Canada's Nuclear Regulator

Radionuclide Information Booklet

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Table of Contents

Radionuclide Information Booklet

The purpose of the *Radionuclide Information Booklet* is to provide practical information to aid radiation protection specialists at Canadian Nuclear Safety Commission (CNSC) licensed facilities.

The *Radionuclide Information Booklet* contains information pages for radionuclides commonly used in the medical, research, and industrial sectors. These information pages may be posted at CNSC-licensed facilities as a convenient way to quickly find information.

The information pages within the *Radionuclide Information Booklet* are organized by atomic number (*Z*). However, it is important to ensure the most recent information pages are being used, and it is ultimately the user's responsibility to use the information appropriately. Radionuclides with long decay chains including multiple short-lived progeny are not included in the *Radionuclide Information Booklet* as their information is too complex to be captured within this format. The following sections describe each of the six parts of the *Radionuclide Information Booklet* pages.

It is important to also consult your CNSC licence, the *Nuclear Substances and Radiation Devices Regulations*, and the *Radiation Protection Regulations* for CNSC's regulatory requirements as the *Radionuclide Information Booklet* does not replace them.

Part 1 – Radionuclide identification

This section includes the chemical symbol, common name, atomic weight, and atomic number of the specified radionuclide.

Part 2 – Radiation characteristics

This section includes the physical half-life and (if applicable) the radioactive progeny. The source of this information is the ENDF/B-VII.1 library (released December 22, 2011) accessed through the Nucleonica Nuclear Science Portal [1]. The energies of the three most abundant emissions and the energies of the three most energetic emissions are provided with their emission probabilities in brackets. The source for this information is the Joint Evaluated Fission and Fusion File (JEFF) 3.1 nuclide library accessed through the Nucleonica Nuclear Science Portal [2]. Only energies above 10 kiloelectron volts (keV) or emission probabilities greater than 0.01% were included with the exception of Fe-55, which has no energies above 10 keV. The energies provided for electron, beta, and positron radiation are the maximum energies.

Also included are:

(1) First and second half value layers (HVL) and the tenth value layers (TVL) for shielding photons using lead, steel and concrete. These broad beam HVL and TVL values were obtained using Nucleonica's Dosimetry & Shielding++ application [3]. The application uses NIST mass attenuation coefficient tables [4] in conjunction with build-up factors from ANSI/ANS-6.4.3-1991. In the case of concrete, Nucleonica uses ordinary concrete (2.3 g/cm^3) from NIST's mass attenuation coefficient table for mixtures and compounds [5]. For validation, select TVL values were also compared against other references (see appendix A).

Below are three scenarios which provide different equations for calculating attenuated dose rate using HVLs and TVLs.

Scenario 1: If the thickness of shielding is less than one first HVL, the dose rate can be estimated using the equation below:

$$R = (\Gamma \times A \times 2^{-t/HVL1}) / d^2$$

Scenario 2: If the thickness of shielding is more than one first HVL but less than one first TVL, the dose rate can be estimated using the equation below:

$$R = (\Gamma \times A \times 0.5 \times 2^{-[t-HVL1]/HVL2}) / d^2$$

Scenario 3: If the thickness of shielding is greater than one first TVL, the dose rate can be estimated using the equation below:

$$R = (\Gamma \times A \times 0{,}1 \times 10^{-[t-TVL1]/TVL2}) / d^2$$

Where:		
R	is the dose rate	(µSv/h)
Γ	is the gamma ray constant for the source at 1 m	(µSv/h par GBq)
A	is the activity of nuclear substance	(GBq)
d	is the distance between the nuclear substance and the location	(m)
t	is the thickness of shielding material, in the direction of travel,* in any shielding wall between the nuclear substance and the location	(mm)
HVL1	is the thickness of shielding material to reduce the unshielded dose rate to one half of the original	(mm)
HVL2	is the thickness of shielding material to reduce the unshielded dose rate to one half of the original	(mm)
TVL1	is the thickness of shielding material to reduce the unshielded dose rate to one tenth of the original	(mm)
TVL2	is the thickness of shielding material, in addition to the first TVL, to reduce the dose rate by another one tenth	(mm)

* Note: If the radiation is penetrating a shielding wall at an oblique angle, the actual thickness of the shielding will be greater than the thickness of the wall.

To calculate the attenuated dose rate using Microsoft Excel 2010, the following syntax can be used (where "X" is the shielding thickness and "DR" is the unshielded dose rate): =DR*IF(X>=TVL1, 0.1*10^(-(X-TVL1)/TVL2), IF(X>=HVL1, 0.5*2^(-(X-HVL1)/HVL2), IF(X<HVL1, 2^(-X/HVL1)))).

(2) Practical ranges in glass and plastic for electrons and beta radiation. These were obtained from the *Radionuclide and Radiation Protection Data Handbook 2002* (2nd Edition) [6]. When energetic electrons and beta radiation interact in high *Z* material (e.g., lead), electromagnetic radiation called bremsstrahlung is produced. Therefore, high *Z* materials such as lead may not be appropriate shielding materials for energetic electrons and beta radiation and low *Z* material should be used first. For low-energy electron or beta emitters such as tritium and carbon-14, bremsstrahlung production is not significant.

Part 3 – Dose rate constants and coefficients

External dose

In this section, dose coefficients are provided for estimating skin dose from direct contamination and whole body effective dose from external exposure to radiation sources. Unless otherwise indicated, the dose rate from skin contamination is from International Atomic Energy Agency (IAEA)-TECDOC-1162 *Generic procedures for assessment and response during a radiological emergency* [7]. The gamma ray dose rate at one meter assumes a point source and anterior-posterior geometry. These values were calculated based on the International Commission on Radiological Protection's (ICRP) fluence to effective dose conversion coefficients (linearly interpolated when necessary) provided in ICRP Publication 116 [8] and the photon energies and probabilities obtained from the JEFF 3.1 nuclide library [2]. All photon emissions above 15 keV with a probability above 0.01% were considered in the calculation. To be conservative, attenuation and build-up in air was not incorporated in the calculation.

Internal dose

This section includes the ICRP internal dose coefficients for workers, which may be used to estimate internal dose from inhalation and ingestion of the radionuclide of interest. Unless otherwise stated, these dose coefficients were obtained from ICRP Publication 68 [9]. In the case of inhalation, the coefficients listed are for a particle size (activity aerodynamic diameter, AMAD) of 5 µm. Some radionuclides have different dose coefficients for different solubility types which depend on the compound. This booklet includes the most conservative dose coefficients.

Part 4 – Clearance and exemption

This section summarizes CNSC exemption quantities in becquerel per gram (Bq/g) and Bq, unconditional clearance levels in Bq/g, and nuclide classification. The surface contamination free-release criteria are based on the values found in table 1 of the American National Standards Institute (ANSI) standard N13.12-2013 [10]. When the radionuclide of interest is present in table 1 of the ANSI standard, the value is given as published in the standard. When the radionuclide is not present, the method described in annex A of the ANSI standard was used to ascertain the group (1, 2, 3, 4 or 5) to which the radionuclide of interest should be attributed, and the corresponding surface contamination free-release value was assigned. This value includes both fixed and removable contamination and applies to the free release (e.g., municipal landfill, recycling) of surface contaminated objects, as opposed to the removable contamination criteria associated with the nuclide class (A,B,C) which relates to the decommissioning of rooms within a licensed facility. Since the surface contamination criteria in ANSI N13.12-2013 are calculated based on exposure scenarios that would yield a "worst case" annual dose to an individual of 10 microsieverts (µSv), these values are suitable for use as conditional clearance levels, as defined in the *Nuclear Substances and Radiation Devices Regulations*.

Part 5 – Detection and measurement

Method of detection

There are two categories under this section: contamination and dose rate. Detector types that are commonly found in instruments used for contamination or dose rate measurement, capable of detecting the radiations emitted by the radionuclide of interest, are included in each category as applicable. When numbers are included under each category, the detector types ranked higher (#1 vs. #2), will yield a distinctly higher measurement efficiency as compared to the detector types ranked lower. The inclusion of a particular detector type on the information sheet does not necessarily guarantee that the instrument will be suited to meet any given regulatory detection criterion, or be able to accurately measure a dose rate to within +/- 20% of the true radiation dose. For example, a halogen quenched thin window *Geiger-Mueller* (GM) contamination meter will only yield a counting efficiency of 0.4% to 0.8% when measuring Tc-99m; however, because Tc-99m is detectable using this type of device, it is included on this nuclide's information sheet. Similarly, an energy compensated GM dose rate meter may only yield a dose response of 5% to 10% (i.e., 90% to 95% below the true dose) when exposed to Cd-109, but again, because Cd-109 is detectable using this type of device, it is included on this nuclide's information sheet. Manufacturers' specifications should always be considered when taking measurements.

Minimum counting times should be established by the users based on minimum detectable activity calculations, which should be set below the regulatory criterion, using published or experimentally verified efficiencies and documented conditions for use. The list of detector types found in the *Radionuclide Information Booklet* may not encompass all detector technologies currently available.

Dosimetry

Dosimetry techniques that could be used to measure radiation doses from the radionuclide of interest are indicated in this section.

Part 6 – Safety precautions

In this section, specific recommendations are provided for the radionuclide of interest.

H-3

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Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: H	Common name: Tritium	Atomic weight: 3	Atomic number: 1

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 12.32 years

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)
Gamma & X-ray	None	None	Not applicable
Beta(-), Beta(+), electrons	18.6 keV (100%)	18.6 keV (100%)	Not applicable

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Tritium is not an external radiation hazard.

Internal dose

Dose coefficients for tritium were obtained from the CNSC's *Health Effects, Dosimetry and Radiological Protection of Tritium* INFO-0799, April 2010.

	Ingestion	Inhalation	
Compound type	Unspecified compounds	Tritiated water	Elemental tritium gas
Worker dose coefficient	2.0E-11 Sv/Bq	2.0E-11 Sv/Bq	2.0E-15 Sv/Bq

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	1 MBq/g or 1 GBq	**CNSC classification:**	Class C
CNSC unconditional Clearance level:	100 Bq/g	**Surface contamination Free-release criterion:**	100 Bq/cm^2 (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (dose rate):
Not applicable

Method of detection (contamination):

1. Hand-held : windowless gas-flow proportional
1. Non-portable: liquid scintillation counter

Dosimetry
External: Not applicable
Internal: Urinalysis

Part 6 – SAFETY PRECAUTIONS

Tritium is not a radiation hazard unless it enters the body. Once in the body, tritiated water is uniformly distributed in body water and can then expose tissue. Tritiated water can be absorbed through the surface of the skin, leading to an internal exposure.

