^{3}H	Nuclide Safety Data Sheet Hydrogen-3 [Tritium]	^{3}H

I. PHYSICAL DATA

Radiation:	Beta (100% abundance)	
Energy:	Max.: 18.6 keV; Average: 5.7 keV	
Half-Life [$T_{½}$] :	Physical $T_{½}$:	12.3 years
	Biological $T_{½}$:	10 - 12 days
	Effective $T_{½}$:	10 - 12 days*

* Large liquid intake (3-4 liters/day) reduces effective $T_{½}$ by a factor of 2+; ^{3}H is easily flushed from the body

Specific Activity:	9650 Ci/g [357 TBq/g] max.	
Beta Range:	Air:	6 mm [0.6 cm; 0.25 inches]
	Water:	0.006 mm [0.0006 cm; 3/10,000 inches]
	Solids/Tissue:	Insignificant [No ^{3}H betas pass through the dead layer of skin]

II. RADIOLOGICAL DATA

Radiotoxicity:	Least radiotoxic of all nuclides; CEDE, ingestion or inhalation: Tritiated water: 1.73E-11 Sv/Bq (0.064 mrem/uCi) of ^{3}H intake Organic Compounds: 4.2E-11 Sv/Bq (0.16 mrem/uCi) of ^{3}H intake
Critical Organ:	Body water or tissue
Exposure Routes:	Ingestion, inhalation, puncture, wound, skin contamination absorption
Radiological Hazard:	External Exposure - None from weak ^{3}H beta Internal Exposure & Contamination - Primary concern

III. SHIELDING

None required - not an external radiation hazard

IV. DOSIMETRY MONITORING

Urine bioassay is the only readily available method to assess intake [for tritium, no intake = no dose] Be sure to provide a urine sample to Radiation Safety for confirmatory bioassay whenever your annual ^{3}H use exceeds 8 mCi. If negative, no further bioassay is required unless use exceeds 100 mCi at one time or 1000 mCi in one year, or after any accident/incident in which an intake is suspected

V. DETECTION & MEASUREMENT

Liquid Scintillation Counting is the only readily available method for detecting ^{3}H
NOTE: PORTABLE SURVEY METERS WILL NOT DETECT LABORATORY QUANTITIES OF ^{3}H

VI. SPECIAL PRECAUTIONS

- Avoid skin contamination [absorption], ingestion, inhalation, & injection [all routes of intake]
- Many tritium compounds readily penetrate gloves and skin; handle such compounds remotely and wear double gloves, changing the outer pair at least every 20 minutes.
- While tritiated DNA precursors are considered more toxic that $^{3}H_2O$, they are generally less volatile and hence do not normally present a greater hazard
- The inability of direct-reading instruments to detect tritium and the slight permeability of most material to [tritiated] water & hydrogen [tritium] facilitates undetected spread of contamination. Use extreme care in handling and storage [e.g. sealed double or multiple containment] to avoid contamination, especially with high specific activity compounds.

^{14}C	Nuclide Safety Data Sheet Carbon-14	^{14}C

I. PHYSICAL DATA

Radiation:	Beta (100% abundance)	
Energy:	Max.: 156 keV; Average: 49 keV	
Half-Life [$T_{½}$] :	Physical $T_{½}$:	5730 years
	Biological $T_{½}$:	12 days
	Effective $T_{½}$:	Bound - 12 days; unbound - 40 days
Specific Activity:	4.46 Ci/g [0.165 TBq/g] max.	
Beta Range:	Air:	24 cm [10 inches]
	Water/Tissue:	0.28 mm [0.012 inches]
	[~1% of ^{14}C betas transmitted through dead skin layer, i.e. 0.007 cm depth]	
	Plastic:	0.25 mm [0.010 inches]

II. RADIOLOGICAL DATA

Radiotoxicity:	0.023 mrem/uCi of $^{14}CO_2$ inhaled; 2.09 mrem/uCi organic compounds inhaled/ingested
Critical Organ:	Fat tissue [most labeled compounds]; bone [some labeled carbonates]
Exposure Routes:	Ingestion, inhalation, puncture, wound, skin contamination absorption
Radiological Hazard:	External Exposure – None from weak ^{14}C beta Internal Exposure & Contamination - Primary concern

III. SHIELDING

None required - mCi quantities not an external radiation hazard

IV. DOSIMETRY MONITORING

Urine bioassay is the most readily available method to assess intake [for ^{14}C, no intake = no dose]
Provide a urine sample to Radiation Safety after any accident/incident in which an intake is suspected

V. DETECTION & MEASUREMENT

Portable Survey Meters: Geiger-Mueller [~10% efficiency];
Beta Scintillator [~5% efficiency]

Wipe Test: Liquid Scintillation Counting is the best readily available method for counting ^{14}C wipe tests

VI. SPECIAL PRECAUTIONS

- Avoid skin contamination [absorption], ingestion, inhalation, & injection [all routes of intake]
- Many ^{14}C compounds readily penetrate gloves and skin; handle such compounds remotely and wear double gloves, changing the outer pair at least every 20 minutes.

