Canada's Nuclear Regulator

Radionuclide Information Booklet

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Canada

Radionuclide Information Booklet

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This document can be viewed on the CNSC website. To request a copy of the document in English or French, please contact:

Canadian Nuclear Safety Commission
280 Slater Street
P.O. Box 1046, Station B
Ottawa, Ontario K1P 5S9
CANADA

Tel.: 613-995-5894 or 1-800-668-5284 (in Canada only)
Facsimile: 613-995-5086
Email: cnsc.info.ccsn@canada.ca
Website: nuclearsafety.gc.ca
Facebook: facebook.com/CanadianNuclearSafetyCommission
YouTube: youtube.com/cnscccsn
Twitter: @CNSC_CCSN
LinkedIn: linkedin.com/company/cnsc-ccsn

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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. 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 decay scheme. The source of this information is the Joint Evaluated Fission and Fusion (JEFF) 3.1 nuclide library, accessed through the Nucleonica Nuclear Science Portal, using the Datasheets application [1]. The decay scheme shows both the half-life and decay mode for each step in the decay chain. The following nomenclature is used: "s" for seconds, "m" for minutes, "h" for hours, "d" for days, "y" for years, "α" for alpha, "β(-)" for beta, "β(+)" for positron, "EC" for electron capture, and "IT" for isomeric transition.

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. When radioactive progeny are in equilibrium with the nuclide of interest, the emissions from the radioactive decay products are also considered. The source for this information is the JEFF 3.1 nuclide library and the 8th Table of Isotopes, accessed through the Nucleonica Nuclear Science Portal [1]. Only energies above 10 kiloelectron volts (keV) and/or emission probabilities greater than 0.01% were included, with the exception of Fe-55, which has no emissions with energies above 10 keV. The energies provided for electron, beta, and positron radiation are the maximum end-point energies.

Also included are:

(1) First and second half value layers (HVL) and 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 H*10 application [2]. This application replaces the older Dosimetry & Shielding version, which was used for previous versions of the *Radionuclide Information Booklet*. The newer application uses the same NIST mass attenuation coefficient tables [3] in conjunction with build-up factors from ANSI/ANS-6.4.3-1991, but with improved interpolation methods. In the case of concrete, Nucleonica uses ordinary concrete (2.4 g/cm^3) from NIST's mass attenuation coefficient table for mixtures and compounds [4]. Ambient dose rate (as opposed to exposure or air kerma) was chosen as the attenuation reference under Options,

and ICRP-107 was chosen as the database. The application defaults to a low energy cut-off value of 15 keV. For validation, select TVL values were also compared against other references (see appendix A).

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

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

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

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

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

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

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

Where:		
R	is the dose rate	(µSv/h)
Γ	is the gamma ray constant for the source at 1 m	(µSv/h 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, 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) The continuous slowing down approximation (CSDA) ranges in mm, are provided for aluminum, Polymethyl methacrylate (PMMA, a.k.a. Plexiglass), water (liquid) and air (dry, sea level) for electrons and/or positrons. These were obtained using Nucleonica's Range & Stopping Power application [5]. The application is not nuclide specific but requires the user to enter the end point

electron (or positron) energy. The most energetic emission from each nuclide's table, with a probability above 1%, was used. For example, Se-75's 3 most abundant electron emissions are at 12.51 keV (4.4%), 84.9 keV (2.6%), and 124.1 keV (1.6%). In this case, the 124.1 keV electron emission was chosen for the CSDA ranges.

When energetic electrons and beta radiation interact in high *Z* material (e.g., lead), electromagnetic radiation called bremsstrahlung is produced. Therefore, high *Z* materials such as lead may not be appropriate shielding materials for energetic electrons and beta radiation and low *Z* material should be used first. For low-energy electron or beta emitters such as tritium and carbon-14, bremsstrahlung production is not significant.

Part 3 – Dose rate constants and coefficients

External dose

In this section, dose conversion factors (DCFs) are provided for estimating skin dose from direct contamination and whole-body effective dose from external exposure to radiation sources. Four external DCFs are provided for a 1 MBq point source at 1 m for photon radiation for an anterior-posterior geometry: Air kerma (mGy/h), Effective (mSv/h), H*10 (mSv/h) and Hp10 (mSv/h). The Air kerma and Effective DCFs were calculated using the conversion factors in Tables A.1 (effective dose per fluence) and A.2 (effective dose per air kerma) of the International Commission on Radiological Protection's (ICRP) Publication 116 [6], linearly interpolated when necessary. The H*10 and Hp10 protection quantity DCFs were calculated using the conversion factors in ICRP Publication 74 [7], which continue to be recommended in ICRP Publication 116. The photon energies and probabilities for each nuclide were obtained from the JEFF 3.1 or 8th Table of Isotopes nuclide library [1]. All photon emissions above 15 keV with a probability above 0.01% were considered in the calculation. The 15-keV low energy cut-off was chosen to match the default cut-off value applied in the Nucleonica application used to calculate HVLs and TVLs, but also to reflect the fact that photons at energies between 10 keV and 15 keV are significantly attenuated by the source container *(e.g.,* steel, plastic, glass vial, human patient, etc). To be conservative, attenuation and build-up in air were not incorporated in the calculation.

For personal dose reconstructions using a source of known activity, the Effective DCFs should always be used by default. The Air kerma, H*10 and Hp10 DCFs may be useful for the purposes of calibrating instruments (H*10 is used for gamma survey meters, Hp10 for personal dosimeters). The Hp10 DCFs may be useful in situations where a dosimeter was accidentally exposed to a source of gamma radiation, to make comparisons between the measured dose and the theoretical dose based on a known source activity. The H*10 DCFs may be useful in situations where a source activity needs to be ascertained based on a gamma survey meter dose rate measurement.

The DCFs from skin contamination were calculated using VARSKIN+ v2.1 [8]. Each nuclide's skin DCF (including radioactive decay products when applicable) was calculated using a 1 cm^2, 1000-Bq disk source directly on the skin (i.e., no air gap, no cover thickness), averaged over 1 cm^2, using both the standard (i.e., Hp(0.07)) epidermis thickness of 70 µm, as well as an epidermis thickness of 400 µm, using the ICRP 107 database. The 400 µm value was selected as a conservative average (male and female) representation of the epidermis layer for the palm side of the hand (also applicable to the sole of the foot), based on guidance in ICRP 89 (page 197) [9]. Particular attention should be paid to radionuclides with alpha emissions above 7 MeV (Pb-212, Ra-223, Ra-224, Ra-226, Ac-225) due to the very high DCFs. Details about alpha contamination and a comparison of the dose evaluation between various computer codes are provided in [10].

Internal dose

This section includes the ICRP internal DCFs for workers, which may be used to estimate internal dose from inhalation and ingestion of the radionuclide of interest. These DCFs were obtained from ICRP Publications 130, 134, 137, 141 and 151 [11], using the ICRP's OIR 2022 Data Viewer tool (available for download from the ICRP website). In the case of inhalation, the coefficients listed are for a particle size (activity aerodynamic diameter, AMAD) of 5 µm. Many radionuclides have different inhalation DCFs for different solubility types which depend on the chemical compound. This booklet includes the most conservative inhalation DCFs. We encourage users that are aware of the solubility type and/or chemical compound of the nuclides in their work environments to download and use the ICRP's OIR 2022 Data Viewer tool so that the most appropriate dose coefficient may be applied.

Part 4 – Clearance and exemption

This section summarizes CNSC exemption quantities (EQ) in becquerel per gram (Bq/g) and Bq, unconditional clearance levels in Bq/g, and nuclide classification. For the nuclides that are not present in Schedule 1of the *Nuclear Substances and Radiation Devices Regulations (NSRDRs)*, EQ values were taken from the NRPB-R306, Exempt Concentrations and Quantities for Radionuclides not included in the European Basic Safety Standards Directive [12]. The same methodology was used to calculate the EQ levels found in this report as those used in the IAEA Safety Standards, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards, No. GSR Part 3 [13], which is the basis for Schedule I in the *NSRDRs.* The nuclides that are not included in Schedule I in the *NSRDRs* are: Zn-62/Cu-62, Ga-68, Sr-82/Rb-82, Zr-89, Tc-94m, Tc-95, Nb-96, I-124, Tb-155, Tb-161, W-188, Ac-225.

Since the EQs listed in the *NSRDRs* are not directly applicable to surface contamination, the values published under "release of surface contaminated objects" are recommended values based on the surface contamination levels associated with the CNSC classes of nuclear substances (Classes A/B/C) and the values for the clearance of items or materials that contain surface radioactivity found in table 1 of the American National Standards Institute (ANSI) standard N13.12-2013 [14]. When the radionuclide of interest is listed in table 1 of the ANSI standard, the recommended value, as published in the standard, is provided. When the radionuclide is not listed, the method described in annex A of the ANSI standard was used to assign the group (Group 1, 2, 3, 4 or 5) to which the radionuclide of interest should be attributed, and the corresponding surface contamination value was assigned. Both values, based either on the CNSC classes of nuclear substances or the ANSI standard, should include total contamination (fixed and removable) and apply to the small-scale free release (e.g., municipal landfill, recycling) of surface contaminated items or objects. These values are examples of suitable surface contamination criteria for use as conditional clearance levels, as defined in the *NSRDRs.*

Part 5 – Detection and measurement

Method of detection

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

information sheet. Similarly, an energy compensated GM dose rate meter may only yield a dose response of 5% to 10% (i.e., 90% to 95% below the true dose) when exposed to Cd-109, but again, because Cd-109 is detectable using this type of device, it is included on this nuclide's information sheet.

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

Dosimetry

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

Part 6 – Safety precautions

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

Uranium (processed, natural isotopic distribution)

The last information page is different than the rest. It deals with processed uranium containing natural isotopic distributions. In other words, U-238, U-235 and U-234 after it has been mined and chemically separated from its progeny, and after the short-lived progeny (Th-234, Pa-234m, and Th-231) have grown back in, without any enrichment. The isotopic ratios (by activity) were computed using published representative isotopic compositions (by mass) [15], along with the specific activities for U-238/235/234 defined in Nucleonica's Datasheets application [1]. The following table summarizes these results:

	Representative isotopic composition (% per g)	Specific activity (Bq/g)	Activity (Bq) in 1 g	% per Bq
U-238	99.27450%	1.2436E+04	1.23E+04	48.28%
U-235	0.72000%	7.9960E+04	5.76E+02	2.25%
U-234	0.00550%	2.3000E+08	1.27E+04	49.47%

The isotopic distributions by activity (i.e., % per Bq) above were used in the uranium information page. When a Bq is quoted on the page, it refers to a Bq of total uranium, in other words, 0.4828 Bq of U-238, Th-234, and Pa-234m, 0.0225 Bq of U-235 and Th-231, and finally, 0.4947 Bq of U-234. These same isotopic distributions were applied to the emissions table. For example, U-235 has a gamma emission at 185.71 keV, with a 57.1% probability. In the emissions table on the uranium information page, this gamma line is assigned a 1.29% probability (57.1% x 0.0225).

For the internal DCFs, while the other nuclide information pages only provide the most conservative coefficient for both inhalation and ingestion, because of the importance of uranium, all coefficients are given for every chemical type, as described in ICRP Publications 130, 134, 137, 141 and 151 [11], using the ICRP's OIR 2022 Data Viewer tool. The internal dose coefficients for processed uranium were calculated by applying a weighted average using each uranium isotope's (U-238, U-235, U-234) published DCF and the isotopic distributions (by activity) described above. The internal dose coefficients on the uranium information page may not be consistent with those in REGDOC-2.7.2; however, they can be used as default values when no site-specific data are available. The internal dose coefficients on the uranium information may not necessarily apply to some uranium compounds that do not fall neatly into

the default Type F, M, S F/M or M/S categories, or for uranium compounds for which the shorter-lived progeny have not yet grown back in (e.g., fresh yellowcake).

For the clearance levels, since all 3 uranium isotopes of interest have identical exemption quantities, unconditional clearance levels, nuclide classes and ANSI N13.12-2013 clearance values, there was no need to perform any isotope distribution averaging.

H-3

Part 1 – RADIONUCLIDE IDENTIFICATION

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

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 12.33 years
Decay scheme: H-3 (12.33 y, β(-) 100%) → He-3 (stable)

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	18.59 keV (100%)	18.59 keV (100%)	Not applicable (energy too low from primary emission)
Alpha	None	None	Not applicable

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Tritium is not an external radiation hazard.

Internal dose

	Ingestion	Inhalation	
Compound type	Unspecified compounds	Tritiated water	Elemental tritium gas
Worker dose coefficient (Sv/Bq)	1.9E-11	2.0E-11	2.0E-15

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	1 MBq/g or 1 GBq	**CNSC classification:**	Class C
CNSC unconditional clearance level:	100 Bq/g	**Release of surface contaminated objects:**	30 or 100 Bq/cm^2 (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma 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: In-vitro (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-11

Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: C-11	Common name: Carbon	Atomic weight: 11	Atomic number: 6

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 20.37 minutes
Decay scheme: C-11 (20.37 m, β(+) 100%) → B-11 (stable)

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 (200%)	511.00 keV (200%)	Lead		Steel		Concrete	
			1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
			5.00	4.48	25.8	17.1	101.1	56.0
			15.2	13.9	62.8	45.2	221.8	144.3
Beta(-), Beta(+), electrons	960.12 keV (100%)	960.12 keV (100%)	Continuous Slowing Down Approximation (CSDA) range					
			Aluminium		PMMA (Plexiglass)		Water	Air
			2.468		4.530		5.030	5048
Alpha	None	None	Not applicable					

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 400 µm)
Air kerma	Effective	H*10	Hp10		
1.398E-04	1.440E-04	1.717E-04	1.752E-04	1.53E+00	6.88E-01

Internal dose

	Ingestion	Inhalation	
Compound type	Unspecified compounds	Aerosol	Vapour
Worker dose coefficient (Sv/Bq)	2.7E-11	1.8E-11	2.6E-11

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	10 Bq/g or 1MBq	**CNSC classification:**	Class C
CNSC unconditional clearance level:	1 Bq/g	**Release of surface contaminated objects:**	30 or 100 Bq/cm² (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma 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: 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: In-vivo, in-vitro

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.

N-13

Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: N-13 Common name: Nitrogen Atomic weight: 13 Atomic number: 7

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 9.97 minutes
Decay scheme: N-13 (9.97 m, β(+) 100%) → C-13 (stable)

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 (200%)	511.00 keV (200%)	Lead		Steel		Concrete	
			1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
			5.00	4.50	25.8	17.0	101.1	56.0
			15.2	13.9	62.8	45.2	221.8	144.2
Beta(-), Beta(+), electrons	1198.04 keV (100%)	1198.04 keV (100%)	Continuous Slowing Down Approximation (CSDA) range					
			Aluminium		PMMA (Plexiglass)		Water	Air
			2.468		4.530		5.030	5048
Alpha	None	None	Not applicable					

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 400 µm)
Air kerma	Effective	H*10	Hp10		
1.399E-04	1.441E-04	1.718E-04	1.753E-04	1.52E+00	7.81E-01

Internal dose

	Ingestion	Inhalation	
Compound type	Unspecified compounds	Aerosol	Vapour
Worker dose coefficient (Sv/Bq)	Not available	Not available	Not available

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	100 Bq/g or 1 GBq	**CNSC classification:**	Class C
CNSC unconditional clearance level:	1 Bq/g	**Release of surface contaminated objects:**	30 or 100 Bq/cm² (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma 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: 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: In-vivo, in-vitro

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.

