

CRWMS/M&O

Calculation Cover Sheet

Complete only applicable items.

1. QA: L

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1. PURPOSE

The purpose of this engineering calculation is to provide the chemical composition for the Department of Energy (DOE) Savannah River Site (SRS) High-Level Waste (HLW) glass. Since the glass is to be co-disposed with other DOE spent nuclear fuels (SNFs) in the Monitored Geologic Repository (MGR), its chemical composition is needed for the design of the co-disposal canisters and waste packages in term of criticality and degradation.

2. METHOD

The chemical composition is expressed in weight percent (wt%). Reference 1 provides the radioisotope contents and chemical composition in compound form (including oxide) for the SRS HLW glass (Tables 6.14 and 6.18). The wt% for the isotopes are calculated directly by knowing their masses in the glass (given in Table 6.14 of Ref. 1) and the total glass weight in the canister (given in Table 6.4 of Ref. 1). The wt% of each element in the compound including the oxide is calculated by the steps listed below. Attachment II provides the formulas involved in the wt% calculations.

- (1) Determine the fraction of each element in the compound using the atomic weight.
- (2) Determine the mass of the compound in the glass.
- (3) Multiply (1) and (2) above to obtain the wt% for each element in the compound including the oxygen.
- (4) Sum the wt% of an element in each compound in which it occurs to obtain the total wt% of each element in the glass.
- (5) Add up the wt% of each element in (4) above to obtain a total, ignoring any unidentified components.
- (6) Normalized the results in (5) above to 100 %.

3. ASSUMPTIONS

- 3.1 For this calculation, only those isotopes with very long half-life and large amount in the glass are considered. The basis for this assumption is that any isotope with a half life of less than 400 years would have already decayed away as compared to the assumed life time of the intact waste package (about 3000 years, CDA Key 074). Also any isotope with an amount of less than 0.0001 wt% would have no effect on criticality. As a result, only U-234, -235, -236, -238; Pu-238, -239, -240, -241, -242 and Cs-133, -135 and -137 are retained for this calculation. This assumption is used in Section 5.1.
- 3.2 Stable Cs is assumed to be Cs-133. Cs-137 is assumed to have decayed to Ba-137 (Ref. 2). This assumption is used in Section 5.1.

- 3.3 It was very difficult to define the "0.58% of Other" group in Table 6.18 of Ref. 1. It is assumed this amount was a result of uncertainty in the chemical analysis and was ignored in this calculation. The weight percent for all other elements was re-normalized to 100%. This assumption is used in Section 5.1.
- 3.4 The dominant (most abundant) alkali or alkaline earth is Na. Consequently, it is assumed that the zeolite can be approximated as analcime, which, because of the high temperature of the pour, is assumed to be anhydrous, i.e. $\text{NaAlSi}_2\text{O}_6$. The chemical compound of zeolite is therefore assumed to take the form of $\text{NaAlSi}_2\text{O}_6$ (Ref. 3). This assumption is used in Section 5.1.

4. USE OF COMPUTER SOFTWARE

4.1 SOFTWARE APPROVED FOR QA WORK

No computer software is used for this calculation.

4.2 SOFTWARE ROUTINES

Microsoft Excel 97, loaded on a 200MHz Pentium PC. Hand calculations of the chemical composition for the SRS HLW glass were performed electronically with this spreadsheet software package. Hardcopies of the spreadsheets containing all inputs and outputs are included in Attachments I, II and III. Calculations and/or data manipulations performed in the spreadsheets are described in Section 5 and may also be examined electronically.

5. CALCULATION

The chemical composition calculations were performed in an Excel spreadsheet. Attachments I, II and III are the printouts of the Excel spreadsheet. Attachment I lists the results of this calculation. Attachments II and III contain the details of the calculations including the formulas used in determining the mole fractions, wt%, etc.

5.1 INPUT PARAMETERS

The input parameters used for this calculation are listed below. Existing data were used in the development of the input parameters presented in this section. Therefore, the use of any data from this calculation for input into documents supporting procurement, fabrication, or construction is required to be identified and tracked as TBV in accordance with appropriate procedures.

- (A) Radioisotope content in the SRS HLW glass (Ref. 1, Table 6.14)
- (B) Chemical composition of SRS HLW glass which contains the chemical compound including the oxides (Ref. 1, Table 6.18)
- (C) Glass total weight (Ref. 1, Table 6.4)
- (D) Atomic weight for each element (Refs. 2 and 4)

Note that two references were used in determining the atomic weight for the different element in the calculations. Reference 2 was used for determining the atomic weight for the natural elements and reference 4 was used for determining the atomic weight for the isotopes.

6. RESULTS

Complete results from this calculation are included in Attachments I, II and III. A summary of the chemical composition for the SRS HLW glass is shown in Table 1 below. Existing data were used in the development of the results presented in this section. Therefore, the use of any data from this calculation for input into documents supporting procurement, fabrication, or construction is required to be identified and tracked as TBV in accordance with appropriate procedures.

