Isotope Fact Sheet

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Isotope Fact Sheet

AMERICIUM-241
[^{241}Am]

PHYSICAL DATA

• Gamma Energy:	60 keV (36%)	
(x-rays from Ba-137m)	18 keV (18%)	
	14 keV (13%)	
• Beta Energy:	no beta	
• Alpha Energy:	5486 keV (85%)	
	5443 keV (13%)	
	5388 keV (1%)	
• Physical Half-Life:	432.7 years	
• Biological Half-Life:	50 years (bone)	
• Effective Half-Life:	45 years (bone)	
• Specific Activity:	3.43 Ci/gram	1.27 x 10^{11} Bq/g
• Specific Gamma Constant: (@ 1 meter)	3.14 x 10^{-1} mR/hr/mCi	8.48 x10^{-5} mSv/hr/MBq

RADIOLOGICAL DATA

- Radiological Toxicity Rating: Group 1 (very high)
- Critical Organ: Bone
- Routes of Intake: Ingestion, Inhalation, Puncture, Wound, Skin Absorption

• Committed Effective Dose Equivalent (CEDE):	3.64 x 10^{3} mrem/uCi (ingestion)	9.84 x 10^{2} mSv/MBq (ingestion)
	4.4 x 10^{5} mrem/uCi (inhalation)	1.2 x 10^{5} mSv/MBq (inhalation)
• Skin Contamination (7 mg/cm^2): (Kocher et al)	7.4 x 10^{-2} rem/hr/uCi/cm^2	1.95 x 10^{-2} mSv/h/kBq/cm^2

SHIELDING

• Half-Value Layer (HVL) for lead	<0.04 inches	<0.1 cm
HVL for steel	0.04 inches	0.1 cm
• Tenth-Value Layer (TVL) for lead	<0.04 inches	<0.1 cm
TVL for steel	0.12 inches	0.3 cm
□	□	□
• Maximum Alpha Range in Air:	1.6 inches	4 cm
• Maximum Alpha Range in Water/Tissue:	0.02 inches	0.06 cm

SURVEY INSTRUMENTATION

- A survey meter equipped with a G-M pancake or thin-window probe (with window thickness < 0.2 mg/cm^2) is effective for detecting Am-241. Detection efficiency is between 5% (end window) and 25% (upper range pancake probe).
- A survey meter equipped with a alpha scintillation probe is suitable for detection of the Am-241. Typical efficiency is 25-35%.
- Either a gamma counter or a liquid scintillation counter may be used to detect removable Am-241 contamination on wipe tests smears. The efficiency for a liquid scintillation counter can be 100% for detection of alphas.

RADIATION MONITORING DOSIMETERS

- Whole Body dosimeter: Required, unless a sealed source completely contained in an instrument.
- Finger dosimeter: Required for unsealed source.
- Whole body count may be required for suspected skin contamination or ingestion.

RADIOACTIVE WASTE

- Solids, liquids, scintillation vials, pathological materials, animal carcasses

REGULATORY COMPLIANCE INFORMATION

• Derived Air Concentration (DAC):	3 x 10^{-12} uCi/cc (occupational)	1.1 x 10^{-7} Bq/cc (occupational)
• Annual Limit of Intake (ALI*): *[1.0 ALI = 5,000 mrem CEDE]	8 x 10^{-1} uCi (ingestion)	3.0 x 10^{4} Bq (ingestion)
	1 uCi (ingestion – bone surface)	3.7 x 10^{4} Bq (ingestion – bone surface)
	6 x 10^{-3} uCi (inhalation)	2.2 x 10^{2} Bq (inhalation)
	1 x 10^{-2} uCi (inhalation – bone surface)	3.7 x 10^{2} Bq (inhalation – bone surface)
• Effluent Release Limit:	2 x 10^{-14} uCi/cc (air)	7.4 x 10^{-10} Bq/cc (air)
	2 x 10^{-8} uCi/cc (water)	7.4 x 10^{-4} Bq/cc (water)

GENERAL RADIOLOGICAL SAFETY INFORMATION

- Often used in a “sealed source” (i.e., encapsulated sources). If the source is designed to release alphas and the activity is greater than or equal to 10 microcuries, the sealed source must be “leak tested” every 3 months. If the source is designed to release only gammas and the activity is greater than or equal to 100 microcuries, the sealed source must be “leak tested” every 6 months. The leak test methodology must be capable of detecting the presence of 0.005 microcuries of removable contamination and must be taken at the nearest accessible location to the source.
- Laboratory coat and gloves must be worn when handling unsealed radioactive material. Monitor hands and change gloves frequently.
- Whole body and ring dosimeter must be worn when handling unsealed Am-241 or a sealed source that is not shielded and encased within the housing of an instrument.
- Unshielded Am-241 should be used in a well ventilated fume hood or a glove box.
- Shielding should be used to minimize exposure from Am-241.
- Store Am-241 in a shielded container.
- Remote handling tools should be used when handling Am-241.
- Practice procedures without radioactivity prior to performing the procedure with Am-241. Practice will improve dexterity and speed, along with providing opportunity to determine errors and practices that are not ALARA.
- After each use of unsealed Am-241 monitor self, work areas and floors using a survey meter equipped with a very thin walled G-M or an alpha.

Gamma exposure rate from 1 mCi point source - unshielded

Distance	mR/hr
1 cm	3140
5 cm	125.6
10 cm	31.4
100 cm	0.314

REFERENCES

Title 10 of the Code of Federal Regulations part 20
Ohio Administration Code 3701:1-38
EPA Federal Guidance Report No. 11
Shleien, The Health Physics and Radiological Health Handbook Revised Edition, (Scinta, Inc., 1992)
Health Physics & Radiological Health Handbook, 3rd Ed. [Baltimore, MD; Williams & Wilkins, 1998]
Delacoix et al, Radiation Protection Dosimetry – Radionuclide and Radiation Protection Data Handbook 2002, (Kent, England: Nuclear Technology Publishing, 2002)
www.stanford.edu/dept/EHS/prod/researchlab/radlaser/rsds.html
www.theroscientific.com
www.ludlums.com

Isotope Fact Sheet

CADMIUM-109
[^{109}Cd]

PHYSICAL DATA

• Gamma Energy:	88 keV (4%) 25 keV (15%) 22 keV (83%)	
• Electron Energy:	87 keV (10%) 84 keV (45%) 63 keV (41%)	
• Alpha Energy:	no alpha	
• Physical Half-Life:	462.6 days	
• Biological Half-Life:	9000 days*	
• Effective Half-Life:	439.4 days*	

* These are “generic” biological and effective half-lives; the specific labeled compound may alter.

• Specific Activity:	2.59 x 10^{3} Ci/gram	9.58 x 10^{13} Bq/g
• Specific Gamma Constant: (@ 1 meter)	1.85 x 10^{-1} mR/hr/mCi	4.98 x10^{-5} mSv/hr/MBq

RADIOLOGICAL DATA

- Radiological Toxicity Rating: Group 3 (moderate)
- Critical Organ: Kidneys
- Routes of Intake: Ingestion, Inhalation, Puncture, Wound, Skin Absorption

• Committed Effective Dose Equivalent (CEDE):	13.1 mrem/uCi (ingestion)	3.55 mSv/MBq (ingestion)
	1.14 x 10^{2} mrem/uCi (inhalation-class D)	3.09 x 10^{1} mSv/MBq (inhalation –class D)
	3.96 x 10^{1} mrem/uCi (inhalation-class W)	1.07 x 10^{1} mSv/MBq (inhalation –class W)
	4.52 x 10^{1} mrem/uCi (inhalation-class Y)	1.22 x 10^{1} mSv/MBq (inhalation –class Y)
• Skin Contamination	2.0 rem/hr/uCi/cm^{2}	5.4 x 10^{-1} mSv/y/kBq/cm^{2}

SHIELDING

• Half-Value Layer (HVL) for lead	<0.004 inches	<0.01 cm
HVL for steel	<0.04 inches	<0.1 cm
• Tenth-Value Layer (TVL) for lead	<0.04 inches	<0.1 cm
TVL for steel	<0.04 inches	<0.1 cm

SURVEY INSTRUMENTATION

- A survey meter equipped with a G-M pancake or thin-window probe is not recommended for detecting Cd-109. Typical efficiency for a G-M pancake survey meter is less than 1%.

- A survey meter equipped with a NaI scintillation probe is suitable for detection of the Cd-109 gamma. Typical efficiency for a thin crystal NaI scintillation probe survey meter is 2% -3%.

RADIATION MONITORING DOSIMETERS

- Whole Body dosimeter: Required

- Finger dosimeter: Required.

- Urine bioassay may be required for suspected skin contamination or ingestion.

RADIOACTIVE WASTE

- Solids, liquids, scintillation vials, pathological materials, animal carcasses

REGULATORY COMPLIANCE INFORMATION

• Derived Air Concentration (DAC):	1×10^{-8} uCi/cc (occupational – class D)	3.7×10^{-4} Bq/cc (occupational – class D)
	1×10^{-8} uCi/cc (occupational – class W or Y)	3.7×10^{-4} Bq/cc (occupational – class W or Y)
• Annual Limit of Intake (ALI*):	3×10^{2} uCi (ingestion)	1.1×10^{7} Bq (ingestion)
	4×10^{2} uCi (ingestion - kidneys)	1.5×10^{7} Bq (ingestion - kidneys)
*[1.0 ALI = 5,000 mrem CEDE]	4×10^{1} uCi (inhalation – class D)	1.5×10^{6} Bq (inhalation – class D)
	5×10^{1} uCi (inhalation – class D/kidneys)	1.8×10^{6} Bq (inhalation – class D/kidneys)
	1×10^{2} uCi (inhalation – class W or Y)	3.7×10^{6} Bq (inhalation – class W or Y)
• Effluent Release Limit:	7×10^{-11} uCi/cc (air – class D)	2.6×10^{-6} Bq/cc (air – class D)
	2×10^{-10} uCi/cc (air – class W or Y)	7.4×10^{-6} Bq/cc (air – class W or Y)
	6×10^{-6} uCi/cc (water)	2.2×10^{-1} Bq/cc (water)

GENERAL RADIOLOGICAL SAFETY INFORMATION

- Most often used in a “sealed source” (i.e., encapsulated sources). If the activity is encapsulated into a sealed source and the activity is greater than or equal to 100 microcuries, the sealed source must be “leak tested” every 6 months. The leak test methodology must be capable of detecting the presence of 0.005 microcuries of removable contamination and must be taken at the nearest accessible location to the source.
- Laboratory coat and gloves must be worn when handling unsealed radioactive material. Monitor hands and change gloves frequently.
- Whole body and ring dosimeter must be worn when handling Cd-109 (sealed or unsealed source).
- Lead shielding shall be used to minimize exposure from Cd-109.
- Indirect viewing aids should be used to minimize exposure from Cd-109.
- Store Cd-109 in lead shielding.
- Remote handling tools should be used when handling Cd-109.
- Practice procedures without radioactivity prior to performing the procedure with Cd-109. Practice will improve dexterity and speed, along with providing opportunity to determine errors and practices that are not ALARA.
- After each use of unsealed Cd-109 monitor self, work areas and floors using a survey meter equipped with a G-M or NaI probe.

Gamma exposure rate from 1 mCi point source - unshielded

Distance	mR/hr
1 cm	1850
5 cm	74
10 cm	19
100 cm	0.19

REFERENCES

Title 10 of the Code of Federal Regulations part 20
Ohio Administration Code 3701:1-38
EPA Federal Guidance Report No. 11
Shleien, The Health Physics and Radiological Health Handbook Third Edition, (Scinta, Inc., 1998)
Delacoix et al, Radiation Protection Dosimetry – Radionuclide and Radiation Protection Data Handbook 2002, (Kent, England: Nuclear Technology Publishing, 2002)
www.stanford.edu/dept/EHS/prod/researchlab/radlaser/rsds.html
http://www.stuarthunt.com/pdfs/Cadmium_109.pdf

Isotope Fact Sheet

CALCIUM-45
[^{45}Ca]

PHYSICAL DATA

- Gamma Energy: no photon
- Maximum Beta Energy: 257 keV (100%)
- Alpha Energy: no alpha

- Physical Half-Life: 163 days
- Biological Half-Life: 49 years*
- Effective Half-Life: 163 days*

* These are "generic" biological and effective half-lives; the specific labeled compound may alter.

- Specific Activity: 1.78 x 10^4 Ci/gram 6.58 x 10^{14} Bq/g

RADIOLOGICAL DATA

- Radiological Toxicity Rating: Group 2 (high)

- Critical Organ: Bone

- Routes of Intake: Ingestion, Inhalation, Puncture, Wound, Skin Absorption

• Committed Effective Dose Equivalent (CEDE):	3.19 mrem/uCi (ingestion)	0.86 mSv/MBq (ingestion)
	6.63 mrem/uCi (inhalation)	1.79 mSv/MBq (inhalation)
• Skin Contamination	3.11 rem/hr/uCi/cm^2	0.84 mSv/hr/kBq/cm^2

SHIELDING

- ¼ inch thick plexiglas/acrylic/lucite/plastic/wood

- Do not use lead foil or sheets as primary barrier! Penetrating bremsstrahlung x-ray will be produced!

- Use lead sheets or foil to shield bremsstrahlung x-rays only **after** low density plexiglas/acrylic/lucite/wood shielding.

• Maximum Beta Range in Air:	22 inches	55 cm
• Maximum Beta Range in Water/Tissue:	0.03 inches	0.07 cm
• Maximum Beta Range in Plastic:	0.02 inches	0.06 cm

SURVEY INSTRUMENTATION

- A survey meter equipped with a G-M pancake or thin-window probe is effective for detecting the betas from the Ca-45. Typical efficiency for a G-M pancake survey meter is 11%-18%.

RADIATION MONITORING DOSIMETERS

- Whole Body dosimeter: Not required
    - Finger dosimeter: Not required
    - Urine bioassay may be required for suspected skin contamination or ingestion.

RADIOACTIVE WASTE

- Solids, liquids, scintillation vials, pathological materials, animal carcasses

REGULATORY COMPLIANCE INFORMATION

• Derived Air Concentration (DAC):	4×10^{-7} uCi/cc (occupational)	1.5×10^{-2} Bq/cc (occupational)
• Annual Limit of Intake (ALI*):	2×10^{3} uCi (ingestion) 8×10^{2} uCi (inhalation)	7.4×10^{7} Bq (ingestion) 3.0×10^{7} Bq (inhalation)
*[1.0 ALI = 5,000 mrem CEDE]		
• Effluent Release Limit:	1×10^{-9} uCi/cc (air) 2×10^{-5} uCi/cc (water)	3.7×10^{-5} Bq/cc (air) 7.4×10^{-1} Bq/cc (water)

GENERAL RADIOLOGICAL SAFETY INFORMATION

- Laboratory coat and gloves must be worn when handling unsealed radioactive material. Monitor hands and change gloves frequently.
- Plastic or other low Z material shielding should be used to minimize exposure from Ca-45.
- Store Ca-45 in plastic or other low Z material.
- Remote handling tools should be used when handling Ca-45.
- Practice procedures without radioactivity prior to performing the procedure with Ca-45. Practice will improve dexterity and speed, along with providing opportunity to determine errors and practices that are not ALARA.
- After each use of unsealed Ca-45 monitor self, work areas and floors using a survey meter equipped with a pancake or thin window G-M probe.

REFERENCES

Title 10 of the Code of Federal Regulations part 20
Ohio Administration Code 3701:1-38
EPA Federal Guidance Report No. 11
Shleien, The Health Physics and Radiological Health Handbook Third Edition, (Scinta, Inc., 1998)
Delacoix et al, Radiation Protection Dosimetry – Radionuclide and Radiation Protection Data Handbook 2002, (Kent, England: Nuclear Technology Publishing, 2002)
www.stanford.edu/dept/EHS/prod/researchlab/radlaser/rsds.html
www.nchps.org/nsds.htm
www.uwm.edu/dept/ehsrm/rad/calcium.html

Isotope Fact Sheet

CARBON-14
[^{14}C]

PHYSICAL DATA

- Gamma Energy: no photon
- Maximum Beta Energy: 157 keV (100%)
- Alpha Energy: no alpha

- Physical Half-Life: 5730 years
- Biological Half-Life: 12 days
- Effective Half-Life: 12 days (bound)
  40 days (unbound)

* These are “generic” biological and effective half-lives; the specific labeled compound may alter.

- Specific Activity: 4.46 Ci/gram 1.65 x 10^{11} Bq/g

RADIOLOGICAL DATA

- Radiological Toxicity Rating: Group 3 (moderate)
- Critical Organ: Fat/Tissue (wholebody)
- Routes of Intake: Ingestion, Inhalation, Puncture, Wound, Skin Absorption
- Committed Effective Dose Equivalent (CEDE):

2.1 mrem/uCi (ingestion)	0.564 mSv/MBq (ingestion)
2.1 mrem/uCi (inhalation-organic compound)	0.564 mSv/MBq (inhalation – organic compound)
2.9 x 10^{-3} mrem/uCi (inhalation-CO)	7.83 x 10^{-4} mSv/MBq (inhalation-organic CO)
2.4 x 10^{-2} mrem/uCi (inhalation-CO_2)	6.36 x 10^{-3} mSv/MBq (inhalation-organic CO_2)

- Skin Contamination (7 mg/cm^2): (Kocher et al)

1.19 rem/h/uCi/cm^2	3.24 x 10^{-1} mSv/h/kBq/cm^2

SHIELDING

- Not required because of low energy of the beta.

• Maximum Beta Range in Air:	10 inches	25 cm
• Maximum Beta Range in Water/Tissue:	0.012 inches	0.030 cm
• Maximum Beta Range in Plastic:	0.010 inches	0.025 cm

SURVEY INSTRUMENTATION

- A survey meter equipped with a G-M pancake or thin-window probe can detect the betas from C-14. Typical efficiency for a G-M pancake survey meter is 4%-6%.

- A liquid scintillation counter should be used to detect removable C-14 contamination on wipe tests smears. Typical efficiency is greater than 85%.

RADIATION MONITORING DOSIMETERS

- Whole Body dosimeter: Not required
    - Finger dosimeter: Not required
    - Urine bioassay may be required for suspected skin contamination or ingestion.

RADIOACTIVE WASTE

- Solids, liquids, scintillation vials, pathological materials, animal carcasses

REGULATORY COMPLIANCE INFORMATION

• Derived Air Concentration (DAC):	1×10^{-6} uCi/cc (occupational) 7×10^{-4} uCi/cc (occupational-CO) 9×10^{-5} uCi/cc (occupatioal-CO_2)	3.7×10^{-2} Bq/cc (occupational) 26 Bq/cc (occupational-CO) 3.3 Bq/cc (occupational-CO_2
• Annual Limit of Intake ALI*): *[1.0 ALI = 5,000 mrem CEDE]	2×10^{3} uCi (ingestion) 2×10^{3} uCi (inhalation-organic compound) 2×10^{6} uCi (inhalation-CO) 2×10^{5} uCi (inhalation-CO_2)	7.4×10^{7} Bq (ingestion) 7.4×10^{7} Bq (inhalation-organic compounds) 7.4×10^{10} Bq (inhalation-CO) 7.4×10^{9} Bq (inhalation-CO_2)
• Effluent Release Limit:	3×10^{-9} uCi/cc (air – organic compounds) 2×10^{-6} uCi/cc (air - CO) 3×10^{-7} uCi/cc (air - CO_2) 3×10^{-5} uCi/cc (water)	1.1×10^{-4} Bq/cc (air – organic compound) 7.4×10^{-2} Bq/cc (air - CO) 1.1×10^{-2} Bq/cc (air – CO_2) 1.1 Bq/cc (water)

GENERAL RADIOLOGICAL SAFETY INFORMATION

- Laboratory coat and gloves must be worn when handling unsealed radioactive material. Monitor hands and change gloves frequently.
- Plastic or other low Z material shielding can be used to minimize exposure from C-14.
- Store C-14 in plastic or other low Z material.
- Remote handling tools should be used when handling C-14.
- Practice procedures without radioactivity prior to performing the procedure with C-14. Practice will improve dexterity and speed, along with providing opportunity to determine errors and practices that are not ALARA.
- After each use of unsealed C-14 monitor self, work areas and floors using a survey meter equipped with a pancake or thin window G-M probe. When performing the monitoring remove cap and never cover the window of the survey meter with the plastic or parafilm, as this can reduce the efficiency of detection to 0%.
- Work with volatile forms of C-14 (e.g., CO, CO_2 or CO^2 formed) shall be performed in a fume hood.

REFERENCES

Title 10 of the Code of Federal Regulations part 20
Ohio Administration Code 3701:1-38
EPA Federal Guidance Report No. 11
Shleien, The Health Physics and Radiological Health Handbook Revised Edition, (Scinta, Inc., 1992)
Health Physics & Radiological Health Handbook, 3rd Ed. [Baltimore, MD; Williams & Wilkins, 1998]
Delacoix et al, Radiation Protection Dosimetry – Radionuclide and Radiation Protection Data Handbook 2002, (Kent, England: Nuclear Technology Publishing, 2002)
http://www.hpschapters.org/northcarolina/nuclide_information_library.php3
www.stanford.edu/dept/EHS/prod/researchlab/radlaser/rsds.html
www.umich.edu/~oseh/isotopes
www.uwm.edu/dept/ehsrm/rad/carbon.html

Isotope Fact Sheet

CESIUM-137
[^{137}Cs]

PHYSICAL DATA

• Gamma Energy:	662 keV (85%)	
(x-rays from Ba-137m)	36 keV (1%)	
	32 keV (6%)	
• Maximum Beta Energy:	173 keV (5%)	
	512 keV (95%)	
• Alpha Energy:	no alpha	
• Physical Half-Life:	30.2 years	
• Biological Half-Life:	70 days*	
• Effective Half-Life:	70 days*	

*These are “generic” biological and effective half-lives; the specific labeled compound may alter.

• Specific Activity:	8.7 x 10^{1} Ci/gram	3.2 x 10^{12} Bq/g
• Specific Gamma Constant:	3.8 x 10^{-1} mR/hr/mCi	1.03 x10^{-4} mSv/hr/MBq
(@ 1 meter)		

RADIOLOGICAL DATA

- Radiological Toxicity Rating: Group 3 (moderate)
- Critical Organ: Soft tissue
- Routes of Intake: Ingestion, Inhalation, Puncture, Wound, Skin Absorption

• Committed Effective Dose Equivalent (CEDE):	5.0 x 10^{1} mrem/uCi (ingestion)	1.35 x 10^{1} mSv/MBq (ingestion)
	3.2 x 10^{1} mrem/uCi (inhalation)	8.63 mSv/Bq (inhalation)
• Skin Contamination (7 mg/cm^2): (Kocher et al)	5.9 rem/h/uCi/cm^2	1.57 mSv/h/kBq/cm^2

SHIELDING

• Half-Value Layer (HVL) for lead	0.3 inches	0.8 cm
HVL for concrete	1.9 inches	4.8 cm
HVL for steel	1.1 inches	2.9 cm
• Tenth-Value Layer (TVL) for lead	0.9 inches	2.4 cm
TVL for concrete	6.2 inches	15.7 cm
TVL for steel	2.8 inches	7.2 cm

• Maximum Beta Range in Air:	57 inches	144 cm
• Maximum Beta Range in Water/Tissue:	0.08 inches	0.20 cm
• Maximum Beta Range in Plastic:	0.06 inches	0.16 cm

SURVEY INSTRUMENTATION

• A survey meter equipped with a G-M pancake or thin-window probe is quite effective for detecting the betas from Cs-137. Typical efficiency for a G-M pancake survey meters is 21-26%.

• A survey meter equipped with a thick crystal NaI scintillation probe is suitable for detection of the Cs-137. Typical efficiency is 2-7%.

• Either a gamma counter or a liquid scintillation counter can be used to detect removable Cs-137 contamination on wipe tests smears.

RADIATION MONITORING DOSIMETERS

- Whole Body dosimeter: Required.
    - Finger dosimeter: Required for unsealed source and sealed sources not contained in an irradiator.
    - Whole body count or urine bioassay may be required for suspected skin contamination or ingestion.

