U. S. NUCLEAR REGULATORY COMMISSION
REGION I

Enforcement Conference Report No. 030-06195/90-001

Docket No. 030-06195

License No. 37-08802-01 Priority 5 Category E Program Code 03620

Licensee: Rorer Group, Inc.
Pharmaceutical Research and Development Division
500 Virginia Drive
Fort Washington, Pennsylvania 19034

Facility Name: Rorer Group, Inc.

Enforcement Conference At: Region I, King of Prussia, Pennsylvania

Enforcement Conference Conducted: January 3, 1990

Inspectors:
Eric H. Reber, Health Physicist
2/1/90
date

John T. Jensen, Health Physicist
2/1/90
date

Approved by:
John D. Kinneman, Chief
Nuclear Materials Safety Section B
2/1/90
date

Enforcement Conference Summary: Enforcement Conference conducted in King of Prussia, Pennsylvania on January 3, 1990

The licensee's representatives discussed the corrective actions taken and planned as a result of the October 31 - November 1, 1989 inspection. The NRC representatives discussed their concern regarding weaknesses in the management control of the radiation safety program and outlined NRC's enforcement options.

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DETAILS

1. Persons Attending

Rorer Group, Inc.

Roger Meacham, Radiation Safety Officer
Ann Keklak, Radiation Safety Specialist
Peter Grebow, Vice President of Drug Development

Nuclear Regulatory Commission

Lee H. Bettenhausen, Chief, Nuclear Materials Safety Branch
John D. Kinneman, Chief, Nuclear Materials Safety Section B
Daniel J. Holody, Enforcement Officer
John T. Jensen, Health Physicist
Eric H. Reber, Health Physicist

2. Conference Summary

   a. Dr. Bettenhausen introduced the NRC staff and discussed the purpose of the Enforcement Conference.

   b. Mr. Jensen briefly discussed the apparent violations identified in the inspection report.

   c. The licensee's representatives agreed with the facts and the descriptions of the apparent violations in the inspection report.

   d. Ms. Keklak stated that, in response to the violation for failing to evaluate airborne concentrations of radioactive material, Rorer has purchased and recently received two air sampling pumps. They intend to use them to measure airborne iodine concentrations during, and for one hour following, all iodinations.

   e. NRC representatives expressed their concern that the licensee's survey activities and radiation safety records and documentation were not adequate to conclusively determine whether the two high whole body dosimeter readings represented actual exposures to the individual. The licensee representatives described their efforts to exert more control over their radiation safety program. They stated that by the end of February, 1990 they will take the following specific actions:

      i) change their personnel dosimetry vendor;

      ii) have the Radiation Safety Specialist (RSS) conduct monthly laboratory radiation surveys and inspections;

      iii) have the RSS conduct informal radiation safety training for current employees;

v) require employees to submit survey plans for their work areas for approval;

vi) require that employees record surveys of their work areas before and after handling radioisotopes;

vii) require that users sign surveys of their work areas;

viii) issue, "A Guide for the Radioisotope Laboratory Worker," which describes the workers' radiation safety responsibilities;

f. Licensee representatives supplied a copy of their new, "Guide for Radioisotope Laboratory Worker," (attached)

g. Mr. Kinneman asked whether the licensee had adequate personnel to administer the program. The licensee representatives stated that they were considering the need for additional personnel. Mr. Grebow said he expected that the company's use of radioactive material would grow much more slowly in the next few years.

h. Mr. Holody reviewed the NRC's enforcement options.

RORER CENTRAL RESEARCH

RADIATION AND RADIOACTIVITY

A GUIDE FOR THE RADIOISOTOPE LABORATORY WORKER

Prepared by: Ann M. Keklak
John C. Keklak, CHP

ENCL. (2)

Your Responsibilities As Radioisotope Workers

Your Responsibilities Include The Following:

YOU MUST

- Be familiar with the isotope(s) you are using; know their radiological, physical and chemical properties; methods of detection, types of hazards that each one presents, etc.
- Be fully knowledgeable of the specific precautions and handling requirements for each isotope you use and of the precautions to be followed with radioisotopes in general.
- Be familiar with the radiation safety rules and regulations instituted at Rorer.
- Inform co-workers and visitors to your isotope areas of the presence of radioactive material(s) and of any precautions that they should take.
- Label all radioactive materials/contaminated surfaces with appropriate stickers.
- Properly secure all radioactive storage items including rooms.
- Maintain inventory records including use, waste, disposal and decay.
- Know how to properly use your survey meter.
- Routinely monitor hands, shoes, clothing and work areas.
- Know how to use any personnel dosimetry devices issued to you.

Radiation and Radioactivity

A Guide for the Radioisotope Laboratory Worker

1. INTRODUCTION

The use of radiation and radiation producing devices has many benefits for man. Medical diagnosis and therapy, scientific research, and power production are the obvious areas in which these benefits may be gained. However, as with any other "tool", there are risks involved with the use of radionuclides or more specifically, ionizing radiation. The goal of Rorer's radiation safety program is to allow you as an employee of Rorer to gain benefits for yourself (e.g. your salary) and for others (e.g. research results) with a minimum of risk (i.e. exposure to radiation).

Various Federal and State regulations, Rorer's radioactive materials license conditions, and common sense dictate that only persons who are adequately trained may handle radioisotopes. At the time of hire or at the time it becomes evident that you will be routinely working with radioisotopes, you will be required to complete a number of forms detailing your previous training and experience.

In order to meet the training responsibility, Rorer will provide a variety of training programs including regular radiation safety orientation lectures; written instructions for ordering, receiving, handling, and disposing of radioisotopes; instructions and protocols for all the radiation monitoring programs; and booklets, pamphlets, and other handout material dealing with radiation safety and related topics. A Guide For The Radioisotope Laboratory Worker is one such booklet and is designed to provide you with a basic knowledge of radiation and radiation protection so that you can work as safely as possible. An attempt has been made to answer the most common questions and to address those topics with which you should become familiar. It must be emphasized that this booklet does not have all the answers and must be used in conjunction with other training materials, reference books, and on-the-job training. Feel free to contact the radiation safety specialist (962-4116) at any time should you wish more information.

2. Types of Radiation

Radiation can be defined as energy which is transmitted in the form of a wave or energetic particle and includes such things as visible light, ultraviolet light, microwaves, radiowaves, laser light and infrared radiation. Although there are hazards associated with these forms of radiation, our chief concern from a health and safety standpoint is ionizing radiation. Ionizing radiation may be defined as radiation which has sufficient energy to break chemical bonds by "ionizing" atoms. More specifically, enough energy is imparted to an atom by either the photon or particle to knock an electron out of its orbit around the nucleus.

Ionizing radiation includes alpha particles, beta particles and electrons, protons, positrons, neutrons, gamma rays and x-rays. The types of radiations you will commonly encounter at Rorer are beta particles, gamma rays and x-rays.

Alpha particles are essentially helium nuclei and consist of 2 protons and 2 neutrons and thus carry 2 positive electrical charges. Alphas originate in the nucleus of some radioisotopes and usually have energies which range from 4 to 8 million electron volts (MeV). Alphas have very limited penetrating ability and can be stopped by a sheet of paper or the dead outer layer of skin and hence are not considered an external radiation hazard. However, since they are high energy, charged particles, they produce a very large number of ionizations along the short distance they travel. They can therefore be a very serious internal hazard. For example, consider the fact that radon daughters are regarded as a significant hazard to the lung and tracheobronchial region and are responsible for an estimated 5,000 to 20,000 lung cancer deaths annually.

Beta particles are essentially electrons which originate from the nucleus of certain radioactive isotopes and carry a single electrical charge. Betas are generally less energetic than alphas but some isotopes emit betas with maximum energies in the same region as alpha particles. Betas penetrate further through matter than alphas do and can therefore present an external hazard. Whether a beta emitting radioisotope presents an external hazard depends on the maximum energy of the beta emitted. For example, H-3, C-14, Ca-45, and S-35 emit relatively low energy betas and do not present much of an external hazard. However, P-32 emits betas up to 1.71 MeV and can present a significant external hazard. All beta emitters and more broadly, **ALL** radioisotopes do present an internal hazard and precautions against inhalation, absorption through skin or wounds, injection, or ingestion must be observed.

Gamma rays and x-rays are electromagnetic radiations which are essentially the same, differing only in that gamma rays originate in the nucleus of an atom whereas x-rays arise outside of the nucleus. Both can be considered "massless" quanta or packets of energy. They are similar to light photons but have greater energy and are invisible. Most gamma emitting nuclides emit photons with energy less than 2 MeV. Gamma and x-rays are very penetrating types of radiation and present the most serious external hazard, and one should take care to minimize external exposure, while also taking care to avoid internal contamination.

Bremsstrahlung is the name given to radiation produced when beta particles are absorbed in a medium. As the beta is slowed down, some of its energy is emitted as x-radiation. The intensity of this Bremsstrahlung increases with both the increasing energy of the beta and with increasing density of the absorbing medium. For "soft" beta emitters like S-35 the energy is low enough that the Bremsstrahlung produced is inconsequential. For isotopes like P-32, the Bremsstrahlung produced can present a more serious external hazard than the betas.

3. Units and Terms

The following is a partial listing of the most common radiation units and terms:

Activity: refers to the number of disintegrations per unit time, and not necessarily the number of particles given off per unit time by the radionuclide.

The unit of activity is the Curie (Ci)

1 Curie (Ci) = 2.2×10^{12} dpm or 3.7×10^{10} dps

1 millicurie(mCi) = 2.2×10^{9} dpm or 3.7×10^{7} dps

1 microcurie (uCi) = 2.2×10^{6} dpm or 3.7×10^{4} dps

In the International System of Units (SI), activity is given in Becquerels (Bq):

1 Bq = 1 dps

Exposure: expresses the amount of ionization/electrical charge produced by x or gamma radiation in a defined mass of air.

The unit of exposure is the Roentgen (R).

1 Roentgen (R) = 2.58×10^{-4} coulombs/kg air

1 R = 1 esu/cc of air at STP

There is no SI unit for exposure.

Absorbed Dose: describes the amount of energy imparted to matter by ionizing radiation. The absorbed dose in a region is determined by dividing the energy absorbed in the region by the mass of the matter in the region. A Roentgen of x or gamma radiation in the range of 0.1 to 3.0 MeV in air is 0.87 rad and in tissue is 0.96 rad. For this reason, we frequently regard the exposure in Roentgen as being approximately equal to the absorbed dose in rads.

