Radiation Protection Service

RADIOISOTOPES : SPECIFIC PROCEDURES AND HAZARD ASSESSMENT

Revised November 2008
# TABLE OF CONTENTS

Alpha Emitters ................................................................. 3
H3, C14 & S35 ................................................................. 3
Ba-133 ................................................................. 4
Ca-45 ................................................................. 4
Cl-36 ................................................................. 5
Co-57 ................................................................. 6
Cr-51 ................................................................. 7
Cu-64 ................................................................. 7
I-125 (IODINATIONS) .................................................... 8
I-125 (R.I.A. KITS) .................................................... 10
K-42 ................................................................. 10
Na-22 ................................................................. 11
Na-24 ................................................................. 13
P-32 ................................................................. 14
P-33 ................................................................. 15
Rb-86 ................................................................. 16
Tc-99m ................................................................. 17
Xe-133 ................................................................. 18
Zn-65 ................................................................. 18
Alpha Emitters

SPECIFIC PROCEDURES
A film badge is not necessary. Because of the radiotoxicity of alpha emitters the sources should always be handled with extreme care.

1. Gloves must be worn.
2. Face masks must be worn if there is any risk of dispersible activity.
3. The surface of the alpha emitter must not be touched by hand or by equipment to avoid possible dislodging of any activity from the source.

HAZARD ASSESSMENT
Under normal experimental conditions, following the correct procedures, the external radiation hazard from alpha emitters is negligible since the maximum $\alpha$-ray energies cannot penetrate the outer layers of skin. However the radiotoxicity of alpha emitters is such that there is considerable radiation hazard from alpha emitters if absorbed within the body through ingestion, inhalation, etc. Therefore all care must be taken to avoid the risk of absorbing any alpha emitter into the body.

H3, C14 & S35

SPECIFIC PROCEDURES
A personal dosimeter is not necessary.

HAZARD ASSESSMENT
Under normal experimental conditions, following the correct procedures, the external radiation hazards from compounds of H-3, C-14 and S-35 are insignificant since the maximum $\beta$-ray energies cannot penetrate the outer layers of skin. However, although the biological half-lives of (separated) H-3, C-14, and S-35 reduce the internal radiation hazard that might be anticipated from the long physical half-lives of H-3 and C-14, it should be noted that many compounds do have significantly long biological half-lives. Because of the low $\beta$-energies from H-3, the radiation cannot be monitored directly, and therefore special care is needed to keep the working environment clean and tidy. Regular monitoring by swab counting is essential to reduce the risk of ingestion due to surface contamination. Surface contamination may also interfere with experimental results.
SPECIFIC PROCEDURES
A personal dosimeter should be worn at all times at chest level, and should be exchanged bi-monthly.

HAZARD ASSESSMENT
The external radiation hazard from Ba-133 can be moderately severe with prolonged exposure and close handling.
The main source of radiation is in the form of 356keV γ-rays and particular care should be exercised to reduce contamination to the absolute minimum in view of the long half-life (7.2 years).
The γ dose rate at the surface of a thin vial containing 4 MBq of Ba-133 is ≈150mSv/hr so that the annual dose limit to the hands (150mSv for a registered radiation worker) would be exceeded in about one hour if the vial were handled directly.
Lead shielding should be used to reduce the γ radiation dose below 2.5mSv/hr.
The intensity of Ba-133 γ-rays on passing through lead is reduced by:-
   a factor of 10 by 1.5 cms of lead
   a factor of 100 by 3 cms of lead
   a factor of 1000 by 4.5 cms of lead
Since γ radiation dose rate decreases inversely with the square of the distance from the source, use must be made of remote handling tools and shielding, with limited time spent near sources, to minimise total dose.
The internal radiation hazard is negligible if normal operating procedures and clean working practices are adopted.