C-14

Part 1 – RADIONUCLIDE IDENTIFICATION

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

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 5700 years
Decay scheme: C-14 (5700 y, β(-) 100%) → N-14 (stable)

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	156.47 keV (100%)	156.47 keV (100%)	Continuous Slowing Down Approximation (CSDA) range			
			Aluminium	PMMA (Plexiglass)	Water	Air
			0.1433	0.2503	0.2768	285.4
Alpha	None	None	Not applicable			

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm^2 at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm^2 at 400 µm)
Not applicable	2.85E-01	0.00E+00

Internal dose

	Ingestion	Inhalation	
Compound type	Unspecified compounds	Aerosol	Vapour
Worker dose coefficient (Sv/Bq)	1.6E-10	6.7E-09	1.7E-10

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	10 kBq/g or 10 MBq	**CNSC classification:**	Class C
CNSC unconditional clearance level:	1 Bq/g	**Release of surface contaminated objects:**	30 or 1 Bq/cm^2 (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma dose rate):
Not applicable

Method of detection (contamination):
1. Hand-held: 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: In-vitro

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.

O-15

Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: O-15 Common name: Oxygen Atomic weight: 15 Atomic number: 8

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 2.04 minutes
Decay scheme: O-15 (2.04 m, β(+) 100%) → N-15 (stable)

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 (200%)	511.00 keV (200%)	Lead		Steel		Concrete	
			1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
			5.03	4.46	25.8	17.1	101.1	56.0
			15.2	13.8	62.8	45.2	221.8	144.3
Beta(-), Beta(+), electrons	1734.46 keV (100%)	1734.46 keV (100%)	Continuous Slowing Down Approximation (CSDA) range					
			Aluminium		PMMA (Plexiglass)		Water	Air
			3.751		6.950		7.723	7713
Alpha	None	None	Not applicable					

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm^2 at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm^2 at 400 µm)
Air kerma	Effective	H*10	Hp10		
1.400E-04	1.442E-04	1.719E-04	1.754E-04	1.48E+00	8.74E-01

Internal dose

	Ingestion	Inhalation	
Compound type	Unspecified compounds	Aerosol	Vapour
Worker dose coefficient (Sv/Bq)	Not available	Not available	Not available

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	100 Bq/g or 1 GBq	**CNSC classification:**	Class C
CNSC unconditional clearance level:	1 Bq/g	**Release of surface contaminated objects:**	30 or 100 Bq/cm^2 (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma 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: 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: In-vivo, in-vitro

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.

F-18

Part 1 – RADIONUCLIDE IDENTIFICATION

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

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 1.83 hours
Decay scheme: F-18 (1.83 h, EC/β(+) 100%) → O-18 (stable)

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		Steel		Concrete	
			1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
			5.03	4.46	25.8	17.1	101.1	56.0
			15.2	13.8	62.8	45.2	221.8	144.3
Beta(-), Beta(+), electrons	633.34 keV (97%)	633.34 keV (97%)	Continuous Slowing Down Approximation (CSDA) range					
			Aluminium		PMMA (Plexiglass)		Water	Air
			1.111		2.010		2.230	2254
Alpha	None	None	Not applicable					

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 400 µm)
Air kerma	Effective	H*10	Hp10		
1.358E-04	1.398E-04	1.667E-04	1.701E-04	1.47E+00	4.41E-01

Internal dose

	Ingestion	Inhalation	
Compound type	Unspecified compounds	Aerosol	Vapour
Worker dose coefficient (Sv/Bq)	4.8E-11	5.1E-11	7.8E-11

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	**Release of surface contaminated objects:**	30 or 10 Bq/cm² (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma 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: 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: In-vivo, in-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

Na-22

Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Na | Common name: Sodium | Atomic weight: 22 | Atomic number: 11

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 2.60 years
Decay scheme: Na-22 (2.60 y, EC/β(+) 100%) → Ne-22 (stable)

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		Steel		Concrete	
			1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
			8.73	10.2	30.4	22.0	108.3	69.7
			34.7	40.3	79.6	66.2	261.0	198.2
Beta(-), Beta(+), electrons	545.41 keV (90%) 1819.81 keV (0.06%)	1819.81 keV (0.06%) 545.41 keV (90%)	Continuous Slowing Down Approximation (CSDA) range					
			Aluminium		PMMA (Plexiglass)		Water	Air
			0.9072		1.637		1.815	1838
Alpha	None	None	Not applicable					

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 400 µm)
Air kerma	Effective	H*10	Hp10		
2.815E-04	2.847E-04	3.349E-04	3.369E-04	1.39E+00	3.37E-01

Internal dose

	Ingestion	Inhalation
Worker dose coefficient (Sv/Bq)	3.5E-09	2.2E-08

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	10 Bq/g or 1 MBq	**CNSC classification:**	Class A
CNSC unconditional clearance level:	0.1 Bq/g	**Release of surface contaminated objects:**	0.3 or 0.1 Bq/cm² (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma 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: 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: In-vivo, in-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

Na-24

Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Na	Common name: Sodium	Atomic weight: 24	Atomic number: 11

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 14.957 hours
Decay scheme: Na-24 (14.957 h, β(-) 100%) → Mg-24 (stable)

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)					
Gamma & X-ray	1368.63 keV (100%) 2754.01 keV (99.9%) 3866.14 keV (0.056%)	3866.14 keV (0.056%) 2754.01 keV (99.9%) 1368.63 keV (100%)	Lead		Steel		Concrete	
			1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
			19.1	16.6	40.8	31.6	134.2	101.0
			57.1	52.9	110.5	90.6	355.1	286.1
Beta(-), Beta(+), electrons	1392.59 keV (99.9%) 279.21 keV (0.057%)	1392.59 keV (99.9%) 279.21 keV (0.057%)	Continuous Slowing Down Approximation (CSDA) range					
			Aluminium		PMMA (Plexiglass)		Water	Air
			2.923		5.386		5.983	5991
Alpha	None	None	Not applicable					

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 400 µm)
Air kerma	Effective	H*10	Hp10		
4.327E-04	4.268E-04	4.870E-04	5.506E-04	1.49E+00	8.00E-01

Internal dose

	Ingestion	Inhalation
Worker dose coefficient (Sv/Bq)	4.8E-10	5.2E-10

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	10 Bq/g or 100 kBq	**CNSC classification:**	Class C
CNSC unconditional clearance level:	1 Bq/g	**Release of surface contaminated objects:**	30 or 100 Bq/cm² (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma 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: 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: In-vivo, in-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

P-32

Part 1 – RADIONUCLIDE IDENTIFICATION

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

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 14.27 days
Decay scheme: P-32 (14.27 d, β(-) 100%) → S-32 (stable)

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	1710.40 keV (100%)	1710.40 keV (100%)	Continuous Slowing Down Approximation (CSDA) range			
			Aluminium	PMMA (Plexiglass)	Water	Air
			3.684	6.824	7.583	7574
Alpha	None	None	Not applicable			

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm^2 at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm^2 at 400 µm)
Not applicable	1.44E+00	8.22E-01

Internal dose

	Ingestion	Inhalation
Worker dose coefficient (Sv/Bq)	1.7E-09	1.5E-09

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	1 kBq/g or 100 kBq	**CNSC classification:**	Class C
CNSC unconditional clearance level:	1 kBq/g	**Release of surface contaminated objects:**	30 or 100 Bq/cm^2 (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma dose rate):
Not applicable

Method of detection (contamination):
1. Hand-held: 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: Beta
Internal: In-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

S-35

Part 1 – RADIONUCLIDE IDENTIFICATION

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

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 87.32 days
Decay scheme: S-35 (87.32 d, β(-) 100%) → Cl-35 (stable)

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	167.14 keV (100%)	167.14 keV (100%)	Continuous Slowing Down Approximation (CSDA) range			
			Aluminium	PMMA (Plexiglass)	Water	Air
			0.1592	0.2785	0.3080	317.3
Alpha	None	None	Not applicable			

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm^2 at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm^2 at 400 µm)
Not applicable	3.12E-01	0.00E+00

Internal dose

	Ingestion	Inhalation	
Compound type	Unspecified compounds	Aerosol	Vapour
Worker dose coefficient (Sv/Bq)	2.7E-11	4.9E-10	1.2E-09

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	100 kBq/g or 100 MBq	**CNSC classification:**	Class C
CNSC unconditional clearance level:	100 Bq/g	**Release of surface contaminated objects:**	30 or 100 Bq/cm^2 (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma dose rate):
Not applicable

Method of detection (contamination):
1. Hand-held: 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: In-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

Cl-36

Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Cl	Common name: Chlorine	Atomic weight: 36	Atomic number: 17

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 300 100 years

Decay scheme: Cl-36 (300 100 y, β(-) 98.1%) → Ar-36 (stable)

↘ (300 100 y, EC/β(+) 1.9%) → S-36 (stable)

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	708.59 keV (98.1%)	708.59 keV (98.1%)	Continuous Slowing Down Approximation (CSDA) range			
			Aluminium	PMMA (Plexiglass)	Water	Air
			1.287	2.333	2.588	2614
Alpha	None	None	Not applicable			

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm^2 at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm^2 at 400 µm)
Not applicable	1.39E+00	4.92E-01

Internal dose

	Ingestion	Inhalation	
Compound type	Unspecified compounds	Aerosol	Vapour
Worker dose coefficient (Sv/Bq)	9.9E-10	5.2E-08	1.0E-09

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	10 kBq/g or 1 MBq	**CNSC classification:**	Class C
CNSC unconditional clearance level:	1 Bq/g	**Release of surface contaminated objects:**	30 or 1 Bq/cm^2 (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma dose rate):

Not applicable

Method of detection (contamination):

1. Hand-held: 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: Beta

Internal: In-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

Ca-45

Part 1 – RADIONUCLIDE IDENTIFICATION

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

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 163.0 days
Decay scheme: Ca-45 (163.0 d, β(-) 100%) → Sc-45 (stable)

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	256.90 keV (100%)	256.90 keV (100%)	Continuous Slowing Down Approximation (CSDA) range			
			Aluminium	PMMA (Plexiglass)	Water	Air
			0.3102	0.5489	0.6077	621.9
Alpha	None	None	Not applicable			

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm^2 at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm^2 at 400 µm)
Not applicable	7.22E-01	3.47E-03

Internal dose

	Ingestion	Inhalation
Worker dose coefficient (Sv/Bq)	2.7E-10	1.1E-09

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	10 kBq/g or 10 MBq	**CNSC classification:**	Class C
CNSC unconditional clearance level:	100 Bq/g	**Release of surface contaminated objects:**	30 or 100 Bq/cm^2 (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma dose rate):
Not applicable

Method of detection (contamination):
1. Hand-held: 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: Beta
Internal: In-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

Sc-46

Part 1 – RADIONUCLIDE IDENTIFICATION

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

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 83.79 days
Decay scheme: Sc-46 (83.79 d, β(-) 100%) → Ti-46 (stable)

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)					
Gamma & X-ray	1120.54 keV (100%) 889.27 keV (100%)	1120.54 keV (100%) 889.27 keV (100%)	Lead		Steel		Concrete	
			1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
			12.4	10.8	32.8	23.7	112.1	74.5
			37.0	33.5	84.2	63.0	272.1	192.4
Beta(-), Beta(+), electrons	356.85 keV (100%) 884.31 keV (0.015%)	884.31 keV (0.015%) 356.85 keV (100%)	Continuous Slowing Down Approximation (CSDA) range					
			Aluminium		PMMA (Plexiglass)		Water	Air
			0.5040		0.8993		0.9964	1015
Alpha	None	None	Not applicable					

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm^2 at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm^2 at 400 µm)
Air kerma	Effective	H*10	Hp10		
2.569E-04	2.573E-04	3.011E-04	3.003E-04	1.07E+00	8.46E-02

Internal dose

	Ingestion	Inhalation
Worker dose coefficient (Sv/Bq)	7.6E-10	4.8E-09

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	10 Bq/g or 1 MBq	**CNSC classification:**	Class A
CNSC unconditional clearance level:	0.1 Bq/g	**Release of surface contaminated objects:**	0.3 or 0.1 Bq/cm^2 (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma 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: 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: In-vivo, in-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

V-48

Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: V-48	Common name: Vanadium	Atomic weight: 48	Atomic number: 23

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 15.97 days
Decay scheme: V-48 (15.97 d, EC/β(+) 100%) → Ti-48 (stable)

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)					
Gamma & X-ray	983.52 keV (100%) 511.00 keV (99.8%) 1312.10 keV (97.5%)	2240.34 keV (2.41%) 1437.3 keV (0.12%) 1312.10 keV (97.5%)	Lead		Steel		Concrete	
			1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
			11.3	11.5	32.2	23.7	111.5	74.4
			38.4	38.7	84.4	66.9	272.9	202.5
Beta(-), Beta(+), electrons	694.68 keV (49.9%)	694.68 keV (49.9%)	Continuous Slowing Down Approximation (CSDA) range					
			Aluminium		PMMA (Plexiglass)		Water	Air
			1.261		2.286		2.537	2561
Alpha	None	None	Not applicable					

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 400 µm)
Air kerma	Effective	H*10	Hp10		
3.690E-04	3.706E-04	4.340E-04	4.341E-04	8.36E-01	3.10E-01

Internal dose

	Ingestion	Inhalation
Worker dose coefficient (Sv/Bq)	1.1E-09	1.7E-09

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	10 Bq/g or 100 kBq	**CNSC classification:**	Class A
CNSC unconditional clearance level:	1 Bq/g	**Release of surface contaminated objects:**	0.1 or 10 Bq/cm² (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma 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: 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: In-vivo, in-vitro

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.

Cr-51

Part 1 – RADIONUCLIDE IDENTIFICATION

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

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 27.7 days
Decay scheme: Cr-51 (27.7 d, EC 100%) → V-51 (stable)

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)					
			Lead		Steel		Concrete	
Gamma & X-ray	320.08 keV (9.9%)	320.08 keV (9.9%)	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
			2.04	1.84	19.9	12.8	93.5	46.5
			6.27	5.90	47.9	34.5	194.1	120.1
Beta(-), Beta(+), electrons	314.62 keV (0.015%)	314.62 keV (0.015%)	Continuous Slowing Down Approximation (CSDA) range					
			Aluminium		PMMA (Plexiglass)		Water	Air
			0.4196		0.7463		0.8267	8435
Alpha	None	None	Not applicable					

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 400 µm)
Air kerma	Effective	H*10	Hp10		
4.201E-06	4.554E-06	5.461E-06	5.693E-06	1.26E-02	1.66E-03

Internal dose

	Ingestion	Inhalation
Worker dose coefficient (Sv/Bq)	1.3E-11	2.8E-11

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	1 kBq/g or 10 MBq	**CNSC classification:**	Class C
CNSC unconditional clearance level:	100 Bq/g	**Release of surface contaminated objects:**	30 or 100 Bq/cm² (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma 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
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: In-vivo, in-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

Mn-52

Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Mn | Common name: Manganese | Atomic weight: 52 | Atomic number: 25

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 5.59 days
Decay scheme: Mn-52 (5.59 d, EC/β(+) 100%) → Cr-52 (stable)

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)					
Gamma & X-ray	1434.05 keV (100%) 935.54 keV (94.9%) 744.21 keV (90.34%)	1981.07 keV (0.035%) 1645.78 keV (0.052%) 1434.05 keV (100%)	Lead		Steel		Concrete	
			1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
			11.5	11.3	32.4	23.8	112.1	74.5
			38.1	40.1	84.7	67.4	273.8	203.9
Beta(-), Beta(+), electrons	575.73 keV (29.6%) 738.23 keV (0.027%) 929.53 keV (0.014%)	929.53 keV (0.014%) 738.23 keV (0.027%) 575.73 keV (29.6%)	Continuous Slowing Down Approximation (CSDA) range					
			Aluminium		PMMA (Plexiglass)		Water	Air
			0.9800		1.768		1.961	1985
Alpha	None	None	Not applicable					

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 400 µm)
Air kerma	Effective	H*10	Hp10		
4.366E-04	4.388E-04	5.132E-04	5.127E-04	5.28E-01	1.70E-01

Internal dose

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

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	10 Bq/g or 100 kBq	**CNSC classification:**	Class A
CNSC unconditional clearance level:	1 Bq/g	**Release of surface contaminated objects:**	0.3 or 1 Bq/cm² (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma 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: 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: In-vivo, in-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