RADIOACTIVE WASTE

- Solids, liquids, scintillation vials, pathological materials, animal carcasses

REGULATORY COMPLIANCE INFORMATION

• Derived Air Concentration (DAC):	6×10^{-8} uCi/cc (occupational)	2.2×10^{-3} Bq/cc (occupational)
• Annual Limit of Intake (ALI*):	1×10^{2} uCi (ingestion) 2×10^{2} uCi (inhalation)	3.7×10^{6} Bq (ingestion) 7.4×10^{6} Bq (inhalation)
*[1.0 ALI = 5,000 mrem CEDE]		
• Effluent Release Limit:	2×10^{-10} uCi/cc (air) 1×10^{-6} uCi/cc (water)	7.4×10^{-6} Bq/cc (air) 3.7×10^{-2} Bq/cc (water)

- Often used in a “sealed source” (i.e., encapsulated sources). If the source is greater than or equal to 100 microcuries, the sealed source must be “leak tested” every 6 months. The leak test methodology must be capable of detecting the presence of 0.005 microcuries of removable contamination and must be taken at the nearest accessible location to the source.
- Laboratory coat and gloves must be worn when handling unsealed radioactive material. Monitor hands and change gloves frequently.
- Whole body and ring dosimeter must be worn when handling unsealed Cs-137 or a sealed source that is not shielded within the housing of the instrument (e.g., an irradiator).
- Lead shielding shall be used to minimize exposure from Cs-137
- Indirect viewing aids should be used to minimize exposure from Cs-137.
- Store Cs-137 in lead shielding.
- Remote handling tools should be used when handling Cs-137.
- Practice procedures without radioactivity prior to performing the procedure with Cs-137. Practice will improve dexterity and speed, along with providing opportunity to determine errors and practices that are not ALARA.
- After each use of unsealed Cs-137 monitor self, work areas and floors using a survey meter equipped with a G-M or NaI probe.

Gamma exposure rate from 1 mCi point source - unshielded

Distance	mR/hr
1 cm	3800
5 cm	152
10 cm	38
100 cm	0.38

REFERENCES

Title 10 of the Code of Federal Regulations part 20
Ohio Administration Code 3701:1-38
EPA Federal Guidance Report No. 11
EPA Federal Guidance Report NO. 12
Shleien, The Health Physics and Radiological Health Handbook Revised Edition, (Scinta, Inc., 1992)
Health Physics & Radiological Health Handbook, 3rd Ed. [Baltimore, MD; Williams & Wilkins, 1998]
Delacoix et al, Radiation Protection Dosimetry – Radionuclide and Radiation Protection Data Handbook 2002, (Kent, England: Nuclear Technology Publishing, 2002)
www.stanford.edu/dept/EHS/prod/researchlab/radlaser/rsds.html
www.nchps.org/nsds.htm
www.umich.edu/~oseh/isotopes

Isotope Fact Sheet

CHLORINE-36
[^{36}Cl]

PHYSICAL DATA

- Gamma Energy: no photon
- Maximum Beta Energy: 709 keV (98%)
- Alpha Energy: no alpha

- Physical Half-Life: 3.08 x 10^5 years
- Biological Half-Life: 29 days*
- Effective Half-Life: 30 days*

* These are "generic" biological and effective half-lives; the specific labeled compound may alter.

• Specific Activity:	3.3 x 10^{-2} Ci/gram	1.23 x 10^9 Bq/g

RADIOLOGICAL DATA

- Radiological Toxicity Rating: Group 2 (high)
- Critical Organ: Lungs
- Routes of Intake: Ingestion, Inhalation, Puncture, Wound, Skin Absorption

• Committed Effective Dose Equivalent (CEDE):	3.04 mrem/uCi (ingestion)	0.818 mSv/MBq (ingestion)
	2.26 mrem/uCi inhalation – class D)	0.606 mSv/MBq (inhalation – class D)
	21.96 mrem/uCi (inhalation-classW)	5.93 mSv/MBq (inhalation-Class W)
• Skin Contamination	6.6 rem/hr/uCi/cm^2	1.8 mSv/hr/kBq/cm^2

SHIELDING

- ¼ - ½ inch thick plexiglas/acrylic/lucite/plastic/wood
- Do not use lead foil or sheets as primary barrier! Penetrating bremsstrahlung x-ray will be produced!
- Use lead sheets or foil to shield bremsstrahlung x-rays only **after** low density plexiglas/acrylic/lucite/wood shielding.

• Maximum Beta Range in Air:	73 inches	186 cm
• Maximum Beta Range in Water/Tissue:	0.12 inches	0.3 cm
• Maximum Beta Range in Plastic:	0.08 inches	0.2 cm

SURVEY INSTRUMENTATION

• A survey meter equipped with a G-M pancake or thin-window probe is effective for detecting the betas from the Cl-36. Typical efficiency for a G-M pancake survey meter is 21%-26%.

• A liquid scintillation counter should be used to detect removable Cl-36 contamination on wipe tests smears. Liquid scintillation counter efficiency is about 100%.

RADIATION MONITORING DOSIMETERS

- Whole Body dosimeter: Required
    - Finger dosimeter: Required.
    - Urine bioassay may be required for suspected skin contamination or ingestion.

RADIOACTIVE WASTE

- Solids, liquids, scintillation vials, pathological materials, animal carcasses

REGULATORY COMPLIANCE INFORMATION

• Derived Air Concentration (DAC):	1×10^{-6} uCi/cc (occupational – class D)	3.7×10^{-2} Bq/cc (occupational – class D)
	1×10^{-7} uCi/cc (occupational – class W)	3.7×10^{-4} Bq/cc (occupational – class W)
• Annual Limit of Intake (ALI*):	2×10^{3} uCi (ingestion)	7.4×10^{7} Bq (ingestion)
	3×10^{3} uCi (inhalation – class D)	1.1×10^{8} Bq (inhalation – class D)
*[1.0 ALI = 5,000 mrem CEDE]	2×10^{2} uC (inhalation – class W)	7.4×10^{6} Bq (inhalation – class W)
• Effluent Release Limit:	3×10^{-9} uCi/cc (air – class D)	1.1×10^{-4} Bq/cc (air- class D)
	3×10^{-10} uCi/cc (air – class W)	1.1×10^{-5} Bq/cc 1.2 (air- class w)
	2×10^{-5} uCi/cc (water)	7.4×10^{-1} Bq/cc (water)

GENERAL RADIOLOGICAL SAFETY INFORMATION

- Laboratory coat and gloves must be worn when handling unsealed radioactive material. Monitor hands and change gloves frequently.
- Whole body and ring dosimeter must be worn when handling Cl-36.
- Plastic or other low Z material shielding shall be used to minimize exposure from Cl-36.
- Indirect viewing aids should be used to minimize exposure from Cl-36.
- Store Cl-36 in plastic or other low Z material.
- Remote handling tools should be used when handling Cl-36.
- Practice procedures without radioactivity prior to performing the procedure with Cl-36. Practice will improve dexterity and speed, along with providing opportunity to determine errors and practices that are not ALARA.
- After each use of unsealed Cl-36 monitor self, work areas and floors using a survey meter equipped with a pancake or thin window G-M probe.

REFERENCES

Title 10 of the Code of Federal Regulations part 20
Ohio Administration Code 3701:1-38
EPA Federal Guidance Report No. 11
Shleien, The Health Physics and Radiological Health Handbook Third Edition, (Scinta, Inc., 1998)
Delacoix et al, Radiation Protection Dosimetry – Radionuclide and Radiation Protection Data Handbook 2002, (Kent, England: Nuclear Technology Publishing, 2002)
www.stanford.edu/dept/EHS/prod/researchlab/radlaser/rsds.html

Isotope Fact Sheet

CHROMIUM-51
[^{51}Cr]

PHYSICAL DATA

- Gamma Energy: 320 keV (10%)
  5 keV (20%)
- Electron Energy: 4 keV (67%)
- Alpha Energy: no alpha

- Physical Half-Life: 27.7 days
- Biological Half-Life: 616 days*
- Effective Half-Life: 26.5 days*

* These are "generic" biological and effective half-lives; the specific labeled compound may alter.

• Specific Activity:	9.2 x 10^{4} Ci/gram	3.42 x 10^{15} Bq/g
• Specific Gamma Constant: (@ 1 meter)	2.34 x 10^{-2} mR/hr/mCi	6.32 x10^{-6} mSv/hr/MBq

RADIOLOGICAL DATA

- Radiological Toxicity Rating: Group 3 (moderate)
- Critical Organ: Lungs
- Routes of Intake: Ingestion, Inhalation, Puncture, Wound, Skin Absorption

• Committed Effective Dose Equivalent (CEDE):	1.5 x 10^{-1} mrem/uCi (ingestion)	3.98 x 10^{-2} mSv/MBq (ingestion)
	1.1 x 10^{-1} mrem/uCi (inhalation – class D)	2.95 x 10^{-2} mSv/MBq (inhalation – class D)
	2.6 x 10^{-1} mrem/uCi (inhalation – class W)	7.08 x 10^{-2} mSv/MBq (inhalation – class W)
	3.3 x 10^{-1} mrem/uCi (inhalation – class Y)	9.03 x 10^{-2} mSv/MBq (inhalation – class Y)
• Skin Contamination	5.6 x 10^{-2} rem/hr/uCi/cm2	1.5 x 10^{-2} mSv/hr/kBq/cm2

SHIELDING

• Half-Value Layer (HVL) for lead	0.08 inches	0.2 cm
HVL for concrete	1.10 inches	2.8 cm
HVL for steel	0.83 inches	2.1 cm
• Tenth-Value Layer (TVL) for lead	0.28 inches	0.7 cm
TVL for concrete	3.66 inches	9.3 cm
TVL for steel	1.97 inches	5.0 cm

SURVEY INSTRUMENTATION

- Survey meter equipped with a G-M pancake or thin-window probe is not efficient for detecting Cr-51. Typical efficiency for a G-M survey meter is less than 1%.
- Survey meters equipped with a NaI scintillation probe is suitable for detection of the Cr-51 gammas. Typical detection efficiency is 1% to 2%.
- Either a gamma counter or a liquid scintillation counter can be used to detect removable Cr-51 contamination on wipe tests smears. Typical LSC efficiency for detecting Cr-51 is 30% or greater. Typical efficiency for a gamma counter is 1% to 2%

RADIATION MONITORING DOSIMETERS

- Whole Body dosimeter: Required
- Finger dosimeter: Required.
- Urine bioassay may be required for suspected skin contamination or ingestion.

RADIOACTIVE WASTE

- Solids, liquids, scintillation vials, pathological materials, animal carcasses

REGULATORY COMPLIANCE INFORMATION

• Derived Air Concentration (DAC):	2×10^{-5} uCi/cc (occupational – class D)	7.4×10^{-1} Bq/cc (occupational - class D)
	1×10^{-5} uCi/cc (occupational – class W)	3.7×10^{-1} Bq/cc (occupational – class W)
	8×10^{-6} uCi/cc (occupational – class Y)	3.0×10^{-1} Bq/cc (occupational – class Y)
• Annual Limit of Intake (ALI*):	4×10^{4} uCi (ingestion)	1.5×10^{9} Bq (ingestion)
*[1.0 ALI = 5,000 mrem CEDE]	5×10^{4} uCi	1.9×10^{9} Bq
	(inhalation – class D)	(inhalation – class D)
	2×10^{4} uCi	7.4×10^{8} Bq
	(inhalation – class W/Y)	(inhalation – class W/Y)
• Effluent Release Limit:	6×10^{-8} uCi/cc	2.2×10^{-3} Bq/cc
	(air – class D)	(air – class D)
	3×10^{-8} uCi/cc	1.1×10^{-3} Bq/cc
	(air – class W or Y)	(air – class W or Y)
□	5×10^{-4} uCi/cc (water)	1.9×10^{1} Bq/cc (water)

GENERAL RADIOLOGICAL SAFETY INFORMATION

- Laboratory coat and gloves must be worn when handling unsealed radioactive material. Monitor hands and change gloves frequently.
- Whole body and ring dosimeter must be worn when handling Cr-51.
- Indirect viewing aids should be used to minimize exposure from Cr-51.
- Store Cr-51 in lead shielding.
- Remote handling tools should be used when handling Cr-51.
- Practice procedures without radioactivity prior to performing the procedure with Cr-51. Practice will improve dexterity and speed, along with providing opportunity to determine errors and practices that are not ALARA.
- After each use of Cr-51 monitor self, work areas and floors using a survey meter equipped with a G-M or NaI probe.

Gamma exposure rate from 1 mCi point source - unshielded

Distance	mR/hr
1 cm	234
5 cm	9.4
10 cm	2.3
100 cm	0.02

REFERENCES

Title 10 of the Code of Federal Regulations part 20

Ohio Administration Code 3701:1-38

EPA Federal Guidance Report No. 11

Shleien, The Health Physics and Radiological Health Handbook Revised Edition, (Scinta, Inc., 1992)

Delacoix et al, Radiation Protection Dosimetry – Radionuclide and Radiation Protection Data Handbook 1998, (Kent, England: Nuclear Technology Publishing, 1998)

www.stanford.edu/dept/EHS/prod/researchlab/radlaser/rsds.html

www.uwm.edu/dept/ehsrm/rad/chromium.html

Isotope Fact Sheet

COBALT-57
[^{57}Co]

PHYSICAL DATA

- Photon Energy: 692 keV (0.14%)
  136 keV (11%)
  122 keV (87%)
  14 keV (9%)
- Electron Energy: 7 keV (70%)
  6 keV (106%)
- Alpha Energy: no alpha

- Physical Half-Life: 271.8 days
- Biological Half-Life: 9.5 days*
- Effective Half-Life: 9.2 days*

* These are "generic" biological and effective half-lives; the specific labeled compound may alter.

• Specific Activity:	8.48 x 10^{3} Ci/gram	3.12 x 10^{14} Bq/g
• Specific Gamma Constant: (@ 1 meter)	9 x 10^{-2} mR/hr/mCi	2.43 x10^{-5} mSv/hr/MBq

RADIOLOGICAL DATA

- Radiological Toxicity Rating: Group 3 (moderate)
- Critical Organ: Liver, Lower Large Intestine, Lung (inhaled)
- Routes of Intake: Ingestion, Inhalation, Puncture, Wound, Skin Absorption

• Committed Effective Dose Equivalent (CEDE):	0.74 mrem/uCi (ingestion)	0.201 mSv/MBq (ingestion)
	2.63 mrem/uCi	0.712 mSv/MBq
	(inhalation - class W)	(inhalation - class W)
	9.07 mrem/uCi	2.45 mSv/MBq
	(inhalation - class Y)	(inhalation - class Y)
• Skin Contamination	4.4 x 10^{-1} rem/hr/uCi/cm^{2}	1.2 x 10^{-2} mSv/hr/kBq/cm^{2}

SHIELDING

• Half-Value Layer (HVL) for lead	<0.04 inches	<0.1 cm
HVL for steel	0.24 inches	0.6 cm
• Tenth-Value Layer (TVL) for lead	0.04 inches	0.1 cm
TVL for steel	0.71 inches	1.8 cm

SURVEY INSTRUMENTATION

- Survey meter equipped with a G-M pancake or thin-window probe is not very efficient for detecting Co-57. Typical efficiency for a G-M pancake survey meter is <1%.
- Survey meters equipped with a NaI scintillation probe is suitable for detection of the Co-57 photons.
- Either a gamma counter or a liquid scintillation counter can be used to detect removable Co-57 contamination on wipe test smears.

RADIATION MONITORING DOSIMETERS

- Whole Body dosimeter: Required
- Finger dosimeter: Required.
- Urine bioassay may be required for suspected skin contamination or ingestion.

RADIOACTIVE WASTE

- Solids, liquids, scintillation vials, pathological materials, animal carcasses

REGULATORY COMPLIANCE INFORMATION

• Derived Air Concentration (DAC):	1×10^{-6} uCi/cc (occupational – class W)	3.7×10^{-2} Bq/cc (occupational – class W)
	3×10^{-7} uCi/cc (occupational – class Y)	1.1×10^{-2} Bq/cc (occupational – class Y)
• Annual Limit of Intake (ALI*):	8×10^{3} uCi	3.0×10^{8} Bq
*[1.0 ALI = 5,000 mrem CEDE]	(ingestion – class W)	(ingestion – class W)
	4×10^{3} uCi	1.5×10^{8} Bq
	(ingestion – class Y)	(ingestion – class Y)
	3×10^{3} uCi	1.1×10^{8} Bq

	(inhalation – class W)	(inhalation – class W)
	$7x\ 10^{2}$ uCi	2.6×10^{7} Bq
	(inhalation – class Y)	(inhalation – class Y)
• Effluent Release Limit:	9×10^{-10} uCi/cc (air)	3.34×10^{-5} Bq/cc (air)
	5×10^{-5} uCi/cc (water)	1.85 Bq/cc (water)

GENERAL RADIOLOGICAL SAFETY INFORMATION

- Often used in a “sealed source” (i.e., encapsulated sources). If the activity is encapsulated into a sealed source and the activity is greater than or equal to 100 microcuries, the sealed source must be “leak tested” every 6 months. The leak test methodology must be capable of detecting the presence of 0.005 microcuries of removable contamination and must be taken at the nearest accessible location to the source.
- Laboratory coat and gloves must be worn when handling unsealed radioactive material. Monitor hands and change gloves frequently.
- Whole body and ring dosimeter must be worn when handling Co-57 (sealed or unsealed source).
- Lead shielding shall be used to minimize exposure from Co-57.
- Indirect viewing aids should be used to minimize exposure from Co-57.
- Store Co-57 in lead shielding.
- Remote handling tools should be used when handling Co-57.
- Practice procedures without radioactivity prior to performing the procedure with Co-57. Practice will improve dexterity and speed, along with providing opportunity to determine errors and practices that are not ALARA.
- After each use of unsealed Co-57 monitor self, work areas and floors using a survey meter equipped with a G-M or NaI probe.

Gamma exposure rate from 1 mCi point source - unshielded

Distance	mR/hr
1 cm	900
5 cm	36
10 cm	9
100 cm	0.09

REFERENCES

Title 10 of the Code of Federal Regulations part 20

Ohio Administration Code 3701:1-38

EPA Federal Guidance Report No. 11

Shleien, The Health Physics and Radiological Health Handbook Revised Edition, (Scinta, Inc., 1992)

Delacoix et al, Radiation Protection Dosimetry – Radionuclide and Radiation Protection Data Handbook 1998, (Kent, England: Nuclear Technology Publishing, 1998)

www.stanford.edu/dept/EHS/prod/researchlab/radlaser/rsds.html

Isotope Fact Sheet

Copper-64
[^{64}Cu]

PHYSICAL DATA

- Photon Energy: 511 keV (36%)
- Maximum Beta Energy: 578 keV (37%)
  653 keV (18%)

- Physical Half-Life: 12.7 hours
- Biological Half-Life: 3.78 days
- Effective Half-Life: 11.1 hours

- Specific Activity: 3.86 x 10^{6} Ci/g — 1.43 x 10^{17} Bq/g
- Specific Gamma Constant: 1.32 x 10^{-1} mR/hr/mCi — 3.57 x10^{-5} mSv/hr/MBq

(@ 1 meter)

RADIOLOGICAL DATA

- Radiological Toxicity Rating: Group 3 (Moderate)
- Critical Organ: GI Tract (LLI)
- Routes of Intake: Ingestion, Inhalation, Puncture, Wound, Skin Absorption

• Committed Effective Dose Equivalent (CEDE):	4.67 x 10^{-1} mrem/uCi (ingestion)	1.26 x 10^{-1} mSv/MBq (ingestion)
	1.96 x 10^{-1} mrem/uCi (inhalation – class D)	5.29 x 10^{-2} mSv/MBq (inhalation – class D)
	2.57 x 10^{-1} mrem/uCi (inhalation – class W)	6.93 x 10^{-2} mSv/MBq (inhalation – class W)
	2.77 x 10^{-1} mrem/uCi (inhalation – class Y)	7.48 x 10^{-2} mSv/MBq (inhalation – class Y)
• Skin Contamination	3.70 rem/hr/uCi/cm^2	1.0 mSv/hr/kBq/cm^2

SHIELDING

- ¾ inch plexiglas/acrylic/lucite/plastic/wood followed by lead.

- Lead foil or sheets should not be used as a primary barrier. Penetrating bremsstrahlung x-ray are produced. Use lead sheets or foil to shield bremsstrahlung x-rays **after** low density plexiglas/acrylic/lucite/wood shielding.

• Total Absorption	Glass	0.39 inches	1.0 cm
	Plastic	0.71 inches	1.8 cm
• Half-Value Layer	(HVL) for lead	0.24 inches	0.6 cm
	(HVL) for steel	1.06 inches	2.7 cm
• Tenth-Value Layer	(TVL) for lead	0.67 inches	1.7 cm
	(TVL) for steel	2.56 inches	6.5 cm

SURVEY INSTRUMENTATION

- A survey meter equipped with a G-M pancake will detect Cu-64 contamination with a typical efficiency is 8% - 10%.
- A survey meter equipped with a thick NaI scintillation probe will detect Cu-64 contamination. Typical efficiency for a thick NaI scintillation probe 1% - 3%.

RADIATION MONITORING DOSIMETERS

- Whole Body dosimeter: Required
- Finger dosimeter: Required
- Urine bioassay may be required for suspected skin contamination or ingestion.

RADIOACTIVE WASTE

- Solids, liquids, scintillation vials, pathological materials, animal carcasses

REGULATORY COMPLIANCE INFORMATION

• Derived Air Concentration (DAC) occupational values:	1×10^{-5} uCi/cc (class D)	3.7×10^{-1} Bq/cc (class D)
	1×10^{-5} uCi/cc (class W)	3.7×10^{-1} Bq/cc (class W)
	9×10^{-6} uCi/cc (class Y)	3.3×10^{-1} Bq/cc (class Y)
• Annual Limit of Intake (ALI*):	3×10^{4} uCi (class D)	1.11×10^{9} Bq (class D)
	2×10^{4} uCi (class W)	7.40×10^{8} Bq (class W)
	2×10^{4} uCi (class Y)	7.40×10^{8} Bq (class Y)

*[1.0 ALI = 5,000 mrem CEDE] Occupational Values

• Effluent Release Limit:	4×10^{-8} uCi/cc (air - class D)	1.48×10^{-3} Bq/cc (air – class D)
	3×10^{-8} uCi/cc (air - class W)	1.11×10^{-3} Bq/cc (air – class W)
	3×10^{-8} uCi/cc (air – class Y)	1.11×10^{-3} Bq/cc (air – class Y)
	2×10^{-4} uCi/cc (water – class D)	7.4 Bq/cc (water – class D)

GENERAL RADIOLOGICAL SAFETY INFORMATION

- Laboratory coat and gloves must be worn when handling unsealed radioactive material. Monitor hands and change gloves frequently.
- Plastic or other low Z material shielding followed by lead should be used to minimize exposure from Cu-64.
- Store Cu-64 in plastic or other low Z material covered by lead.
- Remote handling tools should be used when handling Cu-64.
- Practice procedures without radioactivity prior to performing the procedure with Cu-64. Practice will improve dexterity and speed, along with providing opportunity to determine errors and practices that are not ALARA.
- After each use of unsealed Cu-64 monitor self, work areas and floors using a survey meter equipped with a pancake probe or thick NaI scintillation probe. When performing the monitoring using a pancake probe ensure to remove cap and never cover the window of the survey meter with the plastic or parafilm, as this significantly reduces the efficiency of detection.

Gamma exposure rate from 1 mCi point source - unshielded

Distance	mR/hr
1 cm	1320
5 cm	52.8
10 cm	13.2
100 cm	0.13

REFERENCES

Title 10 of the Code of Federal Regulations part 20
Ohio Administration Code 3701:1-38
EPA Federal Guidance Report No. 11
Shleien, The Health Physics and Radiological Health Handbook Revised Edition, (Scinta, Inc., 1992)
Delacoix et al, Radiation Protection Dosimetry – Radionuclide and Radiation Protection Data Handbook 2002, (Kent, England: Nuclear Technology Publishing, 2002)
http://www.nrc.gov/reading-rm/doc-collections/cfr/part020/appb/Copper-64.html
http://www-ehs.ucsd.edu/rad/radionuclide/Cu-64.pdf

Isotope Fact Sheet

COPPER-67
[^{67}Cu]

PHYSICAL DATA

- Photon Energy: 185 keV (49%)
  93 keV (16%)
  91 keV (7%)
- Beta Energy: 575 keV (20%)
  482 keV (22%)
  390 keV (57%)
- Alpha Energy: no alpha

- Physical Half-Life: 2.58 days
- Biological Half-Life: 3.78 days
  - Effective Half-Life: 1.89 days*

• Specific Activity:	7.56 x 10^{5} Ci/gram	2.80 x 10^{16} Bq/g
• Specific Gamma Constant:	8.7 x 10^{-2} mR/hr/mCi	2.36 x10^{-5} mSv/hr/MBq

(@ 1 meter)

RADIOLOGICAL DATA

- Radiological Toxicity Rating: Group 3 (moderate)
- Critical Organ: GI Tract (LLI)
- Routes of Intake: Ingestion, Inhalation, Puncture, Wound, Skin Absorption

• Committed Effective Dose Equivalent (CEDE):	1.3 mrem/uCi (ingestion)	0.35 mSv/MBq (ingestion)
• Skin Contamination	4.8 rem/hr/uCi/cm^{2}	1.3 mSv/hr/kBq/cm^{2}

SHIELDING

• Half-Value Layer (HVL) for lead	0.04 inches	<0.1 cm
HVL for steel	0.43 inches	1.1 cm
• Tenth-Value Layer (TVL) for lead	0.08 inches	0.2 cm
TVL for steel	1.18 inches	3.0 cm

SURVEY INSTRUMENTATION

• A survey meter equipped with a G-M pancake or thin-window probe can be used to detect the betas from the Cu-67. Typical efficiency for a G-M pancake survey meter is 15%-18%.