Table 1 SRS HLW Glass Chemical Composition

Element	Weight Percent	Element	Weight Percent
⁶ Li	9.5955E-02	⁷ Li	1.3804E+00
¹⁰ B	5.9176E-01	¹¹ B	2.6189E+00
O	4.4770E+01	F	3.1852E-02
Na	8.6284E+00	Mg	8.2475E-01
Al	2.3318E+00	Si	2.1888E+01
S	1.2945E-01	K	2.9887E+00
Ca	6.6188E-01	Ti	5.9676E-01
Mn	1.5577E+00	Fe	7.3907E+00
Ni	7.3490E-01	P	1.4059E-02
Cr	8.2567E-02	Cu	1.5264E-01
Ag	5.0282E-02	Ba-137	1.1267E-01
Pb	6.0961E-02	Cl	1.1591E-01
²³² Th	1.8559E-01	¹³³ Cs	4.0948E-02
¹³⁵ Cs	5.1615E-03	²³⁴ U	3.2794E-04
²³⁶ U	1.0415E-03	Zn	6.4636E-02
²³⁵ U	4.3514E-03	²³⁸ U	1.8666E+00
²³⁹ Pu	5.1819E-03	²³⁹ Pu	1.2412E-02
²⁴⁰ Pu	2.2773E-03	²⁴¹ Pu	9.6857E-04
²⁴² Pu	1.9168E-04		

7. REFERENCES

1. Stout, R.B. and Leider, H.R. 1991. *Preliminary Waste Form Characteristics Report. Version 1.0.* Livermore, California: UC/LLNL. MOL.19940726.0118.
2. Walker, F.W. and Parrington, J.R. 1989. *Nuclides and Isotopes 14th Edition.* San Jose, California: GE Nuclear Energy. 201637.
3. Roberts, W.L.; Rapp, G.R. Jr.; and Weber, J. 1974. *Encyclopedia of Minerals, Zeolite Group,* pages 20 and 685. New York, New York: Van Nostrand Reinhold Company. 241748.
4. Audi, G. and Wapstra, A.H. 1995. *The 1995 Update to the Atomic Mass Evaluation.* Nuclear Physics A595, Vol. A595, no.1, pages 1-65. North-Holland, The Netherlands: Elsevier N.H. 242718.

8. ATTACHMENTS

The first attachment to this document is a printout of the MS Excel spreadsheet showing the results of the SRS HLW glass chemical composition calculation. The second attachment is a printout of the Excel spreadsheet showing the formulas used to calculate the glass chemical composition. The third attachment is a printout of the Excel spreadsheet showing the formulas used to calculate the summary of the glass chemical composition.

Table 2 List of Attachments

Number	Description	Number of Pages
I	SRS HLW Glass Chemical Composition Calculation Results (Printout)	7
II	SRS HLW Glass Chemical Composition Calculation Formulas (Printout)	4
III	SRS HLW Glass Chemical Composition Calculation Summary Formulas (Printout)	2

Attachment I SRS HLW Glass Chemical Composition Calculation Results

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	A	B	C	D	E	F	G	H	I
1	Element/Compound	Atm. Vtl.	Micro in Container	Vol. %	Element Molec.	Moles of Oxygen	Vol. % of Oxygen		
2	Groups	15.9994	(gram)						
3	Oxygen								
4									
5	U-234	234.0409	8.485	0.0003281	1.59335E-08	3.71859E-08	8.64472E-05		
6	U-235	235.04392	72.78	0.004326882	1.84083E-08	4.80914E-08	0.000785434		
7	U-238	238.04556	17.42	0.001835872	4.38759E-08	1.17002E-08	0.000187187		
8	U-238	238.05078	3.12E+04	1.856123682	0.007787175	0.020782467	0.332667004		
9	Total Unstable U Mass		3.15E+04	1.861812428					
10	Total Oxygen								
11	Total U ₂ O ₈ (note a)			2.2			0.333899062		
12									
13	Pu-238	238.04955	88.87	0.005152794	2.18459E-08	4.32818E-08	0.000928402		
14	Pu-239	239.05215	207.8	0.012342449	8.18308E-08	0.000183262	0.001853123		
15	Pu-240	240.05381	38.09	0.002264588	8.43358E-08	1.88872E-08	0.000301883		
16	Pu-241	241.05684	18.2	0.000883159	3.99549E-08	7.89097E-08	0.000127851		
17	Pu-242	242.05875	3.298	0.000180508	7.87439E-07	1.67488E-08	2.81871E-05		
18	Total Unstable Pu Mass		5.82E+02	0.020813585					
19	Total Oxygen								
20							0.002798877		
21	Ca-136	134.00597	88.33	0.00519258	3.80458E-08	1.90228E-08	0.000304333		
22	Ca-137	136.0071	458.9	0.025881118	0.00218851	0.000108328	0.001733148		
23	Unstable Ca ₂ O-Total			0.038831198					
24	Total Ca ₂ O (note a)								
25	Stable Oxide			0.08					
26	Stable Ca Oxide Mass		728.0992234	0.043188802					
27	Total Unstable Mass		865.23						
28	Ca-133	132.90844		0.040717951	0.000308368	0.000153184	0.002450851		
29									
30	Ba-137			0.025881118					
31	(same as Ca137)								
32									

