | 1489.622 | 1438.175 | 1482.194 | 1477.493 | 1442.767 | 1376.862 | 1443.412 | 1450.438 | 1432.844 | 1391.377 | 1421.229 | 1441.195 | 1336.621 | 1295.155 | 1367.692 | 1379.634 |
| | CPM var | 444.5412 | 414.047 | 439.9471 | 437.2206 | 416.7491 | 379.909 | 416.9986 | 421.2794 | 411.2464 | 388.0728 | 404.5695 | 416.6256 | 357.9974 | 336.135 | 374.8421 | 381.3004 |
| | Efficiency | 0.39495 | 0.38131 | 0.392981 | 0.391735 | 0.382528 | 0.365055 | 0.382699 | 0.384562 | 0.379898 | 0.368904 | 0.376819 | 0.382112 | 0.354387 | 0.343393 | 0.362625 | 0.365791 |
| | archived S | 0.014182 | 0.013691 | 0.01411 | 0.014066 | 0.013735 | 0.013108 | 0.013741 | 0.013808 | 0.013641 | 0.013247 | 0.01353 | 0.013722 | 0.012725 | 0.012331 | 0.013021 | 0.013135 |
| | predicted S | 0.00395 | 0.003811 | 0.003929 | 0.003917 | 0.003823 | 0.003651 | 0.003824 | 0.003844 | 0.003799 | 0.003691 | 0.003767 | 0.003821 | 0.003544 | 0.003434 | 0.003627 | 0.003657 |
| | actual STD | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! | #DIV/0! |
| | | | | 8:54 | 9:01 | | | 9:03 | 9:10 | | | 9:11 | 9:18 | | | 9:20 | 9:28 |

# Radiochemistry Instrument Worksheet

**ALS -- Fort Collins**

**Prep Batch:** RA170615-1

**Prep Procedure:** Ra228 Eff Cal Source ID=> 1080

**Analytical QASS / NCR?** Y (N) NA

| Prep Num | LabID | QC Type | Init Alq | Fin Alq | Units | Report Units | Residual Mass (mg) | Cnt 1 File | Cnt 1 Inst/Det | Cnt 1 Pos Chk By | Cnt 2 File | Cnt 2 Inst/Det | Cnt 2 Pos Chk By | Cnt 3 File | Cnt 3 Inst/Det | Cnt 3 Pos Chk By | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1718016-1 | SMP | 1500 | 1496.0 | ml | pCi/l | | | | | | | | | | | |
| 1 | 1718016-2 | SMP | 1500 | 1496.0 | ml | pCi/l | | | | | | | | | | | |
| 1 | 1718016-3 | SMP | 1500 | 1496.0 | ml | pCi/l | | | | | | | | | | | |
| 1 | 1718016-4 | SMP | 1500 | 1496.0 | ml | pCi/l | | | | | | | | | | | |
| 1 | 1718016-5 | SMP | 1500 | 1496.0 | ml | pCi/l | | | | | | | | | | | |

See Maintenance Log 3710 pg 89

Outlier

JP 6/19/17

**Tracer/Carrier Solution Information**

| Soln # | Nuclide | SolnID | Exp Date | Prep Conc | Units | Prep Date | Aliquot | Units | Pipet ID |
|---|---|---|---|---|---|---|---|---|---|
| T1 | BARIUM | 418236 | 1/19/18 | 16,022.768 | pCi/ml | NA | 2 | ml | RS031 |

**Spike Solution Information**

| Soln # | Nuclide | SolnID | Exp Date | Prep Conc | Units | Prep Date | Aliquot | Units | Pipet ID |
|---|---|---|---|---|---|---|---|---|---|
| S1 | Ra-228 | 784.3020.37 | 3/23/18 | 7,552.998 | DPM/g | 06/15/17 | 0.5 | g | RS034 |

## Sample Barcodes

| | | |
|---|---|---|
| 1718016-1<br>RA170615-1PS1 | 1718016-2<br>RA170615-1PS2 | 1718016-3<br>RA170615-1PS3 |
| 1718016-4<br>RA170615-1PS4 | 1718016-5<br>RA170615-1PS5 | RA170615-1CAR<br>RA170615-1PS6 |

## Reporting Units

| LabID: | TstGrpName: | RptUnits: |
|---|---|---|
| 1718016-1 | Ra228_2012 | pCi/l |
| 1718016-2 | Ra228_2012 | pCi/l |
| 1718016-3 | Ra228_2012 | pCi/l |
| 1718016-4 | Ra228_2012 | pCi/l |
| 1718016-5 | Ra228_2012 | pCi/l |

# Radiochemistry Prep Worksheet

**ALS -- Fort Collins**

**Prep Batch:** RA170615-1

**Prep Procedure:** Ra228

**Reviewed By:** lad LAD **Review Date:** 6/19/2017

**Non-Routine Pre-Treatment? Y / N** **Batch:** NA **Re-Prep? Y / N** **Batch:** NA **Prep QASS / NCR? Y / N** NA

**Prep SOP:** SOP749 **Rev:** 4
**Prep SOP:** NONE
**Matrix Class:** liquid

**Prep Analyst:** Lucas A. Daut LAD
**Prep Date:** 6/15/2017
**Prep Dept:** RS

**Balance:** N/A
**Balance:** N/A

| Samp Num | Prep Num | LabID | QC Type | Dish No. | Init Alq ml | Fin Alq ml | Prep Basis | Ingrowth Date/Time | Decay Date/Time | Standards | Prep Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1718016-1 | SMP | NA | 1500 | 1496.002 | Unfiltered | 06/16/17 17:00 | 06/19/17 07:05 | T1,S1 | |
| 2 | 1 | 1718016-2 | SMP | | 1500 | 1496.002 | Unfiltered | 06/16/17 17:00 | 06/19/17 07:05 | T1,S1 | |
| 3 | 1 | 1718016-3 | SMP | | 1500 | 1496.002 | Unfiltered | 06/16/17 17:00 | 06/19/17 07:05 | T1,S1 | |
| 4 | 1 | 1718016-4 | SMP | | 1500 | 1496.002 | Unfiltered | 06/16/17 17:00 | 06/19/17 07:05 | T1,S1 | LAD 6/19 |
| 5 | 1 | 1718016-5 | SMP | | 1500 | 1496.002 | Unfiltered | 06/16/17 17:00 | 06/19/17 07:05 | T1,S1 | |

Comments

**Spiked By:** Lucas A. Daut **Date:** 6/15/2017 **Yttrium Added By:** **Date:**

**Witnessed By:** Andrew R. Steger **Date:** 6/15/2017 **Witnessed By:** **Date:**

**Tracer/Carrier Solution Information**

| Soln # | Nuclide | SolnID | Exp Date | Prep Conc | Units | Prep Date | Aliquot | Units | Pipet ID |
|---|---|---|---|---|---|---|---|---|---|
| T1 | BARIUM | 418236 | 1/19/18 | 16,022.768 | pCi/ml | NA | 2 | ml | RS031 |

**Spike Solution Information**

| Soln # | Nuclide | SolnID | Exp Date | Prep Conc | Units | Prep Date | Aliquot | Units | Pipet ID |
|---|---|---|---|---|---|---|---|---|---|
| S1 | Ra-228 | 784.3020.37 | 3/23/18 | 7,552.998 | DPM/g | 06/15/17 | 0.5 | g | RS034 |

ALS -- Fort Collins

# Radiochemistry Prep Worksheet

**Prep Batch:** RA170615-1

**Prep Procedure:** Ra228

## Prep Batch Not Validated!!!

**Reviewed By:** LAD **Review Date:**

**Non-Routine Pre-Treatment? Y / N** **Batch:** _____ **Re-Prep? Y / N** **Batch:** _____ **Prep QASS / NCR? Y / N** _____

**Prep SOP:** SOP749 **Rev:** 4
**Prep SOP:** NONE
**Matrix Class:** liquid

**Prep Analyst:** Lucas A. Daut
**Prep Date:** 6/15/2017
**Prep Dept:** RS

**Balance:** N/A
**Balance:** N/A

| Samp Num | Prep Num | LabID | QC Type | Dish No. | Init Alq ml | Fin Alq ml | Prep Basis | Ingrowth Date/Time | Decay Date/Time | Standards | Prep Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1718016-1 | SMP | | 1500 | 1496.002 | Unfiltered | 6/16 | 6/19 | T1,S1 | Nomp |
| 2 | 1 | 1718016-2 | SMP | | 1500 | 1496.002 | Unfiltered | 17:00 | 07:05 | T1,S1 | |
| 3 | 1 | 1718016-3 | SMP | | 1500 | 1496.002 | Unfiltered | | | T1,S1 | |
| 4 | 1 | 1718016-4 | SMP | | 1500 | 1496.002 | Unfiltered | | | T1,S1 | |
| 5 | 1 | 1718016-5 | SMP | | 1500 | 1496.002 | Unfiltered | | | T1,S1 | |

Comments

**Spiked By:** Lucas A. Daut **Date:** 6/15/2017 **Yttrium Added By:** _____ **Date:** _____

**Witnessed By:** Andrew R. Steger **Date:** 6/15/2017 **Witnessed By:** _____ **Date:** _____

**Tracer/Carrier Solution Information**

| Soln # | Nuclide | SolnID | Exp Date | Prep Conc | Units | Prep Date | Aliquot | Units | Pipet ID |
|---|---|---|---|---|---|---|---|---|---|
| T1 | BARIUM | 418236 | | 16,022.768 | pCi/ml | NA | 2 | ml | RS031 |

**Spike Solution Information**

| Soln # | Nuclide | SolnID | Exp Date | Prep Conc | Units | Prep Date | Aliquot | Units | Pipet ID |
|---|---|---|---|---|---|---|---|---|---|
| S1 | Ra-228 | 784.3020.37 | | 7,552.998 | DPM/g | 06/15/17 | 0.5 | g | RS034 |

# Radiochemistry ICP Worksheet

**ALS -- Fort Collins**

**Prep Batch: RA170615-1**

Prep Procedure: **Ra228**

Reviewed By: **lad** LAD

Review Date: **6/19/2017**

## BARIUM Recovery Results

### Reference Carrier

| LabID | QC Type | Carr Vol | Ref Carr Dil Vol | Ref Carr ICP Alq | Ref Carr ICP Dil Vol | Ref Carr ICP Run | Ref Carr ICP Conc |
|---|---|---|---|---|---|---|---|
| RA170615-1 | CAR | 2 | 27 | 0.05 | 10.05 | IR170616-2A1 | 5.898432 |

### Samples

| Prep Num | LabID | QC Type | Init Samp Alq (ml) | Car Vol (ml) | Samp Dil Vol (ml) | Init ICP Alq (ml) | Init ICP Dil Vol (ml) | Pre-Con Vol (ml) | Post Con Vol (ml) | Pre-Sep Vol (ml) | Post Sep Vol (ml) | Fin ICP Alq (ml) | Fin ICP Dil Vol (ml) | Initial ICP Run | Final ICP Run | Init ICP Conc (ug/ml) | Fin ICP Conc (ug/ml) | Init Samp Mass (ug) | Ref Mass (ug) | Flag | Fin Samp Mass (ug) | % Yield | Final Sample Alq |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1718016-1 | SMP | 1500 | 2 | 1500 | 1 | 10 | 1499 | 1499 | 1499 | 25 | 0.05 | 10.05 | IR170616-2A1 | IR170616-2A1 | -0.0003 | 6.272993 | 0 | 32010.79 | Z | 31521.79 | 98.47% | 1496 |
| 1 | 1718016-2 | SMP | 1500 | 2 | 1500 | 1 | 10 | 1499 | 1499 | 1499 | 25 | 0.05 | 10.05 | IR170616-2A1 | IR170616-2A1 | 0.06616 | 6.105323 | 991.7684 | 32010.79 | | 30679.25 | 92.96% | 1496 |
| 1 | 1718016-3 | SMP | 1500 | 2 | 1500 | 1 | 10 | 1499 | 1499 | 1499 | 25 | 0.05 | 10.05 | IR170616-2A1 | IR170616-2A1 | 0.09805 | 6.286881 | 1469.783 | 32010.79 | | 31591.58 | 94.36% | 1496 |
| 1 | 1718016-4 | SMP | 1500 | 2 | 1500 | 1 | 10 | 1499 | 1499 | 1499 | 25 | 0.05 | 10.05 | IR170616-2A1 | IR170616-2A1 | 0.00095 | 6.337784 | 14.29576 | 32010.79 | | 31847.36 | 99.45% | 1496 |
| 1 | 1718016-5 | SMP | 1500 | 2 | 1500 | 1 | 10 | 1499 | 1499 | 1499 | 25 | 0.05 | 10.05 | IR170616-2A1 | IR170616-2A1 | -0.0011 | 6.307981 | 0 | 32010.79 | Z | 31697.6 | 99.02% | 1496 |

159 of 223



**FLAG -** LB: low bias (<= 15%) 15%: low bias (>15%)

Z: Negative init. conc. treated as zer

**Supersedes:** NA

IR170616.2A1



| Sample Id1 | Ca | Fe | K | Mg | Na | Sr | Mn | S | Al | Ba | Pb | Ni |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CCV | 50.1627 | 20.0214 | 50.4050 | 50.1827 | 49.1171 | 0.5053 | 1.0018 | 4.9726 | 50.4533 | 1.0028 | 0.9822 | 1.0083 |
| CCB | 0.0121 | 0.0074 | 0.0354 | 0.0154 | 0.0394 | 0.0002 | 0.0002 | 0.0000 | 0.0078 | 0.0008 | 0.0028 | 0.0007 |
| I 1718016-1 | -0.1052 | -0.0075 | -0.0529 | -0.0689 | -0.4648 | -0.0020 | -0.0014 | -0.0365 | -0.0561 | -0.0003 | 0.0084 | 0.0000 |
| I 1718016-2 | 12.3449 | 0.0132 | -0.0618 | -0.0592 | -0.4595 | 0.0035 | -0.0008 | -0.0182 | -0.0496 | 0.0662 | 0.0039 | -0.0003 |
| I 1718016-3 | 11.9360 | 0.0215 | -0.0927 | -0.0711 | -0.4650 | 0.0035 | -0.0009 | -0.0182 | -0.0385 | 0.0981 | 0.0025 | -0.0011 |
| I 1718016-4 | 0.1444 | -0.0038 | -0.0797 | -0.0700 | -0.4919 | -0.0020 | -0.0015 | -0.0319 | -0.0509 | 0.0010 | -0.0001 | -0.0013 |
| I 1718016-5 | -0.1068 | -0.0009 | -0.0752 | -0.0729 | -0.4911 | -0.0021 | -0.0015 | -0.0411 | -0.0476 | -0.0011 | -0.0001 | -0.0002 |
| F 1718016-1 | -0.0999 | -0.0096 | -0.0598 | -0.0598 | 87.1920 | -0.0015 | -0.0014 | 1.5693 | -0.0477 | 6.2730 | 0.0550 | 0.0000 |
| F 1718016-2 | -0.1042 | -0.0088 | -0.0638 | -0.0723 | 86.3241 | -0.0014 | -0.0014 | 1.4781 | -0.0457 | 6.1053 | 0.0382 | 0.0002 |
| F 1718016-3 | -0.1045 | -0.0134 | -0.0793 | -0.0791 | 86.9998 | -0.0015 | -0.0015 | 1.5602 | -0.0437 | 6.2869 | 0.0435 | -0.0021 |
| F 1718016-4 | -0.1058 | -0.0126 | -0.0740 | -0.0803 | 86.5104 | -0.0015 | -0.0017 | 1.5648 | -0.0542 | 6.3378 | 0.0474 | -0.0012 |
| F 1718016-5 | -0.1032 | -0.0129 | -0.0598 | -0.0746 | 86.2083 | -0.0014 | -0.0017 | 1.5648 | -0.0470 | 6.3080 | 0.0560 | -0.0018 |
| RA170615-1RC | -0.1032 | -0.0097 | -0.0667 | -0.0763 | 80.7188 | -0.0010 | -0.0015 | 0.0046 | -0.0542 | 5.8984 | 0.0030 | -0.0002 |
| CCV | 49.7949 | 19.8872 | 50.1529 | 49.8850 | 49.3913 | 0.5013 | 0.9950 | 4.9863 | 50.1172 | 0.9971 | 0.9879 | 1.0063 |
| CCB | 0.0189 | 0.0100 | 0.0382 | 0.0131 | 0.0394 | 0.0001 | 0.0001 | 0.0137 | 0.0235 | 0.0008 | 0.0038 | -0.0005 |

Date 6/19/17

SOP 724r 12

# ALS
## Low Background Gas Flow Proportional Counter Log
## Instrument: LB4100C

*Instrument Daily Response and Background Checks*

| Det. | Daily Response Check Start 1 | Status | Start 2 | Status | Background Check Start 1 | Status | Start 2 | Status | Det. Status |
|---|---|---|---|---|---|---|---|---|---|
| 1 | JP | P | | | JP | P | | | P |
| 2 | | | | | | | | | |
| 3 | | | | | | | | | |
| 4 | | | | | | | | | |
| 5 | | | | | | | | | |
| 6 | | | | | | | | | |
| 7 | | | | | | | | | |
| 8 | | | | | | | | | |
| 9 | | | | | | | | | |
| 10 | | | | | | | | | |
| 11 | | | | | | | | | |
| 12 | | | | | | | | | |
| 13 | | | | | | | | | |
| 14 | | | | | | | | | |
| 15 | | | | | | | | | |
| 16 | | | | | | (HB) | | | OUB |

Det = Detector; α = Alpha; β = Beta; P = Pass; H = High; L = Low; OL = Offline; R = Recount; W = Weekly; NP = Not Processed

*Weekly Background Calibration*

| | Current Calib. File ID | Weekly Calib. Started | Status | File ID |
|---|---|---|---|---|
| Dr A | BKC0607W | | | |
| Dr B | | | | |
| Dr C | | | | |
| Dr D | | | | |

Dr = Drawer

*Gas Supply*

| P-10 Supply | | P-10 Flow | |
|---|---|---|---|
| Tank 1 | 2250 | Dr A | 10 |
| | | Dr B | |
| Tank 2 | 1050 | Dr C | |
| | | Dr D | |

Comments:

Page No.: 473504 A

Form 780r8.doc (6/23/06)

Reviewed By / Date JP 6/19/17

Date 6/19/17 SOP 724r 12

**ALS**

Low Background Gas Flow Proportional Counter Log

**Instrument: LB4100C**

| Det. | Sample ID | Batch | Test | Count Dur. (min) | Start Time | Analyst Initials | File ID | Output Initials |
|---|---|---|---|---|---|---|---|---|
| 1-16 | Daily Eff | — | — | 30 | 6:42 | JP | EFC0619 | JP |
| 1-16 | Daily Bkg | — | — | 60 | 6:53 | JP | BKC0619 | JP |
| 1 | 1718016-1 | RA170615-1 | Ra228 | 8 | 8:08 | JP | RAC0619 | JP |
| 1 | -2 | | EffCal | | 8:16 | JP | A | JP |
| 1 | -3 | | Outlier | | 8:26 | JP | B | JP |
| 1 | -4 | | | | 8:34 | JP | C | JP |
| 1 | -5 | | | | 8:43 | JP | D | JP |
| 1-4 | 1080 | RA170615-1 | Ra228 | 30 | 8:54 | JP | ERA0619A | JP |
| 5-8 | | | EffCal | | 9:03 | JP | B | JP |
| 9-12 | | | | | 9:11 | JP | C | JP |
| 13-16 | | | | | 9:20 | JP | D | |
| 1 | 1706344-1 | AB170616-1 | αβ | 10 | 937 | JKB | ABC0619 | JKB |
| 2 | 2 | | | | | | | |
| 3 | 3 | | | | | | | |
| 4 | 4 | | | | | | | |
| 5 | 5 | | | | | | | |
| 6 | 6 | | | | | | | |
| 7 | 7 | | | | | | | |
| 8 | 8 | | | | | | | |
| 9 | 9 | | | | | | | |
| 10 | 10 | | | | | | | |
| 11 | 11 | | | | | | | |
| 12 | 12 | | | | | | | |
| 13 | 13 | | | | | | | |
| 14 | 14 | | | | | | | |
| 15 | 15 | | | | | | | |
| 1 | 7D | | | | 958 | | ABC0619A | |
| 2 | 16 | | | | | | | |
| 3 | 17 | | | | | | | |
| 4 | 18 | | | | | | | |
| 5 | 19 | | | | | | | |
| 6 | 20 | | | | | | | |
| 7 | AB170616-1ALS | | | | | | | |
| 8 | BLS | | | | | | | |
| 9 | MB | | | | | | | |
| 10 | 1706344-21 | AB170616-2 | | | | | | |
| 11 | 22 | | | | | | | |
| 12 | 23 | | | | | | | |
| 13 | 24 | | | | | | | |
| 14 | 25 | | | | | | | |
| 15 | AB170616-2MB | | | | | | | |
| 1 | ALCS | | | | 1013 | | ABC0619B | |
| 2 | BLCS | | | | | | | |
| 3 | 1706344-21D | | | | | | | |
| 1 | 1706188-1 | AB170616-4 | | 30 | 1041 | JKB | ABC0619C | |
| 2 | 2 | | | | | | | |
| 3 | 3 | | | | | | | |

Comments:

Page No.: 473504 B

(cont. from page MA B)

Form 780r8.doc (6/23/06)

Reviewed By / Date JKB 6/19/17

Date 6/20/17

SOP 724r 12

# ALS

## Low Background Gas Flow Proportional Counter Log

## Instrument: LB4100C

*Instrument Daily Response and Background Checks*

| Det. | Daily Response Check Start 1 | Status | Start 2 | Status | Background Check Start 1 | Status | Start 2 | Status | Det. Status |
|---|---|---|---|---|---|---|---|---|---|
| 1 | JP | P | | | JP | P | | | P |
| 2 | | | | | | | | | |
| 3 | | | | | | | | | |
| 4 | | | | | | | | | |
| 5 | | | | | | | | | |
| 6 | | | | | | | | | |
| 7 | | | | | | | | | |
| 8 | | | | | | | | | |
| 9 | | | | | | | | | |
| 10 | | | | | | | | | |
| 11 | | | | | | | | | |
| 12 | | | | | | | | | |
| 13 | | | | | | | | | |
| 14 | | | | | | | | | |
| 15 | | | | | | | | | |
| 16 | | | | | | (HB) | | | OLB |

Det = Detector; α = Alpha; β = Beta; P = Pass; H = High; L = Low; OL = Offline; R = Recount; W = Weekly; NP = Not Processed

*Weekly Background Calibration*

| | Current Calib. File ID | Weekly Calib. Started | Status | File ID |
|---|---|---|---|---|
| Dr A | BKC0607W | | | |
| Dr B | | | | |
| Dr C | | | | |
| Dr D | | | | |

Dr = Drawer

*Gas Supply*

| P-10 Supply | | P-10 Flow | |
|---|---|---|---|
| Tank 1 | 1950 | Dr A | 10 |
| | | Dr B | |
| Tank 2 | 1050 | Dr C | |
| | | Dr D | |

Comments:

6/14/17 Cs 137 (Gross Beta) Mass Attenuation Curve

Benchsheets: AB160510-2 Source: 1617003-1→18

| Det | 1117 | 1135 | 1146 | 1202 | 1216 | 1229 | 1273 | 1300 | 1326 | 1342 | 1410 | 1426 | 1440 | 1454 | 1508 | 1532 | 1547 | 1602 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 | 1 | 17 | 18 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 |
| A2 | 2 | 1 | 17 | 18 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 |
| A3 | 3 | 2 | 1 | 17 | 18 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 |
| A4 | 4 | 3 | 2 | 1 | 17 | 18 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 |
| B1 ~~A5~~ | 5 | 4 | 3 | 2 | 1 | 17 | 18 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 |
| B2 | 6 | 5 | 4 | 3 | 2 | 1 | 17 | 18 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 |
| B3 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 17 | 18 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| B4 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 17 | 18 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 |
| C1 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 17 | 18 | 16 | 15 | 14 | 13 | 12 | 11 | 10 |
| C2 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 17 | 18 | 16 | 15 | 14 | 13 | 12 | 11 |
| C3 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 17 | 18 | 16 | 15 | 14 | 13 | 12 |
| C4 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 17 | 18 | 16 | 15 | 14 | 13 |
| D1 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 17 | 18 | 16 | 15 | 14 |
| D2 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 17 | 18 | 16 | 15 |
| D3 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 17 | 18 | 16 |
| D4 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 17 | 18 |

Filename
ACS0614

6/19/17 → Ra228 Efficiency Calibration
Benchsheet: RA170615-1 Source ID: 1080
Log File: Ra228-06/17

| Sources | Detectors | Filenames |
|---|---|---|
| 1718016-1 | A1 B1 C1 D1 | ERA0619A |
| -3 | A2 B2 C2 D2 | B |
| -4 | A3 B3 C3 D3 | C |
| -5 | A4 B4 C4 D4 | D |

Continued on Page

Signed 6/19/17 Date

Read and Understood By

Signed 6/20/17 Date

## OUTLIER TEST

| FILE | DET | SAMPLE ID | Beta CPM | Relative % diff. from mean | Within acceptability range | Outlier? | Half-life (days | Separation Date & Time | Count Date & Time | Decay Factor | Chemical Yield | CPM Corrected |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RAC0619 | A1(1) | 1718016-1 | 1594.625 | 2.52% | YES | NO | 0.2554 | 6/19/2017 7:05 | 6/19/2017 8:08 | 0.8880 | 0.9847 | 1823.55 |
| RAC0619A | A1(1) | 1718016-2 | 1580.625 | 3.91% | YES | OUTLIER! | 0.2554 | 6/19/2017 7:05 | 6/19/2017 8:16 | 0.8748 | 0.9296 | 1943.76 |
| RAC0619B | A1(1) | 1718016-3 | 1522.000 | 0.45% | YES | NO | 0.2554 | 6/19/2017 7:05 | 6/19/2017 8:26 | 0.8584 | 0.9436 | 1878.98 |
| RAC0619C | A1(1) | 1718016-4 | 1562.250 | 0.69% | YES | NO | 0.2554 | 6/19/2017 7:05 | 6/19/2017 8:34 | 0.8456 | 0.9945 | 1857.76 |
| RAC0619D | A1(1) | 1718016-5 | 1522.250 | 1.15% | YES | NO | 0.2554 | 6/19/2017 7:05 | 6/19/2017 8:43 | 0.8314 | 0.9902 | 1849.15 |

**Mean of all five planchets:**

| | | | Acceptability range | Relative range |
|---|---|---|---|---|
| Average= | 1870.64 | Upper | 1961.53 | +/- 4.86% |
| Std dev= | 45.447438 | Lower | 1779.75 | |
| 2 Std Dev= | 90.89 | | | **0.048590254** |

**Sample 1718016-2 rejected as outlier.**

Criteria: Potential outliers fall outside acceptability range; which is the mean of all five measurements +/- 2 std dev per the Grubbs statistical test.