• A survey meter equipped with a NaI scintillation probe is suitable for detection of the Cu-67 photons. Typical efficiency for a survey meter equipped with a thin NaI crystal is 3%-5%.

• Either a gamma counter or a liquid scintillation counter can be used to detect removable Cu-67 contamination on wipe test smears. (Liquid Scintillation Counter efficiency is about 10%; gamma counter efficiency is about 60%)

RADIATION MONITORING DOSIMETERS

- Whole Body dosimeter: Required
    - Finger dosimeter: Required.
    - Urine bioassay (taken 4 to 24 hours after event) or whole body counting may be required for suspected skin contamination or ingestion.

RADIOACTIVE WASTE

- Solids, liquids, scintillation vials, pathological materials, animal carcasses

REGULATORY COMPLIANCE INFORMATION

• Derived Air Concentration (DAC):	3×10^{-6} uCi/cc (occupational – class D)	1.1×10^{-1} Bq/cc (occupational – class D)
	2×10^{-6} uCi/cc (occupational – class W)	7.4×10^{-2} Bq/cc (occupational – class W)
• Annual Limit of Intake (ALI*):	5×10^{3} uCi (ingestion - class D)	1.9×10^{8} Bq (ingestion – class D)
*[1.0 ALI = 5,000 mrem CEDE]	8×10^{3} uCi (inhalation – class D)	3.0×10^{8} Bq (inhalation – class D)
	5×10^{3} uCi (inhalation – class W)	1.9×10^{8} Bq (inhalation – class W)
• Effluent Release Limit:	6×10^{-9} uCi/cc (air)	2.2×10^{-4} Bq/cc (air)
	6×10^{-5} uCi/cc (water)	2.4 Bq/cc (water)

GENERAL RADIOLOGICAL SAFETY INFORMATION

- Laboratory coat and gloves must be worn when handling unsealed radioactive material. Monitor hands and change gloves frequently.
- Whole body and ring dosimeter must be worn when handling Cu-67.
- Lead shielding shall be used to minimize exposure from Cu-67.
- Indirect viewing aids should be used to minimize exposure from Cu-67.
- Store Cu-67 in lead shielding.
- Remote handling tools should be used when handling Cu-67.
- Practice procedures without radioactivity prior to performing the procedure with Cu-67. Practice will improve dexterity and speed, along with providing opportunity to determine errors and practices that are not ALARA.
- After each use of unsealed Cu-67 monitor self, work areas and floors using a survey meter equipped with a G-M or NaI probe.

Gamma exposure rate from 1 mCi point source - unshielded

Distance	mR/hr
1 cm	870
5 cm	35
10 cm	8.7
100 cm	0.09

REFERENCES

Title 10 of the Code of Federal Regulations part 20
Ohio Administration Code 3701:1-38
EPA Federal Guidance Report No. 11
Shleien, The Health Physics and Radiological Health Handbook Third Edition, (Scinta, Inc., 1998)
Delacoix et al, Radiation Protection Dosimetry – Radionuclide and Radiation Protection Data Handbook 2002, (Kent, England: Nuclear Technology Publishing, 2002)
Interpretation of Bioassay Measurements (NUREG/CR-4884) US NRC

Isotope Fact Sheet

FLUORINE-18
[^{18}F]

PHYSICAL DATA

- Photon (annihilation) Energy: 511 keV (194%)
- Beta^{+} (positron) Energy: 634 keV (97%)
- Alpha Energy: no alpha

- Physical Half-Life: 1.83 hours
- Biological Half-Life: 6 hours*
- Effective Half-Life: 1.4 hours*

* These are "generic" biological and effective half-lives; the specific labeled compound may alter.

• Specific Activity:	9.5 x 10^{7} Ci/gram	3.52 x 10^{18} Bq/g
• Specific Gamma Constant: (@ 1 meter)	6.96 x 10^{-1} mR/hr/mCi	1.88 x10^{-4} mSv/hr/MBq

RADIOLOGICAL DATA

- Radiological Toxicity Rating: Group 3 (moderate)
- Critical Organ: lung (inhalation), stomach wall (ingestion)
- Routes of Intake: Ingestion, Inhalation, Puncture, Wound, Skin Absorption

• Committed Effective Dose Equivalent (CEDE):	1.2 x 10^{-1} mrem/uCi (ingestion)	3.31 x 10^{-2} mSv/MBq (ingestion)
	8.3 x 10^{-2} mrem/uCi (inhalation – class D)	2.26 x 10^{-2} mSv/MBq (inhalation-class D)
	7.4 x 10^{-2} mSv/MBq (inhalation-class D)	2.01 x 10^{-2} mSv/MBq (inhalation-class W)
	7.8 x 10^{-2} mrem/uCi (inhalation – class W)	2.11 x 10^{-2} mSv/MBq (inhalation – class Y)
• Skin Contamination:	7 rem/hr/uCi/cm^{2}	1.9 mSv/hr/kBq/cm^{2}

SHIELDING

• Half-Value Layer (HVL) for lead	0.24 inches	0.6 cm
HVL for steel	1.06 inches	2.7 cm
• Tenth-Value Layer (TVL) for lead	0.67 inches	1.7 cm
TVL for steel	2.52 inches	6.4 cm
• Maximum Beta Range in Air:	62 inches	158 cm
• Maximum Beta Range in Water/Tissue:	0.09 inches	0.23 cm
• Maximum Beta Range in Plastic:	0.06 inches	0.17 cm

SURVEY INSTRUMENTATION

- A survey meter equipped with a G-M pancake or thin-window probe is quite efficient for detecting the betas from the F-18. Typical efficiency for a G-M pancake survey meter is about 20% - 25%.
- A survey meter equipped with a thick crystal NaI scintillation probe is suitable for detection of the F-18 photons. Typical efficiency for a thick crystal NaI scintillation probe survey meter is about 5% - 10%.
- Either a gamma counter or a liquid scintillation counter can be used to detect removable F-18 contamination on wipe tests smears. Wipe tests must be counted quickly because of the very short half-life.

RADIATION MONITORING DOSIMETERS

- Whole Body dosimeter: Required
- Finger dosimeter: Required.
    - Whole body count may be required in the event of a suspected uptake of F-18. Counting must be done quickly because of the very short half-life.

RADIOACTIVE WASTE

- Solids, liquids, scintillation vials, pathological materials, animal carcasses

• Derived Air Concentration (DAC):	3×10^{-5} uCi/cc (Class D and Y)	1.1 Bq/cc (Class D and Y)
	4×10^{-5} uCi/cc (Class W)	1.5 Bq/cc (Class D and Y)
• Annual Limit of Intake (ALI*):	5×10^{4} uCi (ingestion)	1.85×10^{9} Bq (ingestion)
*[1.0 ALI = 5,000 mrem CEDE]	7×10^{4} uCi (inhalation –Class D)	2.59×10^{9} Bq (inhalation – Class D)
	9×10^{4} uCi (inhalation – Class W)	3.33×10^{9} Bq (inhalation – Class W)
	8×10^{4} uCi (inhalation – Class Y)	2.96×10^{9} Bq (inhalation – Class Y)
• Effluent Release Limit:	1×10^{-7} uCi/cc (air)	3.7×10^{-3} Bq/cc (air)
	7×10^{-4} uCi/cc (water)	2.6×10^{1} Bq/cc (water)

GENERAL RADIOLOGICAL SAFETY INFORMATION

- Laboratory coat and gloves must be worn when handling F-18. Monitor hands and change gloves frequently.
  - Whole body and ring dosimeter must be worn when handling F-18
  - Lead shielding shall be used to minimize exposure from F-18.
  - Indirect viewing aids should be used to minimize exposure from F-18.
  - Remote handling tools should be used when handling F-18.
  - Store F-18 in lead shielding.
  - Practice procedures without radioactivity prior to performing the procedure with F-18. Practice will improve dexterity and speed, along with providing opportunity to determine errors and practices that are not ALARA.
  - After each use of F-18 monitor self, work areas and floor with a survey meter equipped with a G-M pancake or NaI probe.

Gamma exposure rate from 1 mCi point source - unshielded

Distance	mR/hr
1 cm	6960
5 cm	278
10 cm	69.5
100 cm	0.7

REFERENCES

Title 10 of the Code of Federal Regulations part 20
Ohio Administration Code 3701:1-38
EPA Federal Guidance Report No. 11
Shleien, The Health Physics and Radiological Health Handbook Revised Edition, (Scinta, Inc., 1992)
Delacoix et al, Radiation Protection Dosimetry – Radionuclide and Radiation Protection Data Handbook 2002, (Kent, England: Nuclear Technology Publishing, 2002)
www.stanford.edu/dept/EHS/prod/researchlab/radlaser/rsds.html
www.nchps.org/nsds.htm

Isotope Fact Sheet

GALLIUM-67
[^{67}Ga]

PHYSICAL DATA

• Gamma and X-ray Energy:	394 keV (5%)	
(x-rays from Ba-137m)	300 keV (17%)	
	209 keV (2%)	
	185 keV(21%)	
	93 keV (39%)	
	91 keV (3%)	
	9 keV (55%)	
• Electron Energy:	93 keV (6%)	
	84 keV (29%)	
	8 keV (62%)	
• Alpha Energy:	no alpha	
• Physical Half-Life:	3.26 days	
• Biological Half-Life:	6 days*	
• Effective Half-Life:	2.1 days*	

* These are "generic" biological and effective half-lives; the specific labeled compound may alter.

• Specific Activity:	5.97 x 10^{5} Ci/gram	2.21 x 10^{16} Bq/g
• Specific Gamma Constant:	1.1 x 10^{-1} mR/hr/mCi	3.0 x10^{-5} mSv/hr/MBq
(@ 1 meter)		

RADIOLOGICAL DATA

- Radiological Toxicity Rating: Group 3 (moderate)
- Critical Organ: Lower large instestine
- Routes of Intake: Ingestion, Inhalation, Puncture, Wound, Skin Absorption

• Committed Effective Dose Equivalent (CEDE):	7.8 x 10^{-1} mrem/uCi (ingestion)	2.12 x 10^{-1} mSv/MBq (ingestion)
	3.5 x 10^{-1} mrem/uCi (inhalation – class D)	9.50 x 10^{-2} mSv/MBq (inhalation – class D)
	5.5 x 10^{-1} mrem/uCi (inhalation – class W)	1.51 x 10^{-1} mSv/MBq (inhalation – class W)
• Skin Contamination	1.3 rem/hr/uCi/cm^2	3.5 x 10^{-1} mSv/hr/kBq/cm^2

SHIELDING

• Half-Value Layer (HVL) for lead	0.04 inches	0.1 cm
HVL for steel	0.55 inches	1.4 cm
• Tenth-Value Layer (TVL) for lead	0.24 inches	0.6 cm
TVL for steel	1.6 inches	4.1 cm

• Maximum Electron Range in Air:	8 inches	20 cm
• Maximum Electron Range in Water/Tissue:	0.01 inches	0.03 cm
• Maximum Electron Range in Plastic:	0.01 inches	0.02 cm

SURVEY INSTRUMENTATION

- Survey meter equipped with a G-M pancake or thin-window probe is not efficient for detecting Ga-67. Typical efficiency for a G-M pancake survey meter is less than 1%.
- Survey meters equipped with a NaI scintillation probe is suitable for detection of the Ga-67 gamma. Typical efficiency for a NaI scintillation probe survey meter is about 15%.
- Either a gamma counter or a liquid scintillation counter can be used to detect removable Ga-67 contamination on wipe tests smears.

RADIATION MONITORING DOSIMETERS

- Whole Body dosimeter: Required
- Finger dosimeter: Required.
- Whole body count or urine bioassay may be required for suspected skin contamination or ingestion.

RADIOACTIVE WASTE

- Solids, liquids, scintillation vials, pathological materials, animal carcasses

REGULATORY COMPLIANCE INFORMATION

• Derived Air Concentration (DAC):	6×10^{-6} uCi/cc	2.2×10^{-1} Bq/cc
	(occupational – class D)	(occupational – class D)
	4×10^{-6} uCi/cc	1.5×10^{-1} Bq/cc
	(occupational – class W)	(occupational – class D)
• Annual Limit of Intake (ALI*):	7×10^{3} uCi (ingestion)	2.6×10^{8} Bq (ingestion)
*[1.0 ALI = 5,000 mrem CEDE]	1×10^{4} uCi (inhalation)	3.7×10^{8} Bq (inhalation)

• Effluent Release Limit:	2×10^{-8} uCi/cc	7.4×10^{-4} Bq/cc
	(air – class D)	(air – class D)
	1×10^{-8} uCi/cc	3.7×10^{-4} Bq/cc
	(air – class W)	(air – class W)
	1×10^{-4} uCi/cc (water)	3.7 Bq/cc (water)

GENERAL RADIOLOGICAL SAFETY INFORMATION

- Laboratory coat and gloves must be worn when handling unsealed radioactive material. Monitor hands and change gloves frequently.
- Whole body and ring dosimeter must be worn when handling Ga-67.
- Indirect viewing aids should be used to minimize exposure from Ga-67.
- Store Ga-67 in lead shielding.
- Remote handling tools should be used when handling Ga-57.
- Practice procedures without radioactivity prior to performing the procedure with Ga-67. Practice will improve dexterity and speed, along with providing opportunity to determine errors and practices that are not ALARA.
- After each use of unsealed Ga-67 monitor self, work areas and floors using a survey meter equipped with a G-M or NaI probe.

Gamma exposure rate from 1 mCi point source - unshielded

Distance	mR/hr
1 cm	1100
5 cm	44
10 cm	11
100 cm	0.11

REFERENCES

Title 10 of the Code of Federal Regulations part 20

Ohio Administration Code 3701:1-38

EPA Federal Guidance Report No. 11

Shleien, The Health Physics and Radiological Health Handbook Revised Edition, (Scinta, Inc., 1992)

Delacoix et al, Radiation Protection Dosimetry – Radionuclide and Radiation Protection Data Handbook 1998, (Kent, England: Nuclear Technology Publishing, 1998)

www.stanford.edu/dept/EHS/prod/researchlab/radlaser/rsds.html

Isotope Fact Sheet

HYDROGEN-3
[^{3}H]

PHYSICAL DATA

- Gamma Energy: no photon
- Maximum Beta Energy: 18.6 keV (1005)
- Alpha Energy: no alpha

- Physical Half-Life: 12.3 years
- Biological Half-Life: 10-12 days
- Effective Half-Life: 10-12 days*

* Effective half-live can be reduced by a factor of 2 to 3 by forcing liquids.

- Specific Activity: 9.70 x 10^{3} Ci/gram 3.59 x 10^{11} Bq/g

RADIOLOGICAL DATA

- Radiological Toxicity Rating: Group 4 (low)
- Critical Organ: Body water/Tissue
- Routes of Intake: Ingestion, Inhalation, Puncture, Wound, Skin Absorption

• Committed Effective Dose Equivalent (CEDE):	6.4 x 10^{-2} mrem/uCi (ingestion)	1.73 x 10^{-2} mSv/MBq (ingestion)
	6.4 x 10^{-2} mrem/uCi (inhalation)	1.73 x 10^{-2} mSv/MBq (inhalation)
• Skin Contamination	0 (low energy beta stopped by dead layer of skin)	

SHIELDING

- Not required because of low energy of the beta.

• Maximum Beta Range in Air:	0.25 inches	0.6 cm
• Maximum Beta Range in Water/Tissue:	<0.001 inches	<0.001 cm
• Maximum Beta Range in Plastic:	<0.001 inches	<0.001 cm

SURVEY INSTRUMENTATION

- Survey meter equipped with a G-M pancake or thin-window probe **cannot** detect the betas from H-3.

- A liquid scintillation counter should be used to detect removable H-3 contamination on wipe tests smears. Typical LSC efficiency for detecting H-3 is greater than 40%.

RADIATION MONITORING DOSIMETERS

- Whole Body dosimeter: Not required
- Finger dosimeter: Not required
- Urine bioassay is required if quantities greater than 100 millicuries are used. Urine bioassay may be required for suspected skin contamination or ingestion.

RADIOACTIVE WASTE

- Solids, liquids, scintillation vials, pathological materials, animal carcasses

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REGULATORY COMPLIANCE INFORMATION

• Derived Air Concentration (DAC):	2 x 10^{-5} uCi/cc (occupational)	7.4 x 10^{-1} Bq/cc (occupational)
• Annual Limit of Intake (ALI*):	8 x 10^{4} uCi (ingestion)	2.96 x 10^{9} Bq (ingestion)
*[1.0 ALI = 5,000 mrem CEDE]	8 x 10^{4} uCi (inhalation)	2.96 x 10^{4} Bq (inhalation)
• Effluent Release Limit:	1 x 10^{-7} uCi/cc (air)	3.7 x 10^{-3} Bq/cc (air)
	1 x 10^{-3} uCi/cc (water)	3.7 x 10^{1} Bq/cc (water)

GENERAL RADIOLOGICAL SAFETY INFORMATION

- Laboratory coat and gloves must be worn when handling unsealed radioactive material. Monitor hands and change gloves frequently.
- Practice procedures without radioactivity prior to performing the procedure with H-3. Practice will improve dexterity and speed, along with providing opportunity to determine errors and practices that are not ALARA.
- After each use of unsealed H-3 monitor self, work areas and floors using a wipe test counted in a liquid scintillation counter.
- Work involving volatile forms of H-3 (e.g., gas, tritiated water) shall be performed in a fume hood.

REFERENCES

Title 10 of the Code of Federal Regulations part 20
Ohio Administration Code 3701:1-38
EPA Federal Guidance Report No. 11
Shleien, The Health Physics and Radiological Health Handbook Revised Edition, (Scinta, Inc., 1992)
Delacoix et al, Radiation Protection Dosimetry – Radionuclide and Radiation Protection Data Handbook 1998, (Kent, England: Nuclear Technology Publishing, 1998)

www.stanford.edu/dept/EHS/prod/researchlab/radlaser/rsds.html

www.umich.edu/~oseh/isotopes

www.uwm.edu/dept/ehsrm/rad/hydrogen.html

Isotope Fact Sheet

INDIUM-111
[^{111}In]

PHYSICAL DATA

- Gamma Energy: 245 keV (94%)
  171 keV (90%)
  23 keV (69%)
- Electron Energy: 219 keV (5%)
  (decays by electron capture) 145 keV (9%)
- Alpha Energy: no alpha

- Physical Half-Life: 2.8 days
- Biological Half-Life: Indefinite*
- Effective Half-Life: 2.8 days*

* These are "generic" biological and effective half-lives; the specific labeled compound may alter.

• Specific Activity:	4.19 x 10^{5} Ci/gram	1.55 x 10^{16} Bq/g
• Specific Gamma Constant: (@ 1 meter)	5.02 x 10^{-1} mR/hr/mCi	1.356 x10^{-6} mSv/hr/MBq

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RADIOLOGICAL DATA

- Radiological Toxicity Rating: Group 3 (moderate)
- Critical Organ: Lower Large Intestine
- Routes of Intake: Ingestion, Inhalation, Puncture, Wound, Skin Absorption

• Committed Effective Dose Equivalent (CEDE):	1.33 mrem/uCi (ingestion)	0.36 mSv/MBq (ingestion)
	0.78 mrem/uCi (inhalation – class D)	0.21 mSv/MBq (inhalation – class D)
	0.85 mrem/uCi (inhalation – class W)	0.23 mSv/MBq (inhalation-Class D)
• Skin Contamination:	1.4 rem/hr/uCi/cm^2	0.38 mSv/hr/kBq/cm^2

SHIELDING

• Half-Value Layer (HVL) for lead	<0.04 inches	<0.1 cm
HVL for steel	0.35 inches	0.9 cm
• Tenth-Value Layer (TVL) for lead	0.12 inches	0.3 cm
TVL for steel	1.22 inches	3.1 cm
• Shielding 100% absorption of electron in glass:	0.02 inches	0.03 cm
• Shielding 100% absorption of electron in plastic:	0.02 inches	0.05 cm

SURVEY INSTRUMENTATION

- Survey meter equipped with a G-M pancake or thin-window probe is not efficient for In-111. Typical efficiency for a G-M pancake survey meter is <1%.
- Survey meters equipped with a NaI scintillation probe is preferred for detection of the In-111.
- Either a gamma counter or a liquid scintillation counter can be used to detect removable In-111 contamination on wipe tests smears.

RADIATION MONITORING DOSIMETERS

- Whole Body dosimeter: Required
- Finger dosimeter: Required
- Whole body count or urine bioassay may be required for suspected skin contamination or ingestion.

RADIOACTIVE WASTE

- Solids, liquids, scintillation vials, pathological materials, animal carcasses

REGULATORY COMPLIANCE INFORMATION

• Derived Air Concentration (DAC):	3×10^{-6} uCi/cc (occupational)	1.1×10^{-1} Bq/cc (occupational)
• Annual Limit of Intake (ALI*):	4×10^{3} uCi (ingestion)	1.5×10^{8} Bq (ingestion)
*[1.0 ALI = 5,000 mrem CEDE]	6×10^{3} uCi (inhalation)	2.2×10^{6} Bq (inhalation)
• Effluent Release Limit:	9×10^{-9} uCi/cc (air)	3.3×10^{-4} Bq/cc (air)
	6×10^{-5} uCi/cc (water)	2.2 Bq/cc (water)

GENERAL RADIOLOGICAL SAFETY INFORMATION

- Laboratory coat and gloves must be worn when handling In-111. Monitor hands and change gloves frequently.
- Whole body and ring dosimeter must be worn when handling In-111.
- Lead shielding shall be used to minimize exposure from In-111.
- Indirect viewing aids should be used to minimize exposure from In-111.
- Store In-111 in lead shielding.
- Remote handling tools should be used when handling In-111.
- Practice procedures without radioactivity prior to performing the procedure with In-111. Practice will improve dexterity and speed, along with providing opportunity to determine errors and practices that are not ALARA.
- After each use of unsealed In-111 monitor self, work areas and floors using a survey meter equipped with a G-M or NaI probe.

Gamma exposure rate from 1 mCi point source - unshielded

Distance	mR/hr
1 cm	5000
5 cm	200
10 cm	50
100 cm	0.5

REFERENCES

Title 10 of the Code of Federal Regulations part 20

Ohio Administration Code 3701:1-38

EPA Federal Guidance Report No. 11

Shleien, The Health Physics and Radiological Health Handbook Revised Edition, (Scinta, Inc., 1992)

Delacoix et al, Radiation Protection Dosimetry – Radionuclide and Radiation Protection Data Handbook 1998, (Kent, England: Nuclear Technology Publishing, 1998)

www.stanford.edu/dept/EHS/prod/researchlab/radlaser/rsds.html

www.nchps.org/nsds.htm

Isotope Fact Sheet

IODINE-123
[^{123}I]

PHYSICAL DATA

- Gamma Energy: 529 keV (1%)
  159 keV (83%)
  27 keV (71%)
- Electron Energy: 127 keV (14%)
  154 keV (2%)
- Alpha Energy: no alpha

- Physical Half-Life: 13.2 hours
- Biological Half-Life: 138 days*
- Effective Half-Life: 13 hours*

* These are "generic" biological and effective half-lives; the specific labeled compound may alter.