1 rad = 100 ergs/gram

In SI units, the absorbed dose is given in Gray (Gy)

1 Gy = 100 rads

1 rad = 0.01 Gy

Dose Equivalent: The injury produced by a given type of ionization depends not only on the amount of energy imparted to matter but also on the type of particle imparting the energy. This is due to the fact that some particles produce greater effects than others for the same amount of imparted energy. Thus, to arrive at a dose equivalent in the unit of rem, one needs to multiply the absorbed dose (rads) by the appropriate quality factor and any other modifying factors.

1 rem = rads x QF x MF

In radiation protection, a general rule of thumb is that for x, gamma or beta radiation, a Roentgen is a rad is a rem.

In SI units:

100 rems = 1 Seivert (Sv)
1 rem = 0.01 Sv

Half Life: refers to the time it takes for half of a given sample of radioactive material to decay. The half life is an inherent characteristic of the radionuclide, and DOES NOT CHANGE REGARDLESS OF THE PHYSICAL OR

CHEMICAL environment of that the radionuclide happens to be in.

You can determine the activity of the radionuclide at any given time through this simple equation:

$$A_{(t)} = A_{(o)}\, e^{-(0.693\,(t)/T_{1/2})}$$

Where $A_{(t)}$ = activity at time t
$A_{(o)}$ = activity at time 0
t = time
$T_{1/2}$ = half life

When using the above formula, remember that the units of t and T1/2 must be the same; e.g. sec, min, hours, years, etc.

Similarly, the units of $A_{(o)}$ and $A_{(t)}$ must be in the same units; e.g. dpm, cpm, Ci, etc.

<u>Counting Efficiency</u>: is a measure of the detector's ability to identify and record a count when radiation is incident upon the detector. The counting efficiency will vary from detector to detector even though the detector is provided by the same manufacturer. When using a given detector, the counting efficiency will generally vary with the isotope being counted, the physical or chemical characteristics of the sample, the geometry of the counting set up, the condition of the detector's own components, etc.

The percent efficiency can be determined from the formula:

$$\text{Efficiency (\%)} = \frac{\text{Standard count rate (cpm)}}{\text{Standard decay rate (dpm)}} \times 100$$

When you are determining the counting efficiency of your detector, you will want to count the standard under the same conditions you will be counting your sample. In many cases, it will be impractical to count a standard of the isotope with which you are working. In these cases, you will need to count a "mock" standard. A proper mock standard should mimic, as close as possible, the radiation emission of the radionuclide of interest. For example, it is often impractical to keep an NBS traceable I-125 standard on hand. A suitable mock standard would be I-129 as their energies are comparable.

A detector's efficiency is frequently variable and may change from day to day. If the work you are performing requires the activity to be recorded (e.g. dpm or uCi), you must determine the efficiency at that time. Contact the radiation safety specialist if you need assistance in determining your counter's efficiency.

BIOLOGICAL EFFECTS OF IONIZING RADIATION

Since ionizing radiation can break chemical bonds, it has the potential for damaging cells and cell molecules such as the DNA. All biological effects can be broken down into two major divisions - somatic effects (those affecting the individual irradiated); and genetic effects (affecting future generations). The somatic effects may be further subdivided into short term and long term effects. Short term effects include erythema or radiodermatitis, epilation (hair loss), hematological changes, and acute radiation syndrome. These short term or prompt effects generally result from large, acutely delivered doses such as 100 rem or more in a few hours. Long term or delayed effects include an increased risk of cancer or cataracts, embryological effects, and a general shortening of life span. Genetic effects refer to the build up of deleterious genes in the population as a result of exposure of the public to radiation. It should be pointed out that current radiation protection philosophy dictates that any exposure to radiation, no matter how small, has some degree of risk associated with the exposure. This risk may be so infinitesimal as to be indistinguishable from the natural occurrence of any given effect (see Cancer and Other Health Risks). Table I is included to demonstrate some biological effects and the approximates doses at which these effects occur.

RISK TO THE EMBRYO OR FETUS

These are effects that may be observed in children who were exposed during fetal and embryonic stages of development. These may include birth defects (teratogenic effects) such as damage to the nervous system. Birth defects of this nature are associated with doses of radiation above 10 rem (acute exposure to embryo or fetus). Leukemia and other cancers may also occur. The risk of additional cases of leukemia during the first 10 years of life is estimated at about 2 in 10,000 per rem of exposure before birth. The National Council on Radiation Protection and Measurement (NCRP) recommends that the developing fetus should not receive a radiation dose from occupational exposure of the mother of more than 0.5 rem during the gestation period. For more information, see Regulatory Guide 8.13 (US Nuclear Regulatory Commission), available from the Radiation Safety Specialist. Pregnant and potentially pregnant women may wish to schedule a one-to-one session with the RSO for more detailed instructions/information on this topic.

TABLE I

SIGNIFICANCE OF EXTERNAL RADIATION LEVELS

EXPOSURE	SIGNIFICANCE
22 mR/calendar quarter, continuous whole body (0.011 mR/hr)	Background radiation, sea level, out of doors, New York City
41 mR/calendar quarter, continuous whole body	Background radiation altitude of 10,000 ft (ground level)
34 mR/calendar quarter, continuous whole body	Radiation measured inside brick building at sea level
Approximately 100 mrem/year whole body	Average per capita dose to U.S. population, natural background level
Approximately 90 mrem/year whole body	Average per capita dose to US population from medical x-rays an nuclear medicine studies
<1 mrem/year	Average per capita dose to U.S. population from nuclear power
Approximately 1 mrem/year	Consumer products
Approximately 8000 mrad/yr, local, to bronchus	Estimated dose from radioisotopes in cigarette smoke, 3 packs a day
1,250 mrem/quarter	Regulatory limit for occupational exposure of whole body (critical organs are gonads, lens of eye, bone marrow)
18,750 mrem/quarter	Regulatory limit for occupational exposure of hands
125 mrem/quarter	Regulatory limit for non-occupational exposures (including exposure of minors)
15,000 mrem/year	Recommended single tissue or organ limit if not covered in separate recommendation
500 mrem/gestation period	Recommended limit for developing fetus.

CANCER AND OTHER HEALTH RISKS

(Adapted in large part from USNRC Regulatory Guide 8.29)

The cancer risk associated,ated presented in Table II were developed by the National Academy of Science Advisory Committee on the Biological Effects of Ionizing Radiation (BEIR), the International Commission on Radiological Protection (ICRP) and the United Nations Scientific Council on the Effects of Atomic Radiation (UNSCEAR).

It is important to realize that these risk numbers are only estimates. Many difficulties are involved in designating research studies that can accurately measure the small increases in cancer incidences due to exposure to radiation as compared to the normal rate of cancer. There is still uncertainty and a great deal of controversy with regard to estimates of radiation risk. The numbers used here result from studies involving high doses and high dose rates, and they may not apply to doses ar the lower occupational levels of exposure. They are based on a simple linear extrapolation from available data for high doses received over short periods to low doses received over long time periods. In other words, these estimates assume that the risk per unit rem dose as determined for high, short terms doses will be the same at low, occupational dose levels. Furthermore, these estimates also assume that there is no threshold of radiation exposure below which there is no health risk. The Nuclear Regulatory Commission (NRC) and other agencies both in the United States and abroad are continuing extensive long-range research programs in the field of radiation risk assessment.

Some members of the National Academy of Sciences BEIR Advisory Committee and others feel that the risk estimates presented in Table II are higher than would actually occur and represent an upper limit on the risk. Other scientists believe that the estimates are low and that the risks could be higher. However, these estimates are considered by the NRC staff to be the best available that the worker can use to make an informed decision concerning acceptance of the risks associated with exposure to radiation. A worker who decides to accept this risk should make every effort to keep exposure to radiation As Low As Reasonably Achievable (ALARA) to avoid unnecessary risk. The worker, after all, has the first line of responsibility for protecting himself/herself from radiation hazards!

In an effort to explain the significance of these estimates in Table II we will use an approximate average of 300 excess cancer deaths per million people, each exposed to 1 rem of ionizing radiation. Using the linear, nonthreshold (hypothesis) risk model discussed above, of on a group of 10,000 workers each receives 1 rem, we could estimate that three would

TABLE II

Estimates of Excess Cancer Incidence from Exposure to Low-Level Radiation

Source	Number of Additional[a] Cancers Estimated to Occur in 1 Million People After Exposure of Each to 1 Rem of Radiation
BEIR, 1980	160-450[b]
ICRP, 1977	200
UNSCEAR, 1977	150-350

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[a] Additional means above the normal incidence of cancer.

[b] All three groups estimated premature deaths from radiation-induced cancers. The American Cancer Society has recently stated that only about one-half of all cancer cases are fatal. Thus, to estimate incidence of cancer, the published numbers were multiplied by 2. Note that the three groups are in close agreement on the risk of radiation-induced cancer.

develop cancer because of that exposure, although the actual number could be more or less than three.

The American Cancer Society has reported that approximately 25 percent of all adults in the 20 to 65 year age bracket will develop cancer at some time from all possible causes such as smoking, food, alcohol, drugs, air pollutants, and natural background radiation. Thus, in any group of 10,000 workers not exposed to radiation on the job we can expects about 2,500 to develop cancer. Again, using a *linear* extrapolation of risk from high dose data, if this entire group of 10,000 workers were to receive an occupational radiation dose of 1 rem each, we could estimate that three additional cancers might occur, which would give a total number of about 2,503. This means that a 1 rem dose to each of 10,000 workers might increase the cancer rate from 25 percent to 25.03 percent, an increase of about 3 hundredths of one percent.

Perhaps the most useful unit for comparison among health risks is the average number of days of life expectancy lost per unit of exposure to each particular health risk. Estimates are calculated by looking at a large number of persons, recording the age when death occurs from apparent causes, and estimating the number of days of life lost as a result of these early deaths. The total number of days of life lost is then averaged over the total group observed.

Several studies have compared the projected loss of life expectancy resulting from exposure to radiation with other health risks. Some represantative numbers are presented in Table III.

TABLE III

ESTIMATED LOSS OF LIFE EXPECTANCY FROM HEALTH RISKS[A]

HEALTH RISK	ESTIMATES OF DAYS OF LIFE EXPECTANCY LOST, AVERAGE
SMOKING 20 CIGARETTES/DAY	2370 (6.5 YEARS)
OVERWEIGHT (BY 20%)	985 (2.7 YEARS)
ALL ACCIDENTS COMBINED	435 (1.2 YEARS)
AUTO ACCIDENTS	200
ALCOHOL CONSUMPTION (U.S. AVERAGE)	130
HOME ACCIDENTS	95
DROWNING	41
NATURAL BACKGROUND RADIATION CALCULATED	8
MEDICAL DIAGNOSTIC X-RAYS (U.S. AVERAGE), CALCULATED	6
ALL CATASTROPHES (EARTHQUAKE, ETC.)	3.5
1 REM OCCUPATIONAL RADIATION DOSE, CALCULATED (INDUSTRY AVERAGE FOR THE HIGHER-DOSE JOB CATEGORIES IS 0.65 REM/YR)	1
1 REM/YR FOR 30 YEARS, CALCULATED	30

[A] ADAPTED FROM COHEN AND LEE, "A CATALOGUE OF RISKS," HEALTH PHYSICS, VOL. 36, JUNE 1979.