	A	B	C	D	E	F	G	H	I
33	Element/Compound	Atom Wt.	Mass in Canister	Element Wt. %	Compound Wt. %			g/mole	Fractions
34	Group		(gram)		(note e)				of Element
36	Al ₂ O ₃		60007.2						
37	Al	28.981538		2.092832745					0.636250663
38	O			1.884167255					0.470749337
39	Total g/mole							101.961	
40	Total Compound				3.96				
41									
42	BaSO ₄		2354.8						
43	Ba	137.327		0.082376663					0.568396676
44	S	32.066		0.018234879					0.137391894
45	O	15.9994		0.036369136					0.27420813
46	Total g/mole							233.591	
47	Total Compound				0.14				
48									
49	Ca ₃ (PO ₄) ₂		1177.4						
50	Ca	40.078		0.027134144					0.387630633
51	P	30.973762		0.013960181					0.199716869
52	O	15.9994		0.025665675					0.412652498
53	Total g/mole							310.177	
54	Total Compound				0.07				
55									
56	CaO		14297						
57	Ca	40.078		0.607467152					0.714660767
58	O	15.9994		0.242512848					0.283308233
59	Total g/mole							64.0774	
60	Total Compound				0.85				
61									
62	CaSO ₄		1345.6						
63	Ca	40.078		0.023930774					0.26436467
64	S	32.066		0.018642734					0.235634179
65	O	15.9994		0.037606492					0.470081151
66	Total g/mole							136.142	
67	Total Compound				0.96				
68									
69	Cr ₂ O ₃		2018.4						
70	Cr	51.9961		0.082104291					0.664202423
71	O	15.9994		0.037895709					0.315797577
72	Total g/mole							161.99	
73	Total Compound				0.12				
74									
75	CuO		3195.6						

Attachment I SRS HLW Glass Chemical Composition Calculation Results

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	A	B	C	D	E	F	G	H	I
76	Cs	63.646		0.131784284					0.766664546
77	O	15.9994		0.03215736					0.261133432
78	Total gmole							76.8454	
79	Total Compound				0.16				
80									
81	Fe ₂ O ₃		116412.6						
82	Fe	63.647		4.624068581					0.699433034
83	O	15.9994		2.115991439					0.300566966
84	Total gmole							150.862	
85	Total Compound				7.04				
86									
87	FeO		63478.4						
88	Fe	63.647		2.423210446					0.777311041
89	O	15.9994		0.694769251					0.222688959
90	Total gmole							71.8464	
91	Total Compound				3.12				
92									
93	K ₂ O		60215.6						
94	K	39.0983		2.971829042					0.830147777
95	O	15.9994		0.605070958					0.169852223
96	Total gmole							94.166	
97	Total Compound				3.56				
98									
99	MgO		22678.2						
100	Mg	24.305		0.82012682					0.603035667
101	O	15.9994		0.53987118					0.396964103
102	Total gmole							40.3044	
103	Total Compound				1.36				
104									
105	MnO		33640						
106	Mn	54.93805		1.346915277					0.714457636
107	O	15.9994		0.451064723					0.225542362
108	Total gmole							70.6375	
109	Total Compound				2				
110									
111	Na ₂ O		185020						
112	Na	22.989769		8.180432146					0.741857468
113	O	15.9994		2.839567854					0.258142532
114	Total gmole							61.9789	
115	Total Compound				11				
116									
117	Na ₂ SO ₄		6056.2						
118	Na	22.989769		0.116532442					0.323701227

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	A	B	C	D	E	F	G	H	I
119	S	32.066		0.081289036					0.225748322
120	O	15.9994		0.162198183					0.450350432
121	Total g/mole							142.048	
122	Total Compound				0.36				
123									
124	NaCl		3195.8						
125	Na	22.989769		0.074741129					0.393374383
126	Cl	35.4527		0.115258871					0.606625617
127	Total g/mole							58.4425	
128	Total Compound				0.18				
129									
130	NaF		1177.4						
131	Na	22.989769		0.038327075					0.847529645
132	F	18.998403		0.031872925					0.432470355
133	Total g/mole							41.8882	
134	Total Compound				0.07				
135									
136	NiO		15542.8						
137	Ni	58.89		0.730782414					0.785787511
138	O	15.9994		0.199217586					0.214212459
139	Total g/mole							74.8694	
140	Total Compound				0.83				
141									
142	PbS		1177.4						
143	Pb	207.2		0.060818728					0.895981794
144	S	32.066		0.009381274					0.134018206
145	Total g/mole							239.268	
146	Total Compound				0.07				
147									
148	SiO ₂		786487.4						
149	Si	28.0855		21.90100933					0.487454821
150	O	15.9994		24.26899087					0.632545079
151	Total g/mole							60.0843	
152	Total Compound				45.57				
153									
154	ThO ₂		3532.2						
155	Th	232.0381		0.184349968					0.878809363
156	O	15.9994		0.025450034					0.121190637
157	Total g/mole							284.037	
158	Total Compound				0.21				
159									
160	TiO ₂		10051.8						
161	Ti	47.88		0.563414022					0.509408103

