

RADIATION SAFETY MANUAL

**School of Biomedical Sciences
Curtin University of Technology
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WORKING RULES FOR THE USE OF RADIOACTIVE SUBSTANCES IN THE SCHOOL OF BIOMEDICAL SCIENCES

SECTION 1 - INTRODUCTION

These procedures and rules apply to ALL PERSONS working with radioactive substances within the School of Biomedical Sciences.

The two main objectives for adopting rules for working in a Radioisotope Laboratory are :

- (a) to minimise radiation exposure of the individual in accordance with the Recommendations of the International Commission on Radiological Protection; and
- (b) to prevent contamination of the laboratory, benches, equipment and operator.

These objectives are necessary to ensure that :

- i) Experimental results are meaningful; and
- ii) A health hazard, in particular an internal health hazard, is not caused.

Protection from radiation external to the body is obtained in three ways:

- i) Distance
- ii) Short exposure time
- iii) Shielding

If a small gamma emitting source (point source) is considered, the radiation intensity I_2 at a distance d_2 cm from the source will be

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

in which I_1 is the radiation intensity from the "point" source, d_1 is the radius of a sphere surrounding the "point" at its centre, and d_2 is the radius of a larger sphere. Even relatively weak sources should therefore be handled with tweezers, as the **inverse square law** shows that the intensity of radiation will increase considerably between, for example, 10 cm and 0.1 cm.

Alpha and beta emitting sources do not follow the inverse square law. Absorption of the radiation in the walls of the containing vessel provides protection for both alpha and soft beta emitters. With hard beta emitters such as ^{32}P , shielding in the form of perspex or glass 0.5 - 1 cm thick may be necessary. An approximate formula for ascertaining the beta dose rate is :

$$\text{Dose rate} = 3,000 \times C \text{ rads/hour at 10 cm}$$

where C is the source activity in curies

Lead bricks or sheeting may be necessary to provide shielding when manipulating gamma emitters. Table 1 lists the approximate half thickness of lead as a function of the gamma ray energy.

TABLE 1

Gamma Photon Energy MeV	Approximate Half-Thickness of Lead Shielding cm
0.5	0.5
1.0	1.0
1.5	1.5
2.4	2.0

SECTION 2 - GENERAL RULES

Experimental work involving radioactive substances will be performed in the Radioisotope Laboratory (Room 308.124) within the School of Biomedical Sciences, or in the designated Radioisotope Laboratory in the Russell Pathology Building, Technology Park.

Exceptions to this rule and the conditions which then apply are outlined below.

i) Tissue Culture

Tissue culture experiments involving radioactive reagents should be performed in a laminar flow cabinet. The maximum quantity of radionuclide that should be used in this fashion is shown in Table 2. In addition, it is the operator's responsibility to ensure that contaminated materials are returned to the Radioisotope Laboratory and that the radiolabelled tissue cultures are adequately labelled and safely stored. Manipulations in the laminar flow cabinet will be performed over a plastic tray.

Stock sources **should not be diluted** in the laminar flow cabinet.

ii). Inoculation of Animals

Inoculation of animals with radionuclides should be performed in the animal house provided the quantity of radionuclide used does not exceed the limits shown in Table 2. Furthermore, this procedure must be performed over a piece of benchkote and all contaminated syringes, vials, etc. must be returned to the radioisotope laboratory for disposal.

At the completion of animal experiments the animal waste and sawdust etc. must be sealed in a plastic bag for decontamination.

The plastic bag should be subsequently sealed in a heavy duty waste disposal bag and labelled as for Dry Waste disposal (SEE SECTION 6) The bag should then be taken to the Radiation Storage Facility. Contact the Radiation Safety Officer if not familiar with the Storage Facility.

The animals used in the experiment should be sacrificed, placed in a sealed plastic bag and stored in the designated freezer in the animal house until disposal is effected. Please inform the Radiation Safety Officer when you have animal carcasses for disposal.

It is the operators' responsibility to ensure this procedure is completed. Failure to do so will result in the withdrawal of permission to do this type of experiment.

iii). Student Practicals

Due to lack of space it may be necessary for some student practicals using radionuclides to be performed in student laboratories. In this instance, approval must be obtained from the Radiation Officer. Furthermore, the following conditions must be adhered to :

* Maximum quantities of radionuclide per experiment must not exceed that shown in Table 2. In most cases, the limit represents 1% of the maximum amount permitted in a Type C radiation laboratory. Experiments requiring the use of radioisotopes at levels exceeding these limits should be discussed with the Radiation Safety Officer.