These estimates indicate that the health risks from occupational radiation exposures are smaller than the risks associated with many other events or activities we encounter and accept in normal day to day activities.

A second useful comparison is to look at estimates of the average number of days of life expectancy lost from exposure to radiation and from common industrial accidents at radiation-related facilities and to compare this number with days lost from other occupational accidents. Table IV shows average days of life expectancy lost as a result of fatal work related accidents. Note that the data for occupations other than radiation related do not include death risks from other possible hazards such as exposure to toxic chemicals, dusts, or unusual temperatures. Note also that the unlikely occupational exposure at 5 rems per year for 50 years, the maximum allowable risk level, may result in a risk comparable to the average risk in mining and heavy construction.

TABLE IV

ESTIMATED LOSS OF LIFE EXPECTANCY FROM INDUSTRIAL HAZARDS[A]

INDUSTRY TYPE	ESTIMATES OF DAYS OF LIFE EXPECTANCY LOST, AVERAGE
ALL INDUSTRY	74
TRADE	30
MANUFACTURING	43
SERVICE	47
GOVERNMENT	55
TRANSPORTATION AND UTILITIES	164
AGRICULTURE	277
CONSTRUCTION	302
MINING AND QUARRYING	328
RADIATION ACCIDENTS, DEATH FROM EXPOSURE	<1
RADIATION DOSE OF 0.65 REM/YR (INDUSTRY AVERAGE) FOR 50 YEARS CALCULATED	20
RADIATION DOSE OF 5 REMS/YR FOR 50 YEARS	250
INDUSTRIAL ACCIDENTS AT NUCLEAR FACILITIES (NONRADIATION)	58

[A] ADAPTED FROM COHEN AND LEE "A CATALOGUE OF RISK," HEALTH PHYSICS, VOL. 36, JUNE 1979; AND WORLD HEALTH ORGANIZATION, HEALTH IMPLICATIONS OF NUCLEAR POWER PRODUCTION, DECEMBER 1975.

LIMITS AND ALARA

Dose limits are designed in principle to keep radiation exposures at a point where the incurred risks are deemed to be "acceptable" by the exposed individual and/or society.

Occupational limits are based to a large extent on this idea of "acceptable risk". Theoretically, an employee may work all his/her working life around radiation at the maximum limits and incur health risks no greater than incurred in many other occupations. At the same time, both the worker and society gain benefits from the use of radiation. However, since it is prudent to assume that there is some risk associated with any exposure to radiation, it is the goal of Radiation Safety to keep exposures as low as reasonably achievable (ALARA), and any reasonable steps which will lower personnel exposure should be taken. If you work safely it is unlikely that you will reach even 10% of the maximum dose limits. Here at Rorer, radioisotope research workers generally receive less than 30 mrem per year to the whole body, and most such workers seldom, if ever, receive any measurable occupational exposure above that due to natural background radiation. Table V lists some external exposure limits along with certain other external radiation levels and their significance.

TABLE V. Summary of the Biological Significance of Various Exposures

EXPOSURE	SIGNIFICANCE
1 rad, major portion of bone marrow	Risk of occurrence of leukemia is about 1 in 50,000
1 rad, whole body	Risk of eventual appearance of cancer about 2-4 in 10,000 (normal incidence from all causes is about 1 in 4)
10 rem, whole body	Elevated number of chromosome aberrations in peripheral blood; no detectable injury or symptoms
33 rad, reproductive system	Dose for doubling spontaneous mutations (lowest of proposed values)
1 rad, reproductive system, prior to conception	About 5-75 additional genetic disorders per million live births normal incidence of serious genetic disorders from all causes is 30,000 per million live births
[illegible] rem, single dose, whole body	Mild radiation sickness
[illegible] rem, single dose, whole body	Approximately 50% of exposed individuals will not survive even with best care
200-300 rad, locally to skin	Erythema
>300 rad, locally to skin	Radiation dermatitis and erythema
1000-2000 rads to skin	Transdermal injury.
>2000 rad to skin	Radionecrosis
200-500 rad, locally to eye, single exposure	Threshold dose, cataract induction (after latent period)
1000-2500 rad, local, at 200-300 rad/da	Treatment of markedly radiosensitive cancer
2500-5000 rad, local, at 200-300 rad/da	Treatment of a moderately radiosensitive cancer

PRINCIPLES OF RADIATION PROTECTION

There are several principles which you should keep in mind in order to work with radionuclides. These include: time, distance, shielding, and containment.

TIME: The best way to avoid unnecessary exposure is to simply spend as little time as possible in the radiation area. Try to do your work with radioactive materials in the minimum time necessary to do the job properly. Preliminary trials and "mock runs" WITHOUT using actual radionuclides can help in this regard.

DISTANCE: The radiation intensity from a point source varies inversely with the square of the distance from the point source; hence, **"THE INVERSE SQUARE LAW"**:

$$\frac{I_1}{I_2} = \frac{(d_2)^2}{(d_1)^2}$$

where I_1, is the intensity at distance d_1 from the source and I_2 is the intensity at distance d_2 from the source.

In other words, doubling the distance between you and a point source of radiation decreases your exposure by a factor of 4 for a given length of time. Conversely, halving the distance quadruples your exposure. As a practical example, assume that using a pair of tongs allows you to keep a vial of radioactive material 16 cm away from your fingers. At this distance the exposure rate is 8 mR/hr. Assume that you do not use tongs and pick up the vial with your fingers (the source inside the vial is 1 cm from your fingers). The exposure rate to your fingers will be approximately:

$$I(1\text{ cm}) = \frac{(16)^2 \times (8)}{(1)^2} = 2{,}048\text{ mR/hr}$$

This is a factor of 256 times the radiation received when the vial is handled with tongs. To put this exposure in perspective, this is the dose you would expect from a mCi of I-131.

REMEMBER:

1) Maintain as great a distance as possible between you and radiation sources which are external radiation hazards (e.g. energetic betas, gammas, and x-rays).

2) Don't pick up unshielded or inadequately shielded sources with your fingers. Use tongs or forceps whenever possible; it does make a difference!

SHIELDING: A third way to reduce exposure is to use shielding. For low energy beta emitting radionuclides, shielding is unnecessary. Very few betas would penetrate the dead outer layer of skin. For gamma radiation, high density material such as lead generally provides the best shielding choice in the laboratory. The thickness required depends on the energy of the emitted photons and the amount (activity) of the material to be shielded. Very little lead is needed for a "soft" (i.e. low energy) x-ray or gamma emitter like I-125; in fact, less than 1 mm of lead will absorb virtually all the photons. In the lab, you usually don't have to calculate how much shielding you'll need--just add increasing thicknesses around your source and measure its effectiveness with a radiation survey meter. If the exposure rate is reduced to an acceptable level then you have enough shielding.

As noted earlier in this manual, the high energy betas (such as P-32) have a tendency to interact with dense absorbers to produce Bremsstrahlung. For this reason, it is good health physics to shield P-32 first with a low density material such as plexiglass (about 8 mm will suffice) to stop all the betas. One should then shield the plexiglass with a high density material such as lead to absorb the Bremsstrahlung produced in the plexiglass.

When relying on shielding, be sure that it is both adequate and appropriate. Do not hesitate to consult with the RSO regarding shielding requirements for your lab.

Containment: In order to minimize the chance of ingestion, inhalation, or absorption of radionuclides in the body, every effort must be made to confine and limit radioactive contamination. There should be designated radioisotope work and storage areas. Containers should be sealed whenever possible. Any vial, test tube, etc., which contains radioactivity and which will not remain under your immediate control MUST be labeled as radioactive. Work areas should be covered with plastic backed absorbent material. Wear lab coats and gloves to keep contamination off street clothes and skin. Keep your lab coat buttoned. Each radioisotope laboratory should conduct its own radiation safety program, in addition to surveys done by the Radiation Safety personnel. Should a radioactive spill occur, care should be taken to confine the radioactivity to the area of the original spill. Radioisotopes which are part of volatile compounds, or which may break down to volatile compounds, must be stored in properly functioning fume hoods.

SUMMARY

Radionuclides can and are being used at Rorer with a minimum of risk to personnel and the public. Maintaining this safety program depends first and foremost on each individual who handles radioactive material. That person must appreciate the hazards involved and treat radioactive material with the proper respect while also being fully aware that radionuclides used safely can be a valuable tool in research. This booklet is intended to provide some of the basic information needed by individuals working in radionuclide research laboratories. Keep in mind that radiation safety personnel are ALWAYS available to answer your questions or to address concerns regarding radiation protection matters or needs. During working hours you may contact the Radiation Safety Specialist at (x 4116), and during evening hours both the RSO and Radiation Safety Specialist can be reached by dialing the Security Department in your facility.

Appendix A

Isotope Specific Information

ISOTOPE SPECIFIC INFORMATION[1]

ISOTOPE	TYPE OF RADIATION	HALF LIFE	EXTERNAL HAZARD?	AIRBORNE[2] HAZARD?	FILM BADGE REQUIRED?	RING DOSIMETER REQUIRED?	SHIELDING MATERIAL	LAB SURVEY METER OF CHOICE	BIOA REQU
^{3}H	Soft β^-	12.35 y	No	HTO	No	No	N/A	None	Unin
^{14}C	Soft β^-	5,700 y	No	$^{14}CO_2$	No	No	N/A	Thin Window GM	N
^{32}P	β^- (high energy)	14.3 d	Yes	No	Yes	Yes	Plastic, Glass	GM, any type	N
^{35}S	Soft β^-	87.4 d	No	No	No	No	N/A	Thin Window GM	No
^{45}Ca	Soft β^-	163 d	No	No	No	No	N/A	Thin Window GM	No
^{51}Cr	γ	27.7 d	Yes	No	Yes	Maybe	Lead	GM	N
^{125}I	γ, x-ray (both low energy)	60.14 d	Minimal	Yes (I_2, NaI sol.)	Yes	Maybe	Thin Lead	Thin Window (NaI crystal) probe	Thyro
^{131}I	β^-, γ	8.04 d	Yes	Yes (I_2, NaI sol.)	Yes	Yes	Lead	GM	Th

Notes: 1. This table is intended as a quick reference guide only and the information provided may be incomplete for many situations. For example, in most radioimmunoassay work, less stringent requirements than those implied above m be allowed due to the low activity levels used.