^{18}F	Nuclide Safety Data Sheet Fluorine – 18 **www.nchps.org**	^{18}F

I. PHYSICAL DATA

Radiation:	Gamma: 511 keV (194% abundance; positron annihilation radiation)	
	Betas: 634 keV (97% abundance) [Positron]	
Gamma Constant:	1.879E-04 mSv/hr per MBq at 1 meter[1] [6.952E-4 mrem/hr per uCi at 1 m]	
Half-Life [$T_{½}$] :	Physical $T_{½}$:	1.83 hours[2]
	Biological $T_{½}$:	~ 6 hours[3]
	Effective $T_{½}$:	~ 1.4 hours
Specific Activity:	9.51E7 Ci/g [3.52E18 Bq/g] [2]	

II. RADIOLOGICAL DATA

Radiotoxicity[4]:	Ingested:	2.9E-10 Sv/Bq [1.1 mrem/uCi] stomach wall
		3.31E-11 Sv/Bq [0.12 mrem/uCi] CEDE
	Inhaled:	1.4E-10 Sv/Bq [0.52 mrem/uCi] Lung
		2.3E-11 Sv/Bq [0.084 mrem/uCi] CEDE
Critical Organ[4]:	Lung (inhalation); stomach wall (ingestion)	
Exposure Routes:	Ingestion, inhalation, puncture, wound, skin contamination absorption	
Radiological Hazard:	External & Internal Exposure; Contamination	

III. SHIELDING[2]

	Gamma:	Half Value Layer (HVL)	Tenth Value Layer (TVL)
Lead [Pb]		6 mm	17 mm

Beta Shielding: 1.7 mm plastic

- The accessible dose rate should be background but must be < 2 mR/hr

IV. DOSIMETRY MONITORING

- Always wear radiation dosimetry monitoring badges [body & ring] whenever handling ^{18}F

V. DETECTION & MEASUREMENT

Portable Survey Meters	Geiger-Mueller [e.g. Bicron PGM] to assess shielding effectiveness
Wipe Test:	Gamma Counter, Gamma Well Counter, or Liquid Scintillation Counter (wipes must be run soon after sample collection due to short half-life)

VI. SPECIAL PRECAUTIONS

- Store ^{18}F behind lead (Pb) shielding
- Use tools to indirectly handle unshielded sources and potentially contaminated vessels; avoid direct hand contact
- Ensure that an appropriate, operational survey meter (e.g. Bicron PGM) is present in the work area and turned on whenever ^{18}F is handled, so that any external exposure issues will be immediately apparent and hence quickly addressed
- Shield waste containers as needed to maintain accessible dose rate ALARA and < 2 mR/hr
- ^{18}F's short half life (109.8 minutes) makes rigorous inventory tracking unnecessary. Also, storage for decay can normally be accomplished at the point of use, since ^{18}F compounds will decay to background levels within a day or two.

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[1] Shleien et al, Eds. Handbook of Health Phys. & Rad. Health, 3rd ed. (Baltimore, MD: Williams & Wilkins, 1998), p. 6-9

[2] Delacroix et al, Radiation Protection Dosimetry - Radionuclide and Radiation Protection Data Handbook (Kent, England: Nuclear Technology Publishing, 1998), p. 24

[3] Saha, G. Fundamentals of Nuclear Pharmacy, 2nd ed. (New York: Springer-Verlag, 1984), p. 238

[4] Federal Guidance Report No. 11 (Oak Ridge, TN; Oak Ridge National Laboratory, 1988), p. 156, 122

VII. GENERAL PRECAUTIONS

1. Maintain your occupational exposure to radiation As Low As Reasonably Achievable [ALARA].
2. Ensure all persons handling radioactive material are trained, registered, & listed on an approved protocol.
3. Review the nuclide characteristics on (reverse side) prior to working with that nuclide. Review the protocol(s) authorizing the procedure to be performed and follow any additional precautions in the protocol. Contact the responsible Principal Investigator to view the protocol information.
4. Plan experiments to minimize external exposure by reducing exposure time, using shielding and increasing your distance from the radiation source. Reduce internal and external radiation dose by monitoring the worker and the work area after each use of radioactive material, then promptly cleaning up any contamination discovered. Use the smallest amount of radioisotope possible so as to minimize radiation dose and radioactive waste.
5. Keep an accurate inventory of radioactive material, including records of all receipts, transfers & disposal. Perform and record regular lab surveys.
6. Provide for safe disposal of radioactive waste by following institutional Waste Handling & Disposal Procedures. Avoid generating mixed waste (combinations of radioactive, biological, and chemical waste). Note that lab staff may not pour measurable quantities of radioactive material down the drain.
7. If there is a question regarding any aspect of the radiation safety program or radioactive material use, contact Radiation Safety.