* All Students must work over shallow plastic trays resting on a sheet of benchkote.

* Disposable gloves must be worn by students manipulating radioactive solutions.

*The Lecturer in Charge must assume total responsibility for the removal of radioactive waste and the proper treatment of contaminated glassware.

Strict adherence to the above conditions is essential if this practice is to continue. Failure to comply with these conditions will result in withdrawal of this privilege by the Radiation Officer. Subsequent requests for permission to recontinue class practicals of this nature must be referred to the Head of School.

TABLE 2 - Maximum Amounts Per Experiment (Microcuries) of Radionuclides which may be used outside the Radioisotope Laboratory

Radionuclide	Tissue Culture	Animal House	Class Practicals
^3H Thymidine	1000	1000	10000
^{125}I -Protein	10	10	10
^{14}C	100	100	1000
^{35}S	-	-	1000
^{32}P	-	-	1000

SECTION 3 - PROCEDURAL RULES

For your own and your colleagues safety you **MUST** observe a high standard of laboratory technique. In particular, whilst working with radioactive substances -

i) You **WILL NOT** :

- * smoke, eat, drink, lick labels, etc.
- * mouth pipette
- * leave your work area in an untidy state

ii) You **WILL**

- * Fill in the required **Log** sheet upon entering a designated Radioactive Laboratory
- * Wear **laboratory coat** and **film badge**
- * **Monitor** your work area **before** beginning any experiment
- * Use automatic pipettes or pumpettes
- * **Wear gloves** when handling both radioisotopes and scintillants
- * Work over a tray, small area of benchkote or similarly defined safety area - use shielding as required (SEE APPENDIX 5)
- * **Label** all radioactive sources (including working solutions) with date, nature of radioisotope and specific activity
- * Dispense from bulk sources under approved conditions (SEE SECTION 4). Students are not permitted to dispense from bulk sources.
- * **Decontaminate** any spills immediately (SEE SECTION 7)
- * **Dispose** of all contaminated waste **appropriately** (SEE SECTION 6)
- * **Wash** contaminated glassware yourself (SEE SECTION 5)
- * **Monitor** yourself and your surroundings **before quitting** the work area (SEE APPENDIX 5)
NB. When working with isotopes that cannot be detected with a hand held monitor (eg ^3H , ^{14}C), the user must monitor the work area daily with wipe testing and scintillation counting. Consult the Radiation Supervisor to ensure that wipe testing procedures are correct.
- * **Report** contamination of the work environment to the Radiation Supervisor.

Care and tidy work will minimize problems.

SECTION 4 - DISPENSING FROM STOCK SOURCES

- i) This operation **must** be carried out in the Radioisotope Laboratory.
- ii) Work over a suitable spill tray located in the fume hood. Work behind perspex shielding when dispensing ^{32}P .
- iii) Whenever practicable dispense stock isotopes through the rubber inset in the cap of the bottle or vial. Plastic syringes and other disposable containers etc. should always be used for subsequent dilution.
- iv) Label all solutions prepared with activity (specific and total), date, name of radionuclide and operator's name.

SECTION 5 - USE OF GLASSWARE

- i) Minimize use of non-disposable glassware in the Radioisotope Laboratory.
- ii) Two plastic tanks will be provided, one for CONTAMINATED glassware, the other for non-contaminated glassware. The contaminated glassware tank will contain water with DECON detergent. It is your responsibility to ensure that only NON-CONTAMINATED glassware goes into the noncontaminated glassware tank.
- iii) Non-contaminated glassware will be washed in the general washup room and returned to the radioisotope laboratory.
- iv) CONTAMINATED glassware must be washed (after soaking in Decon) by the operator who used it (or his nominee).

NB: Rubber gloves will be used during this washing process and all wash waste must be disposed of in the flush sink.

SECTION 6 - DISPOSAL OF RADIOACTIVE WASTE

There are five (5) types of radioactive waste each of which must be disposed of separately.

i) Scintillation Cocktails

Plastic scintillation vials should be used if possible in preference to glass vials.