Wear a lab coat and polyvinyl chloride (PVC) gloves (0.5 mm thick) because of this material's low permeability to tritiated water. Many tritium compounds readily penetrate gloves and skin. Handle these compounds remotely, wear two pairs of gloves and change the outer layer at least every twenty minutes. Plastic aprons provide added protection, especially against tritiated water. Plastic suits may be necessary for work at TBq levels or in an atmosphere contaminated with tritiated water.

Handle tritiated water, gases and volatile liquids in ventilated enclosures. Use glass containers to store tritium compounds because tritiated water and tritiated organic solvents will permeate through plastic. Use disposable absorbent liners on trays.
See appendix B for emergency procedures.

C-14

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Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: C	Common name: Carbon	Atomic weight: 14	Atomic number: 6

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 5.73E+03 years

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)
Gamma & X-ray	None	None	Not an external radiation hazard
Beta(-), Beta(+), electrons	156.5 keV (100%)	156.5 keV (100%)	Practical range in glass: 0.2 Practical range in plastic: 0.3

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate to skin from direct contamination: 0.32 mSv/h per kBq/cm^2
Gamma ray effective dose rate at 1 m: Not applicable

Internal dose

	Ingestion	Inhalation
Worker dose coefficient	5.8E-10 Sv/Bq	2.0E-11 Sv/Bq *

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	10 kBq/g or 10 MBq	**CNSC classification:**	Class C
CNSC unconditional clearance level:	1 Bq/g	**Surface contamination free-release criterion:**	1 Bq/cm^2 (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (dose rate):
Not applicable

Method of detection (contamination):

1. Hand-held: thick ZnS scintillator with proprietary discrimination, gas-flow proportional, sealed-gas proportional, plastic scintillator, halogen quenched thin window Geiger-Mueller
1. Non-portable: liquid scintillation counter, gas-flow proportional counter

Dosimetry
External: Not applicable
Internal: Urinalysis, lung, feces

Part 6 – SAFETY PRECAUTIONS

Wear disposable lab coat, gloves and wrist guards. Some organic compounds can be absorbed through gloves; wear two pairs and change the outer layer as needed.

Use disposable absorbent liners on trays. Handle potentially volatile or dusty compounds in a fume hood.

See appendix B for emergency procedures.

*Revised $^{14}CO_2$ dose coefficient from Leggett, R.W., Radiation Protection Dosimetry Vol. 208, pp. 203-213 (2004).

F-18

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Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: F	Common name: Fluorine	Atomic weight: 18	Atomic number: 9

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 1.83 hours

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)
Gamma & X-ray	511.00 keV (194%)	511.00 keV (194%)	Lead: 1^{st} HVL = 7, 2^{nd} HVL = 4.5, 1^{st} TVL = 17, 2^{nd} TVL = 14 Steel: 1^{st} HVL = 36, 2^{nd} HVL = 17, 1^{st} TVL = 72, 2^{nd} TVL = 45 Concrete: 1^{st} HVL = 121, 2^{nd} HVL = 56, 1^{st} TVL = 240, 2^{nd} TVL = 144
Beta(-), Beta(+), electrons	633.34 keV (100%)	633.34 keV (100%)	Practical range in glass: 0.9 Practical range in plastic: 1.7

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate to skin from direct contamination: 1.9 mSv/h per kBq/cm^2
Gamma ray effective dose rate at 1 m: 1.398E-04 mSv/h per MBq

Internal dose

	Ingestion	Inhalation
Worker dose coefficient	4.9E-11 Sv/Bq	9.3E-11 Sv/Bq

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	10 Bq/g or 1 MBq	**CNSC classification:**	Class C
CNSC unconditional clearance level:	10 Bq/g	**Surface contamination free-release criterion:**	10 Bq/cm^2 (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (dose rate):

1. Plastic scintillator, ion chamber, ion chamber with window, energy compensated NaI, energy compensated Geiger-Mueller

Method of detection (contamination):

1. Hand-held: thick ZnS scintillator with proprietary discrimination, gas-flow proportional, sealed-gas proportional, NaI scintillator, plastic scintillator, halogen quenched thin window Geiger-Mueller
1. Non-portable: liquid scintillation counter, gas-flow proportional counter, NaI well counter

Dosimetry

External: Gamma/beta
Internal: Whole body counting, urinalysis

Part 6 – SAFETY PRECAUTIONS

Wear disposable plastic, latex, or rubber gloves. Wear a lab coat, which should be monitored before leaving the laboratory. Also wear safety glasses.

Keep handling time to a minimum. Use syringe shields and tongs. Use disposable absorbent liners on trays.

See appendix B for emergency procedures.

P-32

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Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: P	Common name: Phosphorus	Atomic weight: 32	Atomic number: 15

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 14.263 days

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)
Gamma & X-ray	None	None	Not an external radiation hazard
Beta(-), Beta(+), electrons	1710.4 keV (100%)	1710.4 keV (100%)	Practical range in glass: 3.4 Practical range in plastic: 6.3

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate to skin from direct contamination: 1.9 mSv/h per kBq/cm^2
Gamma ray effective dose rate at 1 m: not applicable

Internal dose

	Ingestion	Inhalation
Worker dose coefficient	2.4E-09 Sv/Bq	2.9E-09 Sv/Bq

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	1 kBq/g or 100 kBq	**CNSC classification:**	Class C
CNSC unconditional clearance level:	1 kBq/g	**Surface contamination free-release criterion:**	100 Bq/cm^2 (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (dose rate):
Not applicable

Method of detection (contamination):

1. Hand-held: thick ZnS scintillator with proprietary discrimination, gas-flow proportional, sealed-gas proportional, plastic scintillator, halogen quenched thin window Geiger-Mueller
1. Non-portable: liquid scintillation counter, gas-flow proportional counter

Dosimetry
External: Gamma/beta
Internal: Urinalysis

Part 6 – SAFETY PRECAUTIONS

Phosphocol and sodium phosphate (P-32) solutions may emit radioactive fumes containing P-32 when heated to decomposition.

Wear disposable plastic, latex, or rubber gloves. Wear a lab coat, which should be monitored before leaving the laboratory. Wear safety glasses.

Keep handling time to minimum. Plastic syringe shields and tongs can be used to avoid direct skin contact. When possible work behind a plastic screen. Finger dosimeters should be worn if using quantities greater than a few tens of MBq (~a mCi). Use disposable absorbent liners on trays.

See appendix B for emergency procedures.

S-35

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Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: S	Common name: Sulphur	Atomic weight: 35	Atomic number: 16

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 87.51 days

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)
Gamma & X-ray	None	None	Not an external radiation hazard
Beta(-), Beta(+), electrons	167.14 keV (100%)	167.14 keV (100%)	Practical range in glass: 0.2 Practical range in plastic: 0.3

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate to skin from direct contamination: 0.35 mSv/h per kBq/cm^2
Gamma ray effective dose rate at 1 m: not applicable

Internal dose

	Ingestion	Inhalation
Worker dose coefficient	7.7E-10 Sv/Bq (organic)	1.2E-10 Sv/Bq (organic)
Worker dose coefficient	1.9E-10 Sv/Bq (inorganic)	1.1E-09 Sv/Bq (inorganic)

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	100 kBq/g or 100 MBq	**CNSC classification:**	Class C
CNSC unconditional clearance level:	100 Bq/g	**Surface contamination free-release criterion:**	100 Bq/cm^2 (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (dose rate):
Not applicable

Method of detection (contamination):

1. Hand-held: thick ZnS scintillator with proprietary discrimination, gas-flow proportional, sealed-gas proportional, plastic scintillator, halogen quenched thin window Geiger-Mueller
1. Non-portable: liquid scintillation counter, gas-flow proportional counter

Dosimetry
External: Not applicable
Internal: Urinalysis

Part 6 – SAFETY PRECAUTIONS

Wear a lab coat and monitor it before leaving the laboratory. Wear appropriate gloves for chemicals handled and wear wrist guards.

S-35 is volatile and should be handled in ventilated enclosures. Take care not to generate sulphur dioxide or hydrogen sulphide, which could be inhaled. Use disposable absorbent liners on trays.

See appendix B for emergency procedures.

Ca-45

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Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Ca	Common name: Calcium	Atomic weight: 45	Atomic number: 20

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 162.61 days

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)
Gamma & X-ray	None	None	Not an external radiation hazard
Beta(-), Beta(+), electrons	256.9 keV (100%)	256.9 keV (100%)	Practical range in glass: 0.3 Practical range in plastic: 0.6

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate to skin from direct contamination: 0.84 mSv/h per kBq/cm^2
Gamma ray effective dose rate at 1 m: not applicable

Internal dose

	Ingestion	Inhalation
Worker dose coefficient	7.6E-10 Sv/Bq	2.3E-09 Sv/Bq

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	10 kBq/g or 10 MBq	**CNSC classification:**	Class C
CNSC unconditional clearance level:	100 Bq/g	**Surface contamination free-release criterion:**	100 Bq/cm^2 (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (dose rate):
Not applicable

Method of detection (contamination):

1. Hand-held: thick ZnS scintillator with proprietary discrimination, gas-flow proportional, sealed-gas proportional, plastic scintillator, halogen quenched thin window Geiger-Mueller
1. Non-portable: liquid scintillation counter, gas-flow proportional counter

Dosimetry
External: Gamma/beta
Internal: Urinalysis, feces

Part 6 – SAFETY PRECAUTIONS

When working with unsealed sources wear appropriate protective clothing, such as laboratory coats (which should be monitored before leaving the laboratory), coveralls, gloves, and safety glasses/goggles. Use a suitable mask if the radioactive material is in the form of dust or powder, or if it is potentially volatile.

Monitor equipment and supplies for loose contamination before removing from laboratory. Use disposable absorbent liners on trays.

See appendix B for emergency procedures.