Ca-45

SPECIFIC PROCEDURES
1. A personal dosimeter is not necessary unless experiments incorporating activities greater than 37 MBq are used frequently. Above this level a PERSONAL DOSIMETER is necessary.
2. For β-emitters perspex sheets of at least 1cm thickness should be used to shield all personnel from experiments or stock dispensing when quantities of about 37MBq are involved. This thickness will stop the β-rays from Ca-45. However the slowing down of electrons in perspex produces soft γ-radiation and a thin (1mm) sheet of lead, affixed to the perspex on the side further from the source, should be used to stop this γ-radiation when necessary.
HAZARD ASSESSMENT
The external radiation hazard from Ca-45 should be modest since Ca-45 emits only β-particles of 254 keV.
The maximum range of these β-particles is ≈52 cm in air but they can easily be stopped by ≈3 mm perspex or thick glass vials.
Care should be exercised if using dried samples since the β-dose rate at the surface of an evaporated 37 MBq sample is ≈950 mSv/hr, so that the annual dose limit to the hands (150 mSv for a registered radiation worker) would be exceeded in ≈10 minutes if the sample were handled directly.
Ca-45 sources should be shielded using perspex and remote handling tools when necessary.
Checks on the effectiveness of experimental techniques should be made using T.L.D. finger stalls and/or wrist badges. Some safety glasses can considerably reduce β-doses to the eyes while thick rubber gloves can reduce β-doses to the hands.
The internal radiation hazard is negligible if normal operating procedures and clean working practices are followed. Ca-45 is a bone-seeker and is retained with a long biological half-life.

SPECIFIC PROCEDURES
1. A personal dosimeter is not necessary unless experiments incorporating activities greater than 4 MBq are used frequently. Above this level a personal dosimeter is necessary.
2. Perspex sheets of at least 1 cm thickness should be used to shield all personnel from experiments or stock dispensing when quantities of about 37 MBq are involved. However the slowing down of electrons in perspex produces soft γ-radiation and a thin (1 mm) sheet of lead, affixed to the perspex on the side further from the source, should be used to stop this γ-radiation when necessary.

HAZARD ASSESSMENT
The external radiation hazard from Cl-36 can be quite severe since Cl-36 emits β-particles of maximum energy 0.714 MeV.
The maximum range of the β-particles is ≈5 metres in air and effective shielding is required to minimise the radiation hazard to the whole body in general and to eyes and fingers in particular.
Cl-36 must be shielded by 1 cm of perspex close to the source to stop β-particles. For quantities of activity greater than 370 MBq it is likely that bremsstrahlung (X-rays) will become a problem and shielding by a few mm of
lead or iron should suffice to reduce the dose rate to the required level of 2.5 μSv/hr.
Since radiation dose-rate decreases markedly with distance from the source, use must be made of remote handling tools and perspex shielding, with limited time spent near sources, to minimise total dose.
Checks on the effectiveness of experimental techniques should be made using T.L.D. finger stalls and/or wrist badges. Some safety glasses can considerably reduce β-doses to the eyes while thick rubber gloves can reduce β-doses to the hands.
The internal radiation hazard is negligible if normal operating procedures and clean working practices are adopted.

**SPECIFIC PROCEDURES**
A personal dosimeter is not necessary unless experiments incorporating activities greater than 37 MBq are used frequently. Above this level a personal dosimeter is necessary.

**HAZARD ASSESSMENT**
The external radiation hazard from Co-57 should be relatively modest since the main radiation is in the form of 122 keV γ-rays.
The γ-dose rate at the surface of a thin vial containing 37 MBq of Co-57 is ≈220 mSv/hr so that the annual dose limits to the hands (150mSv for a registered radiation worker) would be exceeded in about 45 minutes if the vial were handled directly and care must therefore be exercised when manipulating stock solutions.
Lead shielding should be used to reduce the γ-radiation dose rate below 2.5 μSv/hr.
The intensity of Co-57 γ-rays on passing through lead bricks is reduced by:-
- a factor of 10 by 1 cm of lead.
- a factor of 100 by 2.5 cms of lead.
- a factor of 1000 by 5cms of lead.
Since γ-radiation dose-rate varies inversely with the square of the distance from the source, use must be made of remote handling tools and shielding, with limited time spent near sources, to minimise total dose.
The internal radiation hazard is negligible if normal operating procedures and clean working practices are adopted.
SPECIFIC PROCEDURES
A personal dosimeter is not necessary unless experiments incorporating activities greater than 37 MBq are used frequently. Above this level a personal dosimeter is necessary.

