

Unsealed Radioactive Materials

Statutory and University Obligations

1. Purchase of radionuclides must only be undertaken by a user licensee. Records of purchase and transfer of radionuclide must be retained in each laboratory.
2. The activities of most unsealed radioactive material will fall below licensable activity. In such cases a purchase and use of unsealed radioactive material must be undertaken under the supervision of the Responsible Principal Investigator (Responsible PI)
3. Unsealed radionuclide sources must be handled by a Responsible PI or a person who is under the supervision or instruction of Responsible PI. The requirements of NRL Code of Safe Practice NRL C1 and the University of Auckland Radiation Safety Plan must be observed. Where the activity of the radionuclide is such that it is classified as exempt (see Schedule 4 of the Radiation Protection Regulations, 1981) the nuclide must be handled according to the requirements of NRL Code of Safe Practice NRL C1 and the University of Auckland Radiation Safety Plan.
4. Responsible PIs must specify Users of Radionuclides under supervision or instruction and ensure that all users complete the relevant Canvas on-line training module.
5. Responsible PIs must ensure that a documented method of contamination monitoring is followed.
6. In cases where licensable activities of ^{125}I are purchased and free iodine is generated, user licensees must ensure that a documented method of personnel monitoring (ie ^{125}I thyroid uptake) is followed.
7. Wherever possible ALARA principles will be employed to ensure the dose to staff and students using radionuclides is as low as possible.

Safe Handling of Unsealed Radioactive Materials

1. There are two fundamental requirements for safe work with unsealed radioactive materials:
 - a) It is essential that unsealed radioactive sources is contained at all times, so that it does not provide a source of contamination where it could be accidentally ingested by others (or be a source of external radiation to the worker or others).
 - b) The worker must take precautions, such using the correct shielding, to limit the dose she/he (and bystanders) receives from sources external to the body.
2. The details of the techniques required to satisfy both these requirements vary depending on the chemical and the nuclear characteristics of the nuclide. Therefore, it is imperative that all users familiarise themselves with the half-life, the type of decay and biological half-life of the isotope they are using by undertaking the relevant Canvas on-line training module.
3. There are five basic rules that must be followed when working with radioisotopes:
 - a) Work with radioactive isotopes must be conducted in labelled radioactive work areas. The work areas do not have to be a permanent fixture in the lab. These radioactive work areas must, however, be clearly identifiable and a method of monitoring for contamination must be employed.
 - b) Care must be taken in all cases to reduce clutter in the radioactive work area and maintain work areas in a clean and tidy manner. Such work practices minimise the risk of contamination and accidental spills and are recommended by the National Radiation Laboratory.

- c) Gloves must be worn at all times when handling any radioactive compound. Use two pairs of gloves (monitoring and discarding the outer pair frequently) when handling high activity unsealed sources [particularly ^{125}I in excess of 3 MBq (100 microCurie)].
- d) Active method of monitoring work area must be undertaken. Regular wipe testing of work and storage areas will be conducted in the case of low energy beta emitting isotopes such as ^3H , ^{14}C , ^{35}S , or ^{33}P .
- e) All containers of radioisotope (either primary or working solutions) must be clearly labelled as such unless the container is temporary and is within a clearly defined radioactive work area.

Containment of Radioactive Material

1. All radioactive material must be handled within designated 'hot areas'. No item should be allowed to leave the hot area until the investigator is satisfied that it does not pose a contamination and/or an external radiation hazard to the worker or others. In some cases 'hot areas' may be temporary and be in place for the duration of an experiment.
2. All hot areas must have adequate shielding and non-permeable surfaces (with absorbent material such as an incontinent pad if desired) to contain spills.
3. The work area must be monitored for contamination and cleaned up as required
4. Work must be double contained (e.g. a test-tube inside a beaker, a microfuge tube rack containing the reaction or a hybridisation bag should be placed on a plastic tray) in case of spillage.
5. As far as possible use disposable plastic laboratory ware. as it is decontaminated easily and is cheap if it has to be disposed).
6. All primary vials and those containers of products containing radionuclide must be labelled with appropriate warnings.
7. All contaminated waste must be disposed correctly.

Dose Limitation – the Role of Time, Distance and Shielding.

1. Use appropriate shielding. Beta radiation may be completely absorbed by the use of shielding material of low atomic number (ie Perspex, not lead), to minimise the production of *bremsstrahlung* radiation. Gamma radiation is never completely absorbed by shielding, it is attenuated. Lead is the best material in most cases.
2. Total dose is also related to both the distance from the radioactive source and the time of exposure, and may be reduced by altering both of these factors.
3. Spend the minimum time necessary in proximity to radioactive work areas. Keep the quantity of radioactivity in the work area to a minimum necessary to do the work. It may be wise to work from a small aliquot periodically replenished from a stock kept at a distance.
4. Where possible, the radioactive reagent should be the last one added to the reaction vessel.
5. Make use of the Inverse Square Law wherever possible, particularly when choosing location of hot area where energetic beta emitters are to be handled.
6. The tops of many isotope containers are designed to facilitate opening and closing of the isotope vial seals and reduce exposure of hands where high energy beta emitters such as ^{32}P are used. The use of these features will also minimise the risk of accidental spills when opening and ensure a tight seal is maintained on the vial when the isotope is returned to storage.

