

Canada's Nuclear Regulator



# Radionuclide Information Booklet

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Canadian Nuclear  
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Canada

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## 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 or the 8th Table of Isotopes 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 ( $2.3 \text{ g/cm}^3$ ) 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:

$$R = (\Gamma \times A \times 0.1 \times 10^{-[t-TVL1]/TVL2}) / d^2$$

<b>Where:</b>		
R	is the dose rate	( $\mu$ Sv/h)
$\Gamma$	is the gamma ray constant for the source at 1 m	( $\mu$ Sv/h per 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, in addition to the first HVL, to reduce the dose rate by another half	(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.

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## 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 or 8th Table of Isotopes 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  $\mu\text{m}$ . 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 ( $\mu\text{Sv}$ ), 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.

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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**

This section refers to the emergency procedures in appendix B and the general safety precautions in appendix C that should be applied if necessary.

## H-3

This page has been printed from the Canadian Nuclear Safety Commission's (CNSC) *Radionuclide Information Booklet*. For references to the information provided, consult the booklet available at <http://www.nuclearsafety.gc.ca/eng/resources/radiation/radionuclide-information.cfm>.

### Part 1 – RADIONUCLIDE IDENTIFICATION

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

Compound type	Ingestion	Inhalation	
	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

<b>CNSC exemption quantity:</b> 1 MBq/g or 1 GBq	<b>CNSC classification:</b> Class C
<b>CNSC unconditional Clearance level:</b> 100 Bq/g	<b>Surface contamination:</b> 100 Bq/cm <sup>2</sup> <b>Free-release criterion:</b> (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

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C and apply if necessary.

Note: Tritium is an internal hazard only and cannot generally be detected with handheld equipment. Tritium can also migrate through conventional latex/nitrile gloves and plastic bottles. Tritium can be absorbed through the skin.



## C-14

This page has been printed from the Canadian Nuclear Safety Commission's (CNSC) *Radionuclide Information Booklet*. For references to the information provided, consult the booklet available at <http://www.nuclearsafety.gc.ca/eng/resources/radiation/radionuclide-information.cfm>.

### 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<sup>2</sup>

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

<b>CNSC exemption quantity:</b>	10 kBq/g or 10 MBq	<b>CNSC classification:</b>	Class C
<b>CNSC unconditional clearance level:</b>	1 Bq/g	<b>Surface contamination free-release criterion:</b>	1 Bq/cm <sup>2</sup> (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

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C and apply if necessary.

Note: C-14 is primarily an internal hazard.

\*Revised <sup>14</sup>CO<sub>2</sub> dose coefficient from Leggett, R.W., Radiation Protection Dosimetry Vol. 208, pp. 203-213 (2004).

## F-18

This page has been printed from the Canadian Nuclear Safety Commission's (CNSC) *Radionuclide Information Booklet*. For references to the information provided, consult the booklet available at <http://www.nuclearsafety.gc.ca/eng/resources/radiation/radionuclide-information.cfm>.

### Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: F	Common name: Fluorine	Atomic weight: 18	Atomic number: 9
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### 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 <sup>st</sup> HVL = 7, 2 <sup>nd</sup> HVL = 4.5, 1 <sup>st</sup> TVL = 17, 2 <sup>nd</sup> TVL = 14 Steel: 1 <sup>st</sup> HVL = 36, 2 <sup>nd</sup> HVL = 17, 1 <sup>st</sup> TVL = 72, 2 <sup>nd</sup> TVL = 45 Concrete: 1 <sup>st</sup> HVL = 121, 2 <sup>nd</sup> HVL = 56, 1 <sup>st</sup> TVL = 240, 2 <sup>nd</sup> TVL = 144
Beta(-), Beta(+), electrons	633.34 keV (96.7%)	633.34 keV (96.7%)	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<sup>2</sup>  
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 <sup>2</sup> (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

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

## Na-22

This page has been printed from the Canadian Nuclear Safety Commission's (CNSC) *Radionuclide Information Booklet*. For references to the information provided, consult the booklet available at <http://www.nuclearsafety.gc.ca/eng/resources/radiation/radionuclide-information.cfm>.

### Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Na	Common name: Sodium	Atomic weight: 22	Atomic number: 11
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### Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 2.60 years

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 (180%) 1274.54 keV (100%)	1274.54 keV (100%) 511.00 keV (180%)	Lead: 1 <sup>st</sup> HVL = 12, 2 <sup>nd</sup> HVL = 12, 1 <sup>st</sup> TVL = 41, 2 <sup>nd</sup> TVL = 40 Steel: 1 <sup>st</sup> HVL = 39, 2 <sup>nd</sup> HVL = 22, 1 <sup>st</sup> TVL = 88, 2 <sup>nd</sup> TVL = 66 Concrete: 1 <sup>st</sup> HVL = 126, 2 <sup>nd</sup> HVL = 69, 1 <sup>st</sup> TVL = 277, 2 <sup>nd</sup> TVL = 198
Beta(-), Beta(+), electrons	545.41 keV (90%)	545.41 keV (90%)	Practical range in glass: 0.8 Practical range in plastic: 1.4

### Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

#### External dose

Dose rate to skin from direct contamination: 1.7 mSv/h per kBq/cm<sup>2</sup>  
Gamma ray effective dose rate at 1 m: 2.841E-04 mSv/h per MBq

#### Internal dose

	Ingestion	Inhalation
Worker dose coefficient	3.2E-09 Sv/Bq	2.0E-09 Sv/Bq

### Part 4 – CLEARANCE AND EXEMPTION

<b>CNSC exemption quantity:</b> 10 Bq/g or 1 MBq	<b>CNSC classification:</b> Class A
<b>CNSC unconditional clearance level:</b> 0.1 Bq/g	<b>Surface contamination free-release criterion:</b> 1 Bq/cm <sup>2</sup> (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

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

## P-32

This page has been printed from the Canadian Nuclear Safety Commission's (CNSC) *Radionuclide Information Booklet*. For references to the information provided, consult the booklet available at <http://www.nuclearsafety.gc.ca/eng/resources/radiation/radionuclide-information.cfm>.

### Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: P	Common name: Phosphorus	Atomic weight: 32	Atomic number: 15
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### 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<sup>2</sup>

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

<b>CNSC exemption quantity:</b> 1 kBq/g or 100 kBq	<b>CNSC classification:</b> Class C
<b>CNSC unconditional clearance level:</b> 1 kBq/g	<b>Surface contamination free-release criterion:</b> 100 Bq/cm <sup>2</sup> (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

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

## S-35

This page has been printed from the Canadian Nuclear Safety Commission's (CNSC) *Radionuclide Information Booklet*. For references to the information provided, consult the booklet available at <http://www.nuclearsafety.gc.ca/eng/resources/radiation/radionuclide-information.cfm>.

### Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: S	Common name: Sulphur	Atomic weight: 35	Atomic number: 16
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### 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<sup>2</sup>

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

<b>CNSC exemption quantity:</b> 100 kBq/g or 100 MBq	<b>CNSC classification:</b> Class C
<b>CNSC unconditional clearance level:</b> 100 Bq/g	<b>Surface contamination free-release criterion:</b> 100 Bq/cm <sup>2</sup> (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

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

## Ca-45

This page has been printed from the Canadian Nuclear Safety Commission's (CNSC) *Radionuclide Information Booklet*. For references to the information provided, consult the booklet available at <http://www.nuclearsafety.gc.ca/eng/resources/radiation/radionuclide-information.cfm>.

### Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Ca	Common name: Calcium	Atomic weight: 45	Atomic number: 20
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### 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<sup>2</sup>

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

<b>CNSC exemption quantity:</b> 10 kBq/g or 10 MBq	<b>CNSC classification:</b> Class C
<b>CNSC unconditional clearance level:</b> 100 Bq/g	<b>Surface contamination free-release criterion:</b> 100 Bq/cm <sup>2</sup> (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

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

## Sc-46

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### Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Sc	Common name: Scandium	Atomic weight: 46	Atomic number: 21
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### 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 <sup>st</sup> HVL = 17, 2 <sup>nd</sup> HVL = 11, 1 <sup>st</sup> TVL = 42, 2 <sup>nd</sup> TVL = 34 Steel: 1 <sup>st</sup> HVL = 41, 2 <sup>nd</sup> HVL = 23, 1 <sup>st</sup> TVL = 92, 2 <sup>nd</sup> TVL = 63 Concrete: 1 <sup>st</sup> HVL = 127, 2 <sup>nd</sup> HVL = 74, 1 <sup>st</sup> TVL = 286, 2 <sup>nd</sup> 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<sup>2</sup>

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

<b>CNSC exemption quantity:</b> 10 Bq/g or 1 MBq	<b>CNSC classification:</b> Class A
<b>CNSC unconditional clearance level:</b> 0.1 Bq/g	<b>Surface contamination free-release criterion:</b> 0.1 Bq/cm <sup>2</sup> (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

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

## Cr-51

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### Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Cr	Common name: Chromium	Atomic weight: 51	Atomic number: 24
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### 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 <sup>st</sup> HVL = 2.8, 2 <sup>nd</sup> HVL = 1.8, 1 <sup>st</sup> TVL = 7, 2 <sup>nd</sup> TVL = 5.9 Steel: 1 <sup>st</sup> HVL = 30, 2 <sup>nd</sup> HVL = 12, 1 <sup>st</sup> TVL = 57, 2 <sup>nd</sup> TVL = 34 Concrete: 1 <sup>st</sup> HVL = 119, 2 <sup>nd</sup> HVL = 45, 1 <sup>st</sup> TVL = 216, 2 <sup>nd</sup> 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<sup>2</sup>

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

<b>CNSC exemption quantity:</b> 1 kBq/g or 10 MBq	<b>CNSC classification:</b> Class C
<b>CNSC unconditional clearance level:</b> 100 Bq/g	<b>Surface contamination free-release criterion:</b> 100 Bq/cm <sup>2</sup> (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

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.



