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ADMINISTRATIVE
HEARINGS

Office of the Revisor of Statutes

Administrative Rules

TITLE: Adopted Permanent Rules Relating to Radiation Safety

AGENCY: Department of Health

MINNESOTA RULES: Chapter 4731

FILED
OCT 2007
(MN) SECRETARY OF STATE

RULE APPROVED

OFFICE OF ADMINISTRATIVE HEARINGS

October 30, 2007

DATE

Kathleen D Sheely

ADMINISTRATIVE LAW JUDGE.

The attached rules are approved for
filing with the Secretary of State

Sandra Glass-Sirany

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Senior Assistant Revisor

0801183

Department of Health

Adopted Permanent Rules Relating to Radiation Safety

4731.0100 DEFINITIONS.

[For text of subps 1 to 21, see M.R.]

Subp. 22. **Authorized medical physicist.** "Authorized medical physicist" means an individual who:

A. meets the requirements in parts 4731.4412 and 4731.4415; or

B. is identified as an authorized medical physicist or teletherapy physicist on:

[For text of subitems (1) to (3), see M.R.]

(4) a permit issued by an NRC master material ~~licensee~~ license broad scope medical use permittee.

Subp. 23. **Authorized nuclear pharmacist.** "Authorized nuclear pharmacist" means a pharmacist who:

A. meets the requirements in parts 4731.4413 and 4731.4415;

[For text of items B to D, see M.R.]

Subp. 24. **Authorized user.** "Authorized user" means a licensed practitioner of the healing arts who:

A. meets the requirements in part 4731.4415 and in parts 4731.4433, 4731.4436, 4731.4443 to 4731.4445, 4731.4458, 4731.4461, or 4731.4479; or

B. is identified as an authorized user on:

(1) an NRC or agreement state license that authorizes the medical use of radioactive material;

(2) a permit issued by an NRC master material

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licensee that is authorized to permit the medical use of radioactive material;

(3) a permit issued by an NRC or agreement state specific licensee of broad scope that is authorized to permit the medical use of radioactive material; or

(4) a permit issued by an NRC master material license broad scope permittee that is authorized to permit the medical use of radioactive material.

[For text of subps 25 to 33, see M.R.]

Subp. 33a. **Certificate holder.** "Certificate holder" means a person who has been issued a certificate of compliance or other package approval by the NRC.

Subp. 33b. **Certificate of compliance.** "Certificate of compliance" means the certificate issued by the NRC under Code of Federal Regulations, title 10, part 71, subpart D, which approves the design of a package for transportation of radioactive material.

[For text of subps 34 to 43, see M.R.]

Subp. 43a. **Consignment.** "Consignment" means each shipment of a package or groups of packages or load of radioactive material offered by a shipper for transport.

[For text of subp 44, see M.R.]

Subp. 44a. **Containment system.** "Containment system" means the assembly of components of the packaging intended to retain the radioactive material during transport.

[For text of subps 45 to 49, see M.R.]

Subp. 49a. **Conveyance.** "Conveyance" means:

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A. for transport by public highway or rail, any transport vehicle or large freight container;

B. for transport by water, any vessel or any hold, compartment, or defined deck area of a vessel, including any transport vehicle on board the vessel; and

C. for transport by air, any aircraft.

[For text of subp 50, see M.R.]

Subp. 50a. **Criticality safety index or CSI.** "Criticality safety index" or "CSI" means the dimensionless number, rounded up to the next tenth, assigned to and placed on the label of a fissile material package, to designate the degree of control of accumulation of packages containing fissile material during transportation. Determination of the criticality safety index is described in parts 4731.0410 and 4731.0411 and Code of Federal Regulations, title 10, section 71.59.

[For text of subps 51 to 59, see M.R.]

Subp. 59a. **Deuterium.** "Deuterium" means, for purposes of parts 4731.0403, subpart 4, and 4731.0410, deuterium and any deuterium compounds, including heavy water, in which the ratio of deuterium atoms to hydrogen atoms exceeds 1:5000.

[For text of subps 60 to 83, see M.R.]

Subp. 84. **Fissile material.** "Fissile material" means the radionuclides plutonium-239, plutonium-241, uranium-233, uranium-235, or any combination of these radionuclides. Fissile material means the fissile nuclides themselves, not material containing fissile nuclides. Unirradiated natural uranium and depleted uranium and natural uranium or depleted uranium, that

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has been irradiated in thermal reactors only, are not included in this definition. Certain exclusions from fissile material controls are provided in parts 4731.0400 to 4731.0455.

[For text of subps 85 to 90, see M.R.]

Subp. 90a. **Graphite.** "Graphite" means graphite with a boron equivalent content less than five parts per million and density greater than 1.5 grams per cubic centimeter.

[For text of subps 91 to 128, see M.R.]

Subp. 129. **Low specific activity material or LSA.** "Low specific activity material" or "LSA" means radioactive material with limited specific activity which is nonfissile or is excepted under part 4731.0403, subpart 3, and that satisfies the descriptions and limits in subpart 130, 131, or 132. Shielding materials surrounding the LSA material may not be considered in determining the estimated average specific activity of the package contents. LSA material must be in group I, group II, or group III.

Subp. 130. **Low specific activity material group I.** "Low specific activity material group I" means:

A. uranium and thorium ores, concentrates of uranium and thorium ores, and other ores containing naturally occurring radioactive radionuclides which are not intended to be processed for the use of these radionuclides;

B. solid unirradiated natural uranium or depleted uranium or natural thorium or their solid or liquid compounds or mixtures;

C. radioactive material for which the A_2 value is

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unlimited; or

D. other radioactive material in which the activity is distributed throughout and the estimated average specific activity does not exceed 30 times the value for exempt material activity concentration determined according to part 4731.0423.

Subp. 131. **Low specific activity material group II.** "Low specific activity material group II" means:

A. water with tritium concentration up to 20.0 Ci/liter (0.8 TBq/liter); or

B. other material in which the activity is distributed throughout and the average specific activity does not exceed 10^{-4} A_2/g for solids and gases or 10^{-5} A_2/g for liquids.

Subp. 132. **Low specific activity material group III.** "Low specific activity material group III" means solids, such as consolidated wastes and activated materials, excluding powders, that satisfy the requirements in Code of Federal Regulations, title 10, section 71.77, in which:

A. the radioactive material is distributed throughout a solid or a collection of solid objects or is essentially uniformly distributed in a solid compact binding agent such as concrete, bitumen, or ceramic;

B. the radioactive material is relatively insoluble or it is intrinsically contained in a relatively insoluble material, so that even under loss of packaging, the loss of radioactive material per package by leaching, when placed in water for seven days, would not exceed 0.1 A_2; and

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C. the estimated average specific activity of the solid does not exceed 2 x 10^{-3} A_2/g.

[For text of subps 133 to 158, see M.R.]

Subp. 159. **Package.** "Package" means the packaging together with its radioactive contents as presented for transport.

A. "Fissile material package" or "Type AF package, Type BF package, Type B(U)F package, or Type B(M)F package" means a fissile material packaging together with its fissile material contents.

B. "Type A package" means a Type A packaging together with its radioactive contents. A Type A package is defined and must comply with DOT regulations in Code of Federal Regulations, title 49, part 173.

C. "Type B package" means a Type B packaging together with its radioactive contents. On approval, a Type B package design is designated by the NRC as B(U) unless the package has a maximum normal operating pressure of more than 100 lb/in^2 (700 kPascal) gauge or a pressure relief device that would allow the release of radioactive material to the environment under the tests specified in Code of Federal Regulations, title 10, section 71.73, for hypothetical accident conditions, in which case it will receive a designation B(M). B(U) refers to the need for unilateral approval of international shipments. B(M) refers to the need for multilateral approval of international shipments. There is no distinction made in how packages with these designations may be used in domestic transportation. To

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determine their distinction for international transportation, see DOT regulations in Code of Federal Regulations, title 49, part 173. A Type B package approved before September 6, 1983, was designated only as Type B. Limitations on its use are specified in Code of Federal Regulations, title 10, section 71.19.

[For text of subps 160 to 173, see M.R.]

Subp. 174. **Preceptor.** "Preceptor" means an individual who provides, directs, or verifies the training and experience required for an individual to become an authorized user, an authorized medical physicist, an authorized nuclear pharmacist, or a radiation safety officer.

[For text of subps 175 to 192, see M.R.]

Subp. 193. **Radiation safety officer or RSO.** "Radiation safety officer" or "RSO" is an individual who:

A. has the training, knowledge, authority, and responsibility to apply appropriate radiation protection regulations according to part 4731.4130 on behalf of the licensee; or

B. meets the requirements in part 4731.4411, subpart 1, item A, or parts 4731.4411, subpart 1, item C, and 4731.4415 or is identified as a radiation safety officer on:

(1) a specific medical use license issued by the commissioner, the NRC, or an agreement state; or

(2) a medical use permit issued by an NRC master material licensee.

[For text of subps 194 to 223, see M.R.]

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Subp. 224. **Special form radioactive material.** "Special form radioactive material" means radioactive material that satisfies the following conditions:

[For text of item A, see M.R.]

B. the piece or capsule has at least one dimension not less than 0.2 inches (5 mm); and

[For text of item C, see M.R.]

[For text of subps 225 to 234, see M.R.]

Subp. 235. **Surface contaminated object or SCO.** "Surface contaminated object" or "SCO" means a solid object that is not itself classed as radioactive material, but that has radioactive material distributed on any of its surfaces. SCO must be in one of two groups, with surface activity not exceeding the following limits:

A. SCO-I is a solid object on which:

[For text of subitems (1) and (2), see M.R.]

(3) the nonfixed contamination plus the fixed contamination on the inaccessible surface averaged over 300 cm^2, or the area of the surface if less than 300 cm^2, does not exceed:

(a) 1.0 $\mu Ci/cm^2$ (4 x 10^4 Bq/cm^2) for beta and gamma and low toxicity alpha emitters; or

(b) 0.1 $\mu Ci/cm^2$ (4 x 10^3 Bq/cm^2) for all other alpha emitters; and

[For text of item B, see M.R.]

[For text of subps 236 to 245, see M.R.]

Subp. 246. **Transport index.** "Transport index" means the dimensionless number, rounded up to the next tenth, placed on

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the label of a package to designate the degree of control to be exercised by the carrier during transportation. The transport index is the number determined by multiplying the maximum radiation level in millisievert (mSv) per hour at 3.3 feet (one meter) from the external surface of the package by 100 (equivalent to the maximum radiation level in millirem per hour at 3.3 feet (one meter)).

[For text of subps 247 to 253, see M.R.]

Subp. 253a. **Unirradiated uranium.** "Unirradiated uranium" means uranium containing not more than 2×10^3 Bq of plutonium per gram of uranium-235, not more than 9×10^6 Bq of fission products per gram of uranium-235, and not more than 5×10^{-3} gram of uranium-236 per gram of uranium-235.

[For text of subps 254 to 269, see M.R.]

4731.0200 GENERAL APPLICATIONS.

[For text of subps 1 to 3, see M.R.]

Subp. 4. **Submissions.** Except as otherwise specified in this chapter, all communications and reports under this chapter must be addressed to or delivered in person to: Radioactive Materials Unit, Minnesota Department of Health, ~~Radiation Control,~~ 625 Robert Street N, P.O. Box 64975, St. Paul, MN 55164-0975.

4731.0280 DELIBERATE MISCONDUCT.

Subpart 1. **Applicability.** This part applies to:

A. a licensee, registrant, industrial radiography certificate holder, or quality assurance program approval

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holder;

B. an applicant for a license or registration, applicant for industrial radiography certificate, or applicant for quality assurance program approval;

C. a contractor, including a supplier or consultant, or subcontractor to any person identified in this subpart; or

D. an employee of any person identified in this subpart.

Subp. 2. **Prohibition.** A person identified in subpart 1 who knowingly provides to any entity listed in subpart 1, any components, equipment, materials, or other goods or services that relate to a licensee's, industrial radiography certificate holder's, quality assurance program approval holder's, registrant's, or applicant's activities in this chapter may not:

A. engage in deliberate misconduct that causes or would have caused, if not detected, any entity listed in subpart 1 to be in violation of a rule; an order; a regulation; or a term, condition, or limitation of a license, certificate, approval, or registration issued by the commissioner; or

B. deliberately submit to the commissioner, a licensee, a registrant, an industrial radiography certificate holder, a quality assurance program approval holder, an applicant for a license, certificate, or quality assurance program approval, or a licensee's, registrant's, or applicant's contractor or subcontractor, any information that the person submitting the information knows to be incomplete or inaccurate in some respect material to the commissioner.

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Subp. 3. **Enforcement.** A person who violates this part may be subject to enforcement action under part 4731.0260.

Subp. 4. **Definition.** For purposes of this part, deliberate misconduct by a person means an intentional act or omission that the person knows:

A. would cause a licensee, registrant, or applicant to be in violation of a rule, an order, or a term, condition, or limitation of a license issued by the commissioner; or

B. constitutes a violation of a requirement, procedure, instruction, contract, purchase order, or policy of a licensee, registrant, applicant, contractor, or subcontractor.

4731.0355 RECIPROCITY.

Subpart 1. **Application; recognition.**

A. Applications for reciprocal recognition of licenses issued by the NRC or other agreement states may be made by completing a report of proposed activity reciprocity form prescribed by the commissioner. The form may be obtained by contacting the Radioactive Materials Unit, Minnesota Department of Health, ~~Radiation Control,~~ 625 Robert Street N, P.O. Box 64975, St. Paul, MN 55164-0975.

[For text of item B, see M.R.]

[For text of subps 2 to 4, see M.R.]

4731.0400 SCOPE; ENFORCEMENT NOTICE.

Subpart 1. **Scope.** Parts 4731.0400 to 4731.0455 establish requirements for the packaging, preparation for shipment, and transportation of licensed material.

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Subp. 2. **Application of other law.** The packaging and transport of licensed material are subject to this chapter; Code of Federal Regulations, title 10, parts 21, 70, and 73; and the regulations of other agencies, such as the NRC, DOT, and United States Postal Service, having jurisdiction over means of transport. The requirements of parts 4731.0400 to 4731.0455 are in addition to, and not in substitution for, other requirements.

Subp. 3. **Applicability.**

A. Parts 4731.0400 to 4731.0455 apply to any licensee authorized by a specific or general license issued by the commissioner to receive, possess, use, or transfer licensed material, if the licensee delivers that material to a carrier for transport, transports the material outside the site of usage as specified in an NRC or agreement state license, or transports that material on public highways. Parts 4731.0400 to 4731.0455 do not authorize possession of licensed material.

B. Parts 4731.0400 to 4731.0455 apply to any person required to obtain a certificate of compliance if the person delivers radioactive material to a common or contract carrier for transport or transports the material outside the confines of the person's plant or other authorized place of use.

Subp. 4. **Enforcement notice.** This part is notice to all persons who knowingly provide to any licensee; radiographer certificate holder; quality assurance program approval holder; applicant for a license, radiographer certificate, or quality assurance program approval; or contractor or subcontractor of any of them components, equipment, materials, or other goods or

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services, that relate to a licensee's, certificate holder's, quality assurance program approval holder's, or applicant's activities subject to parts 4731.0400 to 4731.0455, that they may be individually subject to the commissioner's enforcement action for violation of part 4731.0280.

4731.0401 REQUIREMENT FOR LICENSE.

No licensee shall deliver licensed material to a carrier for transport or transport licensed material, except as authorized in a general license or a specific license issued by the commissioner or as exempted under parts 4731.0400 to 4731.0455.

4731.0402 TRANSPORTATION OF LICENSED MATERIAL.

Subpart 1. **DOT regulations.**

A. A licensee who transports licensed material outside of the site of usage, as specified in a license issued by the NRC or an agreement state, or where transport is on public highways or a licensee who delivers licensed material to a carrier for transport must comply with the applicable DOT regulations in Code of Federal Regulations, title 49, parts 107, 171 to 180, and 390 to 397, appropriate to the mode of transport.

B. A licensee must particularly note DOT regulations in the following areas:

(1) packaging, Code of Federal Regulations, title 49, part 173, subparts A, B, and I;

(2) marking and labeling, Code of Federal Regulations, title 49, part 172, subparts D and E, sections

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172.400 to 172.407 and 172.436 to 172.441;

[For text of subitems (3) to (5), see M.R.]

(6) hazardous material employee training, Code of Federal Regulations, title 49, part 172, subpart H;

(7) security plans, Code of Federal Regulations, title 49, part 172, subpart I; and

(8) hazardous material shipper and carrier registration, Code of Federal Regulations, title 49, part 107, subpart G.

[For text of item C, see M.R.]

[For text of subp 2, see M.R.]

4731.0403 SPECIFIC EXEMPTIONS.

Subpart 1. **Physicians.** A physician licensed by a state to dispense drugs in the practice of medicine is exempt from part 4731.0402 with respect to transport by the physician of licensed material for use in the practice of medicine. A physician operating under this exemption must be licensed under parts 4731.4400 to 4731.4527 or equivalent regulations of the NRC or an agreement state.

Subp. 1a. **Grounds.** On application of any interested person or on the commissioner's own initiative, the commissioner may grant any exemption from parts 4731.0400 to 4731.0455 that the commissioner determines is authorized by law and will not endanger life or property nor the common defense and security.

Subp. 2. **Low-level materials.** A licensee is exempt from the requirements of parts 4731.0400 to 4731.0455 with respect to shipment or carriage of a package of the following low-level

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material:

A. natural material and ores containing naturally occurring radionuclides that are not intended to be processed for use of these radionuclides, provided the activity concentration of the material does not exceed ten times the values specified in part 4731.0422, subpart 3; and

B. materials for which the activity concentration is not greater than the activity concentration values specified in part 4731.0422, subpart 3, or for which the consignment activity is not greater than the limit for an exempt consignment under part 4731.0422, subpart 3.

Subp. 3. **Exemption from classification as fissile material.** Fissile material meeting at least one of the requirements in items A to F is exempt from classification as fissile material and from the fissile material package standards of Code of Federal Regulations, title 10, sections 71.55 and 71.59, but is subject to all other requirements of this chapter, except as noted:

A. an individual package containing two grams or less of fissile material;

B. individual or bulk packaging containing 15 grams or less of fissile material, provided the package has at least 200 grams of solid nonfissile material for every gram of fissile material. Lead, beryllium, graphite, and hydrogenous material enriched in deuterium may be present in the package but must not be included in determining the required mass for solid nonfissile material;

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C. low concentrations of solid fissile material commingled with solid nonfissile material, provided that:

(1) there is at least 2,000 grams of solid nonfissile material for every gram of fissile material. Lead, beryllium, graphite, and hydrogenous material enriched in deuterium may be present in the package but may not be included in determining the required mass of solid nonfissile material; and

(2) there is no more than 180 grams of fissile material distributed within 360 kilograms of contiguous nonfissile material. Lead, beryllium, graphite, and hydrogenous material enriched in deuterium may be present in the package but may not be included in determining the required mass of solid nonfissile material;

D. uranium enriched in uranium-235 to a maximum of one percent by weight, and with total plutonium and uranium-233 content of up to one percent of the mass of uranium-235, provided that the mass of any beryllium, graphite, and hydrogenous material enriched in deuterium constitutes less than five percent of the uranium mass;

E. liquid solutions of uranyl nitrate enriched in uranium-235 to a maximum of two percent by mass, with a total plutonium and uranium-233 content not exceeding 0.002 percent of the mass of uranium, and with a minimum nitrogen to uranium atomic ratio (N/U) of two. The material must be contained in at least a DOT Type A package; or

F. packages containing, individually, a total

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plutonium mass of not more than 1,000 grams, of which not more than 20 percent by mass may consist of plutonium-239, plutonium-241, or any combination of these radionuclides.

4731.0406 GENERAL LICENSE; NRC-APPROVED PACKAGE.

[For text of subpart 1, see M.R.]

Subp. 2. **Approved quality assurance program.** The general license issued under subpart 1 applies only to a licensee who has a quality assurance program approved by the NRC as complying with Code of Federal Regulations, title 10, part 71, subpart H.

Subp. 3. **Compliance with conditions.**

A. The general license issued under subpart 1 applies only to a licensee who:

[For text of subitem (1), see M.R.]

(2) complies with the terms and conditions of the license, certificate, or other approval, as applicable, and the applicable requirements of this chapter and Code of Federal Regulations, title 10, part 71, subpart H; and

[For text of subitem (3), see M.R.]

[For text of item B, see M.R.]

C. For a Type B or fissile material package, the design of which was approved by the NRC before April 1, 1996, the general license under subpart 1 is subject to the additional restrictions of Code of Federal Regulations, title 10, section 71.19.

4731.0408 GENERAL LICENSE; DOT SPECIFICATION CONTAINER.

[For text of subpart 1, see M.R.]

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Subp. 2. **Approved quality assurance program.** The general license issued under subpart 1 applies only to a licensee who has a quality assurance program approved by the NRC as complying with Code of Federal Regulations, title 10, part 71, subpart H.

[For text of subp 3, see M.R.]

Subp. 4. **Use within United States.** The general license issued under subpart 1 is subject to the limitation that the specification container may not be used for a shipment to a location outside the United States except by multilateral approval, as defined under DOT regulations, Code of Federal Regulations, title 49, section 173.403.

Subp. 5. **Expiration date.** This part expires October 1, 2008.

4731.0409 GENERAL LICENSE; FOREIGN-APPROVED PACKAGE.

[For text of subpart 1, see M.R.]

Subp. 2. **Approved quality assurance program.** Except as otherwise provided in parts 4731.0400 to 4731.0455, the general license issued under subpart 1 applies only to a licensee who has a quality assurance program approved by the NRC as complying with Code of Federal Regulations, title 10, part 71, subpart H.

[For text of subp 3, see M.R.]

Subp. 4. **Certificate conditions.** The general license issued under subpart 1 applies only to a licensee who:

[For text of item A, see M.R.]

B. complies with the terms and conditions of the certificate and revalidation and with the applicable requirements of this chapter. With respect to the quality

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assurance provisions of Code of Federal Regulations, title 10, part 71, subpart H, the licensee is exempt from design, construction, and fabrication considerations.

4731.0410 GENERAL LICENSE; FISSILE MATERIAL.

Subpart 1. **License to transport or deliver fissile material.** A general license is issued to any licensee of the commissioner to transport fissile material, or to deliver fissile material to a carrier for transport, if the material is shipped according to this part. The fissile material need not be contained in a package that meets the standards of part 4731.0412 and Code of Federal Regulations, title 10, sections 71.41 to 71.77, if the material is shipped according to this part. However, the material must be contained in a Type A package. The Type A package must also meet the DOT requirements in Code of Federal Regulations, title 49, section 173.417(a).

Subp. 2. **Approved quality assurance program.** The general license issued under subpart 1 applies only to a licensee who has a quality assurance program approved by the NRC as complying with Code of Federal Regulations, title 10, part 71, subpart H.

Subp. 3. **Type A quantity limits.** The general license issued under subpart 1 applies only when a package's contents:

A. contain less than a Type A quantity of fissile material; and

B. contain less than 500 total grams of beryllium, graphite, or hydrogenous material enriched in deuterium.

Subp. 4. **Fissile material labeled with a criticality safety index.**

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A. The general license applies only to packages containing fissile material that are labeled with a criticality safety index that:

(1) has been determined according to subpart 7; and

(2) has a value less than or equal to ten.

B. For a shipment of multiple packages containing fissile material, the sum of the criticality safety indices must be less than or equal to 50 for shipment on a nonexclusive use conveyance and less than or equal to 100 for shipment on an exclusive use conveyance.

Subp. 5. [See repealer.]

Subp. 6. [See repealer.]

Subp. 7. **Criticality safety index values.**

A. The value for the criticality safety index must be greater than or equal to the number calculated by the following equation:

$$CSI = 10\left[\frac{\text{grams of } {}^{235}U}{X} + \frac{\text{grams of } {}^{233}U}{Y} + \frac{\text{grams of Pu}}{Z}\right]$$

B. The calculated criticality safety index must be rounded up to the first decimal place.

C. The values of X, Y, and Z used in the criticality safety index equation must be taken from subpart 8 or 9, as appropriate.

D. If subpart 9 is used to obtain the value of X, then the values for the terms in the equation for uranium-233

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and plutonium must be assumed to be zero.

E. The values in subpart 8 for X, Y, and Z must be used to determine the criticality safety index if:

(1) uranium-233 is present in the package;

(2) the mass of plutonium exceeds one percent of the mass of uranium-235;

(3) the uranium is of unknown uranium-235 enrichment or greater than 24 weight percent enrichment; or

(4) substances having a moderating effectiveness, that is, an average hydrogen density greater than H_2O, for example certain hydrocarbon oils or plastics, are present in any form, except as polyethylene used for packing or wrapping.

Subp. 8. **Mass limits for general license packages containing mixed quantities of fissile material of uranium-235 of unknown enrichment.**

THE FOLLOWING IS AN ALL NEW TABLE:

	Fissile material mass mixed with moderating substances having an average hydrogen density less than or equal to H_2O (grams)	Fissile material mass mixed with moderating substances having an average hydrogen density greater than H_2O[a] (grams)
^{235}U (X)	60	38
^{233}U (Y)	43	27
^{239}Pu or ^{241}Pu (Z)	37	24

[a]When mixtures of moderating substances are present, the lower mass limits shall be used if more than 15 percent of the moderating substance has an average hydrogen density greater than H_2O.

Subp. 9. **Mass limits for general license packages**

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containing uranium-235 of known enrichment.

Uranium enrichment in weight percent of ^{235}U not exceeding	Fissile material mass of ^{235}U (X) (grams)
24	60
20	63
15	67
11	72
10	76
9.5	78
9	81
8.5	82
8	85
7.5	88
7	90
6.5	93
6	97
5.5	102
5	108
4.5	114
4	120
3.5	132
3	150
2.5	180
2	246
1.5	408
1.35	480
1	1,020
0.92	1,800

4731.0411 GENERAL LICENSE; PLUTONIUM-BERYLLIUM SPECIAL FORM MATERIAL.

Subpart 1. **Transport of plutonium-beryllium.** A general license is issued to any licensee of the commissioner to transport fissile material in the form of plutonium-beryllium (Pu-Be) special form sealed sources, or to deliver Pu-Be sealed sources to a carrier for transport, if the material is shipped according to this part. The material need not be contained in a package that meets the requirements of part 4731.0412 and Code of Federal Regulations, title 10, sections 71.41 to 71.77; however, the material must be contained in a Type A package.

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The Type A package must also meet the DOT requirements of Code of Federal Regulations, title 49, section 173.417(a).

Subp. 2. **Approved quality assurance program.** The general license issued under subpart 1 applies only to a licensee who has a quality assurance program approved by the NRC as complying with part 4731.0412 and Code of Federal Regulations, title 10, part 71, subpart H.

Subp. 3. **Package contents.** The general license issued under subpart 1 applies only when a package's contents:

A. contain no more than a Type A quantity of radioactive material; and

B. contain less than 1,000 grams of plutonium, provided that plutonium-239, plutonium-241, or any combination of these radionuclides, constitutes less than 240 grams of total quantity of plutonium in the package.

Subp. 4. **Packages labeled with criticality safety index.** The general license issued under subpart 1 applies only to packages labeled with a criticality safety index that:

A. has been determined according to subpart 5;

B. has a value less than or equal to 100; and

C. for a shipment of multiple packages containing Pu-Be sealed sources, the sum of the criticality safety indices must be less than or equal to 50 (for shipment on a nonexclusive use conveyance) and less than or equal to 100 (for shipment on an exclusive use conveyance).