HAZARD ASSESSMENT
The external radiation hazard from Cr-51 should be relatively modest since the main radiation hazard, which is in the form of 323 keV \( \gamma \)-rays, occurs in only 10% of decays from Cr-51. However, due to the relatively short half-life of 27.8 days, high activity solutions are sometimes required particularly when dispensing from stock.
The \( \gamma \)-dose rate at the surface of a thin vial containing 37 MBq of Cr-51 is \( \approx 40 \) mSv/hr so that the annual dose limit to the hands (150 mSv for a registered radiation worker) would be exceeded in about 4 hours if the vial were handled directly. Lead shielding should be used to reduce the \( \gamma \)-radiation dose rate below 2.5\( \mu \)Sv/hr. The intensity of Cr-51 \( \gamma \)-rays on passing through lead bricks is reduced by:-

- a factor of 10 by 1.5 cms of lead
- a factor of 100 by 3 cms of lead
- a factor of 1000 by 4.5 cms of lead

Since \( \gamma \)-radiation dose rate decreases inversely with the square of the distance from the source, use must be made of remote handling tools and shielding, with limited time spent near sources, to minimise total dose.
The internal radiation hazard is negligible if normal operating procedures and clean working practices are adopted.

SPECIFIC PROCEDURES
A personal dosimeter is not necessary unless experiments incorporating activities greater than 37 MBq are used frequently. Above this level a personal dosimeter is necessary.

HAZARD ASSESSMENT
The external radiation hazard from Cu-64 should be relatively modest since the main radiation is in the form of \( \beta \)-radiation.
The \( \gamma \)-dose rate at the surface of a thin vial containing 37 MBq of Cu-64 is \( \approx 100 \) mSv/hr so that the annual dose limits to the hands (150 mSv for a
registered radiation worker) would be exceeded in about 2 hours if the vial were handled directly and care must therefore be exercised when manipulating stock solutions.

Lead shielding should be used to reduce the $\gamma$-radiation dose rate below 2.5 $\mu$Sv/hr.

The intensity of Cu-64 $\gamma$-rays on passing through lead bricks is reduced by:

- a factor of 10 by 1 cm of lead.
- a factor of 100 by 2.5 cms of lead.
- a factor of 1000 by 5cms of lead.

Since $\gamma$-radiation dose-rate varies inversely with the square of the distance from the source, use must be made of remote handling tools and shielding, with limited time spent near sources, to minimise total dose.

The internal radiation hazard is negligible if normal operating procedures and clean working practices are adopted.

**I-125 (IODINATIONS)**

**SPECIFIC PROCEDURES**

1. A personal dosimeter should be worn at chest level and exchanged bi-monthly.

2. The iodination laboratory is a supervised area and must be locked at all times when not in use. Access is restricted to those persons with written permission from the Departmental Radiation Protection Supervisor (D.R.P.S.) Before this permission will be granted, written permission of competence in standard experimental iodination procedures must be obtained from the D.R.P.S. or one of the competent persons listed on page 1. No person under the age of 18 years will be granted a permit to work in the iodination lab.

3. Access to the iodination lab should be limited to the minimum amount of time compatible with the safe execution of experiments together with the monitoring of the working area (including floor) for contamination.

4. High levels of contamination may exist on articles and drip trays inside the fume cupboard, on the drain pipes and waste pipe of the sink. Contamination levels should be monitored before commencing work. Contaminated articles should be kept in spill trays provided, behind the lead shielding blocks.

5. Work should be carried out over a lined spill tray inside the fume cupboard which should be permanently switched on. Any malfunctions of the fume cupboard should be reported to the D.R.P.S.
6. A lab coat, safety glasses or face shield and two pairs of disposable gloves must be worn. Due to the ability of iodine to permeate rubber and polythene, gloves should be changed rather than worn for prolonged periods.

7. Dialysis of iodinated protein to remove excess free I-125 should be carried out in sealed buffers (i.e. polythene tubes or bottles) in order to reduce airborne contamination and the contents treated as liquid radioactive waste at the end of the manipulation.

8. Radioactive solutions from suppliers or produced in experiments should be stored only when shielding sufficient to reduce the dose rate at the surface of the shielding to less than 2.5μSv/hr has been provided.

9. 1mm of Lead is sufficient to reduce the dose rate from I-125 by a factor greater than 1 million.

