Supplemental material for application

C/N 316378

Numbering referenced to Fax dated Aug. 2, 2007 from Kevin Null to William Yelon

1. Form 313 will be resubmitted (both to Region III, for the possession license and to D.C. for the importation and exempt release license), signed by an officer of Ideal Source International.

2. The irradiation program and the quality assurance program are discussed in detail in the application for the "importation and exempt release" license. Some material in that application is proprietary and should not be disclosed, except as needed for NRC review. Briefly, the stones are irradiated at the Maria reactor in Poland. The irradiation containers are sealed and no loose shielding material is present. Stone are contained in individually wrapped packages, each representing a single size, shape and geologic origin. The stones are all cut and polished, and cleaned rendering them free of removable contamination. After irradiation they are stored for decay, according to their doses and geologic origin, with each type showing a characteristic distribution of the major by-products, ^{54}Mn, ^{182}Ta and ^{46}Sc. Our proprietary material describes the process we use to sort for outliers: those stones with specific activity greater than twice the exempt limit (based on sum-of-ratios) at the time when the average activity of the stones reaches the exempt limit. If carried our correctly, stones that are sent from Poland will have

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average activity equal to, or less than, the NRC exempt limits and will have been sorted to guarantee that not more than 1/1000 stones has more than twice the exempt limit, as required by NUREG-1556 Vol.8.

Shortly after irradiation (allowing for the decay of short-lived isotopes such as ^{24}Na), the stones are measured with a high resolution Ge detector and their "generic" isotope distribution is confirmed. The presence of isotopes, other than those normally found, (and mentioned above) is taken as evidence of surface contamination, usually due to some leakage of pool water into the irradiation container. This is a rare occurrence that triggers a thorough, ultrasonic bath, cleansing of the stones. This is repeated until no further evidence for contamination is found. Prior to shipping, the isotope distribution is again measured. It must conform both to earlier measurements and to the generic distribution for stones of that origin. In many years of dealing with these stones outside the U.S., no problems of removable contamination have arisen. For additional information, refer to the application for the import and exempt release license.

3. The stones that will be used for calibration are based on two isotopes ^{54}Mn and ^{182}Ta. The former is provided by over-irradiating a large (~4-5 g) stone and allowing for a long (>2 year) decay, for the ^{182}Ta to decay to insignificant levels. Stones of this type are currently available. The latter is found during the sorting of stones for outliers. ^{182}Ta is the dominant isotope in the outliers (the Mn

distribution appears to be quite narrow), and stones are found with as much as 100 times the mean. These are held aside and can be used as reference stones. Prior to sending them to Missouri, they will be calibrated using the high-resolution Ge station at Maria. Typical activities for these standards will not exceed 500 bq/g and will represent a total inventory of not more than 10,000 Bq. They will be stored in the "locked storage" when not in use.

4. At the present time William Yelon is the only authorized user. If the work exceeds his capacity, an additional A.U. may be employed.

5. Details of the verification program have been provided in the application for the importation and exempt release license. Briefly, stones that are shipped to the facility will be accompanied by documentation describing the mean activity and the distribution of isotopes. No shipment will occur until those levels meet the exempt standards, based on the sum-of-ratios. Batches, randomly selected for verification, will be measured using a well shielded NaI(Tl) detector. The entire lot will be measured in spectroscopy mode, to verify the isotopic distribution. Subsequently, small batches (~10 gm) will be measured for specific activity, using an efficiency calibration based on the measured isotope concentration. The distribution of the activities in these batches will be stored, to provide a (rough) test for the distribution of activities in the individual stones. It is expected that all stones will pass these tests, if the sorting performed in Poland has been properly carried out. If any batch fails the tests, the entire procedure will be shut down and

no stones released, until the source of error has been identified and corrected, either in the U.S. or in Poland.

6. See attached material. Lectures will eliminate specific reference to Princeton's practices and organization. This course is available on line. While it contains superfluous material, it appears to contain all of the essential components

7. See attached material.

8. In response to this item and subsequent questions, special attention must be paid to the unique form of the radioactive material to be used in the proposed license. All materials are in solid form and are insoluble. Activity levels will be in the range of 20Bq/gm, and once verified, can be released to the general public under the importation and exempt distribution license. With the exception of a few beads containing 30 Bq of ^{152}Eu, the material is non-flammable (consisting of silicate minerals) and the activities cannot be concentrated by any process. Thus, many of the concerns that apply to laboratories handing soluble sources or other forms of by-product material do not apply to this case. For this reason, a variety of surveys (such as air sampling and bioassay measurements) are inappropriate. Similarly, many of the safety procedures (such as contamination controls) are irrelevant. Nevertheless, the facility will be equipped with the following instrumentation for radiation detection:

a. Inspector EXP+, digital survey meter with external G-M probe.

b. DS-pen, self-reading ionization chambers, range 0-200 mR.

c. AT 750 charger for ionization chambers.

These items are being ordered from

Direct Scientific / 124 San Tropez Ct. / Laguna Beach, CA 92651

d. Canberra Model 802 NaI(Tl) detector with Unispec data acquisition system.

Calibration of the NaI(Tl) system has been described in the application for importation and exempt distribution license. It will be performed annually, using the reference stones and with impregnated beads containing 30Bq of ^{152}Eu, prepared at the Maria reactor. In addition daily checks for stability and for background will be carried out using some of the same standards.

Calibration of the DS-pen ionization chambers will be carried out annually by a commercial vendor ***Atlantic Nuclear***. A regular schedule of calibration will be carried out so that ¼ of the detectors are sent for calibration every 3 months. A sufficient number of chambers will be acquired so that all personnel are equipped with calibrated chambers at all times.

Calibration of the G-M survey meters will not be performed unless their behavior is suspect, as these instruments are used only for general survey work. However, it has been requested that the Polish shipper provide contact doses for selected parcels, and the G-M survey meters will be used to check those surface doses as a way to both verify the instruments and to check the reliability of the Polish results.

We will use instruments that meet the radiation monitoring instrument specifications published in Appendix M to NUREG-1556, Vol. 7, 'Program-Specific Guidance about Academic, Research and Development, and other Laboratory Licenses of Limited Scope', dated December 1999. We reserve the right to upgrade our survey instruments as necessary.

9. All shipments from Poland will be accompanied by both electronic and hard copy inventories. The electronic forms, e-mailed prior to shipment, will come in two forms, one as a read-only file (to prevent alteration) and as a file accessible for entry of data, collected during the verification process. The information in the inventories will include for each parcel:

    a. Lot number (identification referring to date and location of irradiation)
    b. Lot size (gms)
    c. Stone size and shape (e.g. oval 4 x 6 mm).
    d. Average activity (Bq/g)
    e. Relative isotope concentrations
    f. Date of activity measurement.

    After verification additional information will be included in the writeable file:

    a. Date of measurement
    b. Average activity.
    c. Relative isotope concentration.
    d. Date and destination of shipment as exempt material.

This form will also be provided, as hard copy, with the shipment from Poland, and as filed hard copy to provide traceability with regard to the final disposition of the exempt material. Paper copies will be maintained for at least three years. In addition, a separate inventory will be maintained for any calibration sources which will be kept in the office. Any calibration sources no longer considered useable will be returned to Poland for disposal.

Shipments from Poland will only be opened by the RSO, and will be checked for surface dose, prior to opening. The surface dose for each individual parcel will be checked prior to transfer to secure storage and subsequent verification testing. The most serious concern for these shipments is that a misidentified parcel, not ready for release, might have inadvertently been shipped. This would appear with a higher than normal surface dose. Such a parcel would be segregated and isolated from the normal storage to prevent exposure to workers. Potentially this parcel could be returned to Poland, or stored locally for decay. Any such incident would result in the generation of an "incident report" that would be permanently stored.

Ideal Source agrees to allow periodic physical inventory verification every six months or with whatever frequency the NRC deems appropriate.

It should be noted that the inventory of radioactive material will change rapidly as gemstones are received and cleared for exempt release. The data stored will accurately reflect the current inventory.

10. We have done a prospective evaluation and determined that employees are not likely to receive, in one year, a radiation dose in excess of 10% of the allowable limits of 10 CFR Part 20. Nevertheless, we prefer to immediately implement a program under which the whole body dose is followed through the use of self-reading ionization chambers. Consequently, all workers will be required to wear such dosimeters while inside the facility, and to leave them behind, when outside. The dosimeters will be collected and read once a week and the accumulated dose entered into a program that tracks the cumulative dose for each employee. In order to minimize doses, only those stones being measured (or about to be measured) will be removed from secure storage. A dosimeter will also be positioned on the wall of the work room, to monitor background effects and to provide evidence for any material that might have inadvertently been left out of storage. After a year in operation, an evaluation will be made as to whether the monitoring program will be maintained, upgraded or eliminated. Procedures for the calibration of self-reading ionization chambers have been described in section 8, above.

11. Because the by-product material contained in the gemstones is insoluble and immobilized, it presents few risks to the worker or to the general public. Individual stones also represent very low dose potential to one not bearing the stone continuously. The only risk is that represented by accumulating a large number of stones in a small area, at which time the doses at contact may reach the level of a few mR/hr. In order to minimize the potential for worker exposure and

comply with ALARA concerns, the quantity of stones taken from secure storage will be limited to only those parcels being measured or immediately scheduled to be measured. As soon as measurement is complete, they will be returned to storage (or to a temporary, shielded storage bin), located away from the work area.

At the same time, these materials are free from removable contamination, and from the risk of spills, that might require emergency clean-up or other response. In this regard, the general procedures described in NUREG-1556, vol. 7, have little direct applicability, except concerning the need to safely and securely store the stones and sources not in use, and to provide adequate security to prevent unintended removal of the stones.

We have carefully considered possible scenarios regarding the stones and find no situation that could require an "Emergency Response Plan".

12. The procedures employed by the irradiation facility in Poland, and the screening of the stones using high resolution gamma counting and NaI(Tl) counting provides a barrier against the possible introduction of removable contamination to the stones. Accidental contamination during irradiation (e.g. from reactor pool water) is easily detected and eliminated by ultrasonic cleaning, prior to screening to remove outliers. Consequently, the potential for contamination of the work area and/or workers is negligible. In addition, calibration sources are similar solids (with activities only a few times exempt limits), and do not represent any contamination potential. It should be noted that workers, at the Polish facility,

routinely screen irradiated stones (that have previously been checked for removable contamination) without latex gloves. Their procedures have been reviewed by the Polish equivalent of the NRC and found to be satisfactory.

The only types of surveys that appear to be appropriate to the nature of the by-product material, consist of G-M meter surveys of hands and work surfaces. It is expected that these would consistently yield negative results, and so any above background reading would be taken as evidence for contamination, not *completely* removed at the source (the irradiation site in Poland). Appropriate action would be taken to:

a. Isolate the source of contamination.

b. Remove the contamination from the workers' hands.