## Fe-55

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### Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Fe	Common name: Iron	Atomic weight: 55	Atomic number: 26
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### 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%)	6.49 keV (3.29%)	Not applicable
	5.89 keV (8.24%)	5.90 keV (16%)	
	6.49 keV (3.29%)	5.89 keV (8.24%)	
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<sup>2</sup>

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

<b>CNSC exemption quantity:</b> 10 kBq/g or 1 MBq	<b>CNSC classification:</b> Class C
<b>CNSC unconditional clearance level:</b> 1 kBq/g	<b>Surface contamination free-release criterion:</b> 100 Bq/cm <sup>2</sup> (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

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C and apply if necessary.

Note: Fe-55 is an internal hazard only and cannot generally be detected with handheld equipment.

## Co-57

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### Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Co	Common name: Cobalt	Atomic weight: 57	Atomic number: 27
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### 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%)	692.0 keV (0.159%)	Lead: 1 <sup>st</sup> HVL = 0.4, 2 <sup>nd</sup> HVL = 0.3, 1 <sup>st</sup> TVL = 1, 2 <sup>nd</sup> TVL = 3.7 Steel: 1 <sup>st</sup> HVL = 7.4, 2 <sup>nd</sup> HVL = 4.3, 1 <sup>st</sup> TVL = 17, 2 <sup>nd</sup> TVL = 18 Concrete: 1 <sup>st</sup> HVL = 87, 2 <sup>nd</sup> HVL = 27, 1 <sup>st</sup> TVL = 148, 2 <sup>nd</sup> TVL = 82
	136.5 keV (10.7%)	569.9 keV (0.015%)	
	14.4 keV (9.2%)	136.5 keV (10.7%)	
Beta(-), Beta(+), electrons	13.6 keV (7.16%)	135.6 keV (0.15%)	Practical range in glass: <0.1 Practical range in plastic: <0.1
	114.9 keV (1.81%)	129.6 keV (1.42%)	
	129.4 keV (1.42%)	114.9 keV (1.81%)	

### Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

#### External dose

Dose rate to skin from direct contamination: 0.12 mSv/h per kBq/cm<sup>2</sup>

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

<b>CNSC exemption quantity:</b> 100 Bq/g or 1 MBq	<b>CNSC classification:</b> Class C
<b>CNSC unconditional clearance level:</b> 1 Bq/g	<b>Surface contamination free-release criterion:</b> 1 Bq/cm <sup>2</sup> (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

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

## Co-58

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### Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Co	Common name: Cobalt	Atomic weight: 58	Atomic number: 27
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### 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%)	1674.7 keV (0.5%)	Lead: 1 <sup>st</sup> HVL = 12, 2 <sup>nd</sup> HVL = 8.4, 1 <sup>st</sup> TVL = 31, 2 <sup>nd</sup> TVL = 26 Steel: 1 <sup>st</sup> HVL = 39, 2 <sup>nd</sup> HVL = 20, 1 <sup>st</sup> TVL = 83, 2 <sup>nd</sup> TVL = 56 Concrete: 1 <sup>st</sup> HVL = 123, 2 <sup>nd</sup> HVL = 65, 1 <sup>st</sup> TVL = 264, 2 <sup>nd</sup> TVL = 171
	511.0 keV (30%)	864.0 keV (0.7%)	
	864.0 keV (0.7%)	810.8 keV (99.5%)	
Beta(-), Beta(+), electrons	475.2 keV (14.9%) 803.7 keV (0.03%)	803.7 keV (0.03%) 475.2 keV (14.9%)	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<sup>2</sup>

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

<b>CNSC exemption quantity:</b> 10 Bq/g or 1 MBq	<b>CNSC classification:</b> Class B
<b>CNSC unconditional clearance level:</b> 1 Bq/g	<b>Surface contamination free-release criterion:</b> 1 Bq/cm <sup>2</sup> (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

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

## Co-60

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### Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Co	Common name: Cobalt	Atomic weight: 60	Atomic number: 27
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### 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 <sup>st</sup> HVL = 20, 2 <sup>nd</sup> HVL = 14, 1 <sup>st</sup> TVL = 50, 2 <sup>nd</sup> TVL = 40 Steel: 1 <sup>st</sup> HVL = 43, 2 <sup>nd</sup> HVL = 26, 1 <sup>st</sup> TVL = 99, 2 <sup>nd</sup> TVL = 69 Concrete: 1 <sup>st</sup> HVL = 131, 2 <sup>nd</sup> HVL = 81, 1 <sup>st</sup> TVL = 305, 2 <sup>nd</sup> 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<sup>2</sup>

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

<b>CNSC exemption quantity:</b> 10 Bq/g or 100 kBq	<b>CNSC classification:</b> Class A
<b>CNSC unconditional clearance level:</b> 0.1 Bq/g	<b>Surface contamination free-release criterion:</b> 0.1 Bq/cm <sup>2</sup> (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