10. A contamination check of the iodination lab must be made every Friday afternoon towards the end of the working day by one of the competent persons and the results recorded in the log book/record sheet. Areas to be surveyed include working surfaces; designated sink and draining areas; floor; hand-washing facilities - sink, taps, soap etc.; sample holders and centrifuges etc.; and working areas of the counting room(s).

11. Pregnancy of female iodine workers should be reported to the U.R.P.A. Such information will be treated in strictest confidence.

HAZARD ASSESSMENT

The external radiation dose from a 37 MBq point source of I-125 at 1m distance is 1.51 μSv/hr., so that a worker spending 1 working year (2000 hours) continuously under these conditions would receive a dose of ≈3 mSv per year. This figure should be compared with the 1 mSv per year which everyone receives from cosmic and background radiation and the annual whole body dose limit allowed for registered radiation workers of 50 mSv per year. The radiation dose rate changes inversely as the square of the distance from the source so that at 10 cm from a 37 MBq source the dose rate increases by a factor of 100. However, shielding can reduce the dose rate arising from ≈35 keV g-rays and X-rays dramatically. A thickness of 0.25mm of lead or 3mm of iron or a single thickness of ordinary brick wall will reduce the dose rate from I-125 by more than a factor of 10,000.

By sensible application of shielding, maximising distances from the source and minimizing the working time near the source the external radiation hazard should be insignificant. Volatilization of iodine may produce an internal radiation hazard because of the propensity of iodine to be collected in the thyroid gland. Iodinations must
be carried out in fume cupboards wherever possible or cooled ion-exchange columns should be used when fume cupboards are not appropriate. Dialysis of iodinated materials must be carried out in closed containers. Opening of vials of compounds with high radioactive concentration can cause minute droplets to become airborne and hence vials should be opened inside fume cupboards. Solutions containing iodide ions should not be made acidic nor stored frozen since volatile elemental iodine can be produced.

**I-125 (R.I.A. KITS)**

**SPECIFIC PROCEDURES**
A personal dosimeter is not necessary unless experiments incorporating activities greater than 37 MBq are used frequently. Above this level a personal dosimeter is necessary.

**HAZARD ASSESSMENT**
Under normal experimental conditions, following the correct procedures the external radiation hazards from R.I.A. kits (usually 370 kBq) are insignificant. The radiation dose from 370 kBq of I-125 at a distance of 1m is $1.51 \times 10^{-2} \mu Sv/hr$, so that a worker spending 1 working year (2000 hrs) continuously under these conditions would receive a dose of $\approx 30 \mu Sv$ per year to be compared with the $1000 \mu Sv$ per year which everyone receives from cosmic and background radiation and the annual whole body dose limit allowed for radiation workers of $50,000 \mu Sv$. However, volatilization of iodine may produce an internal radiation hazard because of the propensity of iodine to be collected in the thyroid. Care should be taken with in-house labelled proteins to remove free iodine ions and solutions should not be frozen.

**SPECIFIC PROCEDURES**
1. A personal dosimeter is not necessary unless experiments incorporating activities greater than 37 MBq are used frequently. Above this level a personal dosimeter is necessary.
2. Perspex sheets of at least 2cm thickness should be used to shield all personnel from experiments or stock dispensing when quantities of about 37MBq are involved. However the slowing down of electrons in perspex produces soft $\gamma$-radiation and a thin (1mm) sheet of lead, affixed to the perspex on the side further from the source, should be used to stop this $\gamma$-radiation when necessary.
HAZARD ASSESSMENT
The external radiation hazard from K-42 is potentially severe since K-42 emits high energy 3.6 MeV $\beta$-particles as well as 1.52 $\gamma$-rays and due to the short half-life of 12.4 hours, high activity solutions are often used particularly when dispensing from stock.
The maximum range of the $\beta$-particles is $\approx$10m. in air and effective shielding is required to minimise the radiation hazard to the whole body in general and to the eyes and fingers in particular.
The $\beta$-dose rate at the surface of a thin vial containing 37 MBq of K-42 is $\approx$13,500 mSv/hr while the $\gamma$-dose rate is $\approx$320 mSv/hr, so that the annual dose limit to the hands (150 mSv for a registered radiation worker) would be exceeded in less than 1 minute if the vial were handled directly. Alternatively, a splash of 37 kBq cm$^{-2}$ on the skin of the hand, if undetected for 24 hours, would cause the annual dose limit to the hands to be exceeded and would result in a radiation burn.
K-42 must be shielded by at least 1 cm of perspex close to the source to stop $\beta$-particles, followed by lead shielding to reduce the $\gamma$-radiation dose rate below 2.5 $\mu$Sv/hr.
The intensity of K-42 $\gamma$-rays on passing through lead bricks is reduced by:
- a factor of 10 by 5 cms of lead.
- a factor of 100 by 9 cms of lead.
- a factor of 1000 by 14 cms of lead.
Since $\gamma$-radiation dose-rate varies inversely with the square of the distance from the source, use must be made of remote handling tools and shielding, with the limited time spent near sources, to minimise total dose.
Checks on the effectiveness of experimental techniques should be made using T.L.D. finger stalls and/or wrist badges. Some safety glasses can considerably reduce $\beta$-doses to the eyes while thick rubber gloves can reduce $\beta$-doses to the hands.
The internal radiation hazard is negligible if normal operating procedures and clean working practices are followed.