OK JP 6/19/17

# PAI - Gas Flow Proportional Sample Analysis LB4100-C

Unit Type: LB4100 -C
Counting Unit ID: Magenta
High Voltage Mode: Simultaneous
Application Revision: 2
Application Version: Standard
Rev.12/01/08 JCP

Data file name: RAC0619
Batch ID: RA170615-1
Count Preset (m): 8
Batch Ended: 6/19/2017 8:16

Background logfile: BKGABW
Date of Bkg. Cal: 6/8/2017
Alpha efficiency logfile: Am241R-06/15 Alpha prog. logfile: n/a
Alpha attenuation calibration: AAM0606, 0607 Alpha prog. attenuation: n/a
Beta efficiency logfile: RA228-06/15 Beta prog. logfile: n/a
Beta attenuation calibration: ASR0607 Beta prog. attenuation: n/a

| Alpha Attenuation Calibration | | Beta Attenuation Calibration | |
|---|---|---|---|
| y = b*m^(a*(mass-x0)) | | y = b*m^(a*(mass-x0)) | |
| Alpha b= | 0.90300 | Beta b= | 0.9681 |
| m= | 0.99110 | m= | 0.9996 |
| a= | 0.8270 | a= | 0.9174 |
| x0= | 21.4875 | x0= | 0.0000 |
| Alpha to Beta X-talk | | Beta to Alpha X-talk | |
| y = b *m^-mass | | y = b*mass + m | |
| a ->b xtalk b= | 0.2511 | b ->a xtalk b= | -1.69E-05 |
| a ->b xtalk m= | 0.9984 | b ->a xtalk m= | 0.0036 |

| Det. ID | Sample ID | Count End Date & Time | Count Dur. (min) | Resid. Mass (mg) | Alpha Activity Gross CPM | Alpha Bkg. CPM | Alpha b>a xtlk CPM | Alpha Base Eff | Alpha Base Cor.Fact. | Alpha Progeny Eff | Alpha Progeny Cor.Fact. | Beta Activity Gross CPM | Beta Bkg. CPM | Beta a>b xtlk CPM | Beta Base Eff | Beta Base Cor.Fact. | Beta Progeny Eff | Beta Progeny Cor.Fact. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 | 1718016-1 | 6/19/2017 8:16 | 8.00 | 0.0 | 16.625 | 0.078 | 5.735 | 0.2138 | 1.058 | n/a | n/a | 1594.625 | 1.436 | 4.1550 | 0.4904 | 0.968 | n/a | n/a |

JP 6/19/17

# PAi - Gas Flow Proportional Sample Analysis LB4100-C

Unit Type: LB4100 -C
Counting Unit ID: Magenta
High Voltage Mode: Simultaneous
Application Revision: 2
Application Version: Standard
Rev.12/01/08 JCP

Data file name: RAC0619A
Batch ID: RA170615-1
Count Preset (m): 8
Batch Ended: 6/19/2017 8:25

Background logfile: BKGABW
Date of Bkg. Cal: 6/8/2017
Alpha efficiency logfile: Am241R-06/15 Alpha prog. logfile: n/a
Alpha attenuation calibration: AAM0606, 0607 Alpha prog. attenuation: n/a
Beta efficiency logfile: RA228-06/15 Beta prog. logfile: n/a
Beta attenuation calibration: ASR0607 Beta prog. attenuation: n/a

| Alpha Attenuation Calibration | | Beta Attenuation Calibration | |
|---|---|---|---|
| y = b*m^(a*(mass-x0)) | | y = b*m^(a*(mass-x0)) | |
| Alpha b= | 0.90300 | Beta b= | 0.9681 |
| m= | 0.99110 | m= | 0.9996 |
| a= | 0.8270 | a= | 0.9174 |
| x0= | 21.4875 | x0= | 0.0000 |
| Alpha to Beta X-talk | | Beta to Alpha X-talk | |
| y = b *m^-mass | | y = b*mass + m | |
| a ->b xtalk b= | 0.2511 | b ->a xtalk b= | -1.69E-05 |
| a ->b xtalk m= | 0.9984 | b ->a xtalk m= | 0.0036 |

| Det. ID | Sample ID | Count End Date & Time | Count Dur. (min) | Resid. Mass (mg) | Alpha Activity Gross CPM | Alpha Bkg. CPM | Alpha b>a xtlk CPM | Alpha Base Eff | Alpha Base Cor.Fact. | Alpha Progeny Eff | Alpha Progeny Cor.Fact. | Beta Activity Gross CPM | Beta Bkg. CPM | Beta a>b xtlk CPM | Beta Base Eff | Beta Base Cor.Fact. | Beta Progeny Eff | Beta Progeny Cor.Fact. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 | 1718016-2 | 6/19/2017 8:25 | 8.00 | 0.0 | 15.875 | 0.078 | 5.685 | 0.2138 | 1.058 | n/a | n/a | 1580.625 | 1.436 | 3.9666 | 0.4904 | 0.968 | n/a | n/a |

JP 6/19/17

# PAI - Gas Flow Proportional Sample Analysis LB4100-C

Unit Type: LB4100 -C
Counting Unit ID: Magenta
High Voltage Mode: Simultaneous
Application Revision: 2
Application Version: Standard
Rev.12/01/08 JCP

Data file name: RAC0619B
Batch ID: RA170615-1
Count Preset (m): 8
Batch Ended: 6/19/2017 8:34

Background logfile: BKGABW
Date of Bkg. Cal: 6/8/2017
Alpha efficiency logfile: Am241R-06/15 Alpha prog. logfile: n/a
Alpha attenuation calibration: AAM0606, 0607 Alpha prog. attenuation: n/a
Beta efficiency logfile: RA228-06/15 Beta prog. logfile: n/a
Beta attenuation calibration: ASR0607 Beta prog. attenuation: n/a

| Alpha Attenuation Calibration y = b*m^(a*(mass-x0)) | | Beta Attenuation Calibration y = b*m^(a*(mass-x0)) | |
|---|---|---|---|
| Alpha b= | 0.90300 | Beta b= | 0.9681 |
| m= | 0.99110 | m= | 0.9996 |
| a= | 0.8270 | a= | 0.9174 |
| x0= | 21.4875 | x0= | 0.0000 |
| Alpha to Beta X-talk y = b *m^-mass | | Beta to Alpha X-talk y = b*mass + m | |
| a ->b xtalk b= | 0.2511 | b ->a xtalk b= | -1.69E-05 |
| a ->b xtalk m= | 0.9984 | b ->a xtalk m= | 0.0036 |

| Det. ID | Sample ID | Count End Date & Time | Count Dur. (min) | Resid. Mass (mg) | Alpha Activity Gross CPM | Alpha Bkg. CPM | Alpha b>a xtlk CPM | Alpha Base Eff | Alpha Base Cor.Fact. | Alpha Progeny Eff | Alpha Progeny Cor.Fact. | Beta Activity Gross CPM | Beta Bkg. CPM | Beta a>b xtlk CPM | Beta Base Eff | Beta Base Cor.Fact. | Beta Progeny Eff | Beta Progeny Cor.Fact. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 | 1718016-3 | 6/19/2017 8:34 | 8.00 | 0.0 | 13.375 | 0.078 | 5.474 | 0.2138 | 1.058 | n/a | n/a | 1522.000 | 1.436 | 3.3389 | 0.4904 | 0.968 | n/a | n/a |

JP 6/19/17

# PAI - Gas Flow Proportional Sample Analysis LB4100-C

Unit Type: LB4100 -C
Counting Unit ID: Magenta
High Voltage Mode: Simultaneous
Application Revision: 2
Application Version: Standard
Rev.12/01/08 JCP

Data file name: RAC0619C
Batch ID: RA170615-1
Count Preset (m): 8
Batch Ended: 6/19/2017 8:43

Background logfile: BKGABW
Date of Bkg. Cal: 6/8/2017
Alpha efficiency logfile: Am241R-06/15
Alpha prog. logfile: n/a
Alpha attenuation calibration: AAM0606, 0607
Alpha prog. attenuation: n/a
Beta efficiency logfile: RA228-06/15
Beta prog. logfile: n/a
Beta attenuation calibration: ASR0607
Beta prog. attenuation: n/a

| Alpha Attenuation Calibration | | Beta Attenuation Calibration | |
|---|---|---|---|
| y = b*m^(a*(mass-x0)) | | y = b*m^(a*(mass-x0)) | |
| Alpha b= | 0.90300 | Beta b= | 0.9681 |
| m= | 0.99110 | m= | 0.9996 |
| a= | 0.8270 | a= | 0.9174 |
| x0= | 21.4875 | x0= | 0.0000 |
| Alpha to Beta X-talk | | Beta to Alpha X-talk | |
| y = b *m^-mass | | y = b*mass + m | |
| a ->b xtalk b= | 0.2511 | b ->a xtalk b= | -1.69E-05 |
| a ->b xtalk m= | 0.9984 | b ->a xtalk m= | 0.0036 |

| Det. ID | Sample ID | Count End Date & Time | Count Dur. (min) | Resid. Mass (mg) | Alpha Activity Gross CPM | Alpha Bkg. CPM | Alpha b>a xtlk CPM | Alpha Base Eff | Alpha Base Cor.Fact. | Alpha Progeny Eff | Alpha Progeny Cor.Fact. | Beta Activity Gross CPM | Beta Bkg. CPM | Beta a>b xtlk CPM | Beta Base Eff | Beta Base Cor.Fact. | Beta Progeny Eff | Beta Progeny Cor.Fact. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 | 1718016-4 | 6/19/2017 8:43 | 8.00 | 0.0 | 14.625 | 0.078 | 5.619 | 0.2138 | 1.058 | n/a | n/a | 1562.250 | 1.436 | 3.6528 | 0.4904 | 0.968 | n/a | n/a |

JP 6/19/17

# PAI - Gas Flow Proportional Sample Analysis LB4100-C

Unit Type: LB4100 -C
Counting Unit ID: Magenta
High Voltage Mode: Simultaneous
Application Revision: 2
Application Version: Standard
Rev.12/01/08 JCP

Data file name: RAC0619D
Batch ID: RA170615-1
Count Preset (m): 8
Batch Ended: 6/19/2017 8:51

Background logfile: BKGABW
Date of Bkg. Cal: 6/8/2017
Alpha efficiency logfile: Am241R-06/15 Alpha prog. logfile: n/a
Alpha attenuation calibration: AAM0606, 0607 Alpha prog. attenuation: n/a
Beta efficiency logfile: RA228-06/15 Beta prog. logfile: n/a
Beta attenuation calibration: ASR0607 Beta prog. attenuation: n/a

| Alpha Attenuation Calibration | | Beta Attenuation Calibration | |
|---|---|---|---|
| y = b*m^(a*(mass-x0)) | | y = b*m^(a*(mass-x0)) | |
| Alpha b= | 0.90300 | Beta b= | 0.9681 |
| m= | 0.99110 | m= | 0.9996 |
| a= | 0.8270 | a= | 0.9174 |
| x0= | 21.4875 | x0= | 0.0000 |
| Alpha to Beta X-talk | | Beta to Alpha X-talk | |
| y = b *m^-mass | | y = b*mass + m | |
| a ->b xtalk b= | 0.2511 | b ->a xtalk b= | -1.69E-05 |
| a ->b xtalk m= | 0.9984 | b ->a xtalk m= | 0.0036 |

| Det. ID | Sample ID | Count End Date & Time | Count Dur. (min) | Resid. Mass (mg) | Alpha Activity Gross CPM | Alpha Bkg. CPM | Alpha b>a xtlk CPM | Alpha Base Eff | Alpha Base Cor.Fact. | Alpha Progeny Eff | Alpha Progeny Cor.Fact. | Beta Activity Gross CPM | Beta Bkg. CPM | Beta a>b xtlk CPM | Beta Base Eff | Beta Base Cor.Fact. | Beta Progeny Eff | Beta Progeny Cor.Fact. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 | 1718016-5 | 6/19/2017 8:51 | 8.00 | 0.0 | 14.125 | 0.078 | 5.475 | 0.2138 | 1.058 | n/a | n/a | 1522.250 | 1.436 | 3.5272 | 0.4904 | 0.968 | n/a | n/a |

JP 6/19/17

Date 6/19/17

SOP 724r 12

# ALS
## Low Background Gas Flow Proportional Counter Log
## Instrument: LB4100C

*Instrument Daily Response and Background Checks*

| Det. | Daily Response Check Start 1 | Status | Start 2 | Status | Background Check Start 1 | Status | Start 2 | Status | Det. Status |
|---|---|---|---|---|---|---|---|---|---|
| 1 | JP | P | | | JP | P | | | P |
| 2 | | | | | | | | | |
| 3 | | | | | | | | | |
| 4 | | | | | | | | | |
| 5 | | | | | | | | | |
| 6 | | | | | | | | | |
| 7 | | | | | | | | | |
| 8 | | | | | | | | | |
| 9 | | | | | | | | | |
| 10 | | | | | | | | | |
| 11 | | | | | | | | | |
| 12 | | | | | | | | | |
| 13 | | | | | | | | | |
| 14 | | | | | | | | | |
| 15 | | | | | | | | | |
| 16 | | | | | | (HB) | | | OUB |

Det = Detector; α = Alpha; β = Beta; P = Pass; H = High; L = Low; OL = Offline; R = Recount; W = Weekly; NP = Not Processed

*Weekly Background Calibration*

| | Current Calib. File ID | Weekly Calib. Started | Status | File ID |
|---|---|---|---|---|
| Dr A | BKC0607W | | | |
| Dr B | | | | |
| Dr C | | | | |
| Dr D | | | | |

Dr = Drawer

*Gas Supply*

| P-10 Supply | | P-10 Flow | |
|---|---|---|---|
| Tank 1 | 2250 | Dr A | 10 |
| | | Dr B | |
| Tank 2 | 1050 | Dr C | |
| | | Dr D | |

Comments:

Page No.: 473504 A

Form 780r8.doc (6/23/06)

Reviewed By / Date JP 6/19/17

Date 6/19/17 SOP 724r 12

**ALS**

Low Background Gas Flow Proportional Counter Log

**Instrument: LB4100C**

| Det. | Sample ID | Batch | Test | Count Dur. (min) | Start Time | Analyst Initials | File ID | Output Initials |
|---|---|---|---|---|---|---|---|---|
| 1-16 | Daily Eff | — | — | 30 | 6:42 | JP | EFC0619 | JP |
| 1-16 | Daily Bkg | — | — | 60 | 6:53 | JP | BKC0619 | JP |
| 1 | 1718016-1 | RA170615-1 | Ra228 | 8 | 8:08 | JP | RAC0619 | JP |
| 1 | -2 | | EffCal | | 8:16 | JP | A | JP |
| 1 | -3 | | Outlier | | 8:26 | JP | B | JP |
| 1 | -4 | | | | 8:34 | JP | C | JP |
| 1 | -5 | | | | 8:43 | JP | D | JP |
| 1-4 | 1080 | RA170615-1 | Ra228 | 30 | 9:54 | JP | ERA0619A | JP |
| 5-8 | | | EffCal | | 9:03 | JP | B | JP |
| 9-12 | | | | | 9:11 | JP | C | JP |
| 13-16 | | | | | 9:20 | JP | D | |
| 1 | 1706344-1 | AB170616-1 | αβ | 10 | 937 | JKB | ABC0619 | JKB |
| 2 | 2 | | | | | | | |
| 3 | 3 | | | | | | | |
| 4 | 4 | | | | | | | |
| 5 | 5 | | | | | | | |
| 6 | 6 | | | | | | | |
| 7 | 7 | | | | | | | |
| 8 | 8 | | | | | | | |
| 9 | 9 | | | | | | | |
| 10 | 10 | | | | | | | |
| 11 | 11 | | | | | | | |
| 12 | 12 | | | | | | | |
| 13 | 13 | | | | | | | |
| 14 | 14 | | | | | | | |
| 15 | 15 | | | | | | | |
| 1 | 7D | | | | 958 | | ABC0619A | |
| 2 | 16 | | | | | | | |
| 3 | 17 | | | | | | | |
| 4 | 18 | | | | | | | |
| 5 | 19 | | | | | | | |
| 6 | 20 | | | | | | | |
| 7 | AB170616-1ALCS | | | | | | | |
| 8 | BLCS | | | | | | | |
| 9 | MB | | | | | | | |
| 10 | 1706344-21 | AB170616-2 | | | | | | |
| 11 | 22 | | | | | | | |
| 12 | 23 | | | | | | | |
| 13 | 24 | | | | | | | |
| 14 | 25 | | | | | | | |
| 15 | AB170616-2MB | | | | | | | |
| 1 | ALCS | | | | 1013 | | ABC0619B | |
| 2 | BLCS | | | | | | | |
| 3 | 1706344-21P | | | | | | | |
| 1 | 1706188-1 | AB170616-4 | | 30 | 1041 | JKB | ABC0619C | |
| 2 | 2 | | | | | | | |
| 3 | 3 | | | | | | | |

Comments:

Page No.: 473504 **B**

(cont. from page MA B)

Form 780r8.doc (6/23/06)

Reviewed By / Date JKB 6/19/17

Date 6/20/17

SOP 724r 12

# ALS
## Low Background Gas Flow Proportional Counter Log
## Instrument: LB4100C

*Instrument Daily Response and Background Checks*

| Det. | Daily Response Check Start 1 | Status | Start 2 | Status | Background Check Start 1 | Status | Start 2 | Status | Det. Status |
|---|---|---|---|---|---|---|---|---|---|
| 1 | JP | P | | | JP | P | | | P |
| 2 | | | | | | | | | |
| 3 | | | | | | | | | |
| 4 | | | | | | | | | |
| 5 | | | | | | | | | |
| 6 | | | | | | | | | |
| 7 | | | | | | | | | |
| 8 | | | | | | | | | |
| 9 | | | | | | | | | |
| 10 | | | | | | | | | |
| 11 | | | | | | | | | |
| 12 | | | | | | | | | |
| 13 | | | | | | | | | |
| 14 | | | | | | | | | |
| 15 | | | | | | | | | |
| 16 | | | | | | (HB) | | | OLB |

Det = Detector; α = Alpha; β = Beta; P = Pass; H = High; L = Low; OL = Offline; R = Recount; W = Weekly; NP = Not Processed

*Weekly Background Calibration*

| | Current Calib. File ID | Weekly Calib. Started | Status | File ID |
|---|---|---|---|---|
| Dr A | BKC0607W | | | |
| Dr B | | | | |
| Dr C | | | | |
| Dr D | | | | |

Dr = Drawer

*Gas Supply*

| P-10 Supply | | P-10 Flow | |
|---|---|---|---|
| Tank 1 | 1950 | Dr A | 10 |
| | | Dr B | |
| Tank 2 | 1050 | Dr C | |
| | | Dr D | |

Comments:

Page No.: 473506 A

Form 780r8.doc (6/23/06)

Reviewed By / Date JP 6/20/17

# Radiochemistry Instrument Worksheet

**ALS -- Fort Collins**

**Prep Batch:** RA170615-1

**Prep Procedure:** Ra228 Outlier

**Analytical QASS / NCR? Y (N)** NA

| Prep Num | LabID | QC Type | Init Alq | Fin Alq | Units | Report Units | Residual Mass (mg) | Cnt 1 File | Cnt 1 Inst/Det | Cnt 1 Pos Chk By | Cnt 2 File | Cnt 2 Inst/Det | Cnt 2 Pos Chk By | Cnt 3 File | Cnt 3 Inst/Det | Cnt 3 Pos Chk By | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1718016-1 | SMP | 1500 | 1496.0 | ml | pCi/l | | RA00619 | 1 | JP | | | | | | | JP 6/19/17 |
| 1 | 1718016-2 | SMP | 1500 | 1496.0 | ml | pCi/l | | | A 1 | JP | | | | | | | Outlier |
| 1 | 1718016-3 | SMP | 1500 | 1496.0 | ml | pCi/l | | | B 1 | JP | | | | | | | |
| 1 | 1718016-4 | SMP | 1500 | 1496.0 | ml | pCi/l | | | C 1 | JP | | | | | | | JP 6/19/17 |
| 1 | 1718016-5 | SMP | 1500 | 1496.0 | ml | pCi/l | | | D 1 | JP | | | | | | | |

**Tracer/Carrier Solution Information**

| Soln # | Nuclide | SolnID | Exp Date | Prep Conc | Units | Prep Date | Aliquot | Units | Pipet ID |
|---|---|---|---|---|---|---|---|---|---|
| T1 | BARIUM | 418236 | 1/19/18 | 16,022.768 | pCi/ml | NA | 2 | ml | RS031 |

**Spike Solution Information**

| Soln # | Nuclide | SolnID | Exp Date | Prep Conc | Units | Prep Date | Aliquot | Units | Pipet ID |
|---|---|---|---|---|---|---|---|---|---|
| S1 | Ra-228 | 784.3020.37 | 3/23/18 | 7,552.998 | DPM/g | 06/15/17 | 0.5 | g | RS034 |