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	A	B	C	D	E	F	G	H	I
162	O	15.9994		0.398565978					
163	Total g/mole								0.400591897
164	Total Compound				0.99			79.6768	
165									
166	NaAlSi ₃ O ₈ (Zeolite)		20069.4						
167	Na	22.989769		0.18993351					
168	Al	28.981659		0.22291213					0.119732841
169	Si	28.0856		0.484085349					0.133480317
170	O	15.9994		0.783069011					0.277683442
171	Total g/mole								0.4746036
172	Total Compound				1.87			202.139	
173									
174	ZnO		1343.6						
175	Zn	65.39		0.084273728					
176	O	15.9994		0.015728274					0.003421678
177	Total g/mole								0.198578434
178	Total Compound				0.06			81.3854	

Attachment I SRS HLW Glass Chemical Composition Calculation Results

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	A	B	C	D	E	F	G	H	I	
179	Element/Compound	Atom Wt.	Moles In Capiglar	Element Wt. %	Element Moles	Moles of Oxygen	Wt. % of Oxygen	g/mole	Fraction of Element	
180	Group									
181										
182	B ₂ O ₃		172.9098		0.295318352	0.442974527	7.067326652			
183	B	10.811028								
184	B-10	10.012937	6.897557782	0.588439221	0.058787984	0.088181831	1.410378004		0.310571337	
185	B-11	11.009305	43.60320793	2.604233527	0.236348396	0.354822566	5.676948648			
186	O	15.9994		7.067326652						
187	Total g/mole						7.067326652		0.689428663	
188	Total Compound (note a)			10.28				69.6203		
189										
190	Li ₂ O		63.1612		0.211503669	0.105751844	1.69196006			
191	Li	6.9408378								
192	Li-6	6.015122	1.604906151	0.095416537	0.015882777	0.007931386	0.126897454		0.464567703	
193	Li-7	7.0160039	23.06743472	1.372817403	0.195640912	0.097820456	1.565068603			
194	O	15.9994		1.69196006						
195	Total g/mole						1.69196006		0.535432297	
196	Total Compound (note a)			3.18				26.8613		
197										
198	Ag (note a)			0.65						
199	Other (note a)			0.58						
200										
201										
202	Note: The total wt.% come from Ref. 1 in the main report.									
203										

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	A	B	C	D	E	F	G	H	I
204	SUMMARY								
205									
206	Element		Wt. %, Not Normalized	Wt. %, Normalized	Element	Wt. %, Not Normalized	Wt. %, Normalized		
207									
208	O		4.4519E+01	4.4770E+01	Ml	7.5078E-01	7.3490E-01		
209	U-234		3.2610E-04	3.2794E-04	Pb	6.0619E-02	6.0961E-02		
210	U-235		4.3270E-03	4.3514E-03	Bi	2.1785E+01	2.1888E+01		
211	U-236		1.0357E-03	1.0418E-03	Th	1.8455E-01	1.8569E-01		
212	U-238		1.8581E+00	1.8696E+00	Tl	6.8341E-01	6.8078E-01		
213	Pu-238		6.1528E-03	6.1819E-03	Zn	6.4274E-02	6.4636E-02		
214	Pu-239		1.2542E-02	1.2412E-02	B-10	6.8844E-01	6.9178E-01		
215	Pu-240		2.2648E-03	2.2773E-03	B-11	2.6042E+00	2.6189E+00		
216	Pu-241		6.6314E-04	6.6857E-04	U-6	9.8417E-02	9.9653E-02		
217	Pu-242		1.9061E-04	1.9188E-04	U-7	1.3726E+00	1.3804E+00		
218	Ce-133		4.0718E-02	4.0948E-02	F	3.1873E-02	3.1852E-02		
219	Ce-135		6.1328E-03	6.1615E-03	Cu	1.8178E-01	1.8264E-01		
220	Ba-137		1.1204E-01	1.1267E-01	Fe	7.3492E+00	7.3907E+00		
221	Al		2.3167E+00	2.3318E+00	K	2.6719E+00	2.6887E+00		
222	S		1.2673E-01	1.2945E-01	Mg	6.2013E-01	6.2475E-01		
223	Ca		6.5817E-01	6.6188E-01	Mn	1.8489E+00	1.8577E+00		
224	P		1.3960E-02	1.4059E-02	Na	8.6800E+00	8.6284E+00		
225	Cr		6.2104E-02	6.2367E-02	Cl	1.1328E-01	1.1361E-01		
226	Ag		6.0000E-02	6.0000E-02					
227									
228	Sub Col Total		4.9611E+01	5.0082E+01		4.9628E+01	4.9908E+01		
229	Total		8.9439E+01	1.0000E+02					
230	Other		6.0000E-01						
231	Check Total		1.0000E+02						
232			From elements					100	
233								From compounds	