SPECIFIC PROCEDURES
1. A personal dosimeter is not necessary unless experiments incorporating activities greater than 37 MBq are used frequently. Above this level a personal dosimeter is necessary.
2. Perspex sheets of at least 1 cm thickness should be used to shield all personnel from experiments or stock dispensing when quantities of about 37 MBq are involved. However the slowing down of electrons

Na-22
in perspex produces soft $\gamma$-radiation and a thin (1mm) sheet of lead, affixed to the perspex on the side further from the source, should be used to stop this $\gamma$-radiation when necessary.

Na-22 also emits relatively high energy $\gamma$-rays (1.28 MeV) and a lead wall of approximately 7cms thickness should be used to shield all personnel from experiments or stock dispensing when quantities of about 4MBq are involved.

HAZARD ASSESSMENT
The external radiation hazard from Na-22 can be quite severe since Na-22 emits $\beta$-particles in the form of 540 keV positrons as well as 1.28 MeV $\gamma$-rays. Whenever positrons are stopped in any material, annihilation radiation is emitted (i.e. two $\gamma$-rays of 511 keV energy in opposite directions.)

The range of the $\beta$-particles is »1m in air and effective shielding is required to minimise the radiation hazard to the whole body in general and to eyes and fingers in particular.

The $\beta$-dose rate at the surface of a thin vial containing 37 MBq of Na-22 is

$\approx$2,000 mSv/hr while the $\gamma$-dose rate is $\approx$2,800 mSv/hr so that the annual dose limit to the hands (150 mSv for a registered radiation worker) would be exceeded in about 2 minutes if the vial were handled directly. Alternatively, a splash of $\approx$37 kBq cm$^{-2}$ on the skin of the hand, if undetected for about 36 hours would cause the annual dose limit to the hands to be exceeded and would result in a radiation burn.

Na-22 must be shielded by 1 cm of perspex close to the source to stop $\beta$-particles, followed by lead shielding to reduce the $\gamma$-radiation dose rate below 2.5$\mu$Sv/hr.

The intensity of Na-22 $\gamma$-rays on passing through lead brick is reduced by:-

- a factor of 10 by 5 cms of lead.
- a factor of 100 by 9 cms of lead.
- a factor of 1000 by 13 cms of lead.

Since $\gamma$-radiation dose-rate varies inversely with the square of the distance from the source, use must be made of remote handling tools and shielding, with the limited time spent near sources, to minimise total dose.

Checks on the effectiveness of experimental techniques should be made using T.L.D. finger stalls and/or wrist badges. Some safety glasses can considerably reduce $\beta$-doses to the eyes while thick rubber gloves can reduce $\beta$-doses to the hands.

The internal radiation hazard is negligible if normal operating procedures and clean working practices are followed.
SPECIFIC PROCEDURES

1. A personal dosimeter is not necessary unless experiments incorporating activities greater than 37 MBq (1mCi) are used frequently. Above this level a personal dosimeter is necessary.

2. Perspex sheets of at least 1cm thickness should be used to shield all personnel from experiments or stock dispensing when quantities of about 37MBq are involved. However the slowing down of electrons in perspex produces soft γ-radiation and a thin (1mm) sheet of lead, affixed to the perspex on the side further from the source, should be used to stop this γ-radiation when necessary.