Subp. 5. **Criticality safety index.**

A. The value for the criticality safety index must be

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greater than or equal to the number calculated by the following equation:

$$CSI = 10\left[\frac{\text{grams of } ^{239}Pu + \text{grams of } ^{241}Pu}{24}\right]$$

B. The calculated criticality safety index must be rounded up to the first decimal place.

4731.0415 ROUTINE DETERMINATIONS.

Before each shipment of licensed material, a licensee must ensure that the package with its contents satisfies the applicable requirements of the license and parts 4731.0400 to 4731.0455. The licensee must determine that:

[For text of items A to K, see M.R.]

4731.0416 AIR TRANSPORT OF PLUTONIUM.

Subpart 1. **Limitations for plutonium transport.** Notwithstanding the provisions of any general license and notwithstanding any exemptions stated directly in parts 4731.0400 to 4731.0455 or included indirectly by citation to Code of Federal Regulations, title 49, chapter I, as may be applicable, a licensee must ensure that plutonium in any form, whether for import, export, or domestic shipment, is not transported by air, or delivered to a carrier for air transport, unless:

[For text of item A, see M.R.]

B. the plutonium is contained in a material in which the specific activity is less than or equal to the activity concentration values for plutonium specified in part 4731.0422,

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subpart 3, and in which the radioactivity is essentially uniformly distributed;

[For text of items C and D, see M.R.]

[For text of subp 2, see M.R.]

4731.0419 ADVANCE NOTIFICATION OF SHIPMENT OF IRRADIATED REACTOR FUEL AND NUCLEAR WASTE.

[For text of subpart 1, see M.R.]

Subp. 2. **Shipments requiring notice.** Advance notification is required under this part for shipments of irradiated reactor fuel in quantities less than that subject to the advance notification requirements of Code of Federal Regulations, title 10, section 73.37, paragraph (f). Advance notification is also required under this part for shipments of licensed material, other than irradiated fuel, meeting the following three conditions:

A. the licensed material is required by parts 4731.0400 to 4731.0455 to be in Type B packaging for transportation;

[For text of item B, see M.R.]

C. the quantity of licensed material in a single package exceeds the least of the following:

[For text of subitems (1) and (2), see M.R.]

(3) 27,000 Ci (1,000 TBq).

Subp. 3. **Procedures for submitting notification.**

A. The notification required under this part must:

[For text of subitems (1) and (2), see M.R.]

(3) if delivered by any other means than mail,

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reach the office of the commissioner and the governor or governor's designee at least four days before the beginning of the seven-day period during which departure of the shipment is estimated to occur.

[For text of item B, see M.R.]

C. The licensee must retain a copy of the notification as a record for three years.

Subp. 4. **Information to be furnished in advance notification of shipment.** An advance notification of shipment of irradiated reactor fuel or nuclear waste must contain the following information:

[For text of items A to F, see M.R.]

Subp. 5. **Revision notice.** A licensee who finds that schedule information, previously furnished under this part to the commissioner and a governor or governor's designee, will not be met must telephone a responsible individual in the commissioner's office and the governor or governor's designee and inform the individual of the extent of the delay beyond the schedule originally reported.

Subp. 5a. **Record retained.** The licensee must maintain a record of the name of the individual contacted for three years.

Subp. 6. **Cancellation notice.**

A. A licensee who cancels an irradiated reactor fuel or nuclear waste shipment for which advance notification has been sent must send a cancellation notice to the commissioner, the governor of each state or the governor's designee previously notified, and the director of the Division of Nuclear Security,

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Office of Nuclear Security and Incident Response, NRC.

B. The licensee must state in the notice that it is a cancellation and identify the advance notification that is being canceled.

C. The licensee must retain a copy of the notice as a record for three years.

4731.0421 QUALITY ASSURANCE ORGANIZATION.

[For text of subps 1 to 7, see M.R.]

Subp. 8. **Access to management.** Irrespective of the organizational structure, the individuals assigned the responsibility for ensuring effective execution of any portion of the quality assurance program, at any location where activities subject to parts 4731.0400 to 4731.0455 are being performed, must have direct access to the levels of management necessary to perform this function.

4731.0422 A_1 AND A_2 VALUES FOR RADIONUCLIDES.

Subpart 1. [See repealer.]

Subp. 1a. **A_1 and A_2 values.**

THE FOLLOWING IS AN ALL NEW TABLE:

Element and atomic number and symbol of radionuclide	A_1 (TBq)	A_1 (Ci)[b]	A_2 (TBq)	A_2 (Ci)[b]
Actinium (89)				
Ac-225[a]	8.0×10^{-1}	2.2×10^{1}	6.0×10^{-3}	1.6×10^{-1}
Ac-227[a]	9.0×10^{-1}	2.4×10^{1}	9.0×10^{-5}	2.4×10^{-3}
Ac-228	6.0×10^{-1}	1.6×10^{1}	5.0×10^{-1}	1.4×10^{1}
Silver (47)				
Ag-105	2.0	5.4×10^{1}	2.0	5.4×10^{1}
Ag-108m[a]	7.0×10^{-1}	1.9×10^{1}	7.0×10^{-1}	1.9×10^{1}

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1	Ag-110m[a]	4.0×10^{-1}	1.1×10^{1}	4.0×10^{-1}	1.1×10^{1}
2	Ag-111	2.0	5.4×10^{1}	6.0×10^{-1}	1.6×10^{1}
3					
4	Aluminum (13)				
5	Al-26	1.0×10^{-1}	2.7	1.0×10^{-1}	2.7
6					
7	Americium (95)				
8	Am-241	1.0×10^{1}	2.7×10^{2}	1.0×10^{-3}	2.7×10^{-2}
9	Am-242m[a]	1.0×10^{1}	2.7×10^{2}	1.0×10^{-3}	2.7×10^{-2}
10	Am-243[a]	5.0	1.4×10^{2}	1.0×10^{-3}	2.7×10^{-2}
11					
12	Argon (18)				
13	Ar-37	4.0×10^{1}	1.1×10^{3}	4.0×10^{1}	1.1×10^{3}
14	Ar-39	4.0×10^{1}	1.1×10^{3}	2.0×10^{1}	5.4×10^{2}
15	Ar-41	3.0×10^{-1}	8.1	3.0×10^{-1}	8.1
16					
17	Arsenic (33)				
18	As-72	3.0×10^{-1}	8.1	3.0×10^{-1}	8.1
19	As-73	4.0×10^{1}	1.1×10^{3}	4.0×10^{1}	1.1×10^{3}
20	As-74	1.0	2.7×10^{1}	9.0×10^{-1}	2.4×10^{1}
21	As-76	3.0×10^{-1}	8.1	3.0×10^{-1}	8.1
22	As-77	2.0×10^{1}	5.4×10^{2}	7.0×10^{-1}	1.9×10^{1}
23					
24	Astatine (85)				
25	At-211[a]	2.0×10^{1}	5.4×10^{2}	5.0×10^{-1}	1.4×10^{1}
26					
27	Gold (79)				
28	Au-193	7.0	1.9×10^{2}	2.0	5.4×10^{1}
29	Au-194	1.0	2.7×10^{1}	1.0	2.7×10^{1}
30	Au-195	1.0×10^{1}	2.7×10^{2}	6.0	1.6×10^{2}
31	Au-198	1.0	2.7×10^{1}	6.0×10^{-1}	1.6×10^{1}
32	Au-199	1.0×10^{1}	2.7×10^{2}	6.0×10^{-1}	1.6×10^{1}
33					
34	Barium (56)				
35	Ba-131[a]	2.0	5.4×10^{1}	2.0	5.4×10^{1}
36	Ba-133	3.0	8.1×10^{1}	3.0	8.1×10^{1}
37	Ba-133m	2.0×10^{1}	5.4×10^{2}	6.0×10^{-1}	1.6×10^{1}
38	Ba-140[a]	5.0×10^{-1}	1.4×10^{1}	3.0×10^{-1}	8.1
39					
40	Beryllium (4)				
41	Be-7	2.0×10^{1}	5.4×10^{2}	2.0×10^{1}	5.4×10^{2}
42	Be-10	4.0×10^{1}	1.1×10^{3}	6.0×10^{-1}	1.6×10^{1}
43					
44	Bismuth (83)				
45	Bi-205	7.0×10^{-1}	1.9×10^{1}	7.0×10^{-1}	1.9×10^{1}
46	Bi-206	3.0×10^{-1}	8.1	3.0×10^{-1}	8.1
47	Bi-207	7.0×10^{-1}	1.9×10^{1}	7.0×10^{-1}	1.9×10^{1}
48	Bi-210	1.0	2.7×10^{1}	6.0×10^{-2}	1.6×10^{1}
49	Bi-210m[a]	6.0×10^{-1}	1.6×10^{1}	2.0×10^{-1}	5.4×10^{-1}
50	Bi-212[a]	7.0×10^{-1}	1.9×10^{1}	6.0×10^{-1}	1.6×10^{1}
51					
52	Berkelium (97)				
53	Bk-247	8.0	2.2×10^{3}	8.0×10^{-4}	2.2×10^{-2}
54	Bk-249[a]	4.0×10^{1}	1.1×10^{3}	3.0×10^{-1}	8.1

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Bromine (35)				
Br-76	4.0×10^{-1}	1.1×10^{1}	4.0×10^{-1}	1.1×10^{1}
Br-77	3.0	8.1×10^{1}	3.0	8.1×10^{1}
Br-82	4.0×10^{-1}	1.1×10^{1}	4.0×10^{-1}	1.1×10^{1}
Carbon (6)				
C-11	1.0	2.7×10^{3}	6.0×10^{-1}	1.6×10^{1}
C-14	4.0×10^{1}	1.1×10^{3}	3.0	8.1×10^{1}
Calcium (20)				
Ca-41	Unlimited	Unlimited	Unlimited	Unlimited
Ca-45	4.0×10^{1}	1.1×10^{3}	1.0	2.7×10^{1}
Ca-47[a]	3.0	8.1×10^{1}	3.0×10^{-1}	8.1
Cadmium (48)				
Cd-109	3.0×10^{1}	8.1×10^{2}	2.0	5.4×10^{1}
Cd-113m	4.0×10^{1}	1.1×10^{3}	5.0×10^{-1}	1.4×10^{1}
Cd-115[a]	3.0	8.1×10^{1}	4.0×10^{-1}	1.1×10^{1}
Cd-115m	5.0×10^{-1}	1.4×10^{1}	5.0×10^{-1}	1.4×10^{1}
Cerium (58)				
Ce-139	7.0	1.9×10^{2}	2.0	5.4×10^{1}
Ce-141	2.0×10^{1}	5.4×10^{2}	6.0×10^{-1}	1.6×10^{1}
Ce-143	9.0×10^{-1}	2.4×10^{1}	6.0×10^{-1}	1.6×10^{1}
Ce-144[a]	2.0×10^{-1}	5.4	2.0×10^{-1}	5.4
Californium (98)				
Cf-248	4.0×10^{1}	1.1×10^{3}	6.0×10^{-3}	1.6×10^{-1}
Cf-249	3.0	8.1×10^{1}	8.0×10^{-4}	2.2×10^{-2}
Cf-250	2.0×10^{1}	5.4×10^{2}	2.0×10^{-3}	5.4×10^{-2}
Cf-251	7.0	1.9×10^{2}	7.0×10^{-4}	1.9×10^{-2}
Cf-252[h]	5.0×10^{-2}	1.4	3.0×10^{-3}	8.1×10^{-2}
Cf-253[a]	4.0×10^{1}	1.1×10^{3}	4.0×10^{-2}	1.1
Cf-254	1.0×10^{-3}	2.7×10^{-2}	1.0×10^{-3}	2.7×10^{-2}
Chlorine (17)				
Cl-36	1.0×10^{1}	2.7×10^{2}	6.0×10^{-1}	1.6×10^{1}
Cl-38	2.0×10^{-1}	5.4	2.0×10^{-1}	5.4
Curium (96)				
Cm-240	4.0×10^{1}	1.1×10^{3}	2.0×10^{-2}	5.4×10^{-1}
Cm-241	2.0	5.4×10^{1}	1.0	2.7×10^{1}
Cm-242	4.0×10^{1}	1.1×10^{3}	1.0×10^{-2}	2.7×10^{-1}
Cm-243	9.0	2.4×10^{2}	1.0×10^{-3}	2.7×10^{-2}
Cm-244	2.0×10^{1}	5.4×10^{2}	2.0×10^{-4}	5.4×10^{-2}
Cm-245	9.0	2.4×10^{2}	9.0×10^{-4}	2.4×10^{-2}
Cm-246	9.0	2.4×10^{2}	9.0×10^{-4}	2.4×10^{-2}
Cm-247[a]	3.0	8.1×10^{1}	1.0×10^{-3}	2.7×10^{-2}
Cm-248	2.0×10^{-2}	5.4×10^{-1}	3.0×10^{-4}	8.1×10^{-3}
Cobalt (27)				
Co-55	5.0×10^{-1}	1.4×10^{1}	5.0×10^{-1}	1.4×10^{1}
Co-56	3.0×10^{-1}	8.1	3.0×10^{-1}	8.1

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Co-57	1.0×10^{1}	2.7×10^{2}	1.0×10^{1}	2.7×10^{2}
Co-58	1.0×10^{1}	2.7×10^{3}	1.0×10^{1}	2.7×10^{3}
Co-58m	4.0×10^{-1}	1.1×10^{1}	4.0×10^{-1}	1.1×10^{1}
Co-60	4.0×10^{-1}	1.1×10^{1}	4.0×10^{-1}	1.1×10^{1}
Chromium (24)				
Cr-51	3.0×10^{1}	8.1×10^{2}	3.0×10^{1}	8.1×10^{2}
Cesium (55)				
Cs-129	4.0×10^{1}	1.1×10^{2}	4.0×10^{1}	1.1×10^{2}
Cs-131	3.0×10^{1}	8.1×10^{1}	3.0×10^{1}	8.1×10^{1}
Cs-132	1.0×10^{-1}	2.7×10^{1}	1.0×10^{-1}	2.7×10^{1}
Cs-134	7.0×10^{1}	1.9×10^{3}	6.0×10^{-1}	1.6×10^{1}
Cs-134m	4.0×10^{1}	1.1×10^{3}	1.0×10^{-1}	2.7×10^{1}
Cs-135	4.0×10^{-1}	1.1×10^{1}	5.0×10^{-1}	1.4×10^{1}
Cs-136[a]	5.0×10^{-1}	1.4×10^{1}	6.0×10^{-1}	1.6×10^{1}
Cs-137	2.0	5.4×10^{1}		
Copper (29)				
Cu-64	6.0	1.6×10^{2}	1.0×10^{-1}	2.7×10^{1}
Cu-67	1.0×10^{1}	2.7×10^{2}	7.0×10^{-1}	1.9×10^{1}
Dysprosium (66)				
Dy-159	2.0×10^{1}	5.4×10^{2}	2.0×10^{1}	5.4×10^{2}
Dy-165[a]	9.0×10^{-1}	2.4×10^{1}	6.0×10^{-1}	1.6×10^{1}
Dy-166	9.0×10^{-1}	2.4×10^{1}	3.0×10^{-1}	8.1
Erbium (68)				
Er-169	4.0×10^{1}	1.1×10^{3}	1.0×10^{-1}	2.7×10^{1}
Er-171	8.0×10^{-1}	2.2×10^{1}	5.0×10^{-1}	1.4×10^{1}
Europium (63)				
Eu-147	2.0	5.4×10^{1}	2.0	5.4×10^{1}
Eu-148	5.0×10^{-1}	1.4×10^{1}	5.0×10^{-1}	1.4×10^{1}
Eu-149	2.0×10^{1}	5.4×10^{2}	2.0×10^{1}	5.4×10^{2}
Eu-150 (short-lived)	2.0	5.4×10^{1}	7.0×10^{-1}	1.9×10^{1}
Eu-150 (long-lived)	7.0×10^{-1}	1.9×10^{1}	7.0×10^{-1}	1.9×10^{1}
Eu-152	1.0	2.7×10^{1}	1.0	2.7×10^{1}
Eu-152m	8.0×10^{-1}	2.2×10^{1}	8.0×10^{-1}	2.2×10^{1}
Eu-154	9.0×10^{-1}	2.4×10^{1}	6.0×10^{-1}	1.6×10^{1}
Eu-155	2.0×10^{1}	5.4×10^{2}	3.0	8.1×10^{1}
Eu-156	7.0×10^{-1}	1.9×10^{1}	7.0×10^{-1}	1.9×10^{1}
Fluorine (9)				
F-18	1.0	2.7×10^{1}	6.0×10^{-1}	1.6×10^{1}
Iron (26)				
Fe-52[a]	3.0×10^{-1}	8.1	3.0×10^{-1}	8.1
Fe-55	4.0×10^{1}	1.1×10^{3}	4.0×10^{1}	1.1×10^{3}
Fe-59	9.0×10^{-1}	2.4×10^{1}	9.0×10^{-1}	2.4×10^{1}

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Fe-60[a]	4.0×10^{1}	1.1×10^{3}	2.0×10^{-1}	5.4	
Gallium (31)					
Ga-67	7.0	1.9×10^{2}	3.0	8.1×10^{1}	
Ga-68	5.0×10^{-1}	1.4×10^{1}	5.0×10^{-1}	1.4×10^{1}	
Ga-72	4.0×10^{-1}	1.1×10^{1}	4.0×10^{-1}	1.1×10^{1}	
Gadolinium (64)					
Gd-146[a]	5.0×10^{-1}	1.4×10^{1}	5.0×10^{-1}	1.4×10^{1}	
Gd-148	2.0×10^{1}	5.4×10^{2}	2.0×10^{-3}	5.4×10^{-2}	
Gd-153	1.0×10^{1}	2.7×10^{2}	9.0	2.4×10^{2}	
Gd-159	3.0	8.1×10^{1}	6.0×10^{-1}	1.6×10^{1}	
Germanium (32)					
Ge-68[a]	5.0×10^{-1}	1.4×10^{1}	5.0×10^{-1}	1.4×10^{1}	
Ge-71	4.0×10^{1}	1.1×10^{3}	4.0×10^{1}	1.1×10^{3}	
Ge-77	3.0×10^{-1}	8.1	3.0×10^{-1}	8.1	
Hafnium (72)					
Hf-172[a]	6.0×10^{-1}	1.6×10^{1}	6.0×10^{-1}	1.6×10^{1}	
Hf-175	3.0	8.1×10^{1}	3.0	8.1×10^{1}	
Hf-181	2.0	5.4×10^{1}	5.0×10^{-1}	1.4×10^{1}	
Hf-182	Unlimited	Unlimited	Unlimited	Unlimited	
Mercury (80)					
Hg-194[a]	1.0	2.7×10^{1}	1.0	2.7×10^{1}	
Hg-195m[a]	3.0	8.1×10^{2}	7.0×10^{-1}	1.9×10^{2}	
Hg-197	2.0×10^{1}	5.4×10^{2}	1.0×10^{1}	2.7×10^{2}	
Hg-197m	1.0×10^{1}	2.7×10^{2}	4.0×10^{-1}	1.1×10^{1}	
Hg-203	5.0	1.4×10^{2}	1.0	2.7×10^{1}	
Holmium (67)					
Ho-166	4.0×10^{-1}	1.1×10^{1}	4.0×10^{-1}	1.1×10^{1}	
Ho-166m	6.0×10^{-1}	1.6×10^{1}	5.0×10^{-1}	1.4×10^{1}	
Iodine (53)					
I-123	6.0	1.6×10^{2}	3.0	8.1×10^{1}	
I-124	1.0	2.7×10^{2}	1.0	2.7×10^{1}	
I-125	2.0×10^{1}	5.4×10^{2}	3.0	8.1×10^{1}	
I-126	2.0	5.4×10^{1}	1.0	2.7×10^{1}	
I-129	Unlimited	Unlimited	Unlimited	Unlimited	
I-131	3.0	8.1×10^{1}	7.0×10^{-1}	1.9×10^{1}	
I-132	4.0×10^{-1}	1.1×10^{1}	4.0×10^{-1}	1.1×10^{1}	
I-133	7.0×10^{-1}	1.9×10^{1}	6.0×10^{-1}	1.6×10^{1}	
I-134[a]	3.0×10^{-1}	8.1	3.0×10^{-1}	8.1	
I-135[a]	6.0×10^{-1}	1.6×10^{1}	6.0×10^{-1}	1.6×10^{1}	
Indium (49)					
In-111	3.0	8.1×10^{2}	3.0	8.1×10^{1}	
In-113m[a]	4.0	1.1×10^{2}	2.0	5.4×10^{1}	
In-114m[a]	1.0×10^{1}	2.7×10^{2}	5.0×10^{-1}	1.4×10^{1}	
In-115m	7.0	1.9×10^{2}	1.0	2.7×10^{1}	
Iridium (77)					

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Ir-189[a]	1.0×10^{1}	2.7×10^{2}	1.0×10^{1}	2.7×10^{2}
Ir-190	7.0×10^{-1}	1.9×10^{1}	7.0×10^{-1}	1.9×10^{1}
Ir-192[c]	1.0	2.7×10^{1}	6.0×10^{-1}	1.6×10^{1}
Ir-194	3.0×10^{-1}	8.1	3.0×10^{-1}	8.1
Potassium (19)				
K-40	9.0×10^{-1}	2.4×10^{1}	9.0×10^{-1}	2.4×10^{1}
K-42	2.0×10^{-1}	5.4	2.0×10^{-1}	5.4
K-43	7.0×10^{-1}	1.9×10^{1}	6.0×10^{-1}	1.6×10^{1}
Krypton (36)				
Kr-81	4.0×10^{1}	1.1×10^{3}	4.0×10^{1}	1.1×10^{3}
Kr-85	1.0×10^{1}	2.7×10^{2}	1.0×10^{1}	2.7×10^{2}
Kr-85m	8.0	2.2×10^{2}	3.0	8.1×10^{1}
Kr-87	2.0×10^{-1}	5.4	2.0×10^{-1}	5.4
Lanthanum (57)				
La-137	3.0×10^{1}	8.1×10^{2}	6.0	1.6×10^{2}
La-140	4.0×10^{-1}	1.1×10^{1}	4.0×10^{-1}	1.1×10^{1}
Lutetium (71)				
Lu-172	6.0×10^{-1}	1.6×10^{1}	6.0×10^{-1}	1.6×10^{1}
Lu-173	8.0	2.2×10^{2}	8.0	2.2×10^{2}
Lu-174	9.0	2.4×10^{2}	9.0	2.4×10^{2}
Lu-174m	2.0×10^{1}	5.4×10^{2}	1.0×10^{1}	2.7×10^{2}
Lu-177	3.0×10^{1}	8.1×10^{2}	7.0×10^{-1}	1.9×10^{1}
Magnesium (12)				
Mg-28[a]	3.0×10^{-1}	8.1	3.0×10^{-1}	8.1
Manganese (25)				
Mn-52	3.0×10^{-1}	8.1	3.0×10^{-1}	8.1
Mn-53	Unlimited	Unlimited	Unlimited	Unlimited
Mn-54	1.0	2.7×10^{1}	1.0	2.7×10^{1}
Mn-56	3.0×10^{-1}	8.1	3.0×10^{-1}	8.1
Molybdenum (42)				
Mo-93[a,i]	4.0×10^{1}	1.1×10^{3}	2.0×10^{1}	5.4×10^{2}
Mo-99[a,i]	1.0	2.7×10^{1}	6.0×10^{-1}	1.6×10^{1}
Nitrogen (7)				
N-13	9.0×10^{-1}	2.4×10^{1}	6.0×10^{-1}	1.6×10^{1}
Sodium (11)				
Na-22	5.0×10^{-1}	1.4×10^{1}	5.0×10^{-1}	1.4×10^{1}
Na-24	2.0×10^{-1}	5.4	2.0×10^{-1}	5.4
Niobium (41)				
Nb-93m	4.0×10^{1}	1.1×10^{3}	3.0×10^{1}	8.1×10^{2}
Nb-94	7.0×10^{-1}	1.9×10^{1}	7.0×10^{-1}	1.9×10^{1}
Nb-95	1.0	2.7×10^{1}	1.0	2.7×10^{1}
Nb-97	9.0×10^{-1}	2.4×10^{1}	6.0×10^{-1}	1.6×10^{1}
Neodymium (60)				

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Nd-147	6.0	1.6×10^{2}	6.0×10^{-1}	1.6×10^{1}
Nd-149	6.0×10^{-1}	1.6×10^{1}	5.0×10^{-1}	1.4×10^{1}
Nickel (28)				
Ni-59	Unlimited	Unlimited	Unlimited	Unlimited
Ni-63	4.0×10^{1}	1.1×10^{3}	3.0×10^{1}	8.1×10^{2}
Ni-65	4.0×10^{-1}	1.1×10^{1}	4.0×10^{-1}	1.1×10^{1}
Neptunium (93)				
Np-235	4.0×10^{1}	1.1×10^{3}	4.0×10^{1}	1.1×10^{3}
Np-236 (short-lived)	2.0×10^{1}	5.4×10^{2}	2.0	5.4×10^{1}
Np-236 (long-lived)	9.0×10^{0}	2.4×10^{2}	2.0×10^{-2}	5.4×10^{-1}
Np-237	2.0×10^{1}	5.4×10^{2}	2.0×10^{-3}	5.4×10^{-2}
Np-239	7.0	1.9×10^{2}	4.0×10^{-1}	1.1×10^{1}
Osmium (76)				
Os-185	1.0	2.7×10^{1}	1.0	2.7×10^{1}
Os-191	1.0×10^{1}	2.7×10^{2}	2.0	5.4×10^{2}
Os-191m	4.0×10^{1}	1.1×10^{3}	3.0×10^{1}	8.1×10^{2}
Os-193[a]	2.0	5.4×10^{1}	6.0×10^{-1}	1.6×10^{1}
Os-194[a]	3.0×10^{-1}	8.1	3.0×10^{-1}	8.1
Phosphorus (15)				
P-32	5.0×10^{-1}	1.4×10^{1}	5.0×10^{-1}	1.4×10^{1}
P-33	4.0×10^{1}	1.1×10^{3}	1.0	2.7×10^{1}
Protactinium (91)				
Pa-230[a]	2.0	5.4×10^{1}	7.0×10^{-2}	1.9
Pa-231	4.0	1.1×10^{2}	4.0×10^{-4}	1.1×10^{-2}
Pa-233	5.0	1.4×10^{2}	7.0×10^{-1}	1.9×10^{1}
Lead (82)				
Pb-201	1.0	2.7×10^{1}	1.0	2.7×10^{1}
Pb-202	4.0×10^{1}	1.1×10^{3}	2.0×10^{1}	5.4×10^{2}
Pb-203	4.0	1.1×10^{2}	3.0	8.1×10^{1}
Pb-205[a]	Unlimited	Unlimited	Unlimited	Unlimited
Pb-210[a]	1.0	2.7×10^{1}	5.0×10^{-2}	1.4
Pb-212[a]	7.0×10^{-1}	1.9×10^{1}	2.0×10^{-1}	5.4
Palladium (46)				
Pd-103[a]	4.0×10^{1}	1.1×10^{3}	4.0×10^{1}	1.1×10^{3}
Pd-107	Unlimited	Unlimited	Unlimited	Unlimited
Pd-109	2.0	5.4×10^{1}	5.0×10^{-1}	1.4×10^{1}
Promethium (61)				
Pm-143	3.0	8.1×10^{1}	3.0	8.1×10^{1}
Pm-144	7.0×10^{-1}	1.9×10^{1}	7.0×10^{-1}	1.9×10^{1}
Pm-145	3.0×10^{1}	8.1×10^{2}	1.0×10^{1}	2.7×10^{2}
Pm-147	4.0×10^{1}	1.1×10^{3}	2.0	5.4×10^{1}
Pm-148m[a]	8.0×10^{-1}	2.2×10^{1}	7.0×10^{-1}	1.9×10^{1}