VIII. LAB PRACTICES

1. Disposable gloves, lab coats, and safety glasses are the minimum PPE [Personal Protective Equipment] required when handling radioactive material. Remove & discard potentially contaminated PPE prior to leaving the area where radioactive material is used.
2. Clearly outline radioactive material use areas with tape bearing the legend "radioactive". Cover lab bench tops where radioactive material will be handled with plastic-backed absorbent paper; change this covering periodically and whenever it's contaminated. Alternatively cover benches with thick plastic sheeting (i.e., painter's drop cloth), periodically wipe it clean and replace it if torn.
3. Label each unattended radioactive material container with the radioactive symbol, isotope, activity, and, except for waste, the ICN [inventory control number]. Place containers too small for such labels in larger labeled containers.
4. Handle radioactive solutions in trays large enough to contain the material in the event of a spill.
5. Never eat, drink, smoke, handle contact lenses, apply cosmetics, or take/apply medicine in the lab; keep food, drinks, cosmetics, etc. out of the lab entirely. Do not pipette by mouth.
6. Never store [human] food and beverage in refrigerators/freezers used for storing radioisotopes.
7. Prevent skin contact with skin-absorbable solvents containing radioactive material.
8. Fume hoods and biological safety cabinets for use with non-airborne radioactive material must be approved (through the protocol) and must be labeled "Caution Radioactive Material".
9. All volatile, gaseous, or aerosolized radioactive material must be used only in a properly operating charcoal and/or HEPA filtered fume hood or Biological Safety Cabinet bearing a Caution Airborne Radioactivity hood label, unless otherwise specified in writing by the Radiation Safety Officer. In particular, radioactive iodination must be performed only in these specially designed fume hoods. The Radiation Safety Officer (through a protocol) must approve all such use.
10. Take special precautions when working with radioactive compounds that tend to become volatile [e.g. ^{35}S labeled amino acids, ^{125}I - iodine tends to volatilize in acidic solutions]. These precautions may include: using the materials only within an approved fume hood, protecting the house vacuum system with primary and secondary vapor trapping devices, and covering active cell cultures with carbon-impregnating paper.
11. Use sealed containers and appropriate secondary containment to carry radioactive material between rooms Notify Radiation Safety staff before taking any radioactive material off site.

^{32}P	Nuclide Safety Data Sheet Phosphorous-32	^{32}P

I. PHYSICAL DATA

Radiation:	Beta (100% abundance)	
Energy:	Maximum: 1,710 keV; Average: 695 keV	
Half-Life [$T_{½}$] :	Physical $T_{½}$:	14.29 days
	Biological $T_{½}$:	Bone ~ 1155 days; Whole Body ~ 257 days[1]
	Effective $T_{½}$:	14.29 days
Specific Activity:	286,500 Ci/g [10,600 TBq/g] max.	
Beta Range:	Air:	610 cm [240 inches; 20 feet]
	Water/Tissue:	0.76 cm [0.33 inches]
	Plastic:	0.61 mm [3/8 inches]

II. RADIOLOGICAL DATA

Radiotoxicity[2]:	94.7 mrem/uCi [Lung] & 15.5 mrem/uCi [CEDE] of ^{32}P inhaled 29.9 mrem/uCi [Bone Marrow] & 8.77 mrem/uCi [CEDE] of ^{32}P ingested
Critical Organ:	Bone [soluble ^{32}P]; Lung [Inhalation]; GI Tract [Ingestion - insoluble compounds]
Exposure Routes:	Ingestion, inhalation, puncture, wound, skin contamination absorption
Radiological Hazard:	External Exposure [unshielded dose rate at 1 mCi ^{32}P vial mouth[3]: approx. 26 rem/hr], Internal Exposure & Contamination

III. SHIELDING

Shield ^{32}P with 3/8 inch Plexiglas and monitor for Bremstrahlung; If Bremstrahlung X-rays detected outside Plexiglas, apply 1/8 to 1/4 inch lead [Pb] shielding outside Plexiglas
The accessible dose rate should be background but must be < 2 mR/hr

IV. DOSIMETRY MONITORING

Wear radiation dosimetry monitoring badges [body & ring] if regularly handling mCi quantities of ^{32}P

V. DETECTION & MEASUREMENT

Portable Survey Meters: Geiger-Mueller
Wipe Test: Liquid Scintillation Counting is an acceptable method for counting ^{32}P wipe tests

VI. SPECIAL PRECAUTIONS

- Avoid skin contamination [absorption], ingestion, inhalation, & injection [all routes of intake].
- Store ^{32}P (including waste) behind Plexiglas shielding [3/8 inch thick]; survey (with GM meter) to check adequacy of shielding (accessible dose rate < 2 mR/hr; should be background); apply lead [Pb] shielding outside Plexiglas if needed.
- Use 3/8 inch Plexiglas shielding to minimize exposure while handling ^{32}P.
- Use tools [e.g. Beta Blocks] to handle ^{32}P sources and contaminated objects; avoid direct hand contact.
  - Always have a portable survey meter present and turned on when handling ^{32}P.
- ^{32}P is not volatile, even when heated, and can be ignored as an airborne contaminant[4] unless aerosolized.

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[1] NCRP Report No. 65, p.88
[2] Federal Guidance Report No. 11 [Oak Ridge, TN; Oak Ridge National Laboratory, 1988], p. 122, 156
[3] Dupont/NEN, Phosphorous-32 Handling Precautions [Boston, MA; NEN Products, 1985]
[4] Bevelacqua, J. Contemporary Health Physics [New York; John Wiley & Sons, 1995], p. 282

^{33}P	Nuclide Safety Data Sheet Phosphorous-33	^{33}P

I. PHYSICAL DATA

Radiation:	Beta (100% abundance)	
Energy:	Maximum: 248.5 keV; Average: 76.4 keV	
Half-Life [$T_{½}$] :	Physical $T_{½}$:	25.3 days
	Biological $T_{½}$:	Bone ~ 1155 days; Whole Body ~ 257 days[1]
	Effective $T_{½}$:	25.3 days
Specific Activity:	156,000 Ci/g	[5,780 TBq/g] max.
Beta Range:	Air:	50 cm [~ 20 inches]
	Water/Tissue:	0.06 cm [0.024 inches]
	Plastic:	0.05 cm [0.02 inches]