Na-24 also emits relatively high energy γ-rays and a lead wall of approximately 7cms thickness should be used to shield all personnel from experiments or stock dispensing when quantities of about 4MBq are involved.

HAZARD ASSESSMENT

The external radiation hazard from Na-24 is potentially severe since Na-24 emits 1.39 MeV β-particles as well as 1.37 MeV and 2.75 MeV γ-rays and due to the short half-life of 15 hours, high activity solutions are often required particularly when dispensing from stock.

The maximum range of the β-particles is several metres in air and effective shielding is required to minimise the radiation hazard to the whole body in general and to the eyes and fingers in particular.

The β-dose rate at the surface of a thin vial containing 37 MBq of Na-24 is \( \approx 5,000 \text{ mSv/hr} \) while the γ-dose rate is \( \approx 4,200 \text{ mSv/hr} \), so that the annual dose limit to the hands (150mSv for a registered radiation worker would be exceeded in about 1 minute if the vial were handled directly. Alternatively, a splash of \( \approx 37 \text{ kBq cm}^{-2} \) on the skin of the hand, if undetected for 24 hours, would cause the annual dose limit to the hands to be exceeded and would result in a radiation burn.

Na-24 must be shielded by 1 cm of perspex close to the source to stop β-particles, followed by lead shielding to reduce the γ-radiation dose rate below 2.5 \( \mu \text{Sv/hr} \).

The intensity of Na-24 γ-rays on passing through lead bricks is reduced by:
- a factor of 10 by 6.5 cms of lead
- a factor of 100 by 12 cms of lead.
- a factor of 1000 by 17.5 cms of lead.
Since $\gamma$-radiation dose-rate varies inversely with the square of the distance from the source, use must be made of remote handling tools and shielding, with limited time spent near sources, to minimise total dose. Checks on the effectiveness of experimental techniques should be made using T.L.D. finger stalls and/or wrist badges. Some safety glasses can considerably reduce $\beta$-doses to the eyes while thick rubber gloves can reduce $\beta$-doses to the hands.

The internal radiation hazard is negligible if normal operating procedures and clean working practices are followed.

**SPECIFIC PROCEDURES**

1. Experimental work should take place in a well ventilated enclosure for quantities of P-32 compounds with an activity greater than 5 MBq.
2. A personal dosimeter should be worn at chest level and exchanged bi-monthly.
3. Due to the high penetrating power of the $\beta$ radiation from P-32 any article or material with a dose rate of 75$\mu$Sv/hr or greater at the surface, must be manipulated with forceps or other remote handling equipment and lead impregnated rubber gloves are recommended. If the dose rate is 2mSv/hr or greater at the surface, the article or material should be placed behind perspex and lead shields, the room should be cleared of personnel, locked and the D.R.P.S. informed.
4. Perspex sheets of at least 1cm thick should be used to shield all personnel from experiments or stock dispensing when quantities of about 37MBq are involved. This thickness will stop the $\beta$-rays from P-32, however the slowing down of electrons in perspex produces soft X-radiation and a thin (1mm) sheet of lead, affixed to the perspex on the side further from the source, should be used to stop this X-radiation when necessary.

**HAZARD ASSESSMENT**

The external radiation hazard from P-32 can be quite severe since P-32 emits $\beta$-particles of maximum energy 1.7MeV and due to the relatively short life (14.3 days) high activity solutions are sometimes used particularly when dispensing from stock.

The maximum range of the $\beta$-particles is \( \approx 7 \) metres in air and effective shielding is required to minimise the radiation hazard to the whole body in general and to eyes and fingers in particular.