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

## Ga-67

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### Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Ga	Common name: Gallium	Atomic weight: 67	Atomic number: 31
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### 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%)	887.7 keV (0.15%)	Lead: 1 <sup>st</sup> HVL = 1.3, 2 <sup>nd</sup> HVL = 1.7, 1 <sup>st</sup> TVL = 5.8, 2 <sup>nd</sup> TVL = 9.9 Steel: 1 <sup>st</sup> HVL = 21, 2 <sup>nd</sup> HVL = 12, 1 <sup>st</sup> TVL = 48, 2 <sup>nd</sup> TVL = 37 Concrete: 1 <sup>st</sup> HVL = 103, 2 <sup>nd</sup> HVL = 41, 1 <sup>st</sup> TVL = 194, 2 <sup>nd</sup> TVL = 118
	184.6 keV (21.2%)	794.4 keV (0.054%)	
	300.2 keV (16.8%)	703.1 keV (0.011%)	
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<sup>2</sup>  
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

<b>CNSC exemption quantity:</b> 100 Bq/g or 1 MBq	<b>CNSC classification:</b> Class C
<b>CNSC unconditional clearance level:</b> 1 Bq/g	<b>Surface contamination free-release criterion:</b> 10 Bq/cm <sup>2</sup> (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

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

## 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
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### 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: 1 <sup>st</sup> HVL = 7.2, 2 <sup>nd</sup> HVL = 4.8, 1 <sup>st</sup> TVL = 18, 2 <sup>nd</sup> TVL = 19 Steel: 1 <sup>st</sup> HVL = 36, 2 <sup>nd</sup> HVL = 17, 1 <sup>st</sup> TVL = 73, 2 <sup>nd</sup> TVL = 47 Concrete: 1 <sup>st</sup> HVL = 123, 2 <sup>nd</sup> HVL = 66, 1 <sup>st</sup> TVL = 264, 2 <sup>nd</sup> TVL = 172
Beta(-), Beta(+), electrons	1898.97 keV (88%) 821.66 keV (1.1%) 15.91 keV (0.2%)	1898.97 keV (88%) 821.66 keV (1.1%) 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<sup>2</sup>  
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

<b>CNSC exemption quantity:</b> 10 Bq/g or 100 kBq	<b>CNSC classification:</b> Class C
<b>CNSC unconditional clearance level:</b> 1 Bq/g	<b>Surface contamination free-release criterion:</b> 1 Bq/cm <sup>2</sup> (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

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

## Ga-68

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### Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Ga	Common name: Gallium	Atomic weight: 68/68	Atomic number: 31
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### 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: 1 <sup>st</sup> HVL = 7.2, 2 <sup>nd</sup> HVL = 4.8, 1 <sup>st</sup> TVL = 18, 2 <sup>nd</sup> TVL = 19 Steel: 1 <sup>st</sup> HVL = 36, 2 <sup>nd</sup> HVL = 17, 1 <sup>st</sup> TVL = 73, 2 <sup>nd</sup> TVL = 47 Concrete: 1 <sup>st</sup> HVL = 123, 2 <sup>nd</sup> HVL = 66, 1 <sup>st</sup> TVL = 264, 2 <sup>nd</sup> TVL = 172
Beta(-), Beta(+), electrons	1898.97 keV (88%) 821.66 keV (1.1%) 15.91 keV (0.2%)	1898.97 keV (88%) 821.66 keV (1.1%) 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<sup>2</sup>

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: 10 Bq/cm <sup>2</sup> free-release criterion: (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

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

## Se-75

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### Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Se	Common name: Selenium	Atomic weight: 75	Atomic number: 34
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### 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%)	572.2 keV (0.036%)	Lead: 1 <sup>st</sup> HVL = 1.6, 2 <sup>nd</sup> HVL = 1.5, 1 <sup>st</sup> TVL = 5.4, 2 <sup>nd</sup> TVL = 7.2 Steel: 1 <sup>st</sup> HVL = 23, 2 <sup>nd</sup> HVL = 11, 1 <sup>st</sup> TVL = 48, 2 <sup>nd</sup> TVL = 34 Concrete: 1 <sup>st</sup> HVL = 110, 2 <sup>nd</sup> HVL = 40, 1 <sup>st</sup> TVL = 199, 2 <sup>nd</sup> TVL = 115
	136.0 keV (59%)	419.1 keV (0.014%)	
	10.5 keV (32%)	400.7 keV (12%)	
Beta(-), Beta(+), electrons	12.51 keV (4.4%)	388.8 keV (0.014%)	Practical range in glass: 0.1 Practical range in plastic: 0.2
	84.9 keV (2.6%)	292.1 keV (0.062%)	
	124.1 keV (1.6%)	278.22 keV (0.02%)	

### Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

#### External dose

Dose rate to skin from direct contamination: 0.14 mSv/h per kBq/cm<sup>2</sup>  
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

<b>CNSC exemption quantity:</b> 100 Bq/g or 1 MBq	<b>CNSC classification:</b> Not available
<b>CNSC unconditional clearance level:</b> 1 Bq/g	<b>Surface contamination free-release criterion:</b> 1 Bq/cm <sup>2</sup> (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

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.