Mn-56

Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Mn | Common name: Manganese | Atomic weight: 56 | Atomic number: 25

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 2.58 hours
Decay scheme: Mn-56 (2.58 h, β(-) 100%) → Fe-56 (stable)

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)					
Gamma & X-ray	846.76 keV (98.8%) 1810.73 keV (27.6%) 2113.09 keV (14.8%)	3369.8 keV (0.17%) 2959.92 keV (0.31%) 2657.56 keV (0.66%)	Lead		Steel		Concrete	
			1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
			13.4	12.7	34.7	26.0	118.0	80.8
			43.6	48.0	92.2	77.0	296.1	235.0
Beta(-), Beta(+), electrons	2848.52 keV (55.3%) 1037.86 keV (28.2%) 735.53 keV (15.1%)	2848.52 keV (55.3%) 1610.31 keV (0.08%) 1037.86 keV (28.2%)	Continuous Slowing Down Approximation (CSDA) range					
			Aluminium		PMMA (Plexiglass)		Water	Air
			6.335		11.91		13.25	13140
Alpha	None	None	Not applicable					

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 400 µm)
Air kerma	Effective	H*10	Hp10		
2.046E-04	2.045E-04	2.384E-04	2.374E-04	1.44E+00	7.68E-01

Internal dose

	Ingestion	Inhalation
Worker dose coefficient (Sv/Bq)	2.0E-10	1.2E-10

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	10 Bq/g or 100 kBq	**CNSC classification:**	Class C
CNSC unconditional clearance level:	10 Bq/g	**Release of surface contaminated objects:**	30 or 100 Bq/cm² (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma 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: 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: In-vivo, in-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

Fe-55

Part 1 – RADIONUCLIDE IDENTIFICATION

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

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 2.74 years
Decay scheme: Fe-55 (2.74 y, EC 100%) → Mn-55 (stable)

Radiation type	Most abundant emissions (>5 keV, >0.01%)	Most energetic emissions (>5 keV, >0.01%)	Shielding information (mm)
Gamma & X-ray	5.90 keV (16%) 5.89 keV (8.24%) 6.49 keV (3.29%)	6.49 keV (3.29%) 5.90 keV (16%) 5.89 keV (8.24%)	Not applicable (energy too low from primary emission)
Beta(-), Beta(+), electrons	5.19 keV (60.7%)	5.19 keV (60.7%)	Not applicable (energy too low from primary emission)
Alpha	None	None	Not applicable

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm^2 at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm^2 at 400 µm)
Not applicable	1.43E-02	2.40E-03

Internal dose

	Ingestion	Inhalation
Worker dose coefficient (Sv/Bq)	2.9E-10	1.2E-09

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	10 kBq/g or 1 MBq	**CNSC classification:**	Class C
CNSC unconditional clearance level:	1 kBq/g	**Release of surface contaminated objects:**	30 or 100 Bq/cm^2 (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma dose rate):
Not applicable

Method of detection (contamination):
1. Non-portable: liquid scintillation counter, NaI well counter

Dosimetry
External: Not applicable
Internal: In-vitro

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-56

Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Co	Common name: Cobalt	Atomic weight: 56	Atomic number: 27

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 77.31 days
Decay scheme: Co-56 (77.31 d, EC/β(+) 100%) → Fe-56 (stable)

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)					
Gamma & X-ray	846.76 keV (99.9%) 1238.29 keV (66.8%) 511.00 keV (39.1%)	3600.70 keV (0.016%) 3548.18 keV (0.19%) 3451.15 keV (0.91%)	Lead		Steel		Concrete	
			1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
			13.8	13.4	35.2	26.6	119.8	83.8
			45.6	48.7	94.8	81.9	305.9	257.0
Beta(-), Beta(+), electrons	1458.83 keV (18.1%) 421.12 keV (0.9%) 584.08 keV (0.02%)	1458.83 keV (18.1%) 839.65 keV (0.03%) 584.08 keV (0.02%)	Continuous Slowing Down Approximation (CSDA) range					
			Aluminium		PMMA (Plexiglass)		Water	Air
			3.096		5.710		6.343	6349
Alpha	None	None	Not applicable					

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 400 µm)
Air kerma	Effective	H*10	Hp10		
4.199E-04	4.188E-04	4.884E-04	4.866E-04	3.36E-01	1.94E-01

Internal dose

	Ingestion	Inhalation
Worker dose coefficient (Sv/Bq)	1.9E-09	5.0E-09

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	10 Bq/g or 100 kBq	**CNSC classification:**	Class A
CNSC unconditional clearance level:	0.1 Bq/g	**Release of surface contaminated objects:**	0.3 or 0.1 Bq/cm² (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma 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: 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

Dosimetry
External: Gamma/beta
Internal: In-vivo, in-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B. For general safety precautions, please refer to appendix C.

Co-57

Part 1 – RADIONUCLIDE IDENTIFICATION

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

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 271.80 days
Decay scheme: Co-57 (271.80 d, EC 100%) → Fe-57 (stable)

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)					
Gamma & X-ray	122.06 keV (85.5%) 136.47 keV (10.7%) 14.41 keV (9.2%)	692.01 keV (0.16%) 569.94 keV (0.015%) 136.47 keV (10.7%)	Lead		Steel		Concrete	
			1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
			0.35	0.27	5.58	4.21	65.5	28.9
			0.97	1.42	15.2	15.3	128.8	81.2
Beta(-), Beta(+), electrons	13.57 keV (7.16%) 114.95 keV (1.81%) 129.36 keV (1.42%)	136.38 (0.021%) 135.63 keV (0.15%) 129.36 keV (1.42%)	Continuous Slowing Down Approximation (CSDA) range					
			Aluminium		PMMA (Plexiglass)		Water	Air
			0.1055		0.1832		0.2025	209.4
Alpha	None	None	Not applicable					

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm^2 at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm^2 at 400 µm)
Air kerma	Effective	H*10	Hp10		
1.337E-05	1.765E-05	2.099E-05	2.270E-05	1.01E-01	8.85E-03

Internal dose

	Ingestion	Inhalation
Worker dose coefficient (Sv/Bq)	1.2E-10	6.4E-10

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	100 Bq/g or 1 MBq	**CNSC classification:**	Class C
CNSC unconditional clearance level:	1 Bq/g	**Release of surface contaminated objects:**	30 or 1 Bq/cm^2 (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma 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
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: In-vivo, in-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

Co-58

Part 1 – RADIONUCLIDE IDENTIFICATION

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

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 70.86 days
Decay scheme: Co-58 (70.86 d, EC/β(+) 100%) → Fe-58 (stable)

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)					
Gamma & X-ray	810.78 keV (99.5%) 511.00 keV (30.0%) 863.96 keV (0.68%)	1674.73 keV (0.52%) 863.96 keV (0.68%) 810.78 keV (99.5%)	Lead		Steel		Concrete	
			1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
			8.80	8.07	29.7	20.8	106.6	66.6
			27.4	26.1	75.0	55.9	248.9	172.1
Beta(-), Beta(+), electrons	475.20 keV (14.9%) 803.66 keV (0.03%)	803.66 keV (0.03%) 475.20 keV (14.9%)	Continuous Slowing Down Approximation (CSDA) range					
			Aluminium		PMMA (Plexiglass)		Water	Air
			0.7487		1.347		1.494	1515
Alpha	None	None	Not applicable					

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 400 µm)
Air kerma	Effective	H*10	Hp10		
1.293E-04	1.309E-04	1.544E-04	1.549E-04	2.64E-01	6.11E-02

Internal dose

	Ingestion	Inhalation
Worker dose coefficient (Sv/Bq)	5.4E-10	1.4E-09

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	10 Bq/g or 1 MBq	**CNSC classification:**	Class B
CNSC unconditional clearance level:	1 Bq/g	**Release of surface contaminated objects:**	3 or 1 Bq/cm² (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma 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: 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: In-vivo, in-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

Co-60

Part 1 – RADIONUCLIDE IDENTIFICATION

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

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 5.27 years
Decay scheme: Co-60 (5.27 y, β(-) 100%) → Ni-60 (stable)

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)					
			Lead		Steel		Concrete	
Gamma & X-ray	1332.49 keV (100%) 1173.23 keV (99.9%)	1332.49 keV (100%) 1173.23 keV (99.9%)	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
			15.2	13.2	35.1	26.1	117.0	81.6
			44.9	39.6	91.8	69.3	292.3	210.6
Beta(-), Beta(+), electrons	318.14 keV (99.9%) 1491.32 keV (0.12%) 1164.90 keV (0.015%)	1491.32 keV (0.12%) 1324.16 keV (0.012%) 1164.90 keV (0.015%)	Continuous Slowing Down Approximation (CSDA) range					
			Aluminium		PMMA (Plexiglass)		Water	Air
			0.4265		0.7587		0.8405	857.4
Alpha	None	None	Not applicable					

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm^2 at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm^2 at 400 µm)
Air kerma	Effective	H*10	Hp10		
3.068E-04	3.059E-04	3.558E-04	3.536E-04	9.49E-01	5.41E-02

Internal dose

	Ingestion	Inhalation
Worker dose coefficient (Sv/Bq)	3.2E-09	3.1E-08

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	10 Bq/g or 100 kBq	**CNSC classification:**	Class A
CNSC unconditional clearance level:	0.1 Bq/g	**Release of surface contaminated objects:**	0.3 or 0.1 Bq/cm^2 (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma 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: 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: In-vivo, in-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

Zn-62

Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Zn	Common name: Zinc	Atomic weight: 62	Atomic number: 30

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 9.26 hours
Decay Scheme: Zn-62 (9.26 h, EC/β(+) 100%) → Cu-62 (9.75 m, β(+) 100%) → Ni-62 (stable)

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 (217%) 596.56 keV (26%) 40.85 keV (25%)	2301.80 keV (0.042%) 1429.70 keV (0.028%) 1389.10 keV (0.012%)	Lead		Steel		Concrete	
			1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
			4.99	4.65	25.3	17.3	99.6	56.7
			15.7	15.1	62.9	46.1	221.6	146.4
Beta(-), Beta(+), electrons	2927.00 keV (99.60%) 1754.00 keV (0.15%) 605.00 keV (8.40%)	2927.00 keV (99.60%) 1754.00 keV (0.15%) 878.00 keV (0.15%)	Continuous Slowing Down Approximation (CSDA) range					
			Aluminium		PMMA (Plexiglass)		Water	Air
			6.470		12.18		13.55	13430
Alpha	None	None	Not applicable					

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 400 µm)
Air kerma	Effective	H*10	Hp10		
2.026E-04	2.080E-04	2.493E-04	2.542E-04	1.58E+00	9.85E-01

Internal dose

	Ingestion	Inhalation
Worker dose coefficient (Sv/Bq)	5.4E-10	4.0E-10

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	100 Bq/g or 1 MBq	**CNSC classification:**	Class C
CNSC unconditional clearance level:	1 Bq/g	**Release of surface contaminated objects:**	30 or 10 Bq/cm² (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma 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: 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: In-vivo, in-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

Cu-62

Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Cu	Common name: Copper	Atomic weight: 62	Atomic number: 29

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 9.75 minutes
Decay scheme: Cu-62 (9.75 m, β(+) 100%) → Ni-62 (stable)

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 (200%)	2301.80 keV (0.042%)	Lead		Steel		Concrete	
	1172.90 keV (0.35%)	1172.90 keV (0.35%)	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
	875.70 keV (0.15%)	1128.90 keV (0.033%)	5.06	4.49	25.8	17.1	101.1	56.2
			15.4	14.5	63.0	45.6	222.2	145.3
Beta(-), Beta(+), electrons	2927.00 keV (99.60%)	2927.00 keV (99.60%)	Continuous Slowing Down Approximation (CSDA) range					
	878.00 keV (0.15%)	1754.00 keV (0.15%)	Aluminium		PMMA (Plexiglass)		Water	Air
	1754.00 keV (0.15%)	878.00 keV (0.15%)	6.470		12.18		13.55	13430
Alpha	None	None	Not applicable					

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 400 µm)
Air kerma	Effective	H*10	Hp10		
1.410E-04	1.452E-04	1.731E-04	1.766E-04	1.42E+00	9.31E-01

Internal dose

	Ingestion	Inhalation
Worker dose coefficient (Sv/Bq)	Not Available	Not Available

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	100 Bq/g or 1 MBq	**CNSC classification:**	Class C
CNSC unconditional clearance level:	1 Bq/g	**Release of surface contaminated objects:**	30 or 100 Bq/cm² (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma 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: 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: In-vivo, in-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

Ni-63

Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Ni	Common name: Nickel	Atomic weight: 63	Atomic number: 28

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 100.6 years
Decay scheme: Ni-63 (100.6 y, β(-) 100%) → Cu-63 (stable)

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	66.95 keV (100%)	66.95 keV (100%)	Continuous Slowing Down Approximation (CSDA) range			
			Aluminium	PMMA (Plexiglass)	Water	Air
			0.03529	0.05997	0.06615	69.27
Alpha	None	None	Not applicable			

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Ni-63 is not an external radiation hazard.

Internal dose

	Ingestion	Inhalation	
Compound type	Unspecified compounds	Aerosol	Vapour
Worker dose coefficient (Sv/Bq)	3.0E-11	1.7E-09	4.7E-10

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	100 kBq/g or 100 MBq	**CNSC classification:**	Class C
CNSC unconditional clearance level:	100 Bq/g	**Release of surface contaminated objects:**	30 or 100 Bq/cm^2 (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma 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: In-vitro (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: Ni-63 is an internal hazard only and cannot generally be detected with handheld equipment.