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Pm-149	2.0	5.4×10^{1}	6.0×10^{-1}	1.6×10^{1}
Pm-151	2.0	5.4×10^{1}	6.0×10^{-1}	1.6×10^{1}
Polonium (84)				
Po-210	4.0×10^{1}	1.1×10^{3}	2.0×10^{-2}	5.4×10^{-1}
Praseodymium (59)				
Pr-142	4.0×10^{-1}	1.1×10^{1}	4.0×10^{-1}	1.1×10^{1}
Pr-143	3.0	8.1×10^{1}	6.0×10^{-1}	1.6×10^{1}
Platinum (78)				
Pt-188[a]	1.0	2.7×10^{1}	8.0×10^{-1}	2.2×10^{1}
Pt-191	4.0	1.1×10^{3}	3.0	8.1×10^{3}
Pt-193	4.0×10^{1}	1.1×10^{3}	4.0×10^{1}	1.1×10^{1}
Pt-193m	4.0×10^{1}	1.1×10^{2}	5.0×10^{-1}	1.4×10^{1}
Pt-195m	1.0×10^{1}	2.7×10^{2}	5.0×10^{-1}	1.4×10^{1}
Pt-197	2.0×10^{1}	5.4×10^{2}	6.0×10^{-1}	1.6×10^{1}
Pt-197m	1.0×10^{1}	2.7×10^{2}	6.0×10^{-1}	1.6×10^{1}
Plutonium (94)				
Pu-236	3.0×10^{1}	8.1×10^{2}	3.0×10^{-3}	8.1×10^{-2}
Pu-237	2.0×10^{1}	5.4×10^{2}	2.0×10^{1}	5.4×10^{-2}
Pu-238	1.0×10^{1}	2.7×10^{2}	1.0×10^{-3}	2.7×10^{-2}
Pu-239	1.0×10^{1}	2.7×10^{2}	1.0×10^{-3}	2.7×10^{-2}
Pu-240[a]	1.0×10^{1}	2.7×10^{3}	1.0×10^{-2}	2.7×10^{-2}
Pu-241[a]	4.0×10^{1}	1.1×10^{2}	6.0×10^{-3}	1.6
Pu-242[a]	1.0×10^{1}	2.7×10^{2}	1.0×10^{-3}	2.7×10^{-2}
Pu-244[a]	4.0×10^{-1}	1.1×10^{1}	1.0×10^{-3}	2.7×10^{-2}
Radium (88)				
Ra-223[a]	4.0×10^{-1}	1.1×10^{1}	7.0×10^{-3}	1.9×10^{-1}
Ra-224[a]	4.0×10^{-1}	1.1×10^{1}	2.0×10^{-3}	5.4×10^{-1}
Ra-225[a]	2.0×10^{-1}	5.4	4.0×10^{-3}	1.1×10^{-2}
Ra-226[a]	2.0×10^{-1}	5.4	3.0×10^{-2}	8.1×10^{-1}
Ra-228[a]	6.0×10^{-1}	1.6×10^{1}	2.0×10^{-2}	5.4×10^{-1}
Rubidium (37)				
Rb-81[a]	2.0	5.4×10^{1}	8.0×10^{-1}	2.2×10^{1}
Rb-83[a]	2.0	5.4×10^{1}	2.0	5.4×10^{1}
Rb-84	1.0	2.7×10^{1}	1.0	2.7×10^{1}
Rb-86	5.0×10^{-1}	1.4×10^{1}	5.0×10^{-1}	1.4×10^{1}
Rb-87	Unlimited	Unlimited	Unlimited	Unlimited
Rb (nat)	Unlimited	Unlimited	Unlimited	Unlimited
Rhenium (75)				
Re-184	1.0	2.7×10^{1}	1.0	2.7×10^{1}
Re-184m	3.0	8.1×10^{1}	1.0	2.7×10^{1}
Re-186	2.0	5.4×10^{1}	6.0×10^{-1}	1.6×10^{1}
Re-187	Unlimited	Unlimited	Unlimited	Unlimited
Re-188[a]	4.0×10^{1}	1.1×10^{1}	4.0×10^{-1}	1.1×10^{1}
Re-189[a]	3.0	8.1×10^{1}	6.0×10^{-1}	1.6×10^{1}
Re (nat)	Unlimited	Unlimited	Unlimited	Unlimited
Rhodium (45)				

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Rh-99	2.0	5.4×10^{2}	2.0	5.4×10^{1}
Rh-101	4.0	1.1×10^{2}	3.0	8.1×10^{1}
Rh-102	5.0×10^{-1}	1.4×10^{1}	5.0×10^{-1}	1.4×10^{1}
Rh-102m	2.0	5.4×10^{3}	2.0	5.4×10^{3}
Rh-103m	4.0×10^{1}	1.1×10^{2}	4.0×10^{1}	1.1×10^{1}
Rh-105	1.0×10^{1}	2.7×10^{2}	8.0×10^{-1}	2.2×10^{1}
Radon (86)				
Rn-222[a]	3.0×10^{-1}	8.1	4.0×10^{-3}	1.1×10^{-1}
Ruthenium (44)				
Ru-97	5.0	1.4×10^{2}	5.0	1.4×10^{2}
Ru-103[a]	2.0	5.4×10^{1}	2.0	5.4×10^{1}
Ru-105	1.0	2.7×10^{1}	6.0×10^{-1}	1.6×10^{1}
Ru-106[a]	2.0×10^{-1}	5.4	2.0×10^{-1}	5.4
Sulphur (16)				
S-35	4.0×10^{1}	1.1×10^{3}	3.0	8.1×10^{1}
Antimony (51)				
Sb-122	4.0×10^{-1}	1.1×10^{1}	4.0×10^{-1}	1.1×10^{1}
Sb-124	6.0×10^{-1}	1.6×10^{1}	6.0×10^{-1}	1.6×10^{1}
Sb-125	2.0	5.4×10^{1}	1.0	2.7×10^{1}
Sb-126	4.0×10^{-1}	1.1×10^{1}	4.0×10^{-1}	1.1×10^{1}
Scandium (21)				
Sc-44	5.0×10^{-1}	1.4×10^{1}	5.0×10^{-1}	1.4×10^{1}
Sc-46	5.0×10^{-1}	1.4×10^{2}	5.0×10^{-1}	1.4×10^{1}
Sc-47	1.0×10^{1}	2.7×10^{2}	7.0×10^{-1}	1.9×10^{1}
Sc-48	3.0×10^{-1}	8.1	3.0×10^{-1}	8.1
Selenium (34)				
Se-75	3.0	8.1×10^{3}	3.0	8.1×10^{1}
Se-79	4.0×10^{1}	1.1×10^{3}	2.0	5.4×10^{1}
Silicon (14)				
Si-31	6.0×10^{-1}	1.6×10^{3}	6.0×10^{-1}	1.6×10^{1}
Si-32	4.0×10^{1}	1.1×10^{3}	5.0×10^{-1}	1.4×10^{1}
Samarium (62)				
Sm-145	1.0×10^{1}	2.7×10^{2}	1.0×10^{1}	2.7×10^{2}
Sm-147	Unlimited	Unlimited	Unlimited	Unlimited
Sm-151	4.0×10^{1}	1.1×10^{3}	1.0×10^{1}	2.7×10^{2}
Sm-153	9.0	2.4×10^{2}	6.0×10^{-1}	1.6×10^{1}
Tin (50)				
Sn-113[a]	4.0	1.1×10^{2}	2.0	5.4×10^{1}
Sn-117m	7.0	1.9×10^{2}	4.0×10^{-1}	1.1×10^{2}
Sn-119m[a]	4.0×10^{1}	1.1×10^{3}	3.0×10^{-1}	8.1×10^{1}
Sn-121m[a]	4.0×10^{1}	1.1×10^{3}	9.0×10^{-1}	2.4×10^{1}
Sn-123	8.0×10^{-1}	2.2×10^{1}	6.0×10^{-1}	1.6×10^{1}
Sn-125[a]	4.0×10^{-1}	1.1×10^{1}	4.0×10^{-1}	1.1×10^{1}
Sn-126[a]	6.0×10^{-1}	1.6×10^{1}	4.0×10^{-1}	1.1×10^{1}

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Strontium (38)					
Sr-82[a]	2.0×10^{-1}	5.4	2.0×10^{-1}	5.4	
Sr-85	2.0	5.4×10^{1}	2.0	5.4×10^{1}	
Sr-85m	5.0	1.4×10^{2}	5.0	1.4×10^{2}	
Sr-87m	3.0	8.1×10^{1}	3.0	8.1×10^{1}	
Sr-89	6.0×10^{-1}	1.6×10^{1}	6.0×10^{-1}	1.6×10^{1}	
Sr-90[a]	3.0×10^{-1}	8.1	3.0×10^{-1}	8.1	
Sr-91[a]	3.0×10^{-1}	8.1	3.0×10^{-1}	8.1	
Sr-92[a]	1.0	2.7×10^{1}	3.0×10^{-1}	8.1	
Tritium (1)					
T (H-3)	4.0×10^{1}	1.1×10^{3}	4.0×10^{1}	1.1×10^{3}	
Tantalum (73)					
Ta-178 (long-lived)	1.0	2.7×10^{2}	8.0×10^{-1}	2.2×10^{2}	
Ta-179	3.0×10^{1}	8.1×10^{1}	3.0×10^{-1}	8.1×10^{1}	
Ta-182	9.0×10^{-1}	2.4×10^{1}	5.0×10^{-1}	1.4×10^{1}	
Terbium (65)					
Tb-157	4.0×10^{1}	1.1×10^{3}	4.0×10^{1}	1.1×10^{3}	
Tb-158	1.0	2.7×10^{1}	1.0	2.7×10^{1}	
Tb-160	1.0	2.7×10^{1}	6.0×10^{-1}	1.6×10^{1}	
Technetium (43)					
Tc-95m[a]	2.0	5.4×10^{1}	2.0	5.4×10^{1}	
Tc-96	4.0×10^{-1}	1.1×10^{1}	4.0×10^{-1}	1.1×10^{1}	
Tc-96m[a]	4.0×10^{-1}	1.1×10^{1}	4.0×10^{-1}	1.1×10^{1}	
Tc-97	Unlimited	Unlimited	Unlimited	Unlimited	
Tc-97m	4.0×10^{1}	1.1×10^{3}	1.0	2.7×10^{1}	
Tc-98	8.0×10^{-1}	2.2×10^{1}	7.0×10^{-1}	1.9×10^{1}	
Tc-99	4.0×10^{1}	1.1×10^{3}	9.0×10^{-1}	2.4×10^{1}	
Tc-99m	1.0×10^{1}	2.7×10^{2}	4.0	1.1×10^{2}	
Tellurium (52)					
Te-121	2.0	5.4×10^{2}	2.0	5.4×10^{1}	
Te-121m	5.0	1.4×10^{2}	3.0	8.1×10^{1}	
Te-123m	8.0	2.2×10^{2}	1.0	2.7×10^{1}	
Te-125m	2.0×10^{1}	5.4×10^{2}	9.0×10^{-1}	2.4×10^{1}	
Te-127	2.0×10^{1}	5.4×10^{2}	7.0×10^{-1}	1.9×10^{1}	
Te-127m[a]	2.0×10^{1}	5.4×10^{2}	5.0×10^{-1}	1.4×10^{1}	
Te-129	7.0×10^{-1}	1.9×10^{1}	6.0×10^{-1}	1.6×10^{1}	
Te-129m[a]	8.0×10^{-1}	2.2×10^{1}	4.0×10^{-1}	1.1×10^{1}	
Te-131m[a]	7.0×10^{-1}	1.9×10^{1}	5.0×10^{-1}	1.4×10^{1}	
Te-132[a]	5.0×10^{-1}	1.4×10^{1}	4.0×10^{-1}	1.1×10^{1}	
Thorium (90)					
Th-227	1.0×10^{1}	2.7×10^{2}	5.0×10^{-3}	1.4×10^{-1}	
Th-228[a]	5.0×10^{-1}	1.4×10^{2}	1.0×10^{-3}	2.7×10^{-2}	
Th-229	5.0	1.4×10^{2}	5.0×10^{-4}	1.4×10^{-2}	
Th-230	1.0×10^{1}	2.7×10^{3}	5.0×10^{-3}	1.4×10^{-2}	
Th-231	4.0×10^{1}	1.1×10^{3}	1.0×10^{-2}	2.7×10^{-1}	
Th-232	Unlimited	Unlimited	2.0×10^{-2}	5.4×10^{-1}	
			Unlimited	Unlimited	

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Th-234[a]	3.0×10^{-1}	8.1	3.0×10^{-1}	8.1
Th (nat)	Unlimited	Unlimited	Unlimited	Unlimited
Titanium (22)				
Ti-44[a]	5.0×10^{-1}	1.4×10^{1}	4.0×10^{-1}	1.1×10^{1}
Thallium (81)				
Tl-200	9.0×10^{-1}	2.4×10^{1}	9.0×10^{-1}	2.4×10^{1}
Tl-201	1.0×10^{1}	2.7×10^{2}	4.0	1.1×10^{2}
Tl-202	2.0	5.4×10^{1}	2.0	5.4×10^{1}
Tl-204	1.0×10^{1}	2.7×10^{2}	7.0×10^{-1}	1.9×10^{1}
Thulium (69)				
Tm-167	7.0	1.9×10^{2}	8.0×10^{-1}	2.2×10^{1}
Tm-170	3.0	8.1×10^{1}	6.0×10^{-1}	1.6×10^{1}
Tm-171	4.0×10^{1}	1.1×10^{3}	4.0×10^{1}	1.1×10^{3}
Uranium (92)				
U-230 (fast lung absorption)[a,d]	4.0×10^{1}	1.1×10^{3}	1.0×10^{-1}	2.7
U-230 (medium lung absorption)[a,e]	4.0×10^{1}	1.1×10^{3}	4.0×10^{-3}	1.1×10^{-1}
U-230 (slow lung absorption)[a,f]	3.0×10^{1}	8.1×10^{2}	3.0×10^{-3}	8.1×10^{-2}
U-232 (fast lung absorption)[d]	4.0×10^{1}	1.1×10^{3}	1.0×10^{-2}	2.7×10^{-1}
U-232 (medium lung absorption)[e]	4.0×10^{1}	1.1×10^{3}	7.0×10^{-3}	1.9×10^{-1}
U-232 (slow lung absorption)[f]	1.0×10^{1}	2.7×10^{2}	1.0×10^{-3}	2.7×10^{-2}
U-233 (fast lung absorption)[d]	4.0×10^{1}	1.1×10^{3}	9.0×10^{-2}	2.4
U-233 (medium lung absorption)[e]	4.0×10^{1}	1.1×10^{3}	2.0×10^{-2}	5.4×10^{-1}
U-233 (slow lung absorption)[f]	4.0×10^{1}	1.1×10^{3}	6.0×10^{-3}	1.6×10^{-1}
U-234 (fast lung absorption)[d]	4.0×10^{1}	1.1×10^{3}	9.0×10^{-2}	2.4
U-234 (medium lung				

	absorption)[e]	4.0×10^{1}	1.1×10^{3}	2.0×10^{-2}	5.4×10^{-1}
	U-234				
	(slow lung absorption)[f]	4.0×10^{1}	1.1×10^{3}	6.0×10^{-3}	1.6×10^{-1}
	U-235				
	(all lung absorption types)[a,d,e,f]	Unlimited	Unlimited	Unlimited	Unlimited
	U-236				
	(fast lung absorption)[d]	Unlimited	Unlimited	Unlimited	Unlimited
	U-236				
	(medium lung absorption)[e]	4.0×10^{1}	1.1×10^{3}	2.0×10^{-2}	5.4×10^{-1}
	U-236				
	(slow lung absorption)[f]	4.0×10^{1}	1.1×10^{3}	6.0×10^{-3}	1.6×10^{-1}
	U-238				
	(all lung absorption types)[d,e,f]	Unlimited	Unlimited	Unlimited	Unlimited
	U (nat)	Unlimited	Unlimited	Unlimited	Unlimited
	U (enriched to 20% or less)[g]	Unlimited	Unlimited	Unlimited	Unlimited
	U (dep)	Unlimited	Unlimited	Unlimited	Unlimited
	Vanadium (23)				
	V-48	4.0×10^{-1}	1.1×10^{1}	4.0×10^{-1}	1.1×10^{1}
	V-49	4.0×10^{1}	1.1×10^{3}	4.0×10^{1}	1.1×10^{3}
	Tungsten (74)				
	W-178[a]	9.0	2.4×10^{2}	5.0	1.4×10^{2}
	W-181	3.0×10^{1}	8.1×10^{2}	3.0×10^{1}	8.1×10^{2}
	W-185	4.0×10^{1}	1.1×10^{3}	8.0×10^{-1}	2.2×10^{1}
	W-187	2.0	5.4×10^{1}	6.0×10^{-1}	1.6×10^{1}
	W-188[a]	4.0×10^{-1}	1.1×10^{1}	3.0×10^{-1}	8.1
	Xenon (54)				
	Xe-122[a]	4.0×10^{-1}	1.1×10^{1}	4.0×10^{-1}	1.1×10^{1}
	Xe-123	2.0	5.4×10^{1}	7.0×10^{-1}	1.9×10^{1}
	Xe-127	4.0	1.1×10^{2}	2.0	5.4×10^{1}
	Xe-131m	4.0×10^{1}	1.1×10^{3}	4.0×10^{1}	1.1×10^{2}
	Xe-133	2.0×10^{1}	5.4×10^{1}	1.0×10^{1}	2.7×10^{1}
	Xe-135	3.0	8.1×10^{1}	2.0	5.4×10^{1}
	Yttrium (39)				
	Y-87[a]	1.0	2.7×10^{1}	1.0	2.7×10^{1}
	Y-88	4.0×10^{-1}	1.1×10^{1}	4.0×10^{-1}	1.1×10^{1}
	Y-90	3.0×10^{-1}	8.1	3.0×10^{-1}	8.1
	Y-91	6.0×10^{-1}	1.6×10^{1}	6.0×10^{-1}	1.6×10^{1}
	Y-91m	2.0	5.4×10^{1}	2.0	5.4×10^{1}

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Y-92	2.0×10^{-1}	5.4	2.0×10^{-1}	5.4
Y-93	3.0×10^{-1}	8.1	3.0×10^{-1}	8.1
Ytterbium (70)				
Yb-169	4.0	1.1×10^{2}	1.0	2.7×10^{1}
Yb-175	3.0×10^{1}	8.1×10^{2}	9.0×10^{-1}	2.4×10^{1}
Zinc (30)				
Zn-65	2.0	5.4×10^{1}	2.0	5.4×10^{1}
Zn-69	3.0	8.1×10^{1}	6.0×10^{-1}	1.6×10^{1}
Zn-69m[a]	3.0	8.1×10^{1}	6.0×10^{-1}	1.6×10^{1}
Zirconium (40)				
Zr-88	3.0	8.1×10^{1}	3.0	8.1×10^{1}
Zr-93[a]	Unlimited	Unlimited	Unlimited	Unlimited
Zr-95[a]	2.0	5.4×10^{1}	8.0×10^{-1}	2.2×10^{1}
Zr-97[a]	4.0×10^{-1}	1.1×10^{1}	4.0×10^{-1}	1.1×10^{1}

[a] A_1 and A_2 values include contributions from daughter nuclides with half-lives less than ten days.

[b] The values of A_1 and A_2 in curies (Ci) are approximate and for information only; the regulatory standard units are Terabecquerels (TBq). See Appendix A to Code of Federal Regulations, title 10, Part 71 - Determination of A_1 and A_2, Section I.

[c] The quantity may be determined from a measurement of the rate of decay or a measurement of the radiation level at a prescribed distance from the source.

[d] These values apply only to compounds of uranium that take the chemical form of UF_6, UO_2F_2, and $UO_2(NO_3)_2$ in both normal and accident conditions of transport.

[e] These values apply only to compounds of uranium that take the chemical form of UO_3, UF_4, and UCl_4 and hexavalent compounds in both normal and accident conditions of transport.

[f] These values apply to all compounds of uranium other than those specified in notes d and e.

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[g] These values apply to unirradiated uranium only.

[h] A_1 = 0.1 TBq (2.7 Ci) and A_2 = 0.001 TBq (0.027 Ci) for Cf-252 for domestic use.

[i] A_2 = 0.74 TBq (20 Ci) for Mo-99 for domestic use.

Subp. 2. **Specific activity.** This subpart specifies specific activity for individual radionuclides.

Element and Atomic Number and Symbol of Radionuclide	Specific Activity (Tbq/g)	(Ci/g)
Actinium (89)		
Ac-225	2.1×10^{3}	5.8×10^{4}
Ac-227	2.7	7.2×10^{1}
Ac-228	8.4×10^{4}	2.2×10^{6}
Silver (47)		
Ag-105	1.1×10^{3}	3.0×10^{4}
Ag-108m	9.7×10^{-1}	2.6×10^{1}
Ag-110m	1.8×10^{2}	4.7×10^{3}
Ag-111	5.8×10^{3}	1.6×10^{5}
Aluminum (13)		
Al-26	7.0×10^{-4}	1.9×10^{-2}
Americium (95)		
Am-241	1.3×10^{-1}	3.4
Am-242m	3.6×10^{-1}	1.0×10^{1}
Am-243	7.4×10^{-3}	2.0×10^{-1}
Argon (18)		
Ar-37	3.7×10^{3}	9.9×10^{4}
Ar-39	1.3	3.4×10^{1}
Ar-41	1.5×10^{6}	4.2×10^{7}
Ar-42	9.6	2.6×10^{2}
Arsenic (33)		
As-72	6.2×10^{4}	1.7×10^{6}
As-73	8.2×10^{2}	2.2×10^{4}
As-74	3.7×10^{3}	9.9×10^{4}
As-76	5.8×10^{4}	1.6×10^{6}
As-77	3.9×10^{4}	1.0×10^{6}
Astatine (85)		
At-211	7.6×10^{4}	2.1×10^{6}
Gold (79)		

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1	Au-193	3.4×10^{4}	9.2×10^{5}
2	Au-194	1.5×10^{2}	4.1×10^{3}
3	Au-195	1.4×10^{3}	3.7×10^{5}
4	Au-196	4.0×10^{3}	1.1×10^{5}
5	Au-198	9.0×10^{3}	2.4×10^{5}
6	Au-199	7.7×10^{3}	2.1×10^{5}
7			
8	Barium (56)		
9	Ba-131	3.1×10^{3}	8.4×10^{4}
10	Ba-133m	2.2×10^{4}	6.1×10^{5}
11	Ba-133	9.4×10^{2}	2.6×10^{4}
12	Ba-140	2.7×10^{3}	7.3×10^{4}
13			
14	Beryllium (4)		
15	Be-7	1.3×10^{4}	3.5×10^{5}
16	Be-10	8.3×10^{-4}	2.2×10^{-2}
17			
18	Bismuth (83)		
19	Bi-205	1.5×10^{-3}	4.2×10^{4}
20	Bi-206	3.8×10^{3}	1.0×10^{5}
21	Bi-207	1.9×10^{1}	5.2×10^{1}
22	Bi-210m	2.1×10^{-5}	5.7×10^{-4}
23	Bi-210	4.6×10^{3}	1.2×10^{5}
24	Bi-212	5.4×10^{5}	1.5×10^{7}
25			
26	Berkelium (97)		
27	Bk-247	3.8×10^{-2}	1.0
28	Bk-249	6.1×10^{1}	1.6×10^{3}
29			
30	Bromine (35)		
31	Br-76	9.4×10^{4}	2.5×10^{6}
32	Br-77	2.6×10^{4}	7.1×10^{5}
33	Br-82	4.0×10^{4}	1.1×10^{6}
34			
35	Carbon (6)		
36	C-11	3.1×10^{7}	8.4×10^{8}
37	C-14	1.6×10^{-1}	4.5
38			
39	Calcium (20)		
40	Ca-41	3.1×10^{-3}	8.5×10^{-2}
41	Ca-45	6.6×10^{2}	1.8×10^{4}
42	Ca-47	2.3×10^{4}	6.1×10^{5}
43			
44	Cadmium (48)		
45	Cd-109	9.6×10^{1}	2.6×10^{3}
46	Cd-113m	8.3×10^{2}	2.2×10^{4}
47	Cd-115m	9.4×10^{4}	2.5×10^{5}
48	Cd-115	1.9×10^{4}	5.1×10^{5}
49			
50	Cerium (58)		
51	Ce-139	2.5×10^{2}	6.8×10^{3}
52	Ce-141	1.1×10^{4}	2.8×10^{5}
53	Ce-143	2.5×10^{4}	6.6×10^{5}
54	Ce-144	1.2×10^{2}	3.2×10^{3}

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	Californium (98)		
	Cf-248	5.8×10^{1}	1.6×10^{3}
	Cf-249	1.5×10^{-1}	4.1
	Cf-250	4.0	1.1×10^{2}
	Cf-251	5.9×10^{-2}	1.6
	Cf-252	2.0×10^{1}	5.4×10^{2}
	Cf-253	1.1×10^{3}	2.9×10^{4}
	Cf-254	3.1×10^{2}	8.5×10^{3}
	Chlorine (17)		
	Cl-36	1.2×10^{-3}	3.3×10^{-2}
	Cl-38	4.9×10^{6}	1.3×10^{8}
	Curium (96)		
	Cm-240	7.5×10^{2}	2.0×10^{4}
	Cm-241	6.1×10^{2}	1.7×10^{4}
	Cm-242	1.2×10^{2}	3.3×10^{3}
	Cm-243	1.9×10^{-3}	5.2×10^{1}
	Cm-244	3.0	8.1×10^{1}
	Cm-245	6.4×10^{-3}	1.7×10^{-1}
	Cm-246	1.1×10^{-2}	3.1×10^{-1}
	Cm-247	3.4×10^{-6}	9.3×10^{-5}
	Cm-248	1.6×10^{-5}	4.2×10^{-3}
	Cobalt (27)		
	Co-55	1.1×10^{5}	3.1×10^{6}
	Co-56	1.1×10^{3}	3.0×10^{4}
	Co-57	3.1×10^{2}	8.4×10^{3}
	Co-58m	2.2×10^{5}	5.9×10^{6}
	Co-58	1.2×10^{3}	3.2×10^{4}
	Co-60	4.2×10^{1}	1.1×10^{3}
	Chromium (24)		
	Cr-51	3.4×10^{3}	9.2×10^{4}
	Cesium (55)		
	Cs-129	2.8×10^{4}	7.6×10^{5}
	Cs-131	3.8×10^{3}	1.0×10^{5}
	Cs-132	5.7×10^{5}	1.5×10^{6}
	Cs-134m	3.0×10^{1}	8.0×10^{3}
	Cs-134	4.8×10^{-5}	1.3×10^{-3}
	Cs-135	4.3×10^{3}	1.2×10^{4}
	Cs-136	2.7×10^{3}	7.3×10^{4}
	Cs-137	3.2	8.7×10^{1}
	Copper (29)		
	Cu-64	1.4×10^{5}	3.9×10^{6}
	Cu-67	2.8×10^{4}	7.6×10^{5}
	Dysprosium (66)		
	Dy-159	2.1×10^{2}	5.7×10^{3}
	Dy-165	3.0×10^{3}	8.2×10^{5}
	Dy-166	8.6×10^{3}	2.3×10^{5}