Sc-46

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Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Sc	Common name: Scandium	Atomic weight: 46	Atomic number: 21

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 83.79 days

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)
Gamma & X-ray	1120.5 keV (100%) 889.3 keV (100%)	1120.5 keV (100%) 889.3 keV (100%)	Lead: 1^{st} HVL = 17, 2^{nd} HVL = 11, 1^{st} TVL = 42, 2^{nd} TVL = 34 Steel: 1^{st} HVL = 41, 2^{nd} HVL = 23, 1^{st} TVL = 92, 2^{nd} TVL = 63 Concrete: 1^{st} HVL = 127, 2^{nd} HVL = 74, 1^{st} TVL = 286, 2^{nd} TVL = 192
Beta(-), Beta(+), electrons	356.8 keV (100%) 884.3 keV (0.015%)	884.3 keV (0.015%) 356.8 keV (100%)	Practical range in glass: 0.5 Practical range in plastic: 0.8

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate to skin from direct contamination: 1.4 mSv/h per kBq/cm^2
Gamma ray effective dose rate at 1 m: 2.566E-04 mSv/h per MBq

Internal dose

	Ingestion	Inhalation
Worker dose coefficient	1.5E-09 Sv/Bq	4.8E-09 Sv/Bq

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	10 Bq/g or 1 MBq	**CNSC classification:**	Class A
CNSC unconditional clearance level:	0.1 Bq/g	**Surface contamination free-release criterion:**	0.1 Bq/cm^2 (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (dose rate):

1. Plastic scintillator, ion chamber, ion chamber with window, energy compensated NaI, energy compensated Geiger-Mueller

Method of Detection (contamination):

1. Hand-held: thick ZnS scintillator with proprietary discrimination, gas-flow proportional, sealed-gas proportional, NaI scintillator, plastic scintillator, halogen quenched thin window Geiger-Mueller
1. Non-portable: liquid scintillation counter, gas-flow proportional counter, NaI well counter

Dosimetry

External: Gamma/beta
Internal: Whole body counting, urinalysis, feces

Part 6 – SAFETY PRECAUTIONS

When working with unsealed sources wear appropriate protective clothing, such as laboratory coats (which should be monitored before leaving the laboratory), coveralls, gloves, and safety glasses/goggles. Use a suitable mask if the radioactive material is in the form of dust or powder, or if it is potentially volatile. Use disposable absorbent liners on trays.

Monitor equipment and supplies for loose contamination before removing from laboratory.

See appendix B for emergency procedures.

Cr-51

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Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Cr	Common name: Chromium	Atomic weight: 51	Atomic number: 24

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 27.7 days

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)
Gamma & X-ray	320.1 keV (9.9%)	320.1 keV (9.9%)	Lead: 1^{st} HVL = 2.8, 2^{nd} HVL = 1.8, 1^{st} TVL = 7, 2^{nd} TVL = 5.9 Steel: 1^{st} HVL = 30, 2^{nd} HVL = 12, 1^{st} TVL = 57, 2^{nd} TVL = 34 Concrete: 1^{st} HVL = 119, 2^{nd} HVL = 45, 1^{st} TVL = 216, 2^{nd} TVL = 120
Beta(-), Beta(+), electrons	314.6 keV (0.015%)	314.6 keV (0.015%)	Practical range in glass: <0.1 Practical range in plastic: <0.1

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate to skin from direct contamination: 0.015 mSv/h per kBq/cm^2
Gamma ray effective dose rate at 1 m: 4.554E-06 mSv/h per MBq

Internal dose

	Ingestion	Inhalation
Worker dose coefficient	3.8E-11 Sv/Bq	3.6E-11 Sv/Bq

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	1 kBq/g or 10 MBq	**CNSC classification:**	Class C
CNSC unconditional clearance level:	100 Bq/g	**Surface contamination free-release criterion:**	100 Bq/cm^2 (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (dose rate):

1. Plastic scintillator, ion chamber, ion chamber with window, energy compensated NaI, energy compensated Geiger-Mueller

Method of detection (contamination):

1. Hand-held: NaI scintillator, thick ZnS scintillator with proprietary discrimination
2. Hand-held: halogen quenched thin window Geiger Mueller, gas-flow proportional, sealed-gas proportional, plastic scintillator
1. Non-portable: NaI well counter

Dosimetry

External: Gamma/beta
Internal: Whole body counting, urinalysis

Part 6 – SAFETY PRECAUTIONS

Wear disposable plastic, latex, or rubber gloves. Wear a lab coat, which should be monitored before leaving the laboratory. Also wear safety glasses.

Keep handling time to a minimum. Use syringe shields and tongs. Use disposable absorbent liners on trays.

See appendix B for emergency procedures.

Fe-55

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Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Fe	Common name: Iron	Atomic weight: 55	Atomic number: 26

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 2.744 years

Radiation type	Most abundant emissions (>5 keV, >0.01%)	Most energetic emissions (>5 keV, >0.01%)	Shielding information (mm)
Gamma & X-ray	5.90 keV (16%) 5.89 keV (8.24%) 6.49 keV (3.29%)	6.49 keV (3.29%) 5.90 keV (16%) 5.89 keV (8.24%)	Not applicable
Beta(-), Beta(+), electrons	5.19 keV (60.7%)	5.19 keV (60.7%)	Not applicable

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate to skin from direct contamination: 0.016 mSv/h per kBq/cm^2
Gamma ray effective dose rate at 1 m: not applicable

Internal dose

	Ingestion	Inhalation
Worker dose coefficient	3.3E-10 Sv/Bq	9.2E-10 Sv/Bq

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	10 kBq/g or 1 MBq	**CNSC classification:**	Class C
CNSC unconditional clearance level:	1 kBq/g	**Surface contamination free-release criterion:**	100 Bq/cm^2 (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (dose rate):
Not applicable

Method of detection (contamination):

1. Non-portable: liquid scintillation counter, NaI well counter

Dosimetry
External: Not applicable
Internal: Urinalysis, feces

Part 6 – SAFETY PRECAUTIONS

Fe-55 emits low energy X-rays and electrons that are absorbed in the dead outer layer of skin. The use of protective clothing should provide sufficient external radiation exposure protection. Wear laboratory coats (which should be monitored before leaving the laboratory), coveralls, gloves, and safety glasses/goggles. Use disposable absorbent liners on trays.

See appendix B for emergency procedures.

Co-57

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Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Co	Common name: Cobalt	Atomic weight: 57	Atomic number: 27

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 271.74 days

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)
Gamma & X-ray	122.1 keV (85.5%) 136.5 keV (10.7%) 14.4 keV (9.2%)	692.0 keV (0.159%) 569.9 keV (0.015%) 136.5 keV (10.7%)	Lead: 1^{st} HVL = 0.4, 2^{nd} HVL = 0.3, 1^{st} TVL = 1, 2^{nd} TVL = 3.7 Steel: 1^{st} HVL = 7.4, 2^{nd} HVL = 4.3, 1^{st} TVL = 17, 2^{nd} TVL = 18 Concrete: 1^{st} HVL = 87, 2^{nd} HVL = 27, 1^{st} TVL = 148, 2^{nd} TVL = 82
Beta(-), Beta(+), electrons	13.6 keV (7.16%) 114.9 keV (1.81%) 129.4 keV (1.42%)	135.6 keV (0.15%) 129.6 keV (1.42%) 114.9 keV (1.81%)	Practical range in glass: <0.1 Practical range in plastic: <0.1

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate to skin from direct contamination: 0.12 mSv/h per kBq/cm^2
Gamma ray effective dose rate at 1 m: 1.808E-05 mSv/h per MBq

Internal dose

	Ingestion	Inhalation
Worker dose coefficient	2.1E-10 Sv/Bq	6.0E-10 Sv/Bq

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	100 Bq/g or 1 MBq	**CNSC classification:**	Class C
CNSC unconditional clearance level:	1 Bq/g	**Surface contamination free-release criterion:**	1 Bq/cm^2 (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (dose rate):

1. Plastic scintillator, ion chamber, ion chamber with window, energy compensated Geiger-Mueller, energy compensated NaI

Method of detection (contamination):

1. Hand-held: NaI scintillator, thick ZnS scintillator with proprietary discrimination
2. Hand-held: halogen quenched thin window Geiger Mueller, gas-flow proportional, sealed-gas proportional, plastic scintillator
1. Non-portable: liquid scintillation counter, NaI well counter

Dosimetry

External: Gamma/beta
Internal: Whole body counting, urinalysis

Part 6 – SAFETY PRECAUTIONS

Wear disposable plastic, latex, or rubber gloves. Wear a lab coat, which should be monitored before leaving the laboratory. Also wear safety glasses/goggles.

Keep handling time to a minimum. Use syringe shields and tongs. Use disposable absorbent liners on trays.

See appendix B for emergency procedures.

Co-58

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Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Co	Common name: Cobalt	Atomic weight: 58	Atomic number: 27

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 70.86 days

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)
Gamma & X-ray	810.8 keV (99.5%) 511.0 keV (30%) 864.0 keV (0.7%)	1674.7 keV (0.5%) 864.0 keV (0.7%) 810.8 keV (99.5%)	Lead: 1st HVL = 12, 2nd HVL = 8.4, 1st TVL = 31, 2nd TVL = 26 Steel: 1st HVL = 39, 2nd HVL = 20, 1st TVL = 83, 2nd TVL = 56 Concrete: 1st HVL = 123, 2nd HVL = 65, 1st TVL = 264, 2nd TVL = 171
Beta(-), Beta(+), electrons	475.2 keV (98%) 803.7 keV (0.03%)	803.7 keV (0.03%) 475.2 keV (98%)	Practical range in glass: 0.7 Practical range in plastic: 1.2

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate to skin from direct contamination: 0.3 mSv/h per kBq/cm^2
Gamma ray effective dose rate at 1 m: 1.309E-04 mSv/h per MBq

Internal dose

	Ingestion	Inhalation
Worker dose coefficient	7.4E-10 Sv/Bq	1.7E-09 Sv/Bq

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	10 Bq/g or 1 MBq	**CNSC classification:**	Class B
CNSC unconditional clearance level:	1 Bq/g	**Surface contamination free-release criterion:**	1 Bq/cm^2 (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (dose rate):

1. Plastic scintillator, ion chamber, ion chamber with window, energy compensated NaI, energy compensated Geiger-Mueller

Method of detection (contamination):

1. Hand-held: thick ZnS scintillator with proprietary discrimination, gas-flow proportional, sealed-gas proportional, NaI scintillator, plastic scintillator, halogen quenched thin window Geiger-Mueller
1. Non-portable: liquid scintillation counter, gas-flow proportional counter, NaI well counter

Dosimetry

External: Gamma/beta
Internal: Whole body counting, urinalysis

Part 6 – SAFETY PRECAUTIONS

Wear disposable plastic, latex, or rubber gloves. Wear a lab coat, which should be monitored before leaving the laboratory. Also wear safety glasses/goggles.