• Specific Activity:	1.93 x 10^{6} Ci/gram	7.14 x 10^{16} Bq/g
• Specific Gamma Constant: (@ 1 meter)	2.77 x 10^{-1} mR/hr/mCi	7.48 x10^{-5} mSv/hr/MBq

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RADIOLOGICAL DATA

- Radiological Toxicity Rating: Group 4 (low)
- Critical Organ: Thyroid
- Routes of Intake: Ingestion, Inhalation, Puncture, Wound, Skin Absorption

• Committed Effective Dose Equivalent (CEDE):	5.30 x10^{-1} mrem/uCi (ingestion)	1.43 x 10^{-1} mSv/MBq (ingestion)
	2.96 x 10^{-1} mrem/uCi (inhalation)	8.01 x 10^{-2} mSv/MBq (inhalation)
• Skin Contamination	1.4 rem/hr/uCi/cm^2	3.8 x 10^{-1} mSv/hr/kBq/cm^2

SHIELDING

• Half-Value Layer (HVL) for lead	0.04 inches	0.1 cm
HVL for steel	0.04 inches	0.1 cm
• Tenth-Value Layer (TVL) for lead	0.08 inches	0.2 cm
TVL for steel	0.83 inches	2.1 cm

SURVEY INSTRUMENTATION

- Survey meter equipped with a G-M pancake or thin-window probe is not efficient for detecting I-123. Typical efficiency for a G-M pancake is <1%.
- Survey meters equipped with a thin crystal NaI scintillation probe is best for detection of the I-123 gamma.
- Either a gamma counter or a liquid scintillation counter can be used to detect removable I-123 contamination on wipe tests smears.

RADIATION MONITORING DOSIMETERS

- Whole Body dosimeter: Required
- Finger dosimeter: Required.
- Thyroid count is the most common form of bioassay. Because of the very short half-life routine thyroid bioassays are not required.
- Urine bioassay may be required for suspected skin contamination or ingestion.

RADIOACTIVE WASTE

- Solids, liquids, scintillation vials, pathological materials, animal carcasses

REGULATORY COMPLIANCE INFORMATION

• Derived Air Concentration (DAC):	3×10^{-6} uCi/cc (occupational)	1.1×10^{-1} Bq/cc (occupational)
• Annual Limit of Intake (ALI*):	1×10^{4} uCi (ingestion)	3.7×10^{8} Bq (ingestion)
*[1.0 ALI = 5,000 mrem CEDE]	3×10^{4} uCi	1.1×10^{9} Bq
	(ingestion – thyroid)	(ingestion - thyroid)
	6×10^{3} uCi (inhalation)	2.2×10^{8} Bq (inhalation)
	2×10^{4} uCi	7.4×10^{8} Bq
	(inhalation – thyroid)	(inhalation - thyroid)
• Effluent Release Limit:	2×10^{-8} uCi/cc (air)	7.4×10^{-4} Bq/cc (air)
	1×10^{-4} uCi/cc (water)	3.7 Bq/cc (water)

GENERAL RADIOLOGICAL SAFETY INFORMATION

- Laboratory coat and gloves must be worn when handling unsealed radioactive material. Monitor hands and change gloves frequently.
- Whole body and ring dosimeter must be worn when handling I-123.
- Lead shielding shall be used to minimize exposure from I-123.
- Indirect viewing aids should be used to minimize exposure from I-123.
- Store I-123 in lead shielding.
- Remote handling tools should be used when handling I-123.
- Practice procedures without radioactivity prior to performing the procedure with I-123. Practice will improve dexterity and speed, along with providing opportunity to determine errors and practices that are not ALARA.
- After each use of unsealed I-123 monitor self, work areas and floors using a survey meter equipped with a G-M or NaI probe.
- Unbound I-123 is inherently volatile. Work with unbound I-123 shall be performed in a fume hood or well ventilated area. Iodinations shall be performed in a hood, approved by the Radiation Safety Office and equipped with charcoal filter and sampling apparatus.
- Acidic and frozen solutions enhance radioiodine volatility. Keep pH of solutions containing I-123 at 7 or higher. Do not freeze solutions containing I-123.

Gamma exposure rate from 1 mCi point source - unshielded

Distance	mR/hr
1 cm	2770
5 cm	111
10 cm	28
100 cm	0.28

REFERENCES

Title 10 of the Code of Federal Regulations part 20

Ohio Administration Code 3701:1-38

EPA Federal Guidance Report No. 11

Shleien, The Health Physics and Radiological Health Handbook Revised Edition, (Scinta, Inc., 1992)

Delacoix et al, Radiation Protection Dosimetry – Radionuclide and Radiation Protection Data Handbook 1998, (Kent, England: Nuclear Technology Publishing, 1998)

www.nchps.org/nsds.htm

Isotope Fact Sheet

IODINE-124
[^{124}I]

PHYSICAL DATA

- Gamma Energy: 511 keV (46%), 603 keV (61%), 1691 keV (11%)
- Maximum Beta Energy: 1532 keV (11%), 2135 keV (11%), 23 keV (8%)
- Physical Half-Life: 4.2 days
- Biological Half-Life: 138 days*
  - Effective Half-Life: 4.1 days

*These are “generic” biological and effective half-lives; the specific labeled compound may alter.

• Specific Activity:	2.52 x 105 Ci/gram	9.33 x 10^{15} Bq/g
• Specific Gamma Constant: (@ 1 meter)	7.58 x 10^{-1} mR/hr/mCi	2.03 x10^{-4} mSv/hr/MBq

RADIOLOGICAL DATA

- Radiological Toxicity Rating: Group 2 (High)
- Critical Organ: Thyroid
- Routes of Intake: Ingestion, Inhalation, Puncture, Wound, Skin Absorption

• Committed Effective Dose Equivalent (CEDE):	4.8 x10^{-8} mrem/uCi (ingestion)	1.3 x 10^{-8} mSv/MBq (ingestion)
	1.7 x 10^{-8} mrem/uCi (inhalation)	4.5 x 10^{-9} mSv/MBq (inhalation)
• Skin Contamination	1.8 x 10^{1} rem/hr/uCi/cm^2	5.2 x 10^{-1} mSv/hr/kBq/cm^2

SHIELDING

• Half-Value Layer (HVL) for lead	0.31 inches	0.8 cm
HVL for steel	1.06 inches	2.7 cm
• Tenth-Value Layer (TVL) for lead	1.22 inches	3.1 cm
TVL for steel	27 inches	76 cm

SURVEY INSTRUMENTATION

- Survey meter equipped with a G-M pancake probe can be used to detect the betas from the I-124. Typical efficiency for a G-M pancake survey meter is 4% -7%.
- Survey meters equipped with a thick crystal NaI scintillation probe is best for detection of the I-124 gamma. Typical efficiency is 3%-5%.

RADIATION MONITORING DOSIMETERS

- Whole Body dosimeter: Required
- Finger dosimeter: Required.
- Thyroid count is the most common form of bioassay. Thyroid bioassays are required if greater than 2 millicuries of I-124 are used. The thyroid bioassay must be performed between 6 hours and 3 working days; however, because of the short physical half life performing the bioassay within 24 hours is preferred.
- Urine bioassay may be required for suspected skin contamination or ingestion.

RADIOACTIVE WASTE

- Solids, liquids, scintillation vials, pathological materials, animal carcasses

REGULATORY COMPLIANCE INFORMATION

• Derived Air Concentration (DAC):	3×10^{-8} uCi/cc (occupational)	1.1×10^{-3} Bq/cc (occupational)
• Annual Limit of Intake (ALI*):	5×10^{1} uCi (ingestion) (ingestion – thyroid)	1.85×10^{6} Bq (ingestion) (ingestion - thyroid)
*[1.0 ALI = 5,000 mrem CEDE]		2.96×10^{6} Bq (inhalation)
	8×10^{-1} uCi (inhalation)	1.1×10^{8} Bq (inhalation - thyroid)
	3×10^{2} uCi (inhalation – thyroid)	
• Effluent Release Limit:	4×10^{-10} uCi/cc (air)	1.48×10^{-5} Bq/cc (air)
	2×10^{-6} uCi/cc (water)	7.4×10^{-2} Bq/cc (water)

GENERAL RADIOLOGICAL SAFETY INFORMATION

- Laboratory coat and gloves must be worn when handling unsealed radioactive material. Monitor hands and change gloves frequently.
- Whole body and ring dosimeter must be worn when handling I-124.
- Lead shielding shall be used to minimize exposure from I-124.
- Indirect viewing aids should be used to minimize exposure from I-124.
- Store I-124 in lead shielding.
- Remote handling tools should be used when handling I-124.
- Practice procedures without radioactivity prior to performing the procedure with I-124. Practice will improve dexterity and speed, along with providing opportunity to determine errors and practices that are not ALARA.
- After each use of unsealed I-124 monitor self, work areas and floors using a survey meter equipped with a G-M or thick crystal NaI probe.
- Unbound I-124 is inherently volatile. Work with unbound I-124 shall be performed in a fume hood or well ventilated area. Iodinations shall be performed in a hood, approved by the Radiation Safety Office and equipped with charcoal filter and sampling apparatus.
- Acidic and frozen solutions enhance radioiodine volatility. Keeps pH of solutions containing I-124 at 7 or higher. Do not freeze solutions containing I-124.

Gamma exposure rate from 1 mCi point source - unshielded

Distance	mR/hr
1 cm	7800
5 cm	312
10 cm	78
100 cm	0.78

REFERENCES

Title 10 of the Code of Federal Regulations part 20
Ohio Administration Code 3701:1-38
EPA Federal Guidance Report No. 11
EPA Federal Guidance Report No. 12
Shleien, The Health Physics and Radiological Health Handbook Third Edition, (Scinta, Inc., 1998)
Delacoix et al, Radiation Protection Dosimetry – Radionuclide and Radiation Protection Data Handbook 2002, (Kent, England: Nuclear Technology Publishing, 2002)
www.nchps.org/nsds.htm
http://www.iem-inc.com/toolgam.html
http://hpschapters.org/northcarolina/NSDS/124IPDF.pdf

Isotope Fact Sheet

IODINE-125
[^{125}I]

PHYSICAL DATA

- Gamma Energy: 36 keV (7%)
  31 keV (26%)
  27 keV (114%)
- Electron Energy: 31 keV (11%)
  23 keV (20%)
  4 keV (79%)
- Alpha Energy: no alpha

- Physical Half-Life: 60.1 days
- Biological Half-Life: 138 days*
- Effective Half-Life: 42 days*

* These are "generic" biological and effective half-lives; the specific labeled compound may alter.

• Specific Activity:	1.74 x 10^{4} Ci/gram	6.45 x 10^{14} Bq/g
• Specific Gamma Constant: (@ 1 meter)	2.75 x 10^{-1} mR/hr/mCi	7.43 x10^{-5} mSv/hr/MBq

RADIOLOGICAL DATA

- Radiological Toxicity Rating: Group 2 (high)
- Critical Organ: Thyroid
- Routes of Intake: Ingestion, Inhalation, Puncture, Wound, Skin Absorption

• Committed Effective Dose Equivalent (CEDE):	3.85 x 10^{1} mrem/uCi (ingestion)	1.04 x 10^{1} mSv/MBq (ingestion)
	2.42 x 10^{1} mrem/uCi (inhalation)	6.53 mSv/MBq (inhalation)
• Skin Contamination	7.8 x 10^{-2} rem/hr/uCi/cm^2	2.11 x 10^{-2} mSv/h/kBq/cm^2

SHIELDING

• Half-Value Layer (HVL) for lead	<0.04 inches	<0.1 cm
HVL for steel	<0.04 inches	<0.1 cm

• Tenth-Value Layer (TVL) for lead	<0.04 inches	<0.1 cm
TVL for steel	<0.04 inches	<0.1 cm

SURVEY INSTRUMENTATION

- A survey meter equipped with a G-M pancake or thin-window probe is not recommended for detecting I-125. Typical efficiency for a G-M pancake is <1%.
- A survey meter equipped with a thin crystal NaI scintillation probe is best for detection of the I-125 gamma. Typical efficiency is 29%-33%.
- Either a gamma counter or a liquid scintillation counter can be used to detect removable I-125 contamination on wipe tests smears. Both have efficiencies for detecting I-125 of about 70%.

RADIATION MONITORING DOSIMETERS

- Whole Body dosimeter: Required
- Finger dosimeter: Required.
- Thyroid count is the most common form of bioassay. Thyroid bioassays are required if greater than 2 millicuries of I-125 are used. The thyroid bioassay must be performed between 6 hours and 3 working days; however, performing the bioassay within 72 hours is preferred.
- Urine bioassay may be required for suspected skin contamination or ingestion.

RADIOACTIVE WASTE

- Solids, liquids, scintillation vials, pathological materials, animal carcasses

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REGULATORY COMPLIANCE INFORMATION

• Derived Air Concentration (DAC):	3×10^{-8} uCi/cc (occupational)	1.1×10^{-3} Bq/cc (occupational)
• Annual Limit of Intake (ALI*):	4×10^{1} uCi (ingestion)	1.5×10^{6} Bq (ingestion)
*[1.0 ALI = 5,000 mrem CEDE]	1×10^{2} uCi (ingestion – thyroid)	3.7×10^{6} Bq (ingestion - thyroid)
	6×10^{1} uCi (inhalation)	2.2×10^{6} Bq (inhalation)
	2×10^{2} uCi (inhalation – thyroid)	7.4×10^{6} Bq (inhalation - thyroid)
• Effluent Release Limit:	3×10^{-10} uCi/cc (air)	1.1×10^{-5} Bq/cc (air)
	2×10^{-6} uCi/cc (water)	7.4×10^{-2} Bq/cc (water)

GENERAL RADIOLOGICAL SAFETY INFORMATION

- Laboratory coat and gloves must be worn when handling unsealed radioactive material. Monitor hands and change gloves frequently.

- Whole body and ring dosimeter must be worn when handling I-125.
- Lead shielding shall be used to minimize exposure from I-125 for mCi or greater activities. Shielding is not required when using RIA kits less than 10 µCi or other very low activity sources. RIA kits can be handled safely with reasonable care on the open bench.
- Indirect viewing aids should be used to minimize exposure from I-125.
- Store I-125 in lead shielding for mCi or greater activities.
- Remote handling tools should be used when handling I-125.
- Practice procedures without radioactivity prior to performing the procedure with I-125. Practice will improve dexterity and speed, along with providing opportunity to determine errors and practices that are not ALARA.
- After each use of unsealed I-125 monitor self, work areas and floors using a survey meter equipped with a G-M or NaI probe.
- Unbound I-125 is inherently volatile. Work with unbound I-125 shall be performed in a fume hood or well ventilated area. Iodinations shall be performed in a hood, approved by the Radiation Safety Office and equipped with charcoal filter and sampling apparatus.
- Acidic and frozen solutions enhance radioiodine volatility. Keeps pH of solutions containing I-125 at 7 or higher. Do not freeze solutions containing I-125.

Gamma exposure rate from 1 mCi point source - unshielded

Distance	mR/hr
1 cm	2750
5 cm	110
10 cm	27.5
100 cm	0.275

REFERENCES

Title 10 of the Code of Federal Regulations part 20

Ohio Administration Code 3701:1-38

EPA Federal Guidance Report No. 11

Shleien, The Health Physics and Radiological Health Handbook Revised Edition, (Scinta, Inc., 1992)

Health Physics & Radiological Health Handbook, 3rd Ed. [Baltimore, MD; Williams & Wilkins, 1998]

Delacoix et al, Radiation Protection Dosimetry – Radionuclide and Radiation Protection Data Handbook 2002, (Kent, England: Nuclear Technology Publishing, 2002)

www.stanford.edu/dept/EHS/prod/researchlab/radlaser/rsds.html

www.umich.edu/~oseh/isotopes

Isotope Fact Sheet

IODINE-131
[^{131}I]

PHYSICAL DATA

- Gamma Energy: 723 keV (2%)
  637 keV (7%)
  365 keV (82%)
  284 keV (6%)
  80 keV (3%)
- Maximum Beta Energy: 606 keV (90%)
  334 keV (7%)
  248 keV (2%)
- Electron Energy: 330 keV (2%)
  46 keV (4%)
- Alpha Energy: no alpha

- Physical Half-Life: 8 days
- Biological Half-Life: 138 days*
- Effective Half-Life: 7.6 days*

* These are "generic" biological and effective half-lives; the specific labeled compound may alter.

• Specific Activity:	1.24 x 10^{5} Ci/gram	4.61 x 10^{15} Bq/g
• Specific Gamma Constant: (@ 1 meter)	2.20 x 10^{-1} mR/hr/mCi	5.94 x10^{-5} mSv/hr/MBq

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RADIOLOGICAL DATA

- Radiological Toxicity Rating: Group 2 (high)
- Critical Organ: Thyroid
- Routes of Intake: Ingestion, Inhalation, Puncture, Wound, Skin Absorption

• Committed Effective Dose Equivalent (CEDE):	53 mrem/uCi (ingestion)	14.4 mSv/MBq (ingestion)
	33 mrem/uCi (inhalation)	8.9 mSv/MBq (inhalation)
• Skin Contamination (7 mg/cm^2):	5.6 x 10^{4} rem/y/uCi/cm^2	1.5 x 10^{-2} Sv/y/Bq/cm^2

(Kocher et al)

SHIELDING

• Half-Value Layer (HVL) for lead	0.12 inches	0.3 cm
HVL for steel	0.91 inches	2.3 cm
• Tenth-Value Layer (TVL) for lead	0.43 inches	1.1 cm
TVL for steel	2.20 inches	5.6 cm
• Maximum Beta Range in Air:	59 inches	149 cm
• Maximum Beta Range in Water/Tissue:	0.08 inches	0.2 cm
• Maximum Beta Range in Plastic:	0.06 inches	0.16 cm

SURVEY INSTRUMENTATION

- Survey meter equipped with a G-M pancake or thin-window probe is efficient for detecting the betas from I-131.
- Survey meters equipped with a NaI scintillation probe is suitable for detection of the I-131 gamma.
- Either a gamma counter or a liquid scintillation counter can be used to detect removable I-131 contamination on wipe tests smears.

RADIATION MONITORING DOSIMETERS

- Whole Body dosimeter: Required
- Finger dosimeter: Required.
- Thyroid count is the most common form of bioassay. Thyroid bioassays are required if greater than 2 millicuries of I-131 are used. The thyroid bioassay must be performed between 6 hours and 3 working days; however, performing the bioassay within 72 hours is preferred.
- Urine bioassay may be required for suspected skin contamination or ingestion.

RADIOACTIVE WASTE

- Solids, liquids, scintillation vials, pathological materials, animal carcasses

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REGULATORY COMPLIANCE INFORMATION

• Derived Air Concentration (DAC):	2×10^{-8} uCi/cc (occupational)	7.4×10^{-4} Bq/cc (occupational)
• Annual Limit of Intake (ALI*):	3×10^{1} uCi (ingestion)	1.1×10^{6} Bq (ingestion)
*[1.0 ALI = 5,000 mrem CEDE]	9×10^{1} uCi	3.3×10^{6} Bq

	(ingestion – thyroid)	(ingestion - thyroid)
	5×10^{1} uCi (inhalation)	1.9×10^{6} Bq (inhalation)
	2×10^{2} uCi	7.4×10^{6} Bq
	(inhalation – thyroid)	(inhalation - thyroid)
• Effluent Release Limit:	3×10^{-8} uCi/cc (air)	1.1×10^{-3} Bq/cc (air)
	1×10^{-4} uCi/cc (water)	3.7 Bq/cc (water)

GENERAL RADIOLOGICAL SAFETY INFORMATION

- Laboratory coat and gloves must be worn when handling unsealed radioactive material. Monitor hands and change gloves frequently.
- Whole body and ring dosimeter must be worn when handling I-131.
- Lead shielding shall be used to minimize exposure from I-131.
- Indirect viewing aids should be used to minimize exposure from I-131.
- Store I-131 in lead shielding.
- Remote handling tools should be used when handling I-131.
- Practice procedures without radioactivity prior to performing the procedure with I-131. Practice will improve dexterity and speed, along with providing opportunity to determine errors and practices that are not ALARA.
- After each use of unsealed I-131 monitor self, work areas and floors using a survey meter equipped with a G-M or NaI probe.
- Unbound I-131 is inherently volatile. Work with unbound I-131 shall be performed in a fume hood or well ventilated area. Iodinations shall be performed in a hood, approved by the Radiation Safety Office and equipped with charcoal filter and sampling apparatus.
- Acidic and frozen solutions enhance radioiodine volatility. Keep pH of solutions containing I-131 at 7 or higher. Do not freeze solutions containing I-131.

Gamma exposure rate from 1 mCi point source - unshielded

Distance	mR/hr
1 cm	2200
5 cm	88
10 cm	22
100 cm	0.22

REFERENCES

Title 10 of the Code of Federal Regulations part 20

Ohio Administration Code 3701:1-38

EPA Federal Guidance Report No. 11

Shleien, The Health Physics and Radiological Health Handbook Revised Edition, (Scinta, Inc., 1992)

Delacoix et al, Radiation Protection Dosimetry – Radionuclide and Radiation Protection Data Handbook 1998, (Kent, England: Nuclear Technology Publishing, 1998)

www.stanford.edu/dept/EHS/prod/researchlab/radlaser/rsds.html

www.nchps.org/nsds.htm

www.umich.edu/~oseh/isotopes

Isotope Fact Sheet

IRON-55
[^{55}Fe]

PHYSICAL DATA

- Photon Energy: 6 keV (28%)
  7 keV (3%)
- Electron Energy: 5 keV (61%)
- Alpha Energy: no alpha
- Physical Half-Life: 2.7 years
- Biological Half-Life: 2000 days*
- Effective Half-Life: 1.8 years*

* These are "generic" biological and effective half-lives; the specific labeled compound may alter.

• Specific Activity:	2.43 x 10^{3} Ci/gram	8.98 x 10^{13} Bq/g
• Specific Gamma Constant: (@ 1 meter)	insufficient data	insufficient data

RADIOLOGICAL DATA

- Radiological Toxicity Rating: Group 3 (moderate)
- Critical Organ: Spleen (blood)
- Routes of Intake: Ingestion, Inhalation, Puncture, Wound, Skin Absorption

• Committed Effective Dose Equivalent (CEDE):	0.59 mrem/uCi (ingestion)	0.16 mSv/MBq (ingestion)
	2.7 mrem/uCi	0.73 mSv/MBq
□	(inhalation - class D)	(inhalation - class D)
	1.3 mrem/uCi	0.36 mSv/MBq
□	(inhalation - class W)	(inhalation - class W)
• Skin Contamination	5.9 x 10^{-2} rem/hr/uCi/cm^2	1.6 x 10^{-2} mSv/hr/kBq/cm^2

SHIELDING

• Half-Value Layer (HVL) for lead	<0.1 inches	<0.1 cm
HVL for steel	<0.1 inches	<0.1 cm
• Tenth-Value Layer (TVL) for lead	<0.1 inches	<0.1 cm

TVL for steel	<0.1 inches	<0.1 cm

SURVEY INSTRUMENTATION

- Survey meter equipped with a G-M pancake or thin-window probe is not recommended for detecting Fe-55.
- Survey meters equipped with a thin crystal NaI scintillation probe is most suitable for detection of the Fe-55 photons.
- Either a gamma counter or a liquid scintillation counter can be used to detect removable Fe-55 contamination on wipe test smears.

RADIATION MONITORING DOSIMETERS

- Whole Body dosimeter: Required
- Finger dosimeter: Required.
- Urine bioassay (taken within the first 24 hours) or blood samples may be required for suspected skin contamination or ingestion.

RADIOACTIVE WASTE

- Solids, liquids, scintillation vials, pathological materials, animal carcasses

REGULATORY COMPLIANCE INFORMATION

• Derived Air Concentration (DAC):	8×10^{-7} uCi/cc (occupational – class D)	3.0×10^{-2} Bq/cc (occupational – class W)
	2×10^{-6} uCi/cc (occupational – class W)	7.4×10^{-2} Bq/cc (occupational – class Y)
• Annual Limit of Intake (ALI*):	9×10^{3} uCi	3.3×10^{8} Bq
*[1.0 ALI = 5,000 mrem CEDE]	(ingestion - class D)	(ingestion – class D)
	2×10^{3} uCi	7.4×10^{7} Bq
	(inhalation – class D)	(inhalation – class D)
	4×10^{3} uCi	1.5×10^{8} Bq
	(inhalation – class W)	(inhalation – class W)
• Effluent Release Limit:	3×10^{-9} uCi/cc (air)	1.1×10^{-4} Bq/cc (air)
□	1×10^{-4} uCi/cc (water)	3.7 Bq/cc (water)

GENERAL RADIOLOGICAL SAFETY INFORMATION

- Laboratory coat and gloves must be worn when handling unsealed radioactive material. Monitor hands and change gloves frequently.