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Erbium (68)		
Er-169	3.1×10^{3}	8.3×10^{4}
Er-171	9.0×10^{4}	2.4×10^{6}
Einsteinium (99)		
Es-253	---	---
Es-254	---	---
Es-254m	---	---
Es-255	---	---
Europium (63)		
Eu-147	1.4×10^{3}	3.7×10^{4}
Eu-148	6.0×10^{2}	1.6×10^{3}
Eu-149	3.5×10^{2}	9.4×10^{3}
Eu-150	6.1×10^{4}	1.6×10^{6}
Eu-152m	8.2×10^{4}	2.2×10^{6}
Eu-152	6.5	1.8×10^{2}
Eu-154	9.8	2.6×10^{2}
Eu-155	1.8×10^{1}	4.9×10^{2}
Eu-156	2.0×10^{3}	5.5×10^{4}
Fluorine (9)		
F-18	3.5×10^{6}	9.5×10^{7}
Iron (26)		
Fe-52	2.7×10^{5}	7.3×10^{6}
Fe-55	8.8×10^{1}	2.4×10^{3}
Fe-59	1.8×10^{3}	5.0×10^{4}
Fe-60	7.4×10^{-4}	2.0×10^{-2}
Fermium (100)		
Fm-255	---	---
Fm-257	---	---
Gallium (31)		
Ga-67	2.2×10^{4}	6.0×10^{5}
Ga-68	1.5×10^{6}	4.1×10^{7}
Ga-72	1.1×10^{5}	3.1×10^{6}
Gadolinium (64)		
Gd-146	6.9×10^{2}	1.9×10^{4}
Gd-148	1.2	3.2×10^{1}
Gd-153	1.3×10^{2}	3.5×10^{3}
Gd-159	3.9×10^{4}	1.1×10^{6}
Germanium (32)		
Ge-68	2.6×10^{2}	7.1×10^{3}
Ge-71	5.8×10^{5}	1.6×10^{7}
Ge-77	1.3×10^{5}	3.6×10^{6}
Hydrogen (1)		
H-3 (T)	3.6×10^{2}	9.7×10^{3}

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	Hafnium (72)		
	Hf-172	4.1×10^{1}	1.1×10^{3}
	Hf-175	3.9×10^{2}	1.1×10^{4}
	Hf-181	6.3×10^{2}	1.7×10^{4}
	Hf-182	8.1×10^{-6}	2.2×10^{-4}
	Mercury (80)		
	Hg-194	1.3×10^{-1}	3.5
	Hg-195m	1.5×10^{4}	4.0×10^{5}
	Hg-197m	2.5×10^{3}	6.7×10^{5}
	Hg-197	9.2×10^{2}	2.5×10^{4}
	Hg-203	5.1×10^{2}	1.4×10^{4}
	Holmium (67)		
	Ho-163	2.7	7.6×10^{1}
	Ho-166m	6.6×10^{-2}	1.8
	Ho-166	2.6×10^{4}	7.0×10^{5}
	Iodine (53)		
	I-123	7.1×10^{4}	1.9×10^{6}
	I-124	9.3×10^{3}	2.5×10^{5}
	I-125	6.4×10^{2}	1.7×10^{4}
	I-126	2.9×10^{3}	8.0×10^{4}
	I-129	6.5×10^{-6}	1.8×10^{-4}
	I-131	4.6×10^{3}	1.2×10^{5}
	I-132	3.8×10^{5}	1.0×10^{7}
	I-133	4.2×10^{4}	1.1×10^{6}
	I-134	9.9×10^{5}	2.7×10^{7}
	I-135	1.3×10^{5}	3.5×10^{6}
	Indium (49)		
	In-111	1.5×10^{4}	4.2×10^{5}
	~~In-113m~~	~~6.2×10^{5}~~	~~1.7×10^{7}~~
	In-113m	6.2×10^{5}	1.7×10^{7}
	~~In-114m~~	~~8.6×10^{2}~~	~~2.3×10^{4}~~
	In-114m	8.6×10^{2}	2.3×10^{4}
	In-115m	2.2×10^{5}	6.1×10^{6}
	Iridium (77)		
	Ir-189	1.9×10^{3}	5.2×10^{4}
	Ir-190	2.3×10^{3}	6.2×10^{4}
	Ir-192	3.4×10^{2}	9.2×10^{3}
	Ir-193m	2.4×10^{3}	6.4×10^{4}
	Ir-194	3.1×10^{4}	8.4×10^{5}
	Potassium (19)		
	K-40	2.4×10^{-7}	6.4×10^{-6}
	K-42	2.2×10^{5}	6.0×10^{6}
	K-43	1.2×10^{5}	3.3×10^{6}

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	Krypton (36)		
	Kr-81	7.8×10^{-4}	2.1×10^{-2}
	Kr-85m	3.0×10^{5}	8.2×10^{6}
	Kr-85	1.5×10^{1}	3.9×10^{2}
	Kr-87	1.0×10^{6}	2.8×10^{7}
	Lanthanum (57)		
	La-137	1.6×10^{-3}	4.4×10^{-2}
	La-140	2.1×10^{4}	5.6×10^{5}
	Lutetium (71)		
	Lu-172	4.2×10^{3}	1.1×10^{5}
	Lu-173	5.6×10^{1}	1.5×10^{3}
	Lu-174m	2.0×10^{2}	5.3×10^{3}
	Lu-174	2.3×10^{1}	6.2×10^{2}
	Lu-177	4.1×10^{3}	1.1×10^{5}
	Magnesium (12)		
	Mg-28	2.0×10^{5}	5.4×10^{6}
	Manganese (25)		
	Mn-52	1.6×10^{4}	4.4×10^{5}
	Mn-53	6.8×10^{-5}	1.8×10^{-3}
	Mn-54	2.9×10^{2}	7.7×10^{3}
	Mn-56	8.0×10^{5}	2.2×10^{7}
	Molybdenum (42)		
	Mo-93	4.1×10^{-2}	1.1
	Mo-99	1.8×10^{4}	4.8×10^{5}
	Nitrogen (7)		
	N-13	5.4×10^{7}	1.5×10^{9}
	Sodium (11)		
	Na-22	2.3×10^{2}	6.3×10^{3}
	Na-24	3.2×10^{5}	8.7×10^{6}
	Niobium (41)		
	Nb-92m	5.2×10^{3}	1.4×10^{5}
	Nb-93m	8.8	2.4×10^{2}
	Nb-94	6.9×10^{-3}	1.9×10^{-1}
	Nb-95	1.5×10^{3}	3.9×10^{4}
	Nb-97	9.9×10^{5}	2.7×10^{7}
	Neodymium (60)		
	Nd-147	3.0×10^{3}	8.1×10^{4}
	Nd-149	4.5×10^{5}	1.2×10^{7}
	Nickel (28)		
	Ni-59	3.0×10^{-3}	8.0×10^{-2}
	Ni-63	2.1	5.7×10^{1}
	Ni-65	7.1×10^{5}	1.9×10^{7}
	Neptunium (93)		

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1	Np-235	$5.2 \times 10^{1}_{-4}$	$1.4 \times 10^{3}_{-2}$
2	Np-236	4.7×10^{-5}	1.3×10^{-4}
3	Np-237	2.6×10^{3}	7.1×10^{5}
4	Np-239	8.6×10^{3}	2.3×10^{5}
5			
6	Osmium (76)		
7	Os-185	$2.8 \times 10^{2}_{4}$	$7.5 \times 10^{3}_{6}$
8	Os-191m	4.6×10^{3}	1.3×10^{4}
9	Os-191	1.6×10^{4}	4.4×10^{5}
10	Os-193	2.0×10^{1}	5.3×10^{2}
11	Os-194	1.1×10^{1}	3.1×10^{2}
12			
13	Phosphorus (15)		
14	P-32	$1.1 \times 10^{4}_{3}$	$2.9 \times 10^{5}_{5}$
15	P-33	5.8×10^{3}	1.6×10^{5}
16			
17	Protactinium (91)		
18	Pa-230	$1.2 \times 10^{3}_{-3}$	$3.3 \times 10^{4}_{-2}$
19	Pa-231	1.7×10^{2}	4.7×10^{4}
20	Pa-233	7.7×10^{2}	2.1×10^{4}
21			
22	Lead (82)		
23	Pb-201	$6.2 \times 10^{4}_{-4}$	$1.7 \times 10^{6}_{-3}$
24	Pb-202	1.2×10^{4}	3.4×10^{5}
25	Pb-203	1.1×10^{4}	3.0×10^{-4}
26	Pb-205	4.5×10^{-6}	1.2×10^{1}
27	Pb-210	2.8	$7.6 \times 10^{1}_{6}$
28	Pb-212	5.1×10^{4}	1.4×10^{6}
29			
30	Palladium (46)		
31	Pd-103	$2.8 \times 10^{3}_{-5}$	$7.5 \times 10^{4}_{-4}$
32	Pd-107	1.9×10^{4}	5.1×10^{6}
33	Pd-109	7.9×10^{4}	2.1×10^{6}
34			
35	Promethium (61)		
36	Pm-143	$1.3 \times 10^{2}_{1}$	$3.4 \times 10^{3}_{3}$
37	Pm-144	9.2×10^{1}	2.5×10^{2}
38	Pm-145	5.2	1.4×10^{2}
39	Pm-147	$3.4 \times 10^{1}_{2}$	$9.3 \times 10^{2}_{4}$
40	Pm-148m	7.9×10^{4}	2.1×10^{5}
41	Pm-149	1.5×10^{4}	4.0×10^{5}
42	Pm-151	2.7×10^{4}	7.3×10^{5}
43			
44	Polonium (84)		
45	Po-208	$2.2 \times 10^{1}_{-1}$	$5.9 \times 10^{2}_{1}$
46	Po-209	6.2×10^{2}	1.7×10^{3}
47	Po-210	1.7×10^{2}	4.5×10^{3}
48			
49	Praseodymium (59)		
50	Pr-142	$4.3 \times 10^{4}_{3}$	$1.2 \times 10^{6}_{4}$
51	Pr-143	2.5×10^{3}	6.7×10^{4}
52			
53	Platinum (78)		
54	Pt-188	2.5×10^{3}	6.8×10^{4}

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1	Pt-191	8.7×10^{3}	2.4×10^{5}
2	Pt-193m	5.8×10^{3}	1.6×10^{5}
3	Pt-193	1.4×10^{3}	3.7×10^{5}
4	Pt-195m	6.2×10^{5}	1.7×10^{7}
5	Pt-197m	3.7×10^{4}	1.0×10^{5}
6	Pt-197	3.2×10^{4}	8.7×10^{5}
7			
8	Plutonium (94)		
9	Pu-236	2.0×10^{1}	5.3×10^{2}
10	Pu-237	4.5×10^{2}	1.2×10^{4}
11	Pu-238	6.3×10^{-1}	1.7×10^{1}
12	Pu-239	2.3×10^{-3}	6.2×10^{-2}
13	Pu-240	8.4×10^{-3}	2.3×10^{-1}
14	Pu-241	3.8×10^{2}	1.0×10^{2}
15	Pu-242	1.5×10^{-4}	3.9×10^{-3}
16	Pu-244	6.7×10^{-7}	1.8×10^{-5}
17			
18	Radium (88)		
19	Ra-223	1.9×10^{3}	5.1×10^{4}
20	Ra-224	5.9×10^{3}	1.6×10^{5}
21	Ra-225	1.5×10^{3}	3.9×10^{4}
22	Ra-226	3.7×10^{-2}	1.0
23	Ra-228	1.0×10^{1}	2.7×10^{2}
24			
25	Rubidium (37)		
26	Rb-81	3.1×10^{5}	8.4×10^{6}
27	Rb-83	6.8×10^{2}	1.8×10^{4}
28	Rb-84	1.8×10^{3}	4.7×10^{4}
29	Rb-86	3.0×10^{3}	8.1×10^{4}
30	Rb-87	3.2×10^{-9}	8.6×10^{-8}
31	Rb (natural)	6.7×10^{6}	1.8×10^{8}
32			
33	Rhenium (75)		
34	Re-183	3.8×10^{2}	1.0×10^{4}
35	Re-184m	1.6×10^{2}	4.3×10^{3}
36	Re-184	6.9×10^{2}	1.9×10^{4}
37	Re-186	6.9×10^{3}	1.9×10^{5}
38	Re-187	1.4×10^{-9}	3.8×10^{-8}
39	Re-188	3.6×10^{4}	9.8×10^{5}
40	Re-189	2.5×10^{4}	6.8×10^{5}
41	Re (natural)	---	2.4×10^{-8}
42			
43	Rhodium (45)		
44	Rh-99	3.0×10^{3}	8.2×10^{4}
45	Rh-101	4.1×10^{1}	1.1×10^{3}
46	Rh-102m	2.3×10^{2}	6.2×10^{3}
47	Rh-102	4.5×10^{1}	1.2×10^{3}
48	Rh-103m	1.2×10^{6}	3.3×10^{7}
49	Rh-105	3.1×10^{4}	8.4×10^{5}
50			
51	Radon (86)		
52	Rn-222	5.7×10^{3}	1.5×10^{5}
53			
54	Ruthenium (44)		

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1	Ru-97	$1.7 \times 10^{4}_{3}$	$4.6 \times 10^{5}_{4}$
2	Ru-103	$1.2 \times 10^{5}_{5}$	$3.2 \times 10^{6}_{6}$
3	Ru-105	$2.5 \times 10^{2}_{2}$	$6.7 \times 10^{3}_{3}$
4	Ru-106	1.2×10^{2}	3.3×10^{3}
5			
6	Sulfur (16)		
7	S-35	1.6×10^{3}	4.3×10^{4}
8			
9	Antimony (51)		
10	Sb-122	$1.5 \times 10^{4}_{2}$	$4.0 \times 10^{5}_{4}$
11	Sb-124	$6.5 \times 10^{2}_{1}$	$1.7 \times 10^{3}_{3}$
12	Sb-125	$3.9 \times 10^{1}_{3}$	$1.0 \times 10^{3}_{4}$
13	Sb-126	3.1×10^{3}	8.4×10^{4}
14			
15	Scandium (21)		
16	Sc-44	$6.7 \times 10^{5}_{3}$	$1.8 \times 10^{7}_{4}$
17	Sc-46	$1.3 \times 10^{4}_{4}$	$3.4 \times 10^{5}_{5}$
18	Sc-47	$3.1 \times 10^{4}_{4}$	$8.3 \times 10^{5}_{6}$
19	Sc-48	5.5×10^{4}	1.5×10^{6}
20			
21	Selenium (34)		
22	Se-75	$5.4 \times 10^{2}_{-3}$	$1.5 \times 10^{4}_{-2}$
23	Se-79	2.6×10^{-3}	7.0×10^{-2}
24			
25	Silicon (14)		
26	Si-31	1.4×10^{6}	$3.9 \times 10^{7}_{2}$
27	Si-32	3.9	1.1×10^{2}
28			
29	Samarium (62)		
30	Sm-145	$9.8 \times 10^{1}_{-1}$	$2.6 \times 10^{3}_{-8}$
31	Sm-147	8.5×10^{-1}	$2.3 \times 10^{1}_{1}$
32	Sm-151	9.7×10^{4}	$2.6 \times 10^{5}_{1}$
33	Sm-153	1.6×10^{4}	4.4×10^{5}
34			
35	Tin (50)		
36	Sn-113	$3.7 \times 10^{2}_{3}$	$1.0 \times 10^{4}_{4}$
37	Sn-117m	$3.0 \times 10^{2}_{2}$	$8.2 \times 10^{3}_{3}$
38	Sn-119m	1.4×10^{2}	$3.7 \times 10^{3}_{1}$
39	Sn-121m	2.0	$5.4 \times 10^{1}_{3}$
40	Sn-123	$3.0 \times 10^{2}_{3}$	$8.2 \times 10^{3}_{5}$
41	Sn-125	$4.0 \times 10^{3}_{-3}$	$1.1 \times 10^{5}_{-2}$
42	Sn-126	1.0×10^{-3}	2.8×10^{-2}
43			
44	Strontium (38)		
45	Sr-82	$2.3 \times 10^{3}_{6}$	$6.2 \times 10^{4}_{7}$
46	Sr-85m	$1.2 \times 10^{2}_{2}$	$3.3 \times 10^{4}_{4}$
47	Sr-85	$8.8 \times 10^{2}_{5}$	$2.4 \times 10^{4}_{7}$
48	Sr-87m	$4.8 \times 10^{3}_{3}$	$1.3 \times 10^{4}_{4}$
49	Sr-89	1.1×10^{3}	$2.9 \times 10^{2}_{2}$
50	Sr-90	5.1	$1.4 \times 10^{2}_{6}$
51	Sr-91	$1.3 \times 10^{5}_{5}$	$3.6 \times 10^{6}_{7}$
52	Sr-92	4.7×10^{5}	1.3×10^{7}
53			
54	Tritium (1)		

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1	T (H-3)	3.6×10^{2}	9.7×10^{3}
2			
3	Tantalum (73)		
4	Ta-178	4.2×10^{6}	1.1×10^{8}
5	Ta-179	4.1×10^{1}	1.1×10^{3}
6	Ta-182	2.3×10^{2}	6.2×10^{3}
7			
8	Terbium (65)		
9	Tb-157	5.6×10^{-1}	1.5×10^{1}
10	Tb-158	5.6×10^{-1}	1.5×10^{1}
11	Tb-160	4.2×10^{2}	1.1×10^{4}
12			
13	Technetium (43)		
14	Tc-95m	8.3×10^{2}	2.2×10^{4}
15	Tc-96m	1.4×10^{6}	3.8×10^{7}
16	Tc-96	1.2×10^{4}	3.2×10^{5}
17	Tc-97m	5.6×10^{2}	1.5×10^{4}
18	Tc-97	5.2×10^{-5}	1.4×10^{-3}
19	Tc-98	3.2×10^{-5}	8.7×10^{-4}
20	Tc-99m	1.9×10^{5}	5.3×10^{6}
21	Tc-99	6.3×10^{-4}	1.7×10^{-2}
22			
23	Tellurium (52)		
24	Te-118	6.8×10^{3}	1.8×10^{5}
25	Te-121m	2.6×10^{2}	7.0×10^{3}
26	Te-121	2.4×10^{3}	6.4×10^{4}
27	Te-123m	3.3×10^{2}	8.9×10^{3}
28	Te-125m	6.7×10^{2}	1.8×10^{4}
29	Te-127m	3.5×10^{2}	9.4×10^{3}
30	Te-127	9.8×10^{4}	2.6×10^{6}
31	Te-129m	1.1×10^{3}	3.0×10^{4}
32	Te-129	7.7×10^{5}	2.1×10^{7}
33	Te-131m	3.0×10^{4}	8.0×10^{5}
34	Te-132	1.1×10^{4}	8.0×10^{5}
35			
36	Thorium (90)		
37	Th-227	1.1×10^{3}	3.1×10^{4}
38	Th-228	3.0×10^{1}	8.2×10^{2}
39	Th-229	7.9×10^{-3}	2.1×10^{-1}
40	Th-230	7.6×10^{-4}	2.1×10^{-2}
41	Th-231	2.0×10^{4}	5.3×10^{5}
42	Th-232	4.0×10^{-9}	1.1×10^{-7}
43	Th-234	8.6×10^{2}	2.3×10^{4}
44	Th (natural)	8.1×10^{-9}	2.2×10^{-7}
45			
46	Titanium (22)		
47	Ti-44	6.4	1.7×10^{2}
48			
49	Thallium (81)		
50	Tl-200	2.2×10^{4}	6.0×10^{5}
51	Tl-201	7.9×10^{3}	2.1×10^{5}
52	Tl-202	2.0×10^{3}	5.3×10^{4}
53	Tl-204	1.7×10^{1}	4.6×10^{2}
54			

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1	Thulium (69)		
2	Tm-167	3.1×10^{3}	8.5×10^{4}
3	Tm-168	3.1×10^{2}	8.3×10^{3}
4	Tm-170	2.2×10^{2}	6.0×10^{3}
5	Tm-171	4.0×10^{1}	1.1×10^{3}
6			
7	Uranium (92)		
8	U-230	1.0×10^{3}	2.7×10^{4}
9	U-232	8.3×10^{-1}	2.2×10^{1}
10	U-233	3.6×10^{-4}	9.7×10^{-3}
11	U-234	2.3×10^{-8}	6.2×10^{-6}
12	U-235	8.0×10^{-6}	2.2×10^{-5}
13	U-236	2.4×10^{-8}	6.5×10^{-7}
14	U-238	1.2×10^{-8}	3.4×10^{-7}
15	U (natural)	2.6×10^{-8}	7.1×10^{-7}
16	U (enriched 5%		(See part
17	or less)	---	4731.0424)
18	U (enriched		(See part
19	more than 5%)	---	4731.0424)
20	U (depleted)	---	(See part
21			4731.0424)
22			
23	Vanadium (23)		
24	V-48	6.3×10^{3}	1.7×10^{5}
25	V-49	3.0×10^{2}	8.1×10^{3}
26			
27	Tungsten (74)		
28	W-178	1.3×10^{3}	3.4×10^{4}
29	W-181	2.2×10^{2}	6.0×10^{3}
30	W-185	3.5×10^{4}	9.4×10^{5}
31	W-187	2.6×10^{2}	7.0×10^{4}
32	W-188	3.7×10^{2}	1.0×10^{4}
33			
34	Xenon (54)		
35	Xe-122	4.8×10^{4}	1.3×10^{6}
36	Xe-123	4.4×10^{5}	1.2×10^{7}
37	Xe-127	1.0×10^{3}	2.8×10^{4}
38	Xe-131m	3.1×10^{3}	8.4×10^{4}
39	Xe-133	6.9×10^{3}	1.9×10^{5}
40	Xe-135	9.5×10^{4}	2.6×10^{6}
41			
42	Yttrium (39)		
43	Y-87	1.7×10^{4}	4.5×10^{5}
44	Y-88	5.2×10^{2}	1.4×10^{4}
45	Y-90	2.0×10^{4}	5.4×10^{5}
46	Y-91m	1.5×10^{6}	4.2×10^{7}
47	Y-91	9.1×10^{2}	2.5×10^{4}
48	Y-92	3.6×10^{5}	9.6×10^{6}
49	Y-93	1.2×10^{5}	3.3×10^{6}
50			
51	Ytterbium (70)		
52	Yb-169	8.9×10^{2}	2.4×10^{4}
53	Yb-175	6.6×10^{3}	1.8×10^{5}
54			

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Zinc (30)		
Zn-65	3.0×10^{2}	8.2×10^{3}
Zn-69m	1.2×10^{5}	3.3×10^{6}
Zn-69	1.8×10^{6}	4.9×10^{7}
Zirconium (40)		
Zr-88	6.6×10^{2}	1.8×10^{4}
Zr-93	9.3×10^{-5}	2.5×10^{-3}
Zr-95	7.9×10^{2}	2.1×10^{4}
Zr-97	7.1×10^{4}	1.9×10^{6}

Subp. 3. **Exempt material activity concentrations and exempt consignment activity limits.** This subpart specifies exempt material activity concentrations and exempt consignment activity levels for radionuclides.

THE FOLLOWING IS AN ALL NEW TABLE:

Element and atomic number and symbol of radionuclide	Activity concentration for exempt material (Bq/g)	Activity concentration for exempt material (Ci/g)	Activity limit for exempt consignment (Bq)	Activity limit for exempt consignment (Ci)
Actinium (89)				
Ac-225	$1.0 \times 10^{1}_{-1}$	$2.7 \times 10^{-10}_{-12}$	$1.0 \times 10^{4}_{3}$	$2.7 \times 10^{-7}_{-8}$
Ac-227	1.0×10^{1}	2.7×10^{-10}	1.0×10^{6}	2.7×10^{-5}
Ac-228				
Silver (47)				
Ag-105	$1.0 \times 10^{2}_{1}$	$2.7 \times 10^{-9}_{-10}$	$1.0 \times 10^{6}_{6}$	$2.7 \times 10^{-5}_{-5}$
Ag-108m[a]	1.0×10^{1}	2.7×10^{-10}	1.0×10^{6}	2.7×10^{-5}
Ag-110m	1.0×10^{1}	2.7×10^{-10}	1.0×10^{6}	2.7×10^{-5}
Ag-111	1.0×10^{3}	2.7×10^{-8}	1.0×10^{6}	2.7×10^{-5}
Aluminum (13)				
Al-26	1.0×10^{1}	2.7×10^{-10}	1.0×10^{5}	2.7×10^{-6}
Americium (95)				
Am-241	1.0	2.7×10^{-11}	1.0×10^{4}	2.7×10^{-7}
Am-242m[a]	1.0	2.7×10^{-11}	1.0×10^{4}	2.7×10^{-7}
Am-243[a]	1.0	2.7×10^{-11}	1.0×10^{3}	2.7×10^{-8}
Argon (18)				
Ar-37	$1.0 \times 10^{6}_{7}$	$2.7 \times 10^{-5}_{-4}$	$1.0 \times 10^{8}_{4}$	$2.7 \times 10^{-3}_{-7}$
Ar-39	1.0×10^{2}	2.7×10^{-9}	1.0×10^{9}	2.7×10^{-2}
Ar-41				
Arsenic (33)				
As-72	1.0×10^{1}	2.7×10^{-10}	1.0×10^{5}	2.7×10^{-6}

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1	As-73	1.0×10^{3}	2.7×10^{-8}	1.0×10^{7}	2.7×10^{-4}
2	As-74	1.0×10^{1}	2.7×10^{-10}	1.0×10^{6}	2.7×10^{-5}
3	As-76	1.0×10^{2}	2.7×10^{-9}	1.0×10^{5}	2.7×10^{-6}
4	As-77	1.0×10^{3}	2.7×10^{-8}	1.0×10^{6}	2.7×10^{-5}
5					
6	Astatine (85)				
7	At-211	1.0×10^{3}	2.7×10^{-8}	1.0×10^{7}	2.7×10^{-4}
8					
9	Gold (79)				
10	Au-193	1.0×10^{2}	2.7×10^{-9}	1.0×10^{7}	2.7×10^{-4}
11	Au-194	1.0×10^{1}	2.7×10^{-10}	1.0×10^{6}	2.7×10^{-5}
12	Au-195	1.0×10^{2}	2.7×10^{-9}	1.0×10^{7}	2.7×10^{-4}
13	Au-198	1.0×10^{2}	2.7×10^{-9}	1.0×10^{6}	2.7×10^{-5}
14	Au-199	1.0×10^{2}	2.7×10^{-9}	1.0×10^{6}	2.7×10^{-5}
15					
16	Barium (56)				
17	Ba-131	1.0×10^{2}	2.7×10^{-9}	1.0×10^{6}	2.7×10^{-5}
18	Ba-133	1.0×10^{2}	2.7×10^{-9}	1.0×10^{6}	2.7×10^{-5}
19	Ba-133m	1.0×10^{1}	2.7×10^{-10}	1.0×10^{5}	2.7×10^{-6}
20	Ba-140[a]	1.0×10^{1}	2.7×10^{-10}	1.0×10^{5}	2.7×10^{-6}
21					
22	Beryllium (4)				
23	Be-7	1.0×10^{3}	2.7×10^{-8}	1.0×10^{7}	2.7×10^{-4}
24	Be-10	1.0×10^{4}	2.7×10^{-7}	1.0×10^{6}	2.7×10^{-5}
25					
26	Bismuth (83)				
27	Bi-205	1.0×10^{1}	2.7×10^{-10}	1.0×10^{6}	2.7×10^{-5}
28	Bi-206	1.0×10^{1}	2.7×10^{-10}	1.0×10^{5}	2.7×10^{-6}
29	Bi-207	1.0×10^{1}	2.7×10^{-10}	1.0×10^{6}	2.7×10^{-5}
30	Bi-210	1.0×10^{3}	2.7×10^{-8}	1.0×10^{6}	2.7×10^{-5}
31	Bi-210m	1.0×10^{1}	2.7×10^{-10}	1.0×10^{5}	2.7×10^{-6}
32	Bi-212[a]	1.0×10^{1}	2.7×10^{-10}	1.0×10^{5}	2.7×10^{-6}
33					
34	Berkelium (97)				
35	Bk-247	1.0	2.7×10^{-11}	1.0×10^{4}	2.7×10^{-7}
36	Bk-249	1.0×10^{3}	2.7×10^{-8}	1.0×10^{6}	2.7×10^{-5}
37					
38	Bromine (35)				
39	Br-76	1.0×10^{1}	2.7×10^{-10}	1.0×10^{5}	2.7×10^{-6}
40	Br-77	1.0×10^{2}	2.7×10^{-9}	1.0×10^{6}	2.7×10^{-5}
41	Br-82	1.0×10^{1}	2.7×10^{-10}	1.0×10^{6}	2.7×10^{-5}
42					
43	Carbon(6)				
44	C-11	1.0×10^{1}	2.7×10^{-10}	1.0×10^{6}	2.7×10^{-5}
45	C-14	1.0×10^{4}	2.7×10^{-7}	1.0×10^{7}	2.7×10^{-4}
46					
47	Calcium (20)				
48	Ca-41	1.0×10^{5}	2.7×10^{-6}	1.0×10^{7}	2.7×10^{-4}
49	Ca-45	1.0×10^{4}	2.7×10^{-7}	1.0×10^{7}	2.7×10^{-4}
50	Ca-47	1.0×10^{1}	2.7×10^{-10}	1.0×10^{6}	2.7×10^{-5}
51					
52	Cadmium (48)				
53	Cd-109	1.0×10^{4}	2.7×10^{-7}	1.0×10^{6}	2.7×10^{-5}
54	Cd-113m	1.0×10^{3}	2.7×10^{-8}	1.0×10^{6}	2.7×10^{-5}