Keep handling time to a minimum. Use syringe shields and tongs. Use disposable absorbent liners on trays.

See appendix B for emergency procedures.

Co-60

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Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Co	Common name: Cobalt	Atomic weight: 60	Atomic number: 27

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 5.27 years

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)
Gamma & X-ray	1332.5 keV (100%) 1173.2 keV (99.9%)	1332.5 keV (100%) 1173.2 keV (99.9%)	Lead: 1^{st} HVL = 20, 2^{nd} HVL = 14, 1^{st} TVL = 50, 2^{nd} TVL = 40 Steel: 1^{st} HVL = 43, 2^{nd} HVL = 26, 1^{st} TVL = 99, 2^{nd} TVL = 69 Concrete: 1^{st} HVL = 131, 2^{nd} HVL = 81, 1^{st} TVL = 305, 2^{nd} TVL = 211
Beta(-), Beta(+), electrons	318.1 keV (99.9%) 1491.3 keV (0.12%) 1164.9 keV (0.015%)	1491.3 keV (0.12%) 1324.2 keV (0.012%) 1164.9 keV (0.015%)	Practical range in glass: 0.4 Practical range in plastic: 0.7

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate to skin from direct contamination: 0.78 mSv/h per kBq/cm^2
Gamma ray effective dose rate at 1 m: 3.045E-04 mSv/h per MBq

Internal dose

	Ingestion	Inhalation
Worker dose coefficient	3.4E-09 Sv/Bq	1.7E-08 Sv/Bq

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	10 Bq/g or 100 kBq	**CNSC classification:**	Class A
CNSC unconditional clearance level:	0.1 Bq/g	**Surface contamination free-release criterion:**	0.1 Bq/cm^2 (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (dose rate):

1. Plastic scintillator, ion chamber, ion chamber with window, energy compensated NaI, energy compensated Geiger-Mueller

Method of detection (contamination):

1. Hand-held: thick ZnS scintillator with proprietary discrimination, gas-flow proportional, sealed-gas proportional, NaI scintillator, plastic scintillator, halogen quenched thin window Geiger-Mueller
1. Non-portable: liquid scintillation counter, gas-flow proportional counter, NaI well counter

Dosimetry

External: Gamma/beta
Internal: Whole body counting, urinalysis

Part 6 – SAFETY PRECAUTIONS

When working with unsealed sources, wear disposable plastic, latex, or rubber gloves, a lab coat (which should be monitored before leaving the laboratory), and safety glasses/goggles.

Keep handling time to a minimum. Use syringe shields and tongs. Use disposable absorbent liners on trays.

See appendix B for emergency procedures.

Ga-67

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Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Ga	Common name: Gallium	Atomic weight: 67	Atomic number: 31

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 3.26 days

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)
Gamma & X-ray	93.3 keV (39.2%) 184.6 keV (21.2%) 300.2 keV (16.8%)	887.7 keV (0.15%) 794.4 keV (0.054%) 703.1 keV (0.011%)	Lead: 1^{st} HVL = 1.3, 2^{nd} HVL = 1.7, 1^{st} TVL = 5.8, 2^{nd} TVL = 9.9 Steel: 1^{st} HVL = 21, 2^{nd} HVL = 12, 1^{st} TVL = 48, 2^{nd} TVL = 37 Concrete: 1^{st} HVL = 103, 2^{nd} HVL = 41, 1^{st} TVL = 194, 2^{nd} TVL = 118
Beta(-), Beta(+), electrons	83.7 keV (29.4%) 92.1 keV (3.61%) 174.9 keV (0.33%)	199.29 keV (0.019%) 183.4 keV (0.035%) 174.9 keV (0.33%)	Practical range in glass: 0.1 Practical range in plastic: 0.2

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate to skin from direct contamination: 0.35 mSv/h per kBq/cm^2
Gamma ray effective dose rate at 1 m: 2.254E-05 mSv/h per MBq

Internal dose

	Ingestion	Inhalation
Worker dose coefficient	1.9E-10 Sv/Bq	2.8E-10 Sv/Bq

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	100 Bq/g or 1 MBq	**CNSC classification:**	Class C
CNSC unconditional clearance level:	1 Bq/g	**Surface contamination free-release criterion:**	10 Bq/cm^2 (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (dose rate):

1. Plastic scintillator, ion chamber, ion chamber with window, energy compensated NaI
2. Energy compensated Geiger-Mueller

Method of detection (contamination):

1. Hand-held: NaI scintillator, thick ZnS scintillator with proprietary discrimination
2. Hand-held: halogen quenched thin window Geiger Mueller, gas-flow proportional, sealed-gas proportional, plastic scintillator
1. Non-portable: liquid scintillation counter, NaI well counter

Dosimetry

External: Gamma/beta
Internal: Whole body counting, urinalysis

Part 6 – SAFETY PRECAUTIONS

Wear disposable plastic, latex, or rubber gloves. Wear a lab coat, which should be monitored before leaving the laboratory. Also wear safety glasses/goggles.

Keep handling time to a minimum. Use syringe shields and tongs. Use disposable absorbent liners on trays.

See appendix B for emergency procedures.

Ge-68/Ga-68

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Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Ge/Ga	Common name: Gallium	Atomic weight: 68	Atomic number: 32/31

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: Ge-68 (270.95 days), Ga-68 (1.129 hours)

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)
Gamma & X-ray	511.00 keV (178%) 10 keV (44.2%) 1077.34 keV (3.2%)	1883.16 keV (0.14%) 1261.08 keV (0.094%) 1077.34 keV (3.2%)	Lead: 1st HVL = 7.2, 2nd HVL = 4.8, 1st TVL = 18, 2nd TVL = 19 Steel: 1st HVL = 36, 2nd HVL = 17, 1st TVL = 73, 2nd TVL = 47 Concrete: 1st HVL = 123, 2nd HVL = 66, 1st TVL = 264, 2nd TVL = 172
Beta(-), Beta(+), electrons	1898.97 keV (96.7%) 821.66 keV (3.0%) 15.91 keV (0.2%)	1898.97 keV (96.7%) 821.66 keV (3.0%) 15.91 keV (0.2%)	Practical range in glass: 3.9 Practical range in plastic: 7.2

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate to skin from direct contamination: 1.8 mSv/h per kBq/cm^2
Gamma ray effective dose rate at 1 m: 1.336E-04 mSv/h per MBq

Internal dose

	Ingestion	Inhalation
Worker dose coefficient	1.3E-09 Sv/Bq	7.9E-09 Sv/Bq

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	10 Bq/g or 100 kBq	**CNSC classification:**	Class C
CNSC unconditional clearance level:	1 Bq/g	**Surface contamination free-release criterion:**	1 Bq/cm^2 (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (dose rate):

1. Plastic scintillator, ion chamber, ion chamber with window, energy compensated NaI, energy compensated Geiger-Mueller

Method of detection (contamination):

1. Hand-held: thick ZnS scintillator with proprietary discrimination, gas-flow proportional, sealed-gas proportional, NaI scintillator, plastic scintillator, halogen quenched thin window Geiger-Mueller
1. Non-portable: liquid scintillation counter, gas-flow proportional counter, NaI well counter

Dosimetry

External: Gamma/beta
Internal: Whole body counting, urinalysis

Part 6 – SAFETY PRECAUTIONS

Wear disposable plastic, latex, or rubber gloves. Wear a lab coat, which should be monitored before leaving the laboratory. Also wear safety glasses/goggles.

Keep handling time to a minimum. Use syringe shields and tongs. Use disposable absorbent liners on trays.

See appendix B for emergency procedures.

Ga-68

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Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Ga	Common name: Gallium	Atomic weight: 68/68	Atomic number: 31

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 1.129 hours

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)
Gamma & X-ray	511.00 keV (178%) 1077.34 keV (3.2%) 1883.16 keV (0.14%)	1883.16 keV (0.14%) 1261.08 keV (0.094%) 1077.34 keV (3.2%)	Lead: 1st HVL = 7.2, 2nd HVL = 4.8, 1st TVL = 18, 2nd TVL = 19 Steel: 1st HVL = 36, 2nd HVL = 17, 1st TVL = 73, 2nd TVL = 47 Concrete: 1st HVL = 123, 2nd HVL = 66, 1st TVL = 264, 2nd TVL = 172
Beta(-), Beta(+), electrons	1898.97 keV (96.7%) 821.66 keV (3.0%) 15.91 keV (0.2%)	1898.97 keV (96.7%) 821.66 keV (3.0%) 15.91 keV (0.2%)	Practical range in glass: 3.9 Practical range in plastic: 7.2

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate to skin from direct contamination: 1.8 mSv/h per kBq/cm^2
Gamma ray effective dose rate at 1 m: 1.336E-04 mSv/h per MBq

Internal dose

	Ingestion	Inhalation
Worker dose coefficient	1.0E-10 Sv/Bq	8.1E-11 Sv/Bq

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	10 Bq/g or 10 kBq	**CNSC classification:**	Class C
CNSC unconditional clearance level:	1 Bq/g	**Surface contamination free-release criterion:**	10 Bq/cm^2 (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (dose rate):

1. Plastic scintillator, ion chamber, ion chamber with window, energy compensated NaI, energy compensated Geiger-Mueller

Method of detection (contamination):

1. Hand-held: thick ZnS scintillator with proprietary discrimination, gas-flow proportional, sealed-gas proportional, NaI scintillator, plastic scintillator, halogen quenched thin window Geiger-Mueller
1. Non-portable: liquid scintillation counter, gas-flow proportional counter, NaI well counter

Dosimetry

External: Gamma/beta
Internal: Whole body counting, urinalysis

Part 6 – SAFETY PRECAUTIONS

Wear disposable plastic, latex, or rubber gloves. Wear a lab coat, which should be monitored before leaving the laboratory. Also wear safety glasses/goggles.

Keep handling time to a minimum. Use syringe shields and tongs. Use disposable absorbent liners on trays.

See appendix B for emergency procedures.

