CARLETON UNIVERSITY

RADIATION SAFETY MANUAL

JANUARY 2023

Forward

Carleton University's radioisotope activities are regulated and licensed by the Canadian Nuclear Safety Commission (CNSC). The CNSC requires radioisotope workers have training in basic radiation safety and the regulatory conditions. This manual is used for training purposes.

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REGULATORY REQUIREMENTS

Note: This section contains the author's interpretation of the regulations. For complete details please consult the actual Canadian Nuclear Safety Commission Regulations.

ABBREVIATIONS:

GN = General Nuclear Safety & Control Regulations

NS = Nuclear Substances and Radiation Devices Regulations

RP = Radiation Protection Regulations

SC = Nuclear Safety and Control Act

1 CANADIAN NUCLEAR SAFETY AND CONTROL ACT

An act of parliament relating to the development and control of nuclear energy. This act gives the Canadian Nuclear Safety Commission (CNSC) power to impose regulations on the users of nuclear and states the penalties that can be imposed for non-compliance.

2 CONSOLIDATED RADIOISOTOPE LICENCE

Carleton University operates under a Consolidated Radioisotope Licence issued by the Canadian Nuclear Safety Commission. A consolidated licence is a single broad-scope licence issued to an institution having many users of radioactive materials primarily in one location.

3 RADIATION SAFETY COMMITTEE – TERMS OF REFERENCE

Carleton University is committed to providing a safe and healthy environment for its faculty, staff, and students in which to work and study. The University has an obligation to ensure that its teaching and research activities are conducted in a responsible and accountable manner. The Radiation Safety Committee was formed as an advisory committee to monitor the use of radioactive materials and X-ray devices at the University.

3.1 COMPOSITION

Members are appointed by the Vice-President (Finance and Administration) as follows:

- Three (3) faculty members with active research involving radioactive materials, representing at least two different departments, preferably also at least two different faculties
- Two (2) staff members with work involving radioactive materials
- One (1) member from Science Stores
- One (1) member from Purchasing Services
- One (1) member from Facilities Management and Planning
- Dean, Faculty of Science
- Manager, Environmental Health and Safety
- Radiation Safety Officer.

3.2 Chair

The Chair will be appointed by the VP (Finance and Administration).

3.3 Terms of Office

The term of office will be three (3) years. Members may serve subsequent terms.
The term of the Chair will be three (3) years.

3.4 Reporting Channel

The Radiation Safety Committee is advisory to the Vice-President (Finance and Administration) and will file: annual reports, meeting minutes, and special reports as required.

3.5 Meetings

Meetings will be held once per year and as required.

A quorum is five members. Issues are decided by consensus of the members present.

3.6 Duties

The duties of the Radiation Safety Committee are as follows:

1) Oversee the radiation safety program

2) Make recommendations on radiation safety matters, including the safe use of radioactive materials and X-ray devices

3) Review annual summaries of the occupational radiation exposures received by persons to determine whether these exposures respect the ALARA principle of dose limitation

4) Review reports concerning any incidents or unusual occurrences that involve radioactive materials or X-ray devices

5) Make recommendations on matters involving contraventions of the legislation and incidents involving intentional or unintentional release of radioactive materials

6) Make recommendations for resources or support required to establish, maintain, or improve the radiation safety program

7) Maintain written records of committee activities.

4 RADIATION SAFETY OFFICER

(CNSC CONSULTATIVE DOCUMENT C-121)

4.1 Responsibilities

The Radiation Safety Officer (RSO) shall administer the consolidated radioisotope licence issued to Carleton University by the CNSC by overseeing and coordinating all aspects of radiation safety within the University.

4.2 Duties with respect to the University

The Radiation Safety Officer shall:

a) act as the agent of the University with respect to licensing matters;

b) be available to radioisotope users effectively on a full-time basis;

c) establish, implement and maintain a radiation safety control and assessment program in conjunction with the Radiation Safety Committee;

d) systematically and periodically review survey programs for radiation and contamination levels in all areas where radioactive materials are used, stored or disposed of;

e) implement a personnel monitoring program, including bioassays, when applicable;

f) ensure that radiation safety instruments are available in sufficient number and are calibrated and serviced as required;

g) conduct a quarterly review of occupational radiation exposures and recommend ways of reducing exposures in the interest of the ALARA principle;

h) supervise decontamination procedures;

i) provide waste-disposal procedures in accordance with conditions of the radioisotope licence;

j) ensure that necessary leak testing of sealed sources is performed;

k) control the purchasing, use and disposal of radioactive materials via enforcement of conditions of user permits;

l) ensure that appropriate radiation protection training is provided on a regular basis as part of an ongoing “radiation protection awareness program” for all users, as well as for those who occasionally come into contact with radioactive materials (i.e., cleaning staff, maintenance people);

m) maintain required records;

n) ensure that each user permit is amended when necessitated by changes to facilities, equipment, policies, isotopes, conditions of use, procedures or personnel;

o) coordinate the development of plans to be used in the case of an emergency involving radioactive materials;

p) investigate all overexposures, accidents and losses of radioactive materials and report to the CNSC, when necessary; and

q) liaise with radioisotope users to ensure that the doses of radiation are consistent with the ALARA principle.

4.3 Duties with Respect to the Radiation Safety Committee

The Radiation Safety Officer shall:

a) function as the link between the Radiation Safety Committee and radioisotope users within the institution;

b) prepare, or review in consultation with the Radiation Safety Committee, a comprehensive Radiation Safety Manual;

c) have a major input in matters pertaining to:

    i) facility and equipment design,

    ii) work practices and procedures,

    iii) waste storage and disposal management,

    iv) evaluation, issuance and enforcement of user permits,

    v) disciplinary action necessitated by non-compliance, and

    vi) radiation safety training; and

d) prepare an annual report for the CNSC as required by CNSC licence.

5 Responsibilities of Permit Holders

Permit holders are responsible for:

a) ensuring that the conditions stated in the permit are fulfilled and that safe laboratory practices are followed (see Appendices B1 and B2);

b) ensuring that all staff using radioactive materials have been authorized to use these radioactive materials;

c) ensuring that all staff using radioisotopes have been issued, and wear, a thermoluminescent dosimeter and participate in bioassay programs, if required;

d) designating specific work and storage areas for radioactive materials and ensuring that these areas are kept clean, are properly labelled, have adequate ventilation, and are adequately shielded (see CNSC Regulatory Document R-52 (Rev. 1);

e) ensuring that all staff using radioactive materials have received adequate radiation protection training from the University and have been informed of the risks associated with exposure to ionizing radiation. Further, permit holders are responsible for the provision of specific training in radioisotope handling that is necessary for the safe use of the radioisotopes in their laboratories;

f) maintaining inventories of all radioactive materials, as well as storage and disposal records;

g) maintaining all area monitoring and/or wipe test records; and

h) reporting all radiation incidents (including loss or theft of radioactive material) to the Radiation Safety Officer.

6 RESPONSIBILITIES OF USERS

Users must:

a) be aware of and comply with all conditions of the internal radioisotope permit, laboratory rules, and other procedures identified in the Radiation Safety Manual;

b) perform work in a manner that will minimize radiation exposure to all laboratory personnel; and

c) report to the permit holder or RSO any incident involving a known or suspected radiation exposure, contamination that may exceed established limits, or loss or theft of radioactive material.

7 NUCLEAR ENERGY WORKER (NEW) [RP 7, RP 24]

Any person who in the course of his work, business or occupation is likely to receive a dose of ionizing radiation in excess of the limit for a member of the general public (1 mSv/year whole body or 50 mSv/year to the hands). Employer should specify in writing those persons that have been designated as NEW's and maintain a list of these workers. All pregnant women should notify the employer as soon as they are aware of their pregnancy.

8 DOSE LIMITS [RP 13, 14]

Whole Body Dose Limits - Canadian Nuclear Safety Commission Radiation Protection Regulations

Person	Period of Time	Equivalent Dose (mSv)
Nuclear Energy Worker, Including a Pregnant Nuclear Energy Worker	One year dosimetry period Five year dosimetry period	50 100
Pregnant Nuclear Energy Worker	The balance of the pregnancy	4
Any Other Person	One calendar year	1

Dose Limits to Skin, Hands, or Feet - Canadian Nuclear Safety Commission Radiation Protection Regulations

Nuclear Energy Worker	One Year Dosimetry Period	500 mSv
Any Other Person	One Year	50 mSv

8.1 DOSIMETER [RP 8]

A badge worn by an individual to measure radiation dose. Whole body badges are use to measure the dose to the trunk of the body; extremity badges are worn to measure dose to hands. Dosimeter must be worn if you have a reasonable probability of receiving more than 5 mSv to the whole body in a one-year dosimetry period. You may choose to wear a badge even if you are not likely to exceed this limit. Employer should keep records of dosimetry reports.

8.2 Bioassays

As used in radiation protection, the term bioassay refers to some analysis procedure, such as urinalysis or thyroid counting, used to determine the nature and activity of any internal contamination present in a person.

8.2.1 H-3 (Tritium) Bioassay

Tritium screening should be performed on all individuals manipulating more than the following quantities of tritium during any two-week period:

Containment	H-3 gas/water	H-3 nucleic acid	H-3 components
None	400 MBq	400 MBq	4 GBq
Fume Hood	700 MBq	2 GBq	20 GBq

The term "manipulating" means that the worker is exposed to the amounts described above by handling solutions, or by being otherwise directly involved in experimental procedures.

8.2.2 I-125 and I-131 Bioassay (CNSC Regulatory Document R-58)

Every person shall undergo thyroid screening within five days who:

(a) uses in a 24-hour period a quantity of Iodine-125 or Iodine-131 exceeding;

(i) 2 MBq in an open room;
(ii) 200 MBq in a fume hood;
(iii) 20 000 MBq in a glove box;
(iv) any other quantity in other containment approved in writing by the Commission or a person authorized by the Commission; or

(b) is involved in a spill of greater than 2 MBq of Iodine-125 or Iodine-131; or

(c) on whom Iodine-125 or Iodine-131 external contamination is detected.

9 REPORTING OCCURRENCE [RP 6]

Any radioactive exposure in excess of the legal limit shall be reported to the CNSC immediately. Remove the person from work immediately, establish root cause, and take action to prevent recurrence and minimize the exposure of any person to ionizing radiation resulting from the occurrence. For additional situations requiring immediate reporting see section 38 of the nuclear Substances and Radiation Devices Regulations and section 29 of the General Nuclear Safety and Control Regulations.

10 ALARA PRINCIPLE

The Management and RSO of Carleton University are committed to keeping the radiation doses to workers and the public As Low As Reasonable Achievable (ALARA). To accomplish this, the RSO will:

a) Ensure that all employees are aware of management’s commitment to ALARA.
b) Practice oversight to radiation safety practices through internal inspections, review of dosimetry results, and feedback from staff.
c) Make necessary adjustments to radiation safety practices based on information gathered from internal oversight or CNSC recommendations.
d) Develop procedures to assist staff in performing their duties in a manner that will minimize exposures.
e) Encourage workers to report unusual situations that may compromise radiation safety.

f) Ensure that all workers are properly trained and qualified to use radioactive material.

11 INSPECTIONS

A CNSC appointed inspector may at any reasonable times enter a licensed facility for the purpose of carrying out an inspection. Licensee may demand to see inspector's certificate.

12 LOSS OR THEFT OF NUCLEAR MATERIAL

[GN 29 (1) (A), SC 27 (B)]

Any loss or theft of a radioactive material should be reported to the RSO immediately. RSO must immediately notify the CNSC. A more complete report should follow as soon as possible.

13 STORAGE AREA [GN 12. (1) (C) (J), NS 23]

Storage area should be accessible only to persons authorized by licence (keep storage room locked when not in use).

Storage area should be posted with emergency contact phone number and name of person to contact, radiation warning, and details on the nature form and quantity of radioactives.

Dose rate should not exceed 2.5 µSv/h at any occupied location.