- Whole body and ring dosimeter must be worn when handling Fe-55.
- Lead shielding may be useful to minimize exposure from Fe-55.
- Remote handling tools should be used when handling Fe-55.
- Practice procedures without radioactivity prior to performing the procedure with Fe-55. Practice will improve dexterity and speed, along with providing opportunity to determine errors and practices that are not ALARA.
- After each use of unsealed Fe-55 monitor self, work areas and floors using a survey meter equipped with a G-M or NaI probe (NaI probe preferred).

Gamma exposure rate from 1 mCi point source - unshielded

Distance	mR/hr
1 cm	insufficient data
5 cm	insufficient data
10 cm	insufficient data
100 cm	insufficient data

REFERENCES

Title 10 of the Code of Federal Regulations part 20

Ohio Administration Code 3701:1-38

EPA Federal Guidance Report No. 11

Shleien, The Health Physics and Radiological Health Handbook Revised Edition, (Scinta, Inc., 1992)

Delacoix et al, Radiation Protection Dosimetry – Radionuclide and Radiation Protection Data Handbook 1998, (Kent, England: Nuclear Technology Publishing, 1998)

www.nchps.org

www.perkinelmer.com

Isotope Fact Sheet

IRON-59
[^{59}Fe]

PHYSICAL DATA

- Photon Energy: 1292 keV (43.2%)
  1099 keV (56.5%)
  192 keV (3.1%)
  143 kev (1.0%)
- Beta Energy: 1565 keV (0.2%)
  465 keV (53.1%)
  273 keV (45.2%)
  131 keV (1.4%)
- Alpha Energy: no alpha

- Physical Half-Life: 44.5 days
- Biological Half-Life: 700 days
- Effective Half-Life: 42 days

• Specific Activity:	4.92 x 10^{4} Ci/gram	1.82 x 10^{15} Bq/g
• Specific Gamma Constant:	6.4 x 10^{-1} mR/hr/mCi	1.73 x10^{-4} mSv/hr/MBq
(@ 1 meter)		

RADIOLOGICAL DATA

- Radiological Toxicity Rating: Group 3 (moderate)
- Critical Organ: Spleen (blood), lungs (inhalation) and LLI (ingestion)
- Routes of Intake: Ingestion, Inhalation, Puncture, Wound, Skin Absorption

• Committed Effective Dose Equivalent (CEDE):	6.6 mrem/uCi (ingestion)	1.81 mSv/MBq (ingestion)
	14.8 mrem/uCi	4.0 mSv/MBq
	(inhalation - class D)	(inhalation - class D)
	12.2 mrem/uCi	3.30 mSv/MBq
	(inhalation - class W)	(inhalation - class W)
• Skin Contamination	3.6 rem/hr/uCi/cm^{2}	9.7 x 10^{-1} mSv/hr/kBq/cm^{2}

SHIELDING

• Half-Value Layer (HVL) for lead	0.59 inches	1.5 cm
HVL for steel	1.38 inches	3.5 cm
• Tenth-Value Layer (TVL) for lead	1.77 inches	4.5 cm
TVL for steel	3.58 inches	9.1 cm

SURVEY INSTRUMENTATION

- Survey meter equipped with a G-M pancake or thin-window probe is suitable for detecting Fe-59. Typical efficiency for a G-M pancake survey meter is 20-25%.
- Survey meters equipped with a NaI scintillation probe is suitable for detection of the Fe-59 photons. Typical efficiency for a survey meter equipped with a NaI crystal is 3-5%.
- Either a gamma counter or a liquid scintillation counter can be used to detect removable Fe-59 contamination on wipe test smears. (LSC efficiency ~90%; gamma counter efficiency ~70%)

RADIATION MONITORING DOSIMETERS

- Whole Body dosimeter: Required
- Finger dosimeter: Required.
- Urine bioassay (taken 4 to 24 hours after event) or whole body counting may be required for suspected skin contamination or ingestion.

RADIOACTIVE WASTE

- Solids, liquids, scintillation vials, pathological materials, animal carcasses

REGULATORY COMPLIANCE INFORMATION

• Derived Air Concentration (DAC):	1×10^{-7} uCi/cc (occupational – class D)	3.7×10^{-3} Bq/cc (occupational – class D)
	2×10^{-7} uCi/cc (occupational – class W)	7.4×10^{-3} Bq/cc (occupational – class W)
• Annual Limit of Intake (ALI*):	8×10^{2} uCi	3.0×10^{7} Bq
*[1.0 ALI = 5,000 mrem CEDE]	(ingestion - class D)	(ingestion – class D)
	3×10^{2} uCi	1.1×10^{7} Bq
	(inhalation – class D)	(inhalation – class D)

	5×10^{2} uCi	1.9×10^{7} Bq
	(inhalation – class W)	(inhalation – class W)
• Effluent Release Limit:	5×10^{-10} uCi/cc (air)	1.9×10^{-5} Bq/cc (air)
	1×10^{-5} uCi/cc (water)	3.7×10^{-1} Bq/cc (water)

GENERAL RADIOLOGICAL SAFETY INFORMATION

- Laboratory coat and gloves must be worn when handling unsealed radioactive material. Monitor hands and change gloves frequently.
- Whole body and ring dosimeter must be worn when handling Fe-59.
- Lead shielding shall be used to minimize exposure from Fe-59.
- Indirect viewing aids should be used to minimize exposure from Fe-59.
- Store Fe-59 in lead shielding.
- Remote handling tools should be used when handling Fe-59.
- Practice procedures without radioactivity prior to performing the procedure with Fe-59. Practice will improve dexterity and speed, along with providing opportunity to determine errors and practices that are not ALARA.
- After each use of unsealed Fe-59 monitor self, work areas and floors using a survey meter equipped with a G-M or NaI probe (NaI probe preferred).

Gamma exposure rate from 1 mCi point source - unshielded

Distance	mR/hr
1 cm	6400*
5 cm	256*
10 cm	64
100 cm	0.6

* There is also a very significant additional dose from the betas at close distances.

REFERENCES

Title 10 of the Code of Federal Regulations part 20

Ohio Administration Code 3701:1-38

EPA Federal Guidance Report No. 11

Shleien, The Health Physics and Radiological Health Handbook Revised Edition, (Scinta, Inc., 1992)

Delacoix et al, Radiation Protection Dosimetry – Radionuclide and Radiation Protection Data Handbook 1998, (Kent, England: Nuclear Technology Publishing, 1998)

www.sciencegateway.org/isotope

www.perkinelmer.com

Isotope Fact Sheet

LEAD-212
[^{212}Pb]

PHYSICAL DATA*

- Photon Energy: 583 keV (30%)
  2615 keV (36%)
- Beta Energy: 1519 keV (18%)
  1794 keV (20%)
  2246 keV (53%)
- Alpha Energy: 6051 keV (25%)
  6090 keV (10%)
  8785 keV (71%)
- Physical Half-Life: 10.6 hours
- Specific Activity: 3.4 x 10^{-7} Ci/g 5.1404 x 10^{16} Bq/g

- Specific Gamma Constant: 2.73 x 10^{-4} mR/hr/mCi 7.389 x 10^{-5} mSv/hr/MBq

(@ 1 meter)
Part of Thorium series of decay. Pb-212 decays to Bismuth-212 (Bi-212). Bi-212 decays to Thallium-208 (Tl-208) and Polonium-212 (Po-212). This decay from radioactive parent to radioactive progeny continues until ending with the stable isotope Lead-208 (Pb-208). The above assumes all in equilibrium.

RADIOLOGICAL DATA

- Radiological Toxicity Rating: Group 2 (High)
- Critical Organ: Bone
- Routes of Intake: Ingestion, Inhalation, Puncture, Wound, Skin Absorption

- Committed Effective Dose Equivalent (CEDE): 4.55 x 10^{1} mrem/uCi (ingestion) 1.23 x 10^{1} mSv/MBq (ingestion)

SHIELDING

- Half-Value Layer (HVL) for lead 0.87 inches 2.2 cm

SURVEY INSTRUMENTATION

- Survey meter equipped with a G-M pancake or thin-window probe is efficient for detecting ^{212}Pb . Typical efficiency for a G-M pancake survey meter is 21% -26%.

RADIATION MONITORING DOSIMETERS

- Whole Body dosimeter: Required
- Finger dosimeter: Required.
- Whole body or urine bioassay may be required for suspected skin contamination or ingestion.

RADIOACTIVE WASTE

- Solids, liquids, scintillation vials, pathological materials, animal carcasses

REGULATORY COMPLIANCE INFORMATION

• Derived Air Concentration (DAC):	1×10^{-8} uCi/cc (occupational – class D)	3.7×10^{-4} Bq/cc (occupational – class D)
• • Annual Limit of Intake (ALI*): *[1.0 ALI = 5,000 mrem CEDE]	8×10^{1} uCi (ingestion – bone surfaces) 3×10^{1} uCi (inhalation – class D bone surfaces)	2.96×10^{5} Bq (ingestion – bone surfaces) 1.1×10^{6} Bq (inhalation – class D – bone surfaces)
• Effluent Release Limit:	5×10^{-11} uCi/cc (air- class D)	1.85×10^{-6} Bq/cc (air – class D)

GENERAL RADIOLOGICAL SAFETY INFORMATION

- Laboratory coat and gloves must be worn when handling unsealed radioactive material. Monitor hands and change gloves frequently.
- Whole body and ring dosimeter must be worn when handling specifically licensed Pb-212.
- Because of the decay daughter, lead shielding shall be used to minimize exposure from Pb-212.
- Remote handling tools should be used when handling Pb-212.
- Practice procedures without radioactivity prior to performing the procedure with Pb-212. Practice will improve dexterity and speed, along with providing opportunity to determine errors and practices that are not ALARA.
- After each use of unsealed Pb-212 monitor self, work areas and floors using a survey meter equipped with a G-M.
- Procedures involving dusty operations, vapors or aerosols should be performed in a fume hood.
- Because of the high energy beta, the possibility of skin contamination or direct handling of Pb-212 needs to be minimized. If skin contamination is detect decontamination needs to be initiated immediately. Even low activities of Pb-212 skin contamination for a short period of time can result in a significant dose to the skin.

Beta exposure rate from 1 mCi point source - unshielded

Distance	mR/hr
1 cm	2.73
5 cm	1.09×10^{-1}
10 cm	2.73×10^{-2}
100 cm	2.73×10^{-4}

REFERENCES

Title 10 of the Code of Federal Regulations part 20
Ohio Administration Code 3701:1-38
EPA Federal Guidance Report No. 11
Shleien, The Health Physics and Radiological Health Handbook Third Edition, (Scinta, Inc., 1998)
www.stanford.edu/dept/EHS/prod/researchlab/radlaser/rsds.html

Isotope Fact Sheet

MANGANESE-54
[^{54}Mn]

PHYSICAL DATA

- Photon Energy: 5 keV (23%)
  6 keV (3%)
  835 keV (100%)
- Electron Energy: 4 keV (67%)
- Alpha Energy: no alpha

- Physical Half-Life: 312.7 days
  4-25 days*
- Biological Half-Life:
  (40 days bone)
  4-23 days*
- Effective Half-Life:
  (35 days bone)

* These are "generic" biological and effective half-lives; the specific labeled compound may alter.

• Specific Activity:	7.76 x 10^{3} Ci/gram	2.87 x 10^{14} Bq/g
• Specific Gamma Constant: (@ 1 meter)	5.1 x 10^{-1} mR/hr/mCi	1.38 x10^{-4} mSv/hr/MBq

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RADIOLOGICAL DATA

- Radiological Toxicity Rating: Group 2 (moderate/high)
- Critical Organ: Liver, GI Tract (LLI), Lung
- Routes of Intake: Ingestion, Inhalation, Puncture, Wound, Skin Absorption

• Committed Effective Dose Equivalent (CEDE):	2.8 mrem/uCi (ingestion)	0.75 mSv/MBq (ingestion)
	5.26 mrem/uCi	1.42 mSv/MBq
	(inhalation - class D)	(inhalation - class D)
	6.70 mrem/uCi	1.81 mSv/MBq
	(inhalation - class W)	(inhalation - class W)
• Skin Contamination	2.3 x 10^{-1} rem/hr/uCi/cm^2	6.2 x 10^{-2} mSv/hr/kBq/cm^2

SHIELDING

• Half-Value Layer (HVL) for lead	0.43 inches	1.1 cm
HVL for steel	1.26 inches	3.2 cm
• Tenth-Value Layer (TVL) for lead	1.26 inches	3.2 cm
TVL for steel	3.11 inches	7.9 cm

SURVEY INSTRUMENTATION

- Survey meter equipped with a G-M pancake or thin-window probe is not very efficient for detecting Mn-54. Typical efficiency for a G-M pancake survey meter is <1%.
- Survey meters equipped with a NaI scintillation probe is suitable for detection of the Mn-54 photons. Typical efficiency for a survey meter equipped with a NaI crystal is about 5%.
- Either a gamma counter or a liquid scintillation counter can be used to detect removable Mn-54 contamination on wipe test smears. (LSC efficiency ~30%; gamma counter efficiency ~5%)

RADIATION MONITORING DOSIMETERS

- Whole Body dosimeter: Required
- Finger dosimeter: Required.
- Urine bioassay (taken 4 to 24 hours after event) or whole body counting may be required for suspected skin contamination or ingestion.

RADIOACTIVE WASTE

- Solids, liquids, scintillation vials, pathological materials, animal carcasses

REGULATORY COMPLIANCE INFORMATION

• Derived Air Concentration (DAC):	4×10^{-7} uCi/cc (occupational – class D)	1.5×10^{-2} Bq/cc (occupational – class D)
	3×10^{-7} uCi/cc (occupational – class W)	1.1×10^{-2} Bq/cc (occupational – class W)
• Annual Limit of Intake (ALI*):	2×10^{3} uCi	7.4×10^{7} Bq
*[1.0 ALI = 5,000 mrem CEDE]	(ingestion - class D)	(ingestion – class D)
	9×10^{2} uCi	3.3×10^{7} Bq
	(inhalation – class D)	(inhalation – class D)

	$8x\ 10^{2}$ uCi	3.0×10^{7} Bq
	(inhalation – class W)	(inhalation – class W)
• Effluent Release Limit:	1×10^{-9} uCi/cc (air)	3.7×10^{-5} Bq/cc (air)
	3×10^{-5} uCi/cc (water)	1.1 Bq/cc (water)

GENERAL RADIOLOGICAL SAFETY INFORMATION

- Laboratory coat and gloves must be worn when handling unsealed radioactive material. Monitor hands and change gloves frequently.
- Whole body and ring dosimeter must be worn when handling Mn-54.
- Lead shielding shall be used to minimize exposure from Mn-54.
- Indirect viewing aids should be used to minimize exposure from Mn-54.
- Store Mn-54 in lead shielding.
- Remote handling tools should be used when handling Mn-54.
- Practice procedures without radioactivity prior to performing the procedure with Mn-54. Practice will improve dexterity and speed, along with providing opportunity to determine errors and practices that are not ALARA.
- After each use of unsealed Mn-54 monitor self, work areas and floors using a survey meter equipped with a G-M or NaI probe (NaI probe preferred).

Gamma exposure rate from 1 mCi point source - unshielded

Distance	mR/hr
1 cm	5000
5 cm	200
10 cm	50
100 cm	0.5

REFERENCES

Title 10 of the Code of Federal Regulations part 20

Ohio Administration Code 3701:1-38

EPA Federal Guidance Report No. 11

Shleien, The Health Physics and Radiological Health Handbook Revised Edition, (Scinta, Inc., 1992)

Delacoix et al, Radiation Protection Dosimetry – Radionuclide and Radiation Protection Data Handbook 1998, (Kent, England: Nuclear Technology Publishing, 1998)

www.wsu.edu/~wsurso/isotopes

www.uwm.edu/dept/ehsrm/rad

www.sciencegateway.org/isotope

www.perkinelmer.com

Isotope Fact Sheet

Mercury-203
[^{203}Hg]

PHYSICAL DATA

• Photon or X-ray Energy:	279 keV (82%) 73 keV (6%) 71 keV (4%)	
• Maximum Beta Energy:	212 keV (100%)	
• Physical Half-Life:	46.6 days	
• Biological Half-Life:	35 - 90 days	
• Effective Half-Life:	20 - 31 days	
• Specific Activity:	13807 Ci/gram	5.1085 x 10^{14} Bq/g
• Specific Gamma Constant: (@ 1 meter)	2.53 x 10^{-1} mR/hr/mCi	6.84 x10^{-5} mSv/hr/MBq

RADIOLOGICAL DATA

- Radiological Toxicity Rating: Group 3 (Moderate)
- Critical Organ: Kidneys
- Routes of Intake: Ingestion, Inhalation, Puncture, Wound, Skin Absorption

• Committed Effective Dose Equivalent (CEDE):	1.14 x 10^{1} mrem/uCi (ingestion)	3.09 mSv/MBq (ingestion)
	7.33 mrem/uCi (inhalation – class D)	1.98 mSv/MBq (inhalation – class D)
	6.41 mrem/uCi (inhalation – vapor)	1.73 mSv/MBq (inhalation – vapor)
• Skin Contamination	3.29 rem/hr/uCi/cm^2	8.9 x 10^{-1} mSv/hr/kBq/cm^2

SHIELDING

- ¼ inch plexiglas/acrylic/lucite/plastic/wood followed by lead.

- Lead foil or sheets should not be used as a primary barrier. Penetrating bremsstrahlung x-ray are produced. Use lead sheets or foil to shield bremsstrahlung x-rays **after** low density plexiglas/acrylic/lucite/wood shielding.

• Half-Value Layer: (HVL) for lead	0.08 inches	0.2 cm
HVL for steel	0.71 inches	1.8 cm
• Tenth-Value Layer: (TVL) for lead	0.20 inches	0.5 cm
TVL for steel	1.77 inches	4.5 cm

• Maximum Beta Range in Air:	13.4 inches	34 cm
• Maximum Beta Range in Water/Tissue:	0.016 inches	0.04 cm
• Maximum Beta Range in Plastic:	0.016 inches	0.04 cm

SURVEY INSTRUMENTATION

- A survey meter equipped with a G-M pancake will readily detect low level Hg-203 contamination. Typical efficiency for a G-M pancake survey meter is 14% - 21%.
- A survey meter equipped with a thin NaI scintillation probe will detect Hg-203 contamination. Typical efficiency for a thin NaI scintillation probe 9% - 11%.

RADIATION MONITORING DOSIMETERS

- Whole Body dosimeter: Required
- Finger dosimeter: Required
- Urine bioassay may be required for suspected skin contamination or ingestion.

RADIOACTIVE WASTE

- Solids, liquids, scintillation vials, pathological materials, animal carcasses

REGULATORY COMPLIANCE INFORMATION

• Derived Air Concentration (DAC) occupational values:	4×10^{-7} uCi/cc (vapor) 3×10^{-7} uCi/cc (organic D)	1.48×10^{-2}Bq/cc (vapor) 1.11×10^{-2}Bq/cc (organic D)
• Annual Limit of Intake (ALI*): *[1.0 ALI = 5,000 mrem CEDE] Occupational Values	5×10^{2} uCi (Organic D) 8×10^{2} uCi (inhalation-vapor) 8×10^{2} uCi (inhalation-organic D)	1.85×10^{7}Bq(organic D) 2.96×10^{7} Bq (inhalation-vapor) 2.96×10^{7} Bq (inhalation-organic D)
• Effluent Release Limit:	1×10^{-9} uCi/cc (air – vapor) 1×10^{-9} uCi/cc (air – organic D) 7×10^{-6} uCi/cc (water – organic D)	3.7×10^{-5} Bq/cc (air – vapor) 3.7×10^{-5} Bq/cc (air – organic D) 2.59×10^{-1} Bq/cc (water – organic D)

GENERAL RADIOLOGICAL SAFETY INFORMATION

- Laboratory coat and gloves must be worn when handling unsealed radioactive material. Monitor hands and change gloves frequently.
- Plastic or other low Z material shielding followed by lead should be used to minimize exposure from Hg-203.
- Store Hg-203 in plastic or other low Z material covered by lead.
- Remote handling tools should be used when handling Hg-203.
- Practice procedures without radioactivity prior to performing the procedure with Hg-203. Practice will improve dexterity and speed, along with providing opportunity to determine errors and practices that are not ALARA.
- After each use of unsealed Hg-203 monitor self, work areas and floors using a survey meter equipped with a pancake probe or thin NaI scintillation probe. When performing the monitoring using a pancake probe ensure to remove cap and never cover the window of the survey meter with the plastic or parafilm, as this significantly reduces the efficiency of detection.

Gamma exposure rate from 1 mCi point source - unshielded

Distance	mR/hr
1 cm	2530
5 cm	101.2
10 cm	25.3
100 cm	0.25

REFERENCES

Title 10 of the Code of Federal Regulations part 20
Ohio Administration Code 3701:1-38
EPA Federal Guidance Report No. 11
Shleien, The Health Physics and Radiological Health Handbook Third Edition, (Scinta, Inc., 1998)
Delacoix et al, Radiation Protection Dosimetry – Radionuclide and Radiation Protection Data Handbook 2002, (Kent, England: Nuclear Technology Publishing, 2002)
http://www.stanford.edu/dept/EHS/prod/researchlab/radlaser/RSDS_sheets/Hg-203.pdf
http://ehsrms.uaa.alaska.edu/RSDS/203Hg.pdf
http://www.wolframalpha.com/entities/isotopes/mercury_203/td/hf/9b/
http://www.crcnetbase.com/doi/abs/10.1201/9781420037197.ax5

Isotope Fact Sheet

NICKEL-63
[^{63}Ni]

PHYSICAL DATA

- Gamma Energy: no photon
- Maximum Beta Energy: 66 keV (100%)
- Alpha Energy: no alpha

- Physical Half-Life: 100 years
- Biological Half-Life: 667 days*
- Effective Half-Life: 645 days*

* These are "generic" biological and effective half-lives; the specific labeled compound may alter.

- Specific Activity: 5.7 x 10^{1} Ci/gram 2.1 x 10^{12} Bq/g

RADIOLOGICAL DATA

- Radiological Toxicity Rating: Group 3 (moderate)
- Critical Organ: Lower Large Intestine
- Routes of Intake: Ingestion, Inhalation, Puncture, Wound, Skin Absorption

• Committed Effective Dose Equivalent (CEDE):	0.59 mrem/uCi (ingestion)	0.156 mSv/MBq (ingestion)
	3.1 mrem/uCi (inhalation – class D)	0.839 mSv/MBq (inhalation – class D)
	2.3 mrem/uCi (inhalation – class W)	0.622 mSv/MBq (inhalation – class W)
	6.3 mrem/uCi (inhalation – class W)	1.700 mSv/MBq (inhalation – vapor)
• Skin Contamination	0 (low energy beta stopped by dead layer of skin)	

SHIELDING

- Not required because of low energy beta

• Maximum Beta Range in Air:	2.0 inches	5 cm
• Maximum Beta Range in Water/Tissue:	0.001 inches	0.003 cm
• Maximum Beta Range in Plastic:	0.001 inches	0.002 cm

SURVEY INSTRUMENTATION

- Survey meter equipped with a G-M pancake or thin-window probe **cannot** detect the betas from Ni-63.
- A liquid scintillation counter should be used to detect removable Ni-63 contamination on wipe tests smears.

RADIATION MONITORING DOSIMETERS

- Whole Body dosimeter: Not required
- Finger dosimeter: Not required.
- Urine bioassay may be required for suspected skin contamination or ingestion.

RADIOACTIVE WASTE

- Solids, liquids, scintillation vials, pathological materials, animal carcasses

REGULATORY COMPLIANCE INFORMATION

• Derived Air Concentration (DAC):	7.0×10^{-7} uCi/cc (occupational – class D)	2.6×10^{-2} Bq/cc (occupational – class D)
	1.0×10^{-6} uCi/cc (occupational – class W)	3.7×10^{-2} Bq/cc (occupational – class W)
• Annual Limit of Intake (ALI*):	9.0×10^{3} uCi (ingestion)	3.3×10^{8} Bq (ingestion)
*[1.0 ALI = 5,000 mrem CEDE]	2.0×10^{4} uCi (inhalation)	7.4×10^{8} Bq (inhalation)
• Effluent Release Limit:	2.0×10^{-9} uCi/cc	7.4×10^{-5} Bq/cc
	(air – class D)	(air – class D
	4.0×10^{-9} uCi/cc	1.5×10^{-4} Bq/cc
	(air – class W)	(air – class W)
	1.0×10^{-4} uCi/cc	3.7 Bq/cc
	(water)	(water)

GENERAL RADIOLOGICAL SAFETY INFORMATION

- Laboratory coat and gloves must be worn when handling unsealed radioactive material. Monitor hands and change gloves frequently.
- Practice procedures without radioactivity prior to performing the procedure with Ni-63. Practice will improve dexterity and speed, along with providing opportunity to determine errors and practices that are not ALARA.
- After each use of unsealed Ni-63 monitor self, work areas and floors using a wipe test counted in a liquid scintillation counter.
- A common use of Ni-63 is a foil within an electron capture detector of a gas chromatograph. Electron capture detectors are considered a "sealed source". Temperature controls on the gas chromatograph shall not be tampered with to minimize the probability of the Ni-63 becoming volatile or detaching from the foil. The exhaust port from the electron capture detector shall be leak tested every 6-month to ensure the integrity of the Ni-63 foil has not been compromised.