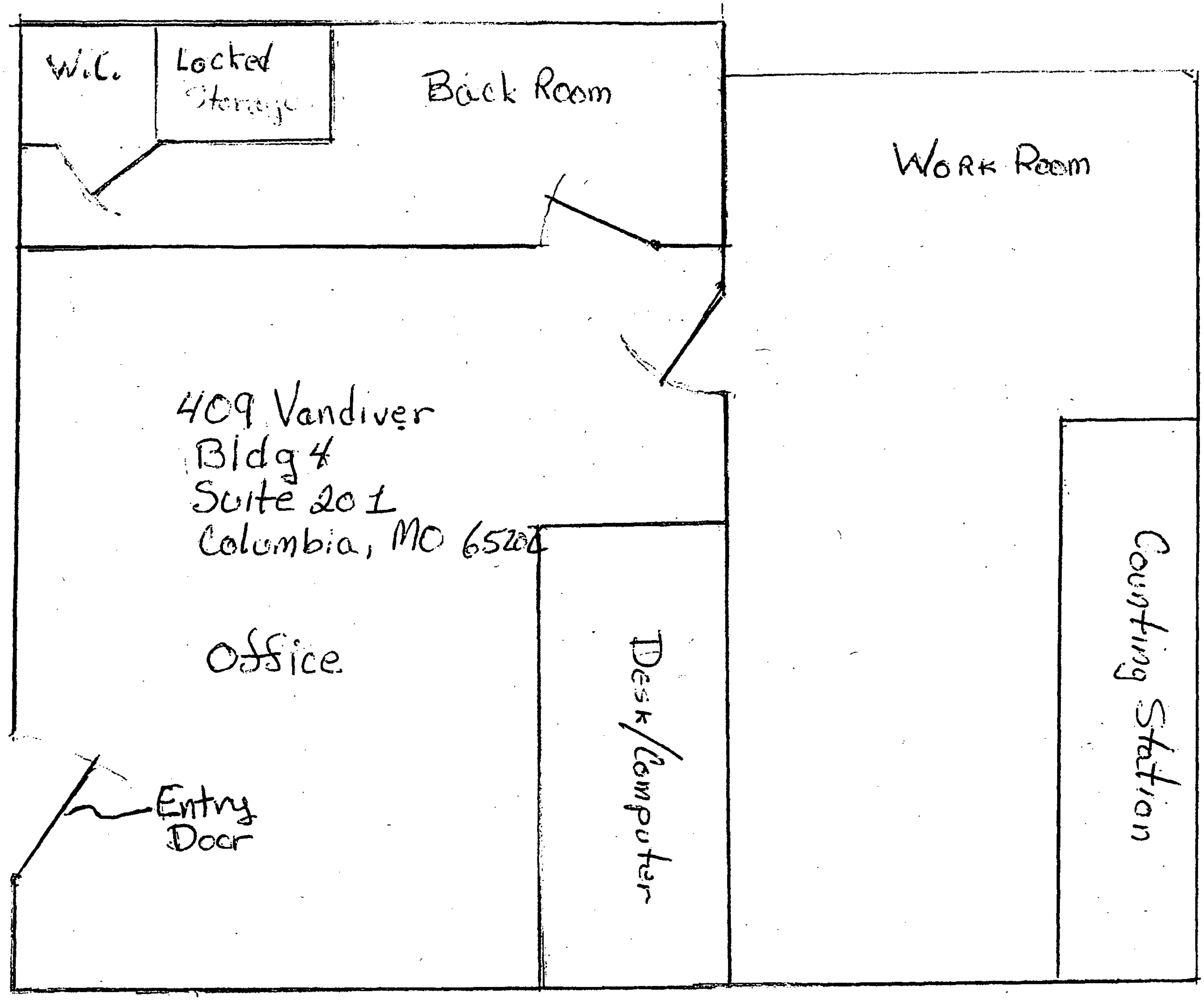
c. Remove the contamination from the work area.

Decontamination wipes will be available for these actions. An incident report would be generated and discussions with the irradiator would begin, in order to locate the source of the problem and to prevent its recurrence. However, in many years of irradiating stones, for sale outside the U.S., this problem has never been observed. We are confident that the procedures in place will protect against this potential.

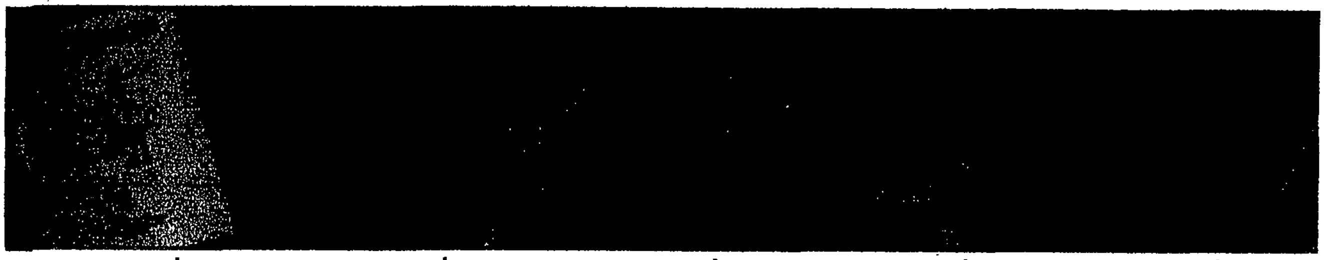
No other surveys are planned for the work area.

13. Because of the lack of removable contamination of gemstones and calibration sources and the total containment of the by-product material inside an inert, insoluble matrix, workers will not need to use gloves, and other work items, such

as wipes, will not be part of a waste stream. The only waste likely to be produced is stone fragments resulting from mechanical damage to the stones, which makes the stones un-salable. Those stones will be returned to the irradiator for disposal as part of their regular radioactive waste stream. The Polish irradiation facility has agreed to accept these waste materials, and a letter certifying this acceptance will be provided to the NRC as soon as it has been formally transmitted to Ideal Source.


W.C.
Locked Storage
Back Room
Work Room
409 Vandiver
Bldg 4
Suite 201
Columbia, MO 65202
Office
Desk/Computer
Counting Station
Entry Door

Princeton University **Environmental Health**



Open Source Training Modules

Introduction
Radiation Properties
Background Radiation
Biological Effects
Regulations
External & Internal Dose Limits
Radiation Monitoring
Radiation Basics Test

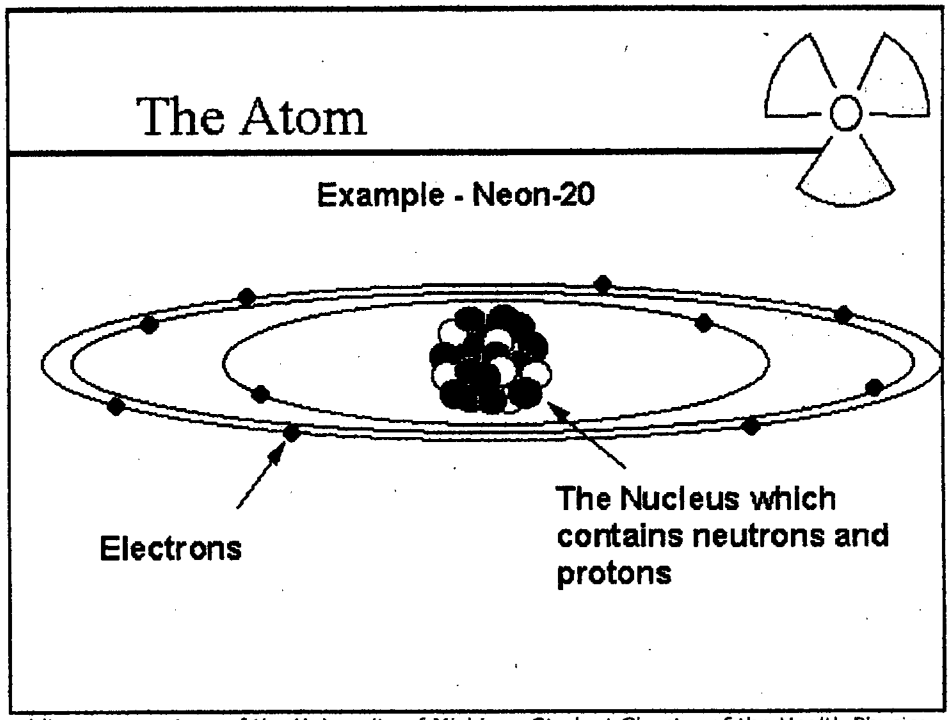
Open Source Radiation Safety Training

Module 1: Radiation Properties

This module provides information about the following topics:

- The Atom
- Radiation
- Radioactive Decay
- Alpha Particles
- Beta Particles
- Gamma Rays
- X-Rays
- Radiation Units
- Half-Life

The Atom



(diagram courtesy of the University of Michigan Student Chapter of the Health Physics Society)

The Bohr Model of the atom consists of a central nucleus composed of neutrons and protons surrounded by a number of orbital electrons equal to the number of protons.

Protons are positively charged, while **neutrons** have no charge. Each has a mass of about 1 atomic mass unit or amu. **Electrons** are negatively charged and have mass of 0.00055 amu.

The number of protons in a nucleus determines the element of the atom. For example, the number of protons in uranium is 92 while the number in neon is 10. The proton number is often referred to as Z.

An element may have several isotopes. **An isotope** of an element is comprised of atoms containing the same number of protons as all other isotopes of that element, but each isotope has a different number of neutrons than other isotopes of that element. Isotopes may be expressed using the nomenclature Neon-20 or 20Ne10, where 20 represents the combined number of neutrons and protons in the atom (often referred to as the mass number A), and 10 represents the number of protons (the atomic number Z).

While many isotopes are stable, others are not. Unstable isotopes normally release energy by undergoing nuclear transformations (also called decay) through one of several radioactive processes described later in this module.

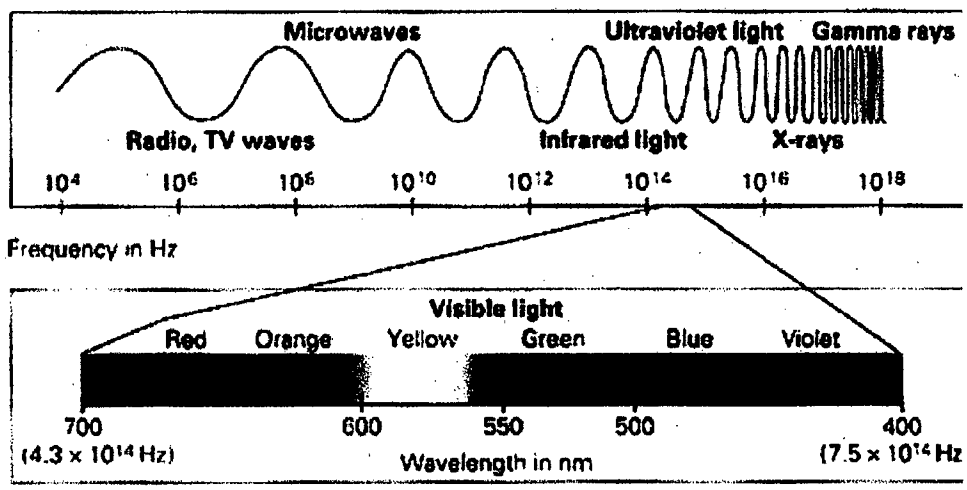
Elements are arranged in the periodic table with increasing Z. Radioisotopes are arranged by A and Z in the chart of the nuclides.