II. RADIOLOGICAL DATA

Radiotoxicity[2]: 15.6 mrem/uCi [Lung] & 2.32 mrem/uCi [CEDE] of ^{33}P inhaled
1.85 mrem/uCi [Bone Marrow] & 0.92 mrem/uCi [CEDE] of ^{33}P ingested

Critical Organ: Bone [soluble ^{33}P]; Lung [Inhalation]; GI Tract [Ingestion - insoluble compounds]

Exposure Routes: Ingestion, inhalation, puncture, wound, skin contamination absorption

Radiological Hazard: External Exposure – mCi quantities not considered an external hazard
Internal Exposure & Contamination - Primary concern

III. SHIELDING

None required - mCi quantities not an external radiation hazard

IV. DOSIMETRY MONITORING

Urine bioassay is the most readily available method to assess intake [for ^{33}P, no intake = no dose].
Provide a urine sample to Radiation Safety after any accident/incident in which an intake is suspected.
No dosimetry badges needed when working with ^{33}P [beta energy too low to be detected]

V. DETECTION & MEASUREMENT

Portable Survey Meters: Geiger-Mueller
Wipe Test: Liquid Scintillation Counting works well for counting ^{33}P wipe tests

VI. SPECIAL PRECAUTIONS

- Avoid skin contamination [absorption], ingestion, inhalation, & injection [all routes of intake]
- ^{33}P is not volatile, even when heated, and can be ignored as an airborne contaminant[3] unless aerosolized.

[1] NCRP Report No. 65, p.88
[2] Federal Guidance Report No. 11 [Oak Ridge, TN; Oak Ridge National Laboratory, 1988], p. 122, 156
[3] Bevelacqua, J. Contemporary Health Physics [New York; John Wiley & Sons, 1995], p. 282

^{35}S	Nuclide Safety Data Sheet Sulfur-35	^{35}S

I. PHYSICAL DATA

Radiation:	Beta (100% abundance)	
Energy:	Maximum: 167.47 keV; Average: 48.8 keV	
Half-Life [$T_{½}$] :	Physical $T_{½}$:	87.44 days
	Biological $T_{½}$:	623 days [unbound ^{35}S]; 90 days [bound ^{35}S]
	Effective $T_{½}$:	44 - 76 days [unbound ^{35}S]
Specific Activity:	42,707 Ci/g [1,580 TBq/g] max.	
Beta Range:	Air:	26 cm [10.2 inches]
	Water/Tissue:	0.32 mm [0.015 inches]
	Plastic:	0.25 mm [0.010 inches]

II. RADIOLOGICAL DATA

Radiotoxicity[1]:	2.48 mrem/uCi [CEDE] of ^{35}S inhaled 0.733 mrem/uCi of ^{35}S ingested
Critical Organ:	Testis
Exposure Routes:	Ingestion, inhalation, puncture, wound, skin contamination absorption
Radiological Hazard:	External Exposure – None from weak ^{35}S beta Internal Exposure & Contamination - Primary concern

III. SHIELDING

None required - mCi quantities not an external radiation hazard

IV. DOSIMETRY MONITORING

Urine bioassay is the most readily available method to assess intake [for ^{35}S, no intake = no dose]
Provide a urine sample to Radiation Safety after any accident/incident in which an intake is suspected

V. DETECTION & MEASUREMENT

Portable Survey Meters: Geiger-Mueller [~10% efficiency]
Beta Scintillator [~5% efficiency]

Wipe Test: Liquid Scintillation Counting is the best readily available method for counting ^{35}S wipe tests

VI. SPECIAL PRECAUTIONS

- Avoid skin contamination [absorption], ingestion, inhalation, & injection [all routes of intake]
  - Many ^{35}S compounds and metabolites are slightly volatile and may create contamination problems if not sealed or otherwise controlled. This occurs particularly when ^{35}S amino acids are thawed, and when they are added to cell culture media and incubated. Therefore vent thawing ^{35}S vials in a hood. Incubators used with ^{35}S will have an activated charcoal trap placed in the incubator. Possibility of volatilization must be taken into account when surveying after use.

[1] Federal Guidance Report No. 11 [Oak Ridge, TN; Oak Ridge National Laboratory, 1988], p. 122,156

^{45}Ca	Nuclide Safety Data Sheet Calcium-45	^{45}Ca

I. PHYSICAL DATA

Radiation:	Beta (100% abundance)	
Energy:	Maximum: 257 keV; Average: 77 keV	
Half-Life [$T_{½}$] :	Physical $T_{½}$:	162.61 days
	Biological $T_{½}$:	Bone ~ 18,000 days[1]
	Effective $T_{½}$:	163 Days
Specific Activity:	17,800 Ci/g [659 TBq/g] max.	
Beta Range:	Air:	52 cm [20 inches]
	Water/Tissue:	0.062 cm [0.024 inches]
	Plastic	0.053 cm [0.021 inches]

II. RADIOLOGICAL DATA

Radiotoxicity[2]: 35.8 mrem/uCi [Lung] & 16.2 mrem/uCi [Bone] of ^{45}Ca inhaled
19.4 mrem/uCi [Bone] & 3.2 mrem/uCi [CEDE] of ^{45}Ca ingested

Critical Organ: Bone; Lung [Inhalation]

Exposure Routes: Ingestion, inhalation, puncture, wound, skin contamination absorption

Radiological Hazard: External Exposure - mCi quantities not considered an external hazard
Internal Exposure & Contamination - Primary concern

III. SHIELDING

None required - mCi quantities not an external radiation hazard

IV. DOSIMETRY MONITORING

Urine bioassay is the most readily available method to assess intake. Provide a urine sample to Radiation Safety after any accident/incident in which an intake is suspected.
No dosimetry badges needed to work with mCi quantities of ^{45}Ca.