2. Any isotope may be a potential airborne hazard as fumes, dust, mist, or as part of a volatile compound. This column identifies the most common forms of either the contaminent or the material from which a contaminent will likely arise in the research laboratory.

Appendix B

Radiological Data For Isotopes Commonly Used In Research Laboratories

RADIOLOGICAL DATA FOR ^3H

Half Life	Radiation Type	Energy (MeV)	Intensity(% per disintegration)	Range in Air	Range in Tissue
12.35 yr	β -	max 0.01860 avg 0.00568	100	0.45 cm	0.006 cm

Maximum Permissible Body Burden..........	Critical Organ
2000 uCi (HTO)	Total Body
1000 uCi (HTO)	Body Tissue

Radiation Precautions: No external hazard; shielding not required; film badge not required.

Tritiated compounds can be a serious internal radiation hazard. Tritiated nucleic acids and nucleic acid precursors are generally considered to be a more serious internal radiation hazard than other chemical forms.

Precautions should be taken against ingestion, inhalation, accidental injection, or absorption through the skin. (e.g. Use protective clothing and absorbent material on work surfaces, no mouth pipetting, etc.) Urinalysis is required for persons handling more than 10 mCi of ^3H either per container or at any one time. Contact the Office of Radiation Safety, Ext. 7813 for instructions. Tritiated water vapor (HTO or ^3H_2O) is a common possible airborne hazard. In addition to being used directly in this form, HTO may also be a byproduct of experimental reaction(s) or of the breakdown of other compounds. Tritiated sodium borohydride ($NaBH_4[^3H]$) is an example of a compound whose use usually results in airborne release of HTO vapor. Contact the Radiation Safety Office for possible air monitoring. Maximum permissible airborne concentration in a controlled area is 5.0 x 10-6 uCi/ml, averaged over 40 hr.

RADIOLOGICAL DATA FOR C-14

Half Life	Radiation Type	Energy (MeV)	Intensity (% per disintegration)	Range In Air	Range In Tissue
5730 years	β -	0.156 (max) 0.049 (avg)	100	28 cm	0.029

Maximum Permissible Body Burden..........	Critical Organ
300 uCi	Body Fat
400 uCi	Total Body

Radiation Precautions:

Negligible external hazard; shielding not required; film badge not required. The chief concern regarding ^{14}C is a potential internal radiation hazard. Precautions should be taken against ingestion, inhalation, accidental injection or absorption through broken skin. Use protective clothing and absorbent material on work surfaces, no pipetting by mouth, etc. ^{14}C may become airborne when used to study certain metabolic processes which result in the formation of $^{14}CO_2$. Any experimental procedures in which ^{14}C may attach to dusts, mists, etc. may also result in airborne ^{14}C. Use fume hoods or other local ventilation to control any such hazards. Maximum permissible airborne concentration of "soluble" ^{14}C in a controlled area is 4 x 10-6 uCi/ml, averaged over 40 hours. The MPCA40hrs for airborne $^{14}CO_2$ (based on "submersion" dose) is 5 x 10-5 uCi/ml.

ADIOLOGICAL DATA FOR P-32

Half Life	Radiation Type	Energy (MeV)	Intensity(% per disintegration)
14.3 da	β-	1.71 (max) 0.695 (avg)	100%

Maximum Permissible Body Burden..........	Critical Organ	Maximum Beta Range in Air	Tissue
6 uCi	Bone	635 cm	0.76 cm
30 uCi	Total Body		

Radiation Precautions:

32P poses a significant external radiation hazard. Dose rate at 1 foot from a 1 mCi unshielded point source is approximately 300 mrad/hr. 32P betas are also energetic enough to cause significant x-ray production when being stopped in an absorbing medium. (This type of x-radiation is called Bremsstrahlung.) Use low density material to shield the betas (8 mm of plexiglass or equivalent will stop all the betas). If necessary, high density shielding (e.g. lead) may then be used to shield any Bremsstrahlung arising in the low density beta shield. Minimize time of exposure and maximize distance from source to further decrease your dose. Dose to the hands and fingers may be especially significant if proper precautions are not taken. As with all isotopes, take precautions against ingestion, inhalation, accidental ingestion, or absorption through broken skin. Use protective clothing and gloves, do not pipette by mouth, etc. Any experimental procedure in which 32P may become attached to dusts, mists, etc. may result in airborne 32P. Use fume hoods or other local ventilation to control such hazards. Maximum permissible airborne contamination for soluble 32P in a controlled area is 8x10-8 uCi/ml, averaged over 40 hours.

RADIOLOGICAL DATA FOR S-35

Half Life	Radiation Type	Energy (MeV)	Intensity (% per disintegration)	Range In Air	Tissue
87.4 days	β -	0.167 (max) 0.049 (avg)	100	31 cm	0.32 c

Maximum Permissible Body Burden..........	Critical Organ
90 uCi	Testis
400 uCi	Total Body

Radiation Precautions:

Negligible external hazard: shielding not required: film badge not required.
The chief concern regarding 32S is a potential internal radiation hazard. Precautions should be taken against ingestion, inhalation, accidental injection or absorption through broken skin. Use protective clothing and absorbent material on work surfaces, no pipetting by mouth, etc. Gases containing 35S (e.g. 35SO$_2$) may be formed during some chemical procedures and may pose an airborne hazard. Any experimental procedures in which 35S may attach to dusts, mists, etc. may also result in airborne 35S. Use fume hoods or other local ventilation to control any such hazards. Maximum permissible airborne concentration of 35S in a controlled area is 3 x 10-7 uCi/ml, averaged over 40 hours.

RADIOLOGICAL DATA FOR Ca-45

Half Life	Radiation Type	Energy (MeV)	Intensity (% per disintegration)	Range In Air	Range In Tis
163 days	β-	0.257 (max) 0.077 (avg)	100	53 cm	0.0.

Maximum Permissible Body Burden..........	Critical Organ
30 uCi	Bone

Radiation Precautions:

Negligible external hazard; shielding not required; film badge not required. The chief concern regarding Ca-45 is a potential internal radiation hazard. Precautions should be taken against ingestion, inhalation, accidental injection or absorbtion through broken skin. Use protective clothing and absorbent material on work surfaces, no pipetting by mouth, etc. Any experimental procedures in which ^{45}Ca may attach to dusts, mists etc. may result in airborne ^{45}Ca. Use fume hoods or other local ventilation to control any such hazards. Maximum permissible airborne concentration of ^{45}Ca in a controlled are is 3×10^{-8} uCi/ml, averaged over 40 hours.

RADIOLOGICAL DATA FOR Cr-51

Half Life	Radiation Type	Energy (MeV)	Intensity(% per disintegration)	Half Value Layer in Pb
27.7 da	γ	0.32	9.8	0.17 cm

Maximum Permissible Body Burden..........	Critical Organ
800 uCi	Lower large intestine
500 uCi	Total body

Radiation Precautions:

Moderate external hazard to whole body and extremities. Gamma dose rate from 1 mCi point source is 0.016 mR/hr at 1 meter or 160 mR/hr at 1 cm. Use lead shielding (1 cm of lead will reduce exposure rate by about 60X). Use remote handling tools for manipulating unshielded sources or containers. Film badges required, ring dosimeters required for persons handling mCi amounts. As with any radionuclide, take precautions against accidenta ingestion, injection, inhalation or absorption through broken skin (utilize contamination control measures, etc.) Any expermental procedure in which ^{51}Cr may attach to dusts, mists etc., may result in an airborne hazard. Use fume hoods or other local ventilation to control such hazards. Maximium permissible airborne concentration in a controlled area is x 10^{-5} uCi/ml, averaged over 40 hours.

RADIOLOGICAL DATA FOR I-125

Half Life	Radiation Type	Energy (MeV)	Intensity(% per disintegration)	Half Value Layer in Pb
60.14 da	X-rays	0.0272-0.0355	139.8	0.002 cm
	Y-rays	0.0355	6.7	

Maximum Permissible Body Burden..........	Critical Organ
4.00 uCi	Total Body
1.15 uCi	Thyroid

Radiation Precautions:

Generally low external hazard: chief concern is exposure of extremities and fingers while handling mCi quantities. Minimal lead shielding needed (0.02 cm of lead will reduce exposure rate by about 1000x). Film badge usually required. Ring dosimeter required for persons handling mCi amounts. Like all radioiodines, I-125 that enters the body concentrates in the thyroid gland. Precautions must be taken against ingestion, inhalation, and accidental injection. "Free" I-125 (I_2 or aqueous NaI) is easily absorbed through intact skin and can penetrate plastics. "Free" forms are easily volatilized, especially in acid solutions and present a serious airborne hazard. Use of "free" forms of I-125 must take place in a fume hood approved for this purpose by the Office of Radiation Safety. Externa thyroid counting is required for persons handling > 1 mCi of free I-125 and air sampling may be required during procedures involving free I-T25. Contact the Office of Radiation Safety for further details. Maximum permissible airborne concentration in a controlled area is 5 x 10-9 uCi/ml averaged over 40 hours.

RADIOLOGICAL DATA FOR I-131

Half Life: 8.04 da
Maximum Beta Range: in Tissue — 0.21 cm in Air — 165 cm
Half Value Layer (photons) in Lead: 2.4 cm
Gamma Dose Rates from 1 mCi Point Source: 0.21 mR/hr @ 1 meter
2,100 mR/hr @1 cm

Maximum permissible body burden	Critical Organ
0.14 uCi	Thyroid
50 uCi	Body

Radiation Type	Energy (MeV)	Intensity (% per disintegration)
beta$^-$	0.334 max	7.36
beta$^-$	0.606 max	89.4
3 Others emitted	0.806 max	—
Total (avg.)	0.182	100

Radiation Type	Energy (MeV)	Intensity (% per disintegration)
X-rays	0.295-0.336	4.81
gamma$_1$	0.080	2.62
gamma$_7$	0.284	6.06
gamma$_{14}$	0.364	81.2
gamma$_{17}$	0.637	7.27
gamma$_{19}$	0.723	1.80
14 others emitted		1.33

Radiation Precautions:

External hazard to whole body from gamma exposure and to skin from beta exposure. Use remote handling and/or lead shielding (1.0 cm of lead will reduce gamma exposure rate by about 15x). Film badge and ring dosimeters required. Like all radioiodines, I-131 that enters the body concentrates in the thyroid gland. Precautions must be taken against ingestion, inhalation, and accidental injection. "Free" I-131 (I_2 or aqueous NaI) is easil absorbed through intact skin and can penetrate plastics. "Free" forms are easily volatilized, especially in acid solutions and present a serious airborne hazard. Use of "free" forms of I-131 must take place in a fume hood approved for this purpose by the Office of Radiation Safety. External thyroid counting is required for persons handling > 1 mCi of free I-131 and air sampling may be required during procedures involving free I-T31. Contac the Office of Radiation Safety for further details. Maximum permissible airborne concentration in a controlled area is 9 x 10-9 uCi/ml, averaged over 40 hours.