Go to a detailed periodic table of the nuclides

Return to top

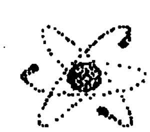
Radiation

Radiation is energy transmitted through space in the form of electromagnetic waves or energetic particles. Electromagnetic radiation, like light or radio waves, has no mass or charge. The following chart shows the electromagnetic spectrum.



This training is concerned with radiation that has sufficient energy to remove electrons from atoms in materials through which the radiation passes. This process is called **ionization**, and the high frequency electromagnetic waves and energetic particles that can produce ionizations are called **ionizing radiations.** Examples of ionizing radiation include:

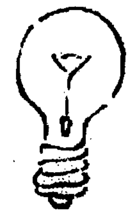
- alpha particle radiation
- beta particle radiation
- neutrons
- gamma rays
- x-rays



Nonionizing radiations are not energetic enough to ionize atoms and interact with materials in ways that create different hazards than ionizing radiation. Examples of nonionizing radiation include:

- microwaves
- visible light
- radio waves
- TV waves

▸ultraviolet light



Return to the Top

Radioactive Decay

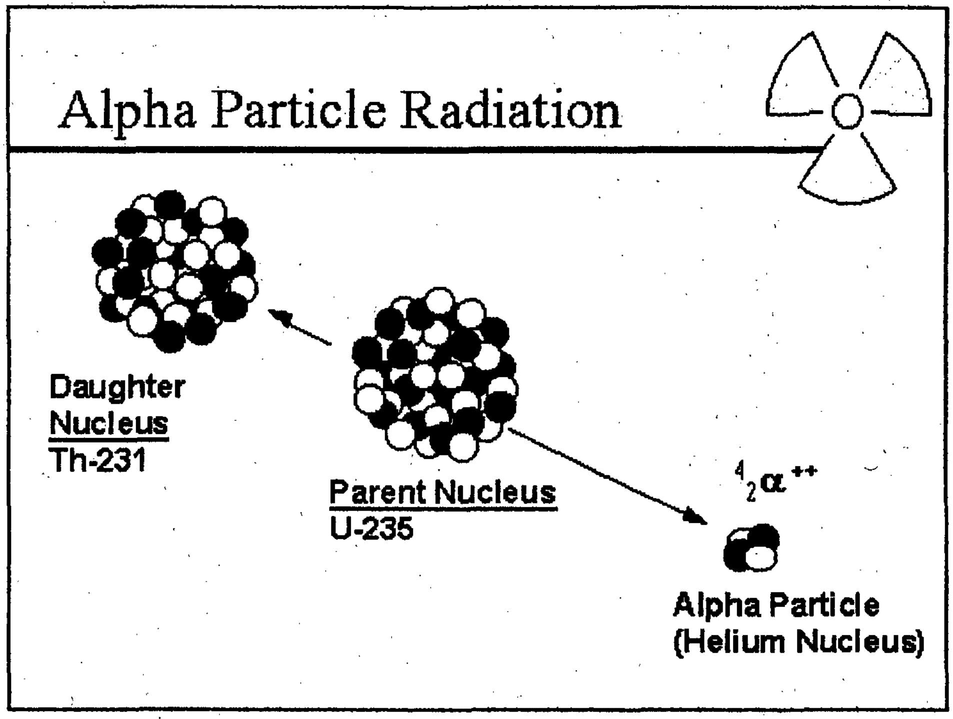
The atomic structure for certain isotopes of elements is naturally unstable. **Radioactivity** is the natural and spontaneous process by which the unstable atoms of an isotope of an element transform or decay to a different state and emit or radiate excess energy in the form of particles or waves. These emissions are energetic enough to ionize atoms and are called ionizing radiation. Depending on how the nucleus loses this excess energy, either a lower energy atom of the same form results or a completely different nucleus and atom is formed.

A given radioactive isotope decays through a specific transformation or set of transformations. The type of emissions, along with the energy of the emissions, that result from the radioactive decay are unique to that isotope. For instance, an atom of phosphorus-32 decays to an atom of non-radioactive sulfur-32, accompanied by the emission of a beta particle with an energy up to 1.71 million electron-volts.

The following sections describe the radiations associated with the radioactive decay of the radioisotopes most commonly used in research at Princeton University.

Return to the Top

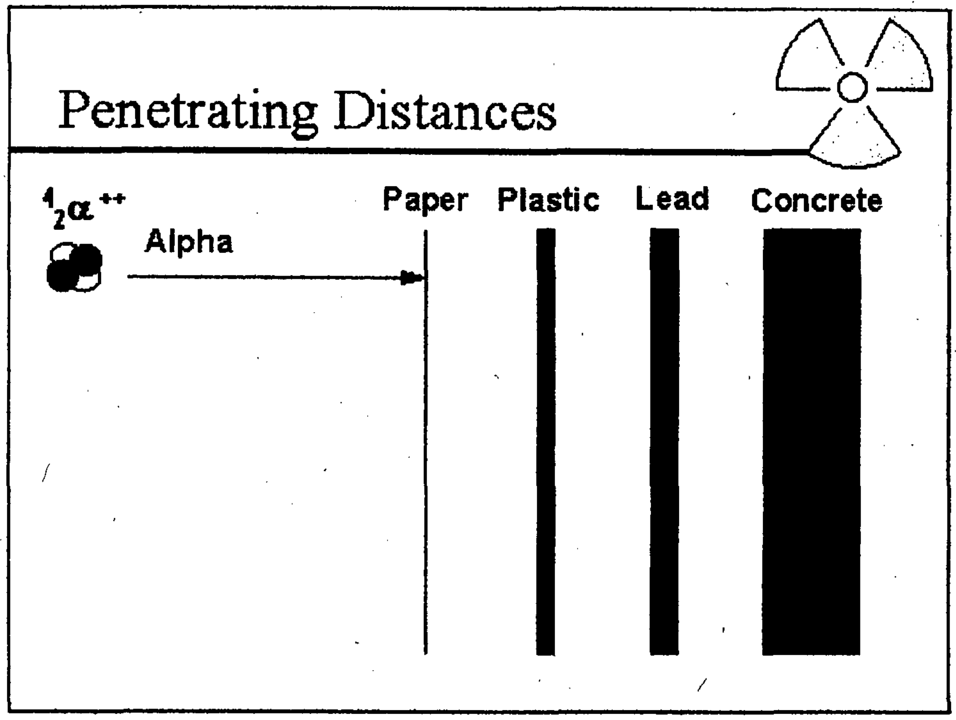
Alpha Particle Radiation



(diagram courtesy of the University of Michigan Student Chapter of the Health Physics Society)

An **alpha particle** consists of two neutrons and two protons ejected from the nucleus of an atom. The alpha particle is identical to the nucleus of a helium atom. Examples of alpha emitters are radium, radon, thorium, and uranium.

Because alpha particles are charged and relatively heavy, they interact intensely with atoms in materials they encounter, giving up their energy over a very short range. In air, their travel distances are limited to no more than a few centimeters. As shown in the following illustration, alpha particles are easily shielded against and can be stopped by a single sheet of paper.



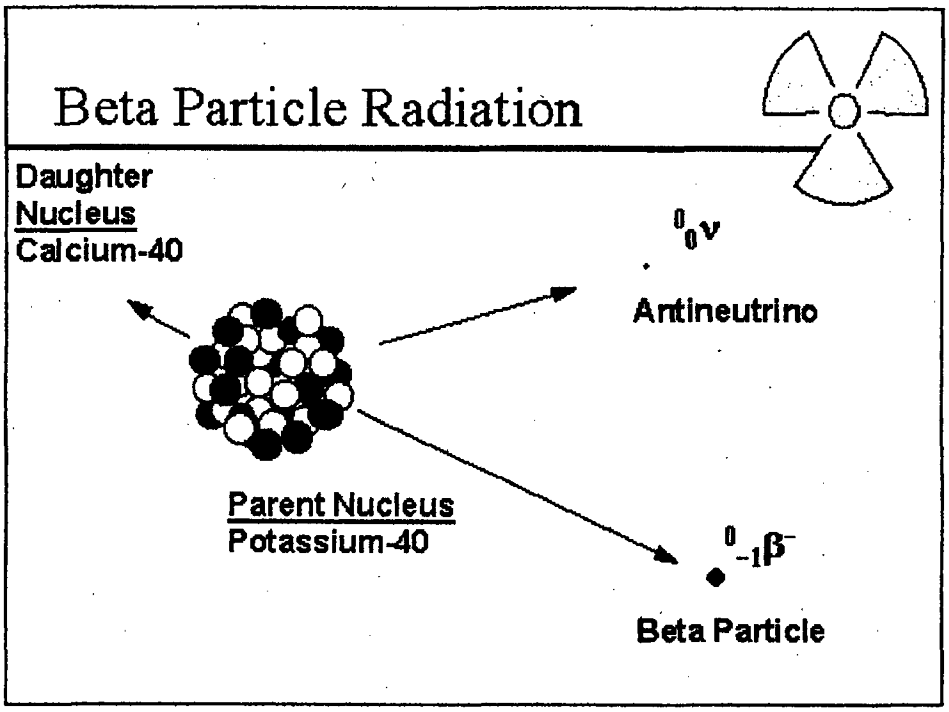
(diagram courtesy of the University of Michigan Student Chapter of the Health Physics Society)

Since alpha particles cannot penetrate the dead layer of the skin, they do not present a hazard from exposure external to the body.

However, due to the very large number of ionizations they produce in a very short distance, alpha emitters can present a serious hazard when they are in close proximity to cells and tissues such as the lung. Special precautions are taken to ensure that alpha emitters are not inhaled, ingested or injected.