## Sample Barcodes

| | | |
|---|---|---|
| 1718016-1<br>RA170615-1PS1 | 1718016-2<br>RA170615-1PS2 | 1718016-3<br>RA170615-1PS3 |
| 1718016-4<br>RA170615-1PS4 | 1718016-5<br>RA170615-1PS5 | RA170615-1CAR<br>RA170615-1PS6 |

## Reporting Units

| LabID: | TstGrpName: | RptUnits: |
|---|---|---|
| 1718016-1 | Ra228_2012 | pCi/l |
| 1718016-2 | Ra228_2012 | pCi/l |
| 1718016-3 | Ra228_2012 | pCi/l |
| 1718016-4 | Ra228_2012 | pCi/l |
| 1718016-5 | Ra228_2012 | pCi/l |

# Radiochemistry Prep Worksheet

**ALS -- Fort Collins**

**Prep Batch:** RA170615-1

**Prep Procedure:** Ra228

**Reviewed By:** lad LAD **Review Date:** 6/19/2017

**Non-Routine Pre-Treatment? Y / N** **Batch:** NA **Re-Prep? Y / N** **Batch:** NA **Prep QASS / NCR? Y / N** NA

**Prep SOP:** SOP749 **Rev:** 4
**Prep SOP:** NONE
**Matrix Class:** liquid

**Prep Analyst:** Lucas A. Daut LAD
**Prep Date:** 6/15/2017
**Prep Dept:** RS

**Balance:** N/A
**Balance:** N/A

| Samp Num | Prep Num | LabID | QC Type | Dish No. | Init Alq ml | Fin Alq ml | Prep Basis | Ingrowth Date/Time | Decay Date/Time | Standards | Prep Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1718016-1 | SMP | NA | 1500 | 1496.002 | Unfiltered | 06/16/17 17:00 | 06/19/17 07:05 | T1,S1 | |
| 2 | 1 | 1718016-2 | SMP | | 1500 | 1496.002 | Unfiltered | 06/16/17 17:00 | 06/19/17 07:05 | T1,S1 | |
| 3 | 1 | 1718016-3 | SMP | | 1500 | 1496.002 | Unfiltered | 06/16/17 17:00 | 06/19/17 07:05 | T1,S1 | |
| 4 | 1 | 1718016-4 | SMP | | 1500 | 1496.002 | Unfiltered | 06/16/17 17:00 | 06/19/17 07:05 | T1,S1 | LAD 6/19 |
| 5 | 1 | 1718016-5 | SMP | | 1500 | 1496.002 | Unfiltered | 06/16/17 17:00 | 06/19/17 07:05 | T1,S1 | |

Comments

**Spiked By:** Lucas A. Daut **Date:** 6/15/2017 **Yttrium Added By:** **Date:**

**Witnessed By:** Andrew R. Steger **Date:** 6/15/2017 **Witnessed By:** **Date:**

**Tracer/Carrier Solution Information**

| Soln # | Nuclide | SolnID | Exp Date | Prep Conc | Units | Prep Date | Aliquot | Units | Pipet ID |
|---|---|---|---|---|---|---|---|---|---|
| T1 | BARIUM | 418236 | 1/19/18 | 16,022.768 | pCi/ml | NA | 2 | ml | RS031 |

**Spike Solution Information**

| Soln # | Nuclide | SolnID | Exp Date | Prep Conc | Units | Prep Date | Aliquot | Units | Pipet ID |
|---|---|---|---|---|---|---|---|---|---|
| S1 | Ra-228 | 784.3020.37 | 3/23/18 | 7,552.998 | DPM/g | 06/15/17 | 0.5 | g | RS034 |

ALS -- Fort Collins

# Radiochemistry Prep Worksheet

**Prep Batch:** RA170615-1

**Prep Procedure:** Ra228

## Prep Batch Not Validated!!!

**Reviewed By:** LAD **Review Date:**

**Non-Routine Pre-Treatment? Y / N** **Batch:** _____ **Re-Prep? Y / N** **Batch:** _____ **Prep QASS / NCR? Y / N** _____

**Prep SOP:** SOP749 **Rev:** 4
**Prep SOP:** NONE
**Matrix Class:** liquid

**Prep Analyst:** Lucas A. Daut
**Prep Date:** 6/15/2017
**Prep Dept:** RS

**Balance:** N/A
**Balance:** N/A

| Samp Num | Prep Num | LabID | QC Type | Dish No. | Init Alq ml | Fin Alq ml | Prep Basis | Ingrowth Date/Time | Decay Date/Time | Standards | Prep Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1718016-1 | SMP | | 1500 | 1496.002 | Unfiltered | 6/16 | 6/19 | T1,S1 | None |
| 2 | 1 | 1718016-2 | SMP | | 1500 | 1496.002 | Unfiltered | 17:00 | 07:05 | T1,S1 | |
| 3 | 1 | 1718016-3 | SMP | | 1500 | 1496.002 | Unfiltered | | | T1,S1 | |
| 4 | 1 | 1718016-4 | SMP | | 1500 | 1496.002 | Unfiltered | | | T1,S1 | |
| 5 | 1 | 1718016-5 | SMP | | 1500 | 1496.002 | Unfiltered | | | T1,S1 | |

Comments

**Spiked By:** Lucas A. Daut **Date:** 6/15/2017 *** Yttrium Added By:** _____ **Date:** _____

**Witnessed By:** Andrew R. Steger **Date:** 6/15/2017 **Witnessed By:** _____ **Date:** _____

**Tracer/Carrier Solution Information**

| Soln # | Nuclide | SolnID | Exp Date | Prep Conc | Units | Prep Date | Aliquot | Units | Pipet ID |
|---|---|---|---|---|---|---|---|---|---|
| T1 | BARIUM | 418236 | | 16,022.768 | pCi/ml | NA | 2 | ml | RS031 |

**Spike Solution Information**

| Soln # | Nuclide | SolnID | Exp Date | Prep Conc | Units | Prep Date | Aliquot | Units | Pipet ID |
|---|---|---|---|---|---|---|---|---|---|
| S1 | Ra-228 | 784.3020.37 | | 7,552.998 | DPM/g | 06/15/17 | 0.5 | g | RS034 |

# Radiochemistry ICP Worksheet

**ALS -- Fort Collins**

**Prep Batch: RA170615-1**

Prep Procedure: **Ra228**

Reviewed By: **lad** LAD

Review Date: **6/19/2017**

## BARIUM Recovery Results

### Reference Carrier

| LabID | QC Type | Carr Vol | Ref Carr Dil Vol | Ref Carr ICP Alq | Ref Carr ICP Dil Vol | Ref Carr ICP Run | Ref Carr ICP Conc |
|---|---|---|---|---|---|---|---|
| RA170615-1 | CAR | 2 | 27 | 0.05 | 10.05 | IR170616-2A1 | 5.898432 |

### Samples

| Prep Num | LabID | QC Type | Init Samp Alq (ml) | Car Vol (ml) | Samp Dil Vol (ml) | Init ICP Alq (ml) | Init ICP Dil Vol (ml) | Pre-Con Vol (ml) | Post Con Vol (ml) | Pre-Sep Vol (ml) | Post Sep Vol (ml) | Fin ICP Alq (ml) | Fin ICP Dil Vol (ml) | Initial ICP Run | Final ICP Run | Init ICP Conc (ug/ml) | Fin ICP Conc (ug/ml) | Init Samp Mass (ug) | Ref Mass (ug) | Flag | Fin Samp Mass (ug) | % Yield | Final Sample Alq |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1718016-1 | SMP | 1500 | 2 | 1500 | 1 | 10 | 1499 | 1499 | 1499 | 25 | 0.05 | 10.05 | IR170616-2A1 | IR170616-2A1 | -0.0003 | 6.272993 | 0 | 32010.79 | Z | 31521.79 | 98.47% | 1496 |
| 1 | 1718016-2 | SMP | 1500 | 2 | 1500 | 1 | 10 | 1499 | 1499 | 1499 | 25 | 0.05 | 10.05 | IR170616-2A1 | IR170616-2A1 | 0.06616 | 6.105323 | 991.7684 | 32010.79 | | 30679.25 | 92.96% | 1496 |
| 1 | 1718016-3 | SMP | 1500 | 2 | 1500 | 1 | 10 | 1499 | 1499 | 1499 | 25 | 0.05 | 10.05 | IR170616-2A1 | IR170616-2A1 | 0.09805 | 6.286881 | 1469.783 | 32010.79 | | 31591.58 | 94.36% | 1496 |
| 1 | 1718016-4 | SMP | 1500 | 2 | 1500 | 1 | 10 | 1499 | 1499 | 1499 | 25 | 0.05 | 10.05 | IR170616-2A1 | IR170616-2A1 | 0.00095 | 6.337784 | 14.29576 | 32010.79 | | 31847.36 | 99.45% | 1496 |
| 1 | 1718016-5 | SMP | 1500 | 2 | 1500 | 1 | 10 | 1499 | 1499 | 1499 | 25 | 0.05 | 10.05 | IR170616-2A1 | IR170616-2A1 | -0.0011 | 6.307981 | 0 | 32010.79 | Z | 31697.6 | 99.02% | 1496 |



**FLAG -** LB: low bias (<= 15%) 15%: low bias (>15%)

Z: Negative init. conc. treated as zer

**Supersedes:** NA

IR170616.2A1



| Sample Id1 | Ca | Fe | K | Mg | Na | Sr | Mn | S | Al | Ba | Pb | Ni |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CCV | 50.1627 | 20.0214 | 50.4050 | 50.1827 | 49.1171 | 0.5053 | 1.0018 | 4.9726 | 50.4533 | 1.0028 | 0.9822 | 1.0083 |
| CCB | 0.0121 | 0.0074 | 0.0354 | 0.0154 | 0.0394 | 0.0002 | 0.0002 | 0.0000 | 0.0078 | 0.0008 | 0.0028 | 0.0007 |
| I 1718016-1 | -0.1052 | -0.0075 | -0.0529 | -0.0689 | -0.4648 | -0.0020 | -0.0014 | -0.0365 | -0.0561 | -0.0003 | 0.0084 | 0.0000 |
| I 1718016-2 | 12.3449 | 0.0132 | -0.0618 | -0.0592 | -0.4595 | 0.0035 | -0.0008 | -0.0182 | -0.0496 | 0.0662 | 0.0039 | -0.0003 |
| I 1718016-3 | 11.9360 | 0.0215 | -0.0927 | -0.0711 | -0.4650 | 0.0035 | -0.0009 | -0.0182 | -0.0385 | 0.0981 | 0.0025 | -0.0011 |
| I 1718016-4 | 0.1444 | -0.0038 | -0.0797 | -0.0700 | -0.4919 | -0.0020 | -0.0015 | -0.0319 | -0.0509 | 0.0010 | -0.0001 | -0.0013 |
| I 1718016-5 | -0.1068 | -0.0009 | -0.0752 | -0.0729 | -0.4911 | -0.0021 | -0.0015 | -0.0411 | -0.0476 | -0.0011 | -0.0001 | -0.0002 |
| F 1718016-1 | -0.0999 | -0.0096 | -0.0598 | -0.0598 | 87.1920 | -0.0015 | -0.0014 | 1.5693 | -0.0477 | 6.2730 | 0.0550 | 0.0000 |
| F 1718016-2 | -0.1042 | -0.0088 | -0.0638 | -0.0723 | 86.3241 | -0.0014 | -0.0014 | 1.4781 | -0.0457 | 6.1053 | 0.0382 | 0.0002 |
| F 1718016-3 | -0.1045 | -0.0134 | -0.0793 | -0.0791 | 86.9998 | -0.0015 | -0.0015 | 1.5602 | -0.0437 | 6.2869 | 0.0435 | -0.0021 |
| F 1718016-4 | -0.1058 | -0.0126 | -0.0740 | -0.0803 | 86.5104 | -0.0015 | -0.0017 | 1.5648 | -0.0542 | 6.3378 | 0.0474 | -0.0012 |
| F 1718016-5 | -0.1032 | -0.0129 | -0.0598 | -0.0746 | 86.2083 | -0.0014 | -0.0017 | 1.5648 | -0.0470 | 6.3080 | 0.0560 | -0.0018 |
| RA170615-1RC | -0.1032 | -0.0097 | -0.0667 | -0.0763 | 80.7188 | -0.0010 | -0.0015 | 0.0046 | -0.0542 | 5.8984 | 0.0030 | -0.0002 |
| CCV | 49.7949 | 19.8872 | 50.1529 | 49.8850 | 49.3913 | 0.5013 | 0.9950 | 4.9863 | 50.1172 | 0.9971 | 0.9879 | 1.0063 |
| CCB | 0.0189 | 0.0100 | 0.0382 | 0.0131 | 0.0394 | 0.0001 | 0.0001 | 0.0137 | 0.0235 | 0.0008 | 0.0038 | -0.0005 |

Prepare a primary dilution of (Analytics SRS 70035-307) RSO #784 by diluting contents to approx 40g w/ 0.1 N HCl in a 40 ml VOA vial.

1) Prepare 2L 0.1 M HCl by diluting 83 ml conc. HCl, Fisher lot # 060506, in 2L DI water.

2) Transfer contents of ampoule to 40 ml VOA vial.

Mass of VOA vial w/ lid = 24.9925 g (Bal 12)
vial + STD 784 = 29.7652 g
net std transferred = 4.7727 g

3) Dilute w/ 0.1 M HCl BS 5/30/06

Mass of vial (from above) = 24.9925 g
vial + std + 0.1 M HCl = 64.2671 g (Bal 12)
net mass of std = 39.2746 g

4) Final Activity Calc.

$$\frac{(2.308\times10^{4}\ \text{dps})(60\ \frac{\text{dpm}}{\text{dps}})(4.7727\ \text{g})}{(5.00994\ \text{g})(39.2746\ \text{g})} = 33{,}589.8\ \frac{\text{dpm}}{\text{g}}$$

Continued on Page

Read and Understood By

Signed: [signature] Date: 5/30/06 Signed: [signature] Date: 8/24/06

ANALYTICS

RSO # 784
Rec'd 2/2/05
JCB

1380 Seaboard Industrial Blvd.
Atlanta, Georgia 30318 • U.S.A.

Phone (404) 352-8677
Fax (404) 352-2837

# CERTIFICATE OF CALIBRATION
## Standard Radionuclide Source

70035-307

Ra-228 5 mL Liquid in Flame Sealed Vial

This standard radionuclide source was prepared gravimetrically from a calibrated master solution. The master solution was calibrated using a germanium gamma spectrometer system.

Radionuclide purity and calibration were checked with a germanium gamma spectrometer system. The nuclear decay rate and assay date for this source are given below.

ANALYTICS maintains traceability to the National Institute of Standards and Technology through Measurements Assurance Programs as described in USNRC Reg. Guide 4.15, Revision 1.

| | |
|---|---|
| ISOTOPE: | Ra-228 |
| ACTIVITY (dps): | 2.308 E4 |
| HALF-LIFE: | 5.75 years |
| CALIBRATION DATE: | January 28, 2005 12:00 EST |
| RELATIVE EXPANDED UNCERTAINTY (k=2): | 3.3% |

Impurities: γ-impurities (other than decay products) <0.1%

5.00994 grams 0.1M HCl solution with 25 μg/g Ba carrier.

P O NUMBER 71239, Item 2

SOURCE PREPARED BY: M. Dimitrova
M. Dimitrova, Radiochemist

Q A APPROVED: 2-1-05

# Radiochemistry Solution Report

| | | | | | |
|---|---|---|---|---|---|
| **Solution Id:** | 418236 | **Name:** | Ba carrier | **Type:** | IS |
| | | **Lot:** | | **Vendor Name:** | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Final Vol:** | 4000 | **Dept:** | RD | **Prep By** | SDW | **on** | 1/19/2017 | **Reviewed By** | tde | **on** | 1/26/2017 |
| **Units:** | mL | **Location:** | RS | **Opened By** | | **on** | | **Verified By** | SDW | **on** | 1/19/2017 |
| **Matrix:** | LIQUID | **ExpireDate:** | 1/19/2018 | **Received By** | | **on** | | **Deactivated By** | | **on** | |

**Comment:**

| Component Name | Component ID | Volume Added | Units |
|---|---|---|---|
| Barium Stable Carrier Source<1> | 3756 B07592 | 114.0018 | g |

| CompName | Calibrated Primary Act/Conc | Calibration Date | Reference Date | 1/2 Life (Yrs) | Final Act/Conc | Summed Conc | Units |
|---|---|---|---|---|---|---|---|
| BARIUM | 562193.5 | | 3/9/2017 | | 16022.77 | | pCi/ml |

## Associated Parent IDs

3756 B07592

**Abbreviations: NC = Not Calculated for reagents when the volume added is not entered.**
**NE = Not Entered**

**(Prnt) = Secular equilibrium; parent half life used to calculate concentration.**

## Internal Calculation Verifications

# ICBs

# &

# ICVs

# Rad Preliminary Data Report

**Laboratory Name:** ALS -- Fort Collins
**Analytical Run:** RA170612-13A

**Prep SOP:** SOP749
**Analytical SOP:** PAI 724

| Sample ID / QC Type | Nuclide / Type | Sample Date/Time | Prep Batch / QCBatchID | Ingrowth Date /Time | Decay Date/Time | Matrix / %Moist. | Samp Alq / Analy Alq | Inst ID / Det ID | File Name | Count Date/Time | GrossCPM / BkgCPM | BaseEff / ProgEff | CntDur(min) / Yield | Activity +/- / 2 s TPU | MDC / DecLev | ReportUnits / ReportBasis | DER / RPD | %Spk. Recov. / Flags |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1718017-1 | Ra-228 | | RA170612-13 | 6/16/2017 | 6/20/2017 | Liquid | 1500 ml | LB4100-C | | 6/20/2017 | 10.233 | 48.75% | 90 | 6.6 | 0.5 | pCi/l | NA | 96.1 |
| SMP | Trg. Analyte | | RA170612-13-1 | 3:05:00 PM | 7:10:00 AM | NA | 1500 ml | A1 | RAC0620 | 8:03 AM | 1.436 | NA | 99.3% | 1.6 | NA | Unfiltered | NA | |
| 1718017-2 | Ra-228 | | RA170612-13 | 6/16/2017 | 6/20/2017 | Liquid | 1500 ml | LB4100-C | | 6/20/2017 | 9.900 | 48.05% | 90 | 6.5 | 0.5 | pCi/l | NA | 94.6 |
| SMP | Trg. Analyte | | RA170612-13-1 | 3:05:00 PM | 7:10:00 AM | NA | 1500 ml | B3 | RAC0620 | 8:03 AM | 1.545 | NA | 97.1% | 1.6 | NA | Unfiltered | NA | |
| 1718017-3 | Ra-228 | | RA170612-13 | 6/16/2017 | 6/20/2017 | Liquid | 1500 ml | LB4100-C | | 6/20/2017 | 11.678 | 48.03% | 90 | 8.0 | 0.5 | pCi/l | NA | 116 |
| SMP | Trg. Analyte | | RA170612-13-1 | 3:05:00 PM | 7:10:00 AM | NA | 1500 ml | C3 | RAC0620 | 8:03 AM | 1.640 | NA | 94.8% | 1.9 | NA | Unfiltered | NA | |
| 1718017-4 | Ra-228 | | RA170612-13 | 6/16/2017 | 6/20/2017 | Liquid | 1500 ml | LB4100-C | | 6/20/2017 | 9.856 | 45.96% | 90 | 6.7 | 0.5 | pCi/l | NA | 97.7 |
| SMP | Trg. Analyte | | RA170612-13-1 | 3:05:00 PM | 7:10:00 AM | NA | 1500 ml | D1 | RAC0620 | 8:03 AM | 1.614 | NA | 97.0% | 1.6 | NA | Unfiltered | NA | |
| RA170612-13A | Ra-228 | 6/12/2017 | RA170612-13 | 6/16/2017 | 6/20/2017 | Liquid | 1500 ml | LB4100-C | | 6/20/2017 | 1.767 | 48.51% | 90 | 0.21 | 0.51 | pCi/l | NA | |
| MB | Trg. Analyte | 9:19:38 AM | RA170612-13-1 | 3:05:00 PM | 7:10:00 AM | NA | 1500 ml | A3 | RAC0620 | 8:03 AM | 1.510 | NA | 93.3% | 0.24 | NA | Unfiltered | NA | U |
| RA170612-13B | Ra-228 | 6/12/2017 | RA170612-13 | 6/16/2017 | 6/20/2017 | Liquid | 1500 ml | LB4100-C | | 6/20/2017 | 1.833 | 48.03% | 90 | 0.17 | 0.51 | pCi/l | NA | |
| MB | Trg. Analyte | 9:19:38 AM | RA170612-13-1 | 3:05:00 PM | 7:10:00 AM | NA | 1500 ml | B1 | RAC0620 | 8:03 AM | 1.613 | NA | 97.3% | 0.23 | NA | Unfiltered | NA | U |
| RA170612-13C | Ra-228 | 6/12/2017 | RA170612-13 | 6/16/2017 | 6/20/2017 | Liquid | 1500 ml | LB4100-C | | 6/20/2017 | 2.222 | 47.03% | 90 | 0.45 | 0.53 | pCi/l | NA | |
| MB | Trg. Analyte | 9:19:38 AM | RA170612-13-1 | 3:05:00 PM | 7:10:00 AM | NA | 1500 ml | C2 | RAC0620 | 8:03 AM | 1.659 | NA | 95.6% | 0.28 | NA | Unfiltered | NA | U |
| RA170612-13E | Ra-228 | 6/12/2017 | RA170612-13 | 6/16/2017 | 6/20/2017 | Liquid | 1500 ml | LB4100-C | | 6/20/2017 | 2.011 | 47.02% | 90 | 0.28 | 0.53 | pCi/l | NA | |
| MB | Trg. Analyte | 9:19:38 AM | RA170612-13-1 | 3:05:00 PM | 7:10:00 AM | NA | 1500 ml | D3 | RAC0620 | 8:03 AM | 1.665 | NA | 95.5% | 0.26 | NA | Unfiltered | NA | U |

Control limits => 70-130%

**Comments:**

## Qualifiers/Flags:

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative yield is assumed.

Y2 - Chemical Yield outside default limits.

W - DER is greater than Warning Limit of 1.42

D - DER is greater than Control Limit of 2.13

+ - Duplicate RPD not within limits.

LT - Result is less than Request MDC, greater than sample specific MDC

* - Aliquot Basis is 'As Received' while the Report Basis is 'Dry Weight'.

\# - Aliquot Basis is 'Dry Weight' while the Report Basis is 'As Received'.

M - Requested MDC not met.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

L - LCS Recovery below lower control limit.

H - LCS Recovery above upper control limit.

P - LCS, Matrix Spike Recovery within control limits.

N - Matrix Spike Recovery outside control limits

NC - Not Calculated for duplicate results less than 5 times MDC

B - Analyte concentration greater than MDC.

B3 - Analyte concentration greater than MDC but less than Requested MDC.

## Notes:

1) The Tracer results are not yield corrected (i.e. activity measured not activity added).

2) Where sample time is not available, 12:00 PM (Mountain) is used for decay correction.