Cu-64

Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Cu	Common name: Copper	Atomic weight: 64	Atomic number: 29

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 12.70 hours

Decay scheme: Cu-64 (12.7 h, EC/β(+) 61%) → Ni-64 (stable)

↘ (12.7 h, β(-) 39%) → Zn-64 (2.3E18 y)

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 (35.7%) 1345.77 keV (0.47%)	1345.77 keV (0.47%) 511.00 keV (35.7%)	Lead		Steel		Concrete	
			1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
			5.15	4.64	26.0	17.3	101.4	56.7
			16.0	18.0	63.7	47.2	224.0	148.9
Beta(-), Beta(+), electrons	578.69 keV (39%) 653.05 keV (17.9%)	653.05 keV (17.9%) 578.69 keV (39%)	Continuous Slowing Down Approximation (CSDA) range					
			Aluminium		PMMA (Plexiglass)		Water	Air
			1.157		2.095		2.324	2349
Alpha	None	None	Not applicable					

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm^2 at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm^2 at 400 µm)
Air kerma	Effective	H*10	Hp10		
2.580E-05	2.655E-05	3.162E-05	3.224E-05	7.89E-01	2.06E-01

Internal dose

	Ingestion	Inhalation
Worker dose coefficient (Sv/Bq)	5.4E-11	6.9E-11

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	100 Bq/g or 1 MBq	**CNSC classification:**	Class C
CNSC unconditional clearance level:	100 Bq/g	**Release of surface contaminated objects:**	30 or 100 Bq/cm^2 (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma 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: 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: In-vivo, in-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

Zn-65

Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Zn	Common name: Zinc	Atomic weight: 65	Atomic number: 30

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 244.15 days
Decay scheme: Zn-65 (244.15 d, EC/β(+) 100%) → Cu-65 (stable)

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)					
			Lead		Steel		Concrete	
Gamma & X-ray	1115.54 keV (50.6%) 511.00 keV (2.84%)	1115.54 keV (50.6%) 511.00 keV (2.84%)	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
			13.5	11.8	33.6	24.6	113.6	77.2
			40.2	35.4	87.0	65.3	279.3	198.9
Beta(-), Beta(+), electrons	329.90 keV (1.42%)	329.90 keV (1.42%)	Continuous Slowing Down Approximation (CSDA) range					
			Aluminium		PMMA (Plexiglass)		Water	Air
			0.4498		0.8010		0.8873	904.8
Alpha	None	None	Not applicable					

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 400 µm)
Air kerma	Effective	H*10	Hp10		
7.299E-05	7.298E-05	8.518E-05	8.489E-05	4.50E-02	1.36E-02

Internal dose

	Ingestion	Inhalation
Worker dose coefficient (Sv/Bq)	4.3E-09	3.8E-09

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	10 Bq/g or 1 MBq	**CNSC classification:**	Class A
CNSC unconditional clearance level:	0.1 Bq/g	**Release of surface contaminated objects:**	0.3 or 0.1 Bq/cm² (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma 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
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: In-vivo, in-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

Cu-67

Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Cu	Common name: Copper	Atomic weight: 67	Atomic number: 29

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 2.579 days
Decay scheme: Cu-67 (2.579 d, β(-) 100%) → Zn-67 (stable)

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)					
Gamma & X-ray	184.58 keV (48.7%) 93.31 keV (16.1%) 91.27 keV (7%)	393.53 keV (0.22%) 300.22 keV (0.8%) 208.95 keV (0.12%)	Lead		Steel		Concrete	
			1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
			0.56	0.53	9.28	7.86	74.9	35.5
			1.83	2.35	26.9	23.5	152.7	97.1
Beta(-), Beta(+), electrons	391.00 keV (57.1%) 483.00 keV (21.8%) 576.00 keV (20.0%)	576.00 keV (20.0%) 483.00 keV (21.8%) 391.00 keV (57.1%)	Continuous Slowing Down Approximation (CSDA) range					
			Aluminium		PMMA (Plexiglass)		Water	Air
			0.981		1.769		1.962	1987
Alpha	None	None	Not applicable					

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 400 µm)
Air kerma	Effective	H*10	Hp10		
1.362E-05	1.671E-05	1.996E-05	2.146E-05	1.27E+00	1.32E-01

Internal dose

	Ingestion	Inhalation
Worker dose coefficient (Sv/Bq)	1.2E-10	2.1E-10

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	100 Bq/g or 1 MBq	**CNSC classification:**	Class B
CNSC unconditional clearance level:	1 Bq/g	**Release of surface contaminated objects:**	3 or 10 Bq/cm² (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma 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: 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: In-vivo, in-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

Ga-67

Part 1 – RADIONUCLIDE IDENTIFICATION

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

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 3.26 days
Decay scheme: Ga-67 (3.26 d, EC 100%) → Zn-67 (stable)

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)					
Gamma & X-ray	93.31 keV (39.2%) 184.58 keV (21.2%) 300.22 keV (16.8%)	887.69 keV (0.15%) 794.39 keV (0.054%) 703.11 keV (0.011%)	Lead		Steel		Concrete	
			1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
			0.81	1.31	11.2	11.7	76.7	41.0
			4.56	8.73	37.7	36.5	167.8	119.0
Beta(-), Beta(+), electrons	83.65 keV (29.4%) 92.12 keV (3.61%) 174.92 keV (0.33%)	199.29 keV (0.019%) 183.38 keV (0.035%) 174.92 keV (0.33%)	Continuous Slowing Down Approximation (CSDA) range					
			Aluminium		PMMA (Plexiglass)		Water	Air
			0.06013		0.1033		0.1141	118.7
Alpha	None	None	Not applicable					

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 400 µm)
Air kerma	Effective	H*10	Hp10		
1.904E-05	2.254E-05	2.694E-05	2.868E-05	3.39E-01	1.08E-02

Internal dose

	Ingestion	Inhalation
Worker dose coefficient (Sv/Bq)	5.4E-11	1.1E-10

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	100 Bq/g or 1 MBq	**CNSC classification:**	Class C
CNSC unconditional clearance level:	1 Bq/g	**Release of surface contaminated objects:**	30 or 10 Bq/cm² (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma 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
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, gas-flow proportional counter

Dosimetry

External: Gamma/beta
Internal: In-vivo, in-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B. For general safety precautions, please refer to appendix C.

Ge-68

Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Ge | Common name: Germanium | Atomic weight: 68 | Atomic number: 32

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 270.95 days
Decay scheme: Ge-68 (270.95 d, EC 100%) → Ga-68 (1.128 h, EC/β(+) 100%) → Zn-68 (stable)

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%) 10.00 keV (44.2%) 1077.34 keV (3.2%)	1883.16 keV (0.14%) 1261.08 keV (0.094%) 1077.34 keV (3.2%)	Lead		Steel		Concrete	
			1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
			5.18	4.67	26.0	17.3	101.4	56.8
			16.1	17.6	63.7	47.0	223.9	148.4
Beta(-), Beta(+), electrons	1898.97 keV (88%) 821.66 keV (1.1%)	1898.97 keV (88%) 821.66 keV (1.1%)	Continuous Slowing Down Approximation (CSDA) range					
			Aluminium		PMMA (Plexiglass)		Water	Air
			4.137		7.686		8.542	8520
Alpha	None	None	Not applicable					

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 400 µm)
Air kerma	Effective	H*10	Hp10		
1.299E-04	1.336E-04	1.592E-04	1.623E-04	1.33E+00	8.11E-01

Internal dose

	Ingestion	Inhalation
Worker dose coefficient (Sv/Bq)	2.9E-10	1.7E-08

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	10 Bq/g or 100 kBq	**CNSC classification:**	Class A
CNSC unconditional clearance level:	1 Bq/g	**Release of surface contaminated objects:**	0.3 or 1 Bq/cm² (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma 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: 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: In-vivo, in-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

Ga-68

Part 1 – RADIONUCLIDE IDENTIFICATION

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

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 1.128 hours
Decay scheme: Ga-68 (1.128 h, EC/β(+) 100%) → Zn-68 (stable)

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		Steel		Concrete	
			1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
			5.18	4.67	26.0	17.3	101.4	56.8
			16.1	17.6	63.7	47.0	223.9	148.4
Beta(-), Beta(+), electrons	1898.97 keV (88%) 821.66 keV (1.1%)	1898.97 keV (88%) 821.66 keV (1.1%)	Continuous Slowing Down Approximation (CSDA) range					
			Aluminium		PMMA (Plexiglass)		Water	Air
			4.137		7.686		8.542	8520
Alpha	None	None	Not applicable					

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 400 µm)
Air kerma	Effective	H*10	Hp10		
1.299E-04	1.336E-04	1.592E-04	1.623E-04	1.31E+00	8.05E-01

Internal dose

	Ingestion	Inhalation
Worker dose coefficient (Sv/Bq)	1.1E-10	5.5E-11

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	10 Bq/g or 100 kBq	**CNSC classification:**	Class C
CNSC unconditional clearance level:	1 Bq/g	**Release of surface contaminated objects:**	30 or 10 Bq/cm² (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma 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: 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: In-vivo, in-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

Se-75

Part 1 – RADIONUCLIDE IDENTIFICATION

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

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 119.6 days
Decay scheme: Se-75 (119.6 d, EC 100%) → As-75 (stable)

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)					
Gamma & X-ray	264.66 keV (59.0%) 136.00 keV (58.8%) 10.54 keV (32.0%)	572.20 keV (0.036%) 419.10 keV (0.014%) 400.66 keV (11.5%)	Lead		Steel		Concrete	
			1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
			1.02	1.39	13.7	11.3	83.7	41.4
			4.49	6.77	39.2	33.9	174.8	115.1
Beta(-), Beta(+), electrons	12.51 keV (4.4%) 84.90 keV (2.6%) 124.10 keV (1.6%)	388.80 keV (0.014%) 292.10 keV (0.062%) 278.22 keV (0.02%)	Continuous Slowing Down Approximation (CSDA) range					
			Aluminium		PMMA (Plexiglass)		Water	Air
			0.09853		0.1709		0.1889	195.5
Alpha	None	None	Not applicable					

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 400 µm)
Air kerma	Effective	H*10	Hp10		
4.841E-05	5.580E-05	6.675E-05	7.057E-05	1.11E-01	1.81E-02

Internal dose

	Ingestion	Inhalation
Worker dose coefficient (Sv/Bq)	3.1E-10	1.8E-09

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	100 Bq/g or 1 MBq	**CNSC classification:**	Class B
CNSC unconditional clearance level:	1 Bq/g	**Release of surface contaminated objects:**	3 or 1 Bq/cm² (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma 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
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: In-vivo, in-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

Sr-82

Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Sr | Common name: Strontium | Atomic weight: 82 | Atomic number: 38

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 25.55 days
Decay scheme: Sr-82 (25.55 d, EC 100%) → Rb-82 (1.27 m, EC/β(+) 100%) → Kr-82 (stable)

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 (191%)	2479.65 keV (0.04%)	Lead		Steel		Concrete	
	13.39 keV (49%)	2410.26 keV (0.02%)	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
	776.52 keV (15.1%)	2167.59 keV (0.04%)	5.36	4.90	26.2	17.6	101.6	57.4
			16.8	18.6	64.5	47.8	225.6	150.5
Beta(-), Beta(+), electrons	3377.75 keV (84.8%)	3377.75 keV (84.8%)	Continuous Slowing Down Approximation (CSDA) range					
	11.40 keV (28.4%)	2601.27 keV (10.7%)	Aluminium		PMMA (Plexiglass)		Water	Air
	2601.27 keV (10.7%)	1902.94 keV (0.15%)	7.450		14.10		15.69	15510
Alpha	None	None	Not applicable					

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 400 µm)
Air kerma	Effective	H*10	Hp10		
1.808E-04	1.567E-04	1.925E-04	1.960E-04	1.40E+00	9.29E-01

Internal dose

	Ingestion	Inhalation
Worker dose coefficient (Sv/Bq)	1.6E-09	5.4E-09

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	10 Bq/g or 100 kBq	**CNSC classification:**	Class A
CNSC unconditional clearance level:	1 Bq/g	**Release of surface contaminated objects:**	0.3 or 1 Bq/cm² (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma 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: 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: In-vivo, in-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

Rb-82

Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Rb | Common name: Rubidium | Atomic weight: 82 | Atomic number: 37

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 1.27 minutes
Decay scheme: Rb-82 (1.27 m, EC/β(+) 100%) → Kr-82 (stable)

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 (191%) 776.52 keV (15.1%) 12.60 keV (2.23%)	2479.65 keV (0.04%) 2410.26 keV (0.02%) 2167.59 keV (0.04%)	Lead		Steel		Concrete	
			1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
			5.37	4.90	26.3	17.6	101.7	57.4
			16.8	18.6	64.5	47.8	225.7	150.4
Beta(-), Beta(+), electrons	3377.75 keV (84.8%) 2601.27 keV (10.7%) 10.80 keV (1.43%)	3377.75 keV (84.8%) 2601.27 keV (10.7%) 1902.94 keV (0.15%)	Continuous Slowing Down Approximation (CSDA) range					
			Aluminium		PMMA (Plexiglass)		Water	Air
			7.450		14.10		15.69	15510
Alpha	None	None	Not applicable					

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 400 µm)
Air kerma	Effective	H*10	Hp10		
1.510E-04	1.552E-04	1.848E-04	1.881E-04	1.39E+00	9.23E-01

Internal dose

	Ingestion	Inhalation
Worker dose coefficient (Sv/Bq)	not available	not available

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	10 Bq/g or 100 kBq	**CNSC classification:**	Class C
CNSC unconditional clearance level:	1 Bq/g	**Release of surface contaminated objects:**	30 or 100 Bq/cm² (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma 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: 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: In-vivo, in-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

Kr-85

Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Kr | Common name: Krypton | Atomic weight: 85 | Atomic number: 36

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 10.75 years
Decay scheme: Kr-85 (10.75 y, β(-) 100%) → Rb-85 (stable)

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)					
Gamma & X-ray	514.00 keV (0.44%)	514.00 keV (0.44%)	Lead		Steel		Concrete	
			1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
			5.08	4.51	25.8	17.2	101.2	56.3
			15.4	14.0	63.0	45.3	222.2	144.6
Beta(-), Beta(+), electrons	687.09 keV (99.6%) 173.10 keV (0.44%)	687.09 keV (99.6%) 173.10 keV (0.44%)	Continuous Slowing Down Approximation (CSDA) range					
			Aluminium		PMMA (Plexiglass)		Water	Air
			0.8411		1.514		1.678	1701
Alpha	None	None	Not applicable					

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 400 µm)
Air kerma	Effective	H*10	Hp10		
3.066E-07	3.157E-07	3.763E-07	3.838E-07	Not applicable (noble gas)	Not applicable (noble gas)

Internal dose

	Ingestion	Inhalation
Worker dose coefficient	Not applicable (noble gas)	9.17E-13 Sv/h per Bq/m³ (ICRP 68)

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	100 kBq/g or 10 kBq	**CNSC classification:**	Class C
CNSC unconditional clearance level:	Not applicable (noble gas)	**Release of surface contaminated objects:**	Not applicable (noble gas)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma dose rate):

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

Method of detection (contamination): Not applicable (noble gas)

Dosimetry
External: Gamma/beta
Internal: Not applicable (noble gas)

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

Zr-89

Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Zr	Common name: Zirconium	Atomic weight: 89	Atomic number: 40

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 3.267 days

Decay scheme: Zr-89 (3.267 d, EC/β(+) 99.9%) → Y-89m (15.663 s, IT 100%) → Y-89 (stable)

↘ (3.267 d, EC/β(+) 0.1%) → Y-89 (stable)

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)					
Gamma & X-ray	908.96 keV (99.16%)	1744.60 keV (0.13%)	Lead		Steel		Concrete	
	511.00 keV (45.0%)	1712.90 keV (0.75%)	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
	14.90 keV (41.0%)	1657.00 keV (0.11%)	9.25	9.01	29.9	21.5	106.3	68.7
			30.2	29.7	77.0	58.9	254.0	179.8
Beta(-), Beta(+), electrons	902.00 keV (22.5%)	906.59 keV (0.09%)	Continuous Slowing Down Approximation (CSDA) range					
	13.29 keV (20%)	902.00 keV (22.5%)	Aluminium		PMMA (Plexiglass)		Water	Air
	891.92 keV (0.72%)	891.92 keV (0.72%)	1.752		3.195		3.546	3570
Alpha	None	None	Not applicable					

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 400 µm)
Air kerma	Effective	H*10	Hp10		
1.946E-04	1.543E-04	1.911E-04	1.918E-04	4.18E-01	2.14E-01

Internal dose

	Ingestion	Inhalation
Worker dose coefficient (Sv/Bq)	4.0E-10	3.8E-10

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	10 Bq/g or 1 MBq	**CNSC classification:**	Class C
CNSC unconditional clearance level:	1 Bq/g	**Release of surface contaminated objects:**	30 or 10 Bq/cm² (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma 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: 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: In-vivo, in-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

Sr-90

Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Sr	Common name: Strontium	Atomic weight: 90	Atomic number: 38

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 28.79 years
Decay scheme: Sr-90 (28.79 y, β(-) 100%) → Y-90 (2.671 d, β(-) 100%) → Zr-90 (stable)

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	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%)	Continuous Slowing Down Approximation (CSDA) range			
			Aluminium	PMMA (Plexiglass)	Water	Air
			5.026	9.387	10.44	10380
Alpha	None	None	Not applicable			

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm^2 at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm^2 at 400 µm)
Not applicable	2.72E+00	1.15E+00

Internal dose

	Ingestion	Inhalation
Worker dose coefficient (Sv/Bq)	1.1E-09	2.0E-07

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	100 Bq/g or 10 kBq	**CNSC classification:**	Class B
CNSC unconditional clearance level:	1 Bq/g	**Release of surface contaminated objects:**	3 or 1 Bq/cm^2 (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma dose rate):
Not applicable

Method of detection (contamination):
1. Hand-held: 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: Beta
Internal: In-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

Y-90

Part 1 – RADIONUCLIDE IDENTIFICATION

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

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 2.671 days
Decay scheme: Y-90 (2.671 d, β(-) 100%) → Zr-90 (stable)