Return to the Top

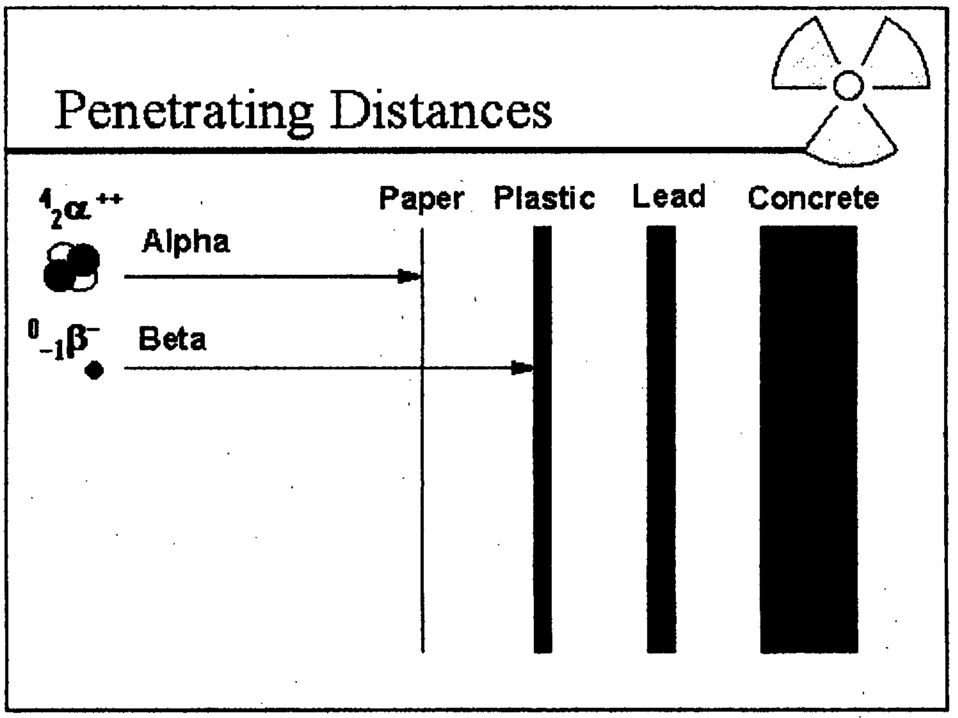
Beta Particle Radiation



(diagram courtesy of the University of Michigan Student Chapter of the Health Physics Society)

A **beta particle** is an electron emitted from the nucleus of a radioactive atom .Examples of beta emitters commonly used in biological research are: hydrogen-3 (tritium), carbon-14,phosphorus-32, phosphorus-33, and sulfur-35.

Beta particles are much less massive and less charged than alpha particles and interact less intensely with atoms in the materials they pass through, which gives them a longer range than alpha particles. Some energetic beta particles, such as those from P-32, will travel up to several meters in air or tens of mm into the skin, while low energy beta particles, such as those from H-3, are not capable of penetrating the dead layer of the skin. Thin layers of metal or plastic stop beta particles.



(diagram courtesy of the University of Michigan Student Chapter of the Health Physics Society)

All beta emitters, depending on the amount present, can pose a hazard if inhaled, ingested or absorbed into the body. In addition, energetic beta emitters are capable of presenting an external radiation hazard, especially to the skin.

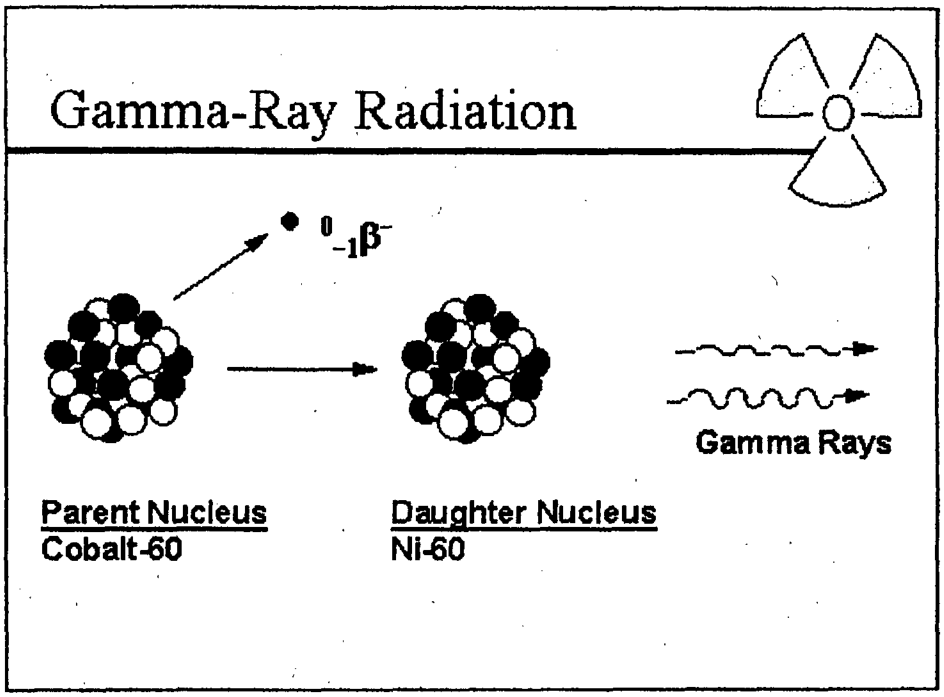
Bremsstrahlung

An important consideration in shielding beta particle radiation is the ability of beta particles to produce a secondary radiation called **bremsstrahlung**. Bremsstrahlung are x-rays produced when beta particles or other electrons decelerate while passing near the nuclei of atoms. The intensity of bremsstrahlung radiation is proportional to the energy of the beta particles and the atomic number of the material through which the betas are passing.

Consequently, bremsstrahlung radiation is generally not a concern for lower energy beta emitters such as carbon-14 and sulfur-35, but the higher energy betas from phosphorus-32 can produce significant bremsstrahlung, especially when passing through shielding materials such as lead. Lower atomic number materials such as Plexiglas are preferred shielding materials for high energy emitters such as phosphorus-32.

Return to the Top

Gamma Ray Radiation

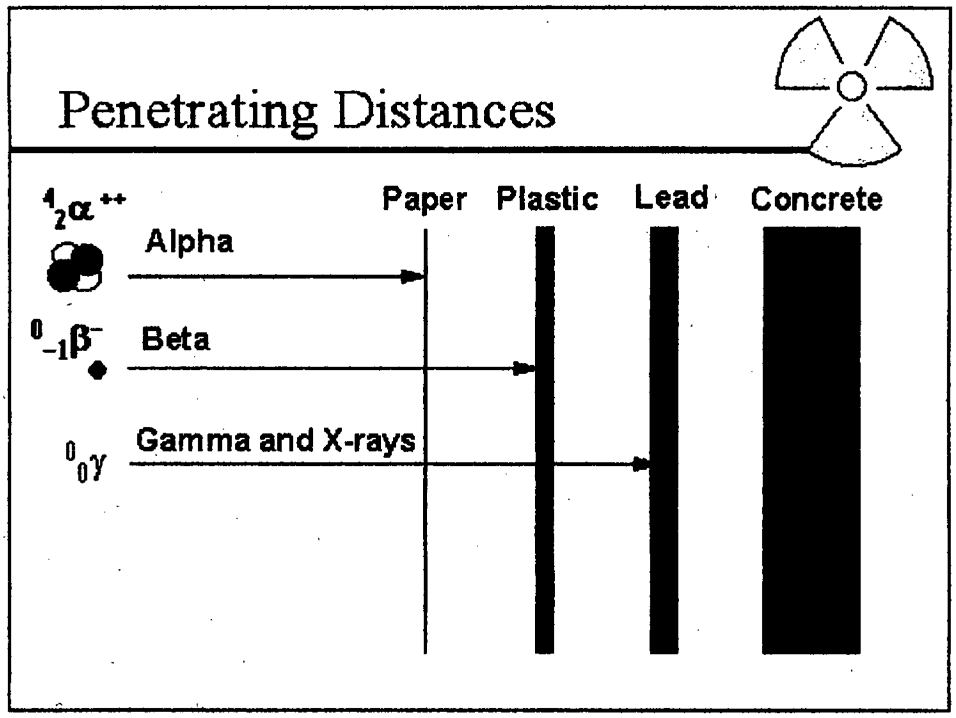


(diagram courtesy of the University of Michigan Student Chapter of the Health Physics Society)

A **gamma ray** is a packet (or photon) of electromagnetic radiation emitted from the nucleus during radioactive decay and occasionally accompanying the emission of an alpha or beta particle. Gamma rays are identical in nature to other electromagnetic radiations such as light or microwaves but are of much higher energy.

Examples of gamma emitters are cobalt-60, zinc-65, cesium-137, and radium-226.

Like all forms of electromagnetic radiation, gamma rays have no mass or charge and interact less intensively with matter than ionizing particles. Because gamma radiation loses energy slowly, gamma rays are able to travel significant distances. Depending upon their initial energy, gamma rays can travel tens or hundreds of meters in air.



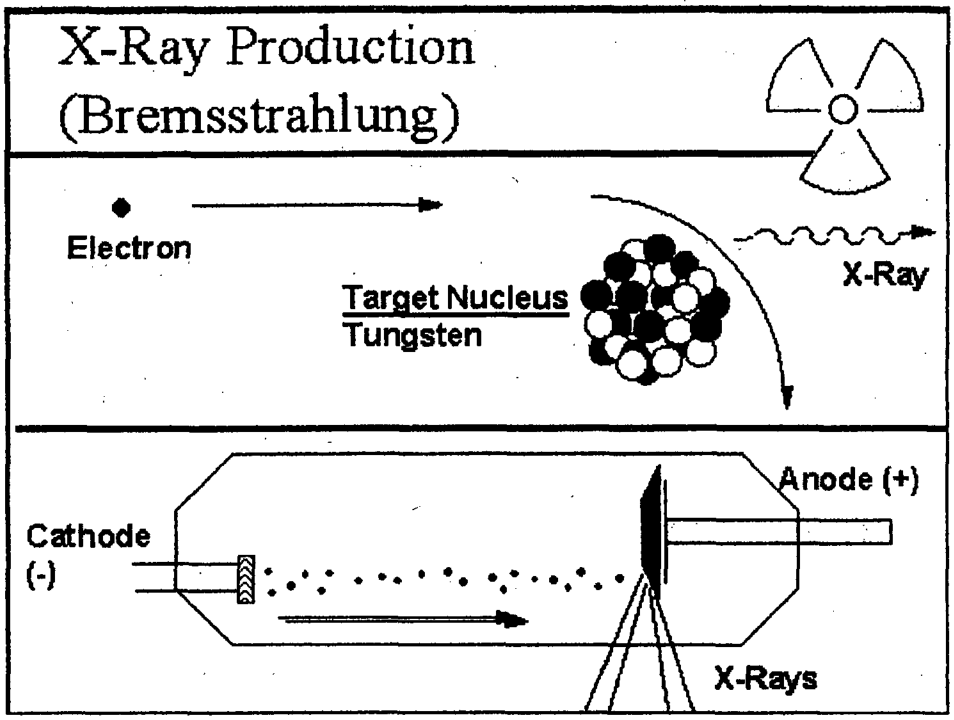
(diagram courtesy of the University of Michigan Student Chapter of the Health Physics Society)

Gamma radiation is typically shielded using **very dense materials** (the denser the material, the more chance that a gamma ray will interact with atoms in the material) such as lead or other dense metals.

Gamma radiation particularly can present a hazard from exposures external to the body.