## Abbreviations:

TR- Tracer TA - Target Analyte

TPU - Total Propagated Uncertainty (see PAI SOP 743)

MDC - Minimum Detectable Concentration (see PAI SOP 709)

DER - Duplicate Error Ratio

BDL - Below Detection Limit



**Date Printed:** Tuesday, June 20, 2017

**ALS -- Fort Collins**
LIMS Version: 6.843

# PAI - Gas Flow Proportional Sample Analysis LB4100-C

Unit Type: LB4100 -C
Counting Unit ID: Magenta
High Voltage Mode: Simultaneous
Application Revision: 2
Application Version: Standard
Rev.12/01/08 JCP

Data file name: RAC0620
Batch ID: RA170612-13
Count Preset (m): 90
Batch Ended: 6/20/2017 9:43

Background logfile: BKGABW
Date of Bkg. Cal: 6/8/2017
Alpha efficiency logfile: Am_WIPE-06/17 Alpha prog. logfile: n/a
Alpha attenuation calibration: AAM0606, 0607 Alpha prog. attenuation: n/a
Beta efficiency logfile: RA228-06/17 Beta prog. logfile: n/a
Beta attenuation calibration: ASR0607 Beta prog. attenuation: n/a

| Alpha Attenuation Calibration | | Beta Attenuation Calibration | |
|---|---|---|---|
| y = b*m^(a*(mass-x0)) | | y = b*m^(a*(mass-x0)) | |
| Alpha b= | 0.90300 | Beta b= | 0.9681 |
| m= | 0.99110 | m= | 0.9996 |
| a= | 0.8270 | a= | 0.9174 |
| x0= | 21.4875 | x0= | 0.0000 |
| Alpha to Beta X-talk | | Beta to Alpha X-talk | |
| y = b *m^-mass | | y = b*mass + m | |
| a ->b xtalk b= | 0.2511 | b ->a xtalk b= | -1.69E-05 |
| a ->b xtalk m= | 0.9984 | b ->a xtalk m= | 0.0036 |

| Det. ID | Sample ID | Count End Date & Time | Count Dur. (min) | Resid. Mass (mg) | Alpha Activity Gross CPM | Alpha Bkg. CPM | Alpha b>a xtlk CPM | Alpha Base Eff | Alpha Base Cor.Fact. | Alpha Progeny Eff | Alpha Progeny Cor.Fact. | Beta Activity Gross CPM | Beta Bkg. CPM | Beta a>b xtlk CPM | Beta Base Eff | Beta Base Cor.Fact. | Beta Progeny Eff | Beta Progeny Cor.Fact. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 | 1718017-1 | 6/20/2017 9:42 | 90.00 | 0.0 | 0.444 | 0.078 | 0.032 | 0.2716 | 1.058 | n/a | n/a | 10.233 | 1.436 | 0.0920 | 0.4875 | 0.968 | n/a | n/a |
| A3 | RA170612-13AMB | 6/20/2017 9:42 | 90.00 | 0.0 | 0.289 | 0.096 | 0.001 | 0.2667 | 1.058 | n/a | n/a | 1.767 | 1.510 | 0.0484 | 0.4851 | 0.968 | n/a | n/a |
| C2 | RA170612-13CMB | 6/20/2017 9:43 | 90.00 | 0.0 | 0.300 | 0.112 | 0.002 | 0.2618 | 1.058 | n/a | n/a | 2.222 | 1.659 | 0.0472 | 0.4703 | 0.968 | n/a | n/a |
| C3 | 1718017-3 | 6/20/2017 9:43 | 90.00 | 0.0 | 0.422 | 0.096 | 0.036 | 0.2629 | 1.058 | n/a | n/a | 11.678 | 1.640 | 0.0819 | 0.4803 | 0.968 | n/a | n/a |
| B1 | RA170612-13BMB | 6/20/2017 9:43 | 90.00 | 0.0 | 0.222 | 0.091 | 0.001 | 0.2653 | 1.058 | n/a | n/a | 1.833 | 1.613 | 0.0329 | 0.4803 | 0.968 | n/a | n/a |
| B3 | 1718017-2 | 6/20/2017 9:43 | 90.00 | 0.0 | 0.278 | 0.084 | 0.030 | 0.2589 | 1.058 | n/a | n/a | 9.900 | 1.545 | 0.0487 | 0.4805 | 0.968 | n/a | n/a |
| D1 | 1718017-4 | 6/20/2017 9:43 | 90.00 | 0.0 | 0.433 | 0.095 | 0.030 | 0.2582 | 1.058 | n/a | n/a | 9.856 | 1.614 | 0.0850 | 0.4596 | 0.968 | n/a | n/a |
| D3 | RA170612-13EMB | 6/20/2017 9:43 | 90.00 | 0.0 | 0.289 | 0.171 | 0.001 | 0.2627 | 1.058 | n/a | n/a | 2.011 | 1.665 | 0.0296 | 0.4702 | 0.968 | n/a | n/a |

JP 6/20/17

Date 6/20/17

SOP 724r 12

# ALS
## Low Background Gas Flow Proportional Counter Log
## Instrument: LB4100C

*Instrument Daily Response and Background Checks*

| Det. | Daily Response Check Start 1 | Status | Start 2 | Status | Background Check Start 1 | Status | Start 2 | Status | Det. Status |
|---|---|---|---|---|---|---|---|---|---|
| 1 | JP | P | | | JP | P | | | P |
| 2 | | | | | | | | | |
| 3 | | | | | | | | | |
| 4 | | | | | | | | | |
| 5 | | | | | | | | | |
| 6 | | | | | | | | | |
| 7 | | | | | | | | | |
| 8 | | | | | | | | | |
| 9 | | | | | | | | | |
| 10 | | | | | | | | | |
| 11 | | | | | | | | | |
| 12 | | | | | | | | | |
| 13 | | | | | | | | | |
| 14 | | | | | | | | | |
| 15 | | | | | | | | | |
| 16 | | | | | | (HB) | | | OLB |

Det = Detector; α = Alpha; β = Beta; P = Pass; H = High; L = Low; OL = Offline; R = Recount; W = Weekly; NP = Not Processed

*Weekly Background Calibration*

| | Current Calib. File ID | Weekly Calib. Started | Status | File ID |
|---|---|---|---|---|
| Dr A | BKC0607W | | | |
| Dr B | | | | |
| Dr C | | | | |
| Dr D | | | | |

Dr = Drawer

*Gas Supply*

| P-10 Supply | | P-10 Flow | |
|---|---|---|---|
| Tank 1 | 1950 | Dr A | 10 |
| | | Dr B | |
| Tank 2 | 1050 | Dr C | |
| | | Dr D | |

Comments:

Page No.: 473506 A

Form 780r8.doc (6/23/06)

Reviewed By / Date JP 6/20/17

Date 6/20/17

SOP 724r 12

**ALS**

Low Background Gas Flow Proportional Counter Log

**Instrument: LB4100C**

| Det. | Sample ID | Batch | Test | Count Dur. (min) | Start Time | Analyst Initials | File ID | Output Initials |
|---|---|---|---|---|---|---|---|---|
| 1-16 | Daily EFP | — | — | 30 | 6:40 | JP | EFC0620 | JP |
| 1-16 | Daily BKG | — | — | 60 | 6:50 | JP | BKC0620 | JP |
| 1 | 1718017-1 | RA170612-13 | Ra228 | 90 | 8:12 | JP | RAC0620 | JP |
| 7 | -2 | | | | | | | |
| 11 | -3 | | | | | | | |
| 13 | -4 | | | | | | | |
| 3 | RA170612-13AMB | | | | | | | |
| 5 | BMB | | | | | | | |
| 10 | CMB | | | | | | | |
| 15 | EMB | | | | | | | |
| 13 | 1706003-8 | SR170604-1 | SR90 | 120 | 952 | JMB | SRC0620 | JP |
| 14 | -13 | | | | | | | |
| 15 | 1706053-6 | | | | | | | |
| 1 | 1706051-3 | | | 90 | 1000 | | SRC0620A | |
| 2 | 6 | | | | | | | |
| 3 | 8 | | | | | | | |
| 4 | 11 | | | | | | | |
| 5 | 14 | | | | | | | |
| 6 | 18 | | | | | | | |
| 7 | 20 | | | | | | | |
| 8 | 1706053-8 | | | | | | | |
| 9 | SR170604-1LCS | | | | | | | |
| 10 | LCSD | | | | | | | |
| 11 | AB170518-4LCS | AB170518-4 | αβ | 30 | 1035 | | ABC0620 | |
| 12 | AB170604-1LCS | AB170604-1 | αβ | 30 | 1120 | JMB | ABC0620A | |
| 1 | 1706133-3 | AB170609-3 | | 240 | 1202 | | ABC0620B | |
| 2 | -3D | | | | | | | |
| 3 | 1706157 | | | | | | | |
| 4 | 1706158-1 | | | | | | | |
| 5 | 2 | | | | | | | |
| 6 | 3 | | | | | | | |
| 7 | 1706230-1 | | | | | | | |
| 8 | 1706~~645~~-1 | AB170612-1 | | | | | | |
| 9 | 1D | | | | | | | |
| 10 | AB170612-1 | | | | | | | |
| 11 | 1706057-1 | AB170609-3 | | 1000 | 1211 | | ABC0620C | |
| 12 | 1706156-1 | | | | | | | |
| 13 | 1706163-1 | | | | | | | |
| 14 | AB170609-3MB | | | | | | | |
| 15 | AB170613-3MB | AB170613-3 | | | 1213 | | ABC0620D | |
| 1 | 1706024-1 | AB170620-2 | | 30 | ~~1607~~ 1607 | | ABC0620E | |
| 2 | 1706025-1 | | | | | | | |
| 3 | -1MS | | | | | | | |
| 4 | 1706369-1 | | | | | | | |
| 5 | -1D | | | | | | | |
| 6 | AB170620-2 MB | | | | | | | |
| 7 | LCS | | | | | | | |

JMB 6/20/17

JMB 6/20/17

Comments:

Page No.: 473506 B

(cont. from page NA B)

Form 780r8.doc (6/23/06)

Reviewed By / Date JP 6/21/17

Date 6/21/17 SOP 724r 12

# ALS

## Low Background Gas Flow Proportional Counter Log

**Instrument: LB4100C**

*Instrument Daily Response and Background Checks*

| Det. | Daily Response Check Start 1 | Status | Start 2 | Status | Background Check Start 1 | Status | Start 2 | Status | Det. Status |
|---|---|---|---|---|---|---|---|---|---|
| 1 | JP | P | | | JP | P | | | P |
| 2 | | | | | | | | | |
| 3 | | | | | | | | | |
| 4 | | | | | | | | | |
| 5 | | | | | | | | | |
| 6 | | | | | | | | | |
| 7 | | | | | | | | | |
| 8 | | | | | | | | | |
| 9 | | | | | | | | | |
| 10 | | | | | | | | | |
| 11 | | | | | | | | | |
| 12 | | | | | | | | | |
| 13 | | | | | | | | | |
| 14 | | | | | | | | | |
| 15 | | | | | | | | | |
| 16 | | | | | | (Ha, Hβ) | | | OL |

Det = Detector; α = Alpha; β = Beta; P = Pass; H = High; L = Low; OL = Offline; R = Recount; W = Weekly; NP = Not Processed

*Weekly Background Calibration*

| | Current Calib. File ID | Weekly Calib. Started | Status | File ID |
|---|---|---|---|---|
| Dr A | BKC0607W | | | |
| Dr B | | | | |
| Dr C | | | | |
| Dr D | | | | |

Dr = Drawer

*Gas Supply*

| P-10 Supply | | P-10 Flow | |
|---|---|---|---|
| Tank 1 | 1600 | Dr A | 10 |
| | | Dr B | |
| Tank 2 | 1050 | Dr C | |
| | | Dr D | |

Comments:

Page No.: 473508 A Form 780r8.doc (6/23/06) Reviewed By / Date JP 6/21/17

# Radiochemistry Instrument Worksheet

**ALS -- Fort Collins**

**Prep Batch:** RA170612-13

**Prep Procedure:** Ra228

**Analytical QASS / NCR? Y / (N) NA**

| Prep Num | LabID | QC Type | Init Alq | Fin Alq | Units | Report Units | Residual Mass (mg) | Cnt 1 File | Cnt 1 Inst/Det | Cnt 1 Pos Chk By | Cnt 2 File | Cnt 2 Inst/Det | Cnt 2 Pos Chk By | Cnt 3 File | Cnt 3 Inst/Det | Cnt 3 Pos Chk By | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1718017-1 | SMP | 1500 | 1496.0 | ml | pCi/l | | RAC0620 | 1 | JKO | | | | | | | |
| 1 | 1718017-2 | SMP | 1500 | 1496.0 | ml | pCi/l | | | 7 | | | | | | | | |
| 1 | 1718017-3 | SMP | 1500 | 1496.0 | ml | pCi/l | | | 11 | | | | | | | | |
| 1 | 1718017-4 | SMP | 1500 | 1496.0 | ml | pCi/l | | | 13 | | | | | | | | |
| 1 | RA170612-13A | MB | 1500 | 1496.0 | ml | pCi/l | | | 3 | | | | | | | | |
| 1 | RA170612-13B | MB | 1500 | 1496.0 | ml | pCi/l | | | 5 | | | | | | | | |
| 1 | RA170612-13C | MB | 1500 | 1496.0 | ml | pCi/l | | | 10 | | | | | | | | |
| 1 | RA170612-13E | MB | 1500 | 1496.0 | ml | pCi/l | | | 15 | | | | | | | | |

JP 6/20/17

**Tracer/Carrier Solution Information**

| Soln # | Nuclide | SolnID | Exp Date | Prep Conc | Units | Prep Date | Aliquot | Units | Pipet ID |
|---|---|---|---|---|---|---|---|---|---|
| T1 | BARIUM | 418236 | 1/19/18 | 16,022.768 | pCi/ml | NA | 2 | ml | RS031 |

**Spike Solution Information**

| Soln # | Nuclide | SolnID | Exp Date | Prep Conc | Units | Prep Date | Aliquot | Units | Pipet ID |
|---|---|---|---|---|---|---|---|---|---|
| S1 | Ra-228 | 1014.4095.79 | 3/23/18 | 91.306 | DPM/ml | 06/12/17 | 0.25 | ml | RS019 |

## Sample Barcodes

| | | |
|---|---|---|
| 1718017-1<br>RA170612-13PS1 | 1718017-2<br>RA170612-13PS2 | 1718017-3<br>RA170612-13PS3 |
| 1718017-4<br>RA170612-13PS4 | RA170612-13AMB<br>RA170612-13PS5 | RA170612-13BMB<br>RA170612-13PS6 |
| RA170612-13CMB<br>RA170612-13PS7 | RA170612-13EMB<br>RA170612-13PS8 | RA170612-13CAR<br>RA170612-13PS9 |

## Reporting Units

| LabID: | TstGrpName: | RptUnits: |
|---|---|---|
| 1718017-1 | Ra228_2012 | pCi/l |
| 1718017-2 | Ra228_2012 | pCi/l |
| 1718017-3 | Ra228_2012 | pCi/l |
| 1718017-4 | Ra228_2012 | pCi/l |





Supersedes: NA

# Radiochemistry ICP Worksheet

**ALS -- Fort Collins**

**Prep Batch: RA170612-13**

Prep Procedure: **Ra228**

Reviewed By: **lad** LAD

Review Date: **6/20/2017**

## BARIUM Recovery Results

### Reference Carrier

| LabID | QC Type | Carr Vol | Ref Carr Dil Vol | Ref Carr ICP Alq | Ref Carr ICP Dil Vol | Ref Carr ICP Run | Ref Carr ICP Conc |
|---|---|---|---|---|---|---|---|
| RA170612-13 | CAR | 2 | 27 | 0.05 | 10.05 | IR170614-2A1 | 6.073369 |

### Samples

| Prep Num | LabID | QC Type | Init Samp Alq (ml) | Car Vol (ml) | Samp Dil Vol (ml) | Init ICP Alq (ml) | Init ICP Dil Vol (ml) | Pre-Con Vol (ml) | Post Con Vol (ml) | Pre-Sep Vol (ml) | Post Sep Vol (ml) | Fin ICP Alq (ml) | Fin ICP Dil Vol (ml) | Initial ICP Run | Final ICP Run | Init ICP Conc (ug/ml) | Fin ICP Conc (ug/ml) | Init Samp Mass (ug) | Ref Mass (ug) | Flag | Fin Samp Mass (ug) | % Yield | Final Sample Alq |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1718017-1 | SMP | 1500 | 2 | 1500 | 1 | 10 | 1499 | 1499 | 1499 | 25 | 0.05 | 10.05 | IR170614-2A1 | IR170614-2A1 | -0.0005 | 6.511771 | 0 | 32960.17 | Z | 32721.65 | 99.28% | 1496 |
| 1 | 1718017-2 | SMP | 1500 | 2 | 1500 | 1 | 10 | 1499 | 1499 | 1499 | 25 | 0.05 | 10.05 | IR170614-2A1 | IR170614-2A1 | -0.0009 | 6.369473 | 0 | 32960.17 | Z | 32006.6 | 97.11% | 1496 |
| 1 | 1718017-3 | SMP | 1500 | 2 | 1500 | 1 | 10 | 1499 | 1499 | 1499 | 25 | 0.05 | 10.05 | IR170614-2A1 | IR170614-2A1 | -0.0011 | 6.220398 | 0 | 32960.17 | Z | 31257.5 | 94.83% | 1496 |
| 1 | 1718017-4 | SMP | 1500 | 2 | 1500 | 1 | 10 | 1499 | 1499 | 1499 | 25 | 0.05 | 10.05 | IR170614-2A1 | IR170614-2A1 | -0.0009 | 6.359601 | 0 | 32960.17 | Z | 31956.99 | 96.96% | 1496 |
| 1 | RA170612-13A | MB | 1500 | 2 | 1500 | 1 | 10 | 1499 | 1499 | 1499 | 25 | 0.05 | 10.05 | IR170614-2A1 | IR170614-2A1 | -0.0012 | 6.120568 | 0 | 32960.17 | Z | 30755.85 | 93.31% | 1496 |
| 1 | RA170612-13B | MB | 1500 | 2 | 1500 | 1 | 10 | 1499 | 1499 | 1499 | 25 | 0.05 | 10.05 | IR170614-2A1 | IR170614-2A1 | -0.0011 | 6.382908 | 0 | 32960.17 | Z | 32074.11 | 97.31% | 1496 |
| 1 | RA170612-13C | MB | 1500 | 2 | 1500 | 1 | 10 | 1499 | 1499 | 1499 | 25 | 0.05 | 10.05 | IR170614-2A1 | IR170614-2A1 | -0.0012 | 6.268415 | 0 | 32960.17 | Z | 31498.79 | 95.57% | 1496 |
| 1 | RA170612-13E | MB | 1500 | 2 | 1500 | 1 | 10 | 1499 | 1499 | 1499 | 25 | 0.05 | 10.05 | IR170614-2A1 | IR170614-2A1 | -6E-05 | 6.263625 | 0 | 32960.17 | Z | 31474.72 | 95.49% | 1496 |



**FLAG -** LB: low bias (<= 15%) 15%: low bias (>15%)

Z: Negative init. conc. treated as zer

**Supersedes:** NA

IR170614-241



| Sample Id1 | Ca | Fe | K | Mg | Na | Sr | Mn | S | Al | Ba | Pb | Ni |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CCV | 50.3317 | 20.1072 | 50.9221 | 50.4221 | 50.3459 | 0.5069 | 1.0057 | 5.0169 | 50.7250 | 1.0168 | 1.0168 | 1.0131 |
| CCB | 0.0255 | 0.0110 | 0.0230 | 0.0172 | 0.0490 | 0.0003 | 0.0005 | -0.0042 | 0.0373 | 0.0008 | 0.0023 | -0.0012 |
| I 1718017-1 | -0.0550 | -0.0189 | -0.0202 | -0.0677 | -0.0105 | -0.0006 | -0.0020 | -0.0042 | -0.0454 | -0.0005 | -0.0011 | -0.0009 |
| I 1718017-2 | -0.0594 | -0.0194 | -0.0235 | -0.0661 | -0.0556 | -0.0007 | -0.0018 | 0.0000 | -0.0535 | -0.0009 | -0.0023 | -0.0010 |
| I 1718017-3 | -0.0591 | -0.0177 | -0.0346 | -0.0634 | -0.0735 | -0.0008 | -0.0017 | 0.0085 | -0.0454 | -0.0011 | -0.0030 | -0.0014 |
| I 1718017-4 | -0.0575 | -0.0096 | -0.0156 | -0.0607 | -0.0495 | -0.0007 | -0.0016 | 0.0042 | 0.0012 | -0.0009 | -0.0026 | 0.0003 |
| I RA170612-13AMB | -0.0613 | -0.0209 | -0.0481 | -0.0677 | -0.0782 | -0.0008 | -0.0020 | 0.0085 | -0.0491 | -0.0012 | -0.0024 | -0.0006 |
| I RA170612-13BMB | -0.0600 | -0.0196 | -0.0276 | -0.0607 | -0.0774 | -0.0007 | -0.0020 | -0.0042 | -0.0485 | -0.0011 | -0.0052 | -0.0006 |
| I RA170612-13CMB | -0.0597 | -0.0197 | -0.0362 | -0.0634 | -0.0772 | -0.0007 | -0.0020 | 0.0000 | -0.0491 | -0.0012 | -0.0004 | -0.0020 |
| I RA170612-13DMB | -0.0594 | -0.0190 | -0.0366 | -0.0639 | -0.0791 | -0.0007 | -0.0018 | 0.0042 | -0.0504 | -0.0001 | -0.0017 | -0.0021 |
| F 1718017-1 | -0.0440 | -0.0153 | -0.0374 | -0.0671 | 93.9554 | 0.0000 | -0.0017 | 1.6737 | -0.0435 | 6.5118 | 0.0421 | -0.0007 |
| F 1718017-2 | -0.0547 | -0.0172 | -0.0325 | -0.0682 | 93.2354 | -0.0001 | -0.0020 | 1.6229 | -0.0404 | 6.3695 | 0.0406 | -0.0012 |
| F 1718017-3 | -0.0531 | -0.0192 | -0.0383 | -0.0703 | 89.8964 | -0.0001 | -0.0020 | 1.6314 | -0.0423 | 6.2204 | 0.0567 | -0.0012 |
| F 1718017-4 | -0.0522 | -0.0193 | -0.0181 | -0.0618 | 92.1948 | 0.0000 | -0.0020 | 1.6610 | -0.0510 | 6.3596 | 0.0502 | -0.0007 |
| F RA170612-13AMB | -0.0563 | -0.0197 | -0.0457 | -0.0687 | 88.4809 | -0.0002 | -0.0018 | 1.5381 | -0.0448 | 6.1206 | 0.0405 | -0.0018 |
| F RA170612-13BMB | -0.0563 | -0.0173 | -0.0407 | -0.0661 | 92.6239 | -0.0001 | -0.0018 | 1.6229 | -0.0460 | 6.3829 | 0.0635 | -0.0008 |
| F RA170612-13CMB | -0.0553 | -0.0192 | -0.0403 | -0.0693 | 91.7990 | -0.0001 | -0.0020 | 1.6017 | -0.0435 | 6.2684 | 0.0507 | -0.0002 |
| F RA170612-13DMB | -0.0560 | -0.0202 | -0.0416 | -0.0720 | 92.5634 | -0.0002 | -0.0020 | 1.5975 | -0.0466 | 6.2636 | 0.0459 | -0.0011 |
| RA170612-13RC | -0.0541 | -0.0191 | -0.0350 | -0.0677 | 85.9417 | 0.0004 | -0.0018 | 0.0085 | -0.0460 | 6.0734 | -0.0021 | -0.0011 |
| CCV | 50.0072 | 19.9678 | 50.9681 | 50.1015 | 50.4180 | 0.5059 | 0.9972 | 4.9831 | 50.7170 | 1.0172 | 0.9980 | 1.0148 |
| CCB | 0.0267 | 0.0122 | 0.0218 | 0.0295 | 0.0544 | 0.0003 | 0.0004 | -0.0042 | 0.0410 | 0.0009 | 0.0020 | 0.0009 |