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	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%)	Continuous Slowing Down Approximation (CSDA) range			
			Aluminium	PMMA (Plexiglass)	Water	Air
			5.026	9.387	10.44	10380
Alpha	None	None	Not applicable			

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm^2 at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm^2 at 400 µm)
Not applicable	1.41E+00	8.41E-01

Internal dose

	Ingestion	Inhalation
Worker dose coefficient (Sv/Bq)	5.6E-10	7.3E-10

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	1 kBq/g or 100 kBq	**CNSC classification:**	Class B
CNSC unconditional clearance level:	1 kBq/g	**Release of surface contaminated objects:**	3 or 100 Bq/cm^2 (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma dose rate):
Not applicable

Method of detection (contamination):
1. Hand-held: 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: Beta
Internal: In-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

Zr-95

Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Zr	Common name: Zirconium	Atomic weight: 95	Atomic number: 40

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 64.032 days

Decay scheme: Zr-95 (64.032 d, β(-) 98.9%) → Nb-95 (34.991 d, β(-) 100%) → Mo-95 (stable)
↘ (64.032 d, β(-) 1.1%) → Nb-95m (3.61 d, IT 94.4%) → Nb-95 (34.991 d, β(-) 100%) → Mo-95 (stable)
↘ (3.61 d, β(-) 5.6%) → Mo-95 (stable)

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)					
Gamma & X-ray	765.80 keV (98.7%)	765.80 keV (98.7%)	Lead		Steel		Concrete	
	756.73 keV (54.4%)	756.73 keV (54.4%)	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
	724.19 keV (44.3%)	724.19 keV (44.3%)	8.95	7.70	29.7	20.7	106.9	66.0
			26.5	23.5	74.6	54.5	248.0	169.0
Beta(-), Beta(+), electrons	159.79 keV (98.9%)	1160.29 keV (0.03%)	Continuous Slowing Down Approximation (CSDA) range					
	368.06 keV (54.5%)	1124.79 keV (0.1%)	Aluminium		PMMA (Plexiglass)		Water	Air
	400.6 keV (44.3%)	889.1 keV (1.08%)	1.714		3.123		3.466	3490
Alpha	None	None	Not applicable					

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 400 µm)
Air kerma	Effective	H*10	Hp10		
1.985E-04	2.007E-04	2.367E-04	2.374E-04	1.31E+00	1.05E-01

Internal dose

	Ingestion	Inhalation
Worker dose coefficient (Sv/Bq)	4.3E-09	3.8E-09

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	10 Bq/g or 1 MBq	**CNSC classification:**	Class A
CNSC unconditional clearance level:	1 Bq/g	**Release of surface contaminated objects:**	0.3 or 1 Bq/cm² (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma 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: 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: In-vivo, in-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

Tc-94m

Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Tc | Common name: Technetium | Atomic weight: 94 | Atomic number: 43

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 52 minutes
Decay scheme: Tc-94m (52 m, EC/β(+) 100%) → Mo-94 (stable)

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)					
Gamma & X-ray	511.0 keV (140%)	3892.7 keV (0.02%)	Lead		Steel		Concrete	
	871.05 keV (94.2%)	3793.1 keV (0.05%)	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
	17.48 keV (10.9%)	3512.5 keV (0.06%)	8.08	8.85	29.2	21.4	105.8	68.8
			30.3	40.9	77.3	67.6	256.7	206.8
Beta(-), Beta(+), electrons	2438.26 keV (67.6%)	2438.26 keV (67.6%)	Continuous Slowing Down Approximation (CSDA) range					
	14.8 keV (6.1%)	1445.11 keV (0.99%)	Aluminium		PMMA (Plexiglass)		Water	Air
	1445.11 keV (0.99%)	1241.89 keV (0.32%)	5.378		10.07		11.19	11120
Alpha	None	None	Not applicable					

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm^2 at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm^2 at 400 µm)
Air kerma	Effective	H*10	Hp10		
2.606E-04	2.517E-04	3.013E-04	3.034E-04	1.04E+00	6.71E-01

Internal dose

	Ingestion	Inhalation
Worker dose coefficient (Sv/Bq)	1.2E-10	4.9E-11

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	10 Bq/g or 100 kBq	**CNSC classification:**	Class C
CNSC unconditional clearance level:	1 Bq/g	**Release of surface contaminated objects:**	30 or 100 Bq/cm^2 (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma 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: 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: In-vivo, in-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

Tc-95

Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Tc | Common name: Technetium | Atomic weight: 95 | Atomic number: 43

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 20.0 hours
Decay scheme: Tc-95 (20.0 h, EC 100%) → Mo-95 (stable)

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)					
			Lead		Steel		Concrete	
Gamma & X-ray	765.79 keV (93.8%) 17.5 keV (55.6%) 19.6 keV (10.7 %)	1551.71 keV (0.02%) 1073.71 keV (3.74%) 947.67 keV (1.95%)	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
			7.43	8.26	25.0	21.8	89.5	160.7
			26.1	25.3	71.9	56.2	238.9	173.5
Beta(-), Beta(+), electrons	14.8 keV (21%) 745.79 keV (0.12%) 184.12 keV (0.01%)	762.92 keV (0.01%) 745.79 keV (0.12%) 184.12 keV (0.01%)	Not applicable (energy too low from primary emission)					
Alpha	None	None	Not applicable					

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm^2 at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm^2 at 400 µm)
Air kerma	Effective	H*10	Hp10		
1.485E-04	1.093E-04	1.441E-04	1.448E-04	2.67E-02	1.93E-02

Internal dose

	Ingestion	Inhalation
Worker dose coefficient (Sv/Bq)	1.4E-10	1.0E-10

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	10 Bq/g or 1 MBq	**CNSC classification:**	Class C
CNSC unconditional clearance level:	1 Bq/g	**Release of surface contaminated objects:**	30 or 100 Bq/cm^2 (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma 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
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: In-vivo, in-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

Tc-96

Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Tc	Common name: Technetium	Atomic weight: 96	Atomic number: 43

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 4.28 days
Decay scheme: Tc-96 (4.28 d, EC 100%) → Mo-96 (stable)

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)					
			Lead		Steel		Concrete	
			1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
Gamma & X-ray	778.22 keV (99.8%) 849.86 keV (97.6%) 812.54 keV (82%)	1497.72 keV (0.09%) 1441.14 keV (0.05%) 1200.17 keV (0.37%)	9.34 29.3	8.79 27.3	28.9 76.4	21.9 57.6	102.3 251.3	70.2 177.3
Beta(-), Beta(+), electrons	14.8 keV (20.2%) 294.27 keV (0.03%) 296.50 keV (0.02%)	296.50 keV (0.02%) 294.27 keV (0.03%) 14.8 keV (20.2%)	Not applicable (energy too low from primary emission)					
Alpha	None	None	Not applicable					

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm^2 at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm^2 at 400 µm)
Air kerma	Effective	H*10	Hp10		
3.716E-04	3.347E-04	4.091E-04	4.096E-04	5.84E-02	4.65E-02

Internal dose

	Ingestion	Inhalation
Worker dose coefficient (Sv/Bq)	8.9E-10	7.1E-10

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	10 Bq/g or 1 MBq	**CNSC classification:**	Class B
CNSC unconditional clearance level:	1 Bq/g	**Release of surface contaminated objects:**	3 or 10 Bq/cm^2 (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma 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
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: In-vivo, in-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

Nb-96

Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Nb	Common name: Niobium	Atomic weight: 96	Atomic number: 41

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 23.35 hours
Decay scheme: Nb-96 (23.35 h, β(-) 100%) → Mo-96 (stable)

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)					
Gamma & X-ray	778.22 keV (96.45%) 568.71 keV (57.97%) 1091.35 keV (48.5%)	1625.90 keV (0.15%) 1497.81 keV (3.28%) 1441.13 keV (0.44%)	Lead		Steel		Concrete	
			1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
			9.18	9.07	30.1	21.6	107.6	68.2
			30.7	32.6	77.4	60.2	255.1	183.0
Beta(-), Beta(+), electrons	748.47 keV (96.7%) 746.17 keV (2.3%) 311.46 keV (0.5%)	748.47 keV (96.7%) 746.17 keV (2.3%) 431.82 keV (0.49%)	Continuous Slowing Down Approximation (CSDA) range					
			Aluminium		PMMA (Plexiglass)		Water	Air
			1.380		2.506		2.780	2806
Alpha	None	None	Not applicable					

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm^2 at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm^2 at 400 µm)
Air kerma	Effective	H*10	Hp10		
3.214E-04	3.252E-04	3.826E-04	3.841E-04	1.41E+00	4.68E-01

Internal dose

	Ingestion	Inhalation
Worker dose coefficient (Sv/Bq)	5.6E-10	4.7E-10

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	10 Bq/g or 100 kBq	**CNSC classification:**	Class C
CNSC unconditional clearance level:	1 Bq/g	**Release of surface contaminated objects:**	30 or 10 Bq/cm^2 (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma 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: 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: In-vivo, in-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

Mo-99

Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Mo	Common name: Molybdenum	Atomic weight: 99	Atomic number: 42

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 2.75 days

Decay scheme: Mo-99 (2.75 d, β(-) 88%) → Tc-99m (6.01 h, IT 100%) → Tc-99 (214 000 y, β(-) 100%) → Ru-99 (stable)
↘ (2.75 d, β(-) 12%) → Tc-99 (214 000 y, β(-) 100%) → Ru-99 (stable)

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		Steel		Concrete	
			1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
			0.86	5.94	11.7	15.3	77.4	48.4
			17.0	23.9	52.2	56.8	190.1	165.7
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%)	Continuous Slowing Down Approximation (CSDA) range					
			Aluminium		PMMA (Plexiglass)		Water	Air
			2.495		4.581		5.088	5104
Alpha	None	None	Not applicable					

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm^2 at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm^2 at 400 µm)
Air kerma	Effective	H*10	Hp10		
3.811E-05	3.656E-05	4.576E-05	4.762E-05	1.58E+00	5.90E-01

Internal dose

	Ingestion	Inhalation
Worker dose coefficient (Sv/Bq)	4.4E-10	4.1E-10

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	100 Bq/g or 1 MBq	**CNSC classification:**	Class B
CNSC unconditional clearance level:	10 Bq/g	**Release of surface contaminated objects:**	3 or 10 Bq/cm^2 (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma 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: 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: In-vivo, in-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

Tc-99m

Part 1 – RADIONUCLIDE IDENTIFICATION

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

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 6.01 hours
Decay scheme: Tc-99m (6.01 h, IT 100%) → Tc-99 (214 000 y, β(-) 100%) → Ru-99 (stable)

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)					
Gamma & X-ray	140.51 keV (89%) 18.37 keV (4.0%) 18.25 keV (2.1%)	142.63 keV (0.019%) 140.51 keV (89%) 20.60 keV (1.2%)	Lead		Steel		Concrete	
			1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
			0.36	0.31	6.47	5.25	66.6	31.7
			1.06	0.94	18.2	15.2	135.3	83.7
Beta(-), Beta(+), electrons	119.47 keV (8.8%) 15.50 keV (2.1%) 137.47 keV (1.1%)	142.05 keV (0.034%) 140.44 keV (0.037%) 139.97 keV (0.19%)	Continuous Slowing Down Approximation (CSDA) range					
			Aluminium		PMMA (Plexiglass)		Water	Air
			0.1164		0.2024		0.2238	231.2
Alpha	None	None	Not applicable					

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 400 µm)
Air kerma	Effective	H*10	Hp10		
1.875E-05	1.853E-05	2.377E-05	2.551E-05	2.05E-01	2.66E-03

Internal dose

	Ingestion	Inhalation
Worker dose coefficient (Sv/Bq)	1.4E-11	1.3E-11

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	100 Bq/g or 10 MBq	**CNSC classification:**	Class C
CNSC unconditional clearance level:	100 Bq/g	**Release of surface contaminated objects:**	30 or 100 Bq/cm² (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma 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
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: In-vivo, in-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

Tc-99

Part 1 – RADIONUCLIDE IDENTIFICATION

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

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 214 000 years
Decay scheme: Tc-99 (214 000 y, β(-) 100%) → Ru-99 (stable)

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	293.70 keV (100%)	293.70 keV (100%)	Continuous Slowing Down Approximation (CSDA) range			
			Aluminium	PMMA (Plexiglass)	Water	Air
			0.3791	0.6731	0.7454	761.3
Alpha	None	None	Not applicable			

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 400 µm)
Not applicable	9.98E-01	2.34E-02

Internal dose

	Ingestion	Inhalation
Worker dose coefficient (Sv/Bq)	2.7E-10	1.6E-08

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	10 kBq/g or 10 MBq	**CNSC classification:**	Class C
CNSC unconditional clearance level:	1 Bq/g	**Release of surface contaminated objects:**	30 or 1 Bq/cm² (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma dose rate):
Not applicable

Method of detection (contamination):

1. Hand-held: 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: Beta
Internal: In-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

Pd-103

Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Pd	Common name: Palladium	Atomic weight: 103	Atomic number: 46

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 16.98 days
Decay scheme: Pd-103 (16.98 d, EC 100%) → Rh-103m (56 m, IT 100%) → Rh-103 (stable)

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)					
Gamma & X-ray	20.22 keV (42.1%) 20.07 keV (22.2%) 22.72 keV (11.5%)	357.41 keV (0.02%) 23.17 keV (1.73%) 22.72 keV (11.5%)	Lead		Steel		Concrete	
			1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
			7.7E-03	7.6E-03	3.7E-02	3.7E-02	1.21	1.15
			2.6E-02	2.8E-02	0.13	0.14	3.90	4.14
Beta(-), Beta(+), electrons	36.34 keV (72%) 17.89 keV (16.7%) 39.13 keV (14.8%)	39.13 keV (14.8%) 36.34 keV (72%) 17.89 keV (16.7%)	Continuous Slowing Down Approximation (CSDA) range					
			Aluminium		PMMA (Plexiglass)		Water	Air
			0.01408		0.02341		0.02578	27.32
Alpha	None	None	Not applicable					

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 400 µm)
Air kerma	Effective	H*10	Hp10		
3.729E-05	5.341E-06	2.356E-05	2.369E-05	8.89E-03	4.11E-03

Internal dose

	Ingestion	Inhalation
Worker dose coefficient (Sv/Bq)	2.5E-11	1.5E-10

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	1 kBq/g or 100 MBq	**CNSC classification:**	Class C
CNSC unconditional clearance level:	1 kBq/g	**Release of surface contaminated objects:**	30 or 100 Bq/cm² (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma dose rate):

1. Specialized equipment may be required

Method of detection (contamination):

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

Dosimetry

External: Gamma/beta
Internal: In-vivo, in-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

Cd-109

Part 1 – RADIONUCLIDE IDENTIFICATION

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

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 1.267 years
Decay scheme: Cd-109 (1.267 y, EC 100%) → Ag-109m (39.6 s, IT 100%) → Ag-109 (stable)

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)					
Gamma & X-ray	22.00 keV (82.9%) 25.00 keV (17.47%) 88.03 keV (3.70%)	88.03 keV (3.70%) 25.00 keV (17.47%) 22.00 keV (82.9%)	Lead		Steel		Concrete	
			1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
			1.0E-02	1.0E-02	5.0E-02	5.1E-02	1.64	1.58
			3.4E-02	6.7E-02	0.18	2.35	5.52	42.9
Beta(-), Beta(+), electrons	84.23 keV (44.0%) 62.52 keV (41.7%) 19.58 keV (13.5%)	88.00 keV (10.5%) 84.23 keV (44.0%) 62.52 keV (41.7%)	Continuous Slowing Down Approximation (CSDA) range					
			Aluminium		PMMA (Plexiglass)		Water	Air
			0.05584		0.09579		0.1058	110.1
Alpha	None	None	Not applicable					

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 400 µm)
Air kerma	Effective	H*10	Hp10		
4.294E-05	9.077E-06	3.166E-05	3.232E-05	1.05E+00	6.19E-03

Internal dose

	Ingestion	Inhalation
Worker dose coefficient (Bq/Bq)	1.0E-09	4.7E-09

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	10 kBq/g or 1 MBq	**CNSC classification:**	Class C
CNSC unconditional clearance level:	1 Bq/g	**Release of surface contaminated objects:**	30 or 1 Bq/cm² (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma 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: In-vivo, in-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

Ag-110m

Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Ag	Common name: Silver	Atomic weight: 110	Atomic number: 63

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 249.78 days

Decay scheme: Ag-110m (249.78 d, β(-) 98.6%) → Cd-110 (stable)
↘ (249.78 d, IT 1.4%) → Ag-110 (24.56 s, β(-) 99.7%) → Cd-110 (stable)
↘ (24.56 s, EC 0.3%) → Pd-110 (6.0E17 y)

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)					
Gamma & X-ray	657.76 keV (94.4%)	1903.52 keV (0.016%)	Lead		Steel		Concrete	
	884.68 keV (74.0%)	1783.46 keV (0.010%)	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
	937.49 keV (34.5%)	1592.80 keV (0.021%)	10.2	9.53	31.1	22.4	109.6	70.4
			32.7	35.8	80.1	62.6	262.0	190.3
Beta(-), Beta(+), electrons	83.04 keV (67.5%)	1357.58 keV (0.014%)	Continuous Slowing Down Approximation (CSDA) range					
	529.84 keV (30.8%)	910.77 keV (0.04%)	Aluminium		PMMA (Plexiglass)		Water	Air
	90.97 keV (0.85%)	880.66 keV (0.012%)	0.8764		1.578		1.750	1774
Alpha	None	None	Not applicable					

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 400 µm)
Air kerma	Effective	H*10	Hp10		
3.573E-04	3.600E-04	4.226E-04	4.231E-04	4.79E-01	1.30E-01

Internal dose

	Ingestion	Inhalation
Worker dose coefficient (Sv/Bq)	2.3E-09	9.3E-09

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	10 Bq/g or 1 MBq	**CNSC classification:**	Class A
CNSC unconditional clearance level:	0.1 Bq/g	**Release of surface contaminated objects:**	0.3 or 0.1 Bq/cm² (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma 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: 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: In-vivo, in-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B. For general safety precautions, please refer to appendix C.