## 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<sup>2</sup>

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

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

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

## Y-90

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### Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Y	Common name: Yttrium	Atomic weight: 90	Atomic number: 39
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### 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<sup>2</sup>

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

<b>CNSC exemption quantity:</b> 1 kBq/g or 100 kBq	<b>CNSC classification:</b> Class B
<b>CNSC unconditional clearance level:</b> 1 kBq/g	<b>Surface contamination free-release criterion:</b> 100 Bq/cm <sup>2</sup> (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

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

## 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 <sup>st</sup> HVL = 1, 2 <sup>nd</sup> HVL = 8.8, 1 <sup>st</sup> TVL = 20, 2 <sup>nd</sup> TVL = 24 Steel: 1 <sup>st</sup> HVL = 16, 2 <sup>nd</sup> HVL = 20, 1 <sup>st</sup> TVL = 61, 2 <sup>nd</sup> TVL = 56 Concrete: 1 <sup>st</sup> HVL = 95, 2 <sup>nd</sup> HVL = 48, 1 <sup>st</sup> TVL = 207, 2 <sup>nd</sup> 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<sup>2</sup>  
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

<b>CNSC exemption quantity:</b> 100 Bq/g or 1 MBq	<b>CNSC classification:</b> Class B
<b>CNSC unconditional clearance level:</b> 10 Bq/g	<b>Surface contamination free-release criterion:</b> 10 Bq/cm <sup>2</sup> (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

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

## Tc-99m

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### Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Tc	Common name: Technetium	Atomic weight: 99	Atomic number: 43
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### 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%)	142.63 keV (0.019%)	Lead: 1 <sup>st</sup> HVL = 0.4, 2 <sup>nd</sup> HVL = 0.3, 1 <sup>st</sup> TVL = 1.1, 2 <sup>nd</sup> TVL = 1 Steel: 1 <sup>st</sup> HVL = 8.1, 2 <sup>nd</sup> HVL = 5.3, 1 <sup>st</sup> TVL = 20, 2 <sup>nd</sup> TVL = 15 Concrete: 1 <sup>st</sup> HVL = 84, 2 <sup>nd</sup> HVL = 30, 1 <sup>st</sup> TVL = 151, 2 <sup>nd</sup> TVL = 83
	18.37 keV (4.0%)	140.51 keV (89%)	
	18.25 keV (2.1%)	20.60 keV (1.2%)	
Beta(-), Beta(+), electrons	119.47 keV (8.8%)	142.05 keV (0.034%)	Practical range in glass: 0.2 Practical range in plastic: 0.3
	15.50 keV (2.1%)	140.44 keV (0.037%)	
	137.47 keV (1.1%)	139.97 keV (0.19%)	

### Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

#### External dose

Dose rate to skin from direct contamination: 0.25 mSv/h per kBq/cm<sup>2</sup>

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

<b>CNSC exemption quantity:</b>	100 Bq/g or 10 MBq	<b>CNSC classification:</b>	Class C
<b>CNSC unconditional clearance level:</b>	100 Bq/g	<b>Surface contamination free-release criterion:</b>	100 Bq/cm <sup>2</sup> (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

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

## Cd-109

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### Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Cd	Common name: Cadmium	Atomic weight: 109	Atomic number: 48
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### 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 <sup>st</sup> HVL = 0.01, 2 <sup>nd</sup> HVL = 0.01, 1 <sup>st</sup> TVL = 0.03, 2 <sup>nd</sup> TVL = 0.04 Steel: 1 <sup>st</sup> HVL = 0.05, 2 <sup>nd</sup> HVL = 0.05, 1 <sup>st</sup> TVL = 0.2, 2 <sup>nd</sup> TVL = 0.3 Concrete: 1 <sup>st</sup> HVL = 1.6, 2 <sup>nd</sup> HVL = 1.5, 1 <sup>st</sup> TVL = 5, 2 <sup>nd</sup> 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<sup>2</sup>

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

<b>CNSC exemption quantity:</b> 10 kBq/g or 1 MBq	<b>CNSC classification:</b> Class C
<b>CNSC unconditional clearance level:</b> 1 Bq/g	<b>Surface contamination free-release criterion:</b> 1 Bq/cm <sup>2</sup> (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

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

## In-111

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### Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: In	Common name: Indium	Atomic weight: 111	Atomic number: 49
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### 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%)	245.35 keV (94.1%)	Lead: 1 <sup>st</sup> HVL = 0.6, 2 <sup>nd</sup> HVL = 0.9, 1 <sup>st</sup> TVL = 2.7, 2 <sup>nd</sup> TVL = 3.2 Steel: 1 <sup>st</sup> HVL = 14, 2 <sup>nd</sup> HVL = 9.8, 1 <sup>st</sup> TVL = 35, 2 <sup>nd</sup> TVL = 28 Concrete: 1 <sup>st</sup> HVL = 85, 2 <sup>nd</sup> HVL = 40, 1 <sup>st</sup> TVL = 171, 2 <sup>nd</sup> TVL = 105
	171.28 keV (90.7%)	171.28 keV (90.7%)	
	23.17 keV (44.6%)	26.10 keV (14.6%)	
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<sup>2</sup>  
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