# Radiochemistry Prep Worksheet

**ALS -- Fort Collins**

**Prep Batch:** RA170612-13

**Prep Procedure:** Ra228

**Reviewed By:** lad LAD **Review Date:** 6/20/2017

**Non-Routine Pre-Treatment? Y / N** **Batch:** NA **Re-Prep? Y / N** **Batch:** NA **Prep QASS / NCR? Y / N** NA

**Prep SOP:** SOP749 **Rev:** 4
**Prep SOP:** NONE
**Matrix Class:** liquid

**Prep Analyst:** Lucas A. Daut LAD
**Prep Date:** 6/12/2017
**Prep Dept:** RS

**Balance:** N/A
**Balance:** N/A

| Samp Num | Prep Num | LabID | QC Type | Dish No. | Init Alq ml | Fin Alq ml | Prep Basis | Ingrowth Date/Time | Decay Date/Time | Standards | Prep Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1718017-1 | SMP | NA | 1500 | 1496.002 | Unfiltered | 06/16/17 15:05 | 06/20/17 07:10 | S1,T1 | |
| 2 | 1 | 1718017-2 | SMP | | 1500 | 1496.002 | Unfiltered | 06/16/17 15:05 | 06/20/17 07:10 | S1,T1 | |
| 3 | 1 | 1718017-3 | SMP | | 1500 | 1496.002 | Unfiltered | 06/16/17 15:05 | 06/20/17 07:10 | S1,T1 | |
| 4 | 1 | 1718017-4 | SMP | | 1500 | 1496.002 | Unfiltered | 06/16/17 15:05 | 06/20/17 07:10 | S1,T1 | |
| 5 | 1 | RA170612-13A | MB | | 1500 | 1496.002 | Unfiltered | 06/16/17 15:05 | 06/20/17 07:10 | T1 | |
| 6 | 1 | RA170612-13B | MB | | 1500 | 1496.002 | Unfiltered | 06/16/17 15:05 | 06/20/17 07:10 | T1 | |
| 7 | 1 | RA170612-13C | MB | | 1500 | 1496.002 | Unfiltered | 06/16/17 15:05 | 06/20/17 07:10 | T1 | |
| 8 | 1 | RA170612-13E | MB | | 1500 | 1496.002 | Unfiltered | 06/16/17 15:05 | 06/20/17 07:10 | T1 | |

LAD 6/20

Comments
ICV's and ICB's for Ra 228

**Spiked By:** Lucas A. Daut **Date:** 6/12/2017 **Yttrium Added By:** _____ **Date:** _____

**Witnessed By:** Andrew R. Steger **Date:** 6/12/2017 **Witnessed By:** _____ **Date:** _____

**Tracer/Carrier Solution Information**

| Soln # | Nuclide | SolnID | Exp Date | Prep Conc | Units | Prep Date | Aliquot | Units | Pipet ID |
|---|---|---|---|---|---|---|---|---|---|
| T1 | BARIUM | 418236 | 1/19/18 | 16,022.768 | pCi/ml | NA | 2 | ml | RS031 |

**Spike Solution Information**

| Soln # | Nuclide | SolnID | Exp Date | Prep Conc | Units | Prep Date | Aliquot | Units | Pipet ID |
|---|---|---|---|---|---|---|---|---|---|
| S1 | Ra-228 | 1014.4095.79 | 3/23/18 | 91.306 | DPM/ml | 06/12/17 | 0.25 | ml | RS019 |

ALS -- Fort Collins

# Radiochemistry Prep Worksheet

**Prep Batch:** RA170612-13

**Prep Procedure:** Ra228

## Prep Batch Not Validated!!!

**Reviewed By:** LAD **Review Date:**

**Non-Routine Pre-Treatment? Y / N** **Batch:** _____ **Re-Prep? Y / N** **Batch:** _____ **Prep QASS / NCR? Y / N** _____

**Prep SOP:** SOP749 **Rev:** 4
**Prep SOP:** NONE
**Matrix Class:** liquid

**Prep Analyst:** Lucas A. Daut
**Prep Date:** 6/12/2017
**Prep Dept:** RS

**Balance:** N/A
**Balance:** N/A

| Samp Num | Prep Num | LabID | QC Type | Dish No. | Init Alq ml | Fin Alq ml | Prep Basis | Ingrowth Date/Time | Decay Date/Time | Standards | Prep Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1718017-1 | SMP | | 1500 | 1500 | Unfiltered | 6/14 6/16 | 6/20 | S1,T1 | |
| 2 | 1 | 1718017-2 | SMP | | 1500 | 1500 | Unfiltered | 18:37 15:06 | 07:10 | S1,T1 | |
| 3 | 1 | 1718017-3 | SMP | | 1500 | 1500 | Unfiltered | | | S1,T1 | |
| 4 | 1 | 1718017-4 | SMP | | 1500 | 1500 | Unfiltered | | | S1,T1 | |
| 5 | 1 | RA170612-13A | MB | | 1500 | 1500 | Unfiltered | | | T1 | |
| 6 | 1 | RA170612-13B | MB | | 1500 | 1500 | Unfiltered | | | T1 | |
| 7 | 1 | RA170612-13C | MB | | 1500 | 1500 | Unfiltered | | | T1 | |
| 8 | 1 | RA170612-13D | MB | | 1500 | 1500 | Unfiltered | | | T1 | |

Comments
ICV's and ICB's for Ra 228

**Spiked By:** Lucas A. Daut **Date:** 6/12/2017 **Yttrium Added By:** _____ **Date:** _____

**Witnessed By:** [signature] **Date:** 6/12/2017 **Witnessed By:** _____ **Date:** _____

**Tracer/Carrier Solution Information**

| Soln # | Nuclide | SolnID | Exp Date | Prep Conc | Units | Prep Date | Aliquot | Units | Pipet ID |
|---|---|---|---|---|---|---|---|---|---|
| T1 | BARIUM | 418236 | 1/19/18 | 16,022.768 | pCi/ml | NA | 2 | ml | RS031 |

**Spike Solution Information**

| Soln # | Nuclide | SolnID | Exp Date | Prep Conc | Units | Prep Date | Aliquot | Units | Pipet ID |
|---|---|---|---|---|---|---|---|---|---|
| S1 | Ra-228 | 1014.4095.79 | 3/23/18 | 91.306 | DPM/ml | 06/12/17 | 0.25 | ml | RS019 |

Project Ra228 working standard 1014.4095.79 79

Continued from Page

Prepare a working dilution of RSO# 1014 TE 1/16/15

1. Density of 8% HNO3, lot # 0000084176
   Mass of 100mL vol. flask: 68.3149g Balance # 12
   Mass of flask & 100mL acid: 172.2758g Balance# 12
   Net Mass: 103.9609g
   Density: 1.0396g/mL

2. Mass of RSO# 1014 transferred:
   Mass of open empty nalgene: 48.3028g Balance# 12
   Mass of nalgene & standard: 53.2851g Balance# 12
   Net mass of standard transferred: 4.9823g Balance# NA

TE 1/16/15 TE 1/16/15

3. Dilute to final volume:
   Mass of nalgene, standard, & diluent: 344.91g Balance# 26
   Mass of empty nalgene (from above): 48.3028g Balance# 12
   Net mass of new dilution: 296.6072g Balance# NA

4. Final activity calculation:

$$195\,Bq/g\left(\frac{60dpm}{1Bq}\right)\left(\frac{4.9823g}{296.6072g}\right)(1.0396\,g/mL) = 204.32\,dpm/mL$$

TE 1/16/15

JP 4/15/15

*Std ID:* 1014.4095.79

*Description:* Ra-228
*Expiration:* 4/9/2016
*Activity:* 204.32 dpm/mL

*2s Uncertainty:* 14.71 dpm/mL
*Ref. Date:* 10/7/2010
*Ref Time:* N/A
*Prep Date:* 1/16/2015 *Prep by:* TE
*Matrix/Comp.* 8% HNO3
*Half Life (y):* 5.75E+00

| Reverification Log | | |
|---|---|---|
| Analysis Date | Initials | Expiration Date |
| 4/2/2016 | JP | 4/02/2017 |
| 3/23/2017 | JP | 3/23/2018 |
| | | |
| | | |
| | | |

JP 4/15/15

Continued on Page

T Ellis 1/16/15
Signed Date

Read and Understood By 4/15/15
Signed Date

RSO 2
1014

National Institute of Standards & Technology

# Certificate

## Standard Reference Material® 4339b

### Radium-228 Radioactivity Standard

This Standard Reference Material (SRM) consists of a solution of a standardized and certified quantity of radioactive radium-228 in a suitably stable and homogeneous matrix. It is intended primarily for the calibration of instruments that are used to measure radioactivity and for the monitoring of radiochemical procedures. A unit of SRM 4339b consists of approximately 5 mL of a solution, whose composition is specified in Tables 1 and 2, contained in a flame-sealed borosilicate-glass ampoule [1].

The certified **radium-228** massic activity value, at a **Reference Time of 1200 EST, 07 October 2010**, is:

$$(195 \pm 14)\ \mathrm{Bq \cdot g^{-1}}$$

A NIST certified value, as used within the context of this certificate, is a value for which NIST has the highest confidence in its uncertainty assessment. It is a "measurement result" [2] obtained directly or indirectly from a "primary reference measurement procedure" [3]. The certified value is traceable to the derived SI unit, Becquerel (Bq).

Additional physical, chemical, and radiological properties for this SRM, as well as details on the standardization method, are given in Tables 1 and 2. Uncertainties for the certified quantities are expanded ($k = 2$). The uncertainties are calculated according to the ISO and NIST Guides [4,5]. Table 3 contains a specification of the components that comprise the uncertainty analyses.

**Expiration of Certification:** The certification of **SRM 4339b** is valid indefinitely, within the measurement uncertainty specified, provided that the SRM is handled and stored properly and that no evaporation or change in composition has occurred. The solution matrix, in an unopened ampoule, is homogeneous and stable within its half-life-dependent useful lifetime provided the SRM is handled in accordance with instructions given in this certificate (see "Instructions for Handling and Storage"). Periodic recertification of this SRM is not required. The certification is nullified if the SRM is damaged, contaminated, or otherwise modified.

**Maintenance of SRM Certification:** NIST will monitor this SRM over the period of its certification. If substantive technical changes occur that affect the certification, NIST will notify the purchaser. Registration (see attached sheet) will facilitate notification.

**Radiological and Chemical Hazard:** Consult the Safety Data Sheet (SDS), enclosed with the SRM shipment, for radiological and chemical hazard information.

This SRM was prepared in the Physical Measurement Laboratory, Radiation and Biomolecular Physics Division, Radioactivity Group, M.P. Unterweger, Group Leader. The overall technical direction and physical measurement leading to certification and photon-emitting impurity analyses were provided by L. Pibida of the NIST Radioactivity Group, with production assistance by J. LaRosa, R. Collé, and L. Laureano-Pérez. Alpha-emitting impurity analyses were provided by J. LaRosa.

Support aspects involved in the issuance of this SRM were coordinated through the NIST Office of Reference Materials.

Lisa R. Karam, Chief
Radiation and Biomolecular Physics Division

Gaithersburg, Maryland 20899

Robert L. Watters, Jr., Director
Office of Reference Materials

Certificate Issue Date: 14 November 2012

Table 1. Certified Massic Activity of SRM 4339b

| | |
|---|---|
| **Radionuclide** | **Radium-228**[a] |
| **Reference time** | **1200 EST, 07 October 2010** |
| **Massic activity of the solution** | **195 Bq•g$^{-1}$** |
| **Relative expanded uncertainty ($k = 2$)** | **7.2 %**[b] |

[a] The final $^{228}$Ra purification from the $^{232}$Th mother solution was performed on 02 September 2010 0920 EST.
[b] The uncertainties on certified values are expanded uncertainties, $U = ku_c$. The quantity $u_c$ is the combined standard uncertainty calculated according to the ISO and NIST Guides [4,5]. The combined standard uncertainty is multiplied by a coverage factor of $k = 2$ and was chosen to obtain what is assumed to be an approximate 95 % level of confidence.

Table 2. Uncertified Information of SRM 4339b

| | |
|---|---|
| Source description | Liquid in a flame-sealed 5 mL borosilicate-glass ampoule [1] |
| Solution composition | 1.3 mol•L$^{-1}$ $HNO_3$ with 19.8 µg•g$^{-1}$ $Ba^{+2}$ |
| Solution density | (1.034 ± 0.002) g•mL$^{-1}$ at 20.8 °C[a] |
| Solution mass | (5.180 ± 0.003) g[a] |
| Photon-emitting impurities | $^{226}$Ra: < 0.5 Bq•g$^{-1}$[b] |
| Alpha-emitting impurities | $^{232}$Th: < 0.08 Bq•g$^{-1}$[c] |
| Half-lives used | $^{228}$Ra: (5.75 ± 0.04) a[d] [6]<br>$^{228}$Ac: (6.15 ± 0.02) h [7]<br>$^{226}$Ra: (1600 ± 7) a [8]<br>$^{232}$Th: (14.02 ± 0.06) x 10$^{9}$ a [9] |
| Calibration methods (and instruments) | The certified massic activity for $^{228}$Ra was obtained by high-resolution gamma-ray spectrometry of three master solution ampoules (eleven separate determinations), as measured on three to five different spectrometers and geometries on each ampoule, and used assumed nuclear data for probabilities per decay for 16 gamma-ray transitions. Confirmatory measurements were performed by 2πα spectrometry of ingrown $^{228}$Th with a planar, ion-implanted Si detector. |

[a] The stated uncertainty is two times the standard uncertainty. See reference 5.
[b] Based on gamma-ray spectrometry of forced-fitted peak at 186.2 keV and assuming a probability per decay of 0.0355 [6].
[c] The maximum $^{232}$Th activity concentration in $^{228}$Ra.
[d] The stated uncertainty is the standard uncertainty. See reference 5.

Table 3. Uncertainty Evaluation for the Massic Activity of SRM 4339b

| | Uncertainty component | Assessment Type[a] | Relative standard uncertainty contribution on massic activity of $^{228}$Ra (%) |
|---|---|---|---|
| 1 | Gamma-ray spectrometry precision; relative standard deviation of the grand mean on the average massic gamma-ray emission rates for 16 measured $^{228}$Ac gamma-ray transitions. Each mean in the grand mean is based on 11 determinations with three sources in three to five different detectors. The uncertainty in the determination of the massic gamma-ray emission rate for any one transition in a given determination ranged from typically 0.5 % to 1.5 %. The relative standard deviation of the mean for the average of the 16 lines, for any one determination, was typically 1 %; whereas the relative standard deviation of the grand mean for the average of the 16 lines across all 11 determinations is 0.34 %[b]. Data passes normality test. | A | 0.84 |
| 2 | Uncertainty due to assumed gamma-ray probabilities per decay for the measured $^{228}$Ac transitions [7]. The uncertainty on each transition has a shared (correlated) component of 2.5 % (see comments in [7]). | B | 3.5 |
| 3 | Detection efficiencies not embodied within component 1 | B | 0.4 |
| 4 | Mass determinations for dilution factors and counting source preparations | B | 0.1 |
| 5 | Decay corrections for $^{228}$Ra half-life uncertainty of 0.7 % [6] | B | 0.003 |
| 6 | Effect of $^{228}$Ra and $^{228}$Ac half-life uncertainties on secular equilibrium ratio | B | 0.02 |
| **Relative combined standard uncertainty** | | | **3.6** |
| **Relative expanded uncertainty ($k = 2$)** | | | **7.2** |

[a] Letter A denotes evaluation by statistical methods; B denotes evaluation by other methods.
[b] Average massic gamma-ray emission rates of 11 geometries ($R_\gamma$) for 16 measured $^{228}$Ac gamma-ray transitions with their respective energy ($E_\gamma$); assumed gamma-ray probabilities per decay ($I_\gamma$) and standard deviation of the mean ($S_m$).

| $E_\gamma$ (keV) | Assumed $I_\gamma$ (%) [1] | Mean $R_\gamma$ ($s^{-1} \cdot g^{-1}$)[i] | $S_m$ (%)[ii] |
|---|---|---|---|
| 129.065 | 2.50 | 1347 | 0.38 |
| 153.967 | 0.754 | 421.6 | 0.40 |
| 209.249 | 3.97 | 2264 | 0.55 |
| 270.245 | 3.55 | 2014 | 0.33 |
| 328.004 | 3.04 | 1822 | 0.43 |
| 338.32 | 11.4 | 6712 | 0.43 |
| 409.46 | 2.02 | 1185 | 0.29 |
| 463.002 | 4.45 | 2645 | 0.33 |
| 755.313 | 1.03 | 593.3 | 0.46 |
| 772.291 | 1.52 | 899.2 | 0.53 |
| 794.942 | 4.31 | 2588 | 0.35 |
| 835.704 | 1.7 | 995.3 | 0.42 |
| 911.196 | 26.2 | 15609 | 0.29 |
| 964.786 | 4.99 | 3007 | 0.35 |
| 968.96 | 15.9 | 9582 | 0.30 |
| 1588.2 | 3.06 | 1889 | 0.28 |

(i) Grand mean for $n = 11$ determinations with three sources in three to five different detectors.
(ii) Relative standard deviation of the grand mean on $R_\gamma$ for $n = 11$.

## INSTRUCTIONS FOR HANDLING AND STORAGE

**Handling:** If the ampoule is transported, it should be packed, marked, labeled, and shipped in accordance with the applicable national, international, and carrier regulations. The solution in the ampoule is a dangerous good (hazardous material) because of both the radioactivity and the strong acid. The ampoule should be opened only by persons qualified to handle both radioactive material and alkaline and/or acidic solutions. Appropriate shielding and/or distance should be used to minimize personnel exposure. Refer to SDS for further information.

**Storage:** SRM 4339b should be stored and used at a temperature between 5 °C and 65 °C. The ampoule (or any subsequent container) should always be clearly marked as containing radioactive material.

## REFERENCES


[1] NIST Physical Measurement Laboratory; *Storage and Handling of Radioactive Standard Reference Materials, Ampoule Specifications and Opening Procedure*, available at http://www.nist.gov/pml/div682/grp04/srm.cfm (accessed Nov 2012). Note: This SRM is contained in a generic borosilicate-glass ampoule and not in the standard NIST ampoule.

[2] JCGM 200:2012; *International Vocabulary of Metrology - Basic and General Concepts and Associated Terms (VIM)* (2008 version with Minor Corrections), 3rd edition; Joint Committee for Guides in Metrology; BIPM, Sevres Cedex, France; p. 19 (2012); available at http://www.bipm.org/utils/common/documents/jcgm/JCGM_200_2012.pdf (accessed Nov 2012).

[3] JCGM 200:2012; *International Vocabulary of Metrology - Basic and General Concepts and Associated Terms (VIM)* (2008 version with Minor Corrections), 3rd edition; Joint Committee for Guides in Metrology; BIPM, Sevres Cedex, France; p. 18 (2012); available at http://www.bipm.org/utils/common/documents/jcgm/JCGM_200_2012.pdf (accessed Nov 2012).

[4] JCGM 100:2008; *Guide to the Expression of Uncertainty in Measurement;* (ISO GUM 1995 with Minor Corrections), Joint Committee for Guides in Metrology; BIPM, Sèvres Cedex, France (2008); available at http://www.bipm.org/utils/common/documents/jcgm/JCGM_100_2008_E.pdf (accessed Nov 2012).

[5] Taylor, B.N.; Kuyatt, C.E.; *Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results*; NIST Technical Note 1297, U.S. Government Printing Office: Washington, DC (1994); available at http://physics.nist.gov/Pubs/ (accessed Nov 2012).

[6] Luca, A.; June 2009, $^{228}$Ra. LNE-LNHB/CEA Table of Radionuclides, available at http://www.nucleide.org/DDEP_WG/Nuclides/Ra-228_tables.pdf (accessed Nov 2012).

[7] Pearce, A.; January 2010, $^{228}$Ac. LNE-LNHB/CEA Table of Radionuclides, available at http://www.nucleide.org/DDEP_WG/Nuclides/Ac-228_tables.pdf (accessed Nov 2012).

[8] Christé, V. and M.M. Bé; December 2006, $^{226}$Ra. LNE-LNHB/CEA Table of Radionuclides, available at http://www.nucleide.org/DDEP_WG/Nuclides/Ra-226_tables.pdf (accessed Nov 2012).

[9] Arinc, A.; September 2008, $^{232}$Th. LNE-LNHB/CEA Table of Radionuclides, available at http://www.nucleide.org/DDEP_WG/Nuclides/Th-232_tables.pdf (accessed Nov 2012).


*Users of this SRM should ensure that the Certificate in their possession is current. This can be accomplished by contacting the SRM Program: telephone (301) 975-2200; fax (301) 948-3730; e-mail srminfo@nist.gov; or via the Internet at http://www.nist.gov/srm.*

# Radiochemistry Solution Report

| | | | | | |
|---|---|---|---|---|---|
| **Solution Id:** | 418236 | **Name:** | Ba carrier | **Type:** | IS |
| | | **Lot:** | | **Vendor Name:** | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Final Vol:** | 4000 | **Dept:** | RD | **Prep By** | SDW | **on** | 1/19/2017 | **Reviewed By** | tde | **on** | 1/26/2017 |
| **Units:** | mL | **Location:** | RS | **Opened By** | | **on** | | **Verified By** | SDW | **on** | 1/19/2017 |
| **Matrix:** | LIQUID | **ExpireDate:** | 1/19/2018 | **Received By** | | **on** | | **Deactivated By** | | **on** | |

**Comment:**

| Component Name | Component ID | Volume Added | Units |
|---|---|---|---|
| Barium Stable Carrier Source<1> | 3756 B07592 | 114.0018 | g |

| CompName | Calibrated Primary Act/Conc | Calibration Date | Reference Date | 1/2 Life (Yrs) | Final Act/Conc | Summed Conc | Units |
|---|---|---|---|---|---|---|---|
| BARIUM | 562193.5 | | 3/9/2017 | | 16022.77 | | pCi/ml |

## Associated Parent IDs

3756 B07592

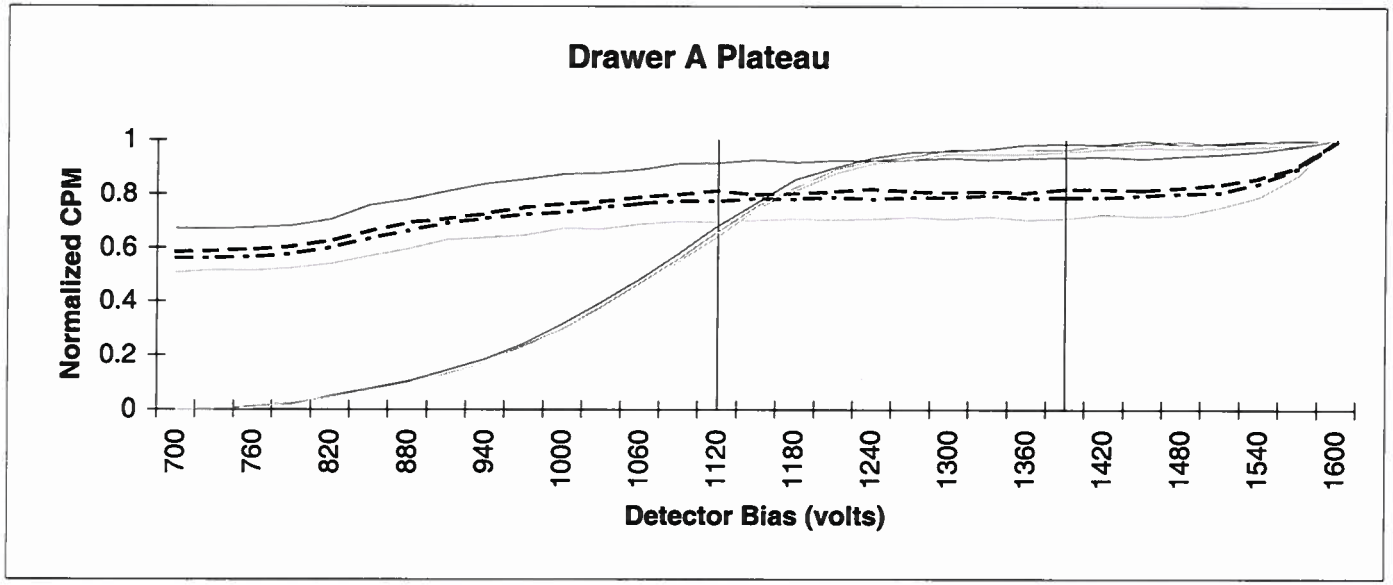
**Abbreviations: NC = Not Calculated for reagents when the volume added is not entered.**
**NE = Not Entered**