An appropriate biodegradable scintillant should be used, avoid scintillation cocktails containing xylene or any other environmentally unfriendly organic solvent. Scintillation vials used for scintillation counting will be collected into heavy duty plastic bags (insure vial caps are secure) and sealed. These should then be placed into the paper Hazardous Waste Disposal bags, sealed and labelled appropriately:

Radioisotope
Approximate Activity in Bq or Ci
Type of Waste (scintillation vials)
Name of individual disposing of waste
School/Dept
Date

The bag should be deposited into the appropriate Drum located in the Radioisotope Room. Inform the Radiation Supervisor when the drum needs to be emptied. Be aware that organic solvents may leach out (along with the radioisotope) of plastic scintillation vials. Long term storage is not recommended. All scintillation waste will be disposed of by land fill (in accordance with Radiation Safety Act regulations) unless legally exempt from classification as radioactive material.

NB. In the event that the amount of isotope is less than or equal to the exempt quantity for classification as radioactive waste (as recorded in Schedule V of the Radiation Safety Regulations 1983), all reference to radiation will be removed from the waste bags and the waste will then be disposed of by incineration (through a licensed contractor for disposal of medically infectious waste). Exempt quantities for commonly used radioisotopes are listed below (see item iii, this section)

ii) Aqueous Liquid Waste

The Regulations prescribed in the Radiation Safety Act permit disposal of liquid waste into the sewers providing that their concentration does not exceed defined limits at the point of exit from the premises. To aid the dilution process the Radioisotope Laboratory is equipped with a special flush sink. All aqueous liquid wastes will be disposed of in this sink.

The maximum amount of radionuclide disposed of at one time must not exceed the following for a 20 L flush:

Chromium 51	970	Ci
Tritium compounds	2000	uCi
Carbon 14 compound	400	uCi
Iodine 125	1	uCi
Iodine 131	1	uCi
Phosphorus 32	10	uCi
Sulphur 35	40	uCi

It is unlikely that large quantities of radioactivity which pose disposal problems will be required within the School. If an individual wishes to use a large quantity of radionuclide which will create a disposal problem then it will be the responsibility of that person to consult the Radiation Supervisor prior to commencing work.

iii) Dry Waste (Flammable)

Tissues, paper towels, plastic tips, syringes, etc. should be placed inside Heavy Duty Waste Disposal bags, labelled as indicated below and then disposed of in the appropriate radioactive waste container in the Radioisotope Laboratory. Such waste will be transported when required to the University Radiation Store and held until it is non-radioactive according to the Radiation Safety Act regulations.

Disposal Limits :

^3H	40 MBq	1.08 mCi
^{14}C	4 MBq	108 uCi
^{51}Cr	40 Mbq	1.08 mCi
^{125}I	40 kBq	1.08 uCi
^{32}P	400 kBq	10.8 uCi
^{35}S	4 Mbq	108 uCi

It is therefore imperative that all radioactive waste be labelled as follows:

Radioisotope
Approximate Activity in Bq or Ci
Type of Waste (scintillation vials)
Name of individual disposing of waste
School/Dept
Date

iv) Dry Waste (Non-flammable)

Glass bottles, glass scintillation vials, pasteur pipettes, etc. should be placed in the appropriate containers for glass waste in the Radioactive Laboratory. This waste is also disposed of by private contractors. Waste of this nature is difficult to dispose of since it must be buried and suitable sites are difficult to find.

Please, therefore -

* keep glass waste to a minimum

and

* do not contaminate with solutions of high activity.

v) Animals

At the conclusion of experimentation involving animals the animals should be sacrificed, placed in a sealed plastic bag and stored in the designated freezer in the animal house until disposal is effected. Please inform the Radiation Safety Officer when you have animal carcasses for disposal.

SECTION 7 - SPILLS OF RADIOACTIVE SUBSTANCES

Even with careful planning and good technique unforeseen events may lead to accidents involving the spread of contamination.

In the event of a spill :

- i) Notify all other persons in the room.
- ii) Confine the spill area and drop absorbent paper on the spilt liquid
- iii) Delineate the area involved and its periphery upon which droplets may have fallen.
- iv) Contact the Radiation Officer and decontaminate the area under supervision.
- v) Monitor all persons involved in the spill and subsequent decontamination.
- vi) Prepare a report of the accident and subsequent decontamination steps to assist in upgrading working procedures.