<b>CNSC exemption quantity:</b> 100 Bq/g or 1 MBq	<b>CNSC classification:</b> Class C
<b>CNSC unconditional clearance level:</b> 10 Bq/g	<b>Surface contamination free-release criterion:</b> 10 Bq/cm <sup>2</sup> (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

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

## I-123

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### Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: I	Common name: Iodine	Atomic weight: 123	Atomic number: 53
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### 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 <sup>st</sup> HVL = 0.06, 2 <sup>nd</sup> HVL = 0.54, 1 <sup>st</sup> TVL = 1.4, 2 <sup>nd</sup> TVL = 12 Steel: 1 <sup>st</sup> HVL = 4.8, 2 <sup>nd</sup> HVL = 8.6, 1 <sup>st</sup> TVL = 24, 2 <sup>nd</sup> TVL = 36 Concrete: 1 <sup>st</sup> HVL = 59, 2 <sup>nd</sup> HVL = 41, 1 <sup>st</sup> TVL = 145, 2 <sup>nd</sup> 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<sup>2</sup>  
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

<b>CNSC exemption quantity:</b> 100 Bq/g or 10 MBq	<b>CNSC classification:</b> Class C
<b>CNSC unconditional clearance level:</b> 100 Bq/g	<b>Surface contamination free-release criterion:</b> 100 Bq/cm <sup>2</sup> (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

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

## I-124

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### Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: I	Common name: Iodine	Atomic weight: 124	Atomic number: 53
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### Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 4.176 days

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)
Gamma & X-ray	602.72 keV (62.9%) 27.00 keV (47%) 511.00 keV (45.6%)	2746.90 keV (0.48%) 2681.50 keV (0.03%) 2453.90 keV (0.07%)	Lead: 1 <sup>st</sup> HVL = 9.7, 2 <sup>nd</sup> HVL = 9.7, 1 <sup>st</sup> TVL = 35, 2 <sup>nd</sup> TVL = 48 Steel: 1 <sup>st</sup> HVL = 36, 2 <sup>nd</sup> HVL = 21, 1 <sup>st</sup> TVL = 84, 2 <sup>nd</sup> TVL = 69 Concrete: 1 <sup>st</sup> HVL = 115, 2 <sup>nd</sup> HVL = 69, 1 <sup>st</sup> TVL = 267, 2 <sup>nd</sup> TVL = 207
Beta(-), Beta(+), electrons	1534.82 keV (11.7%) 2137.51 keV (10.8%) 22.70 keV (8.2%)	2137.51 keV (10.8%) 1534.82 keV (11.7%) 812.04 keV (5.8%)	Practical range in glass: 4.5 Practical range in plastic: 8.4

### Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

#### External dose

Dose rate to skin from direct contamination: 0.52 mSv/h per kBq/cm<sup>2</sup>  
Gamma ray effective dose rate at 1 m: 1.475E-04 mSv/h per MBq

#### Internal dose

	Ingestion	Inhalation
Worker dose coefficient	1.3E-08 Sv/Bq	1.2E-08 Sv/Bq (vapor)

### Part 4 – CLEARANCE AND EXEMPTION

<b>CNSC exemption quantity:</b> 10 Bq/g or 10 kBq	<b>CNSC classification:</b> Class A
<b>CNSC unconditional clearance level:</b> 1 Bq/g	<b>Surface contamination free-release criterion:</b> 1 Bq/cm <sup>2</sup> (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

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.



## I-125

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### Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: I	Common name: Iodine	Atomic weight: 125	Atomic number: 53
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### 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 <sup>st</sup> HVL = 0.02, 2 <sup>nd</sup> HVL = 0.02, 1 <sup>st</sup> TVL = 0.06, 2 <sup>nd</sup> TVL = 0.04 Steel: 1 <sup>st</sup> HVL = 0.09, 2 <sup>nd</sup> HVL = 0.1, 1 <sup>st</sup> TVL = 0.3, 2 <sup>nd</sup> TVL = 0.3 Concrete: 1 <sup>st</sup> HVL = 3.1, 2 <sup>nd</sup> HVL = 2.8, 1 <sup>st</sup> TVL = 9.5, 2 <sup>nd</sup> 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<sup>2</sup>  
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

<b>CNSC exemption quantity:</b> 1 kBq/g or 1 MBq	<b>CNSC classification:</b> Class C
<b>CNSC unconditional clearance level:</b> 100 Bq/g	<b>Surface contamination free-release criterion:</b> 100 Bq/cm <sup>2</sup> (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