**(Prnt) = Secular equilibrium; parent half life used to calculate concentration.**

# Addendum

Unit Type: LB4100/W
Date Performed: 6/2/18 07:55
FileName: PTC0602A
Batch ID: DRWAER A PLAT CHECK

Unit Id: Magenta
Application Revision: 2
Application Version: Standard




Optimum alpha beta simultaneous operating voltage: 1402.5

Optimum alpha only operating voltage: 1120

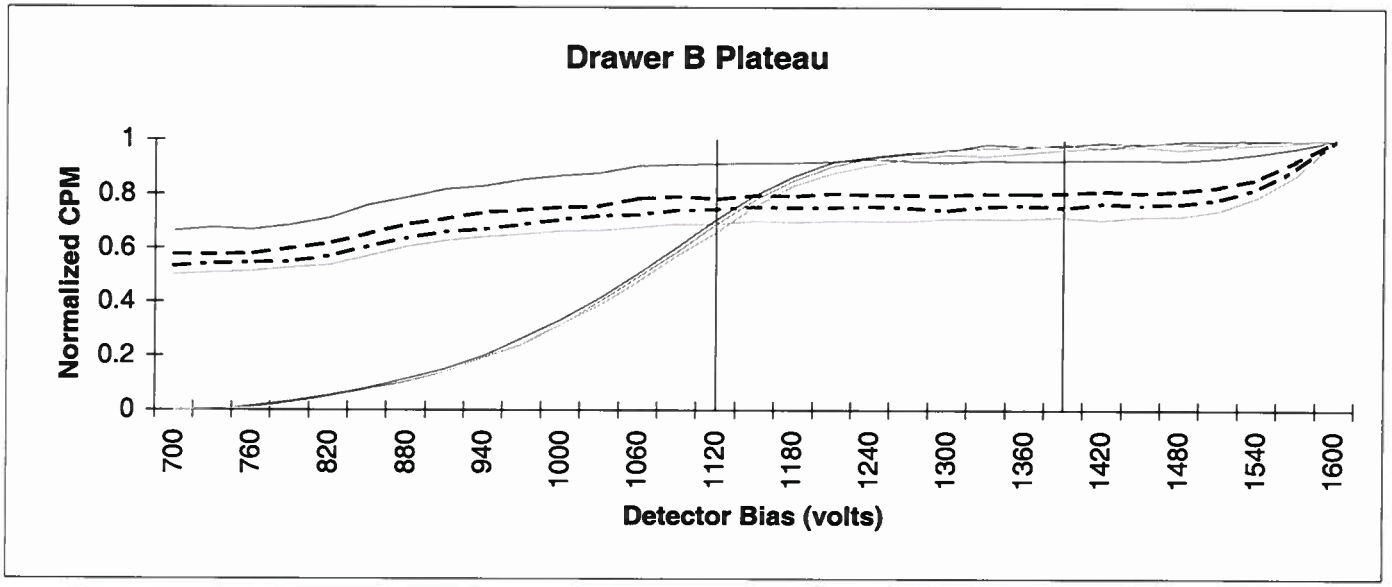
| | A1 | A2 | A3 | A4 |
|---|---|---|---|---|
| Beta slope at beta voltage | 2.10% | 2.20% | 2.41% | 1.51% |
| Alpha slope at beta voltage | 0.33% | 0.97% | 0.93% | 0.20% |
| Alpha slope at alpha voltage | 2.55% | 1.10% | 1.89% | 1.94% |

OK JP 6/3/18

Printed 6/3/2018 6:06 AM

Unit Type: LB4100/W
Date Performed: 6/2/18 07:55
FileName: PTC0602B
Batch ID: DRAWER B PLAT CHECK

Unit Id: Magenta
Application Revision: 2
Application Version: Standard




Optimum alpha beta simultaneous operating voltage: 1402.5

Optimum alpha only operating voltage: 1120

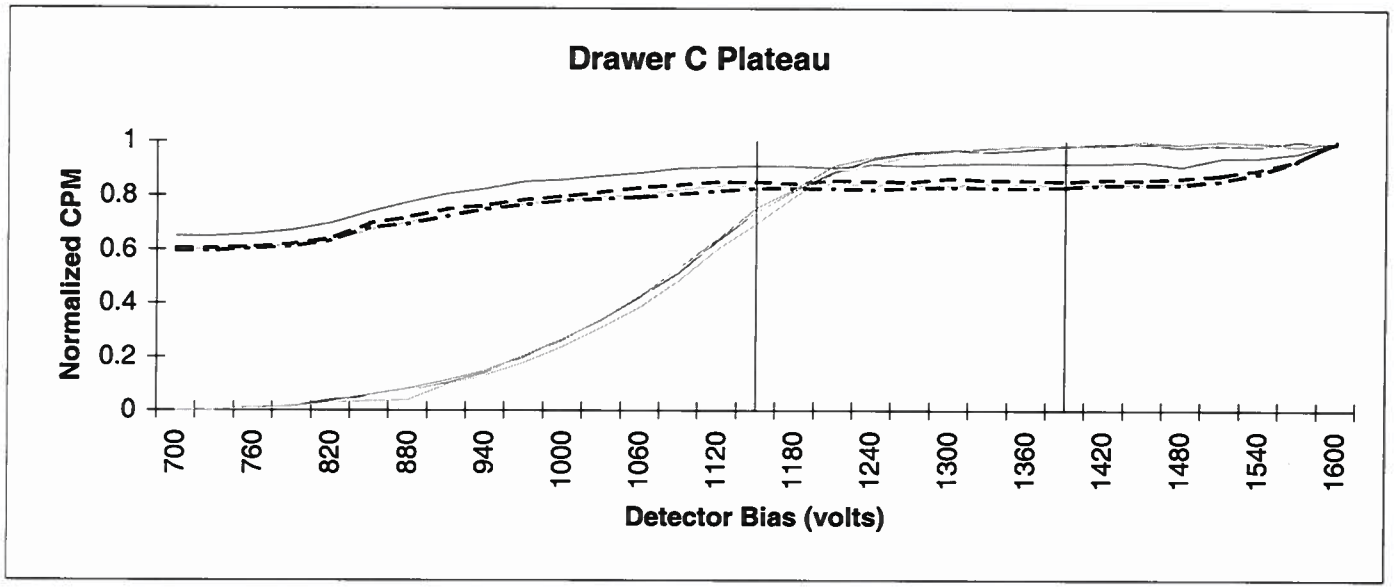
| | B1 | B2 | B3 | B4 |
|---|---|---|---|---|
| Beta slope at beta voltage | 0.42% | 1.22% | 3.10% | 1.72% |
| Alpha slope at beta voltage | 0.20% | 0.62% | 0.40% | 0.91% |
| Alpha slope at alpha voltage | 1.11% | 1.14% | 2.51% | 2.84% |

OK JP 6/3/18

Printed 6/3/2018 6:06 AM

Unit Type: LB4100/W
Date Performed: 6/3/18 07:24
FileName: PTC0603C
Batch ID: DRAWER C PLAT CHECK

Unit Id: Magenta
Application Revision: 2
Application Version: Standard




Optimum alpha beta simultaneous operating voltage: 1402.5

Optimum alpha only operating voltage: 1150

| | C1 | C2 | C3 | C4 |
|---|---|---|---|---|
| Beta slope at beta voltage | 2.92% | 1.83% | 1.22% | 1.27% |
| Alpha slope at beta voltage | 0.25% | 0.07% | -0.04% | 1.28% |
| Alpha slope at alpha voltage | 0.32% | 1.11% | 1.63% | 2.25% |

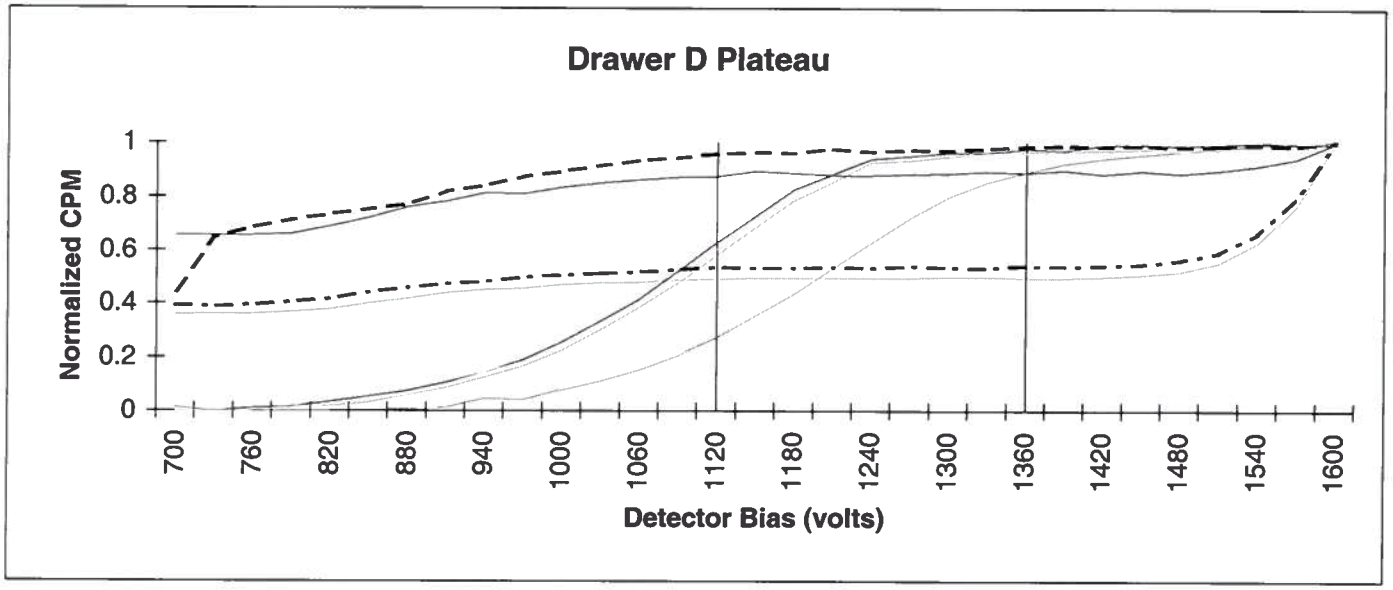
OK JP 6/4/18



Printed 6/4/2018 6:27 AM

Unit Type: LB4100/W
Date Performed: 6/3/18 07:24
FileName: PTC0603D
Batch ID: DRAWER D PLAT CHECK

Unit Id: Magenta
Application Revision: 2
Application Version: Standard




Optimum alpha beta simultaneous operating voltage: 1372.5

Optimum alpha only operating voltage: 1120

| | D1 | D2 | D3 | D4 |
|---|---|---|---|---|
| Beta slope at beta voltage | 2.32% | 13.59% | 1.82% | 1.73% |
| Alpha slope at beta voltage | -0.16% | 1.52% | -0.37% | 1.29% |
| Alpha slope at alpha voltage | 2.52% | 2.72% | 2.90% | 2.27% |

OK JP 6/4/18

Printed 6/4/2018 6:28 AM

Date 6/2/18

SOP 724r 12

# ALS
## Low Background Gas Flow Proportional Counter Log
## Instrument: LB4100C

*Instrument Daily Response and Background Checks*

| Det. | Daily Response Check Start 1 | Status | Start 2 | Status | Background Check Start 1 | Status | Start 2 | Status | Det. Status |
|---|---|---|---|---|---|---|---|---|---|
| 1 | JP | P | | | JP | P | | | P |
| 2 | | | | | | | | | |
| 3 | | | | | | | | | |
| 4 | | | | | | | | | |
| 5 | | | | | | | | | |
| 6 | | | | | | | | | |
| 7 | | | | | | | | | |
| 8 | | | | | | | | | |
| 9 | | | | | | | | | |
| 10 | | | | | | | | | |
| 11 | | | | | | | | | |
| 12 | | | | | | | | | |
| 13 | | | | | | | | | |
| 14 | | α LB | | | | | | | α |
| 15 | | P | | | | | | | P |
| 16 | | | | | | | | | |

Det = Detector; α = Alpha; β = Beta; P = Pass; H = High; L = Low; OL = Offline; R = Recount; W = Weekly; NP = Not Processed

*Weekly Background Calibration*

| | Current Calib. File ID | Weekly Calib. Started | Status | File ID |
|---|---|---|---|---|
| Dr A | BLC0527W | | | |
| Dr B | | | | |
| Dr C | | | | |
| Dr D | | | | |

Dr = Drawer

*Gas Supply*

| P-10 Supply | | P-10 Flow | |
|---|---|---|---|
| Tank 1 | 1300 | Dr A | 10 |
| | | Dr B | |
| Tank 2 | 1600 | Dr C | |
| | | Dr D | |

Comments:

Page No.: 478920 A

Form 780r8.doc (6/23/06)

Reviewed By / Date JP 6/2/18

Date 6/2/18

SOP 724r 12

**ALS**

Low Background Gas Flow Proportional Counter Log

**Instrument: LB4100C**

| Det. | Sample ID | Batch | Test # | Count Dur. (min) | Start Time | Analyst Initials | File ID | Output Initials |
|---|---|---|---|---|---|---|---|---|
| 1-16 | Daily Eff | — | — | 30 | 6:45 | JP | EFC0602 | JP |
| 1-16 | Daily Bks | — | — | 60 | 6:52 | JP | BKC0602 | JP |
| 1-4 | Alpha/Beta | Drawer A Plat Check | Plateau | 5 min/STEP | 7:55 | JP | PTC0602A | JP |
| 5-8 | Beta/Alpha | Drawer B Plat Chk | | | | | PTC0602B | JP |
| 9 | 1806007-2 | AB180601-5 | α/β | 120 | 8:00 | JP | ABC0602 | JP |
| 10 | 1806007-2 | GA180601-1 | α | 60 | 8:02 | | ABC0602A | |
| 11 | GA180601-1MB | | | | | | | |
| 12 | LCS | | | | | | | |
| 13 | AB180601-5LCS | AB180601-5 | α/β | 30 | 8:03 | | ABC0602B | |
| 15 | 1805659-1MS | AB180601-4 | | | 8:13 | JP | ABC0602C | |
| 16 | AB180601-4LCS | | | | | | | |
| 10 | 1805349-1 | AB180531-1 | α/β | 30 | 9:11 | JP | ABC0602D | |
| 11 | -2 | | | | | | | |
| 12 | 1805426-1 | | | | | | | |
| 13 | -2 | | | | | | | |
| 15 | -2D | | | | | | | |
| 16 | -3 | | | | | | | |
| 10 | 1805505-1 | | | | 9:44 | JP | ABC0602E | JP |
| 11 | -2 | | | | | | | |
| 12 | -3 | | | | | | | |
| 13 | -4 | | | | | | | |
| 15 | -5 | | | | | | | |
| 16 | -6 | | | | | | | |
| 9 | 1805509-1 | | | | 10:17 | JP | ABC0602F | |
| 10 | -2 | | | | | | | |
| 11 | 1805516-1 | | | | | | | |
| 12 | -2 | | | | | | | |
| 13 | -3 | | | | | | | |
| 15 | -4 | | | | | | | |
| 16 | -5 | | | | | | | |
| 9 | -6 | | | | 10:49 | JP | ABC0602G | |
| 10 | -6MS | | | | | | | |
| 11 | AB180531 1MB | | | | | | | |
| 12 | LCS | | | | | | | |
| 9 | 1804480-1 | SR180516-1 | Sr 90 | 1000 | 11:24 | JP | SRC0602 | |
| 10 | 4481-1 | | | | | | | |
| 11 | -2 | | | | | | | |
| 12 | SR180516 1MB | | | | | | | |
| 13 | 1806007-1 | AB180601-5 | α/β | 720 | 11:10 | JP | ABC0602H | |
| 15 | 1D | | | | | | | |
| 16 | AB180601 5MB | | | | | | | |

JP 6/3/18

Comments

Page No.: 478920 B

(cont. from page N B)

Form 780r8.doc (6/23/06)

Reviewed By / Date JP 6/3/18

.te 6/3/18

SOP 724r 12

# ALS
## Low Background Gas Flow Proportional Counter Log
## Instrument: LB4100C

*Instrument Daily Response and Background Checks*

| Det. | Daily Response Check Start 1 | Status | Start 2 | Status | Background Check Start 1 | Status | Start 2 | Status | Det. Status |
|---|---|---|---|---|---|---|---|---|---|
| 1 | JP | P | | | JP | P | | | P |
| 2 | | | | | | | | | |
| 3 | | | | | | | | | |
| 4 | | | | | | | | | |
| 5 | | | | | | | | | |
| 6 | | | | | | | | | |
| 7 | | | | | | | | | |
| 8 | | | | | | | | | |
| 9 | | | | | | | | | |
| 10 | | | | | | | | | |
| 11 | | | | | | | | | |
| 12 | | | | | | | | | |
| 13 | | | | | | | | | |
| 14 | | (L,U) | | | | | | | |
| 15 | | P | | | | | | | α |
| 16 | | | | | | | | | P |

Det = Detector; α = Alpha; β = Beta; P = Pass; H = High; L = Low; OL = Offline; R = Recount; W = Weekly; NP = Not Processed

*Weekly Background Calibration*

| | Current Calib. File ID | Weekly Calib. Started | Status | File ID |
|---|---|---|---|---|
| Dr A | BU005270 | | | |
| Dr B | | | | |
| Dr C | | | | |
| Dr D | | | | |

Dr = Drawer

*Gas Supply*

| P-10 Supply | | P-10 Flow | |
|---|---|---|---|
| Tank 1 | | Dr A | 10 |
| | | Dr B | |
| Tank 2 | | Dr C | |
| | | Dr D | |

Comments:

Page No.: 478921 A

Form 780r8.doc (6/23/06)

Reviewed By / Date JP 6/3/18

Date 6/3/18

SOP 724r 12

**ALS**

Low Background Gas Flow Proportional Counter Log

**Instrument: LB4100C**

| Det. | Sample ID | Batch | Test # | Count Dur. (min) | Start Time | Analyst Initials | File ID | Output Initials |
|---|---|---|---|---|---|---|---|---|
| 1-16 | Daily EFF | — | — | 30 | 6:05 | JP | EFC0603 | JP |
| 1-16 | Daily Blks | — | — | 60 | 6:13 | JP | BLC0603 | JP |
| 9-12 | Alpha/Beta | Drawer C Plat Check | Plateau | 5 Min/Step | 7:24 | JP | PTC0603C | JP |
| 13-16 | Beta/Alpha | Drawer D Plat Check | ↓ | ↓ | 7:24 | JP | PTC0603D | JP |
| 1 | 1804255-1 | AB1805363 | αIB | 1000 | 7:26 | JP | ABC0603 | JP |
| 2 | -9 | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ |
| 3 | -17 | | | | | | | |
| 4 | -25 | | | | | | | |
| 5 | -33 | | | | | | | |
| 6 | -41 | | | | | | | |
| 7 | -49 | | | | | | | |
| 8 | 1804298-1 | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ |

JP 6/4/18

Comments:

Page No 478921 B

(cont. from page NA B)

Form 780r8.doc (6 23 06)

Reviewed By / Date JP 6/4/18

2/7/18

Th-230 Co-Precip Mass Attenuation

Filename: ATH0207
ATH0208

Benchsheet: GA170405-1 Source: 1716001->16

| | 8:24 | | | | 2/7/18 | | | | | | | | | | 2/8/18 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 | 1 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 |
| A2 | 2 | 16 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 |
| A3 | 3 | 2 | 1 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 |
| A4 | 4 | 3 | 2 | 1 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 |
| B1 | 5 | 4 | 3 | 2 | 1 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 |
| B2 | 6 | 5 | 4 | 3 | 2 | 1 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 |
| B3 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| B4 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 |
| C1 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 16 | 15 | 14 | 13 | 12 | 11 | 10 |
| C2 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 16 | 15 | 14 | 13 | 12 | 11 |
| C3 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 16 | 15 | 14 | 13 | 12 |
| C4 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 16 | 15 | 14 | 13 |
| D1 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 16 | 15 | 14 |
| D3 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 16 | 15 |
| D4 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 16 |
| | 8:24 | 8:53 | 9:24 | 9:53 | 10:23 | 11:00 | 11:30 | 12:06 | 12:38 | 13:02 | 13:34 | 14:03 | 14:47 | 15:19 | 10:18 | 11:03 |

6/2/18 / 6/3/18

Voltage Plateau Check For 2017 Instrument Calibration Re-Verification

| α Sources Used | | β Sources Used | | Detectors |
|---|---|---|---|---|
| 410 | | 406 | | A1 B1 C1 D1 |
| 411 | Am-241 | 407 | Sr90/Y90 | A2 B2 C2 D2 |
| 412 | 17,800 DPM | 408 | 29,600 DPM | A3 B3 C3 D3 |
| 413 | 2-16-1995 | 409 | 9-15-1992 | A4 B4 C4 D4 |

Parameters

Starting Voltage 700
Ending Voltage 1600
30 V / Step
5 min / Step

Count Preset: 40,000
Time Between Step: 0.1
Weak Check Times: 0.1
Weak Check Limit 20 Cnts

Filenames
PTC06021
↓ B
PTC06030
↓ D

Continued on Page

Read and Understood By

Signed 6/2/18 Date Signed Date

# Rad Preliminary Data Report

**Laboratory Name:** ALS -- Fort Collins
**Analytical Run:** RA180604-4A

**Prep SOP:** SOP749
**Analytical SOP:** PAI 724

| Sample ID / QC Type | Nuclide / Type | Sample Date/Time | Prep Batch / QCBatchID | Ingrowth Date /Time | Decay Date/Time | Matrix / %Moist. | Samp Alq / Analy Alq | Inst ID / Det ID | File Name | Count Date/Time | GrossCPM / BkgCPM | BaseEff / ProgEff | CntDur(min) / Yield | Activity +/- / 2 s TPU | MDC / DecLev | ReportUnits / ReportBasis | DER / RPD | %Spk. Recov. / Flags |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1818003-1 | Ra-228 | | RA180604-4 | 6/05/2018 | 6/07/2018 | Liquid | 1500 ml | LB4100-C | | 6/7/2018 | 9.944 | 47.08% | 90 | 7.1 | 0.5 | pCi/l | NA | 116 |
| SMP | Trg. Analyte | | RA180604-4-1 | 4:00:00 PM | 7:40:00 AM | NA | 1500 ml | A2 | RAC0607 | 8:48 AM | 1.575 | NA | 94.5% | 1.7 | NA | Unfiltered | NA | |
| 1818003-2 | Ra-228 | | RA180604-4 | 6/05/2018 | 6/07/2018 | Liquid | 1500 ml | LB4100-C | | 6/7/2018 | 9.544 | 45.84% | 90 | 6.5 | 0.6 | pCi/l | NA | 107 |
| SMP | Trg. Analyte | | RA180604-4-1 | 4:00:00 PM | 7:40:00 AM | NA | 1500 ml | B2 | RAC0607 | 8:48 AM | 1.759 | NA | 97.9% | 1.6 | NA | Unfiltered | NA | |
| 1818003-3 | Ra-228 | | RA180604-4 | 6/05/2018 | 6/07/2018 | Liquid | 1500 ml | LB4100-C | | 6/7/2018 | 10.000 | 48.66% | 90 | 6.5 | 0.5 | pCi/l | NA | 107 |
| SMP | Trg. Analyte | | RA180604-4-1 | 4:00:00 PM | 7:40:00 AM | NA | 1500 ml | C4 | RAC0607 | 8:48 AM | 1.710 | NA | 98.6% | 1.6 | NA | Unfiltered | NA | |
| 1818003-4 | Ra-228 | | RA180604-4 | 6/05/2018 | 6/07/2018 | Liquid | 1500 ml | LB4100-C | | 6/7/2018 | 9.167 | 47.02% | 90 | 6.2 | 0.5 | pCi/l | NA | 102 |
| SMP | Trg. Analyte | | RA180604-4-1 | 4:00:00 PM | 7:40:00 AM | NA | 1500 ml | D3 | RAC0607 | 8:48 AM | 1.607 | NA | 97.7% | 1.5 | NA | Unfiltered | NA | |
| RA180604-4A | Ra-228 | 6/4/2018 | RA180604-4 | 6/05/2018 | 6/07/2018 | Liquid | 1500 ml | LB4100-C | | 6/7/2018 | 1.756 | 48.51% | 90 | 0.13 | 0.51 | pCi/l | NA | |
| MB | Trg. Analyte | 2:27:19 PM | RA180604-4-1 | 4:00:00 PM | 7:40:00 AM | NA | 1500 ml | A3 | RAC0607 | 8:48 AM | 1.588 | NA | 98.9% | 0.23 | NA | Unfiltered | NA | U |
| RA180604-4B | Ra-228 | 6/4/2018 | RA180604-4 | 6/05/2018 | 6/07/2018 | Liquid | 1500 ml | LB4100-C | | 6/7/2018 | 1.967 | 48.05% | 90 | 0.22 | 0.54 | pCi/l | NA | |
| MB | Trg. Analyte | 2:27:19 PM | RA180604-4-1 | 4:00:00 PM | 7:40:00 AM | NA | 1500 ml | B3 | RAC0607 | 8:48 AM | 1.695 | NA | 97.4% | 0.25 | NA | Unfiltered | NA | U |
| RA180604-4C | Ra-228 | 6/4/2018 | RA180604-4 | 6/05/2018 | 6/07/2018 | Liquid | 1500 ml | LB4100-C | | 6/7/2018 | 1.711 | 47.03% | 90 | 0.01 | 0.55 | pCi/l | NA | |
| MB | Trg. Analyte | 2:27:19 PM | RA180604-4-1 | 4:00:00 PM | 7:40:00 AM | NA | 1500 ml | C2 | RAC0607 | 8:48 AM | 1.694 | NA | 96.7% | 0.24 | NA | Unfiltered | NA | U |
| RA180604-4E | Ra-228 | 6/4/2018 | RA180604-4 | 6/05/2018 | 6/07/2018 | Liquid | 1500 ml | LB4100-C | | 6/7/2018 | 1.744 | 45.96% | 90 | 0.01 | 0.56 | pCi/l | NA | |
| MB | Trg. Analyte | 2:27:19 PM | RA180604-4-1 | 4:00:00 PM | 7:40:00 AM | NA | 1500 ml | D1 | RAC0607 | 8:48 AM | 1.735 | NA | 98.2% | 0.24 | NA | Unfiltered | NA | U |

Control limits 70-~~X~~130%
JP 6/8/18

**Comments:**

## Qualifiers/Flags:

U - Result is less than the sample specific MDC.
Y1 - Chemical Yield is in control at 100-110%. Quantitative yield is assumed.
Y2 - Chemical Yield outside default limits.
W - DER is greater than Warning Limit of 1.42
D - DER is greater than Control Limit of 2.13
+ - Duplicate RPD not within limits.
LT - Result is less than Request MDC, greater than sample specific MDC
* - Aliquot Basis is 'As Received' while the Report Basis is 'Dry Weight'.
# - Aliquot Basis is 'Dry Weight' while the Report Basis is 'As Received'.