Return to the Top

X-Ray Radiation



(diagram courtesy of the University of Michigan Student Chapter of the Health Physics Society)

Like a gamma ray, an **x-ray** is a packet (or photon) of electromagnetic radiation emitted from an atom, except that the x-ray is not emitted from the nucleus. X-rays are produced as the result of changes in the positions of the electrons orbiting the nucleus, as the electrons shift to different energy levels.

Examples of x-ray emitting radioisotopes are Iodine-125 and Iodine-131.

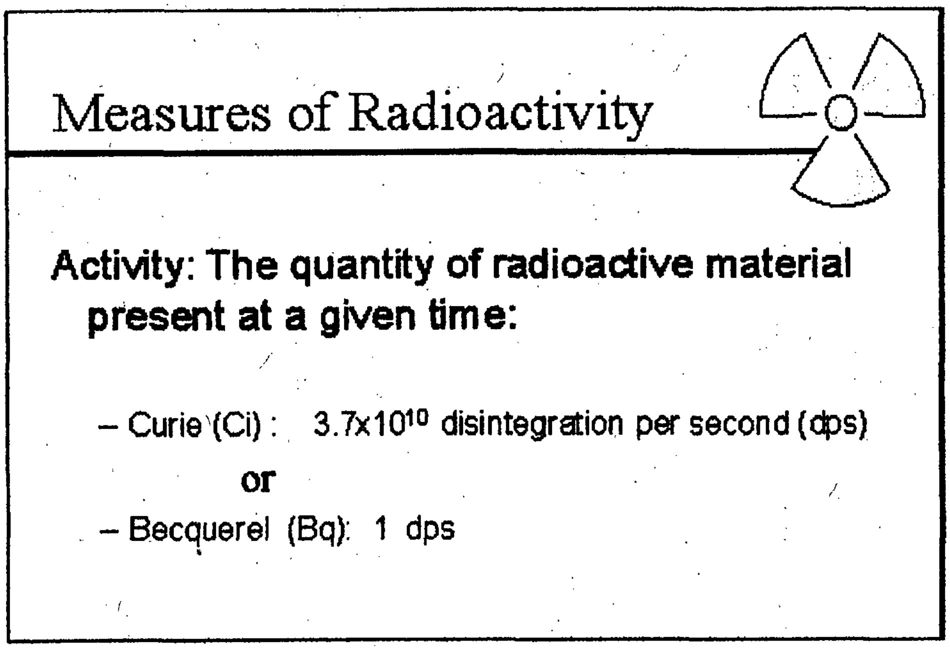
X-rays can be produced during the process of radioactive decay or as bremsstrahlung radiation. Bremsstrahlung radiation are x-rays produced when high-energy electrons strike a target made of a heavy metal, such as tungsten or copper. As electrons collide with this material, some have their paths deflected by the nucleus of the metal atoms. This deflection results in the production of x-rays as the electrons lose energy. This is the process by which an x-ray machine produces x-rays.

Like gamma rays, x-rays are typically shielded using **very dense materials** such as lead or other dense metals.

X-rays particularly can present a hazard from exposures external to the body.

Return to the Top

Radiation Measurement



(diagram courtesy of the University of Michigan Student Chapter of the Health Physics Society)

Quantity

The **quantity** of radioactive material present is generally measured in terms of **activity** rather than mass, where activity is a measurement of the number of radioactive disintegrations or transformations an amount of material undergoes in a given period of time. Activity is related to mass, however, because the greater the mass of radioactive material, the more atoms are present to undergo radioactive decay.

The two most common units of activity are the **Curie** or the **Becquerel** (in the SI system).

1 Curie (Ci) = 3.7×10^{10} disintegrations per second (dps)

1 Becquerel (Bq) = 1 disintegration per second (dps).

Obviously, 1 Curie is a large amount of activity, while 1 Becquerel is a small amount. In the typical Princeton University laboratory, millicurie and microcurie (or kilo and MegaBecquerel) amounts of radioactive material are used.

1 millicurie = 2.2×10^9 disintegrations per minute (dpm) = 3.7×10^7 ~~Bq = 37 MBq~~

1 microcurie = 2.2×10^6 dpm = 3.7×10^4 Bq = 37 kBq

Intensity

For the purposes of radiation protection, it is not always useful to describe the potential hazard of a radioactive material in terms of its activity. For instance, 1 millicurie of tritium a centimeter from the body poses a much different hazard than 1 millicurie of phosphorus-32 a centimeter from the body.

Consequently, it is often preferable to measure radiation by describing the effect of that radiation on the materials through which it passes. The three main quantities which describe radiation field intensity are shown in the following table:

Quantity	Unit	What is measured	Amount
Exposure	Roentgen (R) Coulombs/kg	Amount of charge produced in 1 kg of air by x- or gamma rays	1 R = 2.58 x 10^{-4} Cb/kg
Absorbed Dose	rad Gray (Gy)	Amount of energy absorbed in 1 gram of matter from radiation	1 rad = 100 ergs*/gram 1 Gy = 100 rad
Dose Equivalent	Rem Sievert (Sv)	Absorbed dose modified by the ability of the radiation to cause biological damage	rem = rad x Quality Factor 1 Sv = 100 rem

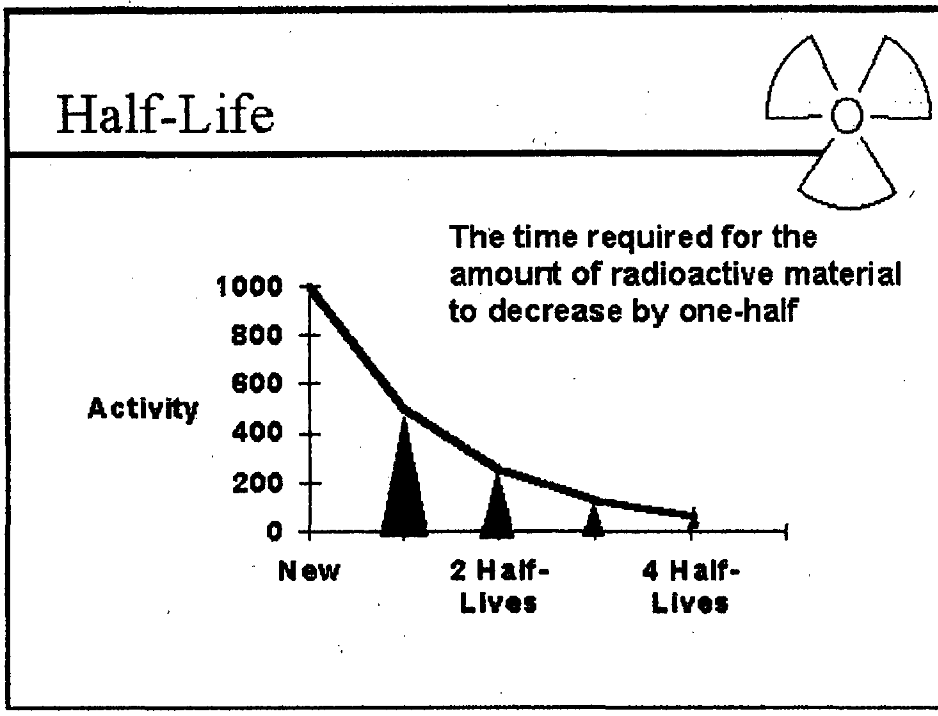
* An erg is a unit of work.

Coulombs/kilogram, the Gray, and the Sievert are the SI units for these quantities.

Go to more detailed information about the meaning of these quantities and units

Return to the Top

Half-Life



(diagram courtesy of the University of Michigan Student Chapter of the Health Physics Society)

Radioactive materials decay at exponential rates unique to each radioisotope. **Half-life** is the time required for a given amount of some radioactive material to be reduced to one-half of its original activity.

The half-life values for radioisotopes vary widely. For example, the following table shows half-lives for radioisotopes commonly used at Princeton University:

Radioisotope	**Half-Life**
Hydrogen-3	12.3 years
Carbon-14	5730 years
Phosphorus-32	14.3 days
Phosphorus-33	25.3 days
Sulfur-35	87.6 days
Iodine-125	60.1days

Go to an on-line calculator that will calculate the activity of these common radionuclides at any elapsed time

Return to the Top

This is the end of the Radiation Basics Module, which is the first of four Radiation Basics modules. The next module is the Background Radiation & Other Sources of Exposure Module.

Go to Module 2 (Background Radiation)

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Open Source Training Modules

Introduction
Radiation Properties
Background Radiation
Biological Effects
Regulations
External & Internal Dose Limits
Radiation Monitoring
Radiation Basics Test

Open Source Radiation Safety Training

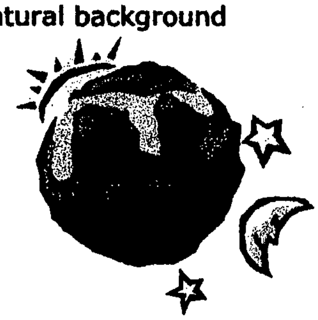
Module 2: Background Radiation & Other Sources of Exposure

This module provides information about the following topics:

Natural background radiation
Radioactivity in the earth
Cosmic radiation
Natural radioactivity in the body
Radiation doses to the U.S. population
Average doses from some common activities

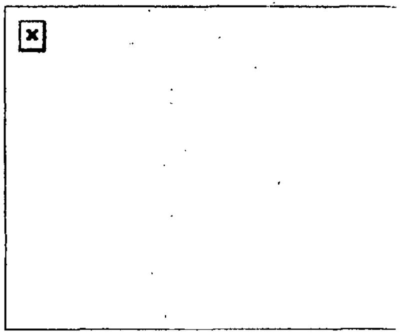
Natural Background Radiation (top)

We are all exposed to ionizing radiation from natural sources at all times. This radiation is called natural background radiation, and its main sources are the following:



- Radioactive substances in the earth's crust
- Emanation of radioactive gas from the earth
- Cosmic rays from outer space which bombard the earth
- Trace amounts of radioactivity in the body

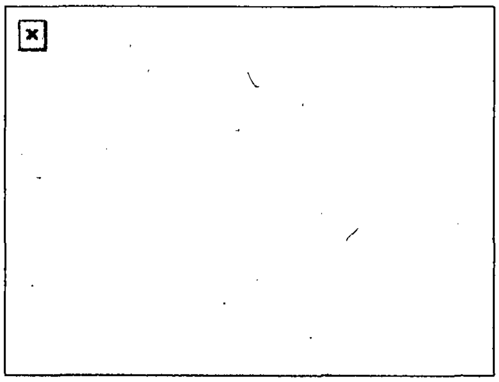
Radioactivity in the Earth (top)



many radioactive isotopes. Since then, all the shorter lived isotopes have decayed. Only those isotopes with very long half lives (100 million years or more) remain, along with the isotopes formed from the decay of the long lived isotopes.

These naturally-occurring isotopes include uranium and thorium and their decay products, such as radon. The presence of these radionuclides in the ground leads to both external gamma ray exposure and internal exposure from radon and its progeny.