V. DETECTION & MEASUREMENT

Portable Survey Meters: Geiger-Mueller
Wipe Test: Liquid Scintillation Counting works well for counting ^{45}Ca wipe tests

VI. SPECIAL PRECAUTIONS

- Avoid skin contamination [absorption], ingestion, inhalation, & injection [all routes of intake]

[1] "Calcium-45 Handling Precautions", E.I. DuPont de Numours & Co., NEN Products [Boston, MA; 1985]
[2] Federal Guidance Report No. 11 [Oak Ridge, TN; Oak Ridge National Laboratory, 1988], p. 122, 156

^{51}Cr	Nuclide Safety Data Sheet Chromium-51	^{51}Cr

I. PHYSICAL DATA

Radiation:	Gamma - 320 keV (9.8% abundance)
	X-ray - 5 keV (22% abundance)
Gamma Constant:	0.018 mR/hr per mCi @ 1.0 meter [6.32E-6 mSv/hr per MBq @ 1.0 meter][1]
Half-Life [$T_{½}$] :	Physical $T_{½}$: 27.7 days
	Biological 616 days
	Effective $T_{½}$: 26.6 days (whole body)
Specific Activity:	9.24E4 Ci/g [3.42E3 TBq/g] max.

II. RADIOLOGICAL DATA

Radiotoxicity:	0.145 mrem/uCi of ^{51}Cr ingested [CEDE]
	0.334 mrem/uCi of ^{51}Cr inhaled [CEDE]
Critical Organ:	Lower Large Intestine [LLI]
Intake Routes:	Ingestion, inhalation, puncture, wound, skin contamination (absorption);
Radiological Hazard:	External & Internal Exposure; Contamination

III. SHIELDING

	Half Value Layer [HVL]	Tenth Value Layer [TVL]
Lead [Pb]	2 mm (0.07 inches)	6.6 mm (0.23 inches)
Concrete	2.8 cm (1.1 inches)	9.3 cm (3.7 inches)
Plexiglas	4.8 cm (1.9 inches)	16 cm (6.3 inches)

The accessible dose rate should be background but must be < 2 mR/hr

IV. DOSIMETRY MONITORING

Wear radiation dosimetry monitoring badges [body & ring] when handling ^{51}Cr

V. DETECTION & MEASUREMENT

Portable Survey Meters	Geiger-Mueller
Wipe Test:	Liquid Scintillation Counter

VI. SPECIAL PRECAUTIONS

- Store ^{51}Cr (including waste) behind lead shielding [¼ - ½ inch thick]; survey (with GM meter) to check adequacy of shielding (accessible dose rate < 2 mR/hr; should be background)
- Avoid skin contamination [absorption], ingestion, inhalation, & injection [all routes of intake]
- Use shielding to minimize exposure while handling ^{51}Cr
- Use tools to handle ^{51}Cr sources and contaminated objects; avoid direct hand contact

[1] Health Physics & Radiological Health Handbook, 3rd Ed. [Baltimore, MD; Williams & Wilkins, 1998] p. 6-9

^{64}Cu	Nuclide Safety Data Sheet Copper - 64 **www.nchps.org**	^{64}Cu

I. PHYSICAL DATA

Radiation[1]:	Gamma & X-ray: 511 keV (36% abundance), 7-8 keV (34% abundance)	
	Betas: 578 keV (37% abundance), 653 keV positron (18% abundance)	
Gamma Constant:	3.6E-5 mSv/hr per MBq at 1 m (0.133 mrem/hr per mCi @ 1m)[1]	
Half-Life [$T_{½}$] :	Physical $T_{½}$:	12.7 hours[1]
	Biological $T_{½}$:	~ 7 day[2]
	Effective $T_{½}$:	~ 11.8 hours
Specific Activity[3]:	3.86E6 Ci/g [1.43E17 Bq/g]	

II. RADIOLOGICAL DATA

Radiotoxicity:	0.466 mrem/uCi [1.26E-10 Sv/Bq] of ^{64}Cu ingested [CEDE][4]
	0.277 mrem/uCi [7.48E-11 Sv/Bq] of ^{64}Cu inhaled [CEDE][4]
Critical Organ:	Lung (inhalation)[3,4]
Exposure Routes:	Ingestion, inhalation, puncture, wound, skin contamination/absorption
Radiological Hazard:	External & Internal Exposure; Contamination

III. SHIELDING

	Half Value Layer (HVL)	Tenth Value Layer (TVL)
Lead [Pb][3]	6 mm	17 mm

- The accessible dose rate should be background but must be < 2 mR/hr

IV. DOSIMETRY MONITORING

- Always wear radiation dosimetry monitoring badges [body & ring] whenever handling ^{64}Cu
- Submit a urine sample to Radiation Safety two to 24 hours [i.e. As Soon As Possible] after any suspected intake of ^{64}Cu; alert Radiation Safety of the short half-lived nuclide involved.