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1	Cd-115	1.0×10^{2}	2.7×10^{-9}	1.0×10^{6}	2.7×10^{-5}
2	Cd-115m	1.0×10^{3}	2.7×10^{-8}	1.0×10^{6}	2.7×10^{-5}
3					
4	Cerium (58)				
5	Ce-139	1.0×10^{2}	2.7×10^{-9}	1.0×10^{6}	2.7×10^{-5}
6	Ce-141	1.0×10^{2}	2.7×10^{-9}	1.0×10^{7}	2.7×10^{-4}
7	Ce-143	1.0×10^{2}	2.7×10^{-9}	1.0×10^{6}	2.7×10^{-5}
8	Ce-144[a]	1.0×10^{2}	2.7×10^{-9}	1.0×10^{5}	2.7×10^{-6}
9					
10	Californium (98)				
11	Cf-248	1.0×10^{1}	2.7×10^{-10}	1.0×10^{4}	2.7×10^{-7}
12	Cf-249	1.0	2.7×10^{-11}	1.0×10^{3}	2.7×10^{-8}
13	Cf-250	1.0×10^{1}	2.7×10^{-10}	1.0×10^{4}	2.7×10^{-7}
14	Cf-251	1.0	2.7×10^{-11}	1.0×10^{3}	2.7×10^{-8}
15	Cf-252	1.0×10^{1}	2.7×10^{-10}	1.0×10^{4}	2.7×10^{-7}
16	Cf-253	1.0×10^{2}	2.7×10^{-9}	1.0×10^{5}	2.7×10^{-6}
17	Cf-254	1.0	2.7×10^{-11}	1.0×10^{3}	2.7×10^{-8}
18					
19	Chlorine (17)				
20	Cl-36	1.0×10^{4}	2.7×10^{-7}	1.0×10^{6}	2.7×10^{-5}
21	Cl-38	1.0×10^{1}	2.7×10^{-10}	1.0×10^{5}	2.7×10^{-6}
22					
23	Curium (96)				
24	Cm-240	1.0×10^{2}	2.7×10^{-9}	1.0×10^{5}	2.7×10^{-6}
25	Cm-241	1.0×10^{2}	2.7×10^{-9}	1.0×10^{6}	2.7×10^{-5}
26	Cm-242	1.0×10^{2}	2.7×10^{-9}	1.0×10^{5}	2.7×10^{-6}
27	Cm-243	1.0	2.7×10^{-11}	1.0×10^{4}	2.7×10^{-7}
28	Cm-244	1.0×10^{1}	2.7×10^{-10}	1.0×10^{4}	2.7×10^{-7}
29	Cm-245	1.0	2.7×10^{-11}	1.0×10^{3}	2.7×10^{-8}
30	Cm-246	1.0	2.7×10^{-11}	1.0×10^{3}	2.7×10^{-8}
31	Cm-247	1.0	2.7×10^{-11}	1.0×10^{4}	2.7×10^{-7}
32	Cm-248	1.0	2.7×10^{-11}	1.0×10^{3}	2.7×10^{-8}
33					
34	Cobalt (27)				
35	Co-55	1.0×10^{1}	2.7×10^{-10}	1.0×10^{6}	2.7×10^{-5}
36	Co-56	1.0×10^{1}	2.7×10^{-10}	1.0×10^{5}	2.7×10^{-6}
37	Co-57	1.0×10^{2}	2.7×10^{-9}	1.0×10^{6}	2.7×10^{-5}
38	Co-58	1.0×10^{1}	2.7×10^{-10}	1.0×10^{6}	2.7×10^{-5}
39	Co-58m	1.0×10^{4}	2.7×10^{-7}	1.0×10^{7}	2.7×10^{-4}
40	Co-60	1.0×10^{1}	2.7×10^{-10}	1.0×10^{5}	2.7×10^{-6}
41					
42	Chromium (24)				
43	Cr-51	1.0×10^{3}	2.7×10^{-8}	1.0×10^{7}	2.7×10^{-4}
44					
45	Cesium (55)				
46	Cs-129	1.0×10^{2}	2.7×10^{-9}	1.0×10^{5}	2.7×10^{-6}
47	Cs-131	1.0×10^{3}	2.7×10^{-8}	1.0×10^{6}	2.7×10^{-5}
48	Cs-132	1.0×10^{1}	2.7×10^{-10}	1.0×10^{5}	2.7×10^{-6}
49	Cs-134	1.0×10^{1}	2.7×10^{-10}	1.0×10^{4}	2.7×10^{-7}
50	Cs-134m	1.0×10^{3}	2.7×10^{-8}	1.0×10^{5}	2.7×10^{-6}
51	Cs-135	1.0×10^{4}	2.7×10^{-7}	1.0×10^{7}	2.7×10^{-4}
52	Cs-136[a]	1.0×10^{1}	2.7×10^{-10}	1.0×10^{5}	2.7×10^{-6}
53	Cs-137[a]	1.0×10^{1}	2.7×10^{-10}	1.0×10^{4}	2.7×10^{-7}
54					

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Copper (29)					
Cu-64	1.0×10^{2}	2.7×10^{-9}	1.0×10^{6}	2.7×10^{-5}	
Cu-67	1.0×10^{2}	2.7×10^{-9}	1.0×10^{6}	2.7×10^{-5}	
Dysprosium (66)					
Dy-159	1.0×10^{3}	2.7×10^{-8}	1.0×10^{7}	2.7×10^{-4}	
Dy-165	1.0×10^{3}	2.7×10^{-8}	1.0×10^{6}	2.7×10^{-5}	
Dy-166	1.0×10^{3}	2.7×10^{-8}	1.0×10^{6}	2.7×10^{-5}	
Erbium (68)					
Er-169	1.0×10^{4}	2.7×10^{-7}	1.0×10^{7}	2.7×10^{-4}	
Er-171	1.0×10^{2}	2.7×10^{-9}	1.0×10^{6}	2.7×10^{-5}	
Europium (63)					
Eu-147	1.0×10^{2}	2.7×10^{-9}	1.0×10^{6}	2.7×10^{-5}	
Eu-148	1.0×10^{1}	2.7×10^{-10}	1.0×10^{6}	2.7×10^{-5}	
Eu-149	1.0×10^{2}	2.7×10^{-9}	1.0×10^{7}	2.7×10^{-4}	
Eu-150					
(short-lived)	1.0×10^{3}	2.7×10^{-8}	1.0×10^{6}	2.7×10^{-5}	
Eu-150					
(long-lived)	1.0×10^{1}	2.7×10^{-10}	1.0×10^{6}	2.7×10^{-5}	
Eu-152	1.0×10^{1}	2.7×10^{-10}	1.0×10^{6}	2.7×10^{-5}	
Eu-152m	1.0×10^{2}	2.7×10^{-9}	1.0×10^{6}	2.7×10^{-5}	
Eu-154	1.0×10^{1}	2.7×10^{-10}	1.0×10^{6}	2.7×10^{-5}	
Eu-155	1.0×10^{2}	2.7×10^{-9}	1.0×10^{7}	2.7×10^{-4}	
Eu-156	1.0×10^{1}	2.7×10^{-10}	1.0×10^{6}	2.7×10^{-5}	
Fluorine (9)					
F-18	1.0×10^{1}	2.7×10^{-10}	1.0×10^{6}	2.7×10^{-5}	
Iron (26)					
Fe-52	1.0×10^{1}	2.7×10^{-10}	1.0×10^{6}	2.7×10^{-5}	
Fe-55	1.0×10^{4}	2.7×10^{-7}	1.0×10^{6}	2.7×10^{-5}	
Fe-59	1.0×10^{1}	2.7×10^{-10}	1.0×10^{6}	2.7×10^{-5}	
Fe-60	1.0×10^{2}	2.7×10^{-9}	1.0×10^{5}	2.7×10^{-6}	
Gallium (31)					
Ga-67	1.0×10^{2}	2.7×10^{-9}	1.0×10^{6}	2.7×10^{-5}	
Ga-68	1.0×10^{1}	2.7×10^{-10}	1.0×10^{5}	2.7×10^{-6}	
Ga-72	1.0×10^{1}	2.7×10^{-10}	1.0×10^{5}	2.7×10^{-6}	
Gadolinium (64)					
Gd-146	1.0×10^{1}	2.7×10^{-10}	1.0×10^{6}	2.7×10^{-5}	
Gd-148	1.0×10^{1}	2.7×10^{-10}	1.0×10^{4}	2.7×10^{-7}	
Gd-153	1.0×10^{2}	2.7×10^{-9}	1.0×10^{7}	2.7×10^{-4}	
Gd-159	1.0×10^{3}	2.7×10^{-8}	1.0×10^{6}	2.7×10^{-5}	
Germanium (32)					
Ge-68	1.0×10^{1}	2.7×10^{-10}	1.0×10^{5}	2.7×10^{-6}	
Ge-71	1.0×10^{4}	2.7×10^{-7}	1.0×10^{8}	2.7×10^{-3}	
Ge-77	1.0×10^{1}	2.7×10^{-10}	1.0×10^{5}	2.7×10^{-6}	
Tritium (1)					
H-3 (T)	1.0×10^{6}	2.7×10^{-5}	1.0×10^{9}	2.7×10^{-2}	

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Hafnium (72)					
Hf-172	1.0×10^{12}	2.7×10^{-9}	2.7×10^{-10}	1.0×10^{6}	2.7×10^{-5}
Hf-175	1.0×10^{12}	2.7×10^{-9}	2.7×10^{-10}	1.0×10^{6}	2.7×10^{-5}
Hf-181	1.0×10^{2}	2.7×10^{-9}	2.7×10^{-9}	1.0×10^{6}	2.7×10^{-5}
Hf-182	1.0×10^{3}	2.7×10^{-8}	2.7×10^{-10}	1.0×10^{6}	2.7×10^{-5}
Mercury (80)					
Hg-194	1.0×10^{2}	2.7×10^{-9}	2.7×10^{-9}	1.0×10^{6}	2.7×10^{-5}
Hg-195m	1.0×10^{2}	2.7×10^{-9}	2.7×10^{-9}	1.0×10^{7}	2.7×10^{-4}
Hg-197	1.0×10^{2}	2.7×10^{-9}	2.7×10^{-9}	1.0×10^{6}	2.7×10^{-5}
Hg-197m	1.0×10^{2}	2.7×10^{-9}	2.7×10^{-9}	1.0×10^{5}	2.7×10^{-6}
Hg-203	1.0×10^{2}	2.7×10^{-9}	2.7×10^{-9}	1.0×10^{5}	2.7×10^{-6}
Holmium (67)					
Ho-166	1.0×10^{3}	2.7×10^{-8}	2.7×10^{-8}	1.0×10^{5}	2.7×10^{-6}
Ho-166m	1.0×10^{1}	2.7×10^{-10}	2.7×10^{-10}	1.0×10^{6}	2.7×10^{-5}
Iodine (53)					
I-123	1.0×10^{2}	2.7×10^{-9}	2.7×10^{-9}	1.0×10^{7}	2.7×10^{-4}
I-124	1.0×10^{1}	2.7×10^{-10}	2.7×10^{-10}	1.0×10^{6}	2.7×10^{-5}
I-125	1.0×10^{3}	2.7×10^{-8}	2.7×10^{-8}	1.0×10^{6}	2.7×10^{-5}
I-126	1.0×10^{2}	2.7×10^{-9}	2.7×10^{-9}	1.0×10^{6}	2.7×10^{-5}
I-129	1.0×10^{2}	2.7×10^{-9}	2.7×10^{-9}	1.0×10^{5}	2.7×10^{-6}
I-131	1.0×10^{2}	2.7×10^{-9}	2.7×10^{-9}	1.0×10^{6}	2.7×10^{-5}
I-132	1.0×10^{1}	2.7×10^{-10}	2.7×10^{-10}	1.0×10^{5}	2.7×10^{-6}
I-133	1.0×10^{1}	2.7×10^{-10}	2.7×10^{-10}	1.0×10^{6}	2.7×10^{-5}
I-134	1.0×10^{1}	2.7×10^{-10}	2.7×10^{-10}	1.0×10^{5}	2.7×10^{-6}
I-135	1.0×10^{1}	2.7×10^{-10}	2.7×10^{-10}	1.0×10^{6}	2.7×10^{-5}
Indium (49)					
In-111	1.0×10^{2}	2.7×10^{-9}	2.7×10^{-9}	1.0×10^{6}	2.7×10^{-5}
In-113m	1.0×10^{2}	2.7×10^{-9}	2.7×10^{-9}	1.0×10^{6}	2.7×10^{-5}
In-114m	1.0×10^{2}	2.7×10^{-9}	2.7×10^{-9}	1.0×10^{6}	2.7×10^{-5}
In-115m	1.0×10^{2}	2.7×10^{-9}	2.7×10^{-9}	1.0×10^{6}	2.7×10^{-5}
Iridium (77)					
Ir-189	1.0×10^{2}	2.7×10^{-9}	2.7×10^{-9}	1.0×10^{7}	2.7×10^{-4}
Ir-190	1.0×10^{1}	2.7×10^{-10}	2.7×10^{-10}	1.0×10^{6}	2.7×10^{-5}
Ir-192	1.0×10^{2}	2.7×10^{-9}	2.7×10^{-9}	1.0×10^{4}	2.7×10^{-7}
Ir-194	1.0×10^{2}	2.7×10^{-9}	2.7×10^{-9}	1.0×10^{5}	2.7×10^{-6}
Potassium (19)					
K-40	1.0×10^{2}	2.7×10^{-9}	2.7×10^{-9}	1.0×10^{6}	2.7×10^{-5}
K-42	1.0×10^{2}	2.7×10^{-9}	2.7×10^{-9}	1.0×10^{6}	2.7×10^{-5}
K-43	1.0×10^{1}	2.7×10^{-10}	2.7×10^{-10}	1.0×10^{6}	2.7×10^{-5}
Krypton (36)					
Kr-81	1.0×10^{4}	2.7×10^{-7}	2.7×10^{-7}	1.0×10^{7}	2.7×10^{-4}
Kr-85	1.0×10^{5}	2.7×10^{-6}	2.7×10^{-6}	1.0×10^{4}	2.7×10^{-7}
Kr-85m	1.0×10^{3}	2.7×10^{-8}	2.7×10^{-8}	1.0×10^{10}	2.7×10^{-1}
Kr-87	1.0×10^{2}	2.7×10^{-9}	2.7×10^{-9}	1.0×10^{9}	2.7×10^{-2}
Lanthanum (57)					

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La-137	1.0×10^{3}	2.7×10^{-8}	1.0×10^{7}	2.7×10^{-4}
La-140	1.0×10^{1}	2.7×10^{-10}	1.0×10^{5}	2.7×10^{-6}
Lutetium (71)				
Lu-172	1.0×10^{1}	2.7×10^{-10}	1.0×10^{6}	2.7×10^{-5}
Lu-173	1.0×10^{2}	2.7×10^{-9}	1.0×10^{7}	2.7×10^{-4}
Lu-174	1.0×10^{2}	2.7×10^{-9}	1.0×10^{7}	2.7×10^{-4}
Lu-174m	1.0×10^{2}	2.7×10^{-9}	1.0×10^{7}	2.7×10^{-4}
Lu-177	1.0×10^{3}	2.7×10^{-8}	1.0×10^{7}	2.7×10^{-4}
Magnesium (12)				
Mg-28	1.0×10^{1}	2.7×10^{-10}	1.0×10^{5}	2.7×10^{-6}
Manganese (25)				
Mn-52	1.0×10^{1}	2.7×10^{-10}	1.0×10^{5}	2.7×10^{-6}
Mn-53	1.0×10^{4}	2.7×10^{-7}	1.0×10^{9}	2.7×10^{-2}
Mn-54	1.0×10^{1}	2.7×10^{-10}	1.0×10^{6}	2.7×10^{-5}
Mn-56	1.0×10^{1}	2.7×10^{-10}	1.0×10^{5}	2.7×10^{-6}
Molybdenum (42)				
Mo-93	1.0×10^{3}	2.7×10^{-8}	1.0×10^{8}	2.7×10^{-3}
Mo-99	1.0×10^{2}	2.7×10^{-9}	1.0×10^{6}	2.7×10^{-5}
Nitrogen (7)				
N-13	1.0×10^{2}	2.7×10^{-9}	1.0×10^{9}	2.7×10^{-2}
Sodium (11)				
Na-22	1.0×10^{1}	2.7×10^{-10}	1.0×10^{6}	2.7×10^{-5}
Na-24	1.0×10^{1}	2.7×10^{-10}	1.0×10^{5}	2.7×10^{-6}
Niobium (41)				
Nb-93m	1.0×10^{4}	2.7×10^{-7}	1.0×10^{7}	2.7×10^{-4}
Nb-94	1.0×10^{1}	2.7×10^{-10}	1.0×10^{6}	2.7×10^{-5}
Nb-95	1.0×10^{1}	2.7×10^{-10}	1.0×10^{6}	2.7×10^{-5}
Nb-97	1.0×10^{1}	2.7×10^{-10}	1.0×10^{6}	2.7×10^{-5}
Neodymium (60)				
Nd-147	1.0×10^{2}	2.7×10^{-9}	1.0×10^{6}	2.7×10^{-5}
Nd-149	1.0×10^{2}	2.7×10^{-9}	1.0×10^{6}	2.7×10^{-5}
Nickel (28)				
Ni-59	1.0×10^{4}	2.7×10^{-7}	1.0×10^{8}	2.7×10^{-3}
Ni-63	1.0×10^{5}	2.7×10^{-6}	1.0×10^{8}	2.7×10^{-3}
Ni-65	1.0×10^{1}	2.7×10^{-10}	1.0×10^{6}	2.7×10^{-5}
Neptunium (93)				
Np-235	1.0×10^{3}	2.7×10^{-8}	1.0×10^{7}	2.7×10^{-4}
Np-236				
(short-lived)	1.0×10^{3}	2.7×10^{-8}	1.0×10^{7}	2.7×10^{-4}
Np-236				
(long-lived)	1.0×10^{2}	2.7×10^{-9}	1.0×10^{5}	2.7×10^{-6}
Np-237[a]	1.0	2.7×10^{-11}	1.0×10^{3}	2.7×10^{-8}
Np-239	1.0×10^{2}	2.7×10^{-9}	1.0×10^{7}	2.7×10^{-4}

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Osmium (76)					
Os-185	1.0×10^{1}	2.7×10^{-10}	2.7×10^{-5}	1.0×10^{6}	2.7×10^{-5}
Os-191	1.0×10^{3}	2.7×10^{-8}	2.7×10^{-4}	1.0×10^{7}	2.7×10^{-4}
Os-191m	1.0×10^{2}	2.7×10^{-9}	2.7×10^{-5}	1.0×10^{6}	2.7×10^{-5}
Os-193	1.0×10^{2}	2.7×10^{-9}	2.7×10^{-6}	1.0×10^{5}	2.7×10^{-6}
Os-194	1.0×10^{2}	2.7×10^{-9}	2.7×10^{-4}	1.0×10^{7}	2.7×10^{-4}
Phosphorus (15)					
P-32	1.0×10^{3}	2.7×10^{-8}	2.7×10^{-6}	1.0×10^{5}	2.7×10^{-6}
P-33	1.0×10^{5}	2.7×10^{-6}	2.7×10^{-3}	1.0×10^{8}	2.7×10^{-3}
Protactinium (91)					
Pa-230	1.0×10^{1}	2.7×10^{-10}	2.7×10^{-5}	1.0×10^{6}	2.7×10^{-5}
Pa-231	1.0	2.7×10^{-11}	2.7×10^{-8}	1.0×10^{3}	2.7×10^{-8}
Pa-233	1.0×10^{2}	2.7×10^{-9}	2.7×10^{-4}	1.0×10^{7}	2.7×10^{-4}
Lead (82)					
Pb-201	1.0×10^{1}	2.7×10^{-10}	2.7×10^{-5}	1.0×10^{6}	2.7×10^{-5}
Pb-202	1.0×10^{3}	2.7×10^{-8}	2.7×10^{-5}	1.0×10^{6}	2.7×10^{-5}
Pb-203	1.0×10^{2}	2.7×10^{-9}	2.7×10^{-5}	1.0×10^{6}	2.7×10^{-5}
Pb-205	1.0×10^{4}	2.7×10^{-7}	2.7×10^{-4}	1.0×10^{7}	2.7×10^{-4}
Pb-210[a]	1.0×10^{1}	2.7×10^{-10}	2.7×10^{-7}	1.0×10^{4}	2.7×10^{-7}
Pb-212[a]	1.0×10^{1}	2.7×10^{-10}	2.7×10^{-6}	1.0×10^{5}	2.7×10^{-6}
Palladium (46)					
Pd-103	1.0×10^{3}	2.7×10^{-8}	2.7×10^{-3}	1.0×10^{8}	2.7×10^{-3}
Pd-107	1.0×10^{3}	2.7×10^{-8}	2.7×10^{-3}	1.0×10^{8}	2.7×10^{-3}
Pd-109	1.0×10^{3}	2.7×10^{-8}	2.7×10^{-5}	1.0×10^{6}	2.7×10^{-5}
Promethium (61)					
Pm-143	1.0×10^{2}	2.7×10^{-9}	2.7×10^{-5}	1.0×10^{6}	2.7×10^{-5}
Pm-144	1.0×10^{1}	2.7×10^{-10}	2.7×10^{-5}	1.0×10^{6}	2.7×10^{-5}
Pm-145	1.0×10^{3}	2.7×10^{-8}	2.7×10^{-4}	1.0×10^{7}	2.7×10^{-4}
Pm-147	1.0×10^{4}	2.7×10^{-7}	2.7×10^{-4}	1.0×10^{7}	2.7×10^{-4}
Pm-148m	1.0×10^{1}	2.7×10^{-10}	2.7×10^{-5}	1.0×10^{6}	2.7×10^{-5}
Pm-149	1.0×10^{3}	2.7×10^{-8}	2.7×10^{-5}	1.0×10^{6}	2.7×10^{-5}
Pm-151	1.0×10^{2}	2.7×10^{-9}	2.7×10^{-5}	1.0×10^{6}	2.7×10^{-5}
Polonium (84)					
Po-210	1.0×10^{1}	2.7×10^{-10}	2.7×10^{-7}	1.0×10^{4}	2.7×10^{-7}
Praseodymium (59)					
Pr-142	1.0×10^{2}	2.7×10^{-9}	2.7×10^{-6}	1.0×10^{5}	2.7×10^{-6}
Pr-143	1.0×10^{4}	2.7×10^{-7}	2.7×10^{-5}	1.0×10^{6}	2.7×10^{-5}
Platinum (78)					
Pt-188	1.0×10^{1}	2.7×10^{-10}	2.7×10^{-5}	1.0×10^{6}	2.7×10^{-5}
Pt-191	1.0×10^{4}	2.7×10^{-7}	2.7×10^{-4}	1.0×10^{7}	2.7×10^{-4}
Pt-193	1.0×10^{3}	2.7×10^{-8}	2.7×10^{-4}	1.0×10^{7}	2.7×10^{-4}
Pt-193m	1.0×10^{2}	2.7×10^{-9}	2.7×10^{-5}	1.0×10^{6}	2.7×10^{-5}
Pt-195m	1.0×10^{3}	2.7×10^{-8}	2.7×10^{-5}	1.0×10^{6}	2.7×10^{-5}
Pt-197	1.0×10^{2}	2.7×10^{-9}	2.7×10^{-5}	1.0×10^{6}	2.7×10^{-5}
Pt-197m	1.0×10^{2}	2.7×10^{-9}	2.7×10^{-5}	1.0×10^{6}	2.7×10^{-5}

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Plutonium (94)					
Pu-236	1.0×10^{1}	2.7×10^{-10}	1.0×10^{4}	2.7×10^{-7}	
Pu-237	1.0×10^{3}	2.7×10^{-8}	1.0×10^{7}	2.7×10^{-4}	
Pu-238	1.0	2.7×10^{-11}	1.0×10^{4}	2.7×10^{-7}	
Pu-239	1.0	2.7×10^{-11}	1.0×10^{4}	2.7×10^{-7}	
Pu-240	1.0	2.7×10^{-11}	1.0×10^{3}	2.7×10^{-8}	
Pu-241	1.0×10^{2}	2.7×10^{-9}	1.0×10^{5}	2.7×10^{-6}	
Pu-242	1.0	2.7×10^{-11}	1.0×10^{4}	2.7×10^{-7}	
Pu-244	1.0	2.7×10^{-11}	1.0×10^{4}	2.7×10^{-7}	
Radium (88)					
Ra-223[a]	1.0×10^{2}	2.7×10^{-9}	1.0×10^{5}	2.7×10^{-6}	
Ra-224[a]	1.0×10^{1}	2.7×10^{-10}	1.0×10^{5}	2.7×10^{-6}	
Ra-225[a]	1.0×10^{2}	2.7×10^{-9}	1.0×10^{5}	2.7×10^{-6}	
Ra-226[a]	1.0×10^{1}	2.7×10^{-10}	1.0×10^{4}	2.7×10^{-7}	
Ra-228[a]	1.0×10^{1}	2.7×10^{-10}	1.0×10^{5}	2.7×10^{-6}	
Rubidium (37)					
Rb-81	1.0×10^{1}	2.7×10^{-10}	1.0×10^{6}	2.7×10^{-5}	
Rb-83	1.0×10^{2}	2.7×10^{-9}	1.0×10^{6}	2.7×10^{-5}	
Rb-84	1.0×10^{1}	2.7×10^{-10}	1.0×10^{6}	2.7×10^{-5}	
Rb-86	1.0×10^{2}	2.7×10^{-9}	1.0×10^{5}	2.7×10^{-6}	
Rb-87	1.0×10^{4}	2.7×10^{-7}	1.0×10^{7}	2.7×10^{-4}	
Rb (nat)	1.0×10^{4}	2.7×10^{-7}	1.0×10^{7}	2.7×10^{-4}	
Rhenium (75)					
Re-184	1.0×10^{1}	2.7×10^{-10}	1.0×10^{6}	2.7×10^{-5}	
Re-184m	1.0×10^{2}	2.7×10^{-9}	1.0×10^{6}	2.7×10^{-5}	
Re-186	1.0×10^{3}	2.7×10^{-8}	1.0×10^{6}	2.7×10^{-5}	
Re-187	1.0×10^{6}	2.7×10^{-5}	1.0×10^{9}	2.7×10^{-2}	
Re-188	1.0×10^{2}	2.7×10^{-9}	1.0×10^{5}	2.7×10^{-6}	
Re-189	1.0×10^{2}	2.7×10^{-9}	1.0×10^{6}	2.7×10^{-5}	
Re (nat)	1.0×10^{6}	2.7×10^{-5}	1.0×10^{9}	2.7×10^{-2}	
Rhodium (45)					
Rh-99	1.0×10^{1}	2.7×10^{-10}	1.0×10^{6}	2.7×10^{-5}	
Rh-101	1.0×10^{2}	2.7×10^{-9}	1.0×10^{7}	2.7×10^{-4}	
Rh-102	1.0×10^{1}	2.7×10^{-10}	1.0×10^{6}	2.7×10^{-5}	
Rh-102m	1.0×10^{2}	2.7×10^{-9}	1.0×10^{6}	2.7×10^{-5}	
Rh-103m	1.0×10^{4}	2.7×10^{-7}	1.0×10^{8}	2.7×10^{-3}	
Rh-105	1.0×10^{2}	2.7×10^{-9}	1.0×10^{7}	2.7×10^{-4}	
Radon (86)					
Rn-222[a]	1.0×10^{1}	2.7×10^{-10}	1.0×10^{8}	2.7×10^{-3}	
Ruthenium (44)					
Ru-97	1.0×10^{2}	2.7×10^{-9}	1.0×10^{7}	2.7×10^{-4}	
Ru-103	1.0×10^{2}	2.7×10^{-9}	1.0×10^{6}	2.7×10^{-5}	
Ru-105[a]	1.0×10^{1}	2.7×10^{-10}	1.0×10^{6}	2.7×10^{-5}	
Ru-106[a]	1.0×10^{2}	2.7×10^{-9}	1.0×10^{5}	2.7×10^{-6}	
Sulfur (16)					
S-35	1.0×10^{5}	2.7×10^{-6}	1.0×10^{8}	2.7×10^{-3}	