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

## I-131

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### Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: I	Common name: Iodine	Atomic weight: 131	Atomic number: 53
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### 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%)	722.91 keV (1.8%)	Lead: 1 <sup>st</sup> HVL = 3.9, 2 <sup>nd</sup> HVL = 3.1, 1 <sup>st</sup> TVL = 12, 2 <sup>nd</sup> TVL = 17 Steel: 1 <sup>st</sup> HVL = 32, 2 <sup>nd</sup> HVL = 14, 1 <sup>st</sup> TVL = 64, 2 <sup>nd</sup> TVL = 42 Concrete: 1 <sup>st</sup> HVL = 118, 2 <sup>nd</sup> HVL = 50, 1 <sup>st</sup> TVL = 226, 2 <sup>nd</sup> TVL = 134
	636.99 keV (7.3%)	642.7 keV (0.22%)	
	284.3 keV (6.1%)	636.99 keV (7.3%)	
Beta(-), Beta(+), electrons	606.31 keV (89.4%)	806.87 keV (0.40%)	Practical range in glass: 0.9 Practical range in plastic: 1.6
	333.81 keV (7.36%)	629.65 keV (0.05%)	
	45.62 keV (3.5%)	606.31 keV (89.4%)	

### Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

#### External dose

Dose rate to skin from direct contamination: 1.6 mSv/h per kBq/cm<sup>2</sup>

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

<b>CNSC exemption quantity:</b> 100 Bq/g or 1 MBq	<b>CNSC classification:</b> Class B
<b>CNSC unconditional clearance level:</b> 10 Bq/g	<b>Surface contamination free-release criterion:</b> 10 Bq/cm <sup>2</sup> (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

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

## Sb-124

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### Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Sb	Common name: Antimony	Atomic weight: 124	Atomic number: 51
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### 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%)	2293.48 keV (0.03%)	Lead: 1 <sup>st</sup> HVL = 15, 2 <sup>nd</sup> HVL = 13, 1 <sup>st</sup> TVL = 47, 2 <sup>nd</sup> TVL = 48 Steel: 1 <sup>st</sup> HVL = 41, 2 <sup>nd</sup> HVL = 24, 1 <sup>st</sup> TVL = 95, 2 <sup>nd</sup> TVL = 74 Concrete: 1 <sup>st</sup> HVL = 129, 2 <sup>nd</sup> HVL = 75, 1 <sup>st</sup> TVL = 296, 2 <sup>nd</sup> TVL = 225
	1690.98 keV (47.6%)	2283.20 keV (0.04%)	
	722.78 keV (10.8%)	2182.40 keV (0.05%)	
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<sup>2</sup>  
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

<b>CNSC exemption quantity:</b> 10 Bq/g or 1 MBq	<b>CNSC classification:</b> Class A
<b>CNSC unconditional clearance level:</b> 1 Bq/g	<b>Surface contamination free-release criterion:</b> 1 Bq/cm <sup>2</sup> (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

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

## Ba-133

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### Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Ba	Common name: Barium	Atomic weight: 133	Atomic number: 56
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### Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 10.54 years

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)
Gamma & X-ray	30.97 keV (64%)	383.85 keV (8.9%)	Lead: 1 <sup>st</sup> HVL = 1.7, 2 <sup>nd</sup> HVL = 2.3, 1 <sup>st</sup> TVL = 6.9, 2 <sup>nd</sup> TVL = 7.3 Steel: 1 <sup>st</sup> HVL = 21, 2 <sup>nd</sup> HVL = 14, 1 <sup>st</sup> TVL = 52, 2 <sup>nd</sup> TVL = 37 Concrete: 1 <sup>st</sup> HVL = 84, 2 <sup>nd</sup> HVL = 53, 1 <sup>st</sup> TVL = 193, 2 <sup>nd</sup> TVL = 126
	356.01 keV (62%)	356.01 keV (62%)	
	30.63 keV (35%)	302.85 keV (18%)	
Beta(-), Beta(+), electrons	45.01 keV (48%) 25.50 keV (14.3%) 17.18 keV (10.5%)	378.13 keV (0.024%) 354.80 keV (0.571%) 350.30 keV (0.218%)	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: 0.13 mSv/h per kBq/cm<sup>2</sup>  
Gamma ray effective dose rate at 1 m: 6.428E-05 mSv/h per MBq

#### Internal dose

	Ingestion	Inhalation
Worker dose coefficient	2.8E-10 Sv/Bq	5.5E-10 Sv/Bq

### Part 4 – CLEARANCE AND EXEMPTION

<b>CNSC exemption quantity:</b> 100 Bq/g or 1 MBq	<b>CNSC classification:</b> Class B
<b>CNSC unconditional clearance level:</b> 1 Bq/g	<b>Surface contamination free-release criterion:</b> 1 Bq/cm <sup>2</sup> (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

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

## 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
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### 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: 1 <sup>st</sup> HVL = 9.4, 2 <sup>nd</sup> HVL = 6.7, 1 <sup>st</sup> TVL = 24, 2 <sup>nd</sup> TVL = 20 Steel: 1 <sup>st</sup> HVL = 38, 2 <sup>nd</sup> HVL = 19, 1 <sup>st</sup> TVL = 79, 2 <sup>nd</sup> TVL = 51 Concrete: 1 <sup>st</sup> HVL = 121, 2 <sup>nd</sup> HVL = 62, 1 <sup>st</sup> TVL = 255, 2 <sup>nd</sup> 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<sup>2</sup>  
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