Contamination Monitoring

1. Higher energy Beta radiation must be monitored with a monitor fitted with a Geiger-Muller tube. Gamma emission must be monitored with a scintillation monitor fitted with a sodium iodide crystal

probe. Do not use a G-M tube to monitor ¹²⁵I labelled compounds or low energy beta emitting nuclides 14C or 3H).

2. Regular wipe testing will be conducted for work areas where low energy beta emitting radionuclides are used and stored. The results of all wipe testing must be documented and retained by licensee.

Disposal of Radioactive Waste

1. Radioactive waste is any waste that contains or is contaminated with radioactive material. This includes liquids, solids, animal carcasses and excreta, used scintillation counting liquids (LSC) etc.
2. Wherever possible, use of radioactive decay to background should be used for waste from radionuclides with short half lives (35S, 33P, 32P and 125 I).
3. Waste from low energy beta emitting radionuclides may be disposed by dispersion to the environment. Limits outlined in Appendix 5 – Waste Disposal Limits of the NRL Code of Safe Practice (NRL C1) will always be observed. Where disposal to sewer is employed, limits at sewer will be used at sink with an additional 5 fold margin of safety.
4. Radioactive waste must never be placed in any non-radioactive waste container or disposed of in the sink. Conversely, general (ie. non-radioactive) waste should enter the radioactive waste stream - this keeps volumes of radioactive waste to a minimum.
5. Specific waste disposal procedures:
 - a) Segregation by half-life: Short half-life wastes (radioactive half-life of less than 50 days) must be kept separate from long half-lived wastes (radioactive half-life or greater than 50 days).
 - b) Dry solid waste must be disposed of in double lined thick plastic bags and labelled with the name of the laboratory, estimated amount of radioactivity, the isotope, the date of disposal and date of decay to almost background. Bags should be placed in the designated decay storage area (consult your licensee).
 - c) Liquid radioactive waste must be collected separately from dry waste and stored in plastic containers. Waste containers should be labelled with the name of the laboratory, estimated amount of radioactivity, the isotope, the date of disposal and date of decay to almost background. Containers should be placed in the designated waste storage area (consult the Responsible PI).
 - d) Liquid scintillation vials containing radioactive material should be kept separate from other liquid waste. If an organic-based scintillant was used, the scintillant should be evaporated in a fumehood prior to disposal. Label and dispose in designated waste storage area (consult the Responsible PI).
 - e) Pipettes of glass or plastic and needles contaminate with radioactive material must be kept separate from all other radioactive waste. Glass and plastic pipettes should be placed in a cardboard box or other suitable container, labelled "Caution, Radioactive Material" and placed in the designated waste storage area (consult your supervisor). Hypodermic needles should be disposed of in a plastic container specifically designed for their disposal and labelled "Caution, Radioactive Material". This container should be placed in the designated waste storage area (consult the Responsible PI).

SOME FEATURES OF COMMONLY USED RADIOISOTOPES

Tritium

1. The beta emission from Tritium is of low energy and gives rise to no external radiation hazard, and therefore makes it difficult to monitor tritium contamination. Therefore care is required when handling these compounds containing this nuclide.
2. Gloves should be worn at all times when handling this compound.
3. Periodic wipe tests must be conducted to determine the extent of contamination wherever this nuclide is stored or used.

Carbon-14, Phosphorus-33 and Sulphur-35

1. Although the metabolism of these compounds containing these nuclides is different, they have comparable radiation hazards. These three nuclides emit relatively low energy beta radiation and their use presents no hazard from external radiation when handling amounts less than 1 μ Ci.
2. A thin end Geiger-Muller tube will detect less than 10% of the beta particles incident upon it. Contamination with these nuclides can be difficult to detect, therefore extra care and regular wipe testing is required.
3. In the case of Carbon-14, the long half-life (about 6000 years) means that contamination may build up over a long period of time, and unless effectively dealt with, will remain a problem permanently.
4. ^{35}S -labelled amino acids used for protein labelling generate radioactive decomposition products during thawing and subsequent labelling reactions. Additional precautions should be observed when handling these compounds. Always thaw vials of ^{35}S -labelled amino acid in a fume hood using a needle through the rubber septum to vent the vial before opening it. When incubating the labelled amino acids with cells, always contain the labelling media in a plastic tray with a separate container of activated charcoal to absorb any volatile ^{35}S sulfate.
5. ^{35}S -labelled volatile compounds that may escape into the incubator. If biosynthetic labelling experiments are performed regularly always use the same incubator and change the water in the bottom tray after every second experiment.
6. In general, Phosphorus-33 labelled compounds do not require shielding over and above that necessary for Carbon-14 and Sulfur-35 labelled compounds. Phosphorus-33 compounds, however, are metabolised in bone and such compounds will have a high toxicity if ingested. As with Carbon-14 and Sulfur-35, accurate assessment of contamination will be difficult using normal survey meters. Extra care, therefore, needs to be taken to avoid contamination and possible subsequent ingestion.
7. Gloves should be worn at all times when handling these compounds.
8. Periodic wipe tests must be conducted to determine the extent of contamination wherever these nuclides are stored or used.