The $\beta$-dose rate at the surface of a thin vial containing 37 MBq of P-32 is 7,800 mSv/hr, so that the annual dose limit to the hands (150 mSv for a registered
radiation worker) would be exceeded in approximately 1 minute if the vial were handled directly. Alternatively, a splash of $\approx 37$ kBq cm$^{-2}$ on the skin of the hand, if undetected for, 24 hours would cause the annual dose limit to the hand to be exceeded and would result in a radiation burn. P-32 must be shielded by 1 cm of perspex close to the source to stop $\beta$-particles. For quantities of activity greater than 370 MBq it is likely that bremsstrahlung (X-rays) will become a problem and shielding by a few mm of lead or iron, affixed to the perspex on the side further from the source, should suffice to reduce the dose rate to the required level of 2.5 $\mu$Sv/hr. Since radiation dose-rate decreases markedly with distance from the source, use must be made of remote handling tools and perspex shielding, with limited time spent near sources, to minimise total dose. Checks on the effectiveness of experimental techniques should be made using T.L.D. finger stalls and/or wrist badges. Some safety glasses can considerably reduce $\beta$-doses to the eyes while thick or lead impregnated rubber gloves can reduce $\beta$-doses to the hands. The internal radiation hazard is negligible if normal operating procedures and clean working practices are adopted.

**SPECIFIC PROCEDURES**

1. A personal dosimeter is not necessary unless experiments incorporating activities greater than 37 MBq are used frequently. Above this level a personal dosimeter is necessary.

2. For $\beta$-emitters perspex sheets of at least 1cm thickness should be used to shield all personnel from experiments or stock dispensing when quantities of about 37MBq are involved. This thickness will stop the $\beta$-rays from P-33. However the slowing down of electrons in perspex produces soft $\gamma$-radiation and a thin (1mm) sheet of lead, affixed to the perspex on the side further from the source, should be used to stop this $\gamma$-radiation when necessary.

**HAZARD ASSESSMENT**

The external radiation hazard from P-33 should be modest since P-33 emits only $\beta$-particles of 250 keV. The maximum range of these $\beta$-particles is $\approx 50$ cm. in air but they can easily be stopped by $\approx 3$ mm perspex or thick glass vials. Care should be exercised if using dried samples since the $\beta$-dose rate at the surface of an evaporated 37 MBq sample is $\approx 950$ mSv/hr, so that the annual
dose limit to the hands (150 mSv for a registered radiation worker) would be exceeded in \( \approx 10 \) minutes if the sample were handled directly. P-33 sources should be shielded using perspex and remote handling tools when necessary. Some safety glasses can considerably reduce \( \beta \)-doses to the eyes while thick rubber gloves can reduce \( \beta \)-doses to the hands. The internal radiation hazard is negligible if normal operating procedures and clean working practices are followed.

**SPECIFIC PROCEDURES**

1. A personal dosimeter should be worn at all times at chest level, and should be exchanged bi-monthly.
2. Perspex sheets of at least 1 cm thickness should be used to shield all personnel from experiments or stock dispensing when quantities of about 37 MBq are involved. This thickness will stop the \( \beta \)-rays from Rb-86. However the slowing down of electrons in perspex produces soft \( \gamma \)-radiation and a thin (1 mm) sheet of lead, affixed to the perspex on the side further from the source, should be used to stop this \( \gamma \)-radiation when necessary.

**HAZARD ASSESSMENT**

The external radiation hazard from Rb-86 can be quite severe since Rb-86 emits predominantly \( \beta \)-particles of maximum energy 1.77 MeV and due to the relatively short half-life (18.7 days) high activity solutions are often required particularly when dispensing from stock. The maximum range of the \( \beta \)-particles is \( \approx 7 \) metres in air and effective shielding is required to minimise the radiation hazard to the whole body in general and to eyes and fingers in particular.

The \( \beta \)-dose rate at the surface of a thin vial containing 37 MBq of Rb-86 is 7,800 mSv/hr while the \( \gamma \)-dose rate is 125 mSv/hr, so that the annual dose limit to the hands (150 mSv for a registered radiation worker) would be exceeded in about 1 minute if the vial were handled directly. Alternatively, a splash of \( \approx 37 \) kBq cm\(^2\) on the skin of the hand, if undetected for 24 hours, would cause the annual dose limit to the hands to be exceeded and would result in a radiation burn. Rb-86 must be shielded by 1 cm of perspex close to the source to stop \( \beta \)-particles, together with lead shielding on the side of the perspex further from the source sufficient to reduce the \( \gamma \)-radiation dose rate below 2.5 \( \mu \)Sv/hr. The intensity of Rb-86 \( \gamma \)-rays on passing through lead bricks is reduced by:-
Since $\gamma$-radiation dose-rate varies inversely with the square of the distance from the source, use must be made of remote handling tools and shielding, with the limited time spent near sources, to minimise total dose.