<b>CNSC exemption quantity:</b> 10 Bq/g or 10 kBq	<b>CNSC classification:</b> Class A
<b>CNSC unconditional clearance level:</b> 0.1 Bq/g	<b>Surface contamination free-release criterion:</b> 0.1 Bq/cm <sup>2</sup> (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

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

## Ir-192

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### Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Ir	Common name: Iridium	Atomic weight: 192	Atomic number: 77
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### 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%)	1061.48 keV (0.05%)	Lead: 1 <sup>st</sup> HVL = 3.8, 2 <sup>nd</sup> HVL = 3.3, 1 <sup>st</sup> TVL = 12, 2 <sup>nd</sup> TVL = 15 Steel: 1 <sup>st</sup> HVL = 32, 2 <sup>nd</sup> HVL = 14, 1 <sup>st</sup> TVL = 63, 2 <sup>nd</sup> TVL = 42 Concrete: 1 <sup>st</sup> HVL = 119, 2 <sup>nd</sup> HVL = 49, 1 <sup>st</sup> TVL = 225, 2 <sup>nd</sup> TVL = 133
	468.07 keV (47.8%)	884.54 keV (0.29%)	
	308.46 keV (29.7%)	612.46 keV (5.34%)	
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<sup>2</sup>  
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

<b>CNSC exemption quantity:</b> 10 Bq/g or 10 kBq	<b>CNSC classification:</b> Class B
<b>CNSC unconditional clearance level:</b> 1 Bq/g	<b>Surface contamination free-release criterion:</b> 1 Bq/cm <sup>2</sup> (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

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

## TI-201

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### Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Tl	Common name: Thallium	Atomic weight: 201	Atomic number: 81
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### 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%)	167.43 keV (10.3%)	Lead: 1 <sup>st</sup> HVL = 0.3, 2 <sup>nd</sup> HVL = 0.3, 1 <sup>st</sup> TVL = 1, 2 <sup>nd</sup> TVL = 1.1 Steel: 1 <sup>st</sup> HVL = 2.5, 2 <sup>nd</sup> HVL = 4, 1 <sup>st</sup> TVL = 15, 2 <sup>nd</sup> TVL = 20 Concrete: 1 <sup>st</sup> HVL = 56, 2 <sup>nd</sup> HVL = 27, 1 <sup>st</sup> TVL = 118, 2 <sup>nd</sup> TVL = 89
	68.90 keV (27.7%)	165.88 keV (0.15%)	
	80.30 keV (20.7%)	135.34 keV (2.7%)	
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<sup>2</sup>  
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

<b>CNSC exemption quantity:</b> 100 Bq/g or 1 MBq	<b>CNSC classification:</b> Class C
<b>CNSC unconditional clearance level:</b> 100 Bq/g	<b>Surface contamination free-release criterion:</b> 100 Bq/cm <sup>2</sup> (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

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

## Am-241

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### Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Am	Common name: Americium	Atomic weight: 241	Atomic number: 95
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### 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 <sup>st</sup> HVL = 0.08, 2 <sup>nd</sup> HVL = 0.12, 1 <sup>st</sup> TVL = 0.4, 2 <sup>nd</sup> TVL = 0.4 Steel: 1 <sup>st</sup> HVL = 0.6, 2 <sup>nd</sup> HVL = 0.8, 1 <sup>st</sup> TVL = 2.4, 2 <sup>nd</sup> TVL = 2.5 Concrete: 1 <sup>st</sup> HVL = 22, 2 <sup>nd</sup> HVL = 15, 1 <sup>st</sup> TVL = 55, 2 <sup>nd</sup> 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<sup>2</sup>

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 <sup>2</sup> (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

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.



## 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 MCNP6 and Nucleonica were within approximately  $\pm 10\%$  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  $2.3 \text{ g/cm}^3$  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

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## **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 tepid 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**

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## Appendix C: General safety precautions

### Unsealed sources

- Wear appropriate personal protective equipment (PPE):
  - laboratory coat
  - coveralls
  - shoe covers
  - safety glasses or goggles
  - disposable gloves (two pairs may be worn as an extra precaution and changed often, especially in cases where materials are volatile and/or could be absorbed through the gloves)
  - suitable respiratory protection (if the radioactive material is in the form of dust or powder, or if it is potentially volatile)
- Non-disposable PPE should be monitored before leaving the laboratory
- Monitor hands and feet after removal of PPE
- Optimize time, distance, and shielding
  - Keep handling time to a minimum
  - Use tongs, syringe shields, plastic screens, and lead aprons where appropriate
- Use disposable absorbent liners on trays
- Gases and volatile liquids should be handled in ventilated enclosures
- Monitor equipment and supplies for loose contamination before removal from laboratory
- Extremity dosimeters should be worn if annual extremity doses may exceed 50 mSv

### Sealed sources

- Optimize time, distance, and shielding
  - Keep handling time to a minimum
  - Use tongs and shielding where appropriate
- Extremity dosimeters should be worn if annual extremity doses may exceed 50 mSv

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