REFERENCES

Title 10 of the Code of Federal Regulations part 20

Ohio Administration Code 3701:1-38

EPA Federal Guidance Report No. 11

Shleien, The Health Physics and Radiological Health Handbook Revised Edition, (Scinta, Inc., 1992)

Delacoix et al, Radiation Protection Dosimetry – Radionuclide and Radiation Protection Data Handbook 1998, (Kent, England: Nuclear Technology Publishing, 1998)

www.stanford.edu/dept/EHS/prod/researchlab/radlaser/rsds.html

PHOSPHORUS-32
[^{32}P]

PHYSICAL DATA

- Gamma Energy: no photon
- Maximum Beta Energy: 1709 keV (100%)
- Alpha Energy: no alpha

- Physical Half-Life: 14.3 days
- Biological Half-Life: 1155 days (bone)* 257 days (whole body)*
- Effective Half-Life: 14.1 days (bone)* 13.5 days (whole body)*

* These are "generic" biological and effective half-lives; the specific labeled compound may alter.

- Specific Activity: 2.86 x 10^5 Ci/gram 1.06 x 10^{16} Bq/g

RADIOLOGICAL DATA

- Radiological Toxicity Rating: Group 3 (moderate)
- Critical Organ: Bone Marrow, Lungs
- Routes of Intake: Ingestion, Inhalation, Puncture, Wound, Skin Absorption

- Committed Effective Dose Equivalent (CEDE):

8.78 mrem/uCi (ingestion)	2.37 mSv/MBq (ingestion)
6.07 mrem/uCi	1.64 mSv/MBq
(inhalation – class D)	(inhalation – class D)
15.5 mrem/uCi	4.19 mSv/MBq
(inhalation – class W)	(inhalation – class W)

- Skin Contamination

(7 mg/cm^2): 7.77 x 10^4 rem/y/uCi/cm^2 2.1 x 10^{-2} Sv/y/Bq/cm^2

(Kocher et al)

SHIELDING

- ½ to ¾ inch plexiglas/acrylic/lucite/plastic/wood
- Do not use lead foil or sheets as primary barrier! Penetrating bremsstrahlung x-ray will be produced!

- Use lead sheets or foil to shield bremsstrahlung x-rays only **after** low density plexiglas/acrylic/lucite/wood shielding.

• Maximum Beta Range in Air:	240 inches	610 cm
• Maximum Beta Range in Water/Tissue:	0.30 inches	0.76 cm
• Maximum Beta Range in Plastic:	0.25 inches	0.63 cm

SURVEY INSTRUMENTATION

- Survey meter equipped with a G-M pancake or thin-window probe can be used to detect the betas from the P-33. Typical efficiency for a G-M pancake survey meter is between 20% and 30%.
- A NaI survey meter may be used; however, the efficiency of detection is low as it is detecting bremsstrahlung x-rays.
- A liquid scintillation counter should be used to detect removable P-32 contamination on wipe tests smears. Detection efficiency using standard liquid scintillation cocktail is generally greater than 90%. Cerenkov counting can also be used, with an efficiency of about 50% to 60%.

RADIATION MONITORING DOSIMETERS

- Whole Body dosimeter: Required
- Finger dosimeter: Required
- Urine bioassay may be required for suspected skin contamination or ingestion.

RADIOACTIVE WASTE

- Solids, liquids, scintillation vials, pathological materials, animal carcasses

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REGULATORY COMPLIANCE INFORMATION

• Derived Air Concentration (DAC):	4×10^{-7} uCi/cc (occupational – class D)	1.5×10^{-2} Bq/cc (occupational – class Dr)
	2×10^{-7} uCi/cc (occupational – class W)	7.4×10^{-3} Bq/cc (occupational – class W)
• Annual Limit of Intake (ALI*):	6×10^{2} uCi (ingestion)	2.2×10^{7} Bq (ingestion)
*[1.0 ALI = 5,000 mrem CEDE]	9×10^{2} uCi (inhalation – class D)	3.3×10^{7} Bq (inhalation – class D)
	4×10^{2} uC (inhalation – class W)	1.5×10^{7} Bq (inhalation – class W)
• Effluent Release Limit:	1×10^{-9} uCi/cc	3.7×10^{-5} Bq/cc

(air – class D)	(air- class D)
5×10^{-10} uCi/cc	1.9×10^{-5} Bq/cc
(air – class W)	(air- class w)
9×10^{-6} uCi/cc (water)	3.3×10^{-1}Bq/cc (water)

GENERAL RADIOLOGICAL SAFETY INFORMATION

- Laboratory coat and gloves, if practical double gloves, must be worn when handling unsealed P-32. Monitor hands and change gloves frequently.
- Whole body and ring dosimeter must be worn when handling P-32.
- Avoid direct eye contact with the P-32 beta. Never look directly upon an unshielded container of P-32.
- Eye protection (safety glasses or goggles) should be worn when handling P-32.
- Plastic or other low Z material shielding shall be used to minimize exposure from P-32.
- Store P-32 in plastic or other low Z material.
- Remote handling tools should be used when handling P-32.
- Practice procedures without radioactivity prior to performing the procedure with P-32. Practice will improve dexterity and speed, along with providing opportunity to determine errors and practices that are not ALARA.
- After each use of unsealed P-32 monitor self, work areas and floors using a survey meter equipped with a pancake or thin window G-M probe.
- Because of the high energy beta, the possibility of skin contamination or direct handling of P-32 needs to be minimized. If skin contamination is detect decontamination needs to be initiated immediately. Even low activities of P-32 skin contamination for a short period of time can result in a significant dose to the skin.

Beta (skin) exposure rate from 1 mCi point source – unshielded*

Distance	mR/hr
1 cm	~300000
5 cm	~12000
10 cm	~3000

*Follows the inverse square law at close distances. Because of the high energy beta, skin dose rates at close distances are very high.

REFERENCES

Title 10 of the Code of Federal Regulations part 20

Ohio Administration Code 3701:1-38

EPA Federal Guidance Report No. 11

Shleien, The Health Physics and Radiological Health Handbook Revised Edition, (Scinta, Inc., 1992)

Delacoix et al, Radiation Protection Dosimetry – Radionuclide and Radiation Protection Data Handbook 1998, (Kent, England: Nuclear Technology Publishing, 1998)

www.stanford.edu/dept/EHS/prod/researchlab/radlaser/rsds.html

www.umich.edu/~oseh/isotopes

Isotope Fact Sheet

PHOSPHORUS-33
[^{33}P]

PHYSICAL DATA

- Gamma Energy: no photon
- Maximum Beta Energy: 249 keV (100%)
- Alpha Energy: no alpha

	25.6 days	
• Biological Half-Life:	1155 days (bone)*	257 days (whole body)*
• Effective Half-Life:	24.9 days (bone)*	23.3 days (whole body)*

* These are "generic" biological and effective half-lives; the specific labeled compound may alter.

- Specific Activity: 1.55 x 10^5 Ci/gram 5.72 x 10^{15} Bq/g

RADIOLOGICAL DATA

- Radiological Toxicity Rating: Group 3 (moderate)
- Critical Organ: Bone Marrow, Lungs
- Routes of Intake: Ingestion, Inhalation, Puncture, Wound, Skin Absorption

• Committed Effective Dose Equivalent (CEDE):	0.919 mrem/uCi (ingestion – class D)	0.248 mSv/MBq (ingestion – class D)
	0.633 mrem/uCi (inhalation – class D)	0.171 mSv/MBq (inhalation – class D)
	2.32 mrem/uCi (inhalation – class W)	0.627 mSv/MBq (inhalation – class W)
• Skin Contamination	3.2 rem/hr/uCi/cm^2	0.86 mSv/hr/kBq/cm^2

SHIELDING

- ¼ inch plexiglas/acrylic/lucite/plastic/wood
- Do not use lead foil or sheets as primary barrier! Penetrating bremsstrahlung x-ray will be produced!
- Use lead sheets or foil to shield bremsstrahlung x-rays only **after** low density plexiglas/acrylic/lucite/wood shielding.

- Maximum Beta Range in Air: 18 inches 46 cm

• Maximum Beta Range in Water/Tissue:	0.02 inches	0.06 cm
• Maximum Beta Range in Plastic:	0.02 inches	0.05 cm

SURVEY INSTRUMENTATION

- Survey meter equipped with a G-M pancake or thin-window probe can be used to detect the betas from the P-33. Typical efficiency for a G-M pancake survey meter is between 4% and 6%.
- A liquid scintillation counter should be used to detect removable P-33 contamination on wipe tests smears. Typical efficiency for a LSC to detect P-33 is greater than 85%.

RADIATION MONITORING DOSIMETERS

- Whole Body dosimeter: Not required
- Finger dosimeter: Not required
- Urine bioassay may be required for suspected skin contamination or ingestion.

RADIOACTIVE WASTE

- Solids, liquids, scintillation vials, pathological materials, animal carcasses

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REGULATORY COMPLIANCE INFORMATION

• Derived Air Concentration (DAC):	4×10^{-6} uCi/cc (occupational – class D)	1.5×10^{-1} Bq/cc (occupational – class Dr)
	1×10^{-6} uCi/cc (occupational – class W)	3.7×10^{-2} Bq/cc (occupational – class W)
• Annual Limit of Intake (ALI*):	6×10^{3} uCi (ingestion)	2.2×10^{8} Bq (ingestion)
*[1.0 ALI = 5,000 mrem CEDE]	8×10^{3} uCi	3.0×10^{8} Bq
	(inhalation – class D)	(inhalation – class D)
	3×10^{2} uC	1.1×10^{7} Bq
	(inhalation – class W)	(inhalation – class W)
• Effluent Release Limit:	1×10^{-8} uCi/cc	3.7×10^{-4} Bq/cc
	(air – class D)	(air- class D)
	4×10^{-9} uCi/cc	1.5×10^{-4} Bq/cc
	(air – class W)	(air- class w)
	8×10^{-5} uCi/cc (water)	3.0 Bq/cc (water)

GENERAL RADIOLOGICAL SAFETY INFORMATION

- Laboratory coat and gloves must be worn when handling unsealed radioactive material. Monitor hands and change gloves frequently.
- Plastic or other low Z material shielding shall be used to minimize exposure from P-33.
- Store P-33 in plastic or other low Z material.
- Remote handling tools should be used when handling P-33.
- Practice procedures without radioactivity prior to performing the procedure with P-33. Practice will improve dexterity and speed, along with providing opportunity to determine errors and practices that are not ALARA.
- After each use of unsealed P-33 monitor self, work areas and floors using a survey meter equipped with a pancake or thin window G-M probe.

REFERENCES

Title 10 of the Code of Federal Regulations part 20

Ohio Administration Code 3701:1-38

EPA Federal Guidance Report No. 11

Shleien, The Health Physics and Radiological Health Handbook Revised Edition, (Scinta, Inc., 1992)

Delacoix et al, Radiation Protection Dosimetry – Radionuclide and Radiation Protection Data Handbook 1998, (Kent, England: Nuclear Technology Publishing, 1998)

www.stanford.edu/dept/EHS/prod/researchlab/radlaser/rsds.html

www.umich.edu/~oseh/isotopes

www.uwm.edu/dept/ehsrm/rad/phosp33.html

Isotope Fact Sheet

Radium 224
[^{224}Ra]

PHYSICAL DATA*

- Photon Energy: 583 keV (30%)
  2615 keV (36%)
- Beta Energy: 1519 keV (18%)
  1794 keV (20%)
  2246 keV (55%)
- Alpha Energy: 6288 keV (100%)
  6779 keV (100%)
  8785 keV (64%)
- Physical Half-Life: 3.66 days
- Specific Activity: 1.6 x10^5 Ci/g — 5.938 x 10^{15} Bq/g
- Specific Gamma Constant: 1.1 x 10^{-2} mR/hr/mCi — 2.97 x10^{-6} mSv/hr/MBq

(@ 1 meter)

* Part of Thorium series of decay. Ra-224 decays to Radon-220 (Rn-220). Rn-220 decays to Polonium-216 (Po-216). Po-216 decays to Lead-212 (Pb-212). Pb-212 decays to Bismuth-212 (Bi-212). Bi-212 decays to Thallium-208 (Tl-208) and Polonium-212 (Po-212). This decay from radioactive parent to radioactive progeny continues until ending with the stable isotope Lead-208 (Pb-208). The above assumes all in equilibrium.

RADIOLOGICAL DATA

- Radiological Toxicity Rating: Group 2 (High)
- Critical Organ: Bone and Bone Marrow
- Routes of Intake: Ingestion, Inhalation, Puncture, Wound, Skin Absorption
- Committed Effective Dose Equivalent (CEDE):
  - 3.66 x 10^2 mrem/uCi (ingestion) — 9.89 x 10^1 mSv/MBq (ingestion)
  - 3.16 x 10^3 mrem/uCi (inhalation – class W) — 8.53 x 10^2 mSv/MBq (inhalation – class W)

SHIELDING

- Half-Value Layer (HVL) for lead — 0.87 inches — 2.2 cm

SURVEY INSTRUMENTATION

- A survey meter equipped with a G-M pancake or thin-window probe is efficient for detecting Ra-224. Detection efficiency is 13%-17%.
- A survey meter equipped with an alpha scintillation probe is suitable for detection of Ra-224.

- Either

RADIATION MONITORING DOSIMETERS

- Whole Body dosimeter: Required
- Finger dosimeter: Required.
- Whole body or urine bioassay may be required for suspected skin contamination or ingestion.

RADIOACTIVE WASTE

- Solids, liquids, scintillation vials, pathological materials, animal carcasses

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REGULATORY COMPLIANCE INFORMATION

• Derived Air Concentration (DAC):	7×10^{-10} uCi/cc (occupational – class W)	2.6×10^{-5} Bq/cc (occupational – class W)
• Annual Limit of Intake (ALI*): *[1.0 ALI = 5,000 mrem CEDE]	8×10^{0} uCi (ingestion) 2×10^{1} uCi (ingestion – bone surfaces) 2×10^{0} uCi (inhalation – class W)	3.0×10^{5} Bq (ingestion) 7.4×10^{5} Bq (ingestion – bone surfaces) 7.4×10^{4} Bq (inhalation – class W)
• Effluent Release Limit:	2×10^{-12} uCi/cc (air- class W) 2×10^{-7} uCi/cc (water)	7.4×10^{-8} Bq/cc (air – class W) 7.4 x 10-3 Bq/cc (water)

GENERAL RADIOLOGICAL SAFETY INFORMATION

- Laboratory coat and gloves must be worn when handling unsealed radioactive material. Monitor hands and change gloves frequently.
- Whole body and ring dosimeter must be worn when handling specifically licensed Ra-224.
- Lead shielding shall be used to minimize exposure from Ra-224.
- Indirect viewing aids should be used to minimize exposure from Ra-224.
- Store Ra-224 in lead shielding.
- Remote handling tools should be used when handling Ra-224.
- Practice procedures without radioactivity prior to performing the procedure with Ra-224. Practice will improve dexterity and speed, along with providing opportunity to determine errors and practices that are not ALARA.
- After each use of unsealed Ra-224 monitor self, work areas and floors using a survey meter equipped with a G-M or alpha probe.
- Procedures involving dusty operations, vapors or aerosols should be performed in a fume hood.

Gamma exposure rate from 1 mCi point source - unshielded

Distance	mR/hr
1 cm	110
5 cm	4.4
10 cm	1.1
100 cm	0.011

REFERENCES

Title 10 of the Code of Federal Regulations part 20
Ohio Administration Code 3701:1-38
EPA Federal Guidance Report No. 11
Shleien, The Health Physics and Radiological Health Handbook Revised Edition, (Scinta, Inc., 1992)
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http://www.nrc.gov/reading-rm/doc-collections/cfr/part020/appb/
http://www.wolframalpha.com/input/?i=Ra+224
http://www.iem-inc.com
Radioactive Material Safety Data Sheet

Isotope Fact Sheet

RUBIDIUM-86
[^{86}Rb]

PHYSICAL DATA

- Gamma Energy: 1077 keV (9%)
- Maximum Beta Energy: 1774 keV (91%)
  689 keV (9%)
- Alpha Energy: no alpha

- Physical Half-Life: 18.64 days
- Biological Half-Life: 45 days*
- Effective Half-Life: 13.2 days*

* These are "generic" biological and effective half-lives; the specific labeled compound may alter.

• Specific Activity:	8.13 x 10^4 Ci/gram	3.01 x 10^{15} Bq/g
• Specific Gamma Constant:	5.4 x 10^{-2} mR/hr/mCi	1.46 x10^{-5} mSv/hr/MBq
(@ 1 meter)		

RADIOLOGICAL DATA

- Radiological Toxicity Rating: Group 3 (moderate)
- Critical Organ: Bone
- Routes of Intake: Ingestion, Inhalation, Puncture, Wound, Skin Absorption

• Committed Effective Dose Equivalent (CEDE):	9.37 mrem/uCi (ingestion)	2.53 mSv/MBq (ingestion)
	6.63 mrem/uCi (inhalation)	1.79 mSv/MBq (inhalation)
• Skin Contamination (7 mg/cm^2):	7.4 x 10^4 rem/y/uCi/cm^2	2.0 x 10^{-2} Sv/y/Bq/cm^2
(Kocher et al)		

SHIELDING

• Half-Value Layer (HVL) for lead	0.6 inches	1.4 cm
HVL for steel	1.4 inches	3.5 cm

• Tenth-Value Layer (TVL) for lead	1.6 inches	4.1 cm
TVL for steel	3.4 inches	8.7 cm
• Maximum Beta Range in Air:	255 inches	650 cm
• Maximum Beta Range in Water/Tissue:	0.30 inches	0.80 cm
• Maximum Beta Range in Plastic:	0.26 inches	0.66 cm

SURVEY INSTRUMENTATION

- Survey meter equipped with a G-M pancake or thin-window probe is quite efficient for detecting the betas from the Rb-86. Typical efficiency for a G-M pancake survey meter is about 25-35%.
- Survey meters equipped with a NaI scintillation probe is suitable for detection of the Rb-86 gamma. The NaI probe may also detect bremsstrahlung generated by the high energy beta. However, because of the low incidence of the Rb-86 gamma, the overall efficiency for a NaI scintillation probe detecting Rb-86 is low.
- Either a gamma counter or a liquid scintillation counter can be used to detect removable Rb-86 contamination on wipe tests smears.

RADIATION MONITORING DOSIMETERS

- Whole Body dosimeter: Required
- Finger dosimeter: Required.
- Urine bioassay may be required for suspected skin contamination or ingestion.

RADIOACTIVE WASTE

- Solids, liquids, scintillation vials, pathological materials, animal carcasses

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REGULATORY COMPLIANCE INFORMATION

• Derived Air Concentration (DAC):	6×10^{-7} uCi/cc (occupational)	2.2×10^{-2} Bq/cc (occupational)
• Annual Limit of Intake (ALI*):	1×10^{3} uCi (ingestion)	3.7×10^{7} Bq (ingestion)
*[1.0 ALI = 5,000 mrem CEDE]	2×10^{3} uCi (inhalation)	7.4×10^{7} Bq (inhalation)
• Effluent Release Limit:	2×10^{-9} uCi/cc (air)	7.4×10^{-5} Bq/cc (air)
	1×10^{-5} uCi/cc (water)	3.7×10^{-1} Bq/cc (water)

GENERAL RADIOLOGICAL SAFETY INFORMATION

- Laboratory coat and gloves must be worn when handling unsealed radioactive material. Monitor hands and change gloves frequently.
- Whole body and ring dosimeter must be worn when handling Rb-86.
- Avoid direct eye contact with the Rb-86 beta. Never look directly upon an unshielded container of Rb-86.
- Eye protection (safety glasses or goggles) should be worn when handing Rb-86.
- Plastic shielding followed by lead shielding shall be used to minimize exposure from Rb-86.
- Indirect viewing aids should be used to minimize exposure from Rb-86.
- Store Rb-86 in plastic shielding covered with lead shielding.
- Remote handling tools should be used when handling Rb-86.
- Practice procedures without radioactivity prior to performing the procedure with Rb-86. Practice will improve dexterity and speed, along with providing opportunity to determine errors and practices that are not ALARA.
- After each use of unsealed Rb-86 monitor self, work areas and floors using a survey meter equipped with a G-M or NaI probe.

Gamma exposure rate from 1 mCi point source - unshielded

Distance	mR/hr
1 cm	540
5 cm	22
10 cm	5.4
100 cm	0.054

REFERENCES

Title 10 of the Code of Federal Regulations part 20

Ohio Administration Code 3701:1-38

EPA Federal Guidance Report No. 11

Shleien, The Health Physics and Radiological Health Handbook Revised Edition, (Scinta, Inc., 1992)

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www.stanford.edu/dept/EHS/prod/researchlab/radlaser/rsds.html

www.nchps.org/nsds.htm

Isotope Fact Sheet

SAMARIUM-153
[^{153}Sm]

PHYSICAL DATA

- Photon Energy: 103 keV (28%)
  97 keV (1%)
  70 keV (5%)
  47 keV (12%)
  42 keV (31%)
  41 keV (12%)
- Maximum Beta Energy: 807 keV (21%)
  703 keV (44%)
  634 keV (35%)
- Electron Energy: 95 keV (6%)
  55 keV (41%)
  21 keV (24%)
- Alpha Energy: no alpha
- Physical Half-Life: 1.95 days

• Specific Activity:	4.4 x 10^{6} Ci/gram	1.62 x 10^{16} Bq/g
• Specific Gamma Constant: (@ 1 meter)	9.0 x 10^{-2} mR/hr/mCi	2.44 x10^{-5} mSv/hr/MBq

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RADIOLOGICAL DATA

- Radiological Toxicity Rating: Group 3 (moderate)
- Critical Organ: Lower large intestine
- Routes of Intake: Ingestion, Inhalation, Puncture, Wound, Skin Absorption

• Committed Effective Dose Equivalent (CEDE):	3.0 mrem/uCi (ingestion)	0.81 mSv/MBq (ingestion)
	1.96 mrem/uCi (inhalation)	0.53 mSv/Bq (inhalation)
• Skin Contamination	5.9 rem/hr/uCi/cm^2	1.6 Sv/hr/kBq/cm^2

SHIELDING

• Half-Value Layer (HVL) for lead	<0.04 inches	<0.1 cm

HVL for steel	0.04 inches	0.1 cm
• Tenth-Value Layer (TVL) for lead	< 0.04 inches	<0.1 cm
TVL for steel	0.28 inches	0.7 cm

• Maximum Beta Range in Air:	88 inches	255 cm
• Maximum Beta Range in Water/Tissue:	0.11 inches	0.30 cm
• Maximum Beta Range in Plastic::	0.09 inches	0.24 cm

SURVEY INSTRUMENTATION

- Survey meter equipped with a G-M pancake or thin-window probe is quite efficient for detecting the betas from Sm-153. Typical efficiency for a G-M pancake is 5% to 10%.
- Survey meters equipped with a NaI scintillation probe is suitable for detection of the Sm-153.
- Either a gamma counter or a liquid scintillation counter can be used to detect removable Sm-153 contamination on wipe tests smears.

RADIATION MONITORING DOSIMETERS

- Whole Body dosimeter: Required.
- Finger dosimeter: Required.
- Whole body count or urine bioassay may be required for suspected skin contamination or ingestion.