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Antimony (51)					
Sb-122	1.0×10^{2}	2.7×10^{-9}	1.0×10^{4}	2.7×10^{-7}	
Sb-124	1.0×10^{1}	2.7×10^{-10}	1.0×10^{6}	2.7×10^{-5}	
Sb-125	1.0×10^{2}	2.7×10^{-9}	1.0×10^{6}	2.7×10^{-5}	
Sb-126	1.0×10^{1}	2.7×10^{-10}	1.0×10^{5}	2.7×10^{-6}	
Scandium (21)					
Sc-44	1.0×10^{1}	2.7×10^{-10}	1.0×10^{5}	2.7×10^{-6}	
Sc-46	1.0×10^{2}	2.7×10^{-10}	1.0×10^{6}	2.7×10^{-5}	
Sc-47	1.0×10^{2}	2.7×10^{-9}	1.0×10^{6}	2.7×10^{-5}	
Sc-48	1.0×10^{1}	2.7×10^{-10}	1.0×10^{5}	2.7×10^{-6}	
Selenium (34)					
Se-75	1.0×10^{2}	2.7×10^{-9}	1.0×10^{6}	2.7×10^{-5}	
Se-79	1.0×10^{4}	2.7×10^{-7}	1.0×10^{7}	2.7×10^{-4}	
Silicon (14)					
Si-31	1.0×10^{3}	2.7×10^{-8}	1.0×10^{6}	2.7×10^{-5}	
Si-32	1.0×10^{3}	2.7×10^{-8}	1.0×10^{6}	2.7×10^{-5}	
Samarium (62)					
Sm-145	1.0×10^{2}	2.7×10^{-9}	1.0×10^{7}	2.7×10^{-4}	
Sm-147	1.0×10^{1}	2.7×10^{-10}	1.0×10^{4}	2.7×10^{-7}	
Sm-151	1.0×10^{4}	2.7×10^{-7}	1.0×10^{8}	2.7×10^{-3}	
Sm-153	1.0×10^{2}	2.7×10^{-9}	1.0×10^{6}	2.7×10^{-5}	
Tin (50)					
Sn-113	1.0×10^{3}	2.7×10^{-8}	1.0×10^{7}	2.7×10^{-4}	
Sn-117m	1.0×10^{2}	2.7×10^{-9}	1.0×10^{6}	2.7×10^{-5}	
Sn-119m	1.0×10^{3}	2.7×10^{-8}	1.0×10^{7}	2.7×10^{-4}	
Sn-121m	1.0×10^{3}	2.7×10^{-8}	1.0×10^{7}	2.7×10^{-4}	
Sn-123	1.0×10^{3}	2.7×10^{-8}	1.0×10^{6}	2.7×10^{-5}	
Sn-125	1.0×10^{2}	2.7×10^{-9}	1.0×10^{5}	2.7×10^{-6}	
Sn-126	1.0×10^{1}	2.7×10^{-10}	1.0×10^{5}	2.7×10^{-6}	
Strontium (38)					
Sr-82	1.0×10^{1}	2.7×10^{-10}	1.0×10^{5}	2.7×10^{-6}	
Sr-85	1.0×10^{2}	2.7×10^{-9}	1.0×10^{6}	2.7×10^{-5}	
Sr-85m	1.0×10^{2}	2.7×10^{-9}	1.0×10^{7}	2.7×10^{-4}	
Sr-87m	1.0×10^{2}	2.7×10^{-9}	1.0×10^{6}	2.7×10^{-5}	
Sr-89	1.0×10^{3}	2.7×10^{-8}	1.0×10^{6}	2.7×10^{-5}	
Sr-90[a]	1.0×10^{2}	2.7×10^{-9}	1.0×10^{4}	2.7×10^{-7}	
Sr-91	1.0×10^{1}	2.7×10^{-10}	1.0×10^{5}	2.7×10^{-6}	
Sr-92	1.0×10^{1}	2.7×10^{-10}	1.0×10^{6}	2.7×10^{-5}	
Tritium (1)					
T (H-3)	1.0×10^{6}	2.7×10^{-5}	1.0×10^{9}	2.7×10^{-2}	
Tantalum (73)					
Ta-178					
(long lived)	1.0×10^{3}	2.7×10^{-10}	1.0×10^{7}	2.7×10^{-5}	
Ta-179	1.0×10^{1}	2.7×10^{-8}	1.0×10^{4}	2.7×10^{-7}	
Ta-182	1.0×10^{1}	2.7×10^{-10}	1.0×10^{4}	2.7×10^{-7}	

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Terbium (65)					
Tb-157	1.0×10^{4}	2.7×10^{-7}	1.0×10^{7}	2.7×10^{-4}
Tb-158	1.0×10^{1}	2.7×10^{-10}	1.0×10^{6}	2.7×10^{-5}
Tb-160	1.0×10^{1}	2.7×10^{-10}	1.0×10^{6}	2.7×10^{-5}
Technetium (43)				
Tc-95m	1.0×10^{1}	2.7×10^{-10}	1.0×10^{6}	2.7×10^{-5}
Tc-96	1.0×10^{1}	2.7×10^{-10}	1.0×10^{6}	2.7×10^{-5}
Tc-96m	1.0×10^{3}	2.7×10^{-8}	1.0×10^{7}	2.7×10^{-4}
Tc-97	1.0×10^{3}	2.7×10^{-8}	1.0×10^{8}	2.7×10^{-3}
Tc-97m	1.0×10^{3}	2.7×10^{-8}	1.0×10^{7}	2.7×10^{-4}
Tc-98	1.0×10^{1}	2.7×10^{-10}	1.0×10^{6}	2.7×10^{-5}
Tc-99	1.0×10^{4}	2.7×10^{-7}	1.0×10^{7}	2.7×10^{-4}
Tc-99m	1.0×10^{2}	2.7×10^{-9}	1.0×10^{7}	2.7×10^{-4}
Tellurium (52)				
Te-121	1.0×10^{1}	2.7×10^{-10}	1.0×10^{6}	2.7×10^{-5}
Te-121m	1.0×10^{2}	2.7×10^{-9}	1.0×10^{5}	2.7×10^{-6}
Te-123m	1.0×10^{2}	2.7×10^{-9}	1.0×10^{7}	2.7×10^{-4}
Te-125m	1.0×10^{3}	2.7×10^{-8}	1.0×10^{7}	2.7×10^{-4}
Te-127	1.0×10^{3}	2.7×10^{-8}	1.0×10^{6}	2.7×10^{-5}
Te-127m	1.0×10^{3}	2.7×10^{-8}	1.0×10^{7}	2.7×10^{-4}
Te-129	1.0×10^{2}	2.7×10^{-9}	1.0×10^{6}	2.7×10^{-5}
Te-129m	1.0×10^{3}	2.7×10^{-8}	1.0×10^{6}	2.7×10^{-5}
Te-131m	1.0×10^{1}	2.7×10^{-10}	1.0×10^{6}	2.7×10^{-5}
Te-132	1.0×10^{2}	2.7×10^{-9}	1.0×10^{7}	2.7×10^{-4}
Thorium (90)				
Th-227[a]	1.0×10^{1}	2.7×10^{-10}	1.0×10^{4}	2.7×10^{-7}
Th-228[a]	1.0	2.7×10^{-11}	1.0×10^{4}	2.7×10^{-7}
Th-229[a]	1.0	2.7×10^{-11}	1.0×10^{3}	2.7×10^{-8}
Th-230	1.0	2.7×10^{-11}	1.0×10^{4}	2.7×10^{-7}
Th-231	1.0×10^{3}	2.7×10^{-8}	1.0×10^{7}	2.7×10^{-4}
Th-232[a]	1.0×10^{1}	2.7×10^{-10}	1.0×10^{4}	2.7×10^{-7}
Th-234[a]	1.0×10^{3}	2.7×10^{-8}	1.0×10^{5}	2.7×10^{-6}
Th (nat)[a]	1.0	2.7×10^{-11}	1.0×10^{3}	2.7×10^{-8}
Titanium (22)				
Ti-44	1.0×10^{1}	2.7×10^{-10}	1.0×10^{5}	2.7×10^{-6}
Thallium (81)				
Tl-200	1.0×10^{1}	2.7×10^{-10}	1.0×10^{6}	2.7×10^{-5}
Tl-201	1.0×10^{2}	2.7×10^{-9}	1.0×10^{6}	2.7×10^{-5}
Tl-202	1.0×10^{2}	2.7×10^{-9}	1.0×10^{6}	2.7×10^{-5}
Tl-204	1.0×10^{4}	2.7×10^{-7}	1.0×10^{4}	2.7×10^{-7}
Thulium (69)				
Tm-167	1.0×10^{2}	2.7×10^{-9}	1.0×10^{6}	2.7×10^{-5}
Tm-170	1.0×10^{3}	2.7×10^{-8}	1.0×10^{6}	2.7×10^{-5}
Tm-171	1.0×10^{4}	2.7×10^{-7}	1.0×10^{8}	2.7×10^{-3}
Uranium (92)				
U-230 (fast lung absorp-				

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tion)[a,b]	1.0×10^{1}	2.7×10^{-10}	1.0×10^{5}	2.7×10^{-6}
U-230 (medium lung absorption)[c]	1.0×10^{1}	2.7×10^{-10}	1.0×10^{4}	2.7×10^{-7}
U-230 (slow lung absorption)[d]	1.0×10^{1}	2.7×10^{-10}	1.0×10^{4}	2.7×10^{-7}
U-232 (fast lung absorption)[a,b]	1.0	2.7×10^{-11}	1.0×10^{3}	2.7×10^{-8}
U-232 (medium lung absorption)[c]	1.0×10^{1}	2.7×10^{-10}	1.0×10^{4}	2.7×10^{-7}
U-232 (slow lung absorption)[d]	1.0×10^{1}	2.7×10^{-10}	1.0×10^{4}	2.7×10^{-7}
U-233 (fast lung absorption)[b]	1.0×10^{1}	2.7×10^{-10}	1.0×10^{4}	2.7×10^{-7}
U-233 (medium lung absorption)[c]	1.0×10^{2}	2.7×10^{-9}	1.0×10^{5}	2.7×10^{-6}
U-233 (slow lung absorption)[d]	1.0×10^{1}	2.7×10^{-10}	1.0×10^{5}	2.7×10^{-6}
U-234 (fast lung absorption)[b]	1.0×10^{1}	2.7×10^{-10}	1.0×10^{4}	2.7×10^{-7}
U-234 (medium lung absorption)[c]	1.0×10^{2}	2.7×10^{-9}	1.0×10^{5}	2.7×10^{-6}
U-234 (slow lung absorption)[d]	1.0×10^{1}	2.7×10^{-10}	1.0×10^{5}	2.7×10^{-6}
U-235 (all lung absorption types)[a,b,c,d]	1.0×10^{1}	2.7×10^{-10}	1.0×10^{4}	2.7×10^{-7}
U-236 (fast lung absorption)[b]	1.0×10^{1}	2.7×10^{-10}	1.0×10^{4}	2.7×10^{-7}
U-236 (medium lung absorption)[c]	1.0×10^{2}	2.7×10^{-9}	1.0×10^{5}	2.7×10^{-6}
U-236 (slow lung absorption)[d]	1.0×10^{1}	2.7×10^{-10}	1.0×10^{4}	2.7×10^{-7}
U-238 (all lung absorption types)[a,b,c,d]	1.0×10^{1}	2.7×10^{-10}	1.0×10^{4}	2.7×10^{-7}
U (nat)[a]	1.0	2.7×10^{-11}	1.0×10^{3}	2.7×10^{-8}
U (enriched to 20% or less)[e]	1.0	2.7×10^{-11}	1.0×10^{3}	2.7×10^{-8}
U (dep)	1.0	2.7×10^{-11}	1.0×10^{3}	2.7×10^{-8}

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Vanadium (23)				
V-48	1.0×10^{1}	2.7×10^{-10}	1.0×10^{5}	2.7×10^{-6}
V-49	1.0×10^{4}	2.7×10^{-7}	1.0×10^{7}	2.7×10^{-4}
Tungsten (74)				
W-178	1.0×10^{1}	2.7×10^{-10}	1.0×10^{6}	2.7×10^{-5}
W-181	1.0×10^{3}	2.7×10^{-8}	1.0×10^{7}	2.7×10^{-4}
W-185	1.0×10^{4}	2.7×10^{-7}	1.0×10^{7}	2.7×10^{-4}
W-187	1.0×10^{2}	2.7×10^{-9}	1.0×10^{6}	2.7×10^{-5}
W-188	1.0×10^{2}	2.7×10^{-9}	1.0×10^{5}	2.7×10^{-6}
Xenon (54)				
Xe-122	1.0×10^{2}	2.7×10^{-9}	1.0×10^{9}	2.7×10^{-2}
Xe-123	1.0×10^{2}	2.7×10^{-9}	1.0×10^{9}	2.7×10^{-2}
Xe-127	1.0×10^{3}	2.7×10^{-8}	1.0×10^{5}	2.7×10^{-6}
Xe-131m	1.0×10^{4}	2.7×10^{-7}	1.0×10^{4}	2.7×10^{-7}
Xe-133	1.0×10^{3}	2.7×10^{-8}	1.0×10^{4}	2.7×10^{-7}
Xe-135	1.0×10^{3}	2.7×10^{-8}	1.0×10^{10}	2.7×10^{-1}
Yttrium (39)				
Y-87	1.0×10^{1}	2.7×10^{-10}	1.0×10^{6}	2.7×10^{-5}
Y-88	1.0×10^{1}	2.7×10^{-10}	1.0×10^{6}	2.7×10^{-5}
Y-90	1.0×10^{3}	2.7×10^{-8}	1.0×10^{5}	2.7×10^{-6}
Y-91	1.0×10^{3}	2.7×10^{-8}	1.0×10^{6}	2.7×10^{-5}
Y-91m	1.0×10^{2}	2.7×10^{-9}	1.0×10^{6}	2.7×10^{-5}
Y-92	1.0×10^{2}	2.7×10^{-9}	1.0×10^{5}	2.7×10^{-6}
Y-93	1.0×10^{2}	2.7×10^{-9}	1.0×10^{5}	2.7×10^{-6}
Ytterbium (70)				
Yb-169	1.0×10^{2}	2.7×10^{-9}	1.0×10^{7}	2.7×10^{-4}
Yb-175	1.0×10^{3}	2.7×10^{-8}	1.0×10^{7}	2.7×10^{-4}
Zinc (30)				
Zn-65	1.0×10^{1}	2.7×10^{-10}	1.0×10^{6}	2.7×10^{-5}
Zn-69	1.0×10^{4}	2.7×10^{-7}	1.0×10^{6}	2.7×10^{-5}
Zn-69m	1.0×10^{2}	2.7×10^{-9}	1.0×10^{6}	2.7×10^{-5}
Zirconium (40)				
Zr-88	1.0×10^{2}	2.7×10^{-9}	1.0×10^{6}	2.7×10^{-5}
Zr-93[a]	1.0×10^{3}	2.7×10^{-8}	1.0×10^{7}	2.7×10^{-4}
Zr-95	1.0×10^{1}	2.7×10^{-10}	1.0×10^{6}	2.7×10^{-5}
Zr-97[a]	1.0×10^{1}	2.7×10^{-10}	1.0×10^{5}	2.7×10^{-6}

[a]Parent nuclides and their progeny included in secular equilibrium are listed in the following:

Sr-90	Y-90
Zr-93	Nb-93m
Zr-97	Nb-97
Ru-106	Rh-106
Cs-137	Ba-137m
Ce-134	La-134
Ce-144	Pr-144

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Ba-140	La-140
Bi-212	Tl-208(0.36), Po-212(0.64)
Pb-210	Bi-210, Po-210
Pb-212	Bi-212, Tl-208 (0.36), Po-212 (0.64)
Rn-220	Po-216
Rn-222	Po-218, Pb-214, Bi-214, Po-214
Ra-223	Rn-219, Po-215, Pb-211, Bi-211, Tl-207
Ra-224	Rn-220, Po-216, Pb-212, Bi-212, Tl-208 (0.36), Po-212 (0.64)
Ra-226	Rn-222, Po-218, Pb-214, Bi-214, Po-214, Pb-210, Bi-210, Po-210
Ra-228	Ac-228
Th-226	Ra-222, Rn-218, Po-214
Th-228	Ra-224, Rn-220, Po-216, Pb-212, Bi-212, Tl-208 (0.36), Po-212 (0.64)
Th-229	Ra-225, Ac-225, Fr-221, At-217, Bi-213, Po-213, Pb-209
Th (nat)	Ra-228, Ac-228, Th-228, Ra-224, Rn-220, Po-216, Pb-212, Bi-212, Tl-208 ~~(0.64)~~ (0.36), Po-212 (0.64)
Th-234	Pa-234m
U-230	Th-226, Ra-222, Rn-218, Po-214
U-232	Th-228, Ra-224, Rn-220, Po-216, Pb-212, Bi-212, Tl-208 (0.36), Po-212 (0.64)
U-235	Th-231
U-238	Th-234, Pa-234m
U (nat)	Th-234, Pa-234m, U-234, Th-230, Ra-226, Rn-222, Po-218, Pb-214, Bi-214, Po-214, Pb-210, Bi-210, Po-210
U-240	Np-240m
Np-237	Pa-233
Am-242m	Am-242
Am-243	Np-239

[b]These values apply only to compounds of uranium that take the chemical form of UF_6, UO_2F_2 and $UO_2(NO_3)_2$ in both normal and accident conditions of transport.

[c]These values apply only to compounds of uranium that take the chemical form of UO_3, UF_4, UCl_4 and hexavalent compounds in both normal and accident conditions of transport.

[d]These values apply to all compounds of uranium other than those specified in notes b and c of this table.

[e]These values apply to unirradiated uranium only.

4731.0423 DETERMINATION OF A_1 AND A_2.

Subpart 1. **Generally.** Values of A_1 and A_2 for individual radionuclides, which are the bases for many activity limits elsewhere in this chapter, are given in part 4731.0422, subpart

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1a. The curie (Ci) values specified are obtained by converting from the Terabecquerel (TBq) values. The Terabecquerel values are the regulatory standard. The curie values are for information only and are not intended to be the regulatory standard. Where values of A_1 and A_2 are unlimited, it is for radiation control purposes only. For nuclear criticality safety, some materials are subject to controls placed on fissile material.

Subp. 2. **Individual radionuclides; not listed in part 4731.0422, subpart 1a.** For individual radionuclides whose identities are known, but which are not listed in part 4731.0422, subpart 1a, the A_1 and A_2 values contained in subpart 6 may be used. Otherwise, the licensee shall obtain prior commissioner, NRC, or agreement state approval of the radionuclides not listed in part 4731.0422, subpart 1a, before shipping the material.

Subp. 2a. **Individual radionuclides; not listed in part 4731.0422, subpart 3.** For individual radionuclides whose identities are known, but which are not listed in part 4731.0422, subpart 3, the exempt material activity concentration and exempt consignment activity values contained in subpart 6 may be used. Otherwise, the licensee shall obtain prior commissioner, NRC, or agreement state approval of the exempt material activity concentration and exempt consignment activity values for radionuclides not listed in part 4731.0422, subpart 3, before shipping the material.

Subp. 2b. **Prior approval.** The licensee must submit

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requests for prior approval, described under subparts 2 and 2a, to the commissioner, NRC, or agreement state, according to this chapter.

Subp. 3. **Radioactive decay chain.** In the calculations of A_1 and A_2 for a radionuclide not in part 4731.0422, subpart 1a, a single radioactive decay chain, in which radionuclides are present in their naturally occurring proportions and in which no daughter nuclide has a half-life longer than ten days or longer than that of the parent nuclide, shall be considered as a single radionuclide. The activity to be taken into account and the A_1 and A_2 value to be applied shall be those corresponding to the parent nuclide of the chain. In the case of radioactive decay chains in which any daughter nuclide has a half-life longer than ten days or greater than that of the parent radionuclide, the parent and those daughter radionuclides shall be considered as mixtures of different radionuclides.

Subp. 4. **Radionuclide mixture.** For mixtures of radionuclides whose identities and respective activities are known, the following conditions apply:

A. For special form radioactive material, the maximum quantity transported in a Type A package:

$$\sum_i \frac{B(i)}{A_1(i)} \leq 1$$

where B(i) is the activity of radionuclide i and $A_1(i)$ is the A_1 value for radionuclide i.

B. For normal form radioactive material, the maximum quantity transported in a Type A package:

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$$\sum_i \frac{B(i)}{A_2(i)} \leq 1$$

where B(i) is the activity of radionuclide i and $A_2(i)$ is the A_2 value for radionuclide i.

C. Alternatively, an A_1 value for mixtures of special form material may be determined as follows:

$$A_1 \text{ for mixture} = \frac{1}{\sum_i \frac{f(i)}{A_1(i)}}$$

where f(i) is the fraction of activity of radionuclide i in the mixture and $A_1(i)$ is the appropriate A_1 value for radionuclide i.

D. Alternatively, the A_2 value for mixtures of normal form material may be determined as follows:

$$A_2 \text{ for mixture} = \frac{1}{\sum_i \frac{f(i)}{A_2(i)}}$$

where f(i) is the fraction of activity of radionuclide i in the mixture and $A_2(i)$ is the appropriate A_2 value for radionuclide i.

E. The exempt activity concentration for mixtures of radionuclides may be determined as follows:

$$\text{Exempt activity concentration for mixture} = \frac{1}{\sum_i \frac{f(i)}{[A](i)}}$$

where f(i) is the fraction of activity concentration of radionuclide i in the mixture, and [A] is the activity

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concentration for exempt material containing radionuclide i.

F. The activity limit for an exempt consignment for mixtures of radionuclides may be determined as follows:

$$\text{Exempt consignment activity limit for mixture} = \frac{1}{\sum_i \frac{f(i)}{A(i)}}$$

where f(i) is the fraction of activity of radionuclide i in the mixture, and A is the activity limit for exempt consignments for radionuclide i.

Subp. 5. **Activities unknown.** When the identity of each radionuclide is known, but the individual activities of some of the radionuclides are not known, the radionuclides may be grouped and the lowest A_1 or A_2 value, as appropriate, for the radionuclides in each group may be used in applying the formulas in subpart 4. Groups may be based on the total alpha activity and the total beta/gamma activity when these are known, using the lowest A_1 or A_2 values for the alpha emitters and beta/gamma emitters.

Subp. 6. **General values for A_1 and A_2.**

	A_1		A_2	
Contents	(TBq)	(Ci)	(TBq)	(Ci)
Only beta- or gamma-emitting radionuclides are known to be present	1×10^{-1}	2.7×10^{0}	2×10^{-2}	5.4×10^{-1}
Only alpha-emitting radionuclides are known to be present	2×10^{-1}	5.4×10^{0}	9×10^{-5}	2.4×10^{-3}

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Contents	Activity concentration for exempt material (Bq/g)	Activity concentration for exempt material (Ci/g)	Activity limits for exempt consignments (Bq)	Activity limits for exempt consignments (Ci)
No relevant data are available	1×10^{-3}	2.7×10^{-2}	9×10^{-5}	2.4×10^{-3}
Only beta- or gamma-emitting radionuclides are known to be present	1×10^{1}	2.7×10^{-10}	1×10^{4}	2.7×10^{-7}
Only alpha-emitting radionuclides are known to be present	1×10^{-1}	2.7×10^{-12}	1×10^{3}	2.7×10^{-8}
No relevant data are available	1×10^{-1}	2.7×10^{-12}	1×10^{3}	2.7×10^{-8}

4731.0455 QUALITY ASSURANCE FOR TRANSPORTATION PACKAGES.

The licensee, certificate holder, and applicant for a certificate of compliance must comply with the requirements for quality assurance for transportation packages in Code of Federal Regulations, title 10, part 71, subpart H.

4731.0610 AUTHORIZED USE OF SPECIAL NUCLEAR MATERIAL.

Subpart 1. **Authority under license.** A licensee must confine the licensee's possession and use of special nuclear material to the locations and purposes authorized in the license. Except as otherwise provided in the license, a license issued under this chapter carries with it the right to receive title to, own, acquire, receive, possess, and use special

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nuclear material. Preparation for shipment and transport of special nuclear material must be according to parts 4731.0400 to 4731.0455.

[For text of subp 2, see M.R.]

4731.0780 FINANCIAL ASSURANCE AND RECORD KEEPING FOR DECOMMISSIONING.

[For text of subps 1 and 2, see M.R.]

Subp. 3. **Between ten mCi and 100 mCi.**

A. An applicant for a specific license authorizing possession and use of quantities of source material greater than ten millicuries (370 MBq) but less than or equal to 100 millicuries (3.7 GBq) in a readily dispersible form must:

(1) submit a decommissioning funding plan according to subpart 4; or

(2) submit a certification that financial assurance for decommissioning has been provided in the amount of $225,000, using one of the methods described under subpart 5. The certification may state that the appropriate assurance will be obtained after the application has been approved and the license issued but before the receipt of licensed material.

B. If an applicant defers execution of the financial instrument until after the license has been issued, a signed original of the financial instrument obtained to satisfy the requirements of subpart 5 must be submitted to the commissioner before receipt of licensed material.

C. If an applicant does not defer execution of the financial instrument, the applicant must submit to the

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commissioner, as part of the certification, a signed original of the financial instrument obtained to satisfy the requirements of subpart 5.