A	B	C	D	E	F	G	H	I
Element/Compound	Atom Pts	Moles in Container (moles)	Masses of Pts. (in 100 g Glass)	Element Extra	Hydroxyl Content	Pt. % of Content		
4 Oxygen	16.0001							
5 U-234	234.040951	0.000	$-(C4)(1662/1000)(P100)$	-04.00	-0.00(0)	-04.00		
6 U-235	235.0439291	0.000	$-(C7)(1662/1000)(P100)$	-07.00	-0.00(0)	-07.00		
7 U-238	238.04558	0.000	$-(C2)(1662/1000)(P100)$	-02.00	-0.00(0)	-02.00		
8 U-236	236.043716	0.000	$-(C5)(1662/1000)(P100)$	-05.00	-0.00(0)	-05.00		
9 Total Uranium Mass		$-(C2)-(C4)-(C5)-(C7)(100)$	$-(C2)(1662/100)$			$-(C2)(1662/100)$		
10 Total Oxygen						$-(C4)-(C7)-(C5)-(C2)(100)$		
11 Total UO ₂			0.00					
12 Pu-239	239.04666	0.000	$-(C1)(1662/1000)(P100)$	-01.00	-0.00(0)	-01.00		
13 Pu-240	240.04740	0.000	$-(C1)(1662/1000)(P100)$	-01.00	-0.00(0)	-01.00		
14 Pu-241	241.04814	0.000	$-(C1)(1662/1000)(P100)$	-01.00	-0.00(0)	-01.00		
15 Pu-242	242.04888	0.000	$-(C1)(1662/1000)(P100)$	-01.00	-0.00(0)	-01.00		
16 Total Plutonium Mass		$-(C1)-(C1)-(C1)-(C1)(100)$	$-(C1)(1662/100)$			$-(C1)(1662/100)$		
17 Total Oxygen						$-(C1)(1662/100)-(C1)(1662/100)$		
18 PuO ₂			0.00					
19 Cs-133	133.00391	0.000	$-(C1)(1662/1000)(P100)$	-01.00	-0.00(0)	-01.00		
20 Cs-137	137.00521	0.000	$-(C1)(1662/1000)(P100)$	-01.00	-0.00(0)	-01.00		
21 Uranium Ox Total			$-(C2)(1662/100)-(C4)(1662/100)$					
22 Total O ₂			0.00					
23 Total O ₂			0.00					
24 Boron Oxide Mass		$-(C3)(1662/100)(P100)$	$-(C3)(1662/100)$					
25 Total Uranium Mass		$-(C2)-(C4)-(C5)-(C7)(100)$						
26 Cs-133	133.00391	0.000	$-(C1)(1662/1000)(P100)$	-01.00	-0.00(0)	-01.00		
27 Cs-137	137.00521	0.000	$-(C1)(1662/1000)(P100)$	-01.00	-0.00(0)	-01.00		
28 (Sum of Cs-133)								

32	Element/Compound Name	Atom %	Moles in Mixture (atoms)	Atom %	Compound M.L.	Moles	Weight of Element
33	Al ₂ O ₃	74.81154	=1.847462E+000	=0.0471857E+000			
34	Al						
35	O						
36	Total phosho						
37	Al ₂ O ₃						
38	Al	137.817					
39	O	137.817					
40	Total phosho						
41	CaO						
42	Ca	28.878					
43	O	57.756					
44	Total phosho						
45	CaO						
46	Ca	30.8782					
47	O	61.7564					
48	Total phosho						
49	CaO						
50	Ca	40.878					
51	O	81.756					
52	Total phosho						
53	CaO						
54	Ca	48.878					
55	O	97.756					
56	Total phosho						
57	CaO						
58	Ca	57.811					
59	O	115.622					
60	Total phosho						
61	CaO						
62	Ca	65.744					
63	O	131.488					
64	Total phosho						
65	CaO						
66	Ca	83.817					
67	O	167.634					
68	Total phosho						
69	CaO						
70	Ca	105.817					
71	O	211.634					
72	Total phosho						
73	CaO						
74	Ca	123.817					
75	O	247.634					
76	Total phosho						
77	CaO						
78	Ca	141.817					
79	O	283.634					
80	Total phosho						
81	CaO						
82	Ca	159.817					
83	O	319.634					
84	Total phosho						
85	CaO						
86	Ca	177.817					
87	O	355.634					
88	Total phosho						
89	CaO						
90	Ca	195.817					
91	O	391.634					
92	Total phosho						
93	CaO						
94	Ca	213.817					
95	O	427.634					
96	Total phosho						
97	CaO						
98	Ca	231.817					
99	O	463.634					
100	Total phosho						