Phosphorus-32

1. The beta emission from this nuclide has a maximum energy of 1.7 MeV, which means that external radiation is an important hazard. Containers and work areas must be shielded with Perspex. The cornea in particular is susceptible to damage and Perspex safety screen must be high enough to shield face.
2. The table below shows the *radiation dose* rates from an Eppendorf tube containing 1.0 MBq of P-32 in 0.1 ml of solution. Holding the tube at the base would give the annual limit *equivalent dose* to the skin in about 6 hours. Holding the tube by the top reduces the dose rate by about one twentieth. The dose rate at arm's length distance is much less, in the range of a few tens of mSv per hour. Even at a distance of 10 cm it would take many days of continuous exposure to reach the annual limit for the eyes.

Measurements of the radiation dose rate from 1.0 MBq of P-32 in 0.1 ml of solution in a 1.5 ml Eppendorf tube (from Ballance et al 1987)

Distance (cm)	Dose rate ($\mu\text{Sv}/\text{min}$)
Surface	1444
10	4.67
20	1.25
30	0.58
40	0.25
50	0.17
60	0.13

3. Lead is an unsuitable screen for ^{32}P as the beta radiation from this nuclide can give rise to hazardous *bremsstrahlung* radiation from lead.
4. As the metabolism of ^{32}P results in its deposition in bone (bone marrow is one of the organs most sensitive to radiation), its toxicity is relatively high. Gloves should be monitored and changed regularly for contamination during all manipulations involving this nuclide to prevent internal contamination.
5. Work with any of these radionuclides must be undertaken in work areas that are clean, tidy and free of clutter. Such work practises will minimise the risk of contamination and accidental spills.
6. Gloves should be worn at all times when handling these compounds.
7. Work with ^{32}P must be monitored continuously using a survey meter fitted with a Geiger Muller detector.

Iodine-125 and Iodine-131

1. The metabolism of iodine involves its concentration and long retention in the thyroid gland, and because of the high concentration in the small volume of tissue comprising this organ, all radioisotopes of iodine have a relative high toxicity.
2. In many chemical forms isotopes of iodine are volatile, and inhalation of the radioactive material in a gaseous form is a significant hazard. Iodination of proteins, which involve the use of high activity unsealed radioactive sources of ^{125}I and the generation of radioactive iodine gas in the reaction, must only be performed in a fume hood in a High Activity Radiation Suite by authorised and trained workers.
3. Persons undertaking radio-iodination procedures must verify that there has been no uptake of radioactive material by external counting of the thyroid gland, within one week of iodination or after iodination experiments have been completed.
4. The gamma radiation emitted by these two isotopes of Iodine can give rise to significant external gamma radiation hazard from activities commonly in use. The provision of lead shielding is necessary.
5. Work with any of these radionuclides must be undertaken in work areas that are clean, tidy and free of clutter. Such work practises will minimise the risk of contamination and accidental spills.
6. Gloves should be worn at all times when handling these compounds.

7. Iodine-125 and Iodine-131 are gamma emitters and must be monitored continuously using a survey monitor fitted with a sodium iodide crystal detector. Survey meters fitted with a Geiger Muller detector must not be used.

The Main Characteristics of the Most Commonly Used Radionuclides

	Carbon 14	Hydrogen 3 (Tritium)	Phosphorus 32	Phosphorus 33	Iodine 125	Sulphur 35
Physical half life	5730 years	12.26 years	14.3 days	25.4 days	60 days	87 days
Biological half life	10 days (whole body)	12 days (whole body)	257 days (whole body) 1155 days (bone)	257 days (whole body) 1155 days (bone)	138 days (thyroid)	90 days (whole body)
Effective half life	10 days (whole body)	12 days (whole body)	13.5 days (whole body) 14.1 days (bone)	24.1 days (whole body) 24.3 days (bone)	42 days (thyroid)	14 days (whole body)
Type of decay	β^- to ^{14}N Emax = 0.156 MeV	β^- to ^3He Emax = 0.018 MeV	β^- to ^{32}S Emax = 1.71 MeV	β^- to ^{35}Cl Emax = 0.249 MeV	Electron capture and γ ray to ^{125}Te	β^- to ^{35}Cl Emax = 0.168 MeV
Critical organ	fat	whole body	bone	bone	thyroid	skin, testis
Maximum allowable Intake	35 MBq	480 MBq	6.3 MBq	8.3 MBq	1.3 MBq	15 MBq
Shielding	None required, emission won't penetrate skin	None required, emission won't penetrate skin	10mm Perspex	5mm perspex	3mm thick lead	5mm perspex