M - Requested MDC not met.
M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.
L - LCS Recovery below lower control limit.
H - LCS Recovery above upper control limit.
P - LCS, Matrix Spike Recovery within control limits.
N - Matrix Spike Recovery outside control limits
NC - Not Calculated for duplicate results less than 5 times MDC
B - Analyte concentration greater than MDC.
B3 - Analyte concentration greater than MDC but less than Requested MDC.

## Notes:

1) The Tracer results are not yield corrected (i.e. activity measured not activity added).
2) Where sample time is not available, 12:00 PM (Mountain) is used for decay correction.

## Abbreviations:

TR- Tracer TA - Target Analyte
TPU - Total Propagated Uncertainty (see PAI SOP 743)
MDC - Minimum Detectable Concentration (see PAI SOP 709)
DER - Duplicate Error Ratio
BDL - Below Detection Limit

# ALS - Gas Flow Proportional Sample Analysis LB4100-C

Unit Type: LB4100 -C
Counting Unit ID: Magenta
High Voltage Mode: Simultaneous
Application Revision: 2
Application Version: Standard
Rev.12/01/08 JCP

Data file name: RAC0607
Batch ID: RA180604-4
Count Preset (m): 90
Batch Ended: 6/7/2018 10:21

Background logfile: BKGABW
Date of Bkg. Cal: 5/28/2018
Alpha efficiency logfile: Am_WIPE-06/17 Alpha prog. logfile: n/a
Alpha attenuation calibration: AAM0606, 0607 Alpha prog. attenuation: n/a
Beta efficiency logfile: RA228-06/17 Beta prog. logfile: n/a
Beta attenuation calibration: ASR0607 Beta prog. attenuation: n/a

| Alpha Attenuation Calibration | | Beta Attenuation Calibration | |
|---|---|---|---|
| y = b*m^(a*(mass-x0)) | | y = b*m^(a*(mass-x0)) | |
| Alpha b= | 0.90300 | Beta b= | 0.9681 |
| m= | 0.99110 | m= | 0.9996 |
| a= | 0.8270 | a= | 0.9174 |
| x0= | 21.4875 | x0= | 0.0000 |
| Alpha to Beta X-talk | | Beta to Alpha X-talk | |
| y = b *m^-mass | | y = b*mass + m | |
| a ->b xtalk b= | 0.2511 | b ->a xtalk b= | -1.69E-05 |
| a ->b xtalk m= | 0.9984 | b ->a xtalk m= | 0.0036 |

| Det. ID | Sample ID | Count End Date & Time | Count Dur. (min) | Resid. Mass (mg) | Alpha Activity Gross CPM | Alpha Bkg. CPM | Alpha b>a xtlk CPM | Alpha Base Eff | Alpha Base Cor.Fact. | Alpha Progeny Eff | Alpha Progeny Cor.Fact. | Beta Activity Gross CPM | Beta Bkg. CPM | Beta a>b xtlk CPM | Beta Base Eff | Beta Base Cor.Fact. | Beta Progeny Eff | Beta Progeny Cor.Fact. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A2 | 1818003-1 | 6/7/2018 10:20 | 90.00 | 0.0 | 0.378 | 0.127 | 0.030 | 0.2663 | 1.058 | n/a | n/a | 9.944 | 1.575 | 0.0630 | 0.4708 | 0.968 | n/a | n/a |
| A3 | RA180604-4AMB | 6/7/2018 10:20 | 90.00 | 0.0 | 0.311 | 0.105 | 0.001 | 0.2667 | 1.058 | n/a | n/a | 1.756 | 1.588 | 0.0518 | 0.4851 | 0.968 | n/a | n/a |
| C2 | RA180604-4CMB | 6/7/2018 10:20 | 90.00 | 0.0 | 0.278 | 0.142 | 0.000 | 0.2618 | 1.058 | n/a | n/a | 1.711 | 1.694 | 0.0341 | 0.4703 | 0.968 | n/a | n/a |
| C4 | 1818003-3 | 6/7/2018 10:20 | 90.00 | 0.0 | 0.522 | 0.171 | 0.030 | 0.2561 | 1.058 | n/a | n/a | 10.000 | 1.710 | 0.0882 | 0.4866 | 0.968 | n/a | n/a |
| D1 | RA180604-4EMB | 6/7/2018 10:20 | 90.00 | 0.0 | 0.178 | 0.122 | 0.000 | 0.2582 | 1.058 | n/a | n/a | 1.744 | 1.735 | 0.0140 | 0.4596 | 0.968 | n/a | n/a |
| D3 | 1818003-4 | 6/7/2018 10:20 | 90.00 | 0.0 | 0.544 | 0.132 | 0.027 | 0.2627 | 1.058 | n/a | n/a | 9.167 | 1.607 | 0.1036 | 0.4702 | 0.968 | n/a | n/a |
| B2 | 1818003-2 | 6/7/2018 10:21 | 90.00 | 0.0 | 0.422 | 0.142 | 0.028 | 0.2570 | 1.058 | n/a | n/a | 9.544 | 1.759 | 0.0704 | 0.4584 | 0.968 | n/a | n/a |
| B3 | RA180604-4BMB | 6/7/2018 10:21 | 90.00 | 0.0 | 0.156 | 0.134 | 0.001 | 0.2589 | 1.058 | n/a | n/a | 1.967 | 1.695 | 0.0054 | 0.4805 | 0.968 | n/a | n/a |

JP 6/8/18

Date 6/7/18

SOP 724r 12

# ALS

## Low Background Gas Flow Proportional Counter Log

**Instrument: LB4100C**

*Instrument Daily Response and Background Checks*

| Det. | Daily Response Check Start 1 | Status | Start 2 | Status | Background Check Start 1 | Status | Start 2 | Status | Det. Status |
|---|---|---|---|---|---|---|---|---|---|
| 1 | NP | P | | | NP | P | | | P |
| 2 | | | | | | | | | |
| 3 | | | | | | | | | |
| 4 | | | | | | | | | |
| 5 | | | | | | | | | |
| 6 | | | | | | | | | |
| 7 | | | | | | | | | |
| 8 | | | | | | | | | |
| 9 | | | | | | | | | |
| 10 | | | | | | | | | |
| 11 | | | | | | | | | |
| 12 | | | | | | | | | |
| 13 | | | | | | | | | |
| 14 | | | | | | | | | OL |
| 15 | | | | | | | | | P |
| 16 | | | | | | | | | |

Det = Detector; α = Alpha; β = Beta; P = Pass; H = High; L = Low; OL = Offline; R = Recount; W = Weekly; NP = Not Processed

*Weekly Background Calibration*

| | Current Calib. File ID | Weekly Calib. Started | Status | File ID |
|---|---|---|---|---|
| Dr A | BKC0527W | | | |
| Dr B | | | | |
| Dr C | | | | |
| Dr D | | | | |

Dr = Drawer

*Gas Supply*

| P-10 Supply | | P-10 Flow | |
|---|---|---|---|
| Tank 1 | 1900 | Dr A | 10 |
| | | Dr B | |
| Tank 2 | 1400 | Dr C | |
| | | Dr D | |

Comments:

Page No.: 478928 A

Form 780r8.doc (6/23/06)

Reviewed By / Date JP 6/7/18

Date 6/7/18

SOP 724r 12

**ALS**

Low Background Gas Flow Proportional Counter Log

**Instrument: LB4100C**

| Det. | Sample ID | Batch | Test | Count Dur. (min) | Start Time | Analyst Initials | File ID | Output Initials |
|---|---|---|---|---|---|---|---|---|
| 1-16 | Daily EFF | — | — | 30 | 6:53 | JP | EFC0607 | JP |
| 1-16 | Daily BKG | — | — | 60 | 7:00 | JP | BKC0607 | JP |
| 8 | 1806074-1 | AB180606-3 | α1B | 240 | 8:05 | JP | ABC0607 | JP |
| 4 | -2 | | | | | | | |
| 9 | -3 | | | | | | | |
| 11 | -6 | | | | | | | |
| 16 | -6D | | | | | | | |
| 1 | AB180606-3MB | | | | | | | |
| 2 | LCS | | | 30 | 8:06 | JP | ABC0607A | JP |
| 13 | AB180508-5LCS | AB180508-5 | | | | | | |
| 15 | AB180509-2LCS | AB180509-2 | | | | | | |
| 3 | 1806012-1MS | AB180605-1 | α1B | 30 | 8:07 | JP | ABC0607B | |
| 5 | AB180605-1LCS | | | | | | | |
| 6 | 1805651-2MS | AB180604-1 | | | | | | |
| 7 | AB180604-1LCS | | | | | | | |
| 10 | 1805593-7MS | AB180601-1 | | | | | | |
| 12 | AB180601-1LCS | | | | | | | |
| 2 | 1818003-1 | RA180604-4 | Ra228 ICV/ICB | 90 | 8:50 | JP | RAC0607 | JP |
| 6 | -2 | | | | | | | |
| 12 | -3 | | | | | | | |
| 15 | -4 | | | | | | | |
| 3 | RA180604-4AMB | | | | | | | |
| 7 | BMB | | | | | | | |
| 10 | CMB | | | | | | | |
| 13 | EMB | | | | | | | |
| 2 | 1805020-1 | AB180605-1 | α1B | 120 | 10:23 | JP | ABC0607C | |
| 3 | -1D | | | | | | | |
| 6 | 1805068-1 | | | | | | | |
| 7 | 1806012-1 | | | | | | | |
| 10 | -2 | | | | | | | |
| 12 | AB180605-1MB | | | | | | | |
| 5 | 1805644-1 | AB180601-1 | α1B | 75 | 10:26 | JP | ABC0607D | |
| 13 | -1D | | | | | | | |
| 15 | -2 | | | | | | | |
| 5 | -1MS | | α1B | 30 | 11:44 | JP | ABC0607E | |
| 1 | 1805593-2 | AB180601-1 | α1B | 120 | 12:28 | JP | ABC0607F | JP |
| 2 | -3 | | | | | | | |
| 3 | -3D | | | | | | | |
| 4 | -4 | | | | | | | |
| 5 | -5 | | | | | | | |
| 6 | -6 | | | | | | | |
| 7 | -8 | | | | | | | |
| 8 | 1805623-1 | | | | | | | |
| 9 | 1805514-1 | AB180531-3 | | | | | | |
| 10 | -1D | | | | | | | |
| 11 | -2 | | | | | | | |
| 13 | 1805559-1 | | | | | | | |

Comments:

Page No.: 478928 **B**

(cont. from page NA B)

Form 780r8.doc (6/23/06)

Reviewed By / Date 6/7/18

# Radiochemistry ICP Worksheet

**ALS -- Fort Collins**

**Prep Batch: RA180604-4**

Prep Procedure: **Ra228**

Reviewed By: lad AD

Review Date: **6/7/2018**

## BARIUM Recovery Results

### Reference Carrier

| LabID | QC Type | Carr Vol | Ref Carr Dil Vol | Ref Carr ICP Alq | Ref Carr ICP Dil Vol | Ref Carr ICP Run | Ref Carr ICP Conc |
|---|---|---|---|---|---|---|---|
| RA180604-4 | CAR | 2 | 27 | 0.05 | 10.05 | IR180605-2A1 | 5.955128 |

### Samples

| Prep Num | LabID | QC Type | Init Samp Alq (ml) | Car Vol (ml) | Samp Dil Vol (ml) | Init ICP Alq (ml) | Init ICP Dil Vol (ml) | Pre-Con Vol (ml) | Post Con Vol (ml) | Pre-Sep Vol (ml) | Post Sep Vol (ml) | Fin ICP Alq (ml) | Fin ICP Dil Vol (ml) | Initial ICP Run | Final ICP Run | Init ICP Conc (ug/ml) | Fin ICP Conc (ug/ml) | Init Samp Mass (ug) | Ref Mass (ug) | Flag | Fin Samp Mass (ug) | % Yield | Final Sample Alq |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1818003-1 | SMP | 1500 | 2 | 1500 | 1 | 10 | 1499 | 1499 | 1499 | 25 | 0.05 | 10.05 | IR180605-2A1 | IR180605-2A1 | -0.0005 | 6.080562 | 0 | 32318.48 | Z | 30554.82 | 94.54% | 1496 |
| 1 | 1818003-2 | SMP | 1500 | 2 | 1500 | 1 | 10 | 1499 | 1499 | 1499 | 25 | 0.05 | 10.05 | IR180605-2A1 | IR180605-2A1 | -0.0005 | 6.296104 | 0 | 32318.48 | Z | 31637.92 | 97.89% | 1496 |
| 1 | 1818003-3 | SMP | 1500 | 2 | 1500 | 1 | 10 | 1499 | 1499 | 1499 | 25 | 0.05 | 10.05 | IR180605-2A1 | IR180605-2A1 | -0.0005 | 6.342999 | 0 | 32318.48 | Z | 31873.57 | 98.62% | 1496 |
| 1 | 1818003-4 | SMP | 1500 | 2 | 1500 | 1 | 10 | 1499 | 1499 | 1499 | 25 | 0.05 | 10.05 | IR180605-2A1 | IR180605-2A1 | -0.0005 | 6.282928 | 0 | 32318.48 | Z | 31571.71 | 97.69% | 1496 |
| 1 | RA180604-4A | MB | 1500 | 2 | 1500 | 1 | 10 | 1499 | 1499 | 1499 | 25 | 0.05 | 10.05 | IR180605-2A1 | IR180605-2A1 | -0.0005 | 6.359548 | 0 | 32318.48 | Z | 31956.73 | 98.88% | 1496 |
| 1 | RA180604-4B | MB | 1500 | 2 | 1500 | 1 | 10 | 1499 | 1499 | 1499 | 25 | 0.05 | 10.05 | IR180605-2A1 | IR180605-2A1 | -0.0005 | 6.263164 | 0 | 32318.48 | Z | 31472.4 | 97.38% | 1496 |
| 1 | RA180604-4C | MB | 1500 | 2 | 1500 | 1 | 10 | 1499 | 1499 | 1499 | 25 | 0.05 | 10.05 | IR180605-2A1 | IR180605-2A1 | -0.0004 | 6.220107 | 0 | 32318.48 | Z | 31256.04 | 96.71% | 1496 |
| 1 | RA180604-4E | MB | 1500 | 2 | 1500 | 1 | 10 | 1499 | 1499 | 1499 | 25 | 0.05 | 10.05 | IR180605-2A1 | IR180605-2A1 | -0.0004 | 6.317217 | 0 | 32318.48 | Z | 31744.02 | 98.22% | 1496 |



**FLAG -** LB: low bias (<= 15%) 15%: low bias (>15%)

Z: Negative init. conc. treated as zer

IRL80605-2A1

Printed 6/5/2018 16:50:06 Page 1

| Sample Id1 | Ca | Fe | K | Mg | Na | Sr | Mn | S | Al | Ba | Pb | U |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CCV | 50.8418 | 20.5804 | 49.8694 | 51.7162 | 49.4837 | 0.4920 | 1.0706 | 5.2673 | 51.2986 | 0.9796 | 1.0251 | 4.9187 |
| CCB | -0.0054 | -0.0017 | 0.1021 | -0.0054 | 0.0202 | -0.0001 | 0.0005 | 0.0000 | -0.0511 | -0.0004 | -0.0021 | -0.0036 |
| I 1818003-1 | 0.0018 | -0.0005 | 0.0529 | -0.0289 | 0.0047 | -0.0002 | -0.0003 | 0.0046 | -0.0805 | -0.0005 | -0.0020 | -0.0151 |
| I 1818003-2 | 0.0039 | -0.0042 | 0.0591 | -0.0257 | 0.0019 | -0.0002 | -0.0003 | 0.0046 | -0.0773 | -0.0005 | -0.0034 | 0.0009 |
| I 1818003-3 | -0.0003 | -0.0014 | 0.0270 | -0.0236 | -0.0050 | -0.0001 | -0.0003 | 0.0184 | -0.0696 | -0.0005 | -0.0021 | 0.0018 |
| I 1818003-4 | 0.0024 | -0.0011 | 0.0311 | -0.0209 | -0.0052 | -0.0001 | -0.0003 | 0.0092 | -0.0696 | -0.0005 | -0.0003 | -0.0071 |
| I RA180604-4AMB | 0.0080 | -0.0011 | 0.0518 | -0.0364 | 0.0267 | -0.0002 | -0.0004 | 0.0138 | -0.0760 | -0.0005 | -0.0012 | -0.0205 |
| I RA180604-4BMB | 0.0039 | -0.0032 | 0.0783 | -0.0214 | 0.0075 | -0.0001 | -0.0001 | 0.0138 | -0.0760 | -0.0005 | -0.0016 | -0.0053 |
| I RA180604-4CMB | 0.0051 | -0.0034 | 0.0451 | -0.0289 | 0.0102 | -0.0002 | -0.0003 | 0.0138 | -0.0696 | -0.0004 | -0.0007 | -0.0027 |
| I RA180604-4EMB | 0.0202 | 0.0004 | 0.0596 | -0.0268 | 0.0196 | -0.0001 | -0.0003 | 0.0046 | -0.0696 | -0.0004 | -0.0017 | -0.0125 |
| F 1818003-1 | -0.0125 | -0.0026 | 0.0788 | -0.0230 | 89.8379 | 0.0006 | -0.0004 | 1.8986 | -0.0760 | 6.0806 | 0.1834 | -0.0080 |
| F 1818003-2 | -0.0068 | -0.0015 | 0.0622 | -0.0268 | 90.6406 | 0.0004 | -0.0002 | 1.9585 | -0.0767 | 6.2961 | 0.1689 | -0.0071 |
| F 1818003-3 | -0.0065 | -0.0008 | 0.0612 | -0.0337 | 91.0810 | 0.0005 | -0.0004 | 1.9723 | -0.0773 | 6.3430 | 0.2162 | -0.0258 |
| F 1818003-4 | -0.0068 | 0.0081 | 0.0824 | -0.0257 | 90.8042 | 0.0005 | -0.0003 | 1.9355 | -0.0620 | 6.2829 | 0.1631 | -0.0054 |
| F RA180604-4AMB | -0.0054 | 0.0040 | 0.0420 | -0.0284 | 90.2479 | 0.0005 | -0.0003 | 1.9124 | -0.0664 | 6.3595 | 0.1632 | -0.0134 |
| F RA180604-4BMB | -0.0077 | -0.0007 | 0.1016 | -0.0230 | 90.2150 | 0.0005 | -0.0001 | 1.9309 | -0.0620 | 6.2632 | 0.1619 | 0.0036 |
| F RA180604-4CMB | -0.0068 | -0.0011 | 0.0695 | -0.0273 | 91.1482 | 0.0005 | -0.0003 | 1.9078 | -0.0664 | 6.2201 | 0.1496 | -0.0089 |
| F RA180604-4EMB | -0.0071 | 0.0014 | 0.0881 | -0.0236 | 90.9280 | 0.0005 | -0.0002 | 1.9493 | -0.0581 | 6.3172 | 0.1710 | -0.0045 |
| RA180604-4RC | -0.0036 | 0.0029 | 0.0420 | -0.0295 | 89.8598 | 0.0007 | -0.0003 | 0.0138 | -0.0607 | 5.9551 | 0.0008 | -0.0143 |
| CCV | 50.8212 | 20.6123 | 49.2583 | 52.0783 | 49.9548 | 0.4950 | 1.0694 | 5.3456 | 52.0263 | 0.9711 | 1.0143 | 4.9330 |
| CCB | -0.0051 | -0.0020 | 0.0627 | -0.0139 | 0.0151 | -0.0001 | 0.0002 | -0.0092 | -0.0466 | -0.0003 | -0.0005 | -0.0232 |

# Radiochemistry Instrument Worksheet

**ALS -- Fort Collins**

**Prep Batch:** RA180604-4

**Prep Procedure:** Ra228 ICVs / ICBs Inst C

Analytical QASS / NCR? Y (N) NA

| Prep Num | LabID | QC Type | Init Alq | Fin Alq | Units | Report Units | Residual Mass (mg) | Cnt 1 File | Cnt 1 Inst/Det | Cnt 1 Pos Chk By | Cnt 2 File | Cnt 2 Inst/Det | Cnt 2 Pos Chk By | Cnt 3 File | Cnt 3 Inst/Det | Cnt 3 Pos Chk By | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1818003-1 | SMP | 1500 | 1496.0 | ml | pCi/l | | RAC0607 | 2 | JP | | | | | | | |
| 1 | 1818003-2 | SMP | 1500 | 1496.0 | ml | pCi/l | | | 6 | | | | | | | | |
| 1 | 1818003-3 | SMP | 1500 | 1496.0 | ml | pCi/l | | | 12 | | | | | | | | |
| 1 | 1818003-4 | SMP | 1500 | 1496.0 | ml | pCi/l | | | 15 | | | | | | | | |
| 1 | RA180604-4A | MB | 1500 | 1496.0 | ml | pCi/l | | | 3 | | | | | | | | |
| 1 | RA180604-4B | MB | 1500 | 1496.0 | ml | pCi/l | | | 7 | | | | | | | | |
| 1 | RA180604-4C | MB | 1500 | 1496.0 | ml | pCi/l | | | 10 | | | | | | | | |
| 1 | RA180604-4E | MB | 1500 | 1496.0 | ml | pCi/l | | | 13 | | | | | | | | |