14 INVENTORY [NS 36]

An inventory of all the radioactive sources should be maintained. If the radioactive source is incorporated into a device, the record should include: Make, model, serial number of source holder, location, isotope, and isotope activity and date. Make sure the inventory is updated whenever you move a source. Keep records of all sources transferred to other facilities or disposed of.

15 SIGNS [RP 20, 21]

Any area, room, enclosure or vehicle where radioactive material is kept must be posted with a radiation warning sign as described in Schedule III of the regulations. Container should also be posted with information with respect to the nature, form, quantity and date of measurement of the radioisotopes.

16 Transfers [GN 13]

Radioactive material may be transferred if the recipient holds a valid licence for possessing the radioactive material. If the material is required to be leak tested then a valid leak test certificate must be supplied to the recipient.

17 LEAK TESTS [NS 18]

Except for gaseous sources leak tests must be performed according to CNSC expectations on all sealed sources containing more than 50 MBq (1.35 mCi) of a radioactive substance.

The frequency of leak testing shall be:

a) every 24 months for a sealed source continuously in storage,

b) Every 12 months for a sealed source contained in a device.

c) every 6 months for any other sealed source.

Leak test records must be kept for 3 years.

18 LABORATORY CLASSIFICATION

[LICENCE]

18.1 Storage Room

A room, where any supplies of sealed or unsealed nuclear substances are kept without being handled. Examples include storage of waste and/or decaying radioactive material and supplies of nuclear substances held for future use.

18.2 Basic, Intermediate, and High Level Rooms

Laboratories are classified by the maximum quantity of each unsealed nuclear substance per container (vial). See chart below.

Radionuclide	Exemption Quantity (MBq)	Basic level (MBq)	Interm. level (MBq)	High level (MBq)
C-14	100	170	1700	17000
H-3	1000	5000	50000	500000
I-123	10	475	4750	47500
I-125	1	6.5	65	650
I-131	1	4.55	45.5	455
P-32	0.1	34.5	345	3450
P-33	100	75	750	7500
Ra-226	0.01	0.0455	0.455	4.55
S-35	100	90	900	900

Example: If a laboratory using only P-32 never orders more than 1 mCi (37 MBq) per vial, then the laboratory will be classified as Basic Level.

19 TRANSPORTATION OF RADIOACTIVE MATERIAL

(PACKAGING AND TRANSPORTAION OF NUCLEAR SUBSTANCES REGULATIONS, AND TRANSPORTATION OF DANGEROUS GOODS REGULATIONS)

Anyone wishing to transport radioactive material should consult the Radiation Safety Officer concerning packaging, labelling, documentation, and placarding requirements.

20 Exemptions

The CNSC allows licensing exemptions for various nuclear substances such as naturally occurring radioactive material, smoke detectors, and sources below the exemption quantity. Carleton University does not maintain controls over non-licensable nuclear substances unless otherwise required by the regulations for such activities as transportation, import/export, and where international safeguards regulations apply.

B RADIATION SAFETY

1 PROPERTIES OF RADIATION

a) Capable of travelling through a medium.

b) Whenever it passes through a medium, it deposits or loses part of its energy in the medium.

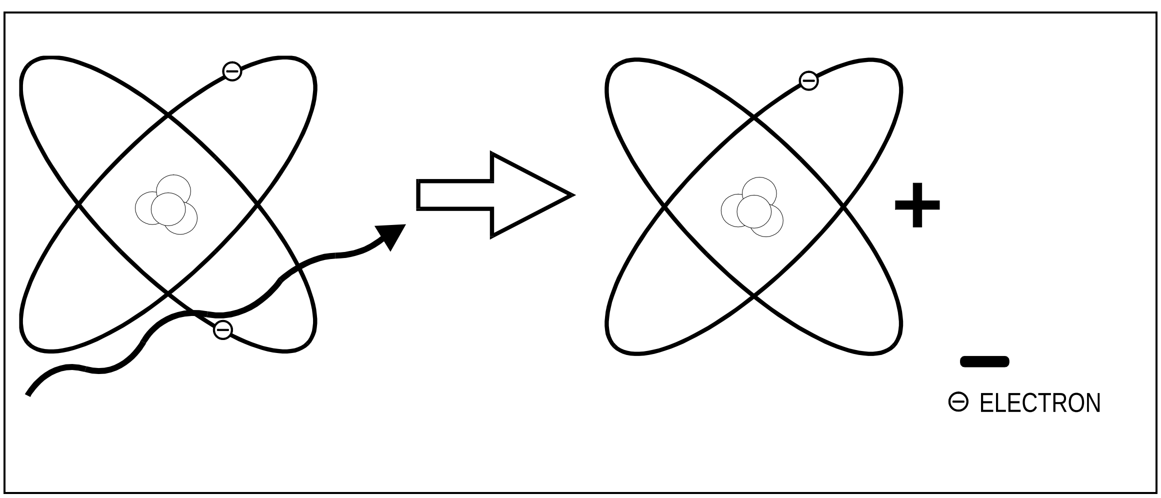
The manner in which radiation deposits its energy differs, depending upon the type of radiation and the medium. Radiation emitted from radioactive isotopes (radioisotopes), as well as X-ray devices, has become known as ionizing radiation. Ionizing radiation is capable of producing ions, or electrical charges, in the absorbing medium.

Ionizing Radiation	Non-ionizing Radiation
radiation from radioisotopes, cosmic radiation, X-ray machines, accelerators, reactors	visible sunlight, microwaves, radiowaves, soundwaves

2 IONIZATION

Ionization is the ability of radiation to produce electrical charges in the medium through which it travels. Ionization is the main process by which ionizing radiation loses its energy.

The Ionization Process

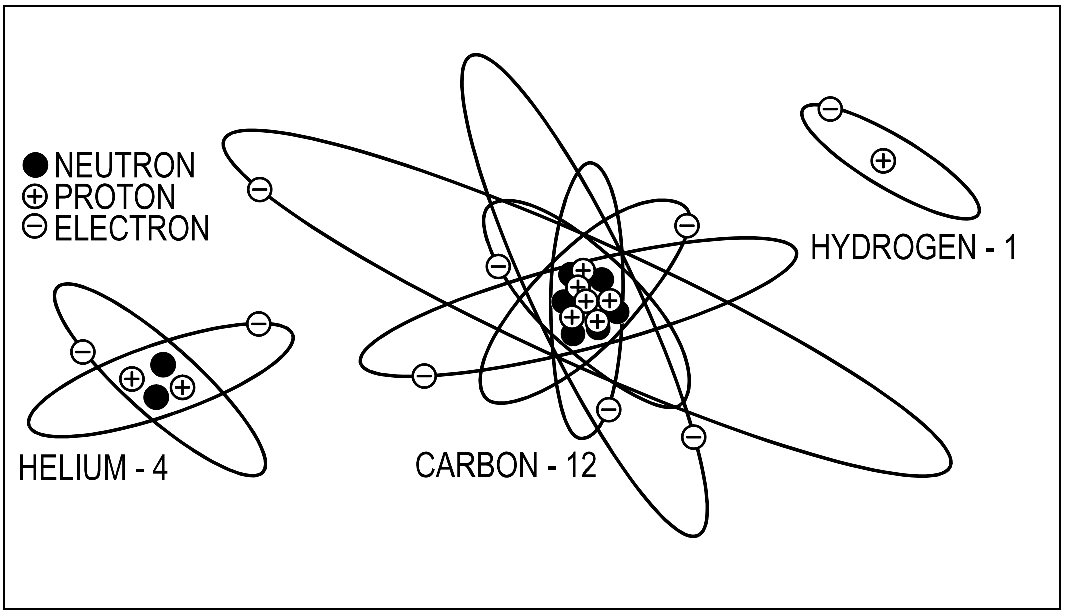


Alpha, beta, gamma, X-ray and neutron radiation can cause ionization — that is, dislodge electrons from molecules in its path. This may cause biological damage if the absorbing material is living tissue.

3 BASIC ATOMIC STRUCTURE

The number of protons in the nucleus determines what element that atom is.

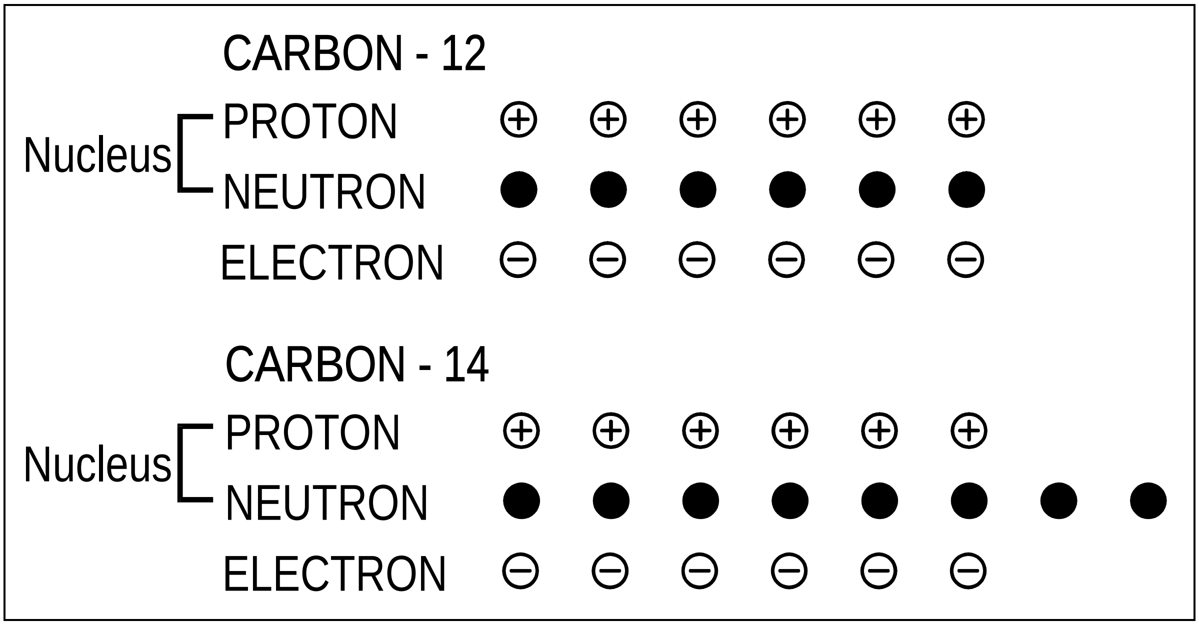
Diagram of Various Stable Atoms



4 RADIOISOTOPES

Radioisotopes are unstable forms of a particular element. Because of their instability, these isotopes can decay or undergo transformations and emit nuclear (ionizing) radiation. Radioisotopes can be naturally occurring or they can be produced in reactors or particle accelerators.

As an example, two isotopes of **carbon** are C-12 and C-14.



Carbon-12 is a stable form of carbon. The nucleus of the atom consists of 6 protons and 6 neutrons.

Carbon-14 is an unstable form of carbon. The nucleus consists of 6 protons and 8 neutrons. As the C-14 undergoes nuclear decay as a result of its instability, it will emit radiation.

Radioisotopes commonly used in research include Hydrogen-3 (tritium), Carbon-14, Sulphur-35, and Phosphorous-32.

Radioisotopes commonly used in industry include Cesium-137, Krypton-85, Strontium-90, Iridium-192, Cobalt-60, Americium-241, etc.