Se-75

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Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Se	Common name: Selenium	Atomic weight: 75	Atomic number: 34

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 119.8 days

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)
Gamma & X-ray	264.7 keV (59%) 136.0 keV (59%) 10.5 keV (32%)	572.2 keV (0.036%) 419.1 keV (0.014%) 400.7 keV (12%)	Lead: 1st HVL = 1.6, 2nd HVL = 1.5, 1st TVL = 5.4, 2nd TVL = 7.2 Steel: 1st HVL = 23, 2nd HVL = 11, 1st TVL = 48, 2nd TVL = 34 Concrete: 1st HVL = 110, 2nd HVL = 40, 1st TVL = 199, 2nd TVL = 115
Beta(-), Beta(+), electrons	12.51 keV (4.4%) 84.9 keV (2.6%) 124.1 keV (1.6%)	388.8 keV (0.014%) 292.1 keV (0.062%) 278.22 keV (0.02%)	Practical range in glass: 0.1 Practical range in plastic: 0.2

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate to skin from direct contamination: 0.14 mSv/h per kBq/cm^2
Gamma ray effective dose rate at 1 m: 5.588E-05 mSv/h per MBq

Internal dose

	Ingestion	Inhalation
Worker dose coefficient	2.6E-09 Sv/Bq	1.7E-09 Sv/Bq

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	100 Bq/g or 1 MBq	**CNSC classification:**	Not available
CNSC unconditional clearance level:	1 Bq/g	**Surface contamination free-release criterion:**	1 Bq/cm^2 (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (dose rate):

1. Plastic scintillator, ion chamber, ion chamber with window, energy compensated NaI, energy compensated Geiger-Mueller

Method of detection (contamination):

1. Hand-held: NaI scintillator, thick ZnS scintillator with proprietary discrimination
2. Hand-held: halogen quenched thin window Geiger Mueller, gas-flow proportional, sealed-gas proportional, plastic scintillator
1. Non-portable: liquid scintillation counter, NaI well counter

Dosimetry

External: Gamma/beta
Internal: Whole body counting, urinalysis

Part 6 – SAFETY PRECAUTIONS

When working with unsealed sources wear appropriate protective clothing, such as lab coats (which should be monitored before leaving the laboratory), coveralls, gloves, and safety glasses/goggles. Use a suitable mask if the radioactive material is in the form of dust or powder, or if it is potentially volatile.

Optimize time, distance and shielding. Monitor equipment and supplies for loose contamination before removing from laboratory. Use disposable absorbent liners on trays.

See appendix B for emergency procedures.

Sr-90/Y-90

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Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Sr/Y	Common name: Strontium/Yttrium	Atomic weight: 90/90	Atomic number: 38/39

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: Sr-90 (28.79 years)/Y-90 (2.67 days)

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)
Gamma & X-ray	None	None	Not an external radiation hazard
Beta(-), Beta(+), electrons	2280.04 keV (100%) 546.00 keV (100%) 1742.70 keV (0.01%)	2280.04 keV (100%) 1742.70 keV (0.01%) 546.00 keV (100%)	Practical range in glass: 4.9 Practical range in plastic: 9.2

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate to skin from direct contamination: 3.5 mSv/h per kBq/cm^2
Gamma ray effective dose rate at 1 m: Not applicable

Internal dose

	Ingestion	Inhalation
Worker dose coefficient	2.8E-08 Sv/Bq	7.7E-08 Sv/Bq

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	100 Bq/g or 10 kBq	**CNSC classification:**	Class B
CNSC unconditional clearance level:	1 Bq/g	**Surface contamination free-release criterion:**	1 Bq/cm^2 (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (dose rate):
Not applicable

Method of detection (contamination):

1. Hand-held: thick ZnS scintillator with proprietary discrimination, gas-flow proportional, sealed-gas proportional, plastic scintillator, halogen quenched thin window Geiger-Mueller
1. Non-portable: liquid scintillation counter, gas-flow proportional counter

Dosimetry
External: Gamma/beta
Internal: Whole body counting, urinalysis

Part 6 – SAFETY PRECAUTIONS

When working with unsealed sources wear appropriate protective clothing, such as laboratory coats (which should be monitored before leaving the laboratory), coveralls, gloves, and safety glasses/goggles. Use a suitable mask, if the radioactive material is in the form of dust or powder, or if it is potentially volatile.

Optimize time, distance and shielding. Monitor equipment and supplies for loose contamination before removing from laboratory. Use disposable absorbent liners on trays.

See appendix B for emergency procedures.

Y-90

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Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Y	Common name: Yttrium	Atomic weight: 90	Atomic number: 39

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 2.67 days

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)
Gamma & X-ray	None	None	Not an external radiation hazard
Beta(-), Beta(+), electrons	2280.04 keV (100%) 519.37 keV (0.012%) 1742.70 keV (0.01%)	2280.04 keV (100%) 1742.70 keV (0.01%) 519.37 keV (0.012%)	Practical range in glass: 4.9 Practical range in plastic: 9.2

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate to skin from direct contamination: 2.0 mSv/h per kBq/cm^2
Gamma ray effective dose Rate at 1 m: Not applicable

Internal dose

	Ingestion	Inhalation
Worker dose coefficient	2.7E-09 Sv/Bq	1.7E-09 Sv/Bq

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	1 kBq/g or 100 kBq	**CNSC classification:**	Class B
CNSC unconditional clearance level:	1 kBq/g	**Surface contamination free-release criterion:**	100 Bq/cm^2 (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (dose rate):
Not applicable

Method of detection (contamination):

1. Hand-held: thick ZnS scintillator with proprietary discrimination, gas-flow proportional, sealed-gas proportional, plastic scintillator, halogen quenched thin window Geiger-Mueller
1. Non-portable: liquid scintillation counter, gas-flow proportional counter

Dosimetry
External: Gamma/beta
Internal: Whole body counting, urinalysis

Part 6 – SAFETY PRECAUTIONS

When working with unsealed sources wear appropriate protective clothing, such as laboratory coats (which should be monitored before leaving the laboratory), coveralls, gloves, and safety glasses/goggles. Use a suitable mask, if the radioactive material is in the form of dust or powder, or if it is potentially volatile.

Optimize time, distance and shielding. Monitor equipment and supplies for loose contamination before removing from laboratory. Use disposable absorbent liners on trays.

See appendix B for emergency procedures.

Mo-99/Tc-99m

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Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Mo/Tc	Common name: Molybdenum/Technetium	Atomic weight: 99/99	Atomic number: 42/43

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: Mo-99 (2.75 days)/Tc-99m (6.01 hours)
Radioactive progeny: Tc-99 (half-life = 2.11E+05 years, 100%)

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)
Gamma & X-ray	140.51 keV (83%) 739.50 keV (12.1%) 181.07 keV (6.0%)	960.75 keV (0.095%) 822.97 keV (0.13%) 777.92 keV (4.3%)	Lead: 1^{st} HVL = 1, 2^{nd} HVL = 8.8, 1^{st} TVL = 20, 2^{nd} TVL = 24 Steel: 1^{st} HVL = 16, 2^{nd} HVL = 20, 1^{st} TVL = 61, 2^{nd} TVL = 56 Concrete: 1^{st} HVL = 95, 2^{nd} HVL = 48, 1^{st} TVL = 207, 2^{nd} TVL = 166
Beta(-), Beta(+), electrons	1214.50 keV (82%) 436.60 keV (16%) 119.47 keV (8.84%)	1214.50 keV (82%) 848.08 keV (1.1%) 718.46 keV (0.018%)	Practical range in glass: 2.2 Practical range in plastic: 4.0

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate to skin from direct contamination: 1.9 mSv/h per kBq/cm^2
Gamma ray effective dose rate at 1 m: 3.656E-05 mSv/h per MBq

Internal dose

	Ingestion	Inhalation
Worker dose coefficient	1.2E-09 Sv/Bq	1.1E-09 Sv/Bq

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	100 Bq/g or 1 MBq	**CNSC classification:**	Class B
CNSC unconditional clearance level:	10 Bq/g	**Surface contamination free-release criterion:**	10 Bq/cm^2 (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (dose rate):

1. Plastic scintillator, ion chamber, ion chamber with window, energy compensated NaI, energy compensated Geiger-Mueller

Method of detection (contamination):

1. Hand-held: thick ZnS scintillator with proprietary discrimination, gas-flow proportional, sealed-gas proportional, NaI scintillator, plastic scintillator, halogen quenched thin window Geiger-Mueller
1. Non-portable: liquid scintillation counter, gas-flow proportional counter, NaI well counter

Dosimetry

External: Gamma/beta
Internal: Whole body counting, urinalysis

Part 6 – SAFETY PRECAUTIONS

When working with unsealed sources wear laboratory coats (which should be monitored before leaving the laboratory), coveralls, gloves, and safety glasses/goggles. Use a suitable mask, if the radioactive material is in the form of dust or powder, or if it is potentially volatile.

Optimize time, distance and shielding. Monitor equipment and supplies for loose contamination before removing from laboratory. Use disposable absorbent liners on trays.

See appendix B for emergency procedures.

Tc-99m

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Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Tc	Common name: Technetium	Atomic weight: 99	Atomic number: 43

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 6.01 hours
Radioactive progeny: Tc-99 (half-life = 2.11E+05 years, 100%)

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)
Gamma & X-ray	140.51 keV (89%) 18.37 keV (4.0%) 18.25 keV (2.1%)	142.63 keV (0.019%) 140.51 keV (89%) 20.60 keV (1.2%)	Lead: 1^{st} HVL = 0.4, 2^{nd} HVL = 0.3, 1^{st} TVL = 1.1, 2^{nd} TVL = 1 Steel: 1^{st} HVL = 8.1, 2^{nd} HVL = 5.3, 1^{st} TVL = 20, 2^{nd} TVL = 15 Concrete: 1^{st} HVL = 84, 2^{nd} HVL = 30, 1^{st} TVL = 151, 2^{nd} TVL = 83
Beta(-), Beta(+), electrons	119.47 keV (8.8%) 15.50 keV (2.1%) 137.47 keV (1.1%)	142.05 keV (0.034%) 140.44 keV (0.037%) 139.97 keV (0.19%)	Practical range in glass: 0.2 Practical range in plastic: 0.3

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate to skin from direct contamination: 0.25 mSv/h per kBq/cm^2
Gamma ray effective dose rate at 1 m: 1.853E-05 mSv/h per MBq

Internal dose

	Ingestion	Inhalation
Worker dose coefficient	2.2E-11 Sv/Bq	2.9E-11 Sv/Bq

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	100 Bq/g or 10 MBq	**CNSC classification:**	Class C
CNSC unconditional clearance level:	100 Bq/g	**Surface contamination free-release criterion:**	100 Bq/cm^2 (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (dose rate):

1. Plastic scintillator, ion chamber, ion chamber with window, energy compensated NaI, energy compensated Geiger-Mueller

Method of detection (contamination):

1. Hand-held: NaI scintillator, thick ZnS scintillator with proprietary discrimination
2. Hand-held: halogen quenched thin window Geiger Mueller, gas-flow proportional, sealed-gas proportional, plastic scintillator
1. Non-portable: liquid scintillation counter, NaI well counter

Dosimetry

External: Gamma/beta
Internal: Whole body counting, urinalysis

Part 6 – SAFETY PRECAUTIONS

When working with unsealed sources wear appropriate protective clothing, such as laboratory coats (which should be monitored before leaving the laboratory), coveralls, gloves, and safety glasses/goggles. Use a suitable mask if the radioactive material is in the form of dust or powder, or if it is potentially volatile.