In-111

Part 1 – RADIONUCLIDE IDENTIFICATION

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

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 2.80 days
Decay scheme: In-111 (2.80 d, EC 100%) → Cd-111 (stable)

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)					
Gamma & X-ray	245.35 keV (94.1%) 171.28 keV (90.7%) 23.00 keV (68.2%)	245.35 keV (94.1%) 171.28 keV (90.7%) 26.10 keV (14.6%)	Lead		Steel		Concrete	
			1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
			0.51	0.81	8.90	9.57	65.1	42.2
			2.46	3.19	30.1	27.4	154.3	105.2
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%)	Continuous Slowing Down Approximation (CSDA) range					
			Aluminium		PMMA (Plexiglass)		Water	Air
			0.2424		0.4273		0.4729	485.0
Alpha	None	None	Not applicable					

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 400 µm)
Air kerma	Effective	H*10	Hp10		
8.054E-05	6.325E-05	9.216E-05	9.698E-05	3.12E-01	2.40E-02

Internal dose

	Ingestion	Inhalation
Worker dose coefficient (Sv/Bq)	1.5E-10	1.5E-10

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	100 Bq/g or 1 MBq	**CNSC classification:**	Class C
CNSC unconditional clearance level:	10 Bq/g	**Release of surface contaminated objects:**	30 or 10 Bq/cm² (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma 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
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: In-vivo, in-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

I-123

Part 1 – RADIONUCLIDE IDENTIFICATION

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

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 13.22 hours
Decay scheme: I-123 (13.22 h, EC 100%) → Te-123 (9.2E16 y)

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%) 27.30 keV (71.1%) 31.00 keV (16.1%)	783.59 keV (0.059%) 735.78 keV (0.062%) 687.95 keV (0.027%)	Lead		Steel		Concrete	
			1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
			9.3E-02	0.51	1.89	8.76	37.3	45.3
			1.32	10.7	20.5	32.3	128.2	106.5
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%)	Continuous Slowing Down Approximation (CSDA) range					
			Aluminium		PMMA (Plexiglass)		Water	Air
			0.1397		0.2439		0.2697	278.2
Alpha	None	None	Not applicable					

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 400 µm)
Air kerma	Effective	H*10	Hp10		
4.173E-05	2.963E-05	4.893E-05	5.121E-05	3.14E-01	5.39E-03

Internal dose

	Ingestion	Inhalation	
Compound type	Unspecified compounds	Aerosol	Vapour
Worker dose coefficient (Sv/Bq)	1.8E-10	1.1E-10	2.0E-10

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	100 Bq/g or 10 MBq	**CNSC classification:**	Class C
CNSC unconditional clearance level:	100 Bq/g	**Release of surface contaminated objects:**	30 or 100 Bq/cm² (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma 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
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: In-vivo (thyroid counting), in-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B. For general safety precautions, please refer to appendix C.

I-124

Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: I	Common name: Iodine	Atomic weight: 124	Atomic number: 53

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 4.176 days
Decay scheme: I-124 (4.176 d, EC/β(+) 100%) → Te-124 (stable)

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 (47.0%) 511.00 keV (46.0%)	2746.90 keV (0.48%) 2681.50 keV (0.03%) 2453.90 keV (0.07%)	Lead		Steel		Concrete	
			1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
			7.15	8.59	27.1	21.8	99.6	69.5
			29.8	45.9	75.9	69.2	252.3	207.7
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 (0.30%)	Continuous Slowing Down Approximation (CSDA) range					
			Aluminium		PMMA (Plexiglass)		Water	Air
			4.693		8.748		9.725	9684
Alpha	None	None	Not applicable					

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 400 µm)
Air kerma	Effective	H*10	Hp10		
1.561E-04	1.475E-04	1.827E-04	1.843E-04	3.61E-01	2.24E-01

Internal dose

	Ingestion	Inhalation	
Compound type	Unspecified compounds	Aerosol	Vapour
Worker dose coefficient (Sv/Bq)	8.6E-09	5.7E-09	8.6E-09

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	10 Bq/g or 1 MBq	**CNSC classification:**	Class A
CNSC unconditional clearance level:	1 Bq/g	**Release of surface contaminated objects:**	0.3 or 1 Bq/cm² (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma 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: 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: In-vivo (thyroid counting), in-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B. For general safety precautions, please refer to appendix C.

I-125

Part 1 – RADIONUCLIDE IDENTIFICATION

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

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 59.41 days
Decay scheme: I-125 (59.41 d, EC 100%) → Te-125 (stable)

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		Steel		Concrete	
			1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
			1.7E-02	1.7E-02	9.3E-02	9.3E-02	3.13	2.80
			5.8E-02	6.4E-02	0.31	0.35	9.67	10.0
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%)	Continuous Slowing Down Approximation (CSDA) range					
			Aluminium		PMMA (Plexiglass)		Water	Air
			0.01133		0.01873		0.0262	21.92
Alpha	None	None	Not applicable					

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 400 µm)
Air kerma	Effective	H*10	Hp10		
4.033E-05	1.449E-05	3.978E-05	4.059E-05	1.40E-02	4.42E-03

Internal dose

	Ingestion	Inhalation	
Compound type	Unspecified compounds	Aerosol	Vapour
Worker dose coefficient (Sv/Bq)	1.3E-08	8.6E-09	1.3E-08

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	1 kBq/g or 1 MBq	**CNSC classification:**	Class C
CNSC unconditional clearance level:	100 Bq/g	**Release of surface contaminated objects:**	30 or 100 Bq/cm² (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma dose rate):

1. Specialized equipment may be required

Method of detection (contamination):

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

Dosimetry

External: Gamma/beta
Internal: In-vivo (thyroid counting), in-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

I-131

Part 1 – RADIONUCLIDE IDENTIFICATION

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

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 8.023 days

Decay scheme: I-131 (8.023 d, β(-) 98.9%) → Xe-131 (stable)

↘ (8.023 d, β(-) 1.1%) → Xe-131m (11.93 d, IT 100%) → Xe-131 (stable)

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		Steel		Concrete	
	636.99 keV (7.3%)	642.7 keV (0.22%)	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
	284.3 keV (6.1%)	636.99 keV (7.3%)	2.83	2.92	21.7	14.8	94.6	51.0
			10.1	15.7	54.2	41.9	205.0	134.4
Beta(-), Beta(+), electrons	606.31 keV (89.4%)	806.87 keV (0.40%)	Continuous Slowing Down Approximation (CSDA) range					
	333.81 keV (7.36%)	629.65 keV (0.05%)	Aluminium		PMMA (Plexiglass)		Water	Air
	45.62 keV (3.5%)	606.31 keV (89.4%)	1.050		1.897		2.104	2128
Alpha	None	None	Not applicable					

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 400 µm)
Air kerma	Effective	H*10	Hp10		
5.202E-05	5.471E-05	6.590E-05	6.808E-05	1.28E+00	2.89E-01

Internal dose

	Ingestion	Inhalation	
Compound type	Unspecified compounds	Aerosol	Vapour
Worker dose coefficient (Sv/Bq)	1.6E-08	1.1E-08	1.7E-08

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	100 Bq/g or 1 MBq	**CNSC classification:**	Class B
CNSC unconditional clearance level:	10 Bq/g	**Release of surface contaminated objects:**	3 or 10 Bq/cm² (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma 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: 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: In-vivo (thyroid counting), in-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B. For general safety precautions, please refer to appendix C.

Sb-124

Part 1 – RADIONUCLIDE IDENTIFICATION

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

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 60.2 days
Decay scheme: Sb-124 (60.2 d, β(-) 98.9%) → Te-124 (stable)

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)					
Gamma & X-ray	602.73 keV (97.9%) 1690.98 keV (47.6%) 722.78 keV (10.8%)	2293.48 keV (0.03%) 2283.20 keV (0.04%) 2182.40 keV (0.05%)	Lead		Steel		Concrete	
			1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
			11.0	12.0	32.8	24.4	113.5	76.6
			40.9	47.6	87.5	74.8	282.6	225.9
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%)	Continuous Slowing Down Approximation (CSDA) range					
			Aluminium		PMMA (Plexiglass)		Water	Air
			5.077		9.483		10.54	10490
Alpha	None	None	Not applicable					

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 400 µm)
Air kerma	Effective	H*10	Hp10		
2.258E-04	2.270E-04	2.652E-04	2.655E-04	1.28E+00	4.66E-01

Internal dose

	Ingestion	Inhalation
Worker dose coefficient (Sv/Bq)	1.1E-09	4.3E-09

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	10 Bq/g or 1 MBq	**CNSC classification:**	Class A
CNSC unconditional clearance level:	1 Bq/g	**Release of surface contaminated objects:**	0.3 or 1 Bq/cm² (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma 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: 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: In-vivo, in-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

Ba-133

Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Ba	Common name: Barium	Atomic weight: 133	Atomic number: 56

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 10.54 years
Decay scheme: Ba-133 (10.54 d, EC 100%) → Cs-133 (stable)

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%) 356.01 keV (62%) 30.63 keV (35%)	383.85 keV (8.9%) 356.01 keV (62%) 302.85 keV (18%)	Lead		Steel		Concrete	
			1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
			0.87	2.21	10.3	15.3	57.4	55.3
			5.96	7.29	42.3	37.3	171.0	127.3
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%)	Continuous Slowing Down Approximation (CSDA) range					
			Aluminium		PMMA (Plexiglass)		Water	Air
			0.4983		0.8889		0.9849	1003
Alpha	None	None	Not applicable					

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm^2 at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm^2 at 400 µm)
Air kerma	Effective	H*10	Hp10		
7.171E-05	6.428E-05	9.079E-05	9.396E-05	1.12E-01	3.02E-02

Internal dose

	Ingestion	Inhalation
Worker dose coefficient (Sv/Bq)	2.0E-10	1.3E-08

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	100 Bq/g or 1 MBq	**CNSC classification:**	Class B
CNSC unconditional clearance level:	1 Bq/g	**Release of surface contaminated objects:**	3 or 1 Bq/cm^2 (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma 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
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: In-vivo, in-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

Cs-137

Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Cs	Common name: Cesium	Atomic weight: 137	Atomic number: 55

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 30.04 years

Decay scheme: Cs-137 (30.04 y, β(-) 94.4%) → Ba-137m (2.55 m, IT 100%) → Ba-137 (stable)
↘ (30.04 y, β(-) 5.6%) → Ba-137 (stable)

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		Steel		Concrete	
			1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
			7.30	6.49	27.9	19.6	103.5	62.5
			22.1	19.9	70.2	51.3	237.5	160.3
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%)	Continuous Slowing Down Approximation (CSDA) range					
			Aluminium		PMMA (Plexiglass)		Water	Air
			2.401		4.406		4.893	4910
Alpha	None	None	Not applicable					

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm^2 at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm^2 at 400 µm)
Air kerma	Effective	H*10	Hp10		
7.699E-05	7.789E-05	9.268E-05	9.353E-05	1.39E+00	3.74E-01

Internal dose

	Ingestion	Inhalation
Worker dose coefficient (Sv/Bq)	1.4E-08	5.1E-08

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	10 Bq/g or 10 kBq	**CNSC classification:**	Class A
CNSC unconditional clearance level:	0.1 Bq/g	**Release of surface contaminated objects:**	0.3 or 0.1 Bq/cm^2 (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of Detection (gamma 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: 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: In-vivo, in-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

Tb-155

Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Tb | Common name: Terbium | Atomic weight: 155 | Atomic number: 65

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 5.32 days
Decay scheme: Tb-155 (5.32 d, EC 100%) → Gd-155 (stable)

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)					
Gamma & X-ray	42.65 keV (86.9%)	647.73 keV (0.01%)	Lead		Steel		Concrete	
	86.55 keV (32.0%)	614.80 keV (0.03%)	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
	105.32 keV (25.1%)	592.08 keV (0.02%)	0.16	0.43	1.29	6.37	34.0	37.5
			1.66	6.46	19.9	34.8	118.1	112.5
Beta(-), Beta(+), electrons	10.39 keV (16.9%)	320.49 keV (0.01%)	Continuous Slowing Down Approximation (CSDA) range					
	36.31 keV (11.6%)	290.43 keV (0.07%)	Aluminium		PMMA (Plexiglass)		Water	Air
	34.90 keV (8.0%)	271.59 keV (0.01%)	0.106		0.185		0.204	211.0
Alpha	None	None	Not applicable					

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 400 µm)
Air kerma	Effective	H*10	Hp10		
2.754E-05	3.022E-05	4.167E-05	4.398E-05	2.11E-01	7.08E-03

Internal dose

	Ingestion	Inhalation
Worker dose coefficient (Sv/Bq)	8.4E-11	1.4E-10

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	100 Bq/g or 10 MBq	**CNSC classification:**	Class B
CNSC unconditional clearance level:	1 Bq/g	**Release of surface contaminated objects:**	3 or 10 Bq/cm² (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of Detection (gamma 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
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: In-vivo, in-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B. For general safety precautions, please refer to appendix C.