V. DETECTION & MEASUREMENT

Portable Survey Meters	Geiger-Mueller [e.g. Bicron PGM] to assess shielding effectiveness
	Low Energy Gamma Detector [e.g. Ludlum 44-21] for contamination surveys
Wipe Test:	Gamma Counter, Well Gamma Counter, or Liquid Scintillation Counter

VI. SPECIAL PRECAUTIONS

- Store ^{64}Cu behind 2 inch [~5 cm] thick lead (Pb) bricks
- Use tools to indirectly handle unshielded sources and potentially contaminated vessels; avoid direct hand contact
- Ensure that an appropriate, operational survey meter (e.g. Bicron PGM) is present in the work area and turned on whenever ^{64}Cu is handled, so that any external exposure issues will be immediately apparent and hence quickly addressed
- Shield waste containers as needed to maintain accessible dose rate ALARA and < 2 mR/hr

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[1] Shleien et al, Handbook of Health Physics and Radiological Health (Baltimore, MD: Williams & Wilkins, 1998), p. 6-9 & 8-53

[2] BNL/NRC, Interpretation of Bioassay Measurements [NUREG/CR-4884] (Nuclear Regulatory Commission, 1987), p.B-58

[3] Delacroix et al, Radiation Protection Dosimetry - Radionuclide and Radiation Protection Data Handbook 2002 (Kent, England: Nuclear Technology Publishing, 2002), p. 60

[4] Federal Guidance Report No. 11 (Oak Ridge, TN; Oak Ridge National Laboratory, 1988), p. 125, 158

VII. GENERAL PRECAUTIONS

1. Maintain your occupational exposure to radiation As Low As Reasonably Achievable [ALARA].
2. Ensure all persons handling radioactive material are trained, registered, & listed on an approved protocol.
3. Review the nuclide characteristics on (reverse side) prior to working with that nuclide. Review the protocol(s) authorizing the procedure to be performed and follow any additional precautions in the protocol. Contact the responsible Principal Investigator to view the protocol information.
4. Plan experiments to minimize external exposure by reducing exposure time, using shielding and increasing your distance from the radiation source. Reduce internal and external radiation dose by monitoring the worker and the work area after each use of radioactive material, then promptly cleaning up any contamination discovered. Use the smallest amount of radioisotope possible so as to minimize radiation dose and radioactive waste.
5. Keep an accurate inventory of radioactive material, including records of all receipts, transfers & disposal. Perform and record regular lab surveys.
6. Provide for safe disposal of radioactive waste by following institutional Waste Handling & Disposal Procedures. Avoid generating mixed waste (combinations of radioactive, biological, and chemical waste). Note that lab staff may not pour measurable quantities of radioactive material down the drain.
7. If there is a question regarding any aspect of the radiation safety program or radioactive material use, contact Radiation Safety.

VIII. LAB PRACTICES

1. Disposable gloves, lab coats, and safety glasses are the minimum PPE [Personal Protective Equipment] required when handling radioactive material. Remove & discard potentially contaminated PPE prior to leaving the area where radioactive material is used.
2. Clearly outline radioactive material use areas with tape bearing the legend "radioactive". Cover lab bench tops where radioactive material will be handled with plastic-backed absorbent paper; change this covering periodically and whenever it's contaminated. Alternatively cover benches with thick plastic sheeting (i.e., painter's drop cloth), periodically wipe it clean and replace it if torn.
3. Label each unattended radioactive material container with the radioactive symbol, isotope, activity, and, except for waste, the ICN [inventory control number]. Place containers too small for such labels in larger labeled containers.
4. Handle radioactive solutions in trays large enough to contain the material in the event of a spill.
5. Never eat, drink, smoke, handle contact lenses, apply cosmetics, or take/apply medicine in the lab; keep food, drinks, cosmetics, etc. out of the lab entirely. Do not pipette by mouth.
6. Never store [human] food and beverage in refrigerators/freezers used for storing radioisotopes.
7. Prevent skin contact with skin-absorbable solvents containing radioactive material.
8. Fume hoods and biological safety cabinets for use with non-airborne radioactive material must be approved (through the protocol) and must be labeled "Caution Radioactive Material".
9. All volatile, gaseous, or aerosolized radioactive material must be used only in a properly operating charcoal and/or HEPA filtered fume hood or Biological Safety Cabinet bearing a Caution Airborne Radioactivity hood label, unless otherwise specified in writing by the Radiation Safety Officer. In particular, radioactive iodination must be performed only in these specially designed fume hoods. The Radiation Safety Officer (through a protocol) must approve all such use.
10. Take special precautions when working with radioactive compounds that tend to become volatile [e.g. ^{35}S labeled amino acids, ^{125}I - iodine tends to volatilize in acidic solutions]. These precautions may include: using the materials only within an approved fume hood, protecting the house vacuum system with primary and secondary vapor trapping devices, and covering active cell cultures with carbon-impregnating paper.
11. Use sealed containers and appropriate secondary containment to carry radioactive material between rooms Notify Radiation Safety staff before taking any radioactive material off site.