Optimize time, distance and shielding. Monitor equipment and supplies for loose contamination before removing from laboratory. Use disposable absorbent liners on trays.

See appendix B for emergency procedures.

Cd-109

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Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Cd	Common name: Cadmium	Atomic weight: 109	Atomic number: 48

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 461.4 days

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)
Gamma & X-ray	22.16 keV (35.5%) 21.99 keV (18.8%) 24.93 keV (9.7%)	25.46 keV (1.78%) 24.93 keV (9.7%) 22.16 keV (35.5%)	Lead: 1^{st} HVL = 0.01, 2^{nd} HVL = 0.01, 1^{st} TVL = 0.03, 2^{nd} TVL = 0.04 Steel: 1^{st} HVL = 0.05, 2^{nd} HVL = 0.05, 1^{st} TVL = 0.2, 2^{nd} TVL = 0.3 Concrete: 1^{st} HVL = 1.6, 2^{nd} HVL = 1.5, 1^{st} TVL = 5, 2^{nd} TVL = 5
Beta(-), Beta(+), electrons	19.58 keV (13.5%)	19.58 keV (13.5%)	Practical range in glass: 0.1 Practical range in plastic: 0.2

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate to skin from direct contamination: 0.54 mSv/h per kBq/cm^2
Gamma ray effective dose rate at 1 m: 5.619E-06 mSv/h per MBq

Internal dose

	Ingestion	Inhalation
Worker dose coefficient	2.0E-09 Sv/Bq	9.6E-09 Sv/Bq

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	10 kBq/g or 1 MBq	**CNSC classification:**	Class C
CNSC unconditional clearance level:	1 Bq/g	**Surface contamination free-release criterion:**	1 Bq/cm^2 (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (dose rate):

1. Plastic scintillator, ion chamber, ion chamber with window, energy compensated NaI
2. Energy compensated Geiger-Mueller

Method of detection (contamination):

1. Hand-held: NaI scintillator
1. Non-portable: liquid scintillation counter, NaI well counter

Dosimetry

External: Gamma/beta
Internal: Whole body counting, urinalysis

Part 6 – SAFETY PRECAUTIONS

Wear disposable plastic, latex, or rubber gloves. Wear a lab coat, which should be monitored before leaving the laboratory. Also wear safety glasses.

Keep handling time to a minimum. Use syringe shields and tongs. Use disposable absorbent liners on trays.

See appendix B for emergency procedures.

In-111

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Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: In	Common name: Indium	Atomic weight: 111	Atomic number: 49

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 2.80 days

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)
Gamma & X-ray	245.35 keV (94.1%) 171.28 keV (90.7%) 23.17 keV (44.6%)	245.35 keV (94.1%) 171.28 keV (90.7%) 26.10 keV (14.6%)	Lead: 1^{st} HVL = 0.6, 2^{nd} HVL = 0.9, 1^{st} TVL = 2.7, 2^{nd} TVL = 3.2 Steel: 1^{st} HVL = 14, 2^{nd} HVL = 9.8, 1^{st} TVL = 35, 2^{nd} TVL = 28 Concrete: 1^{st} HVL = 85, 2^{nd} HVL = 40, 1^{st} TVL = 171, 2^{nd} TVL = 105
Beta(-), Beta(+), electrons	19.30 keV (15.8%) 144.57 keV (8.1%) 218.64 keV (4.95%)	244.58 keV (0.15%) 241.33 keV (0.78%) 218.64 keV (4.95%)	Practical range in glass: 0.3 Practical range in plastic: 0.5

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate to skin from direct contamination: 0.38 mSv/h per kBq/cm^2
Gamma ray effective dose rate at 1 m: 6.325E-05 mSv/h per MBq

Internal dose

	Ingestion	Inhalation
Worker dose coefficient	2.9E-10 Sv/Bq	3.1E-10 Sv/Bq

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	100 Bq/g or 1 MBq	**CNSC classification:**	Class C
CNSC unconditional clearance level:	10 Bq/g	**Surface contamination free-release criterion:**	10 Bq/cm^2 (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (dose rate):

1. Plastic scintillator, ion chamber, ion chamber with window, energy compensated NaI, energy compensated Geiger-Mueller

Method of detection (contamination):

1. Hand-held: NaI scintillator, thick ZnS scintillator with proprietary discrimination
2. Hand-held: halogen quenched thin window Geiger Mueller, gas-flow proportional, sealed-gas proportional, plastic scintillator
1. Non-portable: liquid scintillation counter, NaI well counter

Dosimetry

External: Gamma/beta
Internal: Whole body counting, urinalysis

Part 6 – SAFETY PRECAUTIONS

Wear disposable plastic, latex, or rubber gloves. Wear a lab coat, which should be monitored before leaving the laboratory. Also wear safety glasses.

Keep handling time to a minimum. Use syringe shields and tongs. Use disposable absorbent liners on trays.

See appendix B for emergency procedures.

I-123

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Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: I	Common name: Iodine	Atomic weight: 123	Atomic number: 53

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 13.2 hours

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)
Gamma & X-ray	158.97 keV (83.3%) 27.47 keV (46.3%) 27.20 keV (24.8%)	783.59 keV (0.059%) 735.78 keV (0.062%) 687.95 keV (0.027%)	Lead: 1^{st} HVL = 0.06, 2^{nd} HVL = 0.54, 1^{st} TVL = 1.4, 2^{nd} TVL = 12 Steel: 1^{st} HVL = 4.8, 2^{nd} HVL = 8.6, 1^{st} TVL = 24, 2^{nd} TVL = 36 Concrete: 1^{st} HVL = 59, 2^{nd} HVL = 41, 1^{st} TVL = 145, 2^{nd} TVL = 105
Beta(-), Beta(+), electrons	127.16 keV (13.7%) 22.70 keV (12.4%) 154.03 keV (1.80%)	506.73 keV (0.012%) 154.03 keV (1.80%) 127.16 keV (13.7%)	Practical range in glass: 0.2 Practical range in plastic: 0.3

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate to skin from direct contamination: 0.38 mSv/h per kBq/cm^2
Gamma ray effective dose rate at 1 m: 2.963E-05 mSv/h per MBq

Internal dose

	Ingestion	Inhalation
Worker dose coefficient	2.1E-10 Sv/Bq	2.1E-10 Sv/Bq (vapor)

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	100 Bq/g or 10 MBq	**CNSC classification:**	Class C
CNSC unconditional clearance level:	100 Bq/g	**Surface contamination free-release criterion:**	100 Bq/cm^2 (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (dose rate):

1. Plastic scintillator, ion chamber, ion chamber with window, energy compensated NaI, energy compensated Geiger-Mueller

Method of detection (contamination):

1. Hand-held: NaI scintillator, thick ZnS scintillator with proprietary discrimination
2. Hand-held: plastic scintillator, halogen quenched thin window Geiger Mueller, gas-flow proportional, sealed-gas proportional, plastic scintillator
1. Non-portable: liquid scintillation counter, gas-flow proportional counter, NaI well counter

Dosimetry

External: Gamma/beta
Internal: Whole body counting, thyroid counting, urinalysis

Part 6 – SAFETY PRECAUTIONS

Iodine compound can become volatile. Handle and store in ventilated areas. Iodine can be absorbed through the skin. Heating sodium iodide 123 capsules to decomposition may emit in radioactive fumes containing I -123.

Wear disposable plastic, latex, or rubber gloves. Wear a lab coat, which should be monitored before leaving the laboratory. Also wear safety glasses.

Optimize time, distance, shielding. Syringe shields and tongs should be used. Use disposable absorbent liners on trays.
See appendix B for emergency procedures.

I-125

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Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: I	Common name: Iodine	Atomic weight: 125	Atomic number: 53

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 59.4 days

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)
Gamma & X-ray	27.47 keV (74.4%) 27.20 keV (39.9%) 31.00 keV (25.8%)	35.49 keV (6.7%) 31.00 keV (25.8%) 27.47 keV (74.4%)	Lead: 1^{st} HVL = 0.02, 2^{nd} HVL = 0.02, 1^{st} TVL = 0.06, 2^{nd} TVL = 0.04 Steel: 1^{st} HVL = 0.09, 2^{nd} HVL = 0.1, 1^{st} TVL = 0.3, 2^{nd} TVL = 0.3 Concrete: 1^{st} HVL = 3.1, 2^{nd} HVL = 2.8, 1^{st} TVL = 9.5, 2^{nd} TVL = 9.7
Beta(-), Beta(+), electrons	22.70 keV (20.0%) 30.55 keV (10.7%) 34.49 keV (2.13%)	34.49 keV (2.1%) 30.55 keV (10.7%) 22.70 keV (20.0%)	Practical range in glass: <0.1 Practical range in plastic: <0.1

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate to skin from direct contamination: 0.021 mSv/h per kBq/cm^2
Gamma ray effective dose rate at 1 m: 1.449E-05 mSv/h per MBq

Internal dose

	Ingestion	Inhalation
Worker dose coefficient	1.5E-08 Sv/Bq	1.4E-08 Sv/Bq (vapor)

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	1 kBq/g or 1 MBq	**CNSC classification:**	Class C
CNSC unconditional clearance level:	100 Bq/g	**Surface contamination free-release criterion:**	100 Bq/cm^2 (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (dose rate):

1. Specialized equipment may be required

Method of detection (contamination):

1. Hand-held: NaI scintillator, thick ZnS scintillator with proprietary discrimination
2. Hand-held: halogen quenched thin window Geiger Mueller, gas-flow proportional, sealed-gas proportional, plastic scintillator
1. Non-portable: liquid scintillation counter, NaI well counter

Dosimetry

External: Gamma/beta
Internal: Whole body counting, Thyroid counting, urinalysis

Part 6 – SAFETY PRECAUTIONS

Iodine compound can become volatile. Handle and store in ventilated areas. Iodine can be absorbed through the skin. When iodinated (I-125) albumin injection is heated to decomposition, radioactive fumes containing I-125 may be emitted.