RADIOACTIVE WASTE

- Solids, liquids, scintillation vials, pathological materials, animal carcasses

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REGULATORY COMPLIANCE INFORMATION

• Derived Air Concentration (DAC):	1×10^{-6} uCi/cc (occupational)	3.7×10^{-2} Bq/cc (occupational)
• Annual Limit of Intake (ALI*):	2×10^{3} uCi (ingestion)	7.4×10^{7} Bq (ingestion)
*[1.0 ALI = 5,000 mrem CEDE]	3×10^{3} uCi (inhalation)	1.1×10^{8} Bq (inhalation)
• Effluent Release Limit:	3×10^{-7} uCi/cc (air)	1.1×10^{-2} Bq/cc (air)
	1×10^{-3} uCi/cc (water)	3.7×10^{1} Bq/cc (water)

GENERAL RADIOLOGICAL SAFETY INFORMATION

- Laboratory coat and gloves must be worn when handling unsealed radioactive material. Monitor hands and change gloves frequently.
- Whole body and ring dosimeter must be worn when handling Sm-153.
- Lead shielding shall be used to minimize exposure from Sm-153
- Indirect viewing aids should be used to minimize exposure from Sm-153.
- Store Sm-153 in lead shielding.
- Remote handling tools should be used when handling Sm-153.
- Practice procedures without radioactivity prior to performing the procedure with Sm-153. Practice will improve dexterity and speed, along with providing opportunity to determine errors and practices that are not ALARA.
- After each use of unsealed Sm-153 monitor self, work areas and floors using a survey meter equipped with a G-M or NaI probe.

Gamma exposure rate from 1 mCi point source - unshielded

Distance	mR/hr
1 cm	900
5 cm	360
10 cm	9
100 cm	0.09

REFERENCES

Title 10 of the Code of Federal Regulations part 20

Ohio Administration Code 3701:1-38

EPA Federal Guidance Report No. 11

Shleien, The Health Physics and Radiological Health Handbook Revised Edition, (Scinta, Inc., 1992)

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www.quadramet.com/nojs/hcp/techdata.html

www.quadramet.com/pi.html

Isotope Fact Sheet

SODIUM-22
[^{22}Na]

PHYSICAL DATA

• Gamma Energy:	1275 keV (100%)	
(annihilation photon)	511 keV (181%)	
• Beta^{+} (positron) Energy:	546 keV (90%)	
• Alpha Energy:	no alpha	
• Physical Half-Life:	2.6 years	
• Biological Half-Life:	11 days*	
• Effective Half-Life:	11 hours*	

* These are "generic" biological and effective half-lives; the specific labeled compound may alter.

• Specific Activity:	6.24 x 10^{3} Ci/gram	2.31x 10^{14} Bq/g
• Specific Gamma Constant:	1.34 mR/hr/mCi	3.62 x10^{-4} mSv/hr/MBq
(@ 1 meter)		

RADIOLOGICAL DATA

- Radiological Toxicity Rating: Group 2 (high
- Critical Organ: Red bone marrow
- Routes of Intake: Ingestion, Inhalation, Puncture, Wound, Skin Absorption

• Committed Effective Dose Equivalent (CEDE):	11.48 mrem/uCi (ingestion)	3.10 mSv/MBq (ingestion)
	7.67 mrem/uCi (inhalation)	2.07 mSv/MBq (inhalation)
• Skin Contamination	6.3 rem/hr/uCi/cm2	1.7 mSv/hr/kBq/cm2

SHIELDING

• Half-Value Layer (HVL) for lead	0.4 inches	1.0 cm
HVL for steel	1.2 inches	3.1 cm
• Tenth-Value Layer (TVL) for lead	1.5 inches	3.7 cm
TVL for steel	3.1 inches	8.0 cm

SURVEY INSTRUMENTATION

- Survey meter equipped with a G-M pancake or thin-window probe is efficient for detecting Na-22. Typical efficiency for a G-M pancake is about 20%.
- Survey meters equipped with a NaI scintillation probe is best for detection of the Na-22 gamma. Typical efficiency for a NaI scintillation probe is 30% to 60%
- Either a gamma counter or a liquid scintillation counter can be used to detect removable Na-22 contamination on wipe tests smears. Typical LSC efficiency is 90%. Typical gamma counter efficiency is 30% to 60%.

RADIATION MONITORING DOSIMETERS

- Whole Body dosimeter: Required
- Finger dosimeter: Required.
- Urine bioassay may be required for suspected skin contamination or ingestion.

RADIOACTIVE WASTE

- Solids, liquids, scintillation vials, pathological materials, animal carcasses

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REGULATORY COMPLIANCE INFORMATION

• Derived Air Concentration (DAC):	3×10^{-7} uCi/cc (occupational)	1.1×10^{-2} Bq/cc (occupational)
• Annual Limit of Intake (ALI*):	4×10^{2} uCi (ingestion)	3.7×10^{7} Bq (ingestion)
*[1.0 ALI = 5,000 mrem CEDE]	6×10^{2} uCi (inhalation)	2.2×10^{7} Bq (inhalation)
• Effluent Release Limit:	9×10^{-10} uCi/cc (air)	3.3×10^{-5} Bq/cc (air)
	6×10^{-6} uCi/cc (water)	2.2×10^{-1} Bq/cc (water)

GENERAL RADIOLOGICAL SAFETY INFORMATION

- Laboratory coat and gloves must be worn when handling unsealed radioactive material. Monitor hands and change gloves frequently.
- Whole body and ring dosimeter must be worn when handling Na-22.
- Lead shielding shall be used to minimize exposure from Na-22.
- Indirect viewing aids should be used to minimize exposure from Na-22.
- Store Na-22 in lead shielding.
- Remote handling tools should be used when handling Na-22.
- Practice procedures without radioactivity prior to performing the procedure with Na-22. Practice will improve dexterity and speed, along with providing opportunity to determine errors and practices that are not ALARA.
- After each use of unsealed Na-22 monitor self, work areas and floors using a survey meter equipped with a G-M or NaI probe.

Gamma exposure rate from 1 mCi point source - unshielded

Distance	mR/hr
1 cm	13400
5 cm	536
10 cm	134
100 cm	1.34

REFERENCES

Title 10 of the Code of Federal Regulations part 20

Ohio Administration Code 3701:1-38

EPA Federal Guidance Report No. 11

Shleien, The Health Physics and Radiological Health Handbook Revised Edition, (Scinta, Inc., 1992)

Delacoix et al, Radiation Protection Dosimetry – Radionuclide and Radiation Protection Data Handbook 1998, (Kent, England: Nuclear Technology Publishing, 1998)

www.perkinelemer.com/lifesciences

www.uwm.edu/dept/ehsrm/rad/sodium.html

Isotope Fact Sheet

STRONITIUM-90/YTTRIUM-90
[^{90}Sr/^{90}Y]

PHYSICAL DATA

- Gamma Energy: no photon
- Maximum Beta Energy: 546 keV (100%)
  (from daughter Y-90) 2284 keV (100%)
  (from daughter Y-90) 523 keV (1%)
- Alpha Energy: no alpha

- Physical Half-Life: 29.1 years
- Biological Half-Life: 49 years (bone)*
- Effective Half-Life: 18 years (bone)*

*These are "generic" biological and effective half-lives; the specific labeled compound may alter.

- Specific Activity: 1.41 x 10^2 Ci/gram 5.21 x 10^{12} Bq/g

RADIOLOGICAL DATA

- Radiological Toxicity Rating: Group 2 (high)
- Critical Organ: Bone, Lungs
- Routes of Intake: Ingestion, Inhalation, Puncture, Wound, Skin Absorption

• Committed Effective Dose Equivalent (CEDE):	1.4 x 10^2 mrem/uCi (ingestion)	3.85 x 10^1 mSv/MBq (ingestion)
	2.4 x 10^2 mrem/uCi (inhalation – class D)	6.47 x 10^1 mSv/MBq (inhalation – class D)
	1.3 x 10^3 mrem/uCi (inhalation – class Y)	3.51 x 10^2 mSv/MBq (inhalation – class Y)
• Skin Contamination (7 mg/cm^2): (Kocher et al)	5.9 x 10^4 rem/y/uCi/cm^2	1.6 x 10^{-2} Sv/y/Bq/cm^2

SHIELDING

- ½ to ¾ inch plexiglas/acrylic/lucite/plastic/wood
- Do not use lead foil or sheets as primary barrier! Penetrating bremsstrahlung x-ray will be produced!
- Use lead sheets or foil to shield bremsstrahlung x-rays only **after** low density plexiglas/acrylic/lucite/wood shielding.

• Maximum Beta Range in Air (Y-90 beta):	336 inches	855 cm
• Maximum Beta Range in Water/Tissue (Y-90 beta):	0.43 inches	1.1 cm
• Maximum Beta Range in Plastic (Y-90 beta):	0.36 inches	0.92 cm

SURVEY INSTRUMENTATION

- Survey meter equipped with a G-M pancake or thin-window probe can be used to detect the betas from the Sr-90/Y-90. Typical efficiency for a G-M pancake survey meter is between 30 and 35% (due primarily to the detection of the Y-90 beta).
- A NaI survey meter may be used; however, the efficiency of detection is low as it is detecting bremsstrahlung x-rays from the Y-90 beta.
- A liquid scintillation counter should be used to detect removable Sr-90 contamination on wipe tests smears. Detection efficiency using standard liquid scintillation cocktail is generally greater than 90%.

RADIATION MONITORING DOSIMETERS

- Whole Body dosimeter: Required
- Finger dosimeter: Required
- Urine bioassay may be required for suspected skin contamination or ingestion.

RADIOACTIVE WASTE

- Solids, liquids, scintillation vials, pathological materials, animal carcasses

REGULATORY COMPLIANCE INFORMATION

• Derived Air Concentration (DAC):	8×10^{-9} uCi/cc (occupational – class D)	3.0×10^{-4} Bq/cc (occupational – class Dr)
	2×10^{-9} uCi/cc (occupational – class Y)	7.4×10^{-5} Bq/cc (occupational – class W)
• Annual Limit of Intake (ALI*):	3×10^{1} uCi (ingestion)	1.1×10^{6} Bq (ingestion)
*[1.0 ALI = 5,000 mrem CEDE]	4×10^{1} uCi	1.5×10^{6} Bq
	(ingestion – bone surface)	(ingestion-bone surface)

	2×10^{1} uCi	7.4×10^{5} Bq
	(inhalation – class D and bone surface)	(inhalation – class D and bone surface)
	4 uCi	1.5×10^{5} Bq
	(inhalation – class Y)	(inhalation – class Y)
• Effluent Release Limit:	3×10^{-11} uCi/cc	1.1×10^{-6} Bq/cc
	(air – class D)	(air- class D)
	6×10^{-12} uCi/cc	2.2×10^{-7} Bq/cc
	(air – class W)	(air- class W)
	5×10^{-7} uCi/cc (water)	2.1×10^{-2} Bq/cc (water)

GENERAL RADIOLOGICAL SAFETY INFORMATION

- Laboratory coat and gloves, if practical double gloves, must be worn when handling unsealed Sr-90. Monitor hands and change gloves frequently.
- Whole body and ring dosimeter must be worn when handling Sr-90/Y-90.
- Avoid direct eye contact with the Y-90 beta. Never look directly upon an unshielded container of Sr-90/Y-90.
- Eye protection (safety glasses or goggles) should be worn when handling Sr-90/Y-90.
- Plastic or other low Z material shielding shall be used to minimize exposure from Sr-90/Y-90.
- Store Sr-90/Y-90 in plastic or other low Z material.
- Remote handling tools should be used when handling Sr-90/Y-90.
- Practice procedures without radioactivity prior to performing the procedure with Sr-90/Y-90. Practice will improve dexterity and speed, along with providing opportunity to determine errors and practices that are not ALARA.
- After each use of unsealed Sr-90/Y-90 monitor self, work areas and floors using a survey meter equipped with a pancake or thin window G-M probe.
- Because of the high energy beta from the decay of Y-90, the possibility of skin contamination or direct handling of Sr-90/Y-90 needs to be minimized. If skin contamination is detect decontamination needs to be initiated immediately. Even low activities of Sr-90/Y-90 skin contamination for a short period of time can result in a significant dose to the skin.
- Sr-90 decays to Y-90, which is a radioactive daughter. Sr-90 quickly comes into equilibrium with the daughter Y-90 and the decay of Sr-90 results in both the Sr-90 and Y-90 betas being given off.

Beta (skin) exposure rate from 1 mCi point source – unshielded*

Distance	mR/hr
1 cm	~300000
5 cm	~12000
10 cm	~3000

*Follows the inverse square law at close distances. Because of the high energy beta, skin dose rates at close distances are very high

REFERENCES

Title 10 of the Code of Federal Regulations part 20

Ohio Administration Code 3701:1-38

EPA Federal Guidance Report No. 11

Shleien, The Health Physics and Radiological Health Handbook Revised Edition, (Scinta, Inc., 1992)

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www.stanford.edu/dept/EHS/prod/researchlab/radlaser/rsds.html

www.nchps.org/nsds.htm

Isotope Fact Sheet

SULFUR-35
[^{35}S]

PHYSICAL DATA

- Gamma Energy: no photon
- Maximum Beta Energy: 167 keV (100%)
- Alpha Energy: no alpha

- Physical Half-Life: 87.5 days
- Biological Half-Life: 90 days*
- Effective Half-Life: 44 days*

* These are "generic" biological and effective half-lives; the specific labeled compound may alter

- Specific Activity: 4.27 x 10^4 Ci/gram 1.58 x 10^{15} Bq/g

RADIOLOGICAL DATA

- Radiological Toxicity Rating: Group 3 (moderate)
- Critical Organ: Lungs
- Routes of Intake: Ingestion, Inhalation, Puncture, Wound, Skin Absorption

• Committed Effective Dose Equivalent (CEDE):	7.33 x 10^{-1} mrem/uCi (ingestion)	1.98 x 10^{-1} mSv/MBq (ingestion)
	3.52 x 10^{-1} mrem/uCi (inhalation – vapor)	9.55 x 10-2 mSv/MBq (inhalation – vapor)
	3.02 x 10^{-1} mrem/uCi (inhalation – class D)	8.15 x 10^{-2} mSv/MBq (inhalation – class D)
	2.48 mrem/uCi (inhalation – class W)	6.69 x 10^{-1} mSv/MBq (inhalation – class W)
• Skin Contamination	1.3 rem/hr/uCi/cm^2	0.35 mSv/hr/kBq/cm^2

SHIELDING

- ¼ inch plexiglas/acrylic/lucite/plastic/wood
- Do not use lead foil or sheets as primary barrier! Penetrating bremsstrahlung x-ray will be produced!
- Use lead sheets or foil to shield bremsstrahlung x-rays only **after** low density plexiglas/acrylic/lucite/wood shielding.

- Maximum Beta Range in Air: 10 inches 26 cm

- Maximum Beta Range in Water/Tissue: 0.015 inches 0.04 cm
- Maximum Beta Range in Plastic: 0.01 inches 0.03 cm

SURVEY INSTRUMENTATION

- Survey meter equipped with a G-M pancake or thin-window probe can be used to detect the betas from the S-35. Typical efficiency for a G-M pancake survey meter is between 4% and 6%.
- A liquid scintillation counter should be used to detect removable S-35 contamination on wipe tests smears. Typical efficiency for a LSC to detect S-35 is greater than 85%.

RADIATION MONITORING DOSIMETERS

- Whole Body dosimeter: Not required
- Finger dosimeter: Not required
- Urine bioassay may be required for suspected skin contamination or ingestion.

RADIOACTIVE WASTE

- Solids, liquids, scintillation vials, pathological materials, animal carcasses

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REGULATORY COMPLIANCE INFORMATION

• Derived Air Concentration (DAC):	6×10^{-6} uCi/cc (occupational – vapor)	1.1×10^{-1} Bq/cc (occupational – vapor)
	7×10^{-6} uCi/cc (occupational – class D)	2.6×10^{-1} Bq/cc (occupational – class D)
	9×10^{-7} uCi/cc (occupational – class W)	3.3×10^{-2} Bq/cc (occupational – Class W)
• Annual Limit of Intake (ALI*):	1×10^{4} uCi	3.7×10^{8} Bq
*[1.0 ALI = 5,000 mrem CEDE]	(ingestion – class D)	(ingestion – class D)
	6×10^{3} uCi	2.2×10^{8} Bq
	(ingestion – class W)	(ingestion – class W)
	1×10^{4} uCi	3.7×10^{8} Bq
	(inhalation – vapor)	(inhalation – vapor)
	2×10^{4} uCi	7.4×10^{8} Bq
	(inhalation – class D)	(inhalation – class D)
	2×10^{3} uC	7.4×10^{7} Bq
	(inhalation – class W)	(inhalation – class W)

• Effluent Release Limit:	2×10^{-8} uCi/cc	7.4×10^{-4} Bq/cc
	(air – vapor or class D)	(air- vapor or class D)
	3×10^{-9} uCi/cc	1.1×10^{-4} Bq/cc
	(air – class W)	(air- class W)
	1×10^{-4} uCi/cc (water)	3.7 Bq/cc (water)

GENERAL RADIOLOGICAL SAFETY INFORMATION

- Laboratory coat and gloves must be worn when handling unsealed radioactive material. Monitor hands and change gloves frequently.
- Plastic or other low Z material shielding shall be used to minimize exposure from S-35.
- Store S-35 in plastic or other low Z material.
- Remote handling tools should be used when handling S-35.
- Practice procedures without radioactivity prior to performing the procedure with S-35. Practice will improve dexterity and speed, along with providing opportunity to determine errors and practices that are not ALARA.
- After each use of unsealed S-35 monitor self, work areas and floors using a survey meter equipped with a pancake or thin window G-M probe.
- Radiolysis may occur with S-35 amino acids (e.g., methionine) during storage, with a resulting volatile impurity. New vials and closed vials that have been stored for a period of time should be opened in a fume hood or through an activated charcoal filter. Volatile impurities are generally small (0.05%).
- If practical procedures involving the use of S-35 compounds should be in enclosed containers because of the potential for production of volatile S-35 compounds. Routinely check water baths and the inside of incubators for contamination during and after procedures involving S-35.
- Metabolic behavior of common S-35 labeled organic compounds may be considerably different from common S-35 labeled inorganic compounds. This difference must be considered if uptake occurs.

REFERENCES

Title 10 of the Code of Federal Regulations part 20

Ohio Administration Code 3701:1-38

EPA Federal Guidance Report No. 11

Shleien, The Health Physics and Radiological Health Handbook Revised Edition, (Scinta, Inc., 1992)

Delacoix et al, Radiation Protection Dosimetry – Radionuclide and Radiation Protection Data Handbook 1998, (Kent, England: Nuclear Technology Publishing, 1998)

www.stanford.edu/dept/EHS/prod/researchlab/radlaser/rsds.html

www.umich.edu/~oseh/isotopes

www.uwm.edu/dept/ehsrm/rad/sulfur.html

Isotope Fact Sheet

TECHNETIUM-99m
[^{99m}Tc]

PHYSICAL DATA

- Gamma Energy: 141 keV (89%)
  21 keV (1%)
  18 keV (6%)
- Beta Energy: no betas
- Alpha Energy: no alphas

- Physical Half-Life: 6 hours
- Biological Half-Life: 24 hours*
- Effective Half-Life: 4.8 hours*

* These are "generic" biological and effective half-lives; the specific labeled compound may alter.

• Specific Activity:	5.3 x 10^{6} Ci/gram	1.95 x 10^{17} Bq/g
• Specific Gamma Constant: (@ 1 meter)	7.8 x 10^{-2} mrem/hr/mCi	3.3 x10^{-5} mSv/hr/MBq
• Daughter (decays to):	Tc-99 (physical half-life = 2.1 x 10^{5} years)	

RADIOLOGICAL DATA

- Radiological Toxicity Rating: Group 4 (low)
- Critical Organ: Thyroid
- Routes of Intake: Ingestion, Inhalation, Puncture, Wound, Skin Absorption

• Committed Effective Dose Equivalent (CEDE):	6.3 x 10^{-2} mrem/uCi (ingestion)	1.68 x 10^{-2} mSv/MBq (ingestion)
	3.3 x 10^{-2} mrem/uCi (inhalation – class D)	8.80 x 10^{-3} mSv/MBq (inhalation – class D)
	2.6 x 10^{-2} mrem/uCi (inhalation-class W)	7.21 x 10^{-3} mSv/MBq (inhalation – class W)
• Skin Contamination	9.25 x 10^{-1} rem/hr/uCi/cm^2	2.5 x 10^{-1} Sv/hr/kBq/cm^2

- Tc-99m Pertechnetate ($^{99m}TcO_4$) – behaves similar to iodine and concentrates in the thyroid, salivary glands, brain, blood pool, urinary bladder and stomach and may be used to scan any

of these organs. The stomach receives the majority of the dose and contains ~25% of the administered dose after 4 hours.

- Tc-99m labeled Sulfur Colloid – the majority (>90%) of the intravenous administered dose is localized in the liver and spleen. Used for liver, spleen and bone-marrow scanning.

- Tc-99m labeled MacroAggregated Albumin (MAA) – primarily used for lung scanning. The majority (>90) of the administered dose is trapped in the capillary bed of the lungs within a few seconds after intravenous administration.

- Tc-99m DTPA – used for brain or kidney scan.

SHIELDING

• Half-Value Layer (HVL) for lead	<0.04 inches	<0.1 cm
HVL for steel	0.04 inches	0.1 cm
• Tenth-Value Layer (TVL) for lead	0.04 inches	0.1 cm
TVL for steel	0.75 inches	1.9 cm

SURVEY INSTRUMENTATION

- Survey meter equipped with a G-M pancake or standard G-M probe is not efficient for detecting Tc-99m. Typical efficiency for a G-M pancake survey meter is less than 1%.
- Survey meters equipped with a NaI scintillation probe is suitable for detection of the Tc-99m gamma. Typical efficiency for a NaI scintillation probe survey meter is about 12 – 18%.
- A gamma counter should be used to detect removable Tc-99m contamination on wipe tests smears.

RADIATION MONITORING DOSIMETERS

- Whole Body dosimeter: Required
- Finger dosimeter: Required
- Urine bioassay may be required for suspected skin contamination or ingestion. The urine sample should be taken between 2 and 24 hours after the suspected uptake and, because of the very short half-life of Tc-99m, counted immediately. Whole body bioassay may also be required in the event of skin contamination or suspected uptake of Tc-99m.

RADIOACTIVE WASTE

- Solids, liquids, scintillation vials, pathological materials, animal carcasses

REGULATORY COMPLIANCE INFORMATION

• Derived Air Concentration (DAC):	6×10^{-5} uCi/cc (occupational – class D)	2.2 Bq/cc (occupational – class D)
	1×10^{-5} uCi/cc (occupational – class W)	3.7×10^{-1} Bq/cc (occupational – class D)
• Annual Limit of Intake (ALI*):	8×10^{1} uCi (ingestion)	3×10^{6} Bq (ingestion)
*[1.0 ALI = 5,000 mrem CEDE]	2×10^{2} uCi (inhalation)	7.4×10^{6} Bq (inhalation)
• Effluent Release Limit:	2×10^{-7} uCi/cc (air – class D)	7.4×10^{-3} Bq/cc (air – class D)
	3×10^{-7} uCi/cc (air – class W)	1.1×10^{-2} Bq/cc (air – class W)
	1×10^{-3} uCi/cc (water)	3.7×10^{1} Bq/cc (water)

GENERAL RADIOLOGICAL SAFETY INFORMATION

- Laboratory coat and gloves must be worn when handling unsealed radioactive material. Monitor hands and change gloves frequently.
- Whole body and ring dosimeter must be worn when handling Tc-99m.
- Lead shielding should be used to minimize exposure from Tc-99m.
- Indirect viewing aids should be used to minimize exposure from Tc-99m.
- Remote handling tools shall be used when handling Tc-99m.
- Store Tc-99m in lead shielding.
- Practice procedures without radioactivity prior to performing the procedure with Tc-99m. Practice will improve dexterity and speed, along with providing opportunity to determine errors and practices that are not ALARA.
- Drying can cause airborne Tc-99m dust contamination and rapid boiling can cause Tc-99m aerosol contamination. Expelling Tc-99m solutions through syringe needles and pipette tips can generate airborne aerosols. Use of Tc-99m needs to procedures to prevent or minimize contamination that could be caused from one or more of these actions.
- After each use of Tc-99m monitor self, work areas and floors using a survey meter equipped with a G-M or NaI probe.