5 RADIATION ENERGY UNIT

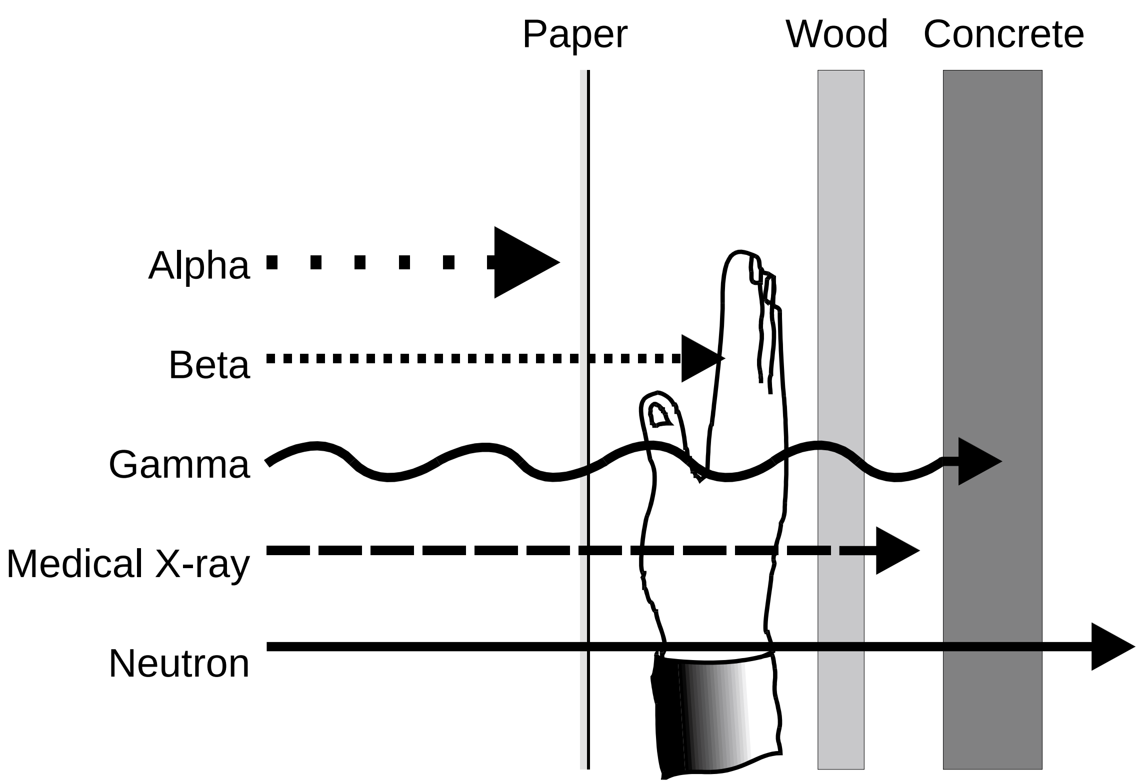
The electron volt (eV) is a small unit of energy (1.6 x 10^{-19} joules) used to measure radiation energy. The radiation emitted from radioisotopes can vary in energy from a few kiloelectron volts (keV) to a few thousand keV. For example, Iodine-125 emits gamma radiation at 27 keV, while Cobalt-60 emits gamma radiation at 1330 keV. The gamma radiation from Co-60 is much higher in energy and would require more shielding material.

6 TYPES OF IONIZING RADIATION

In general more than one type of radiation is emitted from each radioactive element. The yield (fraction emitted per disintegration) and the energy of each type of radiation are unique to the radioactive element. This information can be found in Isotope Tables or in the data sheets provided by the radioisotope supplier.

Penetrating Power of Ionizing Radiation

The various types of radiation have different penetrating powers. This illustration portrays the ability of different forms of ionizing radiation to penetrate paper, the human body, wood and concrete.



6.1 Particles

6.1.1 Alpha

An alpha particle is a helium atom without the electrons (i.e., it has 2 protons and 2 neutrons).

Alpha particles:

- are positively charged
- have high ionizing power
- can travel 2-8 cm in air
- are easily stopped by thin material
- cannot penetrate skin
- are relatively heavy
- are monoenergetic

In order for a nucleus to be capable of releasing so large a particle, the nucleus of the atom must be relatively large itself. With few exceptions, nuclei that decay by alpha emission have an atomic mass of 83 or more.

6.1.2 Beta

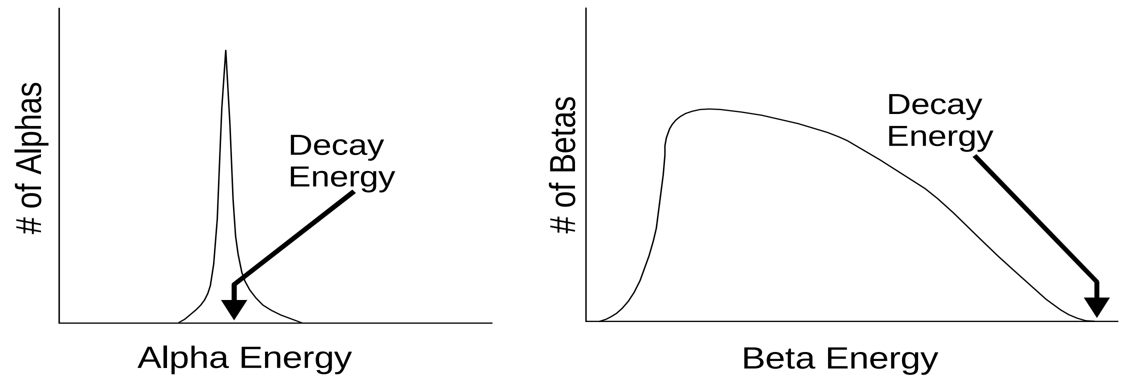
A beta particle is a negatively charged, high-speed particle (electron).

Beta particles:

- can penetrate up to 10 meters in air depending on their energy
- can penetrate skin
- are stopped by plastic, metal or wood

Unlike alpha particles, which are monoenergetic, beta particles are emitted within a range of energies between zero and a maximum for that particular decay.

Typical Alpha and Beta Energy Spectra



Typical alpha and beta energy spectra

When fast-moving electrons are slowed in dense material, they can emit Bremsstrahlung radiation, which is similar to gamma radiation. Bremsstrahlung is more common in high-energy beta particles such as P-32 when directly shielded by high atomic number absorbers such as lead.

6.1.3 Neutrons

A neutron is an uncharged particle from the nucleus of an atom.

Neutrons:

- can penetrate up to 100 metres in air depending on their energy
- are slowed down by hydrogen-rich material such as paraffin

Neutrons are not emitted by pure radioactive material but produced by the interaction of radiation with the nucleus of certain atoms.

For example, Am-241 (alpha emitter) mixed with beryllium will produce neutrons. These sources are found in portable gauges used for checking the moisture content of soil.

6.2 Electromagnetic Radiation (X-rays and Gamma Rays) — also known as Photons

X-rays and gamma rays are uncharged pockets of energy similar to light and microwaves but higher in energy.

Gamma rays and X-rays:

- are distinguished from other types of electromagnetic radiation by their ability to ionize
- are highly penetrating
- require dense material such as lead for shielding

X-rays	Gamma Rays
monoenergetic or continuous depending on mode of production	monoenergetic
usually from X-ray machines	from radioisotopes
usually lower energy than gamma	usually higher energy than X-rays
de-excitation of orbital electron	transition of nucleus from higher to lower energy state

7 ACTIVITY

It is necessary to have units to determine the **amount** of radioactive material. Since radioactivity is the change of one kind of atom into another with the emission of radiation, the activity is determined by the number of atoms changing (also called decaying or disintegrating) per unit time (second). The number of radioactive decays occurring per unit time in a radioactive source is called the **activity**.

7.1 Becquerel

New unit (SI System): becquerel (Bq) = 1 decay/second

Because the becquerel is a small unit, with the amounts used in most open-source labs it is usually preceded by one of the following prefixes: kilo, mega, or giga.

7.2 Curie

Old unit: curie (Ci) = 3.7×10^{10} decays/second

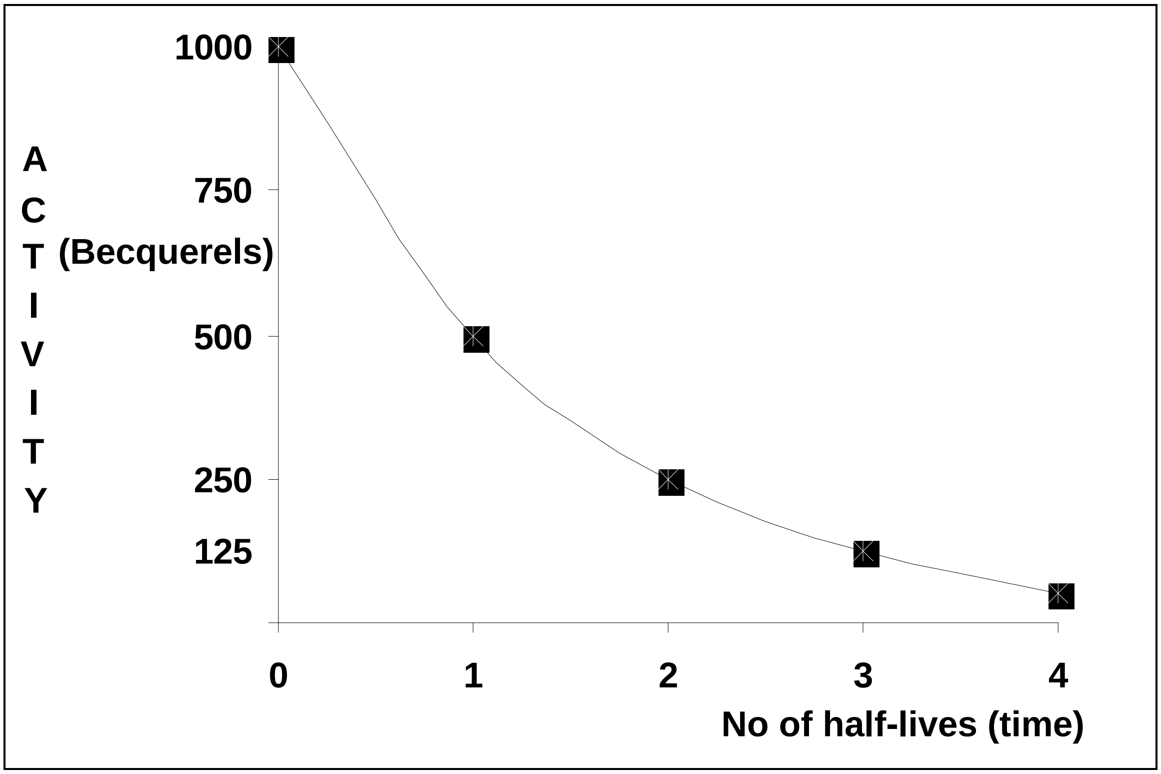
Since the curie is a much larger unit than the becquerel, it is usually preceded by one of the following prefixes: milli or micro.

1 curie = 3.7×10^{10} becquerels = 37 GBq

8 HALF-LIFE (RADIOACTIVE DECAY)

The rate at which radioactive (unstable) isotopes decay is specific to each isotope. **Half-life** is the amount of time it takes for half the activity of an isotope to decay. The half-life of Carbon-14 is 5730 years. The half-life of Cesium-137 is 30 years. The half-life of Phosphorus-32 is 14 days.

Radioactive Decay Curve



For example, a sample of P-32 is measured and found to contain 1000 becquerels (1000 decays/second). Fourteen days later (1 half-life), the sample should contain 500 becquerels of radioactivity.

9 UNITS FOR MEASURING RADIATION ABSORBED AND RADIATION INJURY

Radiation is a form of energy that deposits part of its energy as it travels through a medium. The basic concept of radiation measurement is to measure the energy absorbed by a medium. The energy absorbed can vary, depending on the density of the medium (air, water, a human body, etc.).

9.1 Exposure

QUANTITY: exposure

UNIT: roentgen (R)

1 R = 2.6 x 10^{-4} Coulombs/kg_{air}

The roentgen was used to represent a quantity called exposure (ability of photons to ionize air), but it is no longer used, and no SI equivalent has been proposed for it. The unit is now considered obsolete because it applies only to X-rays and gamma rays (photons) of certain energy and only to an absorbing material of air. However, you may still see gamma survey meters that measure roentgen, so, for practical purposes, we can consider the roentgen equal to the rad (see below), since 0.96 R = 1 tissue rad for commonly encountered photon energies.