Checks on the effectiveness of experimental techniques should be made using T.L.D. finger stalls and/or wrist badges. Some safety glasses can considerably reduce $\beta$-doses to the eyes while thick or lead impregnated rubber gloves can reduce $\beta$-doses to the hands.

The internal radiation hazard is negligible if normal operating procedures and clean working practices are followed.

**SPECIFIC PROCEDURES**

1. A personal dosimeter is not necessary unless experiments incorporating activities greater than 37 MBq are used frequently. Above this level a personal dosimeter is necessary.

2. It is essential to monitor hands, clothing (including shoes/boots) and experimental area after each experiment.

3. All waste (including animal bedding) should be kept for 3 days to 1 week to allow decay. It may then be disposed of as non-radioactive waste.

**HAZARD ASSESSMENT**

The external radiation hazard from Tc-99m is potentially severe due to the amount of activity used in some medical procedures. The major decay mode of Tc-99m is via 140 keV $\gamma$-ray emission. The $\gamma$-radiation dose-rate at the surface of a syringe containing 550MBq of a Tc-99m compound is $\approx$2,000 mSv/hr so that the annual dose limit to the hands (150 mSv for a registered radiation worker) would be exceeded in about 4 minutes if the body of the syringe were handled directly.

Since $\gamma$-radiation dose-rate varies inversely with the square of the distance from the source, use must be made of remote handling tools, lead shielding with limited time spent near sources to minimise total absorbed radiation dose.

Lead of 3.2 mm thickness will reduce the $\gamma$-dose-rate by a factor of 10.

Checks on the effectiveness of experimental techniques should be made using T.L.D. finger stalls (available from Radiation Protection Office) and/or wrist badges.

The internal radiation hazard is negligible if normal operating procedures and clean working practices are followed.
Xe-133

SPECIFIC PROCEDURES
1. A personal dosimeter is not necessary unless experiments incorporating activities greater than 37 MBq are used frequently. Above this level a personal dosimeter is necessary.
2. Experiments must be carried out in a well ventilated area to reduce inhalation of Xe133 gas.
3. It is essential to monitor hands, clothing (including shoes/boots) and experimental area after each experiment.
4. All waste (including animal bedding) should be kept for at least 1 week to allow decay. It may then be disposed of as non-radioactive waste.

HAZARD ASSESSMENT
The external radiation hazard from Xe-133 should be small since Xe-133 emits β-particles of 340 keV together with low energy x-rays and γ-rays of mainly 81 keV.
The maximum range of the β-particles is ≈50 cms but they can easily be stopped by ≈3 mm thick perspex or glass vials. Since Xe-133 is normally used in small quantities of ≈200 kBq and must always be contained before use, the external radiation hazard is small.
However, care must be taken to minimise the internal radiation hazard since in most studies Xe-133 is exhaled by the subject under investigation and can then be inhaled by the researchers. Work should be carried out in well ventilated rooms preferably with fan assisted extraction which should not only reduce the radiation hazard but improve experimental measurements.

Zn-65

SPECIFIC PROCEDURES
A personal dosimeter is not necessary unless experiments incorporating activities greater than 37 MBq are used frequently. Above this level a personal dosimeter is necessary.

HAZARD ASSESSMENT
The external radiation hazard from Zn-65 is in the form of 1.11 MeV γ-rays. The γ-dose rate at the surface of a thin vial containing 37 MBq of Zn-65 is ≈220 mSv/hr so that the annual dose limits to the hands (150mSv for a registered radiation worker) would be exceeded in about 45 minutes if the vial
were handled directly and care must therefore be exercised when manipulating stock solutions.
Lead shielding should be used to reduce the $\gamma$-radiation dose rate below 2.5 $\mu$Sv/hr.
The intensity of Zn-65 $\gamma$-rays on passing through lead bricks is reduced by: -
- a factor of 10 by 1 cm of lead.
- a factor of 100 by 2.5 cms of lead.
- a factor of 1000 by 5 cms of lead.
Since $\gamma$-radiation dose-rate varies inversely with the square of the distance from the source, use must be made of remote handling tools and shielding, with limited time spent near sources, to minimise total dose.
The internal radiation hazard is negligible if normal operating procedures and clean working practices are adopted.