D. A holder of a specific license:

(1) issued on or after July 27, 1990, which is covered by subpart 1 or 2, shall provide financial assurance for decommissioning according to this part; and

(2) issued before July 27, 1990, and of a type described in subpart 1 shall submit a decommissioning funding plan as described in subpart 5 or a certification of financial assurance for decommissioning in an amount at least equal to $1,125,000 according to this part. If the licensee submits the certificate of financial assurance rather than a decommissioning funding plan, the licensee shall include a decommissioning funding plan in any application for license renewal. Licensees required to submit the $1,125,000 amount must do so by December 2, 2004.

[For text of subps 4 to 6, see M.R.]

4731.1010 POSTING WORKER NOTICES.

[For text of subpart 1, see M.R.]

Subp. 2. **Notice to employees.** Each licensee and each applicant for a specific license must prominently post a MDH Form 3, "Notice to Employees," provided by the commissioner. A copy of any revision of the Notice to Employees must be posted within 30 days of receiving the revised notice from the commissioner. Copies of the Notice to Employees may be obtained by writing to the Radioactive Materials Unit, Minnesota

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Department of Health, 625 Robert Street N, P.O. Box 64975, St. Paul, MN 55164-0975.

[For text of subps 3 and 4, see M.R.]

4731.2600 REPORTS; THEFT OR LOSS OF LICENSED MATERIAL.

Subpart 1. **Telephone reports.**

A. A licensee must report by telephone as follows:

(1) immediately after its occurrence becomes known to the licensee, any lost, stolen, or missing licensed material in an aggregate quantity equal to or greater than 1,000 times the quantity under part 4731.2800, under such circumstances that it appears to the licensee that an exposure could result to persons in unrestricted areas; or

(2) within 30 days after an occurrence of any lost, stolen, or missing licensed material becomes known to the licensee, all licensed material in a quantity greater than ten times the quantity under part 4731.2800 that is still missing at the time of the report.

[For text of item B, see M.R.]

[For text of subps 2 to 5, see M.R.]

4731.2800 QUANTITIES OF LICENSED MATERIAL REQUIRING LABELING.

[For text of subps 1 and 2, see M.R.]

Subp. 3. **Quantities requiring labeling.**

The following quantities of licensed material require labeling:

Radionuclide	Abbreviation	Quantity (µCi)
Hydrogen-3	H-3	1,000

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Beryllium-7	Be-7	1,000
Beryllium-10	Be-10	1
Carbon-11	C-11	1,000
Carbon-14	C-14	100
Fluorine-18	F-18	1,000
Sodium-22	Na-22	10
Sodium-24	Na-24	100
Magnesium-28	Mg-28	100
Aluminum-26	Al-26	10
Silicon-31	Si-31	1,000
Silicon-32	Si-32	1
Phosphorus-32	P-32	10
Phosphorus-33	P-33	100
Sulfur-35	S-35	100
Chlorine-36	Cl-36	10
Chlorine-38	Cl-38	1,000
Chlorine-39	Cl-39	1,000
Argon-39	Ar-39	1,000
Argon-41	Ar-41	1,000
Potassium-40	K-40	100
Potassium-42	K-42	1,000
Potassium-43	K-43	1,000
Potassium-44	K-44	1,000
Potassium-45	K-45	1,000
Calcium-41	Ca-41	100
Calcium-45	Ca-45	100
Calcium-47	Ca-47	100
Scandium-43	Sc-43	1,000
Scandium-44m	Sc-44m	100
Scandium-44	Sc-44	100
Scandium-46	Sc-46	10
Scandium-47	Sc-47	100
Scandium-48	Sc-48	100
Scandium-49	Sc-49	1,000
Titanium-44	Ti-44	1
Titanium-45	Ti-45	1,000
Vanadium-47	V-47	1,000
Vanadium-48	V-48	100

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1	Vanadium-49	V-49	1,000
2			
3	Chromium-48	Cr-48	1,000
4	Chromium-49	Cr-49	1,000
5	Chromium-51	Cr-51	1,000
6			
7	Manganese-51	Mn-51	1,000
8	Manganese-52m	Mn-52m	1,000
9	Manganese-52	Mn-52	100
10	Manganese-53	Mn-53	1,000
11	Manganese-54	Mn-54	100
12	Manganese-56	Mn-56	1,000
13			
14	Iron-52	Fe-52	100
15	Iron-55	Fe-55	100
16	Iron-59	Fe-59	10
17	Iron-60	Fe-60	1
18			
19	Cobalt-55	Co-55	100
20	Cobalt-56	Co-56	10
21	Cobalt-57	Co-57	100
22	Cobalt-58m	Co-58m	1,000
23	Cobalt-58	Co-58	100
24	Cobalt-60m	Co-60m	1,000
25	Cobalt-60	Co-60	1
26	Cobalt-61	Co-61	1,000
27	Cobalt-62m	Co-62m	1,000
28			
29	Nickel-56	Ni-56	100
30	Nickel-57	Ni-57	100
31	Nickel-59	Ni-59	100
32	Nickel-63	Ni-63	100
33	Nickel-65	Ni-65	1,000
34	Nickel-66	Ni-66	10
35			
36	Copper-60	Cu-60	1,000
37	Copper-61	Cu-61	1,000
38	Copper-64	Cu-64	1,000
39	Copper-67	Cu-67	1,000
40			
41	Zinc-62	Zn-62	100
42	Zinc-63	Zn-63	1,000
43	Zinc-65	Zn-65	10
44	Zinc-69m	Zn-69m	100
45	Zinc-69	Zn-69	1,000
46	Zinc-71m	Zn-71m	1,000
47	Zinc-72	Zn-72	100
48			
49	Gallium-65	Ga-65	1,000
50	Gallium-66	Ga-66	100
51	Gallium-67	Ga-67	1,000
52	Gallium-68	Ga-68	1,000
53	Gallium-70	Ga-70	1,000
54	Gallium-72	Ga-72	100

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1	Gallium-73	Ga-73	1,000
2			
3	Germanium-66	Ge-66	1,000
4	Germanium-67	Ge-67	1,000
5	Germanium-68	Ge-68	10
6	Germanium-69	Ge-69	1,000
7	Germanium-71	Ge-71	1,000
8	Germanium-75	Ge-75	1,000
9	Germanium-77	Ge-77	1,000
10	Germanium-78	Ge-78	1,000
11			
12	Arsenic-69	As-69	1,000
13	Arsenic-70	As-70	1,000
14	Arsenic-71	As-71	100
15	Arsenic-72	As-72	100
16	Arsenic-73	As-73	100
17	Arsenic-74	As-74	100
18	Arsenic-76	As-76	100
19	Arsenic-77	As-77	100
20	Arsenic-78	As-78	1,000
21			
22	Selenium-70	Se-70	1,000
23	Selenium-73m	Se-73m	1,000
24	Selenium-73	Se-73	100
25	Selenium-75	Se-75	100
26	Selenium-79	Se-79	100
27	Selenium-81m	Se-81m	1,000
28	Selenium-81	Se-81	1,000
29	Selenium-83	Se-83	1,000
30			
31	Bromine-74m	Br-74m	1,000
32	Bromine-74	Br-74	1,000
33	Bromine-75	Br-75	1,000
34	Bromine-76	Br-76	100
35	Bromine-77	Br-77	1,000
36	Bromine-80m	Br-80m	1,000
37	Bromine-80	Br-80	1,000
38	Bromine-82	Br-82	100
39	Bromine-83	Br-83	1,000
40	Bromine-84	Br-84	1,000
41			
42	Krypton-74	Kr-74	1,000
43	Krypton-76	Kr-76	1,000
44	Krypton-77	Kr-77	1,000
45	Krypton-79	Kr-79	1,000
46	Krypton-81	Kr-81	1,000
47	Krypton-83m	Kr-83m	1,000
48	Krypton-85m	Kr-85m	1,000
49	Krypton-85	Kr-85	1,000
50	Krypton-87	Kr-87	1,000
51	Krypton-88	Kr-88	1,000
52			
53	Rubidium-79	Rb-79	1,000
54	Rubidium-81m	Rb-81m	1,000

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1	Rubidium-81	Rb-81	1,000
2	Rubidium-82m	Rb-82m	1,000
3	Rubidium-83	Rb-83	100
4	Rubidium-84	Rb-84	100
5	Rubidium-86	Rb-86	100
6	Rubidium-87	Rb-87	100
7	Rubidium-88	Rb-88	1,000
8	Rubidium-89	Rb-89	1,000
9			
10	Strontium-80	Sr-80	100
11	Strontium-81	Sr-81	1,000
12	Strontium-83	Sr-83	100
13	Strontium-85m	Sr-85m	1,000
14	Strontium-85	Sr-85	100
15	Strontium-87m	Sr-87m	1,000
16	Strontium-89	Sr-89	10
17	Strontium-90	Sr-90	0.1
18	Strontium-91	Sr-91	100
19	Strontium-92	Sr-92	100
20			
21	Yttrium-86m	Y-86m	1,000
22	Yttrium-86	Y-86	100
23	Yttrium-87	Y-87	100
24	Yttrium-88	Y-88	10
25	Yttrium-90m	Y-90m	1,000
26	Yttrium-90	Y-90	10
27	Yttrium-91m	Y-91m	1,000
28	Yttrium-91	Y-91	10
29	Yttrium-92	Y-92	100
30	Yttrium-93	Y-93	100
31	Yttrium-94	Y-94	1,000
32	Yttrium-95	Y-95	1,000
33			
34	Zirconium-86	Zr-86	100
35	Zirconium-88	Zr-88	10
36	Zirconium-89	Zr-89	100
37	Zirconium-93	Zr-93	1
38	Zirconium-95	Zr-95	10
39	Zirconium-97	Zr-97	100
40			
41	Niobium-88	Nb-88	1,000
42	Niobium-89m (66 min)	Nb-89m	1,000
43	Niobium-89 (122 min)	Nb-89	1,000
44	Niobium-89	Nb-89	1,000
45	Niobium-90	Nb-90	100
46	Niobium-93m	Nb-93m	10
47	Niobium-94	Nb-94	1
48	Niobium-95m	Nb-95m	100
49	Niobium-95	Nb-95	100
50	Niobium-96	Nb-96	100
51	Niobium-97	Nb-97	1,000
52	Niobium-98	Nb-98	1,000
53			
54	Molybdenum-90	Mo-90	100

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1	Molybdenum-93m	Mo-93m	100
2	Molybdenum-93	Mo-93	10
3	Molybdenum-99	Mo-99	100
4	Molybdenum-101	Mo-101	1,000
5			
6	Technetium-93m	Tc-93m	1,000
7	Technetium-93	Tc-93	1,000
8	Technetium-94m	Tc-94m	1,000
9	Technetium-94	Tc-94	1,000
10	Technetium-96m	Tc-96m	1,000
11	Technetium-96	Tc-96	100
12	Technetium-97m	Tc-97m	100
13	Technetium-97	Tc-97	1,000
14	Technetium-98	Tc-98	10
15	Technetium-99m	Tc-99m	1,000
16	Technetium-99	Tc-99	100
17	Technetium-101	Tc-101	1,000
18	Technetium-104	Tc-104	1,000
19			
20	Ruthenium-94	Ru-94	1,000
21	Ruthenium-97	Ru-97	1,000
22	Ruthenium-103	Ru-103	100
23	Ruthenium-105	Ru-105	1,000
24	Ruthenium-106	Ru-106	1
25			
26	Rhodium-99m	Rh-99m	1,000
27	Rhodium-99	Rh-99	100
28	Rhodium-100	Rh-100	100
29	Rhodium-101m	Rh-101m	1,000
30	Rhodium-101	Rh-101	10
31	Rhodium-102m	Rh-102m	10
32	Rhodium-102	Rh-102	10
33	Rhodium-103m	Rh-103m	1,000
34	Rhodium-105	Rh-105	100
35	Rhodium-106m	Rh-106m	1,000
36	Rhodium-107	Rh-107	1,000
37			
38	Palladium-100	Pd-100	100
39	Palladium-101	Pd-101	1,000
40	Palladium-103	Pd-103	100
41	Palladium-107	Pd-107	10
42	Palladium-109	Pd-109	100
43			
44	Silver-102	Ag-102	1,000
45	Silver-103	Ag-103	1,000
46	Silver-104m	Ag-104m	1,000
47	Silver-104	Ag-104	1,000
48	Silver-105	Ag-105	100
49	Silver-106m	Ag-106m	100
50	Silver-106	Ag-106	1,000
51	Silver-108m	Ag-108m	1
52	Silver-110m	Ag-110m	10
53	Silver-111	Ag-111	100
54	Silver-112	Ag-112	100

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1	Silver-115	Ag-115	1,000
2			
3	Cadmium-104	Cd-104	1,000
4	Cadmium-107	Cd-107	1,000
5	Cadmium-109	Cd-109	1
6	Cadmium-113m	Cd-113m	0.1
7	Cadmium-113	Cd-113	100
8	Cadmium-115m	Cd-115m	10
9	Cadmium-115	Cd-115	100
10	Cadmium-117m	Cd-117m	1,000
11	Cadmium-117	Cd-117	1,000
12			
13	Indium-109	In-109	1,000
14	Indium-110 (69.1 min)	In-110	1,000
15	Indium-110 (4.9h)	In-110	1,000
16	Indium-111	In-111	100
17	Indium-112	In-112	1,000
18	Indium-113m	In-113m	1,000
19	Indium-114m	In-114m	10
20	Indium-115m	In-115m	1,000
21	Indium-115	In-115	100
22	Indium-116m	In-116m	1,000
23	Indium-117m	In-117m	1,000
24	Indium-117	In-117	1,000
25	Indium-119m	In-119m	1,000
26			
27	Tin-110	Sn-110	100
28	Tin-111	Sn-111	1,000
29	Tin-113	Sn-113	100
30	Tin-117m	Sn-117m	100
31	Tin-119m	Sn-119m	100
32	Tin-121m	Sn-121m	100
33	Tin-121	Sn-121	1,000
34	Tin-123m	Sn-123m	1,000
35	Tin-123	Sn-123	10
36	Tin-125	Sn-125	10
37	Tin-126	Sn-126	10
38	Tin-127	Sn-127	1,000
39	Tin-128	Sn-128	1,000
40			
41	Antimony-115	Sb-115	1,000
42	Antimony-116m	Sb-116m	1,000
43	Antimony-116	Sb-116	1,000
44	Antimony-117	Sb-117	1,000
45	Antimony-118m	Sb-118m	1,000
46	Antimony-119	Sb-119	1,000
47	Antimony-120 (16 min)	Sb-120	1,000
48	Antimony-120 (5.76d)	Sb-120	100
49	Antimony-122	Sb-122	100
50	Antimony-124m	Sb-124m	1,000
51	Antimony-124	Sb-124	10
52	Antimony-125	Sb-125	100
53	Antimony-126m	Sb-126m	1,000
54	Antimony-126	Sb-126	100

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1	Antimony-127	Sb-127	100
2	Antimony-128 (10.4 min)	Sb-128	1,000
3	Antimony-128 (9.01h)	Sb-128	100
4	Antimony-129	Sb-129	100
5	Antimony-130	Sb-130	1,000
6	Antimony-131	Sb-131	1,000
7			
8	Tellurium-116	Te-116	1,000
9	Tellurium-121m	Te-121m	10
10	Tellurium-121	Te-121	100
11	Tellurium-123m	Te-123m	10
12	Tellurium-123	Te-123	100
13	Tellurium-125m	Te-125m	10
14	Tellurium-127m	Te-127m	10
15	Tellurium-127	Te-127	1,000
16	Tellurium-129m	Te-129m	10
17	Tellurium-129	Te-129	1,000
18	Tellurium-131m	Te-131m	10
19	Tellurium-131	Te-131	100
20	Tellurium-132	Te-132	10
21	Tellurium-133m	Te-133m	100
22	Tellurium-133	Te-133	1,000
23	Tellurium-134	Te-134	1,000
24			
25	Iodine-120m	I-120m	1,000
26	Iodine-120	I-120	100
27	Iodine-121	I-121	1,000
28	Iodine-123	I-123	100
29	Iodine-124	I-124	10
30	Iodine-125	I-125	1
31	Iodine-126	I-126	1
32	Iodine-128	I-128	1,000
33	Iodine-129	I-129	1
34	Iodine-130	I-130	10
35	Iodine-131	I-131	1
36	Iodine-132m	I-132m	100
37	Iodine-132	I-132	100
38	Iodine-133	I-133	10
39	Iodine-134	I-134	1,000
40	Iodine-135	I-135	100
41			
42	Xenon-120	Xe-120	1,000
43	Xenon-121	Xe-121	1,000
44	Xenon-122	Xe-122	1,000
45	Xenon-123	Xe-123	1,000
46	Xenon-125	Xe-125	1,000
47	Xenon-127	Xe-127	1,000
48	Xenon-129m	Xe-129m	1,000
49	Xenon-131m	Xe-131m	1,000
50	Xenon-133m	Xe-133m	1,000
51	Xenon-133	Xe-133	1,000
52	Xenon-135m	Xe-135m	1,000
53	Xenon-135	Xe-135	1,000
54	Xenon-138	Xe-138	1,000

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1			
2	Cesium-125	Cs-125	1,000
3	Cesium-127	Cs-127	1,000
4	Cesium-129	Cs-129	1,000
5	Cesium-130	Cs-130	1,000
6	Cesium-131	Cs-131	1,000
7	Cesium-132	Cs-132	100
8	Cesium-134m	Cs-134m	1,000
9	Cesium-134	Cs-134	10
10	Cesium-135m	Cs-135m	1,000
11	Cesium-135	Cs-135	100
12	Cesium-136	Cs-136	10
13	Cesium-137	Cs-137	10
14	Cesium-138	Cs-138	1,000
15			
16	Barium-126	Ba-126	1,000
17	Barium-128	Ba-128	100
18	Barium-131m	Ba-131m	1,000
19	Barium-131	Ba-131	100
20	Barium-133m	Ba-133m	100
21	Barium-133	Ba-133	100
22	Barium-135m	Ba-135m	100
23	Barium-139	Ba-139	1,000
24	Barium-140	Ba-140	100
25	Barium-141	Ba-141	1,000
26	Barium-142	Ba-142	1,000
27			
28	Lanthanum-131	La-131	1,000
29	Lanthanum-132	La-132	100
30	Lanthanum-135	La-135	1,000
31	Lanthanum-137	La-137	10
32	Lanthanum-138	La-138	100
33	Lanthanum-140	La-140	100
34	Lanthanum-141	La-141	100
35	Lanthanum-142	La-142	1,000
36	Lanthanum-143	La-143	1,000
37			
38	Cerium-134	Ce-134	100
39	Cerium-135	Ce-135	100
40	Cerium-137m	Ce-137m	100
41	Cerium-137	Ce-137	1,000
42	Cerium-139	Ce-139	100
43	Cerium-141	Ce-141	100
44	Cerium-143	Ce-143	100
45	Cerium-144	Ce-144	1
46			
47	Praseodymium-136	Pr-136	1,000
48	Praseodymium-137	Pr-137	1,000
49	Praseodymium-138m	Pr-138m	1,000
50	Praseodymium-139	Pr-139	1,000
51	Praseodymium-142m	Pr-142m	1,000
52	Praseodymium-142	Pr-142	100
53	Praseodymium-143	Pr-143	100
54	Praseodymium-144	Pr-144	1,000

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1	Praseodymium-145	Pr-145	100
2	Praseodymium-147	Pr-147	1,000
3			
4	Neodymium-136	Nd-136	1,000
5	Neodymium-138	Nd-138	100
6	Neodymium-139m	Nd-139m	1,000
7	Neodymium-139	Nd-139	1,000
8	Neodymium-141	Nd-141	1,000
9	Neodymium-147	Nd-147	100
10	Neodymium-149	Nd-149	1,000
11	Neodymium-151	Nd-151	1,000
12			
13	Promethium-141	Pm-141	1,000
14	Promethium-143	Pm-143	100
15	Promethium-144	Pm-144	10
16	Promethium-145	Pm-145	10
17	Promethium-146	Pm-146	1
18	Promethium-147	Pm-147	10
19	Promethium-148m	Pm-148m	10
20	Promethium-148	Pm-148	10
21	Promethium-149	Pm-149	100
22	Promethium-150	Pm-150	1,000
23	Promethium-151	Pm-151	100
24			
25	Samarium-141m	Sm-141m	1,000
26	Samarium-141	Sm-141	1,000
27	Samarium-142	Sm-142	1,000
28	Samarium-145	Sm-145	100
29	Samarium-146	Sm-146	1
30	Samarium-147	Sm-147	100
31	Samarium-151	Sm-151	10
32	Samarium-153	Sm-153	100
33	Samarium-155	Sm-155	1,000
34	Samarium-156	Sm-156	1,000
35			
36	Europium-145	Eu-145	100
37	Europium-146	Eu-146	100
38	Europium-147	Eu-147	100
39	Europium-148	Eu-148	10
40	Europium-149	Eu-149	100
41	Europium-150 (12.62h)	Eu-150	100
42	Europium-150 (34.2y)	Eu-150	1
43	Europium-152m	Eu-152m	100
44	Europium-152	Eu-152	1
45	Europium-154	Eu-154	1
46	Europium-155	Eu-155	10
47	Europium-156	Eu-156	100
48	Europium-157	Eu-157	100
49	Europium-158	Eu-158	1,000
50			
51	Gadolinium-145	Gd-145	1,000
52	Gadolinium-146	Gd-146	10
53	Gadolinium-147	Gd-147	100
54	Gadolinium-148	Gd-148	0.001

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1	Gadolinium-149	Gd-149	100
2	Gadolinium-151	Gd-151	10
3	Gadolinium-152	Gd-152	100
4	Gadolinium-153	Gd-153	10
5	Gadolinium-159	Gd-159	100
6			
7	Terbium-147	Tb-147	1,000
8	Terbium-149	Tb-149	100
9	Terbium-150	Tb-150	1,000
10	Terbium-151	Tb-151	100
11	Terbium-153	Tb-153	1,000
12	Terbium-154	Tb-154	100
13	Terbium-155	Tb-155	1,000
14	Terbium-156m (5.0h)	Tb-156m	1,000
15	Terbium-156m (24.4h)	Tb-156m	1,000
16	Terbium-156	Tb-156	100
17	Terbium-157	Tb-157	10
18	Terbium-158	Tb-158	1
19	Terbium-160	Tb-160	10
20	Terbium-161	Tb-161	100
21			
22	Dysprosium-155	Dy-155	1,000
23	Dysprosium-157	Dy-157	1,000
24	Dysprosium-159	Dy-159	100
25	Dysprosium-165	Dy-165	1,000
26	Dysprosium-166	Dy-166	100
27			
28	Holmium-155	Ho-155	1,000
29	Holmium-157	Ho-157	1,000
30	Holmium-159	Ho-159	1,000
31	Holmium-161	Ho-161	1,000
32	Holmium-162m	Ho-162m	1,000
33	Holmium-162	Ho-162	1,000
34	Holmium-164m	Ho-164m	1,000
35	Holmium-164	Ho-164	1,000
36	Holmium-166m	Ho-166m	1
37	Holmium-166	Ho-166	100
38	Holmium-167	Ho-167	1,000
39			
40	Erbium-161	Er-161	1,000
41	Erbium-165	Er-165	1,000
42	Erbium-169	Er-169	100
43	Erbium-171	Er-171	100
44	Erbium-172	Er-172	100
45			
46	Thulium-162	Tm-162	1,000
47	Thulium-166	Tm-166	100
48	Thulium-167	Tm-167	100
49	Thulium-170	Tm-170	10
50	Thulium-171	Tm-171	10
51	Thulium-172	Tm-172	100
52	Thulium-173	Tm-173	100
53	Thulium-175	Tm-175	1,000
54			

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1	Ytterbium-162	Yb-162	1,000
2	Ytterbium-166	Yb-166	100
3	Ytterbium-167	Yb-167	1,000
4	Ytterbium-169	Yb-169	100
5	Ytterbium-175	Yb-175	100
6	Ytterbium-177	Yb-177	1,000
7	Ytterbium-178	Yb-178	1,000
8			
9	Lutetium-169	Lu-169	100
10	Lutetium-170	Lu-170	100
11	Lutetium-171	Lu-171	100
12	Lutetium-172	Lu-172	100
13	Lutetium-173	Lu-173	10
14	Lutetium-174m	Lu-174m	10
15	Lutetium-174	Lu-174	10
16	Lutetium-176m	Lu-176m	1,000
17	Lutetium-176	Lu-176	100
18	Lutetium-177m	Lu-177m	10
19	Lutetium-177	Lu-177	100
20	Lutetium-178m	Lu-178m	1,000
21	Lutetium-178	Lu-178	1,000
22	Lutetium-179	Lu-179	1,000
23			
24	Hafnium-170	Hf-170	100
25	Hafnium-172	Hf-172	1
26	Hafnium-173	Hf-173	1,000
27	Hafnium-175	Hf-175	100
28	Hafnium-177m	Hf-177m	1,000
29	Hafnium-178m	Hf-178m	0.1
30	Hafnium-179m	Hf-179m	10
31	Hafnium-180m	Hf-180m	1,000
32	Hafnium-181	Hf-181	10
33	Hafnium-182m	Hf-182m	1,000
34	Hafnium-182	Hf-182	0.1
35	Hafnium-183	Hf-183	1,000
36	Hafnium-184	Hf-184	100
37			
38	Tantalum-172	Ta-172	1,000
39	Tantalum-173	Ta-173	1,000
40	Tantalum-174	Ta-174	1,000
41	Tantalum-175	Ta-175	1,000
42	Tantalum-176	Ta-176	100
43	Tantalum-177	Ta-177	1,000
44	Tantalum-178	Ta-178	1,000
45	Tantalum-179	Ta-179	100
46	Tantalum-180m	Ta-180m	1,000
47	Tantalum-180	Ta-180	100
48	Tantalum-182m	Ta-182m	1,000
49	Tantalum-182	Ta-182	10
50	Tantalum-183	Ta-183	100
51	Tantalum-184	Ta-184	100
52	Tantalum-185	Ta-185	1,000
53	Tantalum-186	Ta-186	1,000
54			

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1	Tungsten-176	W-176	1,000
2	Tungsten-177	W-177	1,000
3	Tungsten-178	W-178	1,000
4	Tungsten-179	W-179	1,000
5	Tungsten-181	W-181	1,000
6	Tungsten-185	W-185	100
7	Tungsten-187	W-187	100
8	Tungsten-188	W-188	10
9			
10	Rhenium-177	Re-177	1,000
11	Rhenium-178	Re-178	1,000
12	Rhenium-181	Re-181	1,000
13	Rhenium-182 (12.7h)	Re-182	1,000
14	Rhenium-182 (64.0h)	Re-182	100
15	Rhenium-184m	Re-184m	10
16	Rhenium-184	Re-184	100
17	Rhenium-186m	Re-186m	10
18	Rhenium-186	Re-186	100
19	Rhenium-187	Re-187	1,000
20	Rhenium-188m	Re-188m	1,000
21	Rhenium-188	Re-188	100
22	Rhenium-189	Re-189	100
23			
24	Osmium-180	Os-180	1,000
25	Osmium-181	Os-181	1,000
26	Osmium-182	Os-182	100
27	Osmium-185	Os-185	100
28	Osmium-189m	Os-189m	1,000
29	Osmium-191m	Os-191m	1,000
30	Osmium-191	Os-191	100
31	Osmium-193	Os-193	100
32	Osmium-194	Os-194	1
33			
34	Iridium-182	Ir-182	1,000
35	Iridium-184	Ir-184	1,000
36	Iridium-185	Ir-185	1,000
37	Iridium-186	Ir-186	100
38	Iridium-187	Ir-187	1,000
39	Iridium-188	Ir-188	100
40	Iridium-189	Ir-189	100
41	Iridium-190m	Ir-190m	1,000
42	Iridium-190	Ir-190	100
43	Iridium-192 (73.8d)	Ir-192	1
44	Iridium-192m (1.4 min)	Ir-192m	10
45	Iridium-194m	Ir-194m	10
46	Iridium-194	Ir-194	100
47	Iridium-195m	Ir-195m	1,000
48	Iridium-195	Ir-195	1,000
49			
50	Platinum-186	Pt-186	1,000
51	Platinum-188	Pt-188	100
52	Platinum-189	Pt-189	1,000
53	Platinum-191	Pt-191	100
54	Platinum-193m	Pt-193m	100