9.2 Absorbed Dose

QUANTITY: absorbed dose

OLD UNIT: roentgen absorbed dose (rad)

NEW UNIT: gray (Gy)

1 Gy = 1 joule per kg = 100 rad

The absorbed dose is a measurement of the energy deposited in a given mass and can be applied to all ionizing radiations at all energies and in all absorbers, including human tissue. To be strictly correct, the absorbing material should be specified, but in radiation protection it is always understood that the absorber is soft human tissue (strictly speaking, “tissue gray”).

Soon after the absorbed dose came into use, a problem was noticed, which is that neutrons seem to produce more injury per gray than X-rays, even though the same amount of energy is deposited in both cases. This is due to the pattern of the energy deposition, which in the case of neutrons and alpha particles is more damaging than X-rays or gamma rays. This led to the use of a modifying factor, which is applied to the absorbed dose. The modifying factor is called the **weighting factor (w_R)**, and it is multiplied by the absorbed dose to determine the risk of biological injury or **equivalent dose**.

9.3 Equivalent Dose

QUANTITY: equivalent dose = weighting factor(W_R) × absorbed dose

OLD UNIT: rem = W_R × rad

NEW UNIT: sievert (Sv) = W_R × gray

1 sievert = 100 rem

Use of Weighting Factors

Type of Radiation	gray x	weighting factor =	sievert
X-rays and gamma rays	1	1	1
Beta particles	1	1	1
Thermal neutrons	1	5	5
Fast neutrons	1	20	20
Alpha particles	1	20	20

You may come across gamma survey meters that still measure in the old units roentgen, rads, or rem. **For practical purposes**, while measuring gamma radiation, all these units can be regarded as equivalent (1 R ≅ 1 rad ≅ 1 rem) since:

1 roentgen is very nearly equal to 1 rad (tissue); and

1 rad (air) is very nearly equal to 1 rad (tissue); and,

for gamma radiation, 1 rad equals 1 rem.

Also, for gamma radiation:

1 gray (100 rad) = 1 sievert (100 rem)

9.4 Dose Rate

Survey meters are usually calibrated in roentgen/hour or millisievert/hour to describe the rate at which radiation is received. For example, if someone stands in a field of 2 millisieverts/hour for 30 minutes, they will receive 1 millisievert of radiation.

10 Contamination

Radioactive contamination is defined simply as undesired radioactive material on any surface. The contamination can be further classified as either fixed (stuck to the surface) or removable. Removable contamination can potentially contaminate the skin or even be absorbed internally.

10.1 Contamination Limits and Monitoring Frequency

The CNSC requires that a contamination monitoring be performed every week that open-source radioactive material is used. The allowable limits of radioactive contamination as defined by the CNSC are expressed in Bq/cm^2. These limits are taken from Carleton University's Consolidated Radioisotope Licence. If surfaces cannot be contaminated below the regulatory limit, tape over the surface with plastic sheeting or a garbage bag and contact the Radiation Safety Officer.

Radionuclide	Wipes Controlled Area (Bq/cm^2)	Wipes Public Area (Bq/cm^2)
Br-82	30	3
C-14	300	30
Co-57	300	30
Co-58	30	3
Co-60	3	0.3
Cr-51	300	30
F-18	30	3
Fe-59	30	3
Ga-67	30	3
H-3	300	30
I-123	300	30
I-125	300	30
I-131	30	3
In-111	30	3
Na-22	3	0.3
P-32	300	30
P-33	300	30
Ra-226	3	0.3
S-35	300	30
Sb-124	3	0.3
Sr-85	30	3
Tc-99m	300	30
Tl-201	300	30
Xe-133	300	30

10.2 Methods of Monitoring for Contamination

Direct: Using a portable monitor, the area is scanned with the probe to check for contamination.

Indirect: The area is wiped with filter paper, and the wipe is checked for contamination, usually on very sensitive equipment such as a liquid scintillation counter (LSC).

	Advantages	Disadvantages
Direct	• picks up fixed contamination • quicker, easier	• equipment sensitivity is limited • cannot be used in high background area
Indirect	• can be counted on sensitive equipment (i.e., LSC)	• may miss contamination when wiping

Regardless of the method of detection, you must be able to prove that the contamination is below the regulatory limit, i.e., you must be able to convert the counts per minute (cpm) or counts per second (cps) readings into Bq/cm^2 .

10.3 Contamination Calculation: Liquid Scintillation Wipes

Counts Per Minute equivalent of 30 Bq/cm^2

S-35, P-33, C-14 = 14400 cpm above background

H-3 = 9000 cpm above background

P-32 = 18000 cpm above background

10.4 Contamination Calculation: Direct Check

Counts Per Minute equivalent of 30 Bq/cm^2 - Pancake Geiger

S-35, P-33, C-14	= 1800 cpm above background
P-32	= 7200 cpm above background

11 SEALED SOURCE LEAK TESTING

[CNSC REGULATORY DOCUMENT]

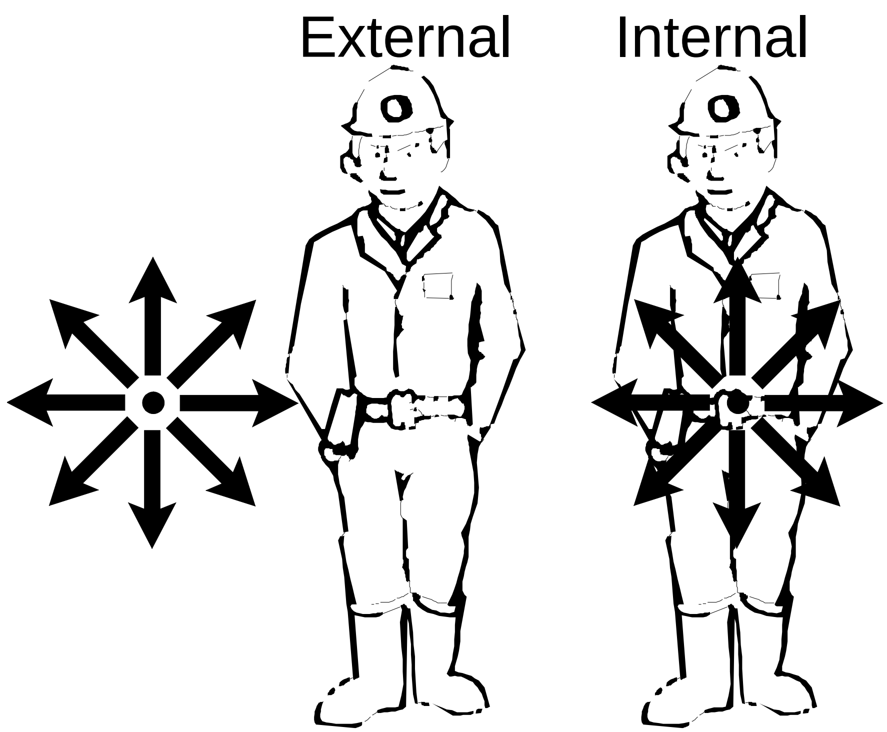
As opposed to open sources of radioactive material, **sealed sources** are described as: any radioactive substance sealed in a capsule or having a bonded cover, the capsule or cover being strong enough to prevent contact with and dispersion of the radioactive material under the conditions of use and wear for which it was designed.

Sealed sources of greater activity than 50 MBq (1.35 mCi) are required to be leak tested. The frequency of leak testing is specified in the internal radioisotope permit (6, 12, or 24 months). If more than 200 Bq of removable contamination is detected on the wipe, the source is assumed to be leaking and shall be removed from service.

See Part A section 18 of this manual for the regulatory requirements of leak testing sealed sources.

12 RADIATION EXPOSURE

Exposure to radiation can occur internally from radioisotopes deposited inside the body or externally from a radiation source outside the body.



External and Internal Radiation Exposure

Ernest Becker, Ph.D., *All About Radiation*,
Canadian Institute for Radiation Safety, 1988, p. 48.

12.1 External Exposure

When living tissue is exposed to an external source of radiation of commonly encountered energies from radioisotopes or X-ray machines, the absorbed radiation causes increased ionization in the living tissue. When the external source of radiation is removed, however, the ions recombine a fraction of a second later. The person who absorbed the radiation does not become radioactive, and, unless the radiation dose was massive, there is no way of detecting, by medical examination, how much radiation the person was exposed to.

People who work in areas of high potential for external radiation exposure wear dosimeters for measuring their radiation dose. There are two types of dosimeters:

1) **whole body dosimeters** are meant to be worn on the torso; they measure the dose to the body;
2) **extremity dosimeters** are worn on the finger or wrist; they measure the dose to the hands.

If a person was exposed to radiation and was not wearing a dosimeter, the dose may be estimated from various factors such as: the strength of the source, amount of time the person spent near the source, distance from source, presence of shielding, etc.

12.1.1 Principles of External Radiation Protection

There are three ways to reduce your external dose from an **external** radiation source: **time, distance, and shielding**.

Time: The less time a person remains in the area of radiation, the less of a radiation dose that person will receive.

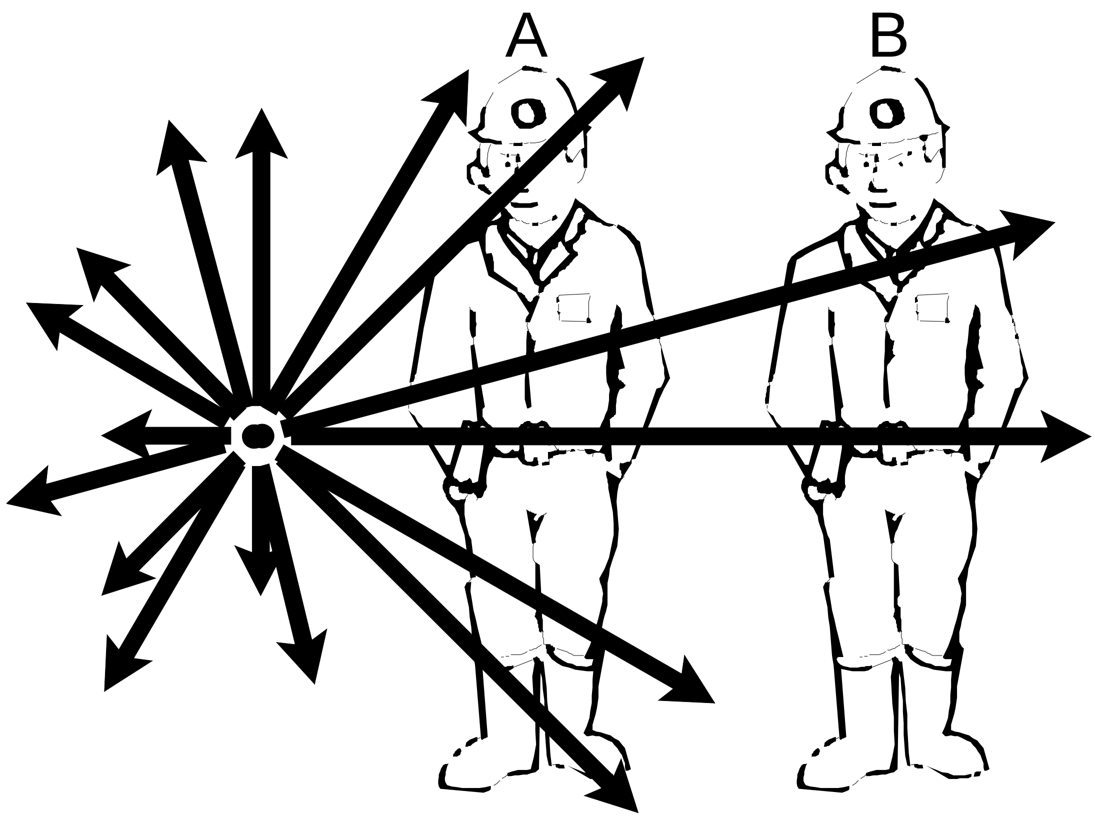
Distance: The intensity of radiation and its effects fall off sharply as you move away from the radioactive source. For example, by moving twice as far away from a gamma source, you are exposed to 1/4 the amount of radiation; moving three times as far away means 1/9 the exposure, and so on. For beta sources, the dose rate drops off even more significantly with distance from the source.