Row	Chemical	Value	Formula	Formula	Formula	Formula	Formula
107	O	-24		-107.00071802^*1000			
108	Total phos				-30.07041077		-30.0704
109	Na ₂ O	22.349768	-11.174871000				
110	Na			-11.174871000^*1000			
111	O	-24		-11.174871000^*1000			
112	Total phos				-30.07041077		-30.07041077
113	Na ₂ O	22.349768	-11.174871000				
114	Na			-11.174871000^*1000			
115	O	-24		-11.174871000^*1000			
116	Total phos				-30.07041077		-30.07041077
117	Na ₂ O	22.349768	-11.174871000				
118	Na			-11.174871000^*1000			
119	O	-24		-11.174871000^*1000			
120	Total phos				-30.07041077		-30.07041077
121	Na ₂ O	22.349768	-11.174871000				
122	Na			-11.174871000^*1000			
123	O	-24		-11.174871000^*1000			
124	Total phos				-30.07041077		-30.07041077
125	Na ₂ O	22.349768	-11.174871000				
126	Na			-11.174871000^*1000			
127	O	-24		-11.174871000^*1000			
128	Total phos				-30.07041077		-30.07041077
129	Na ₂ O	22.349768	-11.174871000				
130	Na			-11.174871000^*1000			
131	O	-24		-11.174871000^*1000			
132	Total phos				-30.07041077		-30.07041077
133	Na ₂ O	22.349768	-11.174871000				
134	Na			-11.174871000^*1000			
135	O	-24		-11.174871000^*1000			
136	Total phos				-30.07041077		-30.07041077
137	Na ₂ O	22.349768	-11.174871000				
138	Na			-11.174871000^*1000			
139	O	-24		-11.174871000^*1000			
140	Total phos				-30.07041077		-30.07041077
141	Na ₂ O	22.349768	-11.174871000				
142	Na			-11.174871000^*1000			
143	O	-24		-11.174871000^*1000			
144	Total phos				-30.07041077		-30.07041077
145	Na ₂ O	22.349768	-11.174871000				
146	Na			-11.174871000^*1000			
147	O	-24		-11.174871000^*1000			
148	Total phos				-30.07041077		-30.07041077
149	Na ₂ O	22.349768	-11.174871000				
150	Na			-11.174871000^*1000			
151	O	-24		-11.174871000^*1000			
152	Total phos				-30.07041077		-30.07041077
153	Na ₂ O	22.349768	-11.174871000				
154	Na			-11.174871000^*1000			
155	O	-24		-11.174871000^*1000			
156	Total phos				-30.07041077		-30.07041077
157	Na ₂ O	22.349768	-11.174871000				
158	Na			-11.174871000^*1000			
159	O	-24		-11.174871000^*1000			
160	Total phos				-30.07041077		-30.07041077

A	B	C	D	E	F	G	H	I
Element/Compound	Atom Wt.	Molar Weight	Percent B ₂ O ₃	Percent B ₂ O ₃	Moles of Oxygen	Moles of Oxygen	Atoms	Equivalent Weight
110								
111	B ₂ O ₃	101.118	100	100	3	3	1	101.118
112	B	10.811	100	100	1.5	1.5	1	7.207
113	B ₂ O ₃ (base metal)	101.118	100	100	3	3	1	101.118
114	B ₂ O ₃ (base metal)	101.118	100	100	3	3	1	101.118
115	B	10.811	100	100	1.5	1.5	1	7.207
116	Total Boron							
117	Li ₂ O	73.891	100	100	2	2	1	73.891
118	Li	6.941	100	100	1	1	1	6.941
119	Li ₂ O (base metal)	73.891	100	100	2	2	1	73.891
120	Li ₂ O (base metal)	73.891	100	100	2	2	1	73.891
121	Li	6.941	100	100	1	1	1	6.941
122	Total Lithium							
123	Ag	107.868						
124	Other							

Note: The value of 0.189 in the D₁₀ column is the atom percent abundance for B-10 which comes from the Chart of Nuclides (Ref. 2 in the Ref. Section of the main report). The same is true for the values of 0.801 (B-11), 0.075 (Li-6) and 0.825 (Li-7).