JP 6/8/18

**Tracer/Carrier Solution Information**

| Soln # | Nuclide | SolnID | Exp Date | Prep Conc | Units | Prep Date | Aliquot | Units | Pipet ID |
|---|---|---|---|---|---|---|---|---|---|
| T1 | BARIUM | 418240 | 10/12/18 | 16,029.992 | pCi/ml | NA | 2 | ml | RS031 |

**Spike Solution Information**

| Soln # | Nuclide | SolnID | Exp Date | Prep Conc | Units | Prep Date | Aliquot | Units | Pipet ID |
|---|---|---|---|---|---|---|---|---|---|
| S1 | Ra-228 | 1014.4095.79 | 3/20/19 | 81.151 | DPM/ml | 06/04/18 | 0.25 | ml | RS019 |

## Sample Barcodes

| | | |
|---|---|---|
| 1818003-1<br>RA180604-4PS1 | 1818003-2<br>RA180604-4PS2 | 1818003-3<br>RA180604-4PS3 |
| 1818003-4<br>RA180604-4PS4 | RA180604-4AMB<br>RA180604-4PS5 | RA180604-4BMB<br>RA180604-4PS6 |
| RA180604-4CMB<br>RA180604-4PS7 | RA180604-4EMB<br>RA180604-4PS1 | RA180604-4CAR<br>RA180604-4PS9 |

## Reporting Units

| LabID: | TstGrpName: | RptUnits: |
|---|---|---|
| 1818003-1 | Ra228_2012 | pCi/l |
| 1818003-2 | Ra228_2012 | pCi/l |
| 1818003-3 | Ra228_2012 | pCi/l |
| 1818003-4 | Ra228_2012 | pCi/l |

# Radiochemistry Prep Worksheet

**ALS -- Fort Collins**

**Prep Batch:** RA180604-4

**Prep Procedure:** Ra228

**Reviewed By:** lad **Review Date:** 6/7/2018

**Non-Routine Pre-Treatment? Y / N** **Batch:** NA **Re-Prep? Y / N** **Batch:** NA **Prep QASS / NCR? Y / N** NA

**Prep SOP:** SOP749 **Rev:** 4
**Prep SOP:** NONE
**Matrix Class:** liquid

**Prep Analyst:** Lucas A. Daut LAD
**Prep Date:** 6/4/2018
**Prep Dept:** RS

**Balance:** N/A
**Balance:** N/A

| Samp Num | Prep Num | LabID | QC Type | Dish No. | Init Alq ml | Fin Alq ml | Prep Basis | Ingrowth Date/Time | Decay Date/Time | Standards | Prep Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1818003-1 | SMP | NA | 1500 | 1496.002 | Unfiltered | 06/05/18 16:00 | 06/07/18 07:40 | S1,T1 | |
| 2 | 1 | 1818003-2 | SMP | | 1500 | 1496.002 | Unfiltered | 06/05/18 16:00 | 06/07/18 07:40 | S1,T1 | |
| 3 | 1 | 1818003-3 | SMP | | 1500 | 1496.002 | Unfiltered | 06/05/18 16:00 | 06/07/18 07:40 | S1,T1 | |
| 4 | 1 | 1818003-4 | SMP | | 1500 | 1496.002 | Unfiltered | 06/05/18 16:00 | 06/07/18 07:40 | S1,T1 | |
| 5 | 1 | RA180604-4A | MB | | 1500 | 1496.002 | Unfiltered | 06/05/18 16:00 | 06/07/18 07:40 | T1 | |
| 6 | 1 | RA180604-4B | MB | | 1500 | 1496.002 | Unfiltered | 06/05/18 16:00 | 06/07/18 07:40 | T1 | |
| 7 | 1 | RA180604-4C | MB | | 1500 | 1496.002 | Unfiltered | 06/05/18 16:00 | 06/07/18 07:40 | T1 | |
| 8 | 1 | RA180604-4E | MB | | 1500 | 1496.002 | Unfiltered | 06/05/18 16:00 | 06/07/18 07:40 | T1 | LAD 6/7 |

Comments
ICV/ICB

**Spiked By:** Lucas A. Daut **Date:** 6/4/2018 **Yttrium Added By:** _____ **Date:** _____

**Witnessed By:** Reilly G. Stockton **Date:** 6/4/2018 **Witnessed By:** _____ **Date:** _____

**Tracer/Carrier Solution Information**

| Soln # | Nuclide | SolnID | Exp Date | Prep Conc | Units | Prep Date | Aliquot | Units | Pipet ID |
|---|---|---|---|---|---|---|---|---|---|
| T1 | BARIUM | 418240 | 10/17/18 | 16,029.992 | pCi/ml | NA | 2 | ml | RS031 |

**Spike Solution Information**

| Soln # | Nuclide | SolnID | Exp Date | Prep Conc | Units | Prep Date | Aliquot | Units | Pipet ID |
|---|---|---|---|---|---|---|---|---|---|
| S1 | Ra-228 | 1014.4095.79 | 3/20/19 | 81.151 | DPM/ml | 06/04/18 | 0.25 | ml | RS019 |

ALS -- Fort Collins

# Radiochemistry Prep Worksheet

**Prep Batch:** RA180604-4

**Prep Procedure:** Ra228

## Prep Batch Not Validated!!!

**Reviewed By:**

**Review Date:**

**Non-Routine Pre-Treatment? Y / N** **Batch:** _____ **Re-Prep? Y / N** **Batch:** _____ **Prep QASS / NCR? Y / N** _____

**Prep SOP:** SOP749 **Rev:** 4
**Prep SOP:** NONE
**Matrix Class:** liquid

**Prep Analyst:** Lucas A. Daut LAD
**Prep Date:** 6/4/2018
**Prep Dept:** RS

**Balance:** N/A
**Balance:** N/A

| Samp Num | Prep Num | LabID | QC Type | Dish No. | Init Alq ml | Fin Alq ml | Prep Basis | Ingrowth Date/Time | Decay Date/Time | Standards | Prep Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1818003-1 | SMP | | 1500 | 1496.002 | | 1600 | 7:40 | S1,T1 | |
| 2 | 1 | 1818003-2 | SMP | | 1500 | 1496.002 | | 6/5/18 | 6/7/18 | S1,T1 | |
| 3 | 1 | 1818003-3 | SMP | | 1500 | 1496.002 | | | | S1,T1 | |
| 4 | 1 | 1818003-4 | SMP | | 1500 | 1496.002 | | | | S1,T1 | |
| 5 | 1 | RA180604-4A | MB | | 1500 | 1496.002 | | | | T1 | |
| 6 | 1 | RA180604-4B | MB | | 1500 | 1496.002 | | | | T1 | |
| 7 | 1 | RA180604-4C | MB | | 1500 | 1496.002 | | | | T1 | |
| 8 | 1 | RA180604-4E | MB | | 1500 | 1496.002 | | | | T1 | |

Comments

**Spiked By:** Lucas A. Daut **Date:** 6/4/2018 **Yttrium Added By:** _____ **Date:** _____

**Witnessed By:** Kelly Stol **Date:** 6/4/2018 **Witnessed By:** _____ **Date:** _____

**Tracer/Carrier Solution Information**

| Soln # | Nuclide | SolnID | Exp Date | Prep Conc | Units | Prep Date | Aliquot | Units | Pipet ID |
|---|---|---|---|---|---|---|---|---|---|
| T1 | BARIUM | 418240 | 10/12/18 | 16,029.992 | pCi/ml | NA | 2 | ml | RS031 |

**Spike Solution Information**

| Soln # | Nuclide | SolnID | Exp Date | Prep Conc | Units | Prep Date | Aliquot | Units | Pipet ID |
|---|---|---|---|---|---|---|---|---|---|
| S1 | Ra-228 | 1014.4095.79 | 3/20/19 | 81.151 | DPM/ml | 06/04/18 | 0.25 | ml | RS019 |

# Radiochemistry Solution Report

| | | | | | |
|---|---|---|---|---|---|
| **Solution Id:** | 418240 | **Name:** | Barium Carrier | **Type:** | IS |
| | | **Lot:** | | **Vendor Name:** | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Final Vol:** | 4000 | **Dept:** | RD | **Prep By** | ARS | **on** | 10/12/2017 | **Reviewed By** | tde | **on** | 10/20/2017 |
| **Units:** | mL | **Location:** | SR/RA | **Opened By** | | **on** | | **Verified By** | ARS | **on** | 10/12/2017 |
| **Matrix:** | LIQUID | **ExpireDate:** | 10/12/2018 | **Received By** | | **on** | | **Deactivated By** | | **on** | |

**Comment:**

| Component Name | Component ID | Volume Added | Units |
|---|---|---|---|
| Barium Stable Carrier Source<1> | 3756 B07592 | 114.0532 | g |

| CompName | Calibrated Primary Act/Conc | Calibration Date | Reference Date | 1/2 Life (Yrs) | Final Act/Conc | Summed Conc | Units |
|---|---|---|---|---|---|---|---|
| BARIUM | 562193.5 | | 12/12/2017 | | 16029.99 | | pCi/ml |

## Associated Parent IDs

3756 B07592

**Abbreviations: NC = Not Calculated for reagents when the volume added is not entered.**
**NE = Not Entered**

**(Prnt) = Secular equilibrium; parent half life used to calculate concentration.**

Prepare a working dilution of RSO# 1014 TE 1/16/15

1. Density of 8% HNO3, lot # 000008417G
   Mass of 100mL vol. flask: 68.3149g Balance # 12
   Mass of flask & 100mL acid: 172.2758g Balance# 12
   Net Mass: 103.9609g
   Density: 1.0396 g/mL

2. Mass of RSO# 1014 transferred:
   Mass of open empty nalgene: 48.3028g Balance# 12
   Mass of nalgene & standard: 53.2851g Balance# 12
   Net mass of standard transferred: 4.9823g Balance# N/A

   TE 1/16/15 TE 1/16/15

3. Dilute to final volume:
   Mass of nalgene, standard, & diluent: 344.91g Balance# 26
   Mass of empty nalgene (from above): 48.3028g Balance# 12
   Net mass of new dilution: 296.6072g Balance# N/A

4. Final activity calculation:

$$195\ Bq/g\left(\frac{60\ dpm}{1\ Bq}\right)\left(\frac{4.9823g}{296.6072g}\right)(1.0396\ g/mL) = 204.32\ dpm/mL$$

TE 1/16/15

JP 4/15/15

*Std ID:* 1014.4095.79

*Description:* Ra-228
*Expiration:* 4/9/2016
*Activity:* 204.32 dpm/mL

*2s Uncertainty:* 14.71 dpm/mL
*Ref. Date:* 10/7/2010
*Ref Time:* N/A
*Prep Date:* 1/16/2015 *Prep by:* TE
*Matrix/Comp.* 8% HNO3
*Half Life (y):* 5.75E+00

| Reverification Log | | |
|---|---|---|
| Analysis Date | Initials | Expiration Date |
| 4/2/2016 | JP | 4/02/2017 |
| 3/23/2017 | JP | 3/23/2018 |
| 3/20/2018 | JP | 3/20/2019 |
| | | |
| | | |

JP 4/15/15

Continued on Page

T Ellis 1/16/15
Signed Date

Read and Understood By 4/15/15
Signed Date

K50 F
1014

# National Institute of Standards & Technology

# Certificate

## Standard Reference Material® 4339b

### Radium-228 Radioactivity Standard

This Standard Reference Material (SRM) consists of a solution of a standardized and certified quantity of radioactive radium-228 in a suitably stable and homogeneous matrix. It is intended primarily for the calibration of instruments that are used to measure radioactivity and for the monitoring of radiochemical procedures. A unit of SRM 4339b consists of approximately 5 mL of a solution, whose composition is specified in Tables 1 and 2, contained in a flame-sealed borosilicate-glass ampoule [1].

**The certified radium-228 massic activity value, at a Reference Time of 1200 EST, 07 October 2010, is:**

$$(195 \pm 14)\ \mathrm{Bq \cdot g^{-1}}$$

A NIST certified value, as used within the context of this certificate, is a value for which NIST has the highest confidence in its uncertainty assessment. It is a "measurement result" [2] obtained directly or indirectly from a "primary reference measurement procedure" [3]. The certified value is traceable to the derived SI unit, Becquerel (Bq).

Additional physical, chemical, and radiological properties for this SRM, as well as details on the standardization method, are given in Tables 1 and 2. Uncertainties for the certified quantities are expanded ($k = 2$). The uncertainties are calculated according to the ISO and NIST Guides [4,5]. Table 3 contains a specification of the components that comprise the uncertainty analyses.

**Expiration of Certification:** The certification of SRM 4339b is valid indefinitely, within the measurement uncertainty specified, provided that the SRM is handled and stored properly and that no evaporation or change in composition has occurred. The solution matrix, in an unopened ampoule, is homogeneous and stable within its half-life-dependent useful lifetime provided the SRM is handled in accordance with instructions given in this certificate (see "Instructions for Handling and Storage"). Periodic recertification of this SRM is not required. The certification is nullified if the SRM is damaged, contaminated, or otherwise modified.

**Maintenance of SRM Certification:** NIST will monitor this SRM over the period of its certification. If substantive technical changes occur that affect the certification, NIST will notify the purchaser. Registration (see attached sheet) will facilitate notification.

**Radiological and Chemical Hazard:** Consult the Safety Data Sheet (SDS), enclosed with the SRM shipment, for radiological and chemical hazard information.

This SRM was prepared in the Physical Measurement Laboratory, Radiation and Biomolecular Physics Division, Radioactivity Group, M.P. Unterweger, Group Leader. The overall technical direction and physical measurement leading to certification and photon-emitting impurity analyses were provided by L. Pibida of the NIST Radioactivity Group, with production assistance by J. LaRosa, R. Collé, and L. Laureano-Pérez. Alpha-emitting impurity analyses were provided by J. LaRosa.

Support aspects involved in the issuance of this SRM were coordinated through the NIST Office of Reference Materials.

Lisa R. Karam, Chief
Radiation and Biomolecular Physics Division

Gaithersburg, Maryland 20899

Robert L. Watters, Jr., Director
Office of Reference Materials

Certificate Issue Date: 14 November 2012

Table 1. Certified Massic Activity of SRM 4339b

| | |
|---|---|
| Radionuclide | Radium-228[a] |
| Reference time | 1200 EST, 07 October 2010 |
| Massic activity of the solution | 195 $Bq \cdot g^{-1}$ |
| Relative expanded uncertainty ($k = 2$) | 7.2 %[b] |

[a] The final $^{228}Ra$ purification from the $^{232}Th$ mother solution was performed on 02 September 2010 0920 EST.
[b] The uncertainties on certified values are expanded uncertainties, $U = ku_c$. The quantity $u_c$ is the combined standard uncertainty calculated according to the ISO and NIST Guides [4,5]. The combined standard uncertainty is multiplied by a coverage factor of $k = 2$ and was chosen to obtain what is assumed to be an approximate 95 % level of confidence.

Table 2. Uncertified Information of SRM 4339b

| | |
|---|---|
| Source description | Liquid in a flame-sealed 5 mL borosilicate-glass ampoule [1] |
| Solution composition | 1.3 $mol \cdot L^{-1}$ $HNO_3$ with 19.8 $\mu g \cdot g^{-1}$ $Ba^{+2}$ |
| Solution density | $(1.034 \pm 0.002)$ $g \cdot mL^{-1}$ at 20.8 °C[a] |
| Solution mass | $(5.180 \pm 0.003)$ g[a] |
| Photon-emitting impurities | $^{226}Ra$: < 0.5 $Bq \cdot g^{-1}$[b] |
| Alpha-emitting impurities | $^{232}Th$: < 0.08 $Bq \cdot g^{-1}$[c] |
| Half-lives used | $^{228}Ra$: $(5.75 \pm 0.04)$ a[d] [6]<br>$^{228}Ac$: $(6.15 \pm 0.02)$ h [7]<br>$^{226}Ra$: $(1600 \pm 7)$ a [8]<br>$^{232}Th$: $(14.02 \pm 0.06) \times 10^9$ a [9] |
| Calibration methods (and instruments) | The certified massic activity for $^{228}Ra$ was obtained by high-resolution gamma-ray spectrometry of three master solution ampoules (eleven separate determinations), as measured on three to five different spectrometers and geometries on each ampoule, and used assumed nuclear data for probabilities per decay for 16 gamma-ray transitions. Confirmatory measurements were performed by $2\pi\alpha$ spectrometry of ingrown $^{228}Th$ with a planar, ion-implanted Si detector. |

[a] The stated uncertainty is two times the standard uncertainty. See reference 5.
[b] Based on gamma-ray spectrometry of forced-fitted peak at 186.2 keV and assuming a probability per decay of 0.0355 [6].
[c] The maximum $^{232}Th$ activity concentration in $^{228}Ra$.
[d] The stated uncertainty is the standard uncertainty. See reference 5.

Table 3. Uncertainty Evaluation for the Massic Activity of SRM 4339b

| | Uncertainty component | Assessment Type[a] | Relative standard uncertainty contribution on massic activity of $^{228}$Ra (%) |
|---|---|---|---|
| 1 | Gamma-ray spectrometry precision; relative standard deviation of the grand mean on the average massic gamma-ray emission rates for 16 measured $^{228}$Ac gamma-ray transitions. Each mean in the grand mean is based on 11 determinations with three sources in three to five different detectors. The uncertainty in the determination of the massic gamma-ray emission rate for any one transition in a given determination ranged from typically 0.5 % to 1.5 %. The relative standard deviation of the mean for the average of the 16 lines, for any one determination, was typically 1 %; whereas the relative standard deviation of the grand mean for the average of the 16 lines across all 11 determinations is 0.34 %[b]. Data passes normality test. | A | 0.84 |
| 2 | Uncertainty due to assumed gamma-ray probabilities per decay for the measured $^{228}$Ac transitions [7]. The uncertainty on each transition has a shared (correlated) component of 2.5 % (see comments in [7]). | B | 3.5 |
| 3 | Detection efficiencies not embodied within component 1 | B | 0.4 |
| 4 | Mass determinations for dilution factors and counting source preparations | B | 0.1 |
| 5 | Decay corrections for $^{228}$Ra half-life uncertainty of 0.7 % [6] | B | 0.003 |
| 6 | Effect of $^{228}$Ra and $^{228}$Ac half-life uncertainties on secular equilibrium ratio | B | 0.02 |
| **Relative combined standard uncertainty** | | | **3.6** |
| **Relative expanded uncertainty ($k = 2$)** | | | **7.2** |

[a] Letter A denotes evaluation by statistical methods; B denotes evaluation by other methods.
[b] Average massic gamma-ray emission rates of 11 geometries ($R_\gamma$) for 16 measured $^{228}$Ac gamma-ray transitions with their respective energy ($E_\gamma$); assumed gamma-ray probabilities per decay ($I_\gamma$) and standard deviation of the mean ($S_m$).

| $E_\gamma$ (keV) | Assumed $I_\gamma$ (%) [1] | Mean $R_\gamma$ ($s^{-1} \cdot g^{-1}$)[i] | $S_m$ (%)[ii] |
|---|---|---|---|
| 129.065 | 2.50 | 1347 | 0.38 |
| 153.967 | 0.754 | 421.6 | 0.40 |
| 209.249 | 3.97 | 2264 | 0.55 |
| 270.245 | 3.55 | 2014 | 0.33 |
| 328.004 | 3.04 | 1822 | 0.43 |
| 338.32 | 11.4 | 6712 | 0.43 |
| 409.46 | 2.02 | 1185 | 0.29 |
| 463.002 | 4.45 | 2645 | 0.33 |
| 755.313 | 1.03 | 593.3 | 0.46 |
| 772.291 | 1.52 | 899.2 | 0.53 |
| 794.942 | 4.31 | 2588 | 0.35 |
| 835.704 | 1.7 | 995.3 | 0.42 |
| 911.196 | 26.2 | 15609 | 0.29 |
| 964.786 | 4.99 | 3007 | 0.35 |
| 968.96 | 15.9 | 9582 | 0.30 |
| 1588.2 | 3.06 | 1889 | 0.28 |

(i) Grand mean for $n = 11$ determinations with three sources in three to five different detectors.
(ii) Relative standard deviation of the grand mean on $R_\gamma$ for $n = 11$.

## INSTRUCTIONS FOR HANDLING AND STORAGE

**Handling:** If the ampoule is transported, it should be packed, marked, labeled, and shipped in accordance with the applicable national, international, and carrier regulations. The solution in the ampoule is a dangerous good (hazardous material) because of both the radioactivity and the strong acid. The ampoule should be opened only by persons qualified to handle both radioactive material and alkaline and/or acidic solutions. Appropriate shielding and/or distance should be used to minimize personnel exposure. Refer to SDS for further information.

**Storage:** SRM 4339b should be stored and used at a temperature between 5 °C and 65 °C. The ampoule (or any subsequent container) should always be clearly marked as containing radioactive material.

## REFERENCES


[1] NIST Physical Measurement Laboratory; *Storage and Handling of Radioactive Standard Reference Materials, Ampoule Specifications and Opening Procedure*, available at http://www.nist.gov/pml/div682/grp04/srm.cfm (accessed Nov 2012). Note: This SRM is contained in a generic borosilicate-glass ampoule and not in the standard NIST ampoule.

[2] JCGM 200:2012; *International Vocabulary of Metrology - Basic and General Concepts and Associated Terms (VIM)* (2008 version with Minor Corrections), 3rd edition; Joint Committee for Guides in Metrology: BIPM, Sevres Cedex, France; p. 19 (2012); available at http://www.bipm.org/utils/common/documents/jcgm/JCGM_200_2012.pdf (accessed Nov 2012).

[3] JCGM 200:2012; *International Vocabulary of Metrology - Basic and General Concepts and Associated Terms (VIM)* (2008 version with Minor Corrections), 3rd edition; Joint Committee for Guides in Metrology: BIPM, Sevres Cedex, France; p. 18 (2012); available at http://www.bipm.org/utils/common/documents/jcgm/JCGM_200_2012.pdf (accessed Nov 2012).

[4] JCGM 100:2008; *Guide to the Expression of Uncertainty in Measurement;* (ISO GUM 1995 with Minor Corrections), Joint Committee for Guides in Metrology: BIPM, Sevres Cedex, France (2008); available at http://www.bipm.org/utils/common/documents/jcgm/JCGM_100_2008_E.pdf (accessed Nov 2012).

[5] Taylor, B.N.; Kuyatt, C.E.; *Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results*; NIST Technical Note 1297, U.S. Government Printing Office: Washington, DC (1994); available at http://physics.nist.gov/Pubs/ (accessed Nov 2012).

[6] Luca, A.; June 2009, $^{228}$Ra. LNE-LNHB/CEA Table of Radionuclides, available at http://www.nucleide.org/DDEP_WG/Nuclides/Ra-228_tables.pdf (accessed Nov 2012).

[7] Pearce, A.; January 2010, $^{228}$Ac. LNE-LNHB/CEA Table of Radionuclides, available at http://www.nucleide.org/DDEP_WG/Nuclides/Ac-228_tables.pdf (accessed Nov 2012).

[8] Christé, V. and M.M. Bé; December 2006, $^{226}$Ra. LNE-LNHB/CEA Table of Radionuclides, available at http://www.nucleide.org/DDEP_WG/Nuclides/Ra-226_tables.pdf (accessed Nov 2012).

[9] Arinc, A.; September 2008, $^{232}$Th. LNE-LNHB/CEA Table of Radionuclides, available at http://www.nucleide.org/DDEP_WG/Nuclides/Th-232_tables.pdf (accessed Nov 2012).


*Users of this SRM should ensure that the Certificate in their possession is current. This can be accomplished by contacting the SRM Program: telephone (301) 975-2200; fax (301) 948-3730; e-mail srminfo@nist.gov; or via the Internet at http://www.nist.gov/srm.*