Shielding: Protective shielding placed between you and the source reduces the level of radiation passing through and thus the amount to which you will be exposed. Because of their high penetrating power, gamma sources are usually shielded with dense material such as concrete, lead, or even depleted uranium. A commonly used term in radiation protection is Half-Value Layer (HVL), which is the material thickness required to reduce the exposure rate to one half the unshielded value.

Half-Value Layers

	HVL (cm)	
Radiation	**Lead**	**Concrete**
Cs-137	0.65	4.8
Co-60	1.20	6.2

For beta emitters, plastic or Lucite is usually used for shielding instead of lead. When shielded with a high-density material, high-energy beta emitters such as P-32 can produce secondary low-energy gamma radiation called Bremsstrahlung.



"B" receives much less radiation exposure than "A" because he is farther from the source

Ernest Becker, Ph.D., *All About Radiation*, Canadian Institute for Radiation Safety, 1988, p. 52.

12.2 Internal Radiation Exposure

As well as posing external exposure risk, open sources of radiation pose internal exposure risk through inhalation, ingestion or absorption through wounds in the skin. Moreover, once radioactive material is inside the body, very little can be done to reduce the absorbed dose. Hence, even small amounts of unsealed radioactive material must be handled with extreme care.

The **critical organ** is the organ that receives the greatest damage as a result of a radioactive intake. Some isotopes have an affinity for certain parts of the body. Iodine collects in the thyroid gland; Ra-226 attaches to bones.

Biological half-life is the time required for the body to eliminate one half of an uptake of any substance by regular process of elimination.

Effective half-life is the time required for a radioactive nuclide in the body to be diminished to 50% as a result of the combined action of radioactive decay and biological elimination.

$$\text{Effective half life} = \frac{\text{biological half-life} \times \text{radiological half-life}}{\text{biological half-life} + \text{radiological half-life}}$$

I-125 has a radiological half-life of 60 days, a biological half-life of 140 days, and an effective half-life of 42 days.

If a person ingests, absorbs or inhales an unknown amount of radioisotopes, there are various ways of estimating how much activity was deposited inside the person. These include whole body counting, thyroid counting (for iodines), urinalysis, etc. Once the activity and the isotope are identified, an estimate of the dose can be made based on the person’s weight, the biodistribution of that particular isotope, etc.

12.2.1 Principles of Internal Radiation Protection

For users of open-source radioactive material, protection against internal radiation exposure means following safe laboratory practices and treating the radioactive material with many of the same precautions you would use for working with dangerous chemicals. A copy of the lab rules for radioisotope use should be posted in your laboratory. (See Appendices A and B — Basic and Intermediate Laboratory Rules.)

12.2.2 Contaminated Skin

As noted in the CNSC Spill Procedures (Appendix C), if your skin becomes contaminated you should decontaminate by removing any contaminated clothes and flushing the contaminated skin with lukewarm water and mild soap. Do not scrub vigorously with a brush, since this may cause skin abrasion and allow absorption though the skin. RSO to calculate skin dose and report to CNSC if > 5 mSv.

13 DOSE LIMITS [RP 13, 14]

Whole Body Dose Limits - Canadian Nuclear Safety Commission Radiation Protection Regulations

Person	Period of Time	Equivalent Dose (mSv)
Nuclear Energy Worker, Including a Pregnant Nuclear Energy Worker	One year dosimetry period Five year dosimetry period	50 100
Pregnant Nuclear Energy Worker	The balance of the pregnancy	4
Any Other Person	One calendar year	1

Dose Limits to Skin, Hands, or Feet - Canadian Nuclear Safety Commission Radiation Protection Regulations

Nuclear Energy Worker	One Year Dosimetry Period	500 mSv
Any Other Person	One Year	50 mSv

14 AVERAGE YEARLY DOSES (NON-OCCUPATIONAL)

Regardless of whether or not you work with radioactive material, you will receive some radiation from various sources. The occupational limits apply only to the radiation you receive from your job.

HOW MUCH IS A
MILLISIEVERT

The average Canadian receives about 3-4 millisieverts (mSv) of radiation each year

Some typical radiation doses received

Cosmic rays	0.3 – 0.4 mSv per year (depending on altitude)
Coast-to-coast return jet flight	0.04 – 0.05 mSv
Radionuclides in the body	0.4 mSv
Medical chest X-Ray	0.1 – 0.2 mSv per year
Consumer products (colour TV, food, smoke detectors. Tobacco products, etc.)	0.01 mSv per year
Naturally radioactive materials (rocks and soil, construction materials)	0.3 – 0.7 mSv per year
Radon Gas	1 – 2 mSv per year

15 EFFECTS OF RADIATION EXPOSURE

15.1 Radiosensitivity

Certain types of cells in the body are more radiosensitive than others. In general, young, rapidly dividing cells of renewing tissue are more radiosensitive, since damage caused to their DNA may produce subsequent bad copies of these cells, thereby affecting their biological function. Types of cells that are radiosensitive include skin, intestines and blood cells. Cancerous cells are also more radiosensitive, as are the rapidly dividing cells of the foetus.

15.2 Immediate Effects of Acute Radiation Exposure

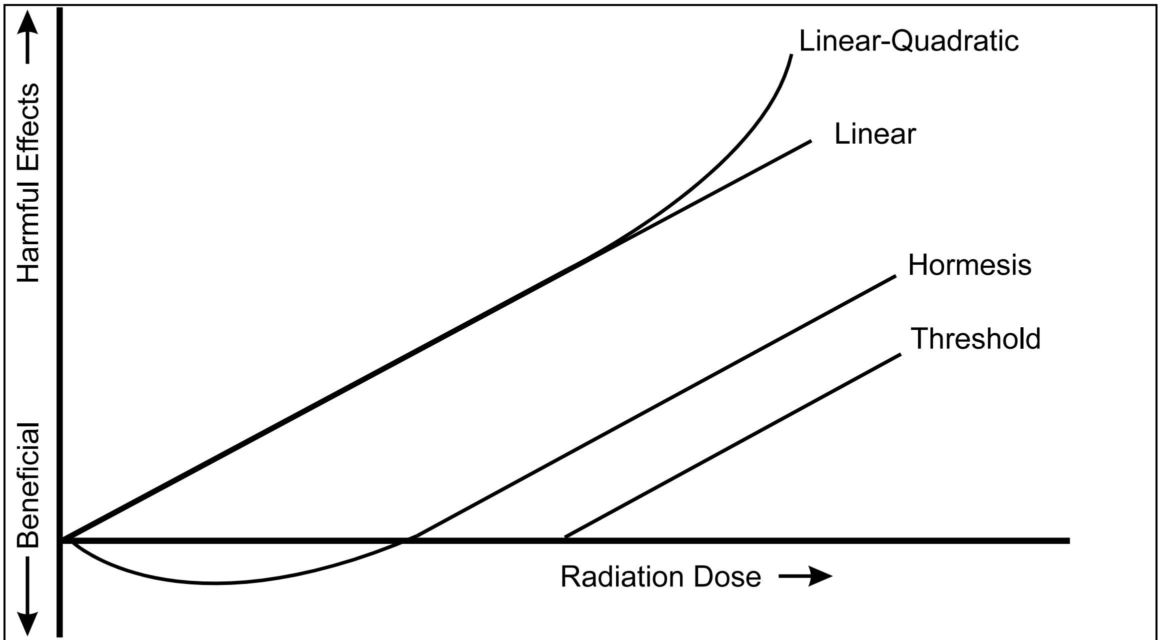
Dose (mSv)	Effect
<1000	None detected
3000	Skin burn, hair loss, vomiting, weakened immune system
5000	Without medical treatment 50% of people die within 30 days

15.3 Long-term Biological Effects of Radiation Exposure

The major long-term biological effect from smaller doses received over a longer period of time is an increased risk of cancer. All radiation-induced cancers have a long latent period before they are expressed.

At occupational exposure levels, the increase in cancer risk is statistically indistinguishable from naturally occurring cancers. Cancer induction is seen at much higher exposure levels, and the relationship is conservatively assumed to be linear at lower doses, but there is still a great deal of debate about the effects of low-level exposure.

Curves for Various Dose Response Theories



Daniel A. Gollnick, *Basic Radiation Protection Technology*, Pacific Radiation Corp., 1994, p. 110.

Based on the linear theory (most conservative), the International Commission on Radiological Protection (ICRP) has estimated that when a population of 10 000 people is exposed to 10 mSv each, one fatal cancer may result. This potential effect would not appear until many years after the exposure and could not be distinguished from the 1600 cancer deaths normally expected to occur among a group of 10 000 from all other causes.

15.4 Risk Comparison for Radiation and Other Activities

Canadians have a life expectancy of about 76 years. Any situation or activity that reduces that expectancy can be calculated as a Loss of Life Expectancy (LLE)

ACTIVITY OR SITUATION RISK	LLE
Smoking 20 cigarettes per day	6.2 years
Construction worker accidents	227 days
All motor vehicle accidents	207 days
Transportation worker accidents	160 days
All home accidents	74 days
Radiation worker exposed to 4.5 mSv/year for 48 years	**23 days**
Amateur scuba diver	7 days
Public air transportation	3.7 days
Insulating a house (traps more radon gas in the home)	3 days
Snowmobiling	2 days
Weather-related transportation accidents	1.8 days
Single exposure to 10 mSv (10 mSv/h for one hour)	**1.5 days**
College football	0.6 days
Strikes by lightning	0.6 days
Single exposure to 0.1 mSv (0.1 mSv/h for one hour)	**2.1 minutes**

16 Waste Disposal

Small amounts of radioactive liquids and solids can be disposed of through municipal sewage or garbage provided there are no other restrictions on the chemical content of the radioactive waste.

16.1 Solids

If you are working with C-14, P-32, P-33 or S-35 and have access to a contamination meter, survey items such as absorbent liners, gloves etc. to determine if these items are contaminated. Non-contaminated material should be placed in regular garbage.

Concentrated solid waste from short-lived radioisotopes should be held for decay. Contaminated solids should be stored in 20 L pails. Each pail should be designated for a particular radioisotope and labelled with radioactive warning tape, permit holder and the radioisotope. When full, the pail should be sealed, dated and held for decay. Later the pail can be opened and surveyed with a portable contamination meter. Non-contaminated items may be disposed of through regular garbage after 10 half-lives.

16.2 Liquids

The University's licence allows for small amounts of radioactive liquid to be disposed of to municipal sewage. Contact the Radiation Safety Officer to adjust your radioisotope permit if you wish to dispose of radioactive waste in this manner.

Most open source work at the University involves labelling proteins or DNA and then washing off the unbound radioactive material. Depending on the protocol, there is usually an initial "hot-wash" which may or may not be followed by subsequent washes. The initial hot-wash should be saved and stored. You should have a designated container for each liquid radioisotope waste produced. Label the container with radioactive warning tape, permit holder and the radioisotope. When the container is full call the RSO to take a sample of the liquid waste in order to determine the disposal method.

The Radiation Safety Officer has tested subsequent washes and found the levels of radioactivity to be well below our legal disposal limits but your lab may periodically be requested to submit samples for analysis.

See Appendix E: Liquid Waste Sampling

16.3 CNL Disposal

If you do not wish to let your waste decay or cannot meet the regulatory requirements for municipal disposal then your radioactive waste must be sent to Canadian Nuclear Laboratories (CNL) – Chalk River. In 1998 CNL developed a characterization of the radioactive wastes produced by the university based on information provided by Carleton’s radioisotope permit holders. CNL identified 8 common waste blocks produced by the university. Wastes that fit into any of the 8 waste blocks should be packaged according to section 16.1. Contact the Radiation Safety Officer for information on how to dispose of any other type of waste.