Tb-161

Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Tb | Common name: Terbium | Atomic weight: 161 | Atomic number: 65

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 6.89 days

Decay scheme: Tb-161 (6.89 d, β(-) 100%) → Dy-161 (stable)

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)					
Gamma & X-ray	25.65 keV (22.0%)	550.25 keV (0.04%)	Lead		Steel		Concrete	
	48.92 keV (15.6%)	475.69 keV (0.02%)	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
	46.00 keV (10.8%)	343.67 keV (0.01%)	3.6E-02	7.1E-02	0.21	0.48	8.25	13.3
			0.25	0.79	1.60	5.62	39.6	56.6
Beta(-), Beta(+), electrons	518.50 keV (61.0%)	593.10 keV (10.0%)	Continuous Slowing Down Approximation (CSDA) range					
	41.13 keV (40.0%)	567.40 keV (5.5%)	Aluminium		PMMA (Plexiglass)		Water	Air
	17.86 keV (38.0%)	518.50 keV (61.0%)	1.020		1.841		2.042	2066
Alpha	None	None	Not applicable					

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 400 µm)
Air kerma	Effective	H*10	Hp10		
1.197E-05	7.606E-06	1.435E-05	1.499E-05	1.19E+00	1.90E-01

Internal dose

	Ingestion	Inhalation
Worker dose coefficient (Sv/Bq)	5.4E-11	3.8E-10

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	1 kBq/g or 1 MBq	**CNSC classification:**	Class C
CNSC unconditional clearance level:	1 Bq/g	**Release of surface contaminated objects:**	30 or 10 Bq/cm² (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of Detection (gamma 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: 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: In-vivo, in-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B. For general safety precautions, please refer to appendix C.

Ho-166

Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Ho	Common name: Holmium	Atomic weight: 166	Atomic number: 67

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 1.1167 days
Decay scheme: Ho-166 (1.1167 d, β(-) 100%) → Er-166 (stable)

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)					
Gamma & X-ray	80.57 keV (6.71%) 49.13 keV (5.5%) 48.22 keV (3.1%)	1749.91 keV (0.028%) 1662.48 keV (0.12%) 1581.89 keV (0.187%)	Lead		Steel		Concrete	
			1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
			0.80	15.3	4.28	31.5	47.8	73.2
			35.2	44.7	71.7	76.7	230.1	233.4
Beta(-), Beta(+), electrons	1853.88 keV (50.0%) 1773.30 keV (49.0%) 70.82 keV (26.5%)	1853.88 keV (50.0%) 1773.30 keV (49.0%) 393.96 keV (0.95%)	Continuous Slowing Down Approximation (CSDA) range					
			Aluminium		PMMA (Plexiglass)		Water	Air
			4.025		7.472		8.304	8285
Alpha	None	None	Not applicable					

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 400 µm)
Air kerma	Effective	H*10	Hp10		
3.840E-06	4.214E-06	5.289E-06	5.476E-06	1.52E+00	7.65E-01

Internal dose

	Ingestion	Inhalation
Worker dose coefficient (Sv/Bq)	3.0E-10	3.6E-10

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	1 kBq/g or 100 kBq	**CNSC classification:**	Class C
CNSC unconditional clearance level:	100 Bq/g	**Release of surface contaminated objects:**	30 or 100 Bq/cm² (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of Detection (gamma 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: 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: In-vivo, in-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B. For general safety precautions, please refer to appendix C.

Yb-169

Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Yb Common name: Ytterbium Atomic weight: 169 Atomic number: 70

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 32.02 days
Decay scheme: Yb-169 (32.02 d, EC 100%) → Tm-169 (stable)

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)					
Gamma & X-ray	50.74 keV (94.0%)	307.74 keV (10.1%)	Lead		Steel		Concrete	
	49.77 keV (53.3%)	261.08 keV (1.69%)	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
	63.12 keV (44.1%)	240.33 keV (0.12%)	0.20	0.41	1.69	8.01	38.8	37.1
			1.55	3.95	21.5	29.2	123.3	107.3
Beta(-), Beta(+), electrons	50.39 keV (35.2%)	305.43 keV (0.03%)	Continuous Slowing Down Approximation (CSDA) range					
	138.57 keV (13.3%)	297.62 keV (0.14%)	Aluminium		PMMA (Plexiglass)		Water	Air
	117.82 keV (10.8%)	258.77 keV (0.01%)	0.1179		0.2051		0.2267	234.2
Alpha	None	None	Not applicable					

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 400 µm)
Air kerma	Effective	H*10	Hp10		
4.323E-05	5.177E-05	6.720E-05	7.178E-05	9.05E-01	1.61E-02

Internal dose

	Ingestion	Inhalation
Worker dose coefficient (Sv/Bq)	1.7E-10	1.0E-09

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	10 Bq/g or 10 kBq	**CNSC classification:**	Class B
CNSC unconditional clearance level:	1 Bq/g	**Release of surface contaminated objects:**	3 or 10 Bq/cm² (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of Detection (gamma 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: 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: In-vivo, in-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

Lu-177

Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Lu	Common name: Lutetium	Atomic weight: 177	Atomic number: 71

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 6.65 days
Decay scheme: Lu-177 (6.65 d, β(-) 100%) → Hf-177 (stable)

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)					
Gamma & X-ray	208.37 keV (10.4%) 112.95 keV (6.2%) 55.79 keV (2.79%)	321.32 keV (0.22%) 249.67 keV (0.20%) 208.37 keV (10.4%)	Lead		Steel		Concrete	
			1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
			0.53	0.65	8.95	8.74	70.8	37.5
			2.13	2.64	28.7	25.9	152.7	101.6
Beta(-), Beta(+), electrons	498.30 keV (79.3%) 176.98 keV (11.6%) 385.35 keV (9.10%)	498.30 keV (79.3%) 385.35 keV (9.1%) 255.97 keV (0.01%)	Continuous Slowing Down Approximation (CSDA) range					
			Aluminium		PMMA (Plexiglass)		Water	Air
			0.8062		1.450		1.607	1630
Alpha	None	None	Not applicable					

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 400 µm)
Air kerma	Effective	H*10	Hp10		
4.078E-06	4.935E-06	5.996E-06	6.420E-06	1.22E+00	1.43E-01

Internal dose

	Ingestion	Inhalation
Worker dose coefficient (Sv/Bq)	3.5E-11	2.9E-10

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	1 kBq/g or 10 MBq	**CNSC classification:**	Class C
CNSC unconditional clearance level:	100 Bq/g	**Release of surface contaminated objects:**	30 or 10 Bq/cm² (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma 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: 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: In-vivo, in-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

W-181

Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: W | Common name: Tungsten | Atomic weight: 181 | Atomic number: 74

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 121.0 days
Decay scheme: W-181 (121.0 d, EC 100%) → Ta-181 (stable)

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)					
Gamma & X-ray	57.53 keV (33.2%) 56.28 keV (19.0%) 65.2 keV (11.2%)	152.31 keV (0.08%) 136.26 keV (0.03%) 67.0 keV (2.82%)	Lead		Steel		Concrete	
			1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
			0.12	0.12	0.81	0.75	24.5	14.0
			0.40	0.42	2.55	2.64	55.7	41.4
Beta(-), Beta(+), electrons	49.65 keV (3.05%) 84.89 keV (0.08%) 68.84 keV (0.04%)	142.43 keV (0.02%) 84.89 keV (0.08%) 68.84 keV (0.04%)	Continuous Slowing Down Approximation (CSDA) range					
			Aluminium		PMMA (Plexiglass)		Water	Air
			0.02119		0.03559		0.03922	41.33
Alpha	None	None	Not applicable					

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 400 µm)
Air kerma	Effective	H*10	Hp10		
5.716E-06	7.410E-06	9.849E-06	1.066E-05	1.06E-02	3.90E-03

Internal dose

	Ingestion	Inhalation
Worker dose coefficient (Sv/Bq)	3.2E-11	1.8E-10

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	1 kBq/g or 10 MBq	**CNSC classification:**	Class C
CNSC unconditional clearance level:	10 Bq/g	**Release of surface contaminated objects:**	30 or 10 Bq/cm² (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma 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
2. Hand-held: halogen quenched thin window Geiger Mueller, gas-flow proportional, sealed-gas proportional, plastic scintillator
1. Non-portable: NaI well counter
2. Non-portable: liquid scintillation counter, gas-flow proportional counter

Dosimetry
External: Gamma/beta
Internal: In-vivo, in-vitro

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.

W-185

Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: W	Common name: Tungsten	Atomic weight: 185	Atomic number: 74

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 75.1 days
Decay scheme: W-185 (75.1 d, β(-) 100%) → Re-185 (stable)

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)					
Gamma & X-ray	61.14 keV (0.02%) 125.36 keV (0.02%) 59.72 keV (0.01%)	125.36 keV (0.02%) 61.14 keV (0.02%) 59.72 keV (0.01%)	Lead		Steel		Concrete	
			1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
			0.21	0.21	1.80	2.95	40.5	25.5
			0.70	0.79	10.0	12.8	98.7	78.6
Beta(-), Beta(+), electrons	432.8 keV (99.9%) 307.4 keV (0.07%) 53.68 keV (0.04%)	432.8 keV (99.9%) 307.4 keV (0.07%) 53.68 keV (0.04%)	Continuous Slowing Down Approximation (CSDA) range					
			Aluminium		PMMA (Plexiglass)		Water	Air
			0.6633		1.189		1.318	1339
Alpha	None	None	Not applicable					

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 400 µm)
Air kerma	Effective	H*10	Hp10		
5.301E-09	7.040E-09	8.782E-09	9.523E-09	1.06E+00	1.09E-01

Internal dose

	Ingestion	Inhalation
Worker dose coefficient (Sv/Bq)	6.1E-11	1.0E-09

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	10 kBq/g or 10 MBq	**CNSC classification:**	Class C
CNSC unconditional clearance level:	1 kBq/g	**Release of surface contaminated objects:**	30 or 100 Bq/cm² (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma 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: gas-flow proportional, sealed-gas proportional, plastic scintillator, halogen quenched thin window Geiger-Mueller
2. Hand-held: NaI scintillator
1. Non-portable: liquid scintillation counter, gas-flow proportional counter
2. Non-portable: NaI well counter

Dosimetry

External: Gamma/beta
Internal: In-vivo, in-vitro

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.

W-188

Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: W	Common name: Tungsten	Atomic weight: 188	Atomic number: 74

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 69.78 days
Decay scheme: W-188 (69.78 d, β(-) 100%) → Re-188 (16.98 h, β(-) 100%) → Os-188 (stable)

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)					
Gamma & X-ray	155.04 keV (15.2%) 63.00 keV (2.37%) 632.98 keV (1.28%)	1956.96 keV (0.015%) 1802.04 keV (0.036%) 1785.95 keV (0.020%)	Lead		Steel		Concrete	
			1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
			1.34	7.00	14.7	17.2	83.2	52.2
			19.8	34.6	57.5	62.1	204.4	180.9
Beta(-), Beta(+), electrons	349.00 keV (99.0%) 2120.37 keV (71.0%) 1965.34 (26.0%)	2120.37 keV (71.0%) 1965.34 (26.0%) 1487.36 keV (1.65%)	Continuous Slowing Down Approximation (CSDA) range					
			Aluminium		PMMA (Plexiglass)		Water	Air
			4.653		8.671		9.640	9600
Alpha	None	None	Not applicable					

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 400 µm)
Air kerma	Effective	H*10	Hp10		
7.337E-06	8.239E-06	9.808E-06	1.023E-05	2.51E+00	8.44E-01

Internal dose

	Ingestion	Inhalation
Worker dose coefficient (Sv/Bq)	6.3E-10	6.2E-09

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	100 Bq/g or 100 kBq	**CNSC classification:**	Class B
CNSC unconditional clearance level:	1 Bq/g	**Release of surface contaminated objects:**	3 or 0.1 Bq/cm² (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma 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: 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: In-vivo, in-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

Ir-192

Part 1 – RADIONUCLIDE IDENTIFICATION

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

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 73.82 days

Decay scheme: Ir-192 (73.82 d, β(-) 95.1%) → Pt-192 (stable)

↘ (73.82 d, EC 4.9%) → Os-192 (stable)

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		Steel		Concrete	
	468.07 keV (47.8%)	884.54 keV (0.29%)	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
	308.46 keV (29.7%)	612.46 keV (5.34%)	2.69	3.00	21.4	14.7	94.9	50.4
			10.4	14.7	53.8	42.3	204.1	134.3
Beta(-), Beta(+), electrons	675.10 keV (47.9%)	675.10 keV (47.9%)	Continuous Slowing Down Approximation (CSDA) range					
	538.80 keV (41.4%)	601.75 keV (0.010%)	Aluminium		PMMA (Plexiglass)		Water	Air
	258.70 keV (5.59%)	600.90 keV (0.015%)	1.209		2.189		2.428	2453
Alpha	None	None	Not applicable					

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm^2 at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm^2 at 400 µm)
Air kerma	Effective	H*10	Hp10		
1.093E-04	1.169E-04	1.396E-04	1.444E-04	1.44E+00	3.39E-01

Internal dose

	Ingestion	Inhalation
Worker dose coefficient (Sv/Bq)	4.5E-10	2.7E-9

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	10 Bq/g or 10 kBq	**CNSC classification:**	Class B
CNSC unconditional clearance level:	1 Bq/g	**Release of surface contaminated objects:**	3 or 1 Bq/cm^2 (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma 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: 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: In-vivo, in-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

Tl-201

Part 1 – RADIONUCLIDE IDENTIFICATION

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

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 3.04 days
Decay scheme: Tl-201 (3.04 d, EC 100%) → Hg-201 (stable)

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		Steel		Concrete	
	68.90 keV (27.7%)	165.88 keV (0.15%)	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
	80.30 keV (20.7%)	135.34 keV (2.7%)	0.24	0.25	1.89	2.31	41.7	23.7
			0.86	1.08	9.59	19.9	96.7	84.1
Beta(-), Beta(+), electrons	84.33 keV (15.9%)	163.87 keV (0.83%)	Continuous Slowing Down Approximation (CSDA) range					
	15.76 keV (9.96%)	152.59 keV (2.69%)	Aluminium		PMMA (Plexiglass)		Water	Air
	17.35 keV (8.64%)	151.04 keV (0.04%)	0.1377		0.2402		0.2656	274.0
Alpha	None	None	Not applicable					

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 400 µm)
Air kerma	Effective	H*10	Hp10		
1.065E-05	1.459E-05	1.771E-05	1.936E-05	2.50E-01	7.55E-03

Internal dose

	Ingestion	Inhalation
Worker dose coefficient (Sv/Bq)	7.2E-11	8.5E-11

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	100 Bq/g or 1 MBq	**CNSC classification:**	Class C
CNSC unconditional clearance level:	100 Bq/g	**Release of surface contaminated objects:**	30 or 100 Bq/cm² (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma 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
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: In-vivo, in-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B.

For general safety precautions, please refer to appendix C.

Pb-212

Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Pb	Common name: Lead	Atomic weight: 212	Atomic number: 82

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 10.64 hours

Decay scheme: Pb-212 (10.64 h, β(-) 100%) →Bi-212 (1 h, β(-) 64.1%) → Po-212 (298 ns, α 100%) → Pb-208 (stable)

↘ (1 h, α 35.9%) → Tl-208 (3.1 m, β(-) 100%) → Pb-208 (stable)

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)					
Gamma & X-ray	238.63 keV (43.5%) 2614.55 keV (35.8%) 583.19 keV (30.6%)	2614.55 keV (35.8%) 1805.96 keV (0.12%) 1679.45 keV (0.07%)	Lead		Steel		Concrete	
			1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
			11.2	15.2	32.2	28.1	115.5	87.8
			48.4	55.3	97.6	92.0	317.7	287.5
Beta(-), Beta(+), electrons	335.37 keV (83.3%) 2254.00 keV (55.2%) 27.20 keV (18.8%)	2254.00 keV (55.2%) 1803.81 keV (17.6%) 1292.47 keV (8.80%)	Continuous Slowing Down Approximation (CSDA) range					
			Aluminium		PMMA (Plexiglass)		Water	Air
			5.800		10.88		12.10	12010
Alpha	8785.06 keV (64.1%) 6050.92 keV (25.1%) 6090.02 keV (9.70%)	8785.06 keV (64.1%) 6090.02 keV (9.70%) 6050.92 keV (25.1%)	Not applicable					

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 400 µm)
Air kerma	Effective	H*10	Hp10		
1.617E-04	1.645E-04	1.924E-04	1.938E-04	1.65E+03	8.69E-01

Internal dose

	Ingestion	Inhalation
Worker dose coefficient (Sv/Bq)	5.6E-09	3.0E-07

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	10 Bq/g or 100 kBq	**CNSC classification:**	Class A
CNSC unconditional clearance level:	0.1 Bq/g	**Release of surface contaminated objects:**	0.3 or 0.1 Bq/cm² (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma 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: thin ZnS scintillator
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: In-vivo, in-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B. For general safety precautions, please refer to appendix C.