^{99m}Tc	Nuclide Safety Data Sheet Technetium - 99m	^{99m}Tc

I. PHYSICAL DATA

Radiation:	Gamma: 141 keV (89% abundance)	
	X-rays: 18 keV (6% abundance), 21 keV (1.2% abundance)	
Gamma Constant:	0.77 R/hr at 1 cm from an unshielded 1 mCi point source[1]	
Half-Life [$T_{½}$] :	Physical $T_{½}$:	6.0 hours
	Biological $T_{½}$:	~ 1 day[2]
	Effective $T_{½}$:	~ 4.8 hours
Specific Activity:	5.27E6 Ci/g [1.95E17 Bq/g]	

II. RADIOLOGICAL DATA

Radiotoxicity:	63 mrem/mCi [1.7E-8 mSv/Bq] of ^{99m}Tc ingested [CEDE][3]
	27 mrem/mCi [7.21E-9 mSv/Bq] of ^{99m}Tc inhaled [CEDE]
Critical Organ:	Thyroid Gland[3]; Upper GI tract[1]
Exposure Routes:	Ingestion, inhalation, puncture, wound, skin contamination absorption
Radiological Hazard:	External & Internal Exposure; Contamination

III. SHIELDING

	Half Value Layer (HVL)	Tenth Value Layer (TVL)
Lead [Pb]	<1 mm (<0.035 inches)	1 mm (0.035 inches)

- The accessible dose rate should be background but must be < 2 mR/hr

IV. DOSIMETRY MONITORING

- Always wear radiation dosimetry monitoring badges [body & ring] whenever handling ^{99m}Tc
- Submit a urine sample to Radiation Safety two to 24 hours [i.e. As Soon As Possible] after any suspected intake of ^{99m}Tc; alert Radiation Safety of the short half-lived nuclide involved.

V. DETECTION & MEASUREMENT

Portable Survey Meters	Geiger-Mueller
Wipe Test:	Liquid Scintillation Counter or Gamma Counter

VI. SPECIAL PRECAUTIONS

- Store ^{99m}Tc behind ¼-inch [~ 0.6 cm] thick lead (Pb) shielding
- Use tools to indirectly handle unshielded sources and potentially contaminated vessels; avoid direct hand contact
- Ensure that an appropriate, operational survey meter is present in the work area and turned on whenever ^{99m}Tc is handled, so that any external exposure issues will be immediately apparent and hence quickly addressed
- Shield waste containers as needed to maintain accessible dose rate ALARA and < 2 mR/hr

[1] Dupont/NEN, Technetium-99-m Handling Precautions (Boston, MA: NEN, 1985)

[2] Delacroix et al, Radiation Protection Dosimetry – Radionuclide and Radiation Protection Data Handbook (Kent, England: Nuclear Technology Publishing, 1998), p. 71

[3] Federal Guidance Report No. 11 (Oak Ridge TN; Oak Ridge National Laboratory, 1988) P. 130, 162

^{111}In	Nuclide Safety Data Sheet Indium-111	^{111}In

I. PHYSICAL DATA

Primary Radiation:	Gamma – 245 keV (94% abundance), 171 keV (90% abundance), 23 keV (69% abundance)
Gamma Constant:	8.9E-6 mrem/hr at 30 cm from 1 mCi [9.9E-4 mSv/hr at 30 cm from1MBq][1]
Physical Half-Life [$T_{½}$] :	2.80 days
Specific Activity:	4.19E5 Ci/g [1.55E16 Bq/g][1]

II. RADIOLOGICAL DATA

Radiotoxicity:	1,330 mrem/mCi [3.59E-7 mSv/Bq] of ^{111}In ingested [CEDE][2] 840 mrem/mCi [2.27E-7 mSv/Bq] of ^{111}In inhaled [CEDE] [2]
Critical Organ:	Lower Large Intestine[1]
Intake Routes:	Ingestion, inhalation, puncture, wound, skin contamination (absorption);
Radiological Hazard:	Internal and External Exposure, Contamination

III. SHIELDING

	Half Value Layer [HVL]	Tenth Value Layer [TVL]
Lead [Pb]	<1 mm (<0.035 inches)	3 mm (0.035 inches)

→ The accessible dose rate should be background but must be < 2 mR/hr

IV. DOSIMETRY MONITORING

- Always wear radiation dosimetry monitoring badges [body & ring] whenever handling ^{111}In

V. DETECTION & MEASUREMENT

Portable Survey Meters:

Geiger-Mueller

Wipe Test: Gamma counter

VI. SPECIAL PRECAUTIONS

- Store ^{111}In behind ¼-inch [~ 0.6 cm] thick lead (Pb) shielding
- Use tools to indirectly handle unshielded sources and potentially contaminated vessels; avoid direct hand contact
- Ensure that an appropriate, operational survey meter is present in the work area and turned on whenever ^{111}In is handled, so that any external exposure issues will be immediately apparent and hence quickly addressed
- Shield waste containers as needed to maintain accessible dose rate ALARA and < 2 mR/hr

[1] Delacroix et al, Radiation Protection Dosimetry – Radionuclide and Radiation Protection Data Handbook (Kent, England: Nuclear Technology Publishing, 1998), p. 78

[2] Federal Guidance Report No. 11 (Oak Ridge TN; Oak Ridge National Laboratory, 1988) P. 130, 162

^{125}I	Nuclide Safety Data Sheet Iodine-125	^{125}I

I. PHYSICAL DATA

Radiation:	Gamma - 35.5 keV (7% abundance)
	X-ray - 27 keV (113% abundance)
Gamma Constant:	0.27 mR/hr per mCi @ 1.0 meter [7.432E-5 mSv/hr per MBq @ 1.0 meter][1]
Half-Life [$T_{½}$] :	Physical $T_{½}$: 60.14 days
	Biological $T_{½}$: 120-138 days (unbound iodine)
	Effective $T_{½}$: 42 days (unbound iodine)
Specific Activity:	1.73E4 Ci/g [642 TBq/g] max.