	A	B	C	D
171	SUMMARY			
172				
173	Element		H ₂ O, H ₂ O ₂ Normalized	H ₂ O, H ₂ O ₂ Normalized
174	O	=D16-D18-D21-D25-D26-D34-D41-D47-D53-D54-D55-D56-D57-D58-D59-D60-D61-D62-D63-D64-D65-D66-D67-D68-D69-D70-D71-D72-D73-D74-D75-D76-D77-D78-D79-D80-D81-D82-D83-D84-D85-D86-D87-D88-D89-D90-D91-D92-D93-D94-D95-D96-D97-D98-D99-D100-D101-D102-D103-D104-D105-D106-D107-D108-D109-D110-D111-D112-D113-D114-D115-D116-D117-D118-D119-D120-D121-D122-D123-D124-D125-D126-D127-D128-D129-D130-D131-D132-D133-D134-D135-D136-D137-D138-D139-D140-D141-D142-D143-D144-D145-D146-D147-D148-D149-D150-D151-D152-D153-D154-D155-D156-D157-D158-D159-D160-D161-D162-D163-D164-D165-D166-D167-D168-D169-D170-D171-D172-D173-D174-D175-D176-D177-D178-D179-D180-D181-D182-D183-D184-D185-D186-D187-D188-D189-D190-D191-D192-D193-D194-D195-D196-D197-D198-D199-D200-D201-D202-D203-D204-D205-D206-D207-D208-D209-D210-D211-D212-D213-D214-D215-D216-D217-D218-D219-D220-D221-D222-D223-D224-D225-D226-D227-D228-D229-D230-D231-D232-D233-D234-D235-D236-D237-D238-D239-D240-D241-D242-D243-D244-D245-D246-D247-D248-D249-D250-D251-D252-D253-D254-D255-D256-D257-D258-D259-D260-D261-D262-D263-D264-D265-D266-D267-D268-D269-D270-D271-D272-D273-D274-D275-D276-D277-D278-D279-D280-D281-D282-D283-D284-D285-D286-D287-D288-D289-D290-D291-D292-D293-D294-D295-D296-D297-D298-D299-D300-D301-D302-D303-D304-D305-D306-D307-D308-D309-D310-D311-D312-D313-D314-D315-D316-D317-D318-D319-D320-D321-D322-D323-D324-D325-D326-D327-D328-D329-D330-D331-D332-D333-D334-D335-D336-D337-D338-D339-D340-D341-D342-D343-D344-D345-D346-D347-D348-D349-D350-D351-D352-D353-D354-D355-D356-D357-D358-D359-D360-D361-D362-D363-D364-D365-D366-D367-D368-D369-D370-D371-D372-D373-D374-D375-D376-D377-D378-D379-D380-D381-D382-D383-D384-D385-D386-D387-D388-D389-D390-D391-D392-D393-D394-D395-D396-D397-D398-D399-D400-D401-D402-D403-D404-D405-D406-D407-D408-D409-D410-D411-D412-D413-D414-D415-D416-D417-D418-D419-D420-D421-D422-D423-D424-D425-D426-D427-D428-D429-D430-D431-D432-D433-D434-D435-D436-D437-D438-D439-D440-D441-D442-D443-D444-D445-D446-D447-D448-D449-D450-D451-D452-D453-D454-D455-D456-D457-D458-D459-D460-D461-D462-D463-D464-D465-D466-D467-D468-D469-D470-D471-D472-D473-D474-D475-D476-D477-D478-D479-D480-D481-D482-D483-D484-D485-D486-D487-D488-D489-D490-D491-D492-D493-D494-D495-D496-D497-D498-D499-D500-D501-D502-D503-D504-D505-D506-D507-D508-D509-D510-D511-D512-D513-D514-D515-D516-D517-D518-D519-D520-D521-D522-D523-D524-D525-D526-D527-D528-D529-D530-D531-D532-D533-D534-D535-D536-D537-D538-D539-D540-D541-D542-D543-D544-D545-D546-D547-D548-D549-D550-D551-D552-D553-D554-D555-D556-D557-D558-D559-D560-D561-D562-D563-D564-D565-D566-D567-D568-D569-D570-D571-D572-D573-D574-D575-D576-D577-D578-D579-D580-D581-D582-D583-D584-D585-D586-D587-D588-D589-D590-D591-D592-D593-D594-D595-D596-D597-D598-D599-D600-D601-D602-D603-D604-D605-D606-D607-D608-D609-D610-D611-D612-D613-D614-D615-D616-D617-D618-D619-D620-D621-D622-D623-D624-D625-D626-D627-D628-D629-D630-D631-D632-D633-D634-D635-D636-D637-D638-D639-D640-D641-D642-D643-D644-D645-D646-D647-D648-D649-D650-D651-D652-D653-D654-D655-D656-D657-D658-D659-D660-D661-D662-D663-D664-D665-D666-D667-D668-D669-D670-D671-D672-D673-D674-D675-D676-D677-D678-D679-D680-D681-D682-D683-D684-D685-D686-D687-D688-D689-D690-D691-D692-D693-D694-D695-D696-D697-D698-D699-D700-D701-D702-D703-D704-D705-D706-D707-D708-D709-D710-D711-D712-D713-D714-D715-D716-D717-D718-D719-D720-D721-D722-D723-D724-D725-D726-D727-D728-D729-D730-D731-D732-D733-D734-D735-D736-D737-D738-D739-D740-D741-D742-D743-D744-D745-D746-D747-D748-D749-D750-D751-D752-D753-D754-D755-D756-D757-D758-D759-D760-D761-D762-D763-D764-D765-D766-D767-D768-D769-D770-D771-D772-D773-D774-D775-D776-D777-D778-D779-D780-D781-D782-D783-D784-D785-D786-D787-D788-D789-D790-D791-D792-D793-D794-D795-D796-D797-D798-D799-D800-D801-D802-D803-D804-D805-D806-D807-D808-D809-D810-D811-D812-D813-D814-D815-D816-D817-D818-D819-D820-D821-D822-D823-D824-D825-D826-D827-D828-D829-D830-D831-D832-D833-D834-D835-D836-D837-D838-D839-D840-D841-D842-D843-D844-D845-D846-D847-D848-D849-D850-D851-D852-D853-D854-D855-D856-D857-D858-D859-D860-D861-D862-D863-D864-D865-D866-D867-D868-D869-D870-D871-D872-D873-D874-D875-D876-D877-D878-D879-D880-D881-D882-D883-D884-D885-D886-D887-D888-D889-D890-D891-D892-D893-D894-D895-D896-D897-D898-D899-D900-D901-D902-D903-D904-D905-D906-D907-D908-D909-D910-D911-D912-D913-D914-D915-D916-D917-D918-D919-D920-D921-D922-D923-D924-D925-D926-D927-D928-D929-D930-D931-D932-D933-D934-D935-D936-D937-D938-D939-D940-D941-D942-D943-D944-D945-D946-D947-D948-D949-D950-D951-D952-D953-D954-D955-D956-D957-D958-D959-D960-D961-D962-D963-D964-D965-D966-D967-D968-D969-D970-D971-D972-D973-D974-D975-D976-D977-D978-D979-D980-D981-D982-D983-D984-D985-D986-D987-D988-D989-D990-D991-D992-D993-D994-D995-D996-D997-D998-D999-D1000		
175	U238	=D4		=C176AC318F100
176	U235	=D5		=C177AC318F100
177	U238	=D6		=C178AC318F100
178	U235	=D7		=C179AC318F100
179	P-234	=D8		=C180AC318F100
180	P-230	=D9		=C181AC318F100
181	P-230	=D10		=C182AC318F100
182	P-230	=D11		=C183AC318F100
183	P-231	=D12		=C184AC318F100
184	P-232	=D13		=C185AC318F100
185	Co-136	=D14		=C186AC318F100
186	Co-136	=D15		=C187AC318F100
187	Co-137	=D16-D18		=C188AC318F100
188	Al	=D19-D121		=C189AC318F100
189	B	=D40-D47-D105-D124		=C190AC318F100
190	Ca	=D48-D51-D56		=C191AC318F100
191	P	=D52		=C192AC318F100
192	P	=D53		=C193AC318F100
193	Cr	=D54		=C194AC318F100
194	Zn	D55		=C195AC318F100
195	Mo Calc Yield	=B0AC178 C183		=B0AC178 C183
196	Yield	=C195-D195		=D195-D195
197	Other	0.04		
198	Check Yield	=C184-D185-C197-B0AC183 C184-D18-H1E08-08		
199		From elements		
200				