Gamma exposure rate from 1 mCi point source - unshielded

Distance	mR/hr
1 cm	780
5 cm	32
10 cm	7.8
100 cm	0.078

REFERENCES

Title 10 of the Code of Federal Regulations part 20

Ohio Administration Code 3701:1-38

Shleien, The Health Physics and Radiological Health Handbook Revised Edition, (Scinta, Inc., 1992)

Delacoix et al, Radiation Protection Dosimetry – Radionuclide and Radiation Protection Data Handbook 1998, (Kent, England: Nuclear Technology Publishing, 1998)

www.nchps.org/nsds.htm

www.umich.edu/~oseh/isotopes

Isotope Fact Sheet

THALLIUM-201
[^{201}TI]

PHYSICAL DATA

- Gamma Energy: 167 keV (10%)
  135 keV (30%)
  71 keV (47%)
- Electron Energy: 153 keV (3%)
  (decays electron capture) 84 keV (16%)
  16 keV (10%)
- Alpha Energy: no alpha

- Physical Half-Life: 3.04 days
- Biological Half-Life: 11 days (TlCl)
- Effective Half-Life: 2.4 days (TlCl)

• Specific Activity:	2.13 x 10^{5} Ci/gram	7.9 x 10^{15} Bq/g
• Specific Gamma Constant: (@ 1 meter)	8.8 x 10^{-2} mR/hr/mCi	2.37 x10^{-5} mSv/hr/MBq

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RADIOLOGICAL DATA

- Radiological Toxicity Rating: Group 3 (moderate)
- Critical Organ: Lungs; Thyroid (TlCl), Kidney (TlCl), heart wall (TlCl)
- Routes of Intake: Ingestion, Inhalation, Puncture, Wound, Skin Absorption

• Committed Effective Dose Equivalent (CEDE):	3.0 x 10^{-1} mrem/uCi (ingestion)	8.11 x 10^{-2} mSv/MBq (ingestion)
	2.3 x 10^{-1} mrem/uCi (inhalation)	6.34 x 10^{-2} mSv/MBq (inhalation)
• Skin Contamination	1 rem/hr/uCi/cm^2	0.27 Sv/hr/kBq/cm^2

SHIELDING

• Half-Value Layer (HVL) for lead	<0.04 inches	<0.1 cm
HVL for steel	0.12 inches	0.3 cm
• Tenth-Value Layer (TVL) for lead	0.04 inches	0.1 cm

TVL for steel	0.47 inches	1.2 cm

SURVEY INSTRUMENTATION

- Survey meter equipped with a G-M pancake or thin-window probe is not efficient for detecting Tl-201. Typical efficiency for a G-M pancake survey meter is < 1%.
- Survey meters equipped with a NaI scintillation probe is suitable for detection of the Tl-201 gamma.
- Either a gamma counter or a liquid scintillation counter can be used to detect removable Tl-201 contamination on wipe tests smears.

RADIATION MONITORING DOSIMETERS

- Whole Body dosimeter: Required
- Finger dosimeter: Required.
- Whole body count or urine bioassay may be required for suspected skin contamination or ingestion.

RADIOACTIVE WASTE

- Solids, liquids, scintillation vials, pathological materials, animal carcasses

REGULATORY COMPLIANCE INFORMATION

• Derived Air Concentration (DAC):	9×10^{-6} uCi/cc (occupational)	3.3×10^{-1} Bq/cc (occupational)
• Annual Limit of Intake (ALI*):	2×10^{3} uCi (ingestion)	7.4×10^{7} Bq (ingestion)
*[1.0 ALI = 5,000 mrem CEDE]	2×10^{3} uCi (inhalation)	7.4×10^{7} Bq (inhalation)
• Effluent Release Limit:	3×10^{-8} uCi/cc (air)	1.1×10^{-3} Bq/cc (air)
	2×10^{-4} uCi/cc (water)	7.4 Bq/cc (water)

GENERAL RADIOLOGICAL SAFETY INFORMATION

- Laboratory coat and gloves must be worn when handling unsealed radioactive material. Monitor hands and change gloves frequently.
- Whole body and ring dosimeter must be worn when handling Tl-201
- Lead shielding shall be used to minimize exposure from Tl-201.
- Indirect viewing aids should be used to minimize exposure from Tl-201.
- Store Tl-201 in lead shielding.
- Remote handling tools should be used when handling Tl-201.

- Practice procedures without radioactivity prior to performing the procedure with Tl-201. Practice will improve dexterity and speed, along with providing opportunity to determine errors and practices that are not ALARA.
- After each use of unsealed Tl-201 monitor self, work areas and floors using a survey meter equipped with a G-M or NaI probe.

Gamma exposure rate from 1 mCi point source - unshielded

Distance	mR/hr
1 cm	880
5 cm	35
10 cm	8.8
100 cm	0.088

REFERENCES

Title 10 of the Code of Federal Regulations part 20

Ohio Administration Code 3701:1-38

EPA Federal Guidance Report No. !!

Shleien, The Health Physics and Radiological Health Handbook Revised Edition, (Scinta, Inc., 1992)

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www.stanford.edu/dept/EHS/prod/researchlab/radlaser/rsds.html

www.nchps.org/nsds.htm

Isotope Fact Sheet

URANIUM-238*
[^{238}U]

***U-238 may also be called depleted uranium, as in its purest form it has been depleted of other isotopes of uranium found naturally. The properties of natural uranium are very similar to U-238 as natural uranium is >99.27% U-238.**

PHYSICAL DATA*

- Photon Energy: 50 keV (<1%)
  15 keV (9%)
- Beta Energy: no beta
- Alpha Energy: 4196 keV (77%)
  4147 keV (23%)
  4036 keV (<1%)
- Physical Half-Life: 4.47 x 10^{9} years
- Specific Activity: 3.4 x 10^{-7} Ci/g — 1.24 x 10^{4} Bq/g
- Specific Gamma Constant: 6.5 x 10^{-2} mR/hr/mCi — 1.763 x10^{-5} mSv/hr/MBq

  (@ 1 meter)

* The listed data is for U-238. U-238 is just the first in a series of radionuclides. U-238 decays to Th-234. Th-234 decays to Ra-234. This decay from radioactive parent to radioactive daughter continues until it ends with the stable isotope Pb-206.

RADIOLOGICAL DATA

- Radiological Toxicity Rating: Group 4 (Low)
- Critical Organ: Lungs
- Routes of Intake: Ingestion, Inhalation, Puncture, Wound, Skin Absorption
- Committed Effective Dose Equivalent (CEDE):
  - 2.55 x 10^{2} mrem/uCi (ingestion) — 6.88 x 10^{1} mSv/MBq (ingestion)
  - 2.45 x 10^{3} mrem/uCi (inhalation – class D) — 6.62 x 10^{2} mSv/MBq (inhalation – class D)
  - 7.0 x 10^{3} mrem/uCi (inhalation – class W) — 1.9 x 10^{2} mSv/MBq (inhalation – class W)
  - 3.2 x 10^{4} mSv/MBq (inhalation – class Y)

	1.2×10^5 mrem/uCi (inhalation – class Y)	
• Skin Contamination	8.5×10^{-1} rem/y/uCi/cm^2	2.0×10^{-2} Sv/y/Bq/cm^2

SHIELDING

• Half-Value Layer (HVL) for lead	<0.04 inches	<0.1 cm
HVL for steel	<0.04 inches	<0.1 cm
• Tenth-Value Layer (TVL) for lead	<0.04 inches	<0.1 cm
TVL for steel	<0.04 inches	<0.1 cm

SURVEY INSTRUMENTATION

- Survey meter equipped with a G-M pancake or thin-window probe is efficient for detecting U-238.
- Survey meters equipped with an alpha scintillation probe is suitable for detection of U-238
- Either a gamma counter or a liquid scintillation counter can be used to detect removable U-238 contamination on wipe tests smears.

RADIATION MONITORING DOSIMETERS

- Whole Body dosimeter: Required
- Finger dosimeter: Required.
- Whole body or urine bioassay may be required for suspected skin contamination or ingestion.

RADIOACTIVE WASTE

- Solids, liquids, scintillation vials, pathological materials, animal carcasses

REGULATORY COMPLIANCE INFORMATION

	6×10^{-10} uCi/cc (occupational – class D)	2.2×10^{-5} Bq/cc (occupational – class D)
• Derived Air Concentration (DAC):	3×10^{-10} uCi/cc (occupational – class W)	1.1×10^{-5} Bq/cc (occupational – class W)
	2×10^{-10} uCi/cc (occupational – class Y)	7.4×10^{-6} Bq/cc (occupational – class Y)
• Annual Limit of Intake (ALI*):	1×10^1 uCi (ingestion)	3.7×10^5 Bq (ingestion)
*[1.0 ALI = 5,000 mrem CEDE]	2×10^1 uCi (ingestion – bone surfaces)	3.7×10^5 Bq

	1 uCi	(ingestion – bone surfaces)
	(inhalation – class D)	3.7×10^4 Bq
	2 uCi	(inhalation – class D)
	(inhalation – class D bone surfaces)	7.4×10^4 Bq
	8×10^{-1} uCi	(inhalation – class D – bone surfaces)
	(inhalation – class W)	3.0×10^4 Bq
	4×10^{-2} uCi	(inhalation – class W)
	(inhalation – class Y)	1.5×10^3 Bq
	3×10^{-12} uCi/cc	(inhalation – class Y) 1.1×10^{-7} Bq/cc
	(air- class D)	(air – class D)
	1×10^{-12} uCi/cc	3.7×10^{-8} Bq/cc
• Effluent Release Limit:	(air- class W)	(air – class W)
	6×10^{-14} uCi/cc	2.24×10^{-9} Bq/cc
	(air- class Y)	(air – class Y)
	3×10^{-7} uCi/cc (water)	1.1×10^{-2} Bq/cc (water)

GENERAL RADIOLOGICAL SAFETY INFORMATION

- Laboratory coat and gloves must be worn when handling unsealed radioactive material. Monitor hands and change gloves frequently.
- Whole body and ring dosimeter must be worn when handling specifically licensed U-238.
- Lead shielding shall be used to minimize exposure from U-238.
- Indirect viewing aids should be used to minimize exposure from U-238.
- Store U-238 in lead shielding.
- Remote handling tools should be used when handling U-238.
- Practice procedures without radioactivity prior to performing the procedure with U-238. Practice will improve dexterity and speed, along with providing opportunity to determine errors and practices that are not ALARA.
- After each use of unsealed U-238 monitor self, work areas and floors using a survey meter equipped with a G-M or alpha probe.
- Procedures involving dusty operations, vapors or aerosols should be performed in a fume hood.
- Common chemical forms of uranium, e.g. uranyl nitrate or acetate, are considered to be more chemically toxic than radiotoxic. Therefore, good chemical safety techniques should always be followed.

- In small quantities some forms of depleted or natural uranium may be received under a “general” license. Under a “general” license dispose of bulk U-238 (e.g., remaining chemical compound) as radioactive waste. Under a “general” license small quantities of low concentration liquid waste may be disposed of into the sanitary sewer.

Gamma exposure rate from 1 mCi point source - unshielded

Distance	mR/hr
1 cm	650
5 cm	262
10 cm	6.5
100 cm	0.065

REFERENCES

Title 10 of the Code of Federal Regulations part 20

Ohio Administration Code 3701:1-38

EPA Federal Guidance Report No. 11

Shleien, The Health Physics and Radiological Health Handbook Revised Edition, (Scinta, Inc., 1992)

Delacoix et al, Radiation Protection Dosimetry – Radionuclide and Radiation Protection Data Handbook 1998, (Kent, England: Nuclear Technology Publishing, 1998)

www.stanford.edu/dept/EHS/prod/researchlab/radlaser/rsds.html

Isotope Fact Sheet

XENON-133
[^{133}Xe]

PHYSICAL DATA

- Gamma Energy: 81 keV (38%)
  35 keV (7%)
  31 keV (38%)
- Maximum Beta Energy: 346 keV (99%)
- Alpha Energy: no alpha

- Physical Half-Life: 5.2 days
- Biological Half-Life: a few minutes
- Effective Half-Life: a few minutes

- Specific Activity: 1.89 x10^{5} Ci/gram 6.98 x 10^{15} Bq/g

- Specific Gamma Constant: 1 x 10^{-1} mR/hr/mCi 2.78 x10^{-5} mSv/hr/MBq

  (@ 1 meter)

RADIOLOGICAL DATA

- Radiological Toxicity Rating: Group 4 (low)
- Critical Organ: Whole body, lungs
- Routes of Intake: Inhalation

- Submersion dose rate: 4.4 x 10^{-4} rem/day/mCi/m^3 1.2 x 10^{-10} Sv/day/Bq/m^3

SHIELDING

- Half-Value Layer (HVL) for lead < 0.04 inches <0.1 cm
  HVL for steel < 0.04 inches <0.1 cm
- Tenth-Value Layer (TVL) for lead < 0.04 inches <0.1 cm
  TVL for steel 0.16 inches 0.4 cm

- Maximum Beta Range in Air: 30 inches 75 cm

• Maximum Beta Range in Water/Tissue:	0.04 inches	0.09 cm
• Maximum Beta Range in Plastic:	0.03 inches	0.08 cm

SURVEY INSTRUMENTATION

- Survey meter equipped with a G-M pancake or thin-window probe can detect Xe-133.
- Survey meters equipped with a NaI scintillation probe is suitable for detection of the Xe-133 gammas.
- Wipe test counting is not adequate for detecting Xe-133, as it is a gas.

RADIATION MONITORING DOSIMETERS

- Whole Body dosimeter: Required
- Finger dosimeter: Required
- Bioassay can not be performed because of the very short biological and effective half-life.

RADIOACTIVE WASTE

- sealed in vials or other leak proof container

REGULATORY COMPLIANCE INFORMATION

• Derived Air Concentration (DAC):	1 x 10^{-4} uCi/cc (occupational)	3.7 Bq/cc (occupational)
• Effluent Release Limit:	5 x 10^{-7} uCi/cc (air)	1.8 x 10^{-2} Bq/cc (air)

GENERAL RADIOLOGICAL SAFETY INFORMATION

- Xe-133 is a gas. It should be stored in a fume hood and used either in a fume hood or well ventilated area.
- Xe-133 gas deliver systems should be leak proof and checked regularly for leakage.
- Xe-133 adheres to some plastics, rubber, greases and oils. Handle and store in glass where possible.
- Laboratory coat and gloves must be worn when handling unsealed radioactive material. Monitor hands and change gloves frequently
- Whole body and ring dosimeter must be worn when handling Xe-133.
- Indirect viewing aids should be used to minimize exposure from Xe-133.
- Store sealed containers of Xe-133 in lead shielding.
- Remote handling tools should be used when handling sealed containers of Xe-133.
- Practice procedures without radioactivity prior to performing the procedure with Xe-133. Practice will improve dexterity and speed, along with providing opportunity to determine errors and practices that are not ALARA. Practice should focus on minimizing release of Xe-133 into the breathing zone.

Gamma exposure rate from 1 mCi point source - unshielded

Distance	mR/hr
1 cm	1000
5 cm	40
10 cm	10
100 cm	0.1

REFERENCES

Title 10 of the Code of Federal Regulations part 20

Ohio Administration Code 3701:1-38

Shleien, The Health Physics and Radiological Health Handbook Revised Edition, (Scinta, Inc., 1992)

Delacoix et al, Radiation Protection Dosimetry – Radionuclide and Radiation Protection Data Handbook 1998, (Kent, England: Nuclear Technology Publishing, 1998)

www.stanford.edu/dept/EHS/prod/researchlab/radlaser/rsds.html

www.nchps.org/nsds.htm

Isotope Fact Sheet

YTTRIUM-90
[^{90}Y]

PHYSICAL DATA

- Gamma Energy: no photon
- Maximum Beta Energy: 2841 keV (100%)
  523 keV (1%)
- Alpha Energy: no alpha

- Physical Half-Life: 2.7 days
- Biological Half-Life: 49 years (bone)*
- Effective Half-Life: 2.7 days (bone)*

* These are "generic" biological and effective half-lives; the specific labeled compound may alter.

- Specific Activity: 5.38 x 10^6 Ci/gram 1.99 x 10^{16} Bq/g

RADIOLOGICAL DATA

- Radiological Toxicity Rating: Group 3 (moderate)
- Critical Organ: Bone, Lungs
- Routes of Intake: Ingestion, Inhalation, Puncture, Wound, Skin Absorption

- Committed Effective Dose Equivalent (CEDE):

10.7 mrem/uCi (ingestion)	2.91 mSv/MBq (ingestion)
7.89 mrem/uCi (inhalation – class D)	2.13 mSv/MBq (inhalation – class D)
8.44 mrem/uCi (inhalation – class Y)	2.28 mSv/MBq (inhalation – class Y)

- Skin Contamination (7 mg/cm^2): 7.8 x 10^4 rem/y/uCi/cm^2 2.1 x 10^{-2} Sv/y/Bq/cm^2

  (Kocher et al)

SHIELDING

- ½ to ¾ inch plexiglas/acrylic/lucite/plastic/wood

- Do not use lead foil or sheets as primary barrier! Penetrating bremsstrahlung x-ray will be produced!
- Use lead sheets or foil to shield bremsstrahlung x-rays only **after** low density plexiglas/acrylic/lucite/wood shielding.

• Maximum Beta Range in Air:	336 inches	855 cm
• Maximum Beta Range in Water/Tissue:	0.43 inches	1.1 cm
• Maximum Beta Range in Plastic:	0.36 inches	0.92 cm

SURVEY INSTRUMENTATION

- Survey meter equipped with a G-M pancake or thin-window probe can be used to detect the betas from the Y-90. Typical efficiency for a G-M pancake survey meter is between 30 and 35%.
- A NaI survey meter may be used; however, the efficiency of detection is low as it is detecting bremsstrahlung x-rays from the Y-90 beta.
- A liquid scintillation counter should be used to detect removable Y-90 contamination on wipe tests smears. Detection efficiency using standard liquid scintillation cocktail is generally greater than 90%.

RADIATION MONITORING DOSIMETERS

- Whole Body dosimeter: Required
- Finger dosimeter: Required
- Urine bioassay may be required for suspected skin contamination or ingestion.

RADIOACTIVE WASTE

- Solids, liquids, scintillation vials, pathological materials, animal carcasses

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REGULATORY COMPLIANCE INFORMATION

• Derived Air Concentration (DAC):	3×10^{-7} uCi/cc (occupational)	1.1×10^{-2} Bq/cc (occupational)
• Annual Limit of Intake (ALI*):	4×10^{2} uCi (ingestion)	1.5×10^{7} Bq (ingestion)
*[1.0 ALI = 5,000 mrem CEDE]	5×10^{2} uCi	1.8×10^{7} Bq
	(ingestion – LLI)	(ingestion-bone surface)
	7×10^{2} uCi	2.6×10^{7} Bq
	(inhalation – class W)	(inhalation – class D)
	6×10^{2} uCi	2.2×10^{7} Bq
	(inhalation – class Y)	(inhalation – class Y)
• Effluent Release Limit:	9×10^{-10} uCi/cc (air)	3.3×10^{-5} Bq/cc (air)

7×10^{-6} uCi/cc (water) 2.6×10^{-1} Bq/cc (water)

GENERAL RADIOLOGICAL SAFETY INFORMATION

- Laboratory coat and gloves, if practical double gloves, must be worn when handling unsealed Y-90. Monitor hands and change gloves frequently.
- Whole body and ring dosimeter must be worn when handling Y-90.
- Avoid direct eye contact with the Y-90 beta. Never look directly upon an unshielded container of Y-90.
- Eye protection (safety glass or goggles) should be worn when handling Y-90.
- Plastic or other low Z material shielding shall be used to minimize exposure from Y-90.
- Store Y-90 in plastic or other low Z material.
- Remote handling tools should be used when handling Y-90.
- Practice procedures without radioactivity prior to performing the procedure with Y-90. Practice will improve dexterity and speed, along with providing opportunity to determine errors and practices that are not ALARA.
- After each use of unsealed Y-90 monitor self, work areas and floors using a survey meter equipped with a pancake or thin window G-M probe.
- Because of the high energy beta from the decay of Y-90, the possibility of skin contamination or direct handling of Y-90 needs to be minimized. If skin contamination is detect decontamination needs to be initiated immediately. Even low activities of Y-90 skin contamination for a short period of time can result in a significant dose to the skin.

Beta (skin) exposure rate from 1 mCi point source – unshielded*

Distance	mR/hr
1 cm	~300000
5 cm	~12000
10 cm	~3000

*Follows the inverse square law at close distances. Because of the high energy beta, skin dose rates at close distances are very high.

REFERENCES

Title 10 of the Code of Federal Regulations part 20

Ohio Administration Code 3701:1-38

EPA Federal Guidance Report No. 11

Shleien, The Health Physics and Radiological Health Handbook Revised Edition, (Scinta, Inc., 1992)

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www.stanford.edu/dept/EHS/prod/researchlab/radlaser/rsds.html

Isotope Fact Sheet

ZINC-65
[^{65}Zn]

PHYSICAL DATA

- Gamma Energy: 1116 keV (51%)
  511 keV (3%)
- Beta Energy (max): 330 keV (2%)
- Alpha Energy: No alpha
- Physical Half-Life: 243.9 days
- Specific Activity: 8.24×10^{3} Ci/gram; 3.05×10^{14} Bq/g
- Specific Gamma Constant: 3.30×10^{-1} mR/hr/mCi; 8.92×10^{-5} mSv/hr/MBq

(@ 1 meter)

RADIOLOGICAL DATA

- Radiological Toxicity Rating: Group 3 (moderate)
- Critical Organ: Lungs
- Routes of Intake: Ingestion, Inhalation, Puncture, Wound, Skin Absorption

• Committed Effective Dose Equivalent (CEDE):	14.4 mrem/uCi (ingestion)	3.90 mSv/MBq (ingestion)
	20.4 mrem/uCi (inhalation)	5.51 mSv/MBq (inhalation)
• Skin Contamination	2.8×10^{-1} rem/hr/uCi/cm^2	7.6×10^{-2} mSv/y/kBq/cm^2

SHIELDING

• Half-Value Layer (HVL) for lead	0.05 inches	1.4 cm
HVL for steel	1.38 inches	3.5 cm
• Tenth-Value Layer (TVL) for lead	1.65 inches	4.2 cm

TVL for steel	3.43 inches	8.7 cm

SURVEY INSTRUMENTATION

- A survey meter equipped with a G-M pancake or thin-window probe is not efficient for detecting Zn-65, due to low % of beta emission and high energy of gamma emissions. Typical efficiency for a G-M pancake survey meter is less than 1%.
- A survey meter equipped with a NaI scintillation probe is suitable for detection of the Zn-65 gammas; however a thick crystal needs to be used. Typical efficiency for thick crystal NaI scintillation probe is 1% - 2%.
-

RADIATION MONITORING DOSIMETERS

- Whole Body dosimeter: Required
  - Finger dosimeter: Required.
  - Urine bioassay may be required for suspected skin contamination or ingestion.

RADIOACTIVE WASTE

- Solids, liquids, scintillation vials, pathological materials, animal carcasses

REGULATORY COMPLIANCE INFORMATION

• Derived Air Concentration (DAC):	1×10^{-7} uCi/cc (occupational)	3.7×10^{-3} Bq/cc (occupational)
• Annual Limit of Intake (ALI*):	4×10^{2} uCi (ingestion) 3×10^{2} uCi (inhalation)	1.5×10^{7} Bq (ingestion) 1.1×10^{7} Bq (inhalation)

*[1.0 ALI = 5,000 mrem CEDE]

• Effluent Release Limit:	4×10^{-10} uCi/cc (air) 5×10^{-6} uCi/cc (water)	1.5×10^{-5} Bq/cc (air – class D) 1.9×10^{-1} Bq/cc (water)

GENERAL RADIOLOGICAL SAFETY INFORMATION

- Laboratory coat and gloves must be worn when handling unsealed radioactive material. Monitor hands and change gloves frequently.
- Whole body and ring dosimeter must be worn when handling Zn-65.
- Lead shielding shall be used to minimize exposure from Zn-65.
- Indirect viewing aids should be used to minimize exposure from Zn-65.
- Store Zn-65 in lead shielding.
- Remote handling tools should be used when handling Zn-65.
- Practice procedures without radioactivity prior to performing the procedure with Zn-65. Practice will improve dexterity and speed, along with providing opportunity to determine errors and practices that are not ALARA.
- After each use of unsealed Zn-65 monitor self, work areas and floors using a survey meter equipped with a G-M or NaI probe.

Gamma exposure rate from 1 mCi point source - unshielded

Distance	mR/hr
1 cm	3300
5 cm	132
10 cm	33
100 cm	0.33

REFERENCES

Title 10 of the Code of Federal Regulations part 20
Ohio Administration Code 3701:1-38
EPA Federal Guidance Report No. 11
Shleien, The Health Physics and Radiological Health Handbook Revised Edition, (Scinta, Inc., 1992)
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www.stanford.edu/dept/EHS/prod/researchlab/radlaser/rsds.html