SECTION 8 -ORDERING RADIOACTIVE SUBSTANCES AND SCHOOL LOG BOOKS

All radioactive substances will be ordered from one request book set aside specifically for this purpose. This book will be kept in the School Clerk's office.

Requests for radioactive substances will be vetted to ensure that Departmental and Institute license requirements are not exceeded. Furthermore, requests for radioactive substances which pose difficult disposal problems will require justification even if they comply with the Institute licensing limits.

The Radiation Safety Act (and the Institute Radiation Safety Officer) require that all radioactive substances entering and leaving the School be accounted for. To ensure this is done a log book will be maintained in the Radioisotope Laboratory.

The entry of radioactive substances into the School or Technology Park Laboratories will be recorded in a log book, together with the name of the operator who instigated the order. The isotope will then be stored in the Radioisotope Laboratory.

The progress of the usage of that isotope and disposal to the waste generated will then be recorded in the log book by the relevant operator.

In addition to the School log there will also be a "Users" log. This log will be used to record the use of radioactive substances of long half life, which are used in small quantities over a long period of time. The Users Log will also be kept in the Radioisotope Laboratory.

The Radiation Supervisor will extract an "isotope balance" from time to time.

SECTION 9 -ADDITIONAL POINTS FOR THE GUIDANCE OF PERSONS USING RADIOACTIVE SUBSTANCES

- i) Any open wounds, cuts or skin damage below the wrist will prohibit that person from handling radioisotopes without gloves. Thought should be given to other areas of damaged skin becoming contaminated.
- ii) Stock solutions should be stored in double containers or trays which will contain the whole contents in the event of accidental spillage.
- iii) Benches and equipment set aside for use with radioisotopes are "active" areas and should not be used for any other procedure. Do not write upon, lean on, or otherwise use an active bench or equipment as contamination will spread rapidly.
- iv) Avoid cross-contamination by segregating glassware and equipment according to activity levels. Active glassware and equipment should not be used for inactive work.
- v) When work at a microcurie level is being done, sources of millicurie level should not be admitted into the work area. When this is unavoidable, the use of highly active sources should be restricted to a limited space only e.g. fume cupboard.
- vi) The quantity of radioactive material chosen for a specific purpose should always be as small as practicable. If possible, solutions rather than dry materials should be used. The manipulation processes, selected should be those which produce the minimum of dust or spray, and which avoid excessive transfers from one vessel to another.
- vii) Extreme care must be taken to avoid cuts or puncture wounds, especially when using the more hazardous radioisotopes. To reduce the chances of injury, cracked or chipped glassware should be discarded.

APPENDIX 1 - Radiation Safety Manual

WESTERN AUSTRALIAN RADIATION SAFETY ACT (1975)

The use of radioactive substances in Western Australia is governed by the Western Australian Radiation Safety Act (1975). This Act is administered by the Public Health Department through the Radiological Council. The Radiological Council operates in conjunction with the Physics Division of the State X-Ray Laboratory, Verdun Street, Nedlands.

To assist users of radioactive substances a code of practice for the disposal of radioactive wastes arising from medical and research use in Western Australia has been prepared. This code supplements the useful information. It should be consulted for problems beyond the scope of the present departmental booklet. Some relevant information from this code is summarized below.

1. Classification of Radionuclide Laboratories

Laboratories designed for handling low levels of radioactivity are described as Type "C"; for intermediate levels as Type "B"; and for high levels as Type "A". The amount of any given radioactive substance that can be handled at any one time will vary according to the type of laboratory available and the type of laboratory suitable for any given amount of material will vary with its toxicity. Table 1 provides a classification of types of laboratories required for various amounts of radioactive substances in the groups defined in Appendix 2. It is unlikely that, at present, there will be the need for a Type "A" laboratory for clinical work in hospitals or in Western Australian research institutions. Table 2 gives modifying factors to be applied according to the nature of the operations being carried out.