Cosmic Radiation (top)



Cosmic rays are extremely energetic particles, primarily protons, which originate in the sun, other stars and from violent cataclysms in the far reaches of space. Cosmic ray particles interact with the upper atmosphere of the earth and produce showers of lower energy particles. Many of these lower energy particles are absorbed by the earth's atmosphere. At sea level, cosmic radiation is composed mainly of muons, with some gamma-rays, neutrons and electrons.

Because the earth's atmosphere acts as a shield, the exposure of an individual to cosmic rays is greater at higher elevations than at sea level. For example, the annual dose from cosmic radiation in Denver is 50 millirem while the annual dose at sea level is 26 millirem

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Natural Radioactivity in the Body (top)

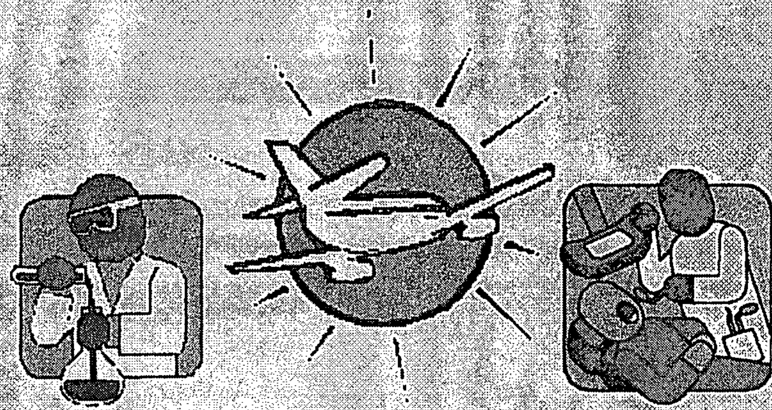
Small traces of many naturally occurring radioactive materials are present in the human body. These come mainly from naturally radioactive isotopes present in the food we eat and in the air we breathe.

These isotopes include tritium (H-3), carbon-14 (C-14), and potassium-40 (K-40).

Radiation Doses to the U.S. Population (top)

Radiation Source	Average Annual Whole Body Dose (millirem/year)
Natural: Cosmic	29
Terrestrial	29
Radon	200
Internal (K-40, C-14, etc.)	40
Manmade: Diagnostic X-ray	39
Nuclear Medicine	14
Consumer Products	11
All others: Fallout, air travel, occupational, etc.	2
Average annual total	360 millirem/year
Tobacco (if you smoke, add ~280 millirem)	

Average doses from some common activities (top)



Activity	Typical Dose
Smoking	280 millirem/year
Using radioactive materials in a Princeton University lab	**<10 millirem/year**
Dental x-ray	10 millirem per x-ray
Chest x-ray	8 millirem per x-ray
Drinking water	5 millirem per year
Cross country round tip by air	5 millirem per year
Coal burning power plant	0.165 millirem/year

This is the end of the Natural Background Radiation Module, which is the second of the six Open Source Radiation Basics modules. The next module is the Biological Effects Module.

Go to Module 3 (Biological Effects)

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Open Source Training Modules

Introduction
Radiation Properties
Background Radiation
Biological Effects
Regulations
External & Internal Dose Limits
Radiation Monitoring
Radiation Basics Test

Open Source Radiation Safety Training

Module 3: Biological Effects

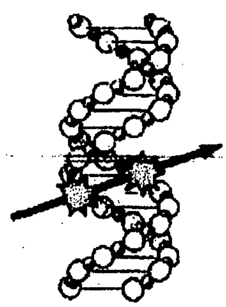
This module provides information about the following topics:

- Mechanisms of Damage
- Tissue Sensitivity
- Prompt vs. Delayed Effects
- Prompt Effects Table
- Partial Body Exposure
- Delayed Effects
- Process of Determining Cancer Risk
- Cancer Risk Estimates
- Risk Perspectives
- Genetic Effects
- Prenatal Radiation Exposure

Mechanisms of Damage

Injury to living tissue results from the transfer of energy to atoms and molecules in the cellular structure. Ionizing radiation causes atoms and molecules to become ionized or excited. These excitations and ionizations can:

- Produce free radicals.
- Break chemical bonds.
- Produce new chemical bonds and cross-linkage between macromolecules.
- Damage molecules that regulate vital cell processes (e.g. DNA, RNA, proteins).



The cell can repair certain levels of cell damage. At low doses, such as that received every day from background radiation, cellular damage is rapidly repaired.

At higher levels, cell death results. At extremely high doses, cells cannot be replaced quickly enough, and tissues fail to function.

Return to the Top

Tissue Sensitivity

In general, the radiation sensitivity of a tissue is:

- proportional to the rate of proliferation of its cells
- inversely proportional to the degree of cell differentiation

For example, the following tissues and organs are listed from most radiosensitive to least radiosensitive:

Most Sensitive: Blood-forming organs
Reproductive organs
Skin
Bone and teeth
Muscle
Least sensitive: Nervous system

This also means that a developing embryo is most sensitive to radiation during the early stages of differentiation, and an embryo/fetus is more sensitive to radiation exposure in the **first** trimester than in later trimesters.

Return to the Top

Prompt and Delayed Effects

Radiation effects can be categorized by **when** they appear.

- **Prompt effects:** effects, including radiation sickness and radiation burns, seen immediately after large doses of radiation delivered ove[r] short periods of time.
- **Delayed effects:** effects such as cataract formation and cancer induction that may appear months or years after a radiation exposure

Return to the Top

Prompt Effects

High doses delivered to the whole body of healthy adults within short periods of time can produce effects such as blood component changes, fatigue, diarrhea, nausea and death. These effects will develop within hours, days or weeks, depending on the size of the dose. The larger the dose, the sooner a given effect will occur.

Effect	Dose
Blood count changes	50 rem
Vomiting (threshold)	100 rem
Mortality (threshold)	150 rem
$LD_{50/60}$* (with minimal supportive care)	320 - 360 rem
$LD_{50/60}$ (with supportive medical treatment)	480 - 540 rem
100% mortality (with best available treatment)	800 rem

(Adapted from NCRP Report No. 98 "Guidance on Radiation Received in Space Activities, NCRP, Bethesda, MD (1989))

* The $LD_{50/60}$ is that dose at which 50%of the exposed population will die within 60 days.

Go to to optional information to see how these dose levels compare with federal dose limits and University investigational levels

Return to the Top

Partial Body Exposure

These acute effects apply only when the whole body is relatively uniformly irradiated. The effects can be significantly different when only portions of the body or an individual organ system are irradiated, such as might occur during the use of radiation for medical treatment. For example, a dose of 500 rem delivered uniformly to the whole body may cause death while a dose of 500 rem delivered to the skin will only cause hair loss and skin reddening.

Go to optional information about how specific organ systems respond to acute exposure

Return to the Top

Delayed Effects of Radiation Exposure

Cataracts

- Cataracts are induced when a dose exceeding approximately 200-300 rem is delivered to the lens of the eye. Radiation-induced cataracts may take many months to years to appear.

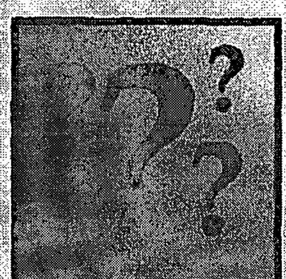
Cancer

- Studies of people exposed to high doses of radiation have shown that there is a risk of cancer induction associated with high doses.
- The specific types of cancers associated with radiation exposure include leukemia, multiple myeloma, breast cancer, lung cancer, and skin cancer.
- Radiation-induced cancers may take 10 - 15 years or more to appear.
- There **may** be a risk of cancer at low doses as well. The following frames discuss the risk of cancer at lower doses.

Return to the Top

The Process of Determining Cancer Risk

Why cancer risks at low doses are uncertain



It has been difficult to estimate cancer induction risks, because most of the radiation exposures that humans receive are very close to background levels. At low dose levels of millirems to tens of rems, the risk of radiation-induced cancers is so low, that **if** the risk exists, it is not readily distinguishable from normal levels of cancer occurrence. *In addition*, leukemia or solid tumors induced by radiation are indistinguishable from those that result from other causes.

Go to optional information about radiation-induced cancer risk studies

Return to the Top

Cancer Risk Estimates

Using the linear no-threshold risk model, the 1990 BEIR* V report provided the following estimate:

- The average lifetime risk of death from cancer following an acute dose equivalent to all body organs of 0.1 Sv (10 rem) is estimated to be 0.8%. This increase in lifetime risk is about 4% of the current baseline risk of death due to cancer in the United States. The current baseline risk of cancer induction in the United States is approximately **25%.**

Another way of stating this risk:

- A dose of **10 mrem** creates a risk of death from cancer of approximately **1 in 1,000,000.**

* The National Academy of Sciences Committee on the Biological Effects of Ionizing Radiation
(the BEIR Committee)

Go to a more detailed excerpt from the BEIR V report

Return to the Top

Putting Risk into Perspective

One way of considering the level of a risk is to look at the number of "days lost" out of a population due to early death from a given cause, then distributing those days lost over the population to get an "average life expectancy lost" due to that cause. The following table provides an estimate of life expectancy lost due to several causes:

Health Risk	Estimated Life Expectancy Lost
Smoking 20 cigarettes a day	6 years
Overweight by 15%	2 years
Alcohol (US average)	1 year
all accidents	207 days
All natural hazards	7 days
Occupational dose of 300 mrem/year	15 days

Source: these estimates are taken from NRC Draft Guide DG-8012 and were adapted from B L. Cohen and L. S. Lee, "Catalogue of Risks Extended and Updates," *Health Physics*, Vol. 61, September 1991.

You can also look at risk by considering the Relative Risk of a **1 in a million** chance of death from activities common to our society:

- Smoking 1.4 cigarettes in a lifetime (lung cancer)
- Eating 40 tablespoons of peanut butter (aflatoxin)
- Spending two days in New York City (air pollution)

- Driving 40 miles in a car (accident)
- Flying 2500 miles in a jet (accident)
- Canoeing for 6 minutes (drowning)
- Receiving a dose of 10 mrem of radiation (cancer)

(Adapted from DOE Radiation Worker Training based on work by B.L. Cohen, Sc.D.)

Return to the Top

Genetic Effects

There is no direct evidence of radiation-induced genetic effects in humans, even at high doses. Various analyses indicate that the rate of genetic disorders produced in humans is expected to be extremely low, on the order of a few disorders per million live born per rem of parental exposure.

Return to the Top

Prenatal Radiation Exposure

Rapidly proliferating and differentiating tissues are most sensitive to radiation damage. Consequently, radiation exposure can produce developmental problems, particularly in the developing brain, when an embryo/fetus is exposed prenatally.