RORER GROUP, INC.

GOOD SAFETY PRACTICES IN RADIOISOTOPE LABORATORIES

1. NEVER pipette by mouth.
2. No smoking or eating permitted in the work areas.
3. Do not apply cosmetics in radioisotope work areas.
4. Gloves and buttoned lab coats are required when using radioisotopes.
5. Prescribed personal monitors must be worn.
6. Hands, shoes, and clothing should be frequently monitored.
7. Radioisotope work should be conducted on a surface lined with absorbant paper.
8. Utilize shielding and maximize distance from a radiation source whenever possible.
9. Dispose of all radioactive waste in appropriate containers.
10. Refrigerators containing radioisotopes SHALL NOT be used for storing food.
11. Monitor radioisotope work areas routinely for contamination; identify (label) contaminated areas and alert supervisor/RSO for appropriate cleanup actions.
12. REPORT accidental ingestion, inhalation, injury or spills promptly to your supervisor and the RSO.
13. Maintain appropriate records of receipt, use, transfer and disposal of radioactive materials.
14. Bioassays--thyroid checks and/or urinalysis will be performed by the RSO or designee as indicated.
15. Assure compliance with State and Federal Regulations as well as Rorer's internal regulations.

IF YOU HAVE ANY QUESTIONS OR NEED ASSISTANCE, CONTACT THE RADIATION SAFETY SPECIALIST AT (x 4116).

RORER CENTRAL RESEARCH

RADIATION AND RADIOACTIVITY

A GUIDE FOR THE RADIOISOTOPE LABORATORY WORKER

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ENCL (2)

Your Responsibilities As Radioisotope Workers

Your Responsibilities Include The Following:

YOU MUST

- Be familiar with the isotope(s) you are using; know their radiological, physical and chemical properties; methods of detection, types of hazards that each one presents, etc.
- Be fully knowledgeable of the specific precautions and handling requirements for each isotope you use and of the precautions to be followed with radioisotopes in general.
- Be familiar with the radiation safety rules and regulations instituted at Rorer.
- Inform co-workers and visitors to your isotope areas of the presence of radioactive material(s) and of any precautions that they should take.
- Label all radioactive materials/contaminated surfaces with appropriate stickers.
- Properly secure all radioactive storage items including rooms.
- Maintain inventory records including use, waste, disposal and decay.
- Know how to properly use your survey meter.
- Routinely monitor hands, shoes, clothing and work areas.
- Know how to use any personnel dosimetry devices issued to you.

Radiation and Radioactivity

A Guide for the Radioisotope Laboratory Worker

1. INTRODUCTION

The use of radiation and radiation producing devices has many benefits for man. Medical diagnosis and therapy, scientific research, and power production are the obvious areas in which these benefits may be gained. However, as with any other "tool", there are risks involved with the use of radionuclides or more specifically, ionizing radiation. The goal of Rorer's radiation safety program is to allow you as an employee of Rorer to gain benefits for yourself (e.g. your salary) and for others (e.g. research results) with a minimum of risk (i.e. exposure to radiation).

Various Federal and State regulations, Rorer's radioactive materials license conditions, and common sense dictate that only persons who are adequately trained may handle radioisotopes. At the time of hire or at the time it becomes evident that you will be routinely working with radioisotopes, you will be required to complete a number of forms detailing your previous training and experience.

In order to meet the training responsibility, Rorer will provide a variety of training programs including regular radiation safety orientation lectures; written instructions for ordering, receiving, handling, and disposing of radioisotopes; instructions and protocols for all the radiation monitoring programs; and booklets, pamphlets, and other handout material dealing with radiation safety and related topics. A Guide For The Radioisotope Laboratory Worker is one such booklet and is designed to provide you with a basic knowledge of radiation and radiation protection so that you can work as safely as possible. An attempt has been made to answer the most common questions and to address those topics with which you should become familiar. It must be emphasized that this booklet does not have all the answers and must be used in conjunction with other training materials, reference books, and on-the-job training. Feel free to contact the radiation safety specialist (962-4116) at any time should you wish more information.

2. Types of Radiation

Radiation can be defined as energy which is transmitted in the form of a wave or energetic particle and includes such things as visible light, ultraviolet light, microwaves, radiowaves, laser light and infrared radiation. Although there are hazards associated with these forms of radiation, our chief concern from a health and safety standpoint is ionizing radiation. Ionizing radiation may be defined as radiation which has sufficient energy to break chemical bonds by "ionizing" atoms. More specifically, enough energy is imparted to an atom by either the photon or particle to knock an electron out of its orbit around the nucleus.

Ionizing radiation includes alpha particles, beta particles and electrons, protons, positrons, neutrons, gamma rays and x rays. The types of radiations you will commonly encounter at Rorer are beta particles, gamma rays and x-rays.

Alpha particles are essentially helium nuclei and consist of 2 protons and 2 neutrons and thus carry 2 positive electrical charges. Alphas originate in the nucleus of some radioisotopes and usually have energies which range from 4 to 8 million electron volts (MeV). Alphas have very limited penetrating ability and can be stopped by a sheet of paper or the dead outer layer of skin and hence are not considered an external radiation hazard. However, since they are high energy, charged particles, they produce a very large number of ionizations along the short distance they travel. They can therefore be a very serious internal hazard. For example, consider the fact that radon daughters are regarded as a significant hazard to the lung and tracheobronchial region and are responsible for an estimated 5,000 to 20,000 lung cancer deaths annually.

Beta particles are essentially electrons which originate from the nucleus of certain radioactive isotopes and carry a single electrical charge. Betas are generally less energetic than alphas but some isotopes emit betas with maximum energies in the same region as alpha particles. Betas penetrate further through matter than alphas do and can therefore present an external hazard. Whether a beta emitting radioisotope presents an external hazard depends on the maximum energy of the beta emitted. For example, H-3, C-14, Ca-45, and S-35 emit relatively low energy betas and do not present much of an external hazard. However, P-32 emits betas up to 1.71 MeV and can present a significant external hazard. All beta emitters and more broadly, **ALL** radioisotopes do present an internal hazard and precautions against inhalation, absorption through skin or wounds, injection, or ingestion must be observed.

Gamma rays and x-rays are electromagnetic radiations which are essentially the same, differing only in that gamma rays originate in the nucleus of an atom whereas x-rays arise outside of the nucleus. Both can be considered "massless" quanta or packets of energy. They are similar to light photons but have greater energy and are invisible. Most gamma emitting nuclides emit photons with energy less than 2 MeV. Gamma and x-rays are very penetrating types of radiation and present the most serious external hazard, and one should take care to minimize external exposure, while also taking care to avoid internal contamination.

Bremsstrahlung is the name given to radiation produced when beta particles are absorbed in a medium. As the beta is slowed down, some of its energy is emitted as x-radiation. The intensity of this Bremsstrahlung increases with both the increasing energy of the beta and with increasing density of the absorbing medium. For "soft" beta emitters like S-35 the energy is low enough that the Bremsstrahlung produced is inconsequential. For isotopes like P-32, the Bremsstrahlung produced can present a more serious external hazard than the betas.

3. Units and Terms

The following is a partial listing of the most common radiation units and terms:

Activity:	refers to the number of disintegrations per unit time, and not necessarily the number of particles given off per unit time by the radionuclide.

The unit of activity is the Curie (Ci)

1 Curie (Ci) = 2.2×10^{12} dpm or 3.7×10^{10} dps

1 millicurie(mCi) = 2.2×10^{9} dpm or 3.7×10^{7} dps

1 microcurie (uCi) = 2.2×10^{6} dpm or 3.7×10^{4} dps

In the International System of Units (SI), activity is given in Becquerels (Bq):

1 Bq = 1 dps

Exposure:	expresses the amount of ionization/electrical charge produced by x or gamma radiation in a defined mass of air.

The unit of exposure is the Roentgen (R).

1 Roentgen (R) = 2.58×10^{-4} coulombs/kg air

1 R = 1 esu/cc of air at STP

There is no SI unit for exposure.

Absorbed Dose: describes the amount of energy imparted to matter by ionizing radiation. The absorbed dose in a region is determined by dividing the energy absorbed in the region by the mass of the matter in the region. A Roentgen of x or gamma radiation in the range of 0.1 to 3.0 MeV in air is 0.87 rad and in tissue is 0.96 rad. For this reason, we frequently regard the exposure in roentgen as being approximately equal to the absorbed dose in rads.

1 rad = 100 ergs/gram

In SI units, the absorbed dose is given in Gray (Gy)

1 Gy = 100 rads

1 rad = 0.01 Gy

Dose Equivalent: The injury produced by a given type of ionization depends not only on the amount of energy imparted to matter but also on the type of particle imparting the energy. This is due to the fact that some particles produce greater effects than others for the same amount of imparted energy. Thus, to arrive at a dose equivalent in the unit of rem, one needs to multiply the absorbed dose (rads) by the appropriate quality factor and any other modifying factors.

1 rem = rads x QF x MF

In radiation protection, a general rule of thumb is that for x, gamma or beta radiation, a Roentgen is a rad is a rem.

In SI units:

100 rems = 1 Seivert (Sv)
1 rem = 0.01 Sv

Half Life: refers to the time it takes for half of a given sample of radioactive material to decay. The half life is an inherent characteristic of the radionuclide, and DOES NOT CHANGE REGARDLESS OF THE PHYSICAL OR

CHEMICAL environment of that the radionuclide happens to be in.

You can determine the activity of the radionuclide at any given time through this simple equation:

$$A(_t) = A(_o)\, e^{-[0.693\,(t)/T_{1/2}]}$$

Where $A(_t)$ = activity at time t
$A(_o)$ = activity at time 0
t = time
$T_{1/2}$ = half life

When using the above formula, remember that the units of t and T1/2 must be the same; e.g. sec, min, hours, years, etc.

Similarly, the units of $A(_o)$ and $A(_t)$ must be in the same units; e.g. dpm, cpm, Ci, etc.