TABLE 1

Classification of Laboratories for Handling Radioactive Substances

Toxicity Group of Radioactive Substance from Appendix 2	Type of Laboratory Required for Levels of Activity specified Below	
	TYPE "C"	TYPE "B"
1	< 10 microcuries	10 microcuries to 1 millicurie
2	< 1 millicurie	1 millicurie to 100 millicuries
3	< 100 millicuries	100 millicuries to 10 curies
4	< 10 curies	10 curies to 1000 curies

TABLE 2

Modifying Factors to be Applied to Table 1

Name of Operation	Modifying Factor
Simple Storage	X 100
Very simple wet operations (e.g. preparation of aliquots of stock solutions)	X 10
Normal chemical operations (e.g. analysis, simple chemical preparations)	X 1
Complex wet operations (e.g. multiple operations or operations with complex glass apparatus)	X 0.1 *
Simple dry operations (e.g. manipulation of powders) and work with volatile radionuclides	X 0.1 *
Dry and dusty operations (e.g. grinding)	X 0.01 *
* These factors could be increased by one or more orders of magnitude if the operations are carried out in closed boxes.	

2. Radioactive Waste Management Concepts

There are three basic concepts which apply to treatment of most radioactive wastes.

"Concentrate and Contain"

Reserved primarily for highly radioactive wastes arising from nuclear reactor operations or fuel reprocessing. Usually stored in tanks on site for hundreds of years.

"Dilute and Disperse"

The method most applicable for the majority of hospital and research applications. Low specific activity aqueous wastes to the sewage system; gaseous wastes to the atmosphere; solid wastes to incineration and or land fill burial.

"Delay and Decay"

A method which is used to reduce the radioactivity by allowing it to decay while in temporary storage prior to release to the sewers, incinerator, or land fill burial site.

The Radiation Safety Act and Regulations require, in effect, that the average concentration of gaseous or liquid radionuclides shall not exceed breathing or drinking water tolerances, and that arrangements for disposal of solid radioactive wastes shall be approved by the Radiological Council.

APPENDIX 2 - Radiation Safety Manual

RADIOTOXICITY OF COMMON RADIONUCLIDES

GROUP 1 Very high radiotoxicity

Nil

GROUP 2 High radiotoxicity

^{22}Na , ^{125}I , ^{131}I , ^{45}Ca

GROUP 3 Moderate radiotoxicity

^{14}C , ^{42}K , ^{47}Ca , ^{51}Cr , ^{59}Fe ,
 ^{57}Co , ^{58}Co , ^{99}Tc , ^{198}Au , ^{32}P , ^{35}S

GROUP 4 Low radiotoxicity

^3H (see note below)

NOTE: Tritiated thymidine, being concentrated in the cell nucleus is about 1000 times more toxic than tritiated water. Tritiated ribonucleosides and tritiated amino acids administered at equal dose should be considered around 30% less toxic than tritiated thymidine.

APPENDIX 3 - Radiation Safety Manual

STORAGE CONDITIONS

Radiochemicals are usually supplied in a form that minimizes self-decomposition.. The following general procedures are recommended by manufacturers :

1. Store at the lowest molar specific activity.
2. Solids should be dispersed as much as possible and stored in a dry atmosphere. Sealing under vacuum or inert gas is usually desirable.
3. When possible, store compounds as dilute solutions in benzene at room temperature. The solvent should be free of oxygen and redistilled before use.
4. Keep all solutions in the dark and add bacteriostats where appropriate.
5. For aqueous solutions, the addition of 1-3% ethanol as a stabiliser is often beneficial.
6. Aqueous solutions of tritiated compounds generally should be stored at 2°C, unless they can be stored at -140°C or lower, which is usually preferable.

Labelled compounds are most stable stored in the unopened containers. A sensible precaution is to purchase the required quantity in a number of smaller package sizes. This is particularly true for those aqueous solutions which are best stored frozen.

APPENDIX4 - Properties of radioisotopes - separate document

APPENDIX 5 - Radiation Safety Manual

(taken from QEII/UWA Radioisotopes Course Manual 1991)