Notes:

1) CNL will not accept liquid waste. Liquid waste must first be absorbed using celite to solidify the liquid.
2) The disposal fees are higher for waste that is not packaged, labelled, or identified properly.

Waste Identification

Block #	Package	Waste Material	Description of Typical Contents
9035	5 gal can	Lab Waste – Biological	**H-3 and/or C-14** • gloves, wipes, pipette tips, syringes, paper towels, filter paper, glass fibre discs, aluminum foil, plastic wrap, glass tubes, Benchkote[tm], micro-titre dishes • mineral oil (trace), boric acid, SDS,Tween-20, Triton-X100, polyethylene glycol (trace), formamide (trace), agarose gels, bromophenol blue (trace), EDTA (trace), ammonium persulphate (trace) • bacteria, human and animal cell cultures, proteins, human and animal DNA, lymphocytes (note, all infectious agents are deactivated before placing them into waste containers)
9036	5 gal can	Lab Waste – Biological	**P-32** same physical / chemical properties as block 9035
9037	5 gal can	Lab Waste – Biological	**S-35** same physical / chemical properties as block 9035
9038	5 gal can	Lab Waste – Non-Biological	**Th-228 and/or Ra-226** gloves, wipes, pipette tips, syringes, paper towels, laboratory glassware, may contain celite
9039	22 L jugs	Aqueous & Aqueous Compatible Liquids (absorbed on celite if transferred to CNL)	**H-3 and/or C-14** environmentally friendly LS cocktails, liquid growth medium, tissue culture medium, EDTA, ammonium persulphate. tri-base
9040	22 L jugs	Aqueous & Aqueous Compatible Liquids (absorbed on celite if transferred to CNL)	**P-32** same physical / chemical properties as block 9039
9041	22 L jugs	Aqueous & Aqueous Compatible Liquids (absorbed on celite if transferred to CNL)	**S-35** same physical / chemical properties as block 9039
9042	5 gallon can	Scintillation Solutions	**H-3 and/or C-14** glass and/or plastic LS vials containing environmentally friendly LS cocktails
9043	5 gallon can	Scintillation Solutions	**P-32** same physical / chemical properties as block 9042
9044	5 gallon can	Scintillation Solutions	**S-35** same physical / chemical properties as block 9042
9045	5 gallon can	Liquid for Processing	**H-3 and/or C-14** polyethylene glycol, formamide, bromophenol blue, xylene, xylene cyanol, toluene based LS cocktails

Note:

1) Waste blocks 9042, 9043, and 9044 are for labs that do not want to decant the liquid scintillation vials. Since CNL will not take liquid waste, these waste blocks must be sent, at an extra fee, to a handling facility to be decanted and solidified.

2) Before solidifying waste blocks 9039, 9040, and 9041, a sample may be counted using liquid scintillation. If below a certain radioactive concentration it may be possible to dispose of as chemical rather than radioactive waste. Contact the RSO for more information.

16.3.1 CNL Waste Collection

Solid, radioactive wastes are collected in the laboratories in 20L (5 imperial gallon) cans that have double bagged liners to collect waste. Prior to placing the bag liners into cans, the bags are marked with the following information:

- Building
- Room Number
- Radionuclide(s) Contained (no quantity cited)
- Waste Block Number

When the bags are nearly full, the bag liners are tied closed. Lids are then placed loosely on the cans. Note: stock vials of radionuclides with residual stock solution are not considered to be routine wastes and are not to be placed into waste cans.

Liquid wastes are collected separately in laboratories as follows:

- aqueous and aqueous compatible solutions, such as tris buffers, growth media and environmentally friendly LS cocktails, are collected in 22L jugs Enough celite is used to absorb 150% of the liquid placed into the jugs.
- alternatively, capped LS vials are placed into double lined “grey cans” (and handled in a similar manner to solid wastes)
- organic liquids are collected in a variety of containers.

Prior to collecting liquids in the containers listed above, the containers are marked with the following information:

- Building
- Room Number
- Radionuclide(s) Contained (no quantity cited)
- Waste Block Number (see Section 16)

When full, containers with free liquid or absorbed liquid are capped and transferred to a central waste handling room (for “grey cans”, lids are placed on loosely).

Contact the Radiation Safety Officer who will pick up the waste and bring to the central waste handling room. Radiation Safety Officer will check to ensure that containers are properly labelled.

In the central waste handling room, wastes are checked to ensure that they are properly labelled. If needed, wastes can be repacked in the central waste handling room. Prior to transferring wastes to CNL or another waste receiver, cans are sealed tightly and jugs of absorbed liquid are packed into cartons for shipping. The sealed cans and shipping cartons are marked with the waste block number corresponding to the block contained inside (blocks are kept separate, they are not mixed during repackaging). For transfer of wastes to CNL, bar-coded ID labels (provided by CNL) are to be placed onto each waste package.

17 PORTABLE INSTRUMENTS

Most portable radiation survey meters are designed to measure either contamination or gamma dose rate (or exposure). There are some dual-purpose contamination/dose rate meters. (See Appendix D — Dual-purpose Survey Meter.)

Portable meters consist of two main components:

1) **detector or probe:** the detector may be internal or external to the device and is either a **gas-filled** (ionization, proportional, or Geiger) or **solid** scintillating type;

2) **electronic device:** accepts current or pulses from detector and displays it on a scale. Make sure your device is set to the proper operating voltage for the probe being used.

Solid scintillators are a type of detector in which the absorbed radiation produces a flash of light. The light pulse is detected and amplified by a photomultiplier, and a signal is sent to the meter. There are several types:

- **Zinc Sulphide (ZnS)** detectors are used for measuring alpha contamination.
- **Sodium Iodide (NaI)** detectors are used for measuring gamma radiation and are very sensitive to low-energy and low-level gamma radiation.
- **Organic** or **plastic** scintillators are a little less sensitive than NaI detectors but give a more accurate reading over a wide range of gamma energies and can give tissue equivalent dose rates (mrem/hr or µSv/hr).

Gas-filled detectors consist of a gas-filled chamber with a negatively charged (cathode) outer wall and a positively charged (anode) inner collecting wire in the middle of the gas-filled chamber. When radiation ionizes the gas in the chamber, the ions move to the charged conductors and the increased signal is displayed on the meter. Ionization chambers operate at the lowest applied voltage and Geiger probes at the highest (usually 900 V).

Geiger counters are the most common portable meters at Carleton. Geiger probes may have window coverings, which should be **open** for measuring **contamination**. The thickness of the window determines the Geiger counter’s efficiency for detecting beta particles. Also, the lower the energy of the beta particle is, the lower the detection limit of the probe will be. Even Geiger probes designed for contamination monitoring (pancake probes) with large, thin windows cannot detect tritium (H-3).

17.1 Contamination Meters

Contamination meters usually read in counts per minute (cpm, counts/min). In order to translate the cpm into Bq/cm^2, you must know the efficiency of the detector for the isotope in question, as well as the surface area of the detector. Anyone who wishes to perform weekly contamination monitoring using a portable instrument must be able to prove that the lower detection limit of the instrument will meet the contamination criteria specified by the licence. (See Part B, Section 10.1.) Check with the Radiation Safety Officer if you are unsure. Since the regulatory limits are so low, most laboratories take wipes (indirect checks) and count them on a very sensitive non-portable instrument known as a liquid scintillation counter. However, despite the fact that a portable instrument may not meet regulatory requirements for weekly monitoring, it may still be quite a useful tool for the radiation worker. In practical terms, taking wipes and running a liquid scintillation counter is a time-consuming method of checking for contamination and is usually performed only weekly. Portable contamination meters can detect certain isotopes to fairly low levels and can give an immediate indication of the presence or absence of contamination.

17.2 Dose Rate Meters

Dose rate meters may display in the following units:

mR/hr	(milliroentgen/hr)
mrad/hr	(millirad/hr)
mrem/hr	(millirem/hr) tissue equivalent
mGy/hr	(milligray/hr)
mSv/hr	(millisievert/hr) tissue equivalent

For **practical purposes**, when measuring **gamma** dose we can assume that:

100 mR/hr ≅ 100 mrad/hr ≅ 100 mrem/hr ≅ 1 mGy/hr ≅ 1 mSv/hr

Most dose rate meters at Carleton are Geiger counters. Some **precautions** when using Geiger dose rate meters are as follows:

1) Very low-energy gamma such as that emitted by I-125 may not be detected.
2) The meter will not give a true beta dose rate. Usually a contamination meter is used to detect the presence or absence of beta contamination.
3) Response time is not quick enough for microsecond flashes from certain X-ray tubes.

17.3 Maintenance and Use of Radiation Detection Instruments

Dose rate meter used for required licensed activity must be calibrated yearly. Before each use of a contamination or dose rate meter, workers should verify that meter is properly functioning by conducting an examination for:

- Battery power
- High voltage setting
- Source response (if available)

C ADDITIONAL RECORD KEEPING

1 PURCHASING/CONTROL OF NUCLEAR SUBSTANCES

The university must seek a Radioisotope licence amendment before obtaining any nuclear source not already listed on the current licence. Permit holders are required to obtain a permit amendment before obtaining any nuclear source not already listed on their permit. Inventory will be updated if any nuclear sources are acquired, transferred or disposed of. Inventory will be updated if sources are moved to another location within company property. The University will maintain records of transfers and disposals. Leak tests must be supplied to the recipient in the event of an exchange of sealed sources greater than 50 MBq. Only valid permit holders can order radioactive material. All purchases must be approved by Radiation Safety Officer.

2 PACKING SLIPS

Packing Slips (see Appendix F) for all radioisotopes received should be kept by the permit holder. For open sources, if the radioisotope is still in stock, the Packing Slip should be kept in an active file, or book. As soon as the radioisotope order has been used, the Packing Slip should be attached to the Inventory Log form and placed in an inactive file.

3 INVENTORY LOG

Inventory Log forms should be generated for each vial of open-source material used. (See Appendix G — Inventory Log.) The top portion of the Inventory Log form should include as much relevant information as possible in order to match the Packing Slip with the Inventory Log. For example: radionuclide, compound, supplier, activity, lot or batch number, and the calibration or reference date. If you receive two or more vials with the same lot number on one Packing Slip, then each vial should be identified A, B, etc. Each vial has to be uniquely identifiable with an Inventory Log and a Packing Slip. The Inventory Log must be updated each time a sample is taken from the vial. An estimate of the amount of waste disposed of for each experiment should be included.

4 MONTHLY CHECKLIST – OPEN SOURCE USERS

The monthly checklist is to be completed by active open source permit holders and sent to the Radiation Safety Officer. See Appendix I.

Appendix A

CARLETON UNIVERSITY
BASIC LABORATORY RULES

24 hour emergency contact: **Norman Barton – Radiation Safety Officer #4444**

- **Do not eat, drink, store food, or smoke in this room.**
- **In case of spill or incident involving a nuclear substance, follow emergency procedures and notify Radiation Safety Officer.**
- **Clearly identify work surfaces and equipment used for handling nuclear substances.**
- **Equipment used for nuclear substances should be stored in radioactive work area**
- **Use Personal Protective Equipment (disposable gloves, safety glasses, lab coats, disposable absorbent liners) when working with nuclear substances.**
- **Contamination monitoring must be done weekly when working with nuclear substances. Records must be maintained.**
- **Wash hands regularly and monitor them for contamination frequently**
- **Check all packages containing nuclear substances for damage upon receipt**
- **Store nuclear substances in a locked room when not in use.**

INTERMEDIATE LEVEL

se of Unsealed Nuclear Substances

This room has been classified as "intermediate level" for the use of unsealed nuclear substances in accordance with Canadian Nuclear Safety Commission guidelines. Below is a list of safe work practices to be followed when working in this room.