The developmental conditions most commonly associated with prenatal radiation exposure include low birth weight, microcephaly, mental retardation, and other neurological problems. These effects are related to the developmental stage at which the exposure occurs. The threshold dose for developmental effects is approximately **10 rem.**

The evidence that the developing embryo/fetus is more sensitive to radiation-induced cancer is inconclusive. But it is prudent to assume that there is some increased sensitivity.

Go to more detailed information about the Princeton University program to control prenatal radiation exposures (the Declared Pregnant Worker Program)

Return to the top

This is the end of the Biological Effects Module, which is the third of the four Radiation Basics modules. The next module is the Regulations Module.

Go to Module 4 (Government Regulations and the Radiation Safety Program)

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Open Source Training Modules

Introduction
Radiation Properties
Background Radiation
Biological Effects
Regulations
External & Internal Dose Limits
Radiation Monitoring
Radiation Basics Test

Open Source Radiation Safety Training

Module 4: Government Regulations and the Radiation Safety Program

This module provides information about the following topics:

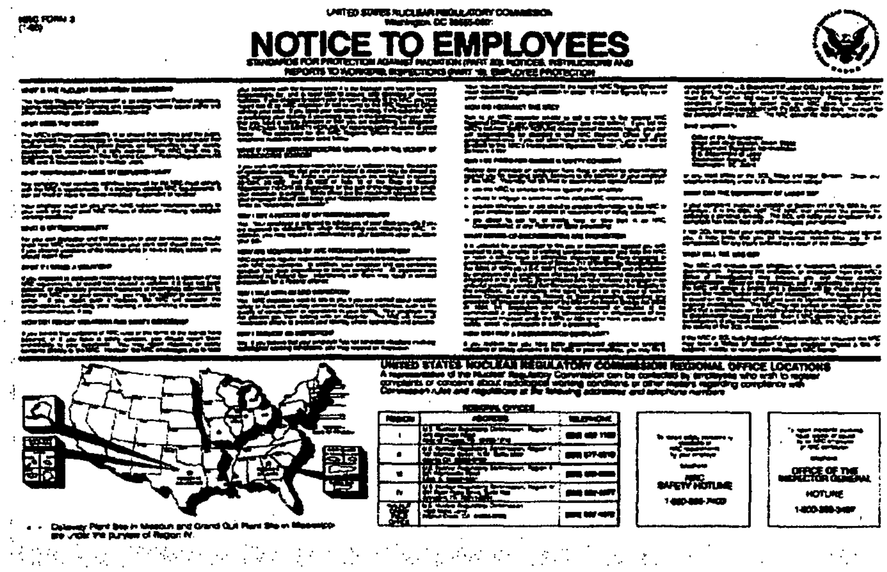
- Regulations
- University Licenses
- Inspections and Audits
- the Radiation Safety Program
- Radiation Safety Committee
- Environmental Health & Safety Office
- Authorized Users
- Radiation Workers

Regulations

Princeton University is licensed by the U.S. Nuclear Regulatory Commission (NRC) and by the New Jersey Department of Environmental Protection (NJDEP) to possess and use many different radioisotopes. The use of most radioisotopes at the University is regulated by the NRC, while the NJDEP regulates the more limited use of accelerator-produced and naturally-occurring radioactive materials.

The NRC Regulations are contained in Title 10 of the Federal Code of Regulations. NJDEP regulations are contained in Chapter 28 of the New Jersey Administrative Code. Copies of the relevant regulations are available from EHS and from the NRC Web site.

A " Notice to Employees" is posted in common places where employees frequently pass. The Notice provides information about how to contact the NRC or NJDEP and describes workers' rights and responsibilities.



NOTICE TO EMPLOYEES

Click on image above for a more detailed view of the form.

Return to the Top

University Licenses

The University currently holds the following licenses to possess and use radioactive materials:

- **NRC Broad License** covering the use of most radioisotopes on campus
- **N. J. State License** for the use of naturally-occurring and accelerator-produced radioisotopes.

These licenses are issued by the NRC and/or NJDEP and specify the quantities, locations, and conditions under which radioisotopes may be used at Princeton University. They require the University to establish policies and procedures to ensure the accountability and safe use of radioactive materials. Copies of these licenses are available from EHS.

Return to the Top

Inspections and Audits

Regulatory Agency Inspections

The NRC and NJDEP each conduct periodic unannounced inspections of the use of radioactive materials at the University. If violations of the regulations or radiation safety program deficiencies are discovered, Notices of Violations may be issued against the University, and fines and other sanctions can be imposed.

Internal Audits

The Princeton University Radiation Safety Committee conducts an annual audit of the radiation safety program, which includes a review of the program and visits to selected laboratories.

Return to the Top

Princeton University's Radiation Safety Program

To meet the requirements of the NRC and NJDEP and to provide a safe working environment, Princeton University has established a radiation safety program with four key components:

- The Radiation Safety Committee
- The Environmental Health and Safety Office
- The Authorized User
- The Radiation Worker

The roles and responsibilities of each are described in the following sections.

Return to the Top

The Radiation Safety Committee

The Radiation Safety Committee, which consists of faculty members, EHS radiation safety staff, and management representatives, meets several times a year. The Committee:

- oversees the radiation safety program
- authorizes the use of radioactive materials
- reviews incidents involving radioactive materials
- sets policies for the use of sources of radiation
- gives general supervision to the implementation of those policies.

Return to the Top

The Environmental Health and Safety Office

The day-to-day operation of the radiation safety program is managed within the Environmental Health & Safety Office (EHS) by the University's Radiation Safety Officer (RSO). The RSO and the Radiation Safety staff advise Authorized Users and radiation workers on radiation safety and regulatory compliance issues and provide the following services:

- radiation safety training
- personal monitoring and dosimetry services
- bioassay
- radiation safety assessment for pregnant radiation workers
- laboratory radiation and contamination surveys
- incident, spill and contamination management
- radioactive waste disposal management

Return to the Top

The Authorized User

Authorized Users are faculty or senior staff members who have been approved by the Radiation Safety Committee to use radioactive materials under specific conditions. An Authorized User is granted approval to possess and use specific isotopes only for the uses described in the authorization application and is issued a possession limit for each of those isotopes.

Any person using radioactive materials at Princeton University is either an Authorized User or is a radiation worker using radioactive materials under an Authorized User's supervision.

Each Authorized User is responsible for:

- the health and safety of anyone using or affected by the use of radioactive materials under his or her direction or supervision
- personally attending initial and annual refresher training and ensuring that his/her employees, staff and visitors receive appropriate training
- ensuring that his/her employees, staff and visitors comply with relevant regulations, policies and procedures.

Return to the Top

The Radiation Worker

A radiation worker is anyone who uses radioactive materials or radiation-producing machines. The radiation worker's thorough training, compliance with regulations and procedures, careful work habits and respect for the health and safety of fellow workers are an integral part of the radiation safety program.

A radiation worker's responsibilities include the following:

- Attend an initial radiation safety training class and annual refresher radiation safety training offered by EHS.

- Be familiar with the isotopes in use; know their radiological, physical and chemical properties, methods of detection, the types of hazards presented by each one, and the specific precautions and handling requirements for each isotope.
- Be familiar with all the relevant procedures of the radiation safety program, including isotope purchasing and waste disposal procedures.
- Know how to properly use the appropriate radiation survey meter.
- Know how to use radiation monitoring badges and exchange them promptly at the end of the monthly or quarterly wear period.
- Maintain appropriate inventory, disposal and survey records.
- Secure radioactive materials by making sure that radioactive materials are locked away or are under immediate supervision within the laboratory.
- Inform coworkers and visitors to the work area about the presence of radioactive materials and of any precautions they should take.
- Know who to call in any incident involving sources of radiation and how to handle spills and personal contamination.

This is the end of the Government Regulations Module, which is the fourth of the six Open Source Radiation Basics modules. The next module is the External & Internal Dose Limits Module.

Go to Module 5 (External & Internal Dose Limits)

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Introduction
Radiation Properties
Background Radiation
Biological Effects
Regulations
External & Internal Dose Limits
Radiation Monitoring
Radiation Basics Test

Open Source Radiation Safety Training

Module 5: External & Internal Dose Limits

Overview of the Module

This module provides information about the following topics:

- Annual Radiation Dose Limits
- As Low As Reasonably Achievable (ALARA)
- Annual Limits of Intake
- Declared Pregnant Worker Program

Annual Radiation Dose Limits

The Nuclear Regulatory Commission (NRC) and the New Jersey Department of Environmental Protection (NJDEP) have established dose limits which are based on recommendations from national and international commissions. The table below lists the limits set by the NRC:

Organ	NRC Limit (mrem/year)	University investigation level (mrem)	Comments
			Includes dose from both internal and external sources. The Whole Body limit applies to exposure of the torso and head

Whole Body	5000	100	when the radiation is penetrating enough to irradiate tissues at a depth of 1 cm where the deeper blood-forming tissues are located.
Lens of the Eye	15,000	300	The Lens of the Eye limit applies to exposure of the eye to radiation penetrating enough to irradiate the lens, at a depth of 0.3 cm.
Extremities	50,000	1000	The extremities include the arm or leg below the elbow or knee. The Extremities limit applies to exposure of the extremities when the radiation is penetrating enough to irradiate tissues at a depth of 1 cm.
Skin	50,000	1000	The Skin limit applies to dose deposited in the skin when the radiation is penetrating enough to irradiate tissues at a depth of 0.007 cm.
Embryo/Fetus	500 (for the entire pregnancy)	50	Applies only when a Declaration of Pregnancy has been submitted
Occupational exposure of a minor	10% of the limits above	50	Applies to anyone under 18 years of age
Member of the general public	100	50	

NJDEP Limits

NJDEP limits apply only to workers who use radiation-producing machine users and the few radioactive materials licensed by NJDEP. NJDEP limits do not differ greatly from NRC limits.

Go to information about NJDEP dose limits

Investigational Levels

S-35	10	20
I-125	0.04	0.06

Return to the Top

Declared Pregnant Worker Program

This section provides a general overview of the Declared Pregnant Worker Program. More detailed information about the program is available in Section 6 of the *Radiation Safety Manual for Laboratory Workers.*

The NRC's Fetal Dose Regulations apply only to a woman who has voluntarily informed her employer, **in writing**, of her pregnancy and the estimated date of conception. The dose to the fetus resulting from occupational exposure of a declared pregnant woman may not exceed 500 mrem for the entire pregnancy.

Submitting a Declaration of Pregnancy
Any radiation worker who is pregnant or believes that she may be pregnant should contact EHS. All inquiries will be kept in confidence. EHS will take the following steps:

- Provide an opportunity to submit a Declaration of Pregnancy. (A Declaration of Pregnancy form is included in the Radiation Safety Manual or may be obtained from EHS.
- Provide information concerning risk of fetal radiation exposure.
- Evaluate the worker's dose history and exposure potential.
- Make recommendations for reducing radiation exposure.
- Monitor the worker's radiation dose with regard to worker and fetal dose limits.

For the type of radiation work performed at Princeton University, it is rarely necessary to recommend reassignment or changes to job duties.