Counting Efficiency: is a measure of the detector's ability to identify and record a count when radiation is incident upon the detector. The counting efficiency will vary from detector to detector even though the detector is provided by the same manufacturer. When using a given detector, the counting efficiency will generally vary with the isotope being counted, the physical or chemical characteristics of the sample, the geometry of the counting set up, the condition of the detector's own components, etc.

The percent efficiency can be determined from the formula:

$$\text{Efficiency (\%)} = \frac{\text{Standard count rate (cpm)}}{\text{Standard decay rate (dpm)}} \times 100$$

When you are determining the counting efficiency of your detector, you will want to count the standard under the same conditions you will be counting your sample. In many cases, it will be impractical to count a standard of the isotope with which you are working. In these cases, you will need to count a "mock" standard. A proper mock standard should mimic, as close as possible, the radiation emission of the radionuclide of interest. For example, it is often impractical to keep an NBS traceable I-125 standard on hand. A suitable mock standard would be I-129 as their energies are comparable.

A detector's efficiency is frequently variable and may change from day to day. If the work you are performing requires the **activity** to be recorded (e.g. dpm or uCi), you must determine the efficiency at that time. Contact the radiation safety specialist if you need assistance in determining your counter's efficiency.

BIOLOGICAL EFFECTS OF IONIZING RADIATION

Since ionizing radiation can break chemical bonds, it has the potential for damaging cells and cell molecules such as the DNA. All biological effects can be broken down into two major divisions - somatic effects (those affecting the individual irradiated); and genetic effects (affecting future generations). The somatic effects may be further subdivided into short term and long term effects. Short term effects include erythema or radiodermatitis, epilation (hair loss), hematological changes, and acute radiation syndrome. These short term or prompt effects generally result from large, acutely delivered doses such as 100 rem or more in a few hours. Long term or delayed effects include an increased risk of cancer or cataracts, embryological effects, and a general shortening of life span. Genetic effects refer to the build up of deleterious genes in the population as a result of exposure of the public to radiation. It should be pointed out that current radiation protection philosophy dictates that any exposure to radiation, no matter how small, has some degree of risk associated with the exposure. This risk may be so infinitesimal as to be indistinguishable from the natural occurrence of any given effect (see **Cancer and Other Health Risks**). Table I is included to demonstrate some biological effects and the approximates doses at which these effects occur.

RISK TO THE EMBRYO OR FETUS

These are effects that may be observed in children who were exposed during fetal and embryonic stages of development. These may include birth defects (teratogenic effects) such as damage to the nervous system. Birth defects of this nature are associated with doses of radiation above 10 rem (acute exposure to embryo or fetus). Leukemia and other cancers may also occur. The risk of additional cases of leukemia during the first 10 years of life is estimated at about 2 in 10,000 per rem of exposure before birth. The National Council on Radiation Protection and Measurement (NCRP) recommends that the developing fetus should not receive a radiation dose from occupational exposure of the mother of more than 0.5 rem during the gestation period. For more information, see Regulatory Guide 8.13 (US Nuclear Regulatory Commission), available from the Radiation Safety Specialist. Pregnant and potentially pregnant women may wish to schedule a one-to-one session with the RSO for more detailed instructions/information on this topic.

TABLE I

SIGNIFICANCE OF EXTERNAL RADIATION LEVELS

EXPOSURE	SIGNIFICANCE
22 mR/calendar quarter, continuous whole body (0.011 mR/hr)	Background radiation, sea level, out of doors, New York City
41 mR/calendar quarter, continuous whole body	Background radiation altitude of 10,000 ft (ground level)
34 mR/calendar quarter, continuous whole body	Radiation measured inside brick building at sea level
Approximately 100 mrem/year whole body	Average per capita dose to U.S. population, natural background level
Approximately 90 mrem/year whole body	Average per capita dose to US population from medical x-rays and nuclear medicine studies
<1 mrem/year	Average per capita dose to U.S. population from nuclear power
Approximately 1 mrem/year	Consumer products
Approximately 8000 mrad/yr, local, to bronchus	Estimated dose from radioisotopes in cigarette smoke, 3 packs a day
1,250 mrem/quarter	Regulatory limit for occupational exposure of whole body (critical organs are gonads, lens of eye, bone marrow)
18,750 mrem/quarter	Regulatory limit for occupational exposure of hands
125 mrem/quarter	Regulatory limit for non-occupational exposures (including exposure of minors)
15,000 mrem/year	Recommended single tissue or organ limit if not covered in separate recommendation
500 mrem/gestation period	Recommended limit for developing fetus.

CANCER AND OTHER HEALTH RISKS

(Adapted in large part from USNRC Regulatory Guide 8.29)

The cancer risk associated,ated presented in Table II were developed by the National Academy of Science Advisory Committee on the Biological Effects of Ionizing Radiation (BEIR), the International Commission on Radiological Protection (ICRP) and the United Nations Scientific Council on the Effects of Atomic Radiation (UNSCEAR).

It is important to realize that these risk numbers are only estimates. Many difficulties are involved in designating research studies that can accurately measure the small increases in cancer incidences due to exposure to radiation as compared to the normal rate of cancer. There is still uncertainty and a great deal of controversy with regard to estimates of radiation risk. The numbers used here result from studies involving high doses and high dose rates, and they may not apply to doses ar the lower occupational levels of exposure. They are based on a simple linear extrapolation from available data for high doses received over short periods to low doses received over long time periods. In other words, these estimates assume that the risk per unit rem dose as determined for high, short terms doses will be the same at low, occupational dose levels. Furthermore, these estimates also assume that there is no threshold of radiation exposure below which there is no health risk. The Nuclear Regulatory Commission (NRC) and other agencies both in the United States and abroad are continuing extensive long-range research programs in the field of radiation risk assessment.

Some members of the National Academy of Sciences BEIR Advisory Committee and others feel that the risk estimates presented in Table II are higher than would actually occur and represent an upper limit on the risk. Other scientists believe that the estimates are low and that the risks could be higher. However, these estimates are considered by the NRC staff to be the best available that the worker can use to make an informed decision concerning acceptance of the risks associated with exposure to radiation. A worker who decides to accept this risk should make every effort to keep exposure to radiation As Low As Reasonably Achievable (ALARA) to avoid unnecessary risk. The worker, after all, has the first line of responsibility for protecting himself/herself from radiation hazards!

In an effort to explain the significance of these estimates in Table II we will use an approximate average of 300 excess cancer deaths per million people, each exposed to 1 rem of ionizing radiation. Using the linear, nonthreshold (hypothesis) risk model discussed above, of on a group of 10,000 workers each receives 1 rem, we could estimate that three would

TABLE II

Estimates of Excess Cancer Incidence from Exposure to Low-Level Radiation

Source	Number of Additional[a] Cancers Estimated to Occur in 1 Million People After Exposure of Each to 1 Rem of Radiation
BEIR, 1980	160-450[b]
ICRP, 1977	200
UNSCEAR, 1977	150-350

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[a] Additional means above the normal incidence of cancer.

[b] All three groups estimated premature deaths from radiation-induced cancers. The American Cancer Society has recently stated that only about one-half of all cancer cases are fatal. Thus, to estimate incidence of cancer, the published numbers were multiplied by 2. Note that the three groups are in close agreement on the risk of radiation-induced cancer.

develop cancer because of that exposure, although the actual number could be more or less than three.

The American Cancer Society has reported that approximately 25 percent of all adults in the 20 to 65 year age bracket will develop cancer at some time from all possible causes such as smoking, food, alcohol, drugs, air pollutants, and natural background radiation. Thus, in any group of 10,000 workers not exposed to radiation on the job we can expects about 2,500 to develop cancer. Again, using a linear extrapolation of risk from high dose data, if this entire group of 10,000 workers were to receive an occupational radiation dose of 1 rem each, we could estimate that three additional cancers might occur, which would give a total number of about 2,503. This means that a 1 rem dose to each of 10,000 workers might increase the cancer rate from 25 percent to 25.03 percent, an increase of about 3 hundredths of one percent.

Perhaps the most useful unit for comparison among health risks is the average number of days of life expectancy lost per unit of exposure to each particular health risk. Estimates are calculated by looking at a large number of persons, recording the age when death occurs from apparent causes, and estimating the number of days of life lost as a result of these early deaths. The total number of days of life lost is then averaged over the total group observed.

Several studies have compared the projected loss of life expectancy resulting from exposure to radiation with other health risks. Some representative numbers are presented in Table III.

These estimates indicate that the health risks from occupational radiation exposures are smaller than the risks associated with many other events or activities we encounter and accept in normal day to day activities.

A second useful comparison is to look at estimates of the average number of days of life expectancy lost from exposure to radiation and from common industrial accidents at radiation-related facilities and to compare this number with days lost from other occupational accidents. Table IV shows average

TABLE III

ESTIMATED LOSS OF LIFE EXPECTANCY FROM HEALTH RISKS[A]

HEALTH RISK	ESTIMATES OF DAYS OF LIFE EXPECTANCY LOST, AVERAGE
SMOKING 20 CIGARETTES/DAY	2370 (6.5 YEARS)
OVERWEIGHT (BY 20%)	985 (2.7 YEARS)
ALL ACCIDENTS COMBINED	435 (1.2 YEARS)
AUTO ACCIDENTS	200
ALCOHOL CONSUMPTION (U.S. AVERAGE)	130
HOME ACCIDENTS	95
DROWNING	41
NATURAL BACKGROUND RADIATION CALCULATED	8
MEDICAL DIAGNOSTIC X-RAYS (U.S. AVERAGE), CALCULATED	6
ALL CATASTROPHES (EARTHQUAKE, ETC.)	3.5
1 REM OCCUPATIONAL RADIATION DOSE, CALCULATED (INDUSTRY AVERAGE FOR THE HIGHER-DOSE JOB CATEGORIES IS 0.65 REM/YR)	1
1 REM/YR FOR 30 YEARS, CALCULATED	30

[A] ADAPTED FROM COHEN AND LEE, "A CATALOGUE OF RISKS," <u>HEALTH PHYSICS</u>, VOL. 36, JUNE 1979.

days of life expectancy lost as a result of fatal work related accidents. Note that the data for occupations other than radiation related do not include death risks from other possible hazards such as exposure to toxic chemicals, dusts, or unusual temperatures. Note also that the unlikely occupational exposure at 5 rems per year for 50 years, the maximum allowable risk level, may result in a risk comparable to the average risk in mining and heavy construction.