Wear disposable plastic, latex, or rubber gloves. Wear a lab coat, which should be monitored before leaving the laboratory. Also wear safety glasses. Some iodine compounds can penetrate surgical rubber gloves. Wear two pairs or polyethylene gloves over rubber. Optimize time, distance, shielding. Use syringe shields and tongs. When possible handle iodine compounds in a fume hood. Use disposable absorbent liners on trays.

See appendix B for emergency procedures.

I-131

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Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: I	Common name: Iodine	Atomic weight: 131	Atomic number: 53

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 8.03 days
Radioactive progeny: Xe-131 (half-life = 11.84 days, 1%)

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)
Gamma & X-ray	364.49 keV (81.2%) 636.99 keV (7.3%) 284.3 keV (6.1%)	722.91 keV (1.8%) 642.7 keV (0.22%) 636.99 keV (7.3%)	Lead: 1^{st} HVL = 3.9, 2^{nd} HVL = 3.1, 1^{st} TVL = 12, 2^{nd} TVL = 17 Steel: 1^{st} HVL = 32, 2^{nd} HVL = 14, 1^{st} TVL = 64, 2^{nd} TVL = 42 Concrete: 1^{st} HVL = 118, 2^{nd} HVL = 50, 1^{st} TVL = 226, 2^{nd} TVL = 134
Beta(-), Beta(+), electrons	606.31 keV (89.4%) 333.81 keV (7.36%) 45.62 keV (3.5%)	806.87 keV (0.40%) 629.65 keV (0.05%) 606.31 keV (89.4%)	Practical range in glass: 0.9 Practical range in plastic: 1.6

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate to skin from direct contamination: 1.6 mSv/h per kBq/cm^2
Gamma ray effective dose rate at 1 m: 5.471E-05 mSv/h per MBq

Internal dose

	Ingestion	Inhalation
Worker dose coefficient	2.2E-08 Sv/Bq	2.0E-08 Sv/Bq (vapor)

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	100 Bq/g or 1 MBq	**CNSC classification:**	Class B
CNSC unconditional clearance level:	10 Bq/g	**Surface contamination free-release criterion:**	10 Bq/cm^2 (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (dose rate):

1. Plastic scintillator, ion chamber, ion chamber with window, energy compensated NaI, energy compensated Geiger-Mueller

Method of detection (contamination):

1. Hand-held: thick ZnS scintillator with proprietary discrimination, gas-flow proportional, sealed-gas proportional, NaI scintillator, plastic scintillator, halogen quenched thin window Geiger-Mueller
1. Non-portable: liquid scintillation counter, gas-flow proportional counter, NaI well counter

Dosimetry

External: Gamma/beta
Internal: Whole body counting, thyroid counting, urinalysis

Part 6 – SAFETY PRECAUTIONS

Iodine compound can become volatile. Handle and store in ventilated areas. Iodine can be absorbed through the skin. Heating sodium iodide to decomposition may result in radioactive fumes containing I-131 to be emitted.

Wear disposable plastic, latex, or rubber gloves. Wear a lab coat, which should be monitored before leaving the laboratory. Fluoroscopy aprons provide no protection against the radiation from I-131. Also wear safety glasses.

Optimize time, distance, shielding. Syringe shields and tongs should be used. Use disposable absorbent liners on trays.

See appendix B for emergency procedures.

Sb-124

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Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Sb	Common name: Antimony	Atomic weight: 124	Atomic number: 51

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 60.2 days

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)
Gamma & X-ray	602.73 keV (97.9%) 1690.98 keV (47.6%) 722.78 keV (10.8%)	2293.48 keV (0.03%) 2283.20 keV (0.04%) 2182.40 keV (0.05%)	Lead: 1^{st} HVL = 15, 2^{nd} HVL = 13, 1^{st} TVL = 47, 2^{nd} TVL = 48 Steel: 1^{st} HVL = 41, 2^{nd} HVL = 24, 1^{st} TVL = 95, 2^{nd} TVL = 74 Concrete: 1^{st} HVL = 129, 2^{nd} HVL = 75, 1^{st} TVL = 296, 2^{nd} TVL = 225
Beta(-), Beta(+), electrons	610.77 keV (51.3%) 2301.71 keV (23.6%) 210.82 keV (8.8%)	2301.71 keV (23.6%) 1655.87 keV (2.6%) 1578.95 keV (4.9%)	Practical range in glass: 5.0 Practical range in plastic: 9.3

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate to skin from direct contamination: 2.2 mSv/h per kBq/cm^2
Gamma ray effective dose rate at 1 m: 2.269E-04 mSv/h per MBq

Internal dose

	Ingestion	Inhalation
Worker dose coefficient	2.5E-09 Sv/Bq	4.7E-09 Sv/Bq

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	10 Bq/g or 1 MBq	**CNSC classification:**	Class A
CNSC unconditional clearance level:	1 Bq/g	**Surface contamination free-release criterion:**	1 Bq/cm^2 (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (dose rate):

1. Plastic scintillator, ion chamber, ion chamber with window, energy compensated NaI, energy compensated Geiger-Mueller

Method of detection (contamination):

1. Hand-held: thick ZnS scintillator with proprietary discrimination, gas-flow proportional, sealed-gas proportional, NaI scintillator, plastic scintillator, halogen quenched thin window Geiger-Mueller
1. Non-portable: liquid scintillation counter, gas-flow proportional counter, NaI well counter

Dosimetry

External: Gamma/beta
Internal: Whole body counting, urinalysis

Part 6 – SAFETY PRECAUTIONS

When working with unsealed sources wear appropriate protective clothing, such as laboratory coats, coveralls, gloves, and safety glasses/goggles. Laboratory coats should be monitored before leaving the laboratory. Use a suitable mask if the radioactive material is in the form of dust or powder, or if it is potentially volatile.

Optimize time, distance, shielding. Use disposable absorbent liners on trays.

See appendix B for emergency procedures.

Cs-137/Ba-137m

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Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Cs/Ba	Common name: Cesium/Barium	Atomic weight: 137/137	Atomic number: 55/56

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: Cs-137 (30.08 years), Ba-137m (2.55 minutes)

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)
Gamma & X-ray	661.66 keV (85.0%) 32.19 keV (3.60%) 31.82 keV (1.95%)	661.66 keV (85.0%) 36.40 keV (1.31%) 32.19 keV (3.60%)	Lead: 1st HVL = 9.4, 2nd HVL = 6.7, 1st TVL = 24, 2nd TVL = 20 Steel: 1st HVL = 38, 2nd HVL = 19, 1st TVL = 79, 2nd TVL = 51 Concrete: 1st HVL = 121, 2nd HVL = 62, 1st TVL = 255, 2nd TVL = 160
Beta(-), Beta(+), electrons	513.97 keV (94.4%) 624.22 keV (7.64%) 1175.62 keV (5.6%)	1175.62 keV (5.6%) 513.97 keV (94.4%) 655.67 keV (1.41%)	Practical range in glass: 2.1 Practical range in plastic: 3.8

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate to skin from direct contamination: 1.6 mSv/h per kBq/cm^2
Gamma ray effective dose rate at 1 m: 7.789E-05 mSv/h per MBq

Internal dose

	Ingestion	Inhalation
Worker dose coefficient	1.3E-08 Sv/Bq	6.7E-09 Sv/Bq

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	10 Bq/g or 10 kBq	**CNSC classification:**	Class A
CNSC unconditional clearance level:	0.1 Bq/g	**Surface contamination free-release criterion:**	0.1 Bq/cm^2 (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of Detection (dose rate):

1. Plastic scintillator, ion chamber, ion chamber with window, energy compensated NaI, energy compensated Geiger-Mueller

Method of Detection (contamination):

1. Hand-held: thick ZnS scintillator with proprietary discrimination, gas-flow proportional, sealed-gas proportional, NaI scintillator, plastic scintillator, halogen quenched thin window Geiger-Mueller
1. Non-portable: liquid scintillation counter, gas-flow proportional counter, NaI well counter

Dosimetry

External: Gamma/beta
Internal: Whole body counting, urinalysis

Part 6 – SAFETY PRECAUTIONS

When working with unsealed sources, wear appropriate protective clothing such as disposable plastic, latex, or rubber gloves, a lab coat (which should be monitored before leaving the laboratory) and safety glasses/goggles. Use a suitable mask if the radioactive material is in the form of dust or powder, or if it is potentially volatile.

Keep handling time to a minimum. Use syringe shields and tongs. Use disposable absorbent liners on trays.

See appendix B for emergency procedures.

Ir-192

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Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Ir	Common name: Iridium	Atomic weight: 192	Atomic number: 77

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 73.83 days

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)
Gamma & X-ray	316.51 keV (82.8%) 468.07 keV (47.8%) 308.46 keV (29.7%)	1061.48 keV (0.05%) 884.54 keV (0.29%) 612.46 keV (5.34%)	Lead: 1^{st} HVL = 3.8, 2^{nd} HVL = 3.3, 1^{st} TVL = 12, 2^{nd} TVL = 15 Steel: 1^{st} HVL = 32, 2^{nd} HVL = 14, 1^{st} TVL = 63, 2^{nd} TVL = 42 Concrete: 1^{st} HVL = 119, 2^{nd} HVL = 49, 1^{st} TVL = 225, 2^{nd} TVL = 133
Beta(-), Beta(+), electrons	675.10 keV (47.9%) 538.80 keV (41.4%) 258.70 keV (5.59%)	675.10 keV (47.9%) 601.75 keV (0.010%) 600.90 keV (0.015%)	Practical range in glass: 1.0 Practical range in plastic: 1.9

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate to skin from direct contamination: 1.9 mSv/h per kBq/cm^2
Gamma ray effective dose rate at 1 m: 1.169E-04 mSv/h per MBq

Internal dose

	Ingestion	Inhalation
Worker dose coefficient	1.4E-09 Sv/Bq	4.9E-09 Sv/Bq

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	10 Bq/g or 10 kBq	**CNSC classification:**	Class B
CNSC unconditional clearance level:	1 Bq/g	**Surface contamination free-release criterion:**	1 Bq/cm^2 (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (dose rate):

1. Plastic scintillator, ion chamber, ion chamber with window, energy compensated NaI, energy compensated Geiger-Mueller

Method of detection (contamination):

1. Hand-held: thick ZnS scintillator with proprietary discrimination, gas-flow proportional, sealed-gas proportional, NaI scintillator, plastic scintillator, halogen quenched thin window Geiger-Mueller
1. Non-portable: liquid scintillation counter, gas-flow proportional counter, NaI well counter

Dosimetry

External: Gamma/beta
Internal: Whole body counting, urinalysis

Part 6 – SAFETY PRECAUTIONS

When working with unsealed sources, wear disposable plastic, latex, or rubber gloves, a lab coat (which should be monitored before leaving the laboratory), and safety glasses.