TABLE OF ISOTOPES

	³ H	¹⁴ C	³⁵ S
T_{1/2}	12.35 Years	5760 Years	87 Days
Biological T_{1/2}	10 Days for ³ H-H ₂ O (oral + inhalation) 190 Days for ³ H thymidine	< 10 Days	44.3 Days
ALI	3 x 10 ⁹ Bq ³ H-H ₂ O (oral + inhalation) 3 x 10 ⁸ Bq ³ H-NAP (oral + inhalation)	9 x 10 ⁷ Bq (oral) 9 x 10 ⁷ Bq (inhalation)	2 x 10 ⁸ Bq (oral) 8 x 10 ⁷ Bq (inhalation)
Emissions Particles (MeV)	β ⁻ E _{max} = 0.018	β ⁻ E _{max} = 0.156	β ⁻ E _{max} = 0.167
Emissions X/γ rays (MeV)	none	none	none
Hazards	Tritiated water passes readily through intact skin. Irradiation in body is due to formation of tritiated water by metabolism. Tritium adheres to glass.	Some carbon labelled compounds may penetrate intact skin and gloves. Critical organs for carbon can be either the bone or fat depending on the compound.	Some compounds are volatile or may emit fine sprays in some circumstances. The whole body and testis are the critical organs for sulphur.
Precautions	Regular cleaning and wipe testing to avoid build up of contamination. Clean spillages promptly. Regular urinalysis. Store in glass as tritium compounds pass readily through plastic.	Regular cleaning and wipe testing to avoid build up of contamination. Regular urinalysis.	Regular cleaning and wipe testing to avoid build up of contamination. Regular urinalysis.
Shielding	None required	None required	None required
Suitable Detectors	Liquid scintillation counting.	Liquid scintillation counting.	Liquid scintillation counting.

TABLE OF ISOTOPES

	32p	131I	125I
T_{1/2}	14.3 Days	8.05 Days	60 Days
Biological T_{1/2}	19 Days	138 Days	138 Days
ALI	2 x 10 ⁷ Bq (oral) 3 x 10 ⁸ Bq (inhalation)	1 x 10 ⁶ Bq (oral) 2 x 10 ⁶ Bq (inhalation)	1 x 10 ⁶ Bq (oral) 2 x 10 ⁶ Bq (inhalation)
Emissions Particles (MeV)	β ⁻ E _{max} = 1.71	β ⁻ E _{max} = 0.61 0.080-0.81	EC = 100%
Emissions X/γ rays (MeV)	none	0.364 0.64 0.284 0.080-0.72	0.035 0.027 0.03
Hazards	Phosphorus is a bone seeker. Readily absorbed onto metals therefore it is difficult to remove.	Iodine is concentrated in the thyroid gland. Females are 3 x more sensitive than males. <u>VOLATILE</u> Easily absorbed onto surfaces. Decontamination of glassware can be difficult. May need to use potassium iodide or sodium thiosulphate.	
Precautions	Work behind perspex shields. Work in fume cupboards with sash down where aerosols and dusts may arise. Clean spillages promptly. Monitor centrifuges for contamination due to aerosol production during spinning.	Work in fume cupboards. Have sodium thiosulphate readily available in the event of a spill to render the spill alkaline and therefore reduce the volatility. Obtain iodine for specific use - don't store as it deteriorates quickly and can release elemental iodine.	
Shielding	Perspex Aluminium	Lead	
Suitable Detectors	Geiger-Muller tubes Beta probes Scintillation detectors	Scintillation detectors	

	⁵⁷Co	⁵⁹Fe	⁵¹Cr
T_{1/2}	271 Days	45 Days	27.7 Days
Biological T_{1/2}	9.5 Days	700 Days	616 Days
ALI	2 x 10 ⁸ Bq (oral) 2 x 10 ⁷ Bq (inhalation)	3 x 10 ⁷ Bq (oral) 1 x 10 ⁷ Bq (inhalation)	1 x 10 ⁹ Bq (oral) 7 x 10 ⁸ Bq (inhalation)
Emissions Particles (MeV)	EC = 100%	β ⁻ 0.46 0.27 1.56	EC = 100%
Emissions X/γ rays (MeV)	0.122 0.014 0.134	1.10 1.29 0.19	0.32
Hazards	Lung is critical organ for inhalation and the lower large intestine is the critical organ for insoluble compounds	Lower large intestine is critical organ for ingestion and spleen and lung for inhalation of soluble and insoluble compounds	Lower large intestine is critical organ for ingestion and the lung is the critical organ for inhalation
Precautions	Clean spillages promptly. Work in fume cupboards when compounds are potentially volatile.	Clean spillages promptly. Work in fume cupboards when compounds are potentially volatile.	Clean spillages promptly. Work in fume cupboards when compounds are potentially volatile.
Shielding	Lead	Lead	Lead
Suitable Detectors	Geiger-Muller tubes Scintillation detectors	Geiger-Muller tubes Scintillation detectors	Geiger-Muller tubes Scintillation detectors