TABLE IV

Estimated Loss of Life Expectancy from Industrial Hazards[A]

Industry Type	Estimates of Days of Life Expectancy Lost, Average
All Industry	74
Trade	30
Manufacturing	43
Service	47
Government	55
Transportation and Utilities	164
Agriculture	277
Construction	302
Mining and Quarrying	328
Radiation Accidents, Death from Exposure	<1
Radiation Dose of 0.65 rem/yr (Industry Average) for 30 Years Calculated	20
Radiation Dose of 5 rems/yr for 50 Years	250
Industrial Accidents at Nuclear Facilities (Nonradiation)	58

[A] Adapted from Cohen and Lee "A Catalogue of Risk," Health Physics, Vol. 36, June 1979; and World Health Organization, Health Implications of Nuclear Power Production, December 1975.

LIMITS AND ALARA

Dose limits are designed in principle to keep radiation exposures at a point where the incurred risks are deemed to be "acceptable" by the exposed individual and/or society.

Occupational limits are based to a large extent on this idea of "acceptable risk". Theoretically, an employee may work all his/her working life around radiation at the maximum limits and incur health risks no greater than incurred in many other occupations. At the same time, both the worker and society gain benefits from the use of radiation. However, since it is prudent to assume that there is some risk associated with any exposure to radiation, it is the goal of Radiation Safety to keep exposures as low as reasonably achievable (ALARA), and any reasonable steps which will lower personnel exposure should be taken. If you work safely it is unlikely that you will reach even 10% of the maximum dose limits. Here at Rorer, radioisotope research workers generally receive less than 30 mrem per year to the whole body, and most such workers seldom, if ever, receive any measurable occupational exposure above that due to natural background radiation. Table V lists some external exposure limits along with certain other external radiation levels and their significance.

TABLE V. *Summary of the Biological Significance of Various Exposures*

EXPOSURE	SIGNIFICANCE
1 rad, major portion of bone marrow	Risk of occurrence of leukemia is about 1 in 50,000
1 rad, whole body	Risk of eventual appearance of cancer about 1-4 in 10,000 (normal incidence from all causes is about 1 in 4)
10 rem, whole body	Elevated number of chromosome aberrations in peripheral blood; no detectable injury or symptoms
20 rad, reproductive system	Dose for doubling spontaneous mutations (lowest of proposed values)
1 rad, reproductive system, prior to conception	About 5-75 additional genetic disorders per million live births (normal incidence of serious genetic disorders from all causes is 10,000 per million live births)
150 rem, single dose, whole body	Mild radiation sickness
450 rem, single dose, whole body	Approximately 50% of exposed individuals will not survive even with best care
200-300 rad, locally to skin	Epilation
>300 rad, locally to skin	Radiation dermatitis and erythema
1000-2000 rads to skin	Transdermal injury.
>2000 rad to skin	Radionecrosis
200-500 rad, locally to eye, single exposure	Threshold dose, cataract induction (after latent period)
1000-2500 rad, local, at 200-300 rad/day	Treatment of markedly radiosensitive cancer
2500-5000 rad, local, at 200-300 rad/day	Treatment of a moderately radiosensitive cancer

PRINCIPLES OF RADIATION PROTECTION

There are several principles which you should keep in mind in order to work with radionuclides. These include: time, distance, shielding, and containment.

TIME: The best way to avoid unnecessary exposure is to simply spend as little time as possible in the radiation area. Try to do your work with radioactive materials in the minimum time necessary to do the job properly. Preliminary trials and "mock runs" WITHOUT using actual radionuclides can help in this regard.

DISTANCE: The radiation intensity from a point source varies inversely with the square of the distance from the point source; hence, **"THE INVERSE SQUARE LAW"**:

$$\frac{I_1}{I_2} = \frac{(d_2)^2}{(d_1)^2}$$

where I_1, is the intensity at distance d_1 from the source and I_2 is the intensity at distance d_2 from the source.

In other words, doubling the distance between you and a point source of radiation decreases your exposure by a factor of 4 for a given length of time. Conversely, halving the distance quadruples your exposure. As a practical example, assume that using a pair of tongs allows you to keep a vial of radioactive material 16 cm away from your fingers. At this distance the exposure rate is 8 mR/hr. Assume that you do not use tongs and pick up the vial with your fingers (the source inside the vial is 1 cm from your fingers). The exposure rate to your fingers will be approximately:

$$I(1\ \text{cm}) = \frac{(16)^2 \times (8)}{(1)^2} = 2{,}048\ \text{mR/hr}$$

This is a factor of 256 times the radiation received when the vial is handled with tongs. To put this exposure in perspective, this is the dose you would expect from a mCi of I-131.

REMEMBER:

1) Maintain as great a distance as possible between you and radiation sources which are external radiation hazards (e.g. energetic betas, gammas, and x-rays).

2) Don't pick up unshielded or inadequately shielded sources with your fingers. Use tongs or forceps whenever possible; it does make a difference!

SHIELDING: A third way to reduce exposure is to use shielding. For low energy beta emitting radionuclides, shielding is unnecessary. Very few betas would penetrate the dead outer layer of skin. For gamma radiation, high density material such as lead generally provides the best shielding choice in the laboratory. The thickness required depends on the energy of the emitted photons and the amount (activity) of the material to be shielded. Very little lead is needed for a "soft" (i.e. low energy) x-ray or gamma emitter like I-125; in fact, less than 1 mm of lead will absorb virtually all the photons. In the lab, you usually don't have to calculate how much shielding you'll need--just add increasing thicknesses around your source and measure its effectiveness with a radiation survey meter. If the exposure rate is reduced to an acceptable level then you have enough shielding.

As noted earlier in this manual, the high energy betas (such as P-32) have a tendency to interact with dense absorbers to produce Bremsstrahlung. For this reason, it is good health physics to shield P-32 first with a low density material such as plexiglass (about 8 mm will suffice) to stop all the betas. One should then shield the plexiglass with a high density material such as lead to absorb the Bremsstrahlung produced in the plexiglass.

When relying on shielding, be sure that it is both adequate and appropriate. Do not hesitate to consult with the RSO regarding shielding requirements for your lab.

Containment: In order to minimize the chance of ingestion, inhalation, or absorption of radionuclides in the body, every effort must be made to confine and limit radioactive contamination. There should be designated radioisotope work and storage areas. Containers should be sealed whenever possible. Any vial, test tube, etc., which contains radioactivity and which will not remain under your immediate control MUST be labeled as radioactive. Work areas should be covered with plastic backed absorbent material. Wear lab coats and gloves to keep contamination off street clothes and skin. Keep your lab coat buttoned. Each radioisotope laboratory should conduct its own radiation safety program, in addition to surveys done by the Radiation Safety personnel. Should a radioactive spill occur, care should be taken to confine the radioactivity to the area of the original spill. Radioisotopes which are part of volatile compounds, or which may break down to volatile compounds, must be stored in properly functioning fume hoods.

SUMMARY

Radionuclides can and are being used at Rorer with a minimum of risk to personnel and the public. Maintaining this safety program depends first and foremost on each individual who handles radioactive material. That person must appreciate the hazards involved and treat radioactive material with the proper respect while also being fully aware that radionuclides used safely can be a valuable tool in research. This booklet is intended to provide some of the basic information needed by individuals working in radionuclide research laboratories. Keep in mind that radiation safety personnel are ALWAYS available to answer your questions or to address concerns regarding radiation protection matters or needs. During working hours you may contact the Radiation Safety Specialist at (x 4116), and during evening hours both the RSO and Radiation Safety Specialist can be reached by dialing the Security Department in your facility.

Appendix A

Isotope Specific Information

ISOTOPE SPECIFIC INFORMATION[1]

ISOTOPE	TYPE OF RADIATION	HALF LIFE	EXTERNAL HAZARD?	AIRBORNE[2] HAZARD?	FILM BADGE REQUIRED?	RING DOSIMETER REQUIRED?	SHIELDING MATERIAL	LAB SURVEY METER OF CHOICE	BIOAS REQUI
^{3}H	Soft β^-	12.35 y	No	HTO	No	No	N/A	None	Urine
^{14}C	Soft β^-	5,700 y	No	$^{14}CO_2$	No	No	N/A	Thin Window GM	No
^{32}P	β^- (high energy)	14.3 d	Yes	No	Yes	Yes	Plastic, Glass	GM, any type	No
^{35}S	Soft β^-	87.4 d	No	No	No	No	N/A	Thin Window GM	No
^{45}Ca	Soft β^-	163 d	No	No	No	No	N/A	Thin Window GM	No
^{51}Cr	γ	27.7 d	Yes	No	Yes	Maybe	Lead	GM	N
^{125}I	γ, x-ray (both low energy)	60.14 d	Minimal	Yes (I_2, NaI sol.)	Yes	Maybe	Thin Lead	Thin Window (NaI crystal) probe	Thyro
^{131}I	β^-, γ	8.04 d	Yes	Yes (I_2, NaI sol.)	Yes	Yes	Lead	GM	Thy

Notes: 1. This table is intended as a quick reference guide only and the information provided may be incomplete for many situations. For example, in most radioimmunoassay work, less stringent requirements than those implied above m be allowed due to the low activity levels used.

2. Any isotope may be a potential airborne hazard as fumes, dust, mist, or as part of a volatile compound. This column identifies the most common forms of either the contaminant or the material from which a contaminant will likely arise in the research laboratory.

Appendix B

Radiological Data For Isotopes Commonly Used In Research Laboratories

RADIOLOGICAL DATA FOR ^3H

Half Life	Radiation Type	Energy (MeV)	Intensity(% per disintegration)	Range in	
				Air	Tissue
12.35 yr	β -	max 0.01860 avg 0.00568	100	0.45 cm	0.006 cm

Maximum Permissible Body Burden..........	Critical Organ
2000 uCi (HTO)	Total Body
1000 uCi (HTO)	Body Tissue

Radiation Precautions: No external hazard; shielding not required; film badge not required.

Tritiated compounds can be a serious internal radiation hazard. Tritiated nucleic acids and nucleic acid precursors are generally considered to be a more serious internal radiation hazard than other chemical forms.

Precautions should be taken against ingestion, inhalation, accidental injection, or absorption through the skin. (e.g. Use protective clothing and absorbent material on work surfaces, no mouth pipetting, etc.) Urinalysis is required for persons handling more than 10 mCi of ^3H either per container or at any one time. Contact the Office of Radiation Safety, Ext. 7813 for instructions. Tritiated water vapor (HTO or ^3H_2O) is a common possible airborne hazard. In addition to being used directly in this form, HTO may also be a byproduct of experimental reaction(s) or of the breakdown of other compounds. Tritiated sodium borohydride ($NaBH_4[^3H]$) is an example of a compound whose use usually results in airborne release of HTO vapor. Contact the Radiation Safety Office for possible air monitoring. Maximum permissible airborne concentration in a controlled area is 5.0×10^{-6} uCi/ml, averaged over 40 hr.