Ra-223

Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Ra	Common name: Radium	Atomic weight: 223	Atomic number: 88

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 11.43 days

Decay scheme: Ra-223 (11.43 d, α 100%) → Rn-219 (3.96 s, α 100%) → Po-215 (1.78 ms, α 100%) → Pb-211 (36.1 m, β(-) 100%) →
→Bi-211 (2.17 m, α 99.7%) → Tl-207 (4.77 m, β(-) 100%) → Pb-207 (stable)
↘ (2.17 m, β(-) 0.3%) → Po-211 (516 ms, α 100%) → Pb-207 (stable)

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)					
Gamma & X-ray	83.78 keV (26.1%)	1196.60 keV (0.013%)	Lead		Steel		Concrete	
	12.10 keV (23.0%)	1109.50 keV (0.15%)	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
	81.07 keV (15.4%)	1080.20 keV (0.015%)	1.61	2.78	15.6	15.0	81.9	48.9
			9.55	22.9	49.0	46.1	190.0	141.0
Beta(-), Beta(+), electrons	1422.00 keV (99.45%)	1422.00 keV (99.45%)	Continuous Slowing Down Approximation (CSDA) range					
	1373.00 keV (90.8%)	1373.00 keV (90.8%)	Aluminium		PMMA (Plexiglass)		Water	Air
	541.00 keV (6.60%)	968.00 keV (1.66%)	2.994		5.519		6.131	6138
Alpha	7386.40 keV (99.9%)	7450.00 keV (0.29%)	Not applicable					
	6623.10 keV (83.4%)	7386.40 keV (99.9%)						
	6819.40 keV (81.0%)	6819.40 keV (81.0%)						

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm^2 at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm^2 at 400 µm)
Air kerma	Effective	H*10	Hp10		
3.835E-05	4.134E-05	4.928E-05	5.156E-05	2.99E+01	1.41E+00

Internal dose

	Ingestion	Inhalation
Worker dose coefficient (Sv/Bq)	4.1E-08	2.2E-06

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	100 Bq/g or 100 kBq	**CNSC classification:**	Class A
CNSC unconditional clearance level:	1 Bq/g	**Release of surface contaminated objects:**	0.3 or 0.1 Bq/cm^2 (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma 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: thin ZnS scintillator
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: In-vivo, in-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B. For general safety precautions, please refer to appendix C.

Ra-224

Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Ra	Common name: Radium	Atomic weight: 224	Atomic number: 88

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 3.64 days

Decay scheme: Ra-224 (3.64 d, α 100%) → Rn-220 (55.8 s, α 100%) → Po-216 (150 ms, α 100%) → Pb-212 (10.64 h, β(-) 100%) →
→Bi-212 (1 h, β(-) 64.1%) → Po-212 (298 ns, α 100%) → Pb-208 (stable)
↘ (1 h, α 35.9%) → Tl-208 (3.1 m, β(-) 100%) → Pb-208 (stable)

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)					
Gamma & X-ray	238.63 keV (43.5%) 2614.55 keV (35.8%) 583.19 keV (30.6%)	2614.55 keV (35.8%) 1805.96 keV (0.12%) 1679.45 keV (0.07%)	Lead		Steel		Concrete	
			1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
			10.8	15.1	31.6	28.0	114.4	86.8
			47.9	55.3	96.8	92.0	315.3	287.3
Beta(-), Beta(+), electrons	335.37 keV (83.3%) 2254.00 keV (55.2%) 27.20 keV (18.8%)	2254.00 keV (55.2%) 1803.81 keV (17.6%) 1292.47 keV (8.80%)	Continuous Slowing Down Approximation (CSDA) range					
			Aluminium		PMMA (Plexiglass)		Water	Air
			5.800		10.88		12.10	12010
Alpha	6778.60 keV (100%) 6288.22 keV (99.9%) 5685.50 keV (94.7%)	10552.1 keV (0.011%) 8785.06 keV (64.1%) 6778.60 keV (100%)	Not applicable					

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 400 µm)
Air kerma	Effective	H*10	Hp10		
1.631E-04	1.660E-04	1.942E-04	1.957E-04	1.65E+03	8.71E-01

Internal dose

	Ingestion	Inhalation
Worker dose coefficient (Sv/Bq)	2.9E-08	1.1E-06

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	10 Bq/g or 100 kBq	**CNSC classification:**	Class A
CNSC unconditional clearance level:	1 Bq/g	**Release of surface contaminated objects:**	0.3 or 0.1 Bq/cm² (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma 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: thin ZnS scintillator
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: In-vivo, in-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B. For general safety precautions, please refer to appendix C.

Ra-226

Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Ra | Common name: Radium | Atomic weight: 226 | Atomic number: 88

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 1600 years

Decay scheme: Ra-226 (1600 y, α 100%) → Rn-222 (3.82 d, α 100%) → Po-218 (3.1 m, α 100%) → Pb-214 (26.8 m, β(-) 100%) → →Bi-214 (19.9 m, β(-) 100%) → Po-214 (163.7 µs, α 100%) → Pb-210 (22.16 y, β(-) 100%) → Bi-210 (5.01 d, β(-) 100%) → →Po-210 (138.4 d, α 100%) → Pb-206 (stable)

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)					
Gamma & X-ray	609.32 keV (47.0%) 351.93 keV (35.4%) 11.16 keV (25.0%)	3053.90 keV (0.022%) 2978.80 keV (0.015%) 2922.10 keV (0.016%)	Lead		Steel		Concrete	
			1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
			9.46	12.6	30.2	24.2	108.8	75.0
			40.1	46.7	85.2	75.7	276.4	228.8
Beta(-), Beta(+), electrons	1161.30 keV (100%) 17.00 keV (84%) 672.08 keV (46.2%)	3270.00 keV (16.1%) 2661.00 keV (0.5%) 2111.00 keV (0.014%)	Continuous Slowing Down Approximation (CSDA) range					
			Aluminium		PMMA (Plexiglass)		Water	Air
			7.284		13.76		15.31	15150
Alpha	7687.04 keV (100%) 6002.50 (100%) 5489.60 (99.9%)	7687.04 keV (100%) 6002.50 (100%) 5489.60 (99.9%)	Not applicable					

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 400 µm)
Air kerma	Effective	H*10	Hp10		
2.170E-04	2.199E-04	2.584E-04	2.600E-04	7.09E+02	1.81E+00

Internal dose

	Ingestion	Inhalation
Worker dose coefficient (Sv/Bq)	1.3E-07	1.3E-05

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	10 Bq/g or 10 kBq	**CNSC classification:**	Class A
CNSC unconditional clearance level:	0.1 Bq/g	**Release of surface contaminated objects:**	0.3 or 0.1 Bq/cm² (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma 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: thin ZnS scintillator
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: In-vivo, in-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B. For general safety precautions, please refer to appendix C.

Ac-225

Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: Ac | Common name: Actinium | Atomic weight: 225 | Atomic number: 89

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 10.0 days

Decay scheme: Ac-225 (10.0 d, α 100%) → Fr-221 (4.8 m, α 100%) → At-217 (32.3 ms, α 100%) →
→ Bi-213 (45.59 m, β(-) 97.9%) → Po-213 (4.2 µs, α 100%) → Pb-209 (3.25 h, β(-) 100%) → Bi-209 (1.9E19 y)
↘ (45.59 m, α 2.09%) → Tl-209 (2.2 m, β(-) 100%) → Bi-209 (1.9E19 y)

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)					
Gamma & X-ray	440.46 keV (26.1%)	1567.00 keV (2.09%)	Lead		Steel		Concrete	
	218.10 keV (11.6%)	1101.00 keV (0.50%)	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
	465.00 keV (2.09%)	808.90 keV (0.29%)	2.98	4.70	20.4	17.2	91.4	54.9
			16.1	41.4	59.6	58.8	214.0	172.8
Beta(-), Beta(+), electrons	644.60 keV (97.9%)	1822.00 keV (2.09%)	Continuous Slowing Down Approximation (CSDA) range					
	1432.00 keV (66%)	1432.00 keV (66%)	Aluminium		PMMA (Plexiglass)		Water	Air
	993.00 keV (30.8%)	993.00 keV (30.8%)	3.949		7.328		8.144	8127
Alpha	7067.00 keV (99.9%)	8376.00 keV (97.9%)	Not applicable					
	8376.00 keV (97.9%)	7067.00 keV (99.9%)						
	6341.10 keV (83.4%)	6341.10 keV (83.4%)						

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 400 µm)
Air kerma	Effective	H*10	Hp10		
2.798E-05	3.023E-05	3.580E-05	3.700E-05	2.04E+03	9.90E-01

Internal dose

	Ingestion	Inhalation
Worker dose coefficient (Sv/Bq)	2.2E-08	2.1E-06

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	10 Bq/g or 10 kBq	**CNSC classification:**	Class A
CNSC unconditional clearance level:	0.1 Bq/g	**Release of surface contaminated objects:**	0.3 or 0.1 Bq/cm² (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma 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: thin ZnS scintillator
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: In-vivo, in-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B. For general safety precautions, please refer to appendix C.

Am-241

Part 1 – RADIONUCLIDE IDENTIFICATION

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

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 432.8 years
Decay scheme: Am-241 (432.8 y, α 100%) → Np-247 (2.14E6 y)

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 (0.021%) 98.97 keV (0.022%) 59.54 keV (36.0%)	Lead		Steel		Concrete	
			1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL	1st H/TVL	2nd H/TVL
			1.6E-02	8.5E-02	8.1E-02	0.62	3.13	19.3
			0.26	0.40	1.70	2.51	41.3	42.3
Beta(-), Beta(+), electrons	10.09 keV (40.4%) 41.93 keV (30.2%) 15.59 keV (17.0%)	94.36 keV (0.096%) 81.36 keV (0.25%) 54.93 keV (10.1%)	Continuous Slowing Down Approximation (CSDA) range					
			Aluminium		PMMA (Plexiglass)		Water	Air
			0.02518		0.04246		0.04681	49.23
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 (mGy/h or mSv/h) @ 1 m per MBq				Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm² at 400 µm)
Air kerma	Effective	H*10	Hp10		
4.042E-06	4.358E-06	6.211E-06	6.696E-06	1.48E-02	3.65E-03

Internal dose

	Ingestion	Inhalation
Worker dose coefficient (Sv/Bq)	5.9E-08	1.7E-05

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	**Release of surface contaminated objects:**	0.3 or 0.1 Bq/cm² (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma 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: thin ZnS scintillator
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: In-vivo, in-vitro

Part 6 – SAFETY PRECAUTIONS

For emergency procedures, please refer to appendix B. For general safety precautions, please refer to appendix C.

Uranium (processed, natural isotopic distribution)

Part 1 – RADIONUCLIDE IDENTIFICATION

Chemical symbol: U	Common name: Uranium	Atomic weight: 238/235/234	Atomic number: 92

Isotopic Distribution (% by mass): U-238 (99.2745%), U-235 (0.7200%), U-234 (0.0055%)
Isotopic Distribution (% by activity): U-238 (48.28%), U-235 (2.25%), U-234 (49.47%)

Part 2 – RADIATION CHARACTERISTICS

Physical half-life: 4.468E09 years (U-238), 7.038E08 years (U-235), 2.457E05 years (U-234)
Decay scheme: U-238 (4.468E09 y, α 100%) → Th-234 (24.09 d, β(-) 100%) → Pa-234m (1.17 m, β(-) 99.85%) → U-234 (2.457E05 y)
U-235 (7.038E08 y, α 100%) → Th-231 (1.0633 d, β(-) 100%) → Pa-231 (3.276E04 y)

Radiation type	Most abundant emissions (>10 keV, >0.01%)	Most energetic emissions (>10 keV, >0.01%)	Shielding information (mm)			
Gamma & X-ray	13.52 keV (14.86%) 92.6 keV (2.52%) 63.30 keV (1.79%) 185.71 keV (1.29%)	1737.80 keV (0.010%) 1001.02 keV (0.40%) 786.27 keV (0.023%) 766.36 keV (0.15%)	Not applicable, significant self-shielding effect			
Beta(-), Beta(+), electrons	2278.00 keV (47.1%) 192.00 keV (35.7%) 98.50 keV (11.2%) 36.90 keV (10.4%)	2278.00 keV (47.1%) 1492.00 keV (0.019%) 1468.00 keV (0.47%) 1234.00 keV (0.50%)	Continuous Slowing Down Approximation (CSDA) range			
			Aluminium	PMMA (Plexiglass)	Water	Air
			5.021	9.377	10.43	10370
Alpha	4198.00 keV (37.4%) 4774.90 keV (35.3%) 4722.60 keV (14.1%) 4150.00 keV (10.8%)	4774.90 keV (35.3%) 4722.60 keV (14.1%) 4603.80 keV (0.098%) 4599.10 keV (0.12%)	Not applicable			

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate (mGy/h or mSv/h) @ 1 m per MBq	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm^2 at 70 µm)	Equivalent dose rate to skin from direct contamination (mSv/h per kBq/cm^2 at 400 µm)
Not scalable, significant self-shielding effect	8.70E-01	3.95E-01

Internal dose

Worker dose coefficients (Sv/Bq)	Ingestion (soluble)		Ingestion (relatively insoluble)	
	3.30E-08		3.30E-09	
Inhalation (Type F)	**Inhalation (Type M)**	**Inhalation (Type S)**	**Inhalation (Type F/M)**	**Inhalation (Type M/S)**
2.35E-07	1.30E-06	1.25E-05	3.85E-07	5.15E-06

Type F: Uranium hexafluoride, uranyl tributyl-phosphate, fA=2E-2
Type M: Uranyl acetylacetonate; depleted uranium aerosols; vaporised uranium metal; all unspecified forms, fA=4E-3
Type S: fA=2E-4
Type F/M: Uranyl nitrate, uranium peroxide hydrate, ammonium diuranate, uranium trioxide, fA=1.6E-2
Type M/S: Uranium octoxide, uranium dioxide, fA=6E-4

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption quantity:	1 Bq/g or 10 kBq	**CNSC classification:**	Class A
CNSC unconditional clearance level:	1 Bq/g	**Release of surface contaminated objects:**	0.3 or 1 Bq/cm^2 (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (gamma 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: thin ZnS scintillator
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: In-vivo, in-vitro

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 13.5 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. To validate the concrete HVL and TVL values, a comparison between various means of calculation was performed. The first and second concrete TVL values for Co-60, Cs-137, F-18, and Tc-99m were also computed using the Monte Carlo N-Particle transport code (MCNP6) for comparison with the values obtained using Nucleonica. The MCNP6 simulation comprised a series of concentric 5 cm thick concrete spheres, with air and a detector placed between each sphere. All TVL values computed using MNCP6 and Nucleonica were within approximately ±10% of each other. A third comparison was also made using RadPro Calculator [16] (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 2.35 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	29.2	28.1
Co-60 TVL 2	19.5	21.1	23.6
Cs-137 TVL 1	26	23.8	23.9
Cs-137 TVL 2	17	16.0	16.3
F-18 TVL 1	24	22.2	21.7
F-18 TVL 2	15.5	14.4	14.8
Tc-99m TVL 1	14.5	13.5	13.5
Tc-99m TVL 2	9.5	8.4	8.7

Appendix B: Emergency procedures

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

Personal decontamination techniques

- Wash well with soap and tepid water and monitor skin (see CNSC Expectations for Licensee Response During (nuclearsafety.gc.ca)
- 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*)

* potentially volatile radionuclides will have an internal dose coefficient for both vapour and aerosol on the information sheet

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

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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[16] Rad Pro Calculator