Keep handling time to a minimum. Use syringe shields and tongs. Use disposable absorbent liners on trays.

See appendix B for emergency procedures.

Tl-201

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Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Tl	Common name: Thallium	Atomic weight: 201	Atomic number: 81

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 3.04 days

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)
Gamma & X-ray	70.82 keV (47.1%) 68.90 keV (27.7%) 80.30 keV (20.7%)	167.43 keV (10.3%) 165.88 keV (0.15%) 135.34 keV (2.7%)	Lead: 1^{st} HVL = 0.3, 2^{nd} HVL = 0.3, 1^{st} TVL = 1, 2^{nd} TVL = 1.1 Steel: 1^{st} HVL = 2.5, 2^{nd} HVL = 4, 1^{st} TVL = 15, 2^{nd} TVL = 20 Concrete: 1^{st} HVL = 56, 2^{nd} HVL = 27, 1^{st} TVL = 118, 2^{nd} TVL = 89
Beta(-), Beta(+), electrons	84.33 keV (15.9%) 15.76 keV (9.96%) 17.35 keV (8.64%)	163.87 keV (0.83%) 152.59 keV (2.69%) 151.04 keV (0.04%)	Practical range in glass: 0.2 Practical range in plastic: 0.3

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate to skin from direct contamination: 0.27 mSv/h per kBq/cm^2
Gamma ray effective dose rate at 1 m: 1.459E-05 mSv/h per MBq

Internal dose

	Ingestion	Inhalation
Worker dose coefficient	9.5E-11 Sv/Bq	7.6E-11 Sv/Bq

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	100 Bq/g or 1 MBq	**CNSC classification:**	Class C
CNSC unconditional clearance level:	100 Bq/g	**Surface contamination free-release criterion:**	100 Bq/cm^2 (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (dose rate):

1. Plastic scintillator, ion chamber, ion chamber with window, energy compensated NaI, energy compensated Geiger-Mueller

Method of detection (contamination):

1. Hand-held: NaI scintillator, thick ZnS scintillator with proprietary discrimination
2. Hand-held: halogen quenched thin window Geiger-Mueller, gas-flow proportional, sealed-gas proportional, plastic scintillator
1. Non-portable: liquid scintillation counter, NaI well counter

Dosimetry

External: Gamma/beta
Internal: Whole body counting, urinalysis

Part 6 – SAFETY PRECAUTIONS

Wear appropriate protective clothing, such as laboratory coats (which should be monitored before leaving the laboratory), coveralls, gloves, and safety glasses/goggles.

Optimize time, distance and shielding. Monitor equipment and supplies for loose contamination before removing from laboratory. Use disposable absorbent liners on trays.

See appendix B for emergency procedures.

Am-241

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Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Am	Common name: Americium	Atomic weight: 241	Atomic number: 95

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 432.6 years
Progeny: No short-lived progeny

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)
Gamma & X-ray	59.54 keV (36.0%) 14.44 keV (33.1%) 26.34 keV (2.4%)	102.96 keV (0.02%) 98.97 keV (0.02%) 59.54 keV (36.0%)	Lead: 1^{st} HVL = 0.08, 2^{nd} HVL = 0.12, 1^{st} TVL = 0.4, 2^{nd} TVL = 0.4 Steel: 1^{st} HVL = 0.6, 2^{nd} HVL = 0.8, 1^{st} TVL = 2.4, 2^{nd} TVL = 2.5 Concrete: 1^{st} HVL = 22, 2^{nd} HVL = 15, 1^{st} TVL = 55, 2^{nd} TVL = 42
Beta(-), Beta(+), electrons	10.09 keV (40.4%) 41.93 keV (30.2%) 15.59 keV (17.0%)	94.36 keV (0.10%) 81.36 keV (0.25%) 54.93 keV (10.1%)	Not applicable
Alpha	5485.68 keV (84.4%) 5442.98 keV (13.1%) 5388.40 keV (1.7%)	5544.24 keV (0.36%) 5511.59 keV (0.22%) 5485.68 keV (84.4%)	Not applicable

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate to skin from direct contamination: 0.019 mSv/h per kBq/cm^2
Gamma ray effective dose rate at 1 m: 4.347E-06 mSv/h per MBq

Internal dose

	Ingestion	Inhalation
Worker dose coefficient	2.0E-07 Sv/Bq	2.7E-05 Sv/Bq

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	1 Bq/g or 10 kBq	**CNSC classification:**	Class A
CNSC unconditional clearance level:	0.1 Bq/g	**Surface contamination free-release criterion:**	0.1 Bq/cm^2 (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (dose rate):

1. Plastic scintillator, ion chamber, ion chamber with window, energy compensated NaI
2. Energy compensated Geiger-Mueller

Method of detection (contamination):

1. Hand-held: thick ZnS scintillator with proprietary discrimination, thin ZnS scintillator, gas-flow proportional
2. Hand-held: halogen-quenched thin window Geiger-Mueller, NaI scintillator, gas-flow proportional, sealed-gas proportional, plastic scintillator
1. Non-portable: liquid scintillation counter, gas-flow proportional counter
2. Non-portable: NaI well counter

Dosimetry

External: Gamma/beta
Internal: Whole body counting, urinalysis, feces

Part 6 – SAFETY PRECAUTIONS

Am-241 sealed sources are low-energy gamma emitters. No protective clothing is necessary for work with sealed sources. Optimize time, distance, and shielding. Manipulate sealed sources remotely to minimize extremity doses.

See appendix B for emergency procedures.

Appendix A: Concrete TVL validation

Published HVL and TVL concrete values can vary considerably. For example, an often quoted TVL for concrete for Tc-99m is 6.6 cm, while the value found in the *Radionuclide Information Booklet* is 15.1 cm. These variations are primarily due to broad beam versus narrow beam calculations. Narrow beam calculations are not representative of an isotropic source (such as an injected patient) and do not factor in build-up in the shielding material. In order to validate the concrete HVL and TVL values, a comparison between various means of calculation was performed. The first and second concrete TVL values for Co-60, Cs-137, F-18, and Tc-99m were also computed using the Monte Carlo N-Particle transport code (MCNP6) for comparison with the values obtained using Nucleonica. The MCNP6 simulation comprised a series of concentric 5 cm thick concrete spheres, with air and a detector placed between each sphere. All TVL values computed using MNCP6 and Nucleonica were within approximately ±10% of each other. A third comparison was also made using RadPro Calculator [11] (using build-up), a free online tool. The first and second TVL values computed using RadPro were very similar to the Nucleonica values. Note that ordinary NIST concrete with a density of 2.3 g/cm^3 was used for all three methods of computation.

Nucleonica results were used throughout the *Radionuclide Information Booklet* because the Nucleonica nuclide library is complete (as opposed to RadPro's available list of nuclides), and MCNP6 simulations are somewhat labour intensive. Below is a table comparing all the results:

CONCRETE TVL (cm)	**MCNP6**	**Nucleonica**	**Rad Pro Calculator**
Co-60 TVL 1	32	30.5	28
Co-60 TVL 2	19.5	21.1	23.6
Cs-137 TVL 1	26	25.5	23.8
Cs-137 TVL 2	17	15.9	16.3
F-18 TVL 1	24	24	21.7
F-18 TVL 2	15.5	14.4	14.7
Tc-99m TVL 1	14.5	15.1	13.3
Tc-99m TVL 2	9.5	8.3	8.7

Appendix B: Emergency Procedures

In the case of an emergency, the radiation safety officer should be contacted as soon as practicable. The following actions, including cleanup, should be carried out by qualified individuals. In cases where life threatening injury has resulted, treat the injury first and deal with personal decontamination second.

Personal decontamination techniques

- Wash well with soap and water and monitor skin
- Do not abrade skin, only blot dry
- Decontamination of clothing and surfaces are covered under operating and emergency procedures

Spill and leak control

- Alert everyone in the area
- Clear area
- Summon aid

Emergency protective equipment

- Gloves
- Footwear covers
- Safety glasses
- Outer layer or easily removed protective clothing
- Suitable respirator (if the radionuclide is potentially volatile)

CNSC duty officer emergency telephone line: 613-995-0479 or 1-844-879-0805

References

[1] Nucleonica GmbH, Reference Data, Nucleonica Nuclear Science Portal, Version 3.0.49, Karlsruher, 2014.

[2] Nucleonica GmbH, Radiations, Nucleonica Nuclear Science Portal, Version 3.0.49, Karlsruher, 2014.

[3] Nucleonica GmbH, Help: Dosimetry & Shielding, Nucleonica Nuclear Science Portal, Version 3.0.49, Karlsruher, 2014.

[4] X-Ray Mass Attenuation Coefficients, Table 3.

[5] X-Ray Mass Attenuation Coefficients, Table 2.

[6] D. Delacroix et al., Radionuclide and Radiation Protection Data Handbook 2002, 2nd Edition, *Radiation Protection Dosimetry,* Vol. 98, No. 1, 2002.

[7] International Atomic Energy Agency, *Generic procedures for assessment and response during a radiological emergency*, IAEA, Vienna, 2000.

[8] International Commission on Radiological Protection. "Conversion Coefficients for Radiological Protection Quantities for External Radiation Exposures"*ICRP Publication* 116, Ann. ICRP 40(2-5), 2010.

[9] ICRP, "Dose Coefficients for Intakes of Radionuclides by Workers" *ICRP Publication* 68. Ann. ICRP 24 (4), 1994.

[10] American National Standards Institute (ANSI), ANSI N13.12 "Surface and Volume Radioactivity Standards for Clearance" *Health Physics Society*, 2013.

[11] Rad Pro Calculator