24-hour emergency contact (name and phone number)	Room identification

- Do not eat, drink, store food, or smoke in this room.
- Wear appropriate dosimeter at all times.
- In case of a spill or incident involving a nuclear substance, follow emergency procedures and notify the Radiation Safety Officer.
- Clearly identify work surfaces used for handling nuclear substances.
- Use protective clothing and equipment when working with nuclear substances.
- After working with nuclear substances, monitor work area for contamination.
- Wash hands regularly and monitor them for contamination frequently.
- Check all packages containing nuclear substances for damage upon receipt.
- Store nuclear substances in a locked room or enclosure when not in use.

A room is classified as "intermediate level" for the use of unsealed nuclear substances where the largest quantity (in becquerels) of a substance handled by any worker does not exceed 50 times its corresponding annual limit of intake (in becquerels). Contact your Radiation Safety Officer for a list of annual limits of intake.

For more information, contact: Canadian Nuclear Safety Commission, Directorate of Nuclear Substance Regulation, P.O. Box 1046, Station B, Ottawa, Ontario, KIP 5S9. Telephone: 1-888-229-2672. Facsimile. (613) 995-5086.

SPILL PROCEDURES

Name and telephone number of the person responsible for enforcing safe work practices with nuclear substances in this work area:

Radiation Safety Officer	**Telephone number**

Person in charge	**Telephone number**

General Precautions

1. Inform persons in the area that a spill has occurred. Keep them away from the contaminated area.
2. Cover the spill with absorbent material to prevent the spread of contamination.

Minor Spills (Typically less than 100 exemption quantities of a nuclear substance)

1. Wearing protective clothing and disposable gloves, clean up the spill using absorbent paper and place it in a plastic bag for transfer to a labelled waste container.
2. Avoid spreading contamination. Work from the outside of the spill towards the centre.
3. Wipe test or survey for residual contamination as appropriate. Repeat decontamination, if necessary, until contamination monitoring results meet the Nuclear Substances and Radiation Devices licence criteria.
4. Check hands, clothing, and shoes for contamination.
5. Report the spill and cleanup to the person in charge and, if necessary, to the Radiation Safety Officer.
6. Record spill details and contamination monitoring results. Adjust inventory and waste records appropriately.

Major Spills (Major spills involve more than 100 exemption quantities, or contamination of personnel, or release of volatile material)

1. Clear the area. Persons not involved in the spill should leave the immediate area. Limit the movement of all personnel who may be contaminated until they are monitored.
2. If the spill occurs in a laboratory, leave the fume hood running to minimize the release of volatile nuclear substances to adjacent rooms and hallways.
3. Close off and secure the spill area to prevent entry. Post warning sign(s).
4. Notify the Radiation Safety Officer or person in charge immediately.
5. The Radiation Safety Officer or person in charge will direct personnel decontamination and will decide about decay or cleanup operations.
6. In general, decontaminate personnel by removing contaminated clothing and flushing contaminated skin with lukewarm water and mild soap.
7. Follow the procedures for minor spills (if appropriate).
8. Record the names of all persons involved in the spill. Note the details of any personal contamination.
9. The Radiation Safety Officer or person in charge will arrange for any necessary bioassay measurements.
10. If required, submit a written report to the Radiation Safety Officer or person in charge.
11. The Radiation Safety Officer or person in charge must submit a report to the CNSC.

Major spill procedures should be implemented whenever minor spill procedures would be inadequate.

If an exposure may have occurred that is in excess of applicable radiation dose limits, the CNSC shall be contacted within 24 hours of the occurrence under Section 16 of the Radiation Protection Regulations

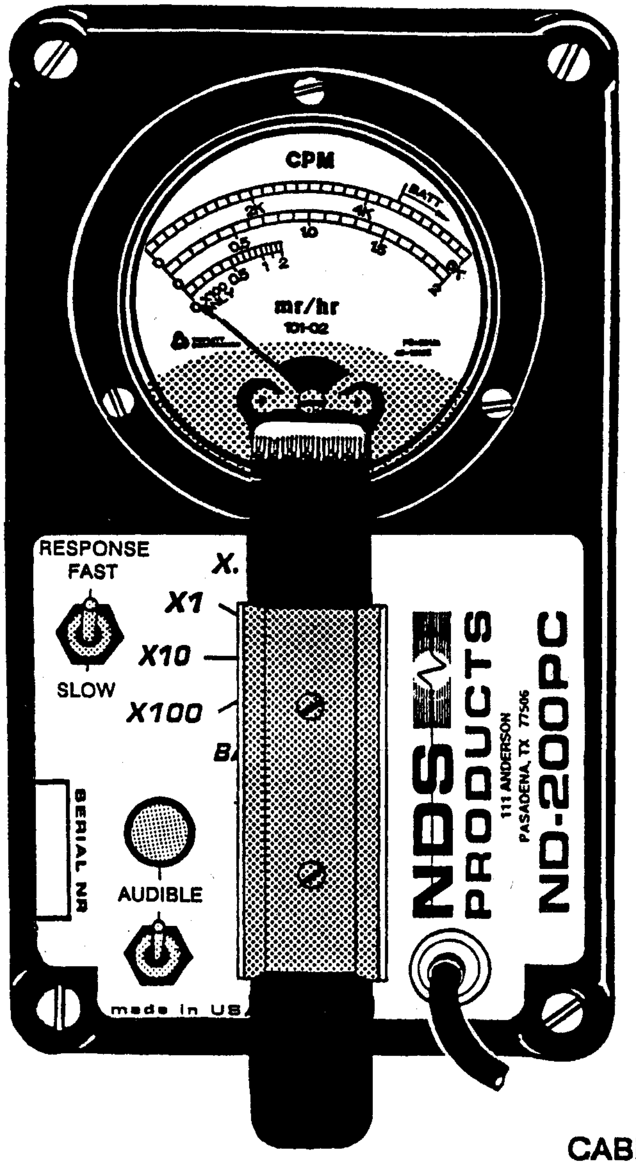
For more information, contact: Directorate of Nuclear Substance Regulation, Canadian Nuclear Safety Commission, P.O. Box 1046, Station B, Ottawa, ON K1P 5S9.
Telephone: 1-888-229-2672. Fax: (613) 995-5086.

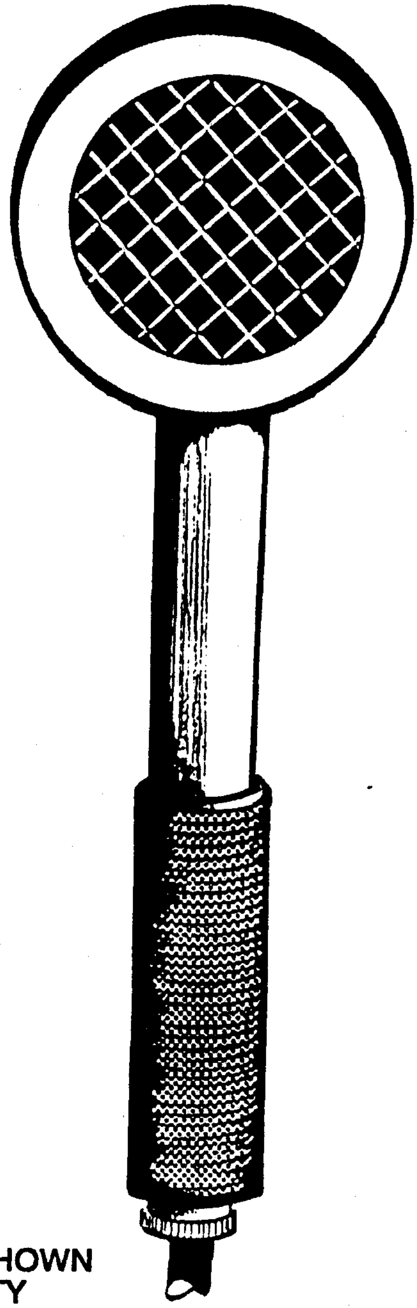
App. D: dual purpose Survey Meter

TECHNICAL DATA
LOW RANGE SURVEY METER

ND-200PC

4 RANGE SURVEY METER
PANCAKE PROBE AND CABLE SUPPLIED WITH INSTRUMENT





CABLE NOT SHOWN
FOR CLARITY

NDS PRODUCTS

111 ANDERSON // PASADENA, TEXAS // PHONE: 713/475-2986 or 713/475-8071 // FAX: 713/477-6741

APPENDIX E: LIQUID WASTE SAMPLING

Information Required From Radioisotope User:

Permit Holder	
Building	
Room Number	
Radioisotope	
Waste liquid (water, acid?)	
Volume of waste liquid in container	

Liquid Scintillation Analysis Information:

Sample ID	
Date analysed	
Volume analysed (ml)	
Detector efficiency (E)	
Counts Per Minute (CPM)	
Background CPM	
Activity (Bq)	
Specific Activity as of analysis (Bq/ml)	

$$\text{Acivity (Bq)} = \frac{\text{CPM} - \text{Bkgd}}{\text{E x 60 sec/min.}}$$

App. F: Packing Slip

7-B-04

99999

-104

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MANDEL Scientific Company Ltd.

LIFE SCIENCE PRODUCTS
ALBANY STREET
TON, MA 02118

LIVRER À/DELIVER TO: CARLETON UNIVERSITY
BIOLOGY DEPARTMENT
OTTAWA, ONT, CANADA
K1S 5B6

(613) 564-3609
EM/YOW
EMERY AIRFREIGHT
ANGELA KISS/BIO/128/TORY
ISOTOPES: P32 I WHITE TRANS.INDEX: .0
TOT ACTIVITY: (.089540 GBQ) (.002420 CI)

ACHEMINEMENT/ROUTE INFORMATION

-NDU À:/
-D TO:

MANDEL SCIENTIFIC COMPANY LTD
2 ADMIRAL PLACE
GUELPH ONTARIO
CANADA N1G4N4

À L'ATTENTION DE/ATTN:

No de COMMANDE/ORDER NO	BON DE COMMANDE DU CLIENT/CUSTOMER PURCHASE ORDER NO.
91208650	S96337R151028

DÉLAI D'EXPÉDITION/SHIP TERMS	VIA	PORT PAYÉ/PAID	PORT DÛ
DDU SCARBOROUGH, CANADA	AIR	X	

POINT D'EXPÉDITION/SHIPPING POINT: NEN 549 ALBANY ST.
BOSTON, MA 02118

No DU CLIENT/CUSTOMER NO.	EXPÉDITION/SHIPMENT COMPLÈTE/COMPLETE	PARTIELLE/PARTIAL	CODE REP./REP. CODE		No DE PERMIS/LICENSE NUMBER	RADIATION SUPERFICIELLE/RADIATION AT SURFACE	INSPECTEUR/INSPECTOR	C/PKG
0001 262	X		064	DE	EXPORT	.0363MR/HR		DI

DATE D'ENTRÉE/ENTRY DATE	DATE D'EXPÉDITION PRÉVUE/SCHEDULED DATE	DATE D'EXPÉDITION/SHIPPING DATE	No AR/AR NUMBER	TAXE/TAX ENDROIT/LOCATION	CLASSE/CLASS	REN	TYPE DE VENTE/SALES CLASS
07/07/97	07/08/97	07/08/97	555710	97423	00	09	

LIGNE NO	QUANTITÉ COMMANDÉE/QUANTITY ORDERED	QUANTITÉ EXPÉDIÉE/QUANTITY SHIPPED	No DE PIÈCE/PART NUMBER	DESCRIPTION/DESCRIPTION	DIMENSION DU COLIS/PACKAGE SIZE	Nos LOT ET SÉRIE/LOT/SERIAL NUMBERS
				*IF NOT DOCUMENTARY COLLECTION *THROUGH A BANK THEN REMIT *PROCEEDS BY WIRE TRANSFER *ONLY AT OUR EXPENSE TO *CHMANBK,NEW YORK,NY-SWIFT *CHAS US 33; TELEX 125563. *CHASE MANHATTAN BANK,NEW YORK * NY,USA FOR ACCT OF E.I. *DUPONT DE NEMOURS & CO *#910-1-484559. PLS MAKE *CERTAIN YOUR BANKERS SHOW *COMPANY NAME & COUNTRY,INV#'S M05513N26453		
	2	2	NEG002H 0117	ADENOSINE 5'-TRIPHOSPHATE TETRA-(TRIETHYLAMMONIUM)SALT [G-32P]-	37000KBQ 1MC	002H07037

POUR TOUTE QUESTION CONCERNANT CETTE COMMANDE, APPELER:/ANY QUESTIONS REGARDING THIS ORDER CALL:
English 800-677-9912 French 800-677-8856 0139

ISOTOPES: P32
D.O.T. LABEL: I WHITE 7-B-04
TOTAL ACTIVITY: .089540 GBQ TRANS. INDEX: .0
TOTAL ACTIVITY: .002420 CI

Appendix G: Inventory Log

Permit holder:	Radionuclide and Compound:	Supplier:
Location of Use:	Activity (mCi or MBq):	Volume (µl or ml):
Date Received:	Lot/Batch Number:	Calibration Date:

note: if more than one vial of same lot number with same date, label each vial (1, 2, 3, etc.)