	E	F	G	H
171				
172				
173	Element	Wt % Not Adjusted	Wt % Adjusted	
174				
175	N	=D118	=F1759C3189*100	
176	N	=D125	=F1769C3189*100	
177	O	=D126-D143	=F1779C3189*100	
178	Y	=D133	=F1789C3189*100	
179	Y	=D134	=F1799C3189*100	
180	Zr	=D142	=F1809C3189*100	
181	B-10	=D156	=F1819C3189*100	
182	B-11	=D167	=F1829C3189*100	
183	Li-6	=D163	=F1839C3189*100	
184	Li-7	=D164	=F1849C3189*100	
185	F	=D114	=F1859C3189*100	
186	Ca	=D67	=F1869C3189*100	
187	K	=D73-D77	=F1879C3189*100	
188	Mg	=D82	=F1889C3189*100	
189	Mn	=D87	=F1899C3189*100	
190	Na	=D92	=F1909C3189*100	
191	Na	=D87-D102-D106-D113-D143	=F1919C3189*100	
192	Cl	=D108	=F1929C3189*100	
193				
194		=SUM(F175:F182)	=SUM(G175:G182)	
195				
196				=H1-E104-SUM(E7:E12)-E16-E18-D18-D19
197				Fluor compounds
198				
199				
200				