If a written declaration of pregnancy is not submitted to EHS, then the worker's dose continues to be controlled under the normal dose limits for radiation workers.

Go to detailed information about Princeton University's Declared Pregnant Worker Program

Return to the Top

This is the end of the Dose Limit Module, which is the fifth of the six Radiation Basics modules.

Go to Module 6 (Radiation Monitoring Badges)

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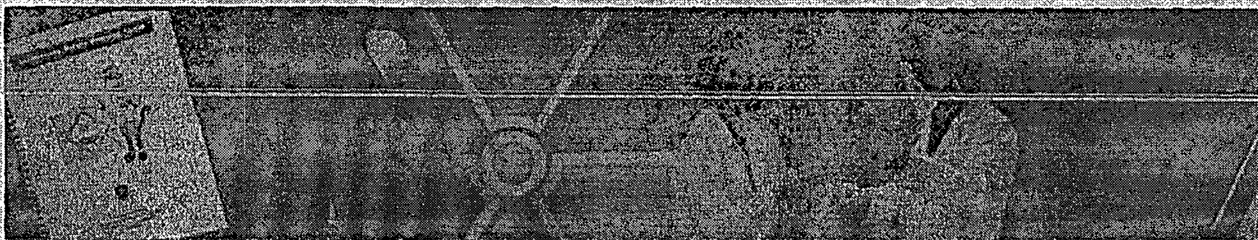
Environmental Health

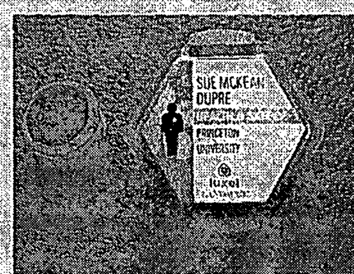


Open Source Training Modules

Introduction
Radiation Properties
Background Radiation
Biological Effects
Regulations
External & Internal Dose Limits
Radiation Monitoring
Radiation Basics Test

Open Source Radiation Safety Training

Module 6: Radiation Monitoring Badge Program



Overview of the Module

This module provides information about the following topics:

- Purpose of Radiation Monitoring
- When Radiation Monitoring Badges Are Required
- When Radiation Monitoring Badges Are Not Issued
- Dose History at Princeton University
- Internal Monitoring

Purpose of Radiation Monitoring

At Princeton University, radiation monitor badges are provided to monitor occupational radiation exposure for those workers who use radiation sources under certain conditions. Princeton University monitor badges should not be used to measure occupational doses received at any other institution or to measure doses from non-occupational sources such as medical x-rays.

Return to the top

When Radiation Monitoring Badges Are Required

State and federal regulations require that those persons who are likely to receive 10% or more of the Annual Radiation Dose Limits must be provided with radiation monitoring badges. This means that federal regulations require monitoring for any person likely to receive a whole body dose of 500 millirem or more or a skin or hand dose of 5000 millirem or more. Additionally, the State of New Jersey requires monitoring of finger exposures for persons working with analytical x-ray machines.

Under Princeton University requirements, you must wear radiation monitoring badges if:

- You operate x-ray machines (including x-ray diffraction equipment and the Molecular Biology Department Faxitronic cabinet x-ray system)
- You are a Declared Pregnant Worker working in a lab where x-ray and gamma emitters or energetic beta emitters are used
- If you use radioactive materials under the following conditions:

Open Sources	
P-32 (and other beta emitters with energies ≥ 250 keV)	Used in amounts of **5 mCi or more** for extended operations. Not required for simple aliquoting from a stock vial
I-125 and Cd-109 (and other x-ray or gamma emitters with energies ≤ 100 keV)	Used in amounts of **1 mCi or more** for extended operations. Not required for simple aliquoting from a stock vial
Cr-51, Co-57, Fe-59 and Zn-65 (and other x-ray or gamma emitters with energies ≥ 100 keV)	Used in amounts of **0.5 mCi or more** for extended operations. Not required for simple aliquoting from a stock vial
Sealed Sources	
Co-60, Cs-137 and Ra-226 and other energetic beta/gamma emitters	Used in amounts ≥ 0.1 mCi

Examples of how the dosimetry criteria are applied

- If your lab receives a 5 mCi vial of P-32 and you briefly handle the 5 mCi vial to withdraw an aliquot of 100 uCi, you **are not** required to wear monitoring badges.

- If you order 5 mCi of P-32 and you perform a synthesis using the entire 5 mCi, you **are** required to wear monitoring badges.

Temporary Badges
Temporary badges are available for workers whose high-level radioisotope use is sporadic. EHS maintains a large supply of temporary badges and can supply you with a temporary badge the same day that you request one.

More Information about Monitoring Badges
Additional information about monitoring badges and about using and wearing them is available in an optional Using and Wearing Monitoring Badges Module (you will **not** be tested on the information in the Using and Wearing Radiation Monitoring Badges page).

Return to the top

When Radiation Monitoring Badges Are Not Issued

Monitoring badges are not routinely provided to workers who do not meet the criteria described in the Required Monitoring section. For example, you will not be routinely provided with badges if:

- You only use H-3, C-14, P-33 or S-35
- You use P-32 in amounts less than 5 mCi
- You use I-125 in amounts less than 1 mCi

If you have concerns about your radiation exposure and would like to be monitored even though you do not meet the Required Monitoring Badge criteria, you may either contact EHS directly or you may ask your Authorized User or your lab manager to request badges for you. If you request badges even though you do not meet the Required Monitoring Badge criteria, badges will be provided for you for a year. After the first year of monitoring, EHS will meet with you to review your dose history and to discuss whether monitoring badges should be continued.

Return to the top

Dose History at Princeton University

In 2000 Princeton University implemented the radiation monitoring badge criteria described in the sections above. Prior to the implementation of the current badging criteria and over the last 30 years, Princeton University provided radiation monitoring badges to many more workers than we currently do. Prior to 2000, Princeton University provided monitoring badges to about 600-800 people a year. Typically, 90% of all monitored persons received no measurable dose. The following table provides information about doses received during the years 1996-1999:

Year	# of People Receiving Whole Body Doses > 50 mrem	Highest WB Dose	# of People Receiving Skin/Hand Doses > 50 mrem	Highest Skin/Hand Dose

1996	5	70 mrem	11	1880 mrem to hand*
1997	7	90 mrem	21	3500 mrem to hand*
1998	7	150 mrem	19	740 mrem to hand
1999	0	< 50 mrem	1	59 mrem to skin
Note: The doses marked with an * were received by a single researcher performing frequent syntheses with 5-10 mCi of P-32 at a time with extended exposure to the entire 5-10 mCi.				

During this period of time, no one received a dose high enough to require monitoring under federal regulations.

Return to the top

Internal Monitoring

More detailed information about internal monitoring procedures is available in Section 6 of the *Radiation Safety Manual for Laboratory Workers*. If you use radioactive materials under circumstances where there is a reasonable likelihood of taking up radioactive material internally, EHS will contact you to make arrangements to conduct bioassays.

Return to the top

You've completed the last of the six Radiation Basics modules. You may now go to the test or you may go to any of the previous modules:

- Go to the Radiation Basics Test
- Go to the Radiation Safety Training Introduction
- Go to the Radiation Properties Module (Module #1)
- Go to the Background Radiation Module (Module #2)
- Go to the Biological Effects Module (Module #3)
- Go to the Government Regulations Module (Module #4)
- Go to the Dose Limits Module (Module #5)

Return to the top

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1. Alpha emitters present serious hazards when:

A. Inhaled, ingested, or injected

B. Exposed to direct sunlight

C. Placed near other radioactive materials

D. Skin is exposed to them

2. Plexiglas should be used when shielding high-energy beta emitters such as phosphorus-32:
A. To make it easier for other lab workers to see the work being done

B. Because plexiglas shields are easier to move than metal shields

C. To reduce the occurrence of bremsstrahlung radiation

D. Only when no other shielding material is available

3. Half-life is a measurement of :
A. The amount of time necessary for a given amount of radioactive material to be reduced to one-half of its original activity

B. The amount of time necessary for a given amount of radioactive material to be reduced to one-half of its original mass

C. The amount of time necessary to complete an experiment using radioactive materials

D. The amount of time necessary for a radioactive material to become non-radioactive

4. The most common units used to express the activity of a radioactive substance are:
A. Alpha and beta

B. Milligrams and micrograms

C. Curie and Becquerel

D. Roentgen and Sievert

4. As a radiation worker, you are responsible for following safe work practices and:
A. Knowing how to respond to a spill

B. Maintaining survey records

C. Securing radioactive materials

D. All of the above

E. a. and c. only

5. Which of the following will show the greatest sensitivity to radiation effects?
A. An embryo exposed in utero at 8 weeks

B. A fetus exposed in utero at 36 weeks

C. An adolescent girl

D. A 55-year old man

6. Studies have established that there is no risk of cancer below a dose of 10 rem.
A. True

B. False

7. If a group of humans are exposed to an acute dose of radiation, what dose will be lethal to 50% of the group within 60 days?
A. Approximately 500 millirem

B. Approximately 400 rem

C. Approximately 25 rem

8. The "Notice to Employees" provides information about:

A. The address and phone number of Nuclear Regulatory Commission

B. New regulations

C. The result of an inspection

9. What is the average radiation dose to the U.S. population (from all sources of exposure)?
A. 360 millirem per year

B. 10 millirem per year

C. 5.25 rem per year

10. What dose do you get from a typical chest x-ray?
A. 8 millirem per x-ray

B. 500 millirem per x-ray

C. Less radiation than you receive lying on the beach each day

11. Which group of the following radioisotopes are the naturally-occurring radioisotopes most commonly found in the human body?
A. Sulfur-35, chromium-51 and iodine-125

B. Tritium (H-3), carbon-14, and potassium-40

12. Nuclear Regulatory Commission regulations require that the occupational dose a radiation worker receives be limited to:
A. A whole body dose of no more than 5000 millirem per year

B. A whole body dose of no more than 5000 millirem for the worker's lifetime

C. A skin dose of of no more than 5 millirem per year

D. There are no specified dose limits. The NRC requires that a radiation worker's dose be limited to the lowest possible dose, in accordance with the ALARA philosophy.

13. A pregnant radiation worker:
A. Must cease use of radioactive materials while she is pregnant

B. Is not allowed to receive a fetal dose in excess of 500 millirem

C. Is required to submit a Declaration of Pregnancy to EHS

D. May voluntarily submit a Declaration of Pregnancy to EHS

14. The Annual Limit of Intake (ALI) for P-32 is 0.6 mCi. If a worker ingests 0.6 mCi of P-32, the worker will receive
A. No dose. Due to metabolic processes, ingestion of radioactive material does not contribute to radiation dose.

B. A skin dose of 50,000 millirem over the course of the worker's lifetime

C. A whole body dose of 5000 millirems over the course of the next year

D. A dose likely to cause severe physiological effects