RADIOLOGICAL DATA FOR C-14

Half Life	Radiation Type	Energy (MeV)	Intensity (% per disintegration)	Range In	
				Air	Tissue
5730 years	β -	0.156 (max) 0.049 (avg)	100	28 cm	0.029

Maximum Permissible Body Burden..........	Critical Organ
300 uCi	Body Fat
400 uCi	Total Body

Radiation Precautions:

Negligible external hazard: shielding not required; film badge not required. The chief concern regarding ^{14}C is a potential internal radiation hazard. Precautions should be taken against ingestion, inhalation, accidental injection or absorption through broken skin. Use protective clothing and absorbent material on work surfaces, no pipetting by mouth, etc. ^{14}C may become airborne when used to study certain metabolic processes which result in the formation of $^{14}CO_2$. Any experimental procedures in which ^{14}C may attach to dusts, mists, etc. may also result in airborne ^{14}C. Use fume hoods or other local ventilation to control any such hazards. Maximum permissible airborne concentration of "soluble" ^{14}C in a controlled area is 4×10^{-6} uCi/ml, averaged over 40 hours. The MPC_{40}hrs for airborne $^{14}CO_2$ (based on "submersion" dose) is 5×10^{-5} uCi/ml.

ADIOLOGICAL DATA FOR P-32

Half Life	Radiation Type	Energy (MeV)	Intensity(% per disintegration)
14.3 da	β-	1.71 (max) 0.695 (avg)	100%

Maximum Permissible Body Bu[illegible]..........	Critical Organ	Maximum Beta Range in Air	Maximum Beta Range in Tissue
6 uCi	Bone	635 cm	0.76 cm
30 uCi	Total Body		

Radiation Precautions:

^{32}P poses a significant external radiation hazard. Dose rate at 1 foot from a 1 mCi unshielded point source is approximately 300 mrad/hr. ^{32}P betas are also energetic enough to cause significant x-ray production when being stopped in an absorbing medium. (This type of x-radiation is called Bremsstrahlung.) Use low density material to shield the betas (8 mm of plexiglass or equivalent will stop all the betas). If necessary, high density shielding (e.g. lead) may then be used to shield any Bremsstrahlung arising in the low density beta shield. Minimize time of exposure and maximize distance from source to further decrease your dose. Dose to the hands and fingers may be especially significant if proper precautions are not taken. As with all isotopes, take precautions against ingestion, inhalation, accidental ingestion, or absorption through broken skin. Use protective clothing and gloves, do not pipette by mouth, etc. Any experimental procedure in which ^{32}P may become attached to dusts, mists, etc. may result in airborne ^{32}P. Use fume hoods or other local ventilation to control such hazards. Maximum permissible airborne contamination for soluble ^{32}P in a controlled area is 8x10-8 uCi/ml, averaged over 40 hours.

RADIOLOGICAL DATA FOR S-35

Half Life	Radiation Type	Energy (MeV)	Intensity (% per disintegration)	Range In Air	Range In Tissue
87.4 days	β -	0.167 (max) 0.049 (avg)	100	31 cm	0.32 c

Maximum Permissible Body Burden..........	Critical Organ
90 uCi	Testis
400 uCi	Total Body

Radiation Precautions:

Negligible external hazard: shielding not required: film badge not required.
The chief concern regarding ^{32}S is a potential internal radiation hazard. Precautions should be taken against ingestion, inhalation, accidental injection or absorption through broken skin. Use protective clothing and absorbent material on work surfaces, no pipetting by mouth, etc. Gases containing ^{35}S (e.g. $^{35}SO_2$) may be formed during some chemical procedures and may pose an airborne hazard. Any experimental procedures in which ^{35}S may attach to dusts, mists, etc. may also result in airborne ^{35}S. Use fume hoods or other local ventilation to control any such hazards. Maximum permissible airborne concentration of ^{35}S in a controlled area is 3 x 10-7 uCi/ml, averaged over 40 hours.

RADIOLOGICAL DATA FOR Ca-45

Half Life	Radiation Type	Energy (MeV)	Intensity (% per disintegration)	Range In Air	Tis
163 days	β^-	0.257 (max) 0.077 (avg)	100	53 cm	0.0.

Maximum Permissible Body Burden..........	Critical Organ
30 uCi	Bone

Radiation Precautions:

Negligible external hazard; shielding not required; film badge not required. The chief concern regarding Ca-45 is a potential internal radiation hazard. Precautions should be taken against ingestion, inhalation, accidental injection or absorbtion through broken skin. Use protective clothing and absorbent material on work surfaces, no pipetting by mouth, etc. Any experimental procedures in which ^{45}Ca may attach to dusts, mists etc. may result in airborne ^{45}Ca. Use fume hoods or other local ventilation to control any such hazards. Maximum permissible airborne concentration of ^{45}Ca in a controlled are is 3×10^{-8} uCi/ml, averaged over 40 hours.

RADIOLOGICAL DATA FOR Cr-51

Half Life	Radiation Type	Energy (MeV)	Intensity(% per disintegration)	Half Value Layer in Pb
27.7 da	γ	0.32	9.8	0.17 cm

Maximum Permissible Body Burden..........	Critical Organ
800 uCi	Lower large intestine
500 uCi	Total body

Radiation Precautions:

Moderate external hazard to whole body and extremities. Gamma dose rate from 1 mCi point source is 0.016 mR/hr at 1 meter or 160 mR/hr at 1 cm. Use lead shielding (1 cm of lead will reduce exposure rate by about 60X). Use remote handling tools for manipulating unshielded sources or containers. Film badges required, ring dosimeters required for persons handling mCi amounts. As with any radionuclide, take precautions against accidenta ingestion, injection, inhalation or absorbtion through broken skin (utilize contamination control measures, etc.) Any expermental procedure in which ^{51}Cr may attach to dusts, mists etc., may result in an airborne hazard. Use fume hoods or other local ventilation to control such hazards. Maximium permissible airborne concentration in a controlled area is $\times 10^{-5}$ uCi/ml, averaged over 40 hours.

RADIOLOGICAL DATA FOR I-125

Half Life	Radiation Type	Energy (MeV)	Intensity(% per disintegration)	Half Value Layer in Pb
60.14 da	X-rays Y-rays	0.0272-0.0355 0.0355	139.8 6.7	0.002 cm

Maximum Permissible Body Burden..........	Critical Organ
4.00 uCi	Total Body
1.15 uCi	Thyroid

Radiation Precautions:

Generally low external hazard: chief concern is exposure of extremities and fingers while handling mCi quantities. Minimal lead shielding needed (0.02 cm of lead will reduce exposure rate by about 1000x). Film badge usually required. Ring dosimeter required for persons handling mCi amounts. Like all radioiodines, I-125 that enters the body concentrates in the thyroid gland. Precautions must be taken against ingestion, inhalation, and accidental injection. "Free" I-125 (I_2 or aqueous NaI) is easily absorbed through intact skin and can penetrate plastics. "Free" forms are easily volatilized, especially in acid solutions and present a serious airborne hazard. Use of "free" forms of I-125 must take place in a fume hood approved for this purpose by the Office of Radiation Safety. External thyroid counting is required for persons handling > 1 mCi of free I-125 and air sampling may be required during procedures involving free I-T25. Contact the Office of Radiation Safety for further details. Maximum permissible airborne concentration in a controlled area is 5 x 10-9 uCi/ml averaged over 40 hours.

RADIOLOGICAL DATA FOR I-131

Half Life: 8.04 da
Maximum Beta Range: in Tissue — 0.21 cm   In Air — 165 cm
Half Value Layer (photons) in Lead: 2.4 mm
Gamma Dose Rates From 1 mCi Point Source: 0.21 mR/hr @ 1 meter
2,100 mR/hr @1 cm

Maximum permissible body burden	Critical Organ
0.14 uCi	Thyroid
50 uCi	Body

Radiation Type	Energy (MeV)	Intensity (% per disintegration)
beta-	0.334 max	7.36
beta-	0.606 max	89.4
3 Others emitted	0.806 max	—
Total (avg.)	0.182	100

Radiation Type	Energy (MeV)	Intensity (% per disintegration)
X-rays	0.295-0.336	4.81
gamma1	0.080	2.62
gamma7	0.284	6.06
gamma14	0.364	81.2
gamma17	0.637	7.27
gamma19	0.723	1.80
14 others emitted		1.33

Radiation Precautions:

External hazard to whole body from gamma exposure and to skin from beta exposure. Use remote handling and/or lead shielding (1.0 cm of lead will reduce gamma exposure rate by about 15x). Film badge and ring dosimeters required. Like all radioiodines, I-131 that enters the body concentrates in the thyroid gland. Precautions must be taken against ingestion, inhalation, and accidental injection. "Free" I-131 (I_2 or aqueous NaI) is easil absorbed through intact skin and can penetrate plastics. "Free" forms are easily volatil- ized, especially in acid solutions and present a serious airborne hazard. Use of "free" forms of I-131 must take place in a fume hood approved for this purpose by the Office of Radiation Safety. External thyroid counting is required for persons handling > 1 mCi of free I-131 and air sampling may be required during procedures involving free I-T31. Contac the Office of Radiation Safety for further details. Maximum permissible airborne concentration in a controlled area is 9 x 10-9 uCi/ml, averaged over 40 hours.

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GOOD SAFETY PRACTICES IN RADIOISOTOPE LABORATORIES

1. NEVER pipette by mouth.
2. No smoking or eating permitted in the work areas.
3. Do not apply cosmetics in radioisotope work areas.
4. Gloves and buttoned lab coats are required when using radioisotopes.
5. Prescribed personal monitors must be worn.
6. Hands, shoes, and clothing should be frequently monitored.
7. Radioisotope work should be conducted on a surface lined with absorbant paper.
8. Utilize shielding and maximize distance from a radiation source whenever possible.
9. Dispose of all radioactive waste in appropriate containers.
10. Refrigerators containing radioisotopes SHALL NOT be used for storing food.
11. Monitor radioisotope work areas routinely for contamination; identify (label) contaminated areas and alert supervisor/RSO for appropriate cleanup actions.
12. REPORT accidental ingestion, inhalation, injury or spills promptly to your supervisor and the RSO.
13. Maintain appropriate records of receipt, use, transfer and disposal of radioactive materials.
14. Bioassays--thyroid checks and/or urinalysis will be performed by the RSO or designee as indicated.
15. Assure compliance with State and Federal Regulations as well as Rorer's internal regulations.

IF YOU HAVE ANY QUESTIONS OR NEED ASSISTANCE, CONTACT THE RADIATION SAFETY SPECIALIST AT (x 4116).