Date Removed from Stock Vial	**User**	**Amount Used ( )**	**Activity Remaining**

Date vial disposed of: ___________________

APPENDIX H: RADIATION UNITS

RADIATION UNITS

Exposure

New		**Old**
None		Roentgen (R)

Absorbed Dose

New		**Old**
1 gray (Gy)	=	100 rad

Dose Equivalent

New		**Old**
1 sievert (Sv)	=	100 rem (rem)
1 millisievert (mSv)	=	100 millirem (mrem)

Activity

New		**Old**
37 gigabecquerel (GBq)	=	1 curie (Ci)
37 megabecquerel (MBq)	=	1 millicurie (mCi)

SI Prefixes

Multiplying Factor			**Prefix**	**Symbol**
1 000 000 000	=	10^{9}	giga	G
1 000 000	=	10^{6}	mega	M
1 000	=	10^{3}	kilo	k
0.001	=	10^{-3}	milli	m
0.000 001	=	10^{-6}	micro	µ
0.000 000 001	=	10^{-9}	nano	n
0.000 000 000 001	=	10^{-12}	pico	p

APPENDIX I: MONTHLY CHECKLIST FOR OPEN SOURCE USERS

Permit Holder: ________________ Labs Listed on Permit: ________________

Checklist for

Month	Year

Item	**Description**	**Yes**	**No**	**N/A**
Permit	Current and posted in all labs listed			
Lab Rules	Posted in all labs listed			
Radiation Warning	Posted on exterior door if radioisotopes are present			
Emergency Contact	Posted on exterior door if radioisotopes are present			
Work area labelling	Designated work area (eg. fume hood, counter) labelled with radiation warning tape			
Inventory	Inventory Log available for each vial			
	User records on Inventory Log			
	Empty/decayed vials noted on Inventory Log, demarked, and sent to waste.			
	Inventory Logs for current and disposed vials are kept separate			
Contamination Monitoring	Bq/cm^2 conversion to CPM limits shown in monitoring log book			
	Performed if open sources have been used. See Inventory Log records			
Storage	Current radioisotope vials stored in container labelled with permit holder's name			
Waste	Liquids and solids stored separately			
	Containers labelled with radiation warning tape and isotope			
	Short lived and long-lived isotope stored separately			

Radioisotopes Received Since Completion of Last Checklist

Radioisotope	Activity (mCi or MBq)	Calibration Date	Lot/Batch No.	Supplier	Storage room

Completed By: ______________ Date: ________________

Return copy to:
Radiation Safety Officer
210 MB

Appendix J: Emergency Response for Sealed Sources – Physics

EQUIPMENT

- Personal Protective Equipment (Lab coat, safety glasses, latex gloves)
- Personal Dosimeter
- Radiation Survey Meter (available from room 1500 CTTC)
- Contamination Meter (available from room 1500 CTTC)
- Lead Shielding (available from Radiation Storage room 118 Steacie Bldg.)
- Long Tongs ((available from Radiation Storage room 118 Steacie Bldg.)

LIMITS

- Annual whole body ionizing radiation dose of 100 mrem (1 mSv).
- Storage Area: maximum dose rate of 0.25 mrem/hr (2.5 microSv/hr) at any occupied location around the area.

TELEPHONE NUMBERS

- RSO and Assistant RSO available through Safety Dispatch #4444
- CNSC 24-hour duty officer: 613-995-0479

PROCEDURE

The following response refers to actions to be taken in the affected area in the event of a radiation emergency involving a sealed source.

Emergency Response

- Assess the situation. If there is reason to believe that a source has been damaged due to fire, explosion or other cause take steps to isolate the source.
- Secure the perimeter of the affected area. This can be done by roping off a perimeter at least 2 meters (6 feet) from the source with appropriate signage or post a person to prevent access to the area.
- Contact the RSO and provide details of the emergency including the source location. In the case of fire, emergency responders should try to keep a minimum of 2 metres (6 feet) away from the source.

The Radiation Safety Officer or Assistant shall:

1) Contact the CNSC
2) Don protective equipment: dosimeter, gloves, lab coats.
3) Measure the radiation in the affected area using the calibrated survey meter. If shielding is damaged, place source in another lead container using tongs.
4) Take a quick contamination wipe of the source container and surrounding area using a filter paper or piece of paper towel. Take the wipes outside the 2 metre perimeter and measure the wipes using the contamination probe. Compare to the background reading. Check hands and feet for contamination using contamination meter. If contamination is detected the source must be isolated by shielding and contained by wrapping in plastic and sealing. Proceed with Spill Procedures Appendix C for decontamination of other surfaces.

Appendix J: Emergency Response for Sealed Sources – Physics

5) If no contamination is detected in step 4, take a leak test sample and send for analysis according to R-116 requirements. If the source is found to be leaking, report to the CNSC and the source must be isolated and contained by wrapping in plastic and sealing. Leaking sources must be disposed of in an approved manner.

6) When the source is secured perform direct contamination check of gloves, shoes, clothing and the area to ensure no additional clean up measures are required.

7)- Contact the CNSC again to report on the results of the emergency response and lead any post incident investigation required by the CNSC.

RESPONDING TO ACCIDENTS INVOLVING PORTABLE GAUGES

Accidents and Suspected Source or Shielding Body Damage

1. Keep people at least 2 m away until the radiation sources are removed, or until radiation levels are known to be safe.
2. **Minor or superficial damage:** Return the radiation sources to the safe, shielded position, notify your supervisor or Radiation Safety Officer (RSO) and check the portable gauge for proper operation. Use the manufacturer's Type A container for transport if the source rod is returned to the safe, shielded position and radiation levels do not exceed transport index (TI) requirements.
3. **Severe damage or the source rod will not retract:** Inform the following persons and follow the steps below for **Transportation of a Damaged Gauge**.

   Supervisor or RSO:
   Work Telephone:
   Home Telephone:

   Specialist Firm (if your procedures require outside services):
   Specialist Firm:
   Telephone:

   Canadian Nuclear Safety Commission (CNSC):
   Duty Officer, Ottawa (24 hours): (613) 995-0479

   Police:
   (for transportation accidents)

Transportation of a Damaged Gauge

An improvised temporary container may be used, made up of a 45 gallon steel drum with a secure lid. Sand and/or gravel may be used as shielding material. Before placing the damaged gauge in the drum, partially fill the drum with shielding material. After the damaged gauge is placed in the drum, add additional shielding material to secure and shield the contents of the drum. Use a calibrated radiation survey meter to ensure safe radiation levels. The CNSC must be contacted as special precautions, packaging and permission may be necessary in order to transport the damaged gauge.

Recovery Action

Recovery actions should always be based upon **ALARA** principles. During recovery, time, distance and shielding should be implemented to minimize radiation exposure.

Time: Minimize time by planning your actions (gathering the necessary tools for the recovery, locating the recovery drum near the accident site, getting assistance).

Distance: Keep non-recovery personnel out of the area. Use long handled tools. Secure the drum in the vehicle at the furthest point from the driver when shipping.

Shielding: Use the body of the gauge as a shield if necessary. Add sand and/or gravel in the drum as shielding material.

Before the accident site is unconditionally released, a calibrated radiation survey meter must be used to perform a radiation survey to verify that all radiation sources have been retrieved.

Loss or Theft of Gauge

Immediately inform your supervisor or RSO, the local police and the CNSC that a loss or theft has occurred.

Pursuant to Section 29 of the General Nuclear Safety and Control Regulations, a full report shall be filed with the CNSC within 21 days.

For more information, please contact:
Canadian Nuclear Safety Commission, Directorate of Nuclear Substance Regulation,
P.O. Box 1046, Station 'B', Ottawa, Ontario K1P 5S9
Telephone: 1-888-229-2672, Facsimile: (613) 995-5086

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RADIATION

App. L

DANGER
RAYONNEMENT

Canadian Nuclear Safety Commission
Commission canadienne de sûreté nucléaire

INFO-0744

GUIDELINES FOR HANDLING PACKAGES CONTAINING NUCLEAR SUBSTANCES

Identifying Packages Containing Nuclear Substances

The packaging and labeling of nuclear substances is governed by the Canadian Nuclear Safety Commission's *Packaging and Transport of Nuclear Substances (PTNS) Regulations*. Nuclear substances may be shipped in “Excepted Packages”, “Type A” or “Type B” packages, “Industrial Packages I, II, III”, and packages for “Fissile Material”. The “radioactive” category labels also show radiation dose rates.

On Excepted Packages, no external labeling is required, and the safety mark “RADIOACTIVE” must be visible upon opening the package. The radiation level at any point on the external surface of the package must not exceed 5 µSv/h. All other packages must be categorized by radiation level and display the corresponding radiation warning labels as follows:

Category 1-WHITE
Does not exceed 5 µSv/h at any location on the external surface of the package

Category II-YELLOW
Does not exceed 500 µSv/h at any location on the external surface of the package and the transport index does not exceed 1.

Category III-YELLOW
Does not exceed 2 mSv/h at any location on the external surface of the package and the transport index does not exceed 10.

The transport index is the maximum radiation level in microsieverts per hour at one metre from the external surface of the package, divided by 10.
Example: 1 µSv/h (0.1 mrem/h) at 1 m equals a TI = 0.1.

Upon receipt of a package containing nuclear substances, keep your distance. Examine the package for damage or leakage. If the package is damaged or leaking, contain and isolate it to minimize radiation exposure and contamination, and comply with Section 19 of the PTNS *Regulations*.

Opening Packages Containing Nuclear Substances

Radiation Safety Officer	**Phone Number**

1. If an appropriate survey monitor is available, monitor the radiation fields around the package. Note any discrepancies.
2. Avoid unnecessary direct contact with unshielded containers.
3. Verify the nuclear substance, the quantity, and other details with the information on the packing slip and with the purchase order. Log the shipment details and any anomalies in the inventory record.
4. Report any anomalies (radiation levels in excess of the package labeling, incorrect transport index, contamination, leakage, short or wrong shipment) to the Radiation Safety Officer.

When opening packages containing unsealed nuclear substances, additional steps should be taken:

5. Wear protective clothing while handling the package.
6. If the material is volatile (unbound iodine, tritium, radioactive gases, etc.) or in a powder form, open the package in a fume hood.
7. Open the outer package and check for possible damage to the contents, broken seals, or discoloration of packing materials. If the contents appear to be damaged, isolate the package to prevent further contamination and notify the Radiation Safety Officer.
8. If no damage is evident, wipe test the inner package or primary container which holds the unsealed nuclear substance. If contamination is detected, monitor all packaging and, if appropriate, all locations in contact with the package, for contamination. Contain the contamination, decontaminate, and dispose in accordance with the conditions of the Nuclear Substances and Radiation Devices licence.

For more information, contact: Directorate of Nuclear Substance Regulation, Canadian Nuclear Safety Commission, P.O. Box 1046, Station B, Ottawa, ON K1P 5S9. Telephone: 1-888-229-2672. Fax: (613) 995-5086.