II. RADIOLOGICAL DATA

Radiotoxicity[2]:	3.44E-7 Sv/Bq (1273 mrem/uCi) of ^{125}I ingested [Thyroid]
	2.16 E-7 Sv/Bq (799 mrem/uCi) of ^{125}I inhaled [Thyroid]
Critical Organ:	Thyroid Gland
Intake Routes:	Ingestion, inhalation, puncture, wound, skin contamination (absorption);
Radiological Hazard:	External & Internal Exposure; Contamination

III. SHIELDING

	Half Value Layer [HVL]	Tenth Value Layer [TVL]
Lead [Pb]	0.02 mm (0.0008 inches)	0.07 mm (0.003 inches)

- The accessible dose rate should be background but must be < 2 mR/hr

IV. DOSIMETRY MONITORING

- Always wear radiation dosimetry monitoring badges [body & ring] whenever handling > 10 µCi of ^{125}I
- Conduct a baseline thyroid scan prior to first use of 1 mCi or more of radioactive iodine
- Conduct thyroid scan no earlier than 6 hours but within 72 hours of handling 1 mCi or more of ^{125}I or after any suspected intake

V. DETECTION & MEASUREMENT

Portable Survey Meters:

Geiger-Mueller

Low Energy Gamma Detector [~19% eff. for ^{125}I] for contamination surveys

Wipe Test: Liquid Scintillation Counter or Gamma Counter

VI. SPECIAL PRECAUTIONS

- Avoid skin contamination [absorption], ingestion, inhalation, & injection [all routes of intake]
- Use shielding [lead or leaded Plexiglas] to minimize exposure while handling mCi quantities of ^{125}I
- Avoid making low pH [acidic] solutions containing ^{125}I to avoid volatilization
- For Iodinations:
  - Use a cannula adapter needle to vent stock vials of ^{125}I used; this prevents puff releases
  - Cover test tubes used to count or separate fractions from iodinations with parafilm or other tight caps to prevent release while counting or moving outside the fume hood.

[1] Health Physics & Radiological Health Handbook, 3rd Ed. [Baltimore, MD; Williams & Wilkins, 1998] p. 6-11

[2] Federal Guidance Report No. 11 (Oak Ridge TN; Oak Ridge National Laboratory, 1988) P. 136, 166

^{131}I	Nuclide Safety Data Sheet Iodine-131	^{131}I

I. PHYSICAL DATA

Radiation:	Gammas & X-rays: primary 364 keV (81% abundance); others 4 – 723 keV
	Betas: primary 606 keV (89% abundance); others 248 – 807 keV
Gamma Constant:	0.28 mR/hr per mCi @ 1.0 meter [7.647E-5 mSv/hr per MBq @ 1.0 meter][1]
Half-Life [$T_{½}$] :	Physical $T_{½}$: 8.04 days
	Biological $T_{½}$: 120-138 days (unbound iodine)
	Effective $T_{½}$: 7.6 days (unbound iodine)
Specific Activity:	1.24E5 Ci/g [4,600 TBq/g] max.

II. RADIOLOGICAL DATA

Radiotoxicity[2]:	4.76 E-7 Sv/Bq (1.76 rem/uCi) of ^{131}I ingested [Thyroid]
	2.92 E-7 Sv/Bq (1.08 rem/uCi) of ^{131}I inhaled [Thyroid]
Critical Organ:	Thyroid Gland
Intake Routes:	Ingestion, inhalation, puncture, wound, skin contamination (absorption);
Radiological Hazard:	External & Internal Exposure; Contamination

III. SHIELDING

	Half Value Layer [HVL]	Tenth Value Layer [TVL]
Lead [Pb][3]	3 mm (0.12 inches)	11 mm (0.43 inches)

→ The accessible dose rate should be background but must be < 2 mR/hr

IV. DOSIMETRY MONITORING

- Always wear radiation dosimetry monitoring badges [body & ring] whenever handling ^{131}I
- Conduct a baseline thyroid scan prior to first use of radioactive iodine
- Conduct thyroid scan no earlier than 6 hours but within 72 hours of handling 1 mCi or more of ^{131}I or after any suspected intake

V. DETECTION & MEASUREMENT

Portable Survey Meters:

Geiger-Mueller to assess shielding effectiveness & contamination

Wipe Test: Liquid Scintillation Counter or Gamma Counter

VI. SPECIAL PRECAUTIONS

- Avoid skin contamination [absorption], ingestion, inhalation, & injection [all routes of intake]
- Use shielding [lead or leaded Plexiglas] to minimize exposure while handling mCi quantities of ^{131}I
- Avoid making low pH [acidic] solutions containing ^{131}I to avoid volatilization
- For Iodinations:
  - Use a cannula adapter needle to vent stock vials of ^{131}I used; this prevents puff releases
  - Cover test tubes used to count or separate fractions from iodinations with parafilm or other tight caps to prevent release while counting or moving outside the fume hood.

[1] Health Physics & Radiological Health Handbook, 3rd Ed. [Baltimore, MD; Williams & Wilkins, 1998] p. 6-11

[2] Federal Guidance Report No. 11 (Oak Ridge TN; Oak Ridge National Laboratory, 1988) P. 136, 166

[3] HVL & TVL values from: Delacroix, D. et al. Radionuclide and Radiation Protectioin Handbook [*Radiation Protection Dosimetry*, vol. 76, nos 1-2, 1998, Nuclear Technology Publishing, Ashford, Kent, England, 1998] p. 90