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1	Platinum-193	Pt-193	1,000
2	Platinum-195m	Pt-195m	100
3	Platinum-197m	Pt-197m	1,000
4	Platinum-197	Pt-197	100
5	Platinum-199	Pt-199	1,000
6	Platinum-200	Pt-200	100
7			
8	Gold-193	Au-193	1,000
9	Gold-194	Au-194	100
10	Gold-195	Au-195	10
11	Gold-198m	Au-198m	100
12	Gold-198	Au-198	100
13	Gold-199	Au-199	100
14	Gold-200m	Au-200m	100
15	Gold-200	Au-200	1,000
16	Gold-201	Au-201	1,000
17			
18	Mercury-193m	Hg-193m	100
19	Mercury-193	Hg-193	1,000
20	Mercury-194	Hg-194	1
21	Mercury-195m	Hg-195m	100
22	Mercury-195	Hg-195	1,000
23	Mercury-197m	Hg-197m	100
24	Mercury-197	Hg-197	1,000
25	Mercury-199m	Hg-199m	1,000
26	Mercury-203	Hg-203	100
27			
28	Thallium-194m	Tl-194m	1,000
29	Thallium-194	Tl-194	1,000
30	Thallium-195	Tl-195	1,000
31	Thallium-197	Tl-197	1,000
32	Thallium-198m	Tl-198m	1,000
33	Thallium-198	Tl-198	1,000
34	Thallium-199	Tl-199	1,000
35	Thallium-200	Tl-200	1,000
36	Thallium-201	Tl-201	1,000
37	Thallium-202	Tl-202	100
38	Thallium-204	Tl-204	100
39			
40	Lead-195m	Pb-195m	1,000
41	Lead-198	Pb-198	1,000
42	Lead-199	Pb-199	1,000
43	Lead-200	Pb-200	100
44	Lead-201	Pb-201	1,000
45	Lead-202m	Pb-202m	1,000
46	Lead-202	Pb-202	10
47	Lead-203	Pb-203	1,000
48	Lead-205	Pb-205	100
49	Lead-209	Pb-209	1,000
50	Lead-210	Pb-210	0.01
51	Lead-211	Pb-211	100
52	Lead-212	Pb-212	1
53	Lead-214	Pb-214	100
54			

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1	Bismuth-200	Bi-200	1,000
2	Bismuth-201	Bi-201	1,000
3	Bismuth-202	Bi-202	1,000
4	Bismuth-203	Bi-203	100
5	Bismuth-205	Bi-205	100
6	Bismuth-206	Bi-206	100
7	Bismuth-207	Bi-207	10
8	Bismuth-210m	Bi-210m	0.1
9	Bismuth-210	Bi-210	1
10	Bismuth-212	Bi-212	10
11	Bismuth-213	Bi-213	10
12	Bismuth-214	Bi-214	100
13			
14	Polonium-203	Po-203	1,000
15	Polonium-205	Po-205	1,000
16	Polonium-207	Po-207	1,000
17	Polonium-210	Po-210	0.1
18			
19	Astatine-207	At-207	100
20	Astatine-211	At-211	10
21			
22	Radon-220	Rn-220	1
23	Radon-222	Rn-222	1
24			
25	Francium-222	Fr-222	100
26	Francium-223	Fr-223	100
27			
28	Radium-223	Ra-223	0.1
29	Radium-224	Ra-224	0.1
30	Radium-225	Ra-225	0.1
31	Radium-226	Ra-226	0.1
32	Radium-227	Ra-227	1,000
33	Radium-228	Ra-228	0.1
34			
35	Actinium-224	Ac-224	1
36	Actinium-225	Ac-225	0.01
37	Actinium-226	Ac-226	0.1
38	Actinium-227	Ac-227	0.001
39	Actinium-228	Ac-228	1
40			
41	Thorium-226	Th-226	10
42	Thorium-227	Th-227	0.01
43	Thorium-228	Th-228	0.001
44	Thorium-229	Th-229	0.001
45	Thorium-230	Th-230	0.001
46	Thorium-231	Th-231	100
47	Thorium-232	Th-232	100
48	Thorium-234	Th-234	10
49	Thorium-natural		100
50			
51	Protactinium-227	Pa-227	10
52	Protactinium-228	Pa-228	1
53	Protactinium-230	Pa-230	0.01
54	Protactinium-231	Pa-231	0.001

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1	Protactinium-232	Pa-232	1
2	Protactinium-233	Pa-233	100
3	Protactinium-234	Pa-234	100
4			
5	Uranium-230	U-230	0.01
6	Uranium-231	U-231	100
7	Uranium-232	U-232	0.001
8	Uranium-233	U-233	0.001
9	Uranium-234	U-234	0.001
10	Uranium-235	U-235	0.001
11	Uranium-236	U-236	0.001
12	Uranium-237	U-237	100
13	Uranium-238	U-238	100
14	Uranium-239	U-239	1,000
15	Uranium-240	U-240	100
16	Uranium-natural		100
17			
18	Neptunium-232	Np-232	100
19	Neptunium-233	Np-233	1,000
20	Neptunium-234	Np-234	100
21	Neptunium-235	Np-235	100
22	Neptunium-236 (1.15×10^5 y)	Np-236	0.001
23	Neptunium-236 (22.5h)	Np-236	1
24	Neptunium-237	Np-237	0.001
25	Neptunium-238	Np-238	10
26	Neptunium-239	Np-239	100
27	Neptunium-240	Np-240	1,000
28			
29	Plutonium-234	Pu-234	10
30	Plutonium-235	Pu-235	1,000
31	Plutonium-236	Pu-236	0.001
32	Plutonium-237	Pu-237	100
33	Plutonium-238	Pu-238	0.001
34	Plutonium-239	Pu-239	0.001
35	Plutonium-240	Pu-240	0.001
36	Plutonium-241	Pu-241	0.01
37	Plutonium-242	Pu-242	0.001
38	Plutonium-243	Pu-243	1,000
39	Plutonium-244	Pu-244	0.001
40	Plutonium-245	Pu-245	100
41			
42	Americium-237	Am-237	1,000
43	Americium-238	Am-238	100
44	Americium-239	Am-239	1,000
45	Americium-240	Am-240	100
46	Americium-241	Am-241	0.001
47	Americium-242m	Am-242m	0.001
48	Americium-242	Am-242	10
49	Americium-243	Am-243	0.001
50	Americium-244m	Am-244m	100
51	Americium-244	Am-244	10
52	Americium-245	Am-245	1,000
53	Americium-246m	Am-246m	1,000
54	Americium-246	Am-246	1,000

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Curium-238	Cm-238	100
Curium-240	Cm-240	0.1
Curium-241	Cm-241	1
Curium-242	Cm-242	0.01
Curium-243	Cm-243	0.001
Curium-244	Cm-244	0.001
Curium-245	Cm-245	0.001
Curium-246	Cm-246	0.001
Curium-247	Cm-247	0.001
Curium-248	Cm-248	0.001
Curium-249	Cm-249	1,000
Berkelium-245	Bk-245	100
Berkelium-246	Bk-246	100
Berkelium-247	Bk-247	0.001
Berkelium-249	Bk-249	0.1
Berkelium-250	Bk-250	10
Californium-244	Cf-244	100
Californium-246	Cf-246	1
Californium-248	Cf-248	0.01
Californium-249	Cf-249	0.001
Californium-250	Cf-250	0.001
Californium-251	Cf-251	0.001
Californium-252	Cf-252	0.001
Californium-253	Cf-253	0.1
Californium-254	Cf-254	0.001
Any alpha emitting radionuclide not listed above or mixtures or alpha emitters of unknown composition		0.001
Einsteinium-250	Es-250	100
Einsteinium-251	Es-251	100
Einsteinium-253	Es-253	0.1
Einsteinium-254m	Es-254m	1
Einsteinium-254	Es-254	0.01
Fermium-252	Fm-252	1
Fermium-253	Fm-253	1
Fermium-254	Fm-254	10
Fermium-255	Fm-255	1
Fermium-257	Fm-257	0.01
Mendelevium-257	Md-257	10
Mendelevium-258	Md-258	0.01
Any radionuclide other than alpha emitter radionuclides not listed above or mixtures of beta emitters of unknown composition		0.01

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4731.3075 TERMS AND CONDITIONS OF LICENSES.

[For text of subps 1 and 2, see M.R.]

Subp. 3. **Scope of license.** A person licensed by the commissioner under this chapter must confine the licensee's possession and use of radioactive material to the locations and purposes authorized in the license. Except as otherwise provided in the license, a license issued under parts 4731.3000 to 4731.7280 carries with it the right to receive, acquire, own, and possess radioactive material. Preparation for shipment and transport of radioactive material must be according to parts 4731.0400 to 4731.0455.

Subp. 4. **Bankruptcy.**

A. A general licensee required to register under part 4731.3215, subpart 3a, and a specific licensee issued a license under this chapter must notify the commissioner, in writing, immediately following the filing of a voluntary or involuntary petition for bankruptcy under any chapter of United States Code, title 11, by or against:

[For text of subitems (1) to (3), see M.R.]

[For text of item B, see M.R.]

[For text of subps 5 to 7, see M.R.]

Subp. 8. **Security requirements for portable gauges.** A portable gauge licensee must use a minimum of two independent physical controls that form tangible barriers to secure portable gauges from unauthorized removal, whenever portable gauges are not under the control and constant surveillance of the licensee.

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4731.3080 FINANCIAL ASSURANCE AND RECORD KEEPING FOR DECOMMISSIONING.

Subpart 1. **Decommissioning funding plan required.**

A. An applicant for a specific license authorizing the possession and use of unsealed radioactive material of half-life greater than 120 days and in quantities exceeding 10^5 times the applicable quantities under part 4731.3160 must submit a decommissioning funding plan according to subpart 5. A decommissioning funding plan must also be submitted when a combination of isotopes is involved, if R divided by 10^5 is greater than one (unity rule), where R is the sum of the ratios of the quantity of each isotope to the applicable value under part 4731.3160.

B. A holder of or an applicant for a specific license authorizing possession and use of sealed sources or plated foils of half-life greater than 120 days and in quantities exceeding 10^{12} times the applicable quantities set forth in part 4731.3160 or, when a combination of isotopes is involved, if R, as defined in subpart 1, divided by 10^{12} is greater than 1, must submit a decommissioning funding plan as described in subpart 5.

Subp. 2. **Plan or financial assurance required.**

A. A holder of or an applicant for a specific license authorizing possession and use of radioactive material of half-life greater than 120 days and in quantities specified in subpart 4 must:

[For text of subitems (1) and (2), see M.R.]

[For text of items B and C, see M.R.]

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[For text of subps 3 to 7, see M.R.]

4731.3215 GENERAL LICENSE; DETECTING, MEASURING, GAUGING, CONTROLLING, AND OTHER DEVICES.

[For text of subps 1 and 2, see M.R.]

Subp. 3. **Requirements.** A person who acquires, receives, possesses, uses, or transfers radioactive material in a device according to the general license issued under subpart 1 must:

[For text of items A to P, see M.R.]

Q. report changes to the mailing address for the location of use, including change in name of the general licensee, to the commissioner within 30 days of the effective date of the change. For a portable device, a report of address change is required only for a change in the device's primary place of storage; and

R. not hold devices that are not in use for more than two years. If a device with shutters is not being used, the shutters must be locked in the closed position. The testing required under item B need not be performed during the period of storage only. When a device is put back into service or transferred to another person, and has not been tested within the required test interval, the device must be tested for leakage before use or transfer and the shutters must be tested before use. Devices kept in standby for future use are excluded from the two-year time limit if the general licensee performs quarterly physical inventories of these devices while they are in standby.

Subp. 3a. **Registration of generally licensed devices.**

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A. A person to whom subpart 3 applies shall register generally licensed devices according to items B and C. These devices contain:

(1) at least ten millicuries (370 MBq) of cesium-137;

(2) at least 0.1 millicurie (3.7 MBq) of strontium-90;

(3) at least one millicurie (37 MBq) of cobalt-60; or

(4) at least one millicurie (37 MBq) of americium-241 or any other transuranic (any other element with an atomic number greater than uranium-92) based on the activity indicated on the label.

B. If in possession of a device meeting the criteria of item A, a person to whom subpart 3 applies must register the device annually with the commissioner and pay the fee required under Minnesota Statutes, section 144.1205.

(1) Registration must be done by verifying, correcting, or adding to the information provided in a request for registration received from the commissioner. Registration information must be submitted to the commissioner within 30 days of the date of the request for registration or as otherwise indicated in the request.

(2) A general licensee holding devices meeting the criteria of item A is subject to the bankruptcy notification requirement under part 4731.3075, subpart 4. Each address for a location of use under item C, subitem (4), represents a separate

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general license and requires a separate registration and fee.

(3) Persons generally licensed by an agreement state with respect to devices meeting the criteria in item A are not subject to registration under this item if the devices are used in areas subject to the commissioner's jurisdiction for a period of less than 180 days in any calendar year. The commissioner shall not request registration information from such licensees.

C. In registering devices under item B, a person to whom subpart 3 applies must furnish the following information and any other information specifically requested by the commissioner:

(1) name and mailing address of the general licensee;

(2) the following information about each device:

(a) the manufacturer or initial transferor;

(b) the model number;

(c) the serial number; and

(d) the radioisotope and activity, as indicated on the label;

(3) name, title, and telephone number of the responsible person designated as a representative of the general licensee under subpart 3, item P;

(4) address or location at which each device is used or stored. For portable devices, the address of the primary place of storage must be furnished;

(5) certification by the responsible

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representative of the general licensee that the information concerning the device has been verified through a physical inventory and checking of label information; and

(6) certification by the responsible representative of the general licensee that the responsible representative is aware of the requirements of the general license.

Subp. 4. **Limitation.** The general license issued under subpart 1 does not authorize the manufacture or import of devices containing radioactive material.

4731.3330 SPECIFIC LICENSE; CERTAIN DEVICES CONTAINING RADIOACTIVE MATERIALS; MANUFACTURE OR INITIAL TRANSFER.

Subpart 1. **Approval criteria.** An application for a specific license to manufacture or initially transfer devices containing radioactive material to a person generally licensed under part 4731.3215 or equivalent regulations of the NRC or an agreement state shall be approved if:

[For text of items A to D, see M.R.]

E. each device meeting the criteria of part 4731.3215, subpart 3a, bears a permanent embossed, etched, stamped, or engraved label affixed to the source housing if separable, or the device if the source housing is not separable, that includes the words "Caution-Radioactive Material" and, if practicable, the radiation symbol described in part 4731.2300.

[For text of subps 2 and 3, see M.R.]

Subp. 4. **Transfer for use under general license; requirements.** If a device containing radioactive material is to

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be transferred for use under a general license issued under part 4731.3215, a person that is licensed under this part must provide the information specified in this subpart to each person to whom a device is to be transferred. The information must be provided before the device may be transferred. In case of a transfer through an intermediate person, the information must also be provided to the intended user before the initial transfer to the intermediate person. The required information includes:

A. a copy of the general license issued under part 4731.3215. If part 4731.3215, subpart 3, items B to D, or 3a, do not apply to the particular device, those items may be omitted;

[For text of items B to E, see M.R.]

[For text of subps 5 to 11, see M.R.]

4731.3395 SPECIFIC LICENSE; RADIOACTIVE DRUGS FOR MEDICAL USE; MANUFACTURE, PREPARATION, OR TRANSFER.

[For text of subpart 1, see M.R.]

Subp. 2. **Pharmacy licensees.**

A. A licensee described in subpart 1, item B, subitem (3) or (4) may:

(1) prepare radioactive drugs for medical use, provided that the radioactive drug is prepared by either an authorized nuclear pharmacist, as specified in subitem (2) or item C, or an individual under the supervision of an authorized nuclear pharmacist, as specified in part 4731.4407; and

(2) allow a pharmacist to work as an authorized

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nuclear pharmacist if:

(a) the individual qualifies as an authorized nuclear pharmacist;

(b) the individual meets the requirements under parts 4731.4413 and 4731.4415 and the licensee has received an approved license amendment identifying the individual as an authorized nuclear pharmacist; or

(c) the individual is designated as an authorized nuclear pharmacist according to item C.

[For text of items B to D, see M.R.]

[For text of subps 3 and 4, see M.R.]

4731.3400 SPECIFIC LICENSE; SOURCES OR DEVICES FOR MEDICAL USE; MANUFACTURE AND DISTRIBUTION.

Subpart 1. **Approval criteria.** An application for a specific license to manufacture and distribute sources and devices containing radioactive material to persons licensed according to parts 4731.4400 to 4731.4527 for use as a calibration, transmission, or reference source or for the uses listed under parts 4731.4450, 4731.4460, and 4731.4463 shall be approved if:

[For text of items A to C, see M.R.]

[For text of subps 2 and 3, see M.R.]

4731.4030 PERFORMANCE REQUIREMENTS; INDUSTRIAL RADIOGRAPHY EQUIPMENT.

[For text of subpart 1, see M.R.]

Subp. 2. **Additional requirements.**

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[For text of items A and B, see M.R.]

C. Radiographic exposure devices intended for use as Type B transport containers must meet the applicable requirements under parts 4731.0400 to 4731.0455.

[For text of item D, see M.R.]

[For text of subps 3 and 4, see M.R.]

4731.4110 LABELING; PACKAGING; SECURITY.

[For text of subpart 1, see M.R.]

Subp. 2. **Required packaging.** A licensee may not transport licensed material unless the material is packaged, and the package is labeled, marked, and accompanied with appropriate shipping papers, according to parts 4731.0400 to 4731.0455.

[For text of subps 3 and 4, see M.R.]

4731.4140 RADIOGRAPHER TRAINING.

Subpart 1. **Requirements; radiographer.** A licensee may not permit an individual to act as a radiographer until the individual:

[For text of items A to C, see M.R.]

D. receives copies of and instruction in parts 4731.0200, 4731.0280, and 4731.0290; the applicable DOT regulations under parts 4731.0400 to 4731.0455; the applicable portions of parts 4731.1000 to 4731.2950; parts 4731.4000 to 4731.4360; the license under which the radiographer will perform industrial radiography; and the licensee's operating and emergency procedures;

[For text of items E to G, see M.R.]

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Subp. 2. **Requirements; radiographer's assistant.** A licensee may not permit an individual to act as a radiographer's assistant until the individual:

A. receives copies of and instruction in parts 4731.0200, 4731.0280, and 4731.0290; the applicable DOT regulations under parts 4731.0400 to 4731.0455; the applicable portions of parts 4731.1000 to 4731.2950; parts 4731.4000 to 4731.4360; the license under which the radiographer's assistant will perform industrial radiography; and the licensee's operating and emergency procedures;

[For text of items B and C, see M.R.]

[For text of subps 3 to 7, see M.R.]

4731.4403 SPECIFIC LICENSE; MEDICAL USE OF RADIOACTIVE MATERIALS.

[For text of subps 1 and 2, see M.R.]

Subp. 3. **License amendments.** A licensee must apply for and receive a license amendment:

[For text of item A, see M.R.]

B. before the licensee permits anyone to work as an authorized user, authorized nuclear pharmacist, or authorized medical physicist under the license, except:

(1) for an authorized user, an individual who meets the requirements under parts 4731.4415 and 4731.4433, subpart 1, item A; 4731.4436, subpart 1, item A; 4731.4443, subpart 1, item A; 4731.4444, item A; 4731.4445, item A; 4731.4458, subpart 1, item A; 4731.4461, item A; or 4731.4479, subpart 1, item A;

(2) for an authorized nuclear pharmacist, an

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individual who meets the requirements under parts 4731.4413, subpart 1, item A, and 4731.4415;

(3) for an authorized medical physicist, an individual who meets the requirements under parts 4731.4412, subpart 1, item A, and 4731.4415; or

[For text of subitem (4), see M.R.]

[For text of items C to G, see M.R.]

Subp. 4. **Notifications of changes.**

A. A licensee must provide the commissioner a copy of the board certification and written attestation signed by a preceptor, the license issued by the NRC or an agreement state, the permit issued by an NRC or agreement state master material license broad scope permittee, or the permit issued by an NRC or agreement state licensee of broad scope for each individual no later than 30 days after the date that the licensee allows, under subpart 3, item B, the individual to work as:

(1) an authorized user;

(2) an authorized nuclear pharmacist; or

(3) an authorized medical physicist.

B. A licensee must notify the commissioner by letter no later than 30 days after:

(1) an authorized user, an authorized nuclear pharmacist, a radiation safety officer, or an authorized medical physicist permanently discontinues performance of duties under the license or has a name change;

(2) the licensee's mailing address changes;

(3) the licensee's name changes, but the name

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change does not constitute a transfer of control of the license as described under part 4731.3075, subpart 2;

(4) the licensee has added to or changed the areas of use identified in the application or license where radioactive material is used according to part 4731.4432 or 4731.4434; or

(5) the licensee permits an authorized user or an individual qualified to be a radiation safety officer under parts 4731.4411 and 4731.4415, to function as a temporary radiation safety officer and to perform the functions of a radiation safety officer as described under part 4731.4405, subpart 1, item C.

C. A licensee must mail required documents to the address under part 4731.0200, subpart 4.

[For text of subps 5 to 7, see M.R.]

4731.4410 SUPPLIERS OF MEDICAL USE SEALED SOURCES OR DEVICES.

For medical use, a licensee may use only:

A. sealed sources or devices manufactured, labeled, packaged, and distributed according to a license issued under parts 4731.3000 to 4731.3175 and 4731.3400 or equivalent requirements of the NRC or an agreement state;

B. sealed sources or devices noncommercially transferred from a licensee licensed under parts 4731.4400 to 4731.4527 or equivalent requirements of the NRC or an agreement state; or

C. teletherapy sources manufactured and distributed according to a license issued under parts 4731.3000 to 4731.3175

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or equivalent requirements of the NRC or an agreement state.

4731.4411 RADIATION SAFETY OFFICER TRAINING.

Subpart 1. **Training and education requirements.** Except as provided under part 4731.4414, a licensee must require an individual fulfilling the responsibilities of a radiation safety officer as provided under part 4731.4405 to be an individual who:

A. is certified by a specialty board whose certification process has been recognized by the NRC or an agreement state and:

(1) has obtained written attestation, signed by a preceptor radiation safety officer, that the individual has satisfactorily completed the requirements in this item and subpart 2 and has achieved a level of radiation safety knowledge sufficient to function independently as a radiation safety officer for a medical use licensee; and

(2) has training in the radiation safety, regulatory issues, and emergency procedures for the types of use for which a licensee seeks approval. This training requirement may be satisfied by completing training that is supervised by a radiation safety officer, authorized medical physicist, authorized nuclear pharmacist, or authorized user, as appropriate, who is authorized for the types of use for which the licensee is seeking approval;

B. (1) has completed a structured educational program consisting of both:

(a) 200 hours of classroom and laboratory training in the following areas:

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i. radiation physics and instrumentation;

ii. radiation protection;

iii. mathematics pertaining to the use and measurement of radioactivity;

iv. radiation biology; and

v. radiation dosimetry;

(b) one year of full-time radiation safety experience under the supervision of an individual identified as the radiation safety officer on an NRC or agreement state license or permit issued by an NRC master material licensee that authorizes similar types of uses of radioactive material involving:

i. shipping, receiving, and performing related radiation surveys;

ii. using and performing checks for proper operation of instruments used to determine the activity of dosages, survey meters, and instruments used to measure radionuclides;

iii. securing and controlling radioactive material;

iv. using administrative controls to avoid mistakes in the administration of radioactive material;

v. using procedures to prevent or minimize radioactive contamination and using proper decontamination procedures;

vi. using emergency procedures to

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control radioactive material; and

vii. disposing of radioactive material;

(2) has obtained written attestation, signed by a preceptor radiation safety officer, that the individual has satisfactorily completed the requirements in this item and has achieved a level of radiation safety knowledge sufficient to function independently as a radiation safety officer for a medical use licensee; and

(3) has training in the radiation safety, regulatory issues, and emergency procedures for the types of use for which a licensee seeks approval. This training requirement may be satisfied by completing training that is supervised by a radiation safety officer, authorized medical physicist, authorized nuclear pharmacist, or authorized user, as appropriate, who is authorized for the types of use for which the licensee is seeking approval;

C. is a medical physicist who has been certified by a specialty board whose certification process has been recognized by the NRC or an agreement state under part 4731.4412 and has experience in radiation safety for similar types of use of radioactive material for which the licensee is seeking approval of the individual as radiation safety officer and:

(1) has obtained written attestation, signed by a preceptor radiation safety officer, that the individual has satisfactorily completed the requirements in this item and has achieved a level of radiation safety knowledge sufficient to

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function independently as a radiation safety officer for a medical use licensee; and

(2) has training in the radiation safety, regulatory issues, and emergency procedures for the types of use for which a licensee seeks approval. This training requirement may be satisfied by completing training that is supervised by a radiation safety officer, authorized medical physicist, authorized nuclear pharmacist, or authorized user, as appropriate, who is authorized for the types of use for which the licensee is seeking approval; or

D. is an authorized user, authorized medical physicist, or authorized nuclear pharmacist identified on the licensee's license and has experience with the radiation safety aspects of similar types of use of radioactive material for which the individual has radiation safety officer responsibilities and:

(1) has obtained written attestation, signed by a preceptor radiation safety officer, that the individual has satisfactorily completed the requirements in this item and has achieved a level of radiation safety knowledge sufficient to function independently as a radiation safety officer for a medical use licensee; and

(2) has training in the radiation safety, regulatory issues, and emergency procedures for the types of use for which a licensee seeks approval. This training requirement may be satisfied by completing training that is supervised by a radiation safety officer, authorized medical physicist,

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authorized nuclear pharmacist, or authorized user, as appropriate, who is authorized for the types of use for which the licensee is seeking approval.

Subp. 2. **Certification requirements.** A specialty board under subpart 1, item A, shall require all candidates for certification to:

A. (1) hold a bachelor's or graduate degree from an accredited college or university in physical science or engineering or biological science with a minimum of 20 college credits in physical science;

(2) have five or more years of professional experience in health physics, including at least three years in applied health physics. Graduate training may be substituted for no more than two years of the required experience; and

(3) pass an examination administered by diplomates of the specialty board, which evaluates knowledge and competence in radiation physics and instrumentation, radiation protection, mathematics pertaining to the use and measurement of radioactivity, radiation biology, and radiation dosimetry; or

B. (1) hold a master's or doctor's degree in physics, medical physics, other physical science, engineering, or applied mathematics from an accredited college or university;

(2) have two years of full-time practical training or supervised experience in medical physics:

(a) under the supervision of a medical physicist who is certified in medical physics by a specialty board recognized by the NRC or an agreement state; or

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(b) in clinical nuclear medicine facilities providing diagnostic or therapeutic services under the direction of physicians who meet the requirements for authorized users in part 4731.4436 or 4731.4443; and

(3) pass an examination, administered by diplomates of the specialty board, that assesses knowledge and competence in clinical diagnostic radiological or nuclear medicine physics and in radiation safety.

4731.4412 AUTHORIZED MEDICAL PHYSICIST TRAINING.

Subpart 1. **Training and education requirements.** Except as provided in part 4731.4414, a licensee must require an authorized medical physicist to be an individual who:

A. is certified by a specialty board whose certification process has been recognized by the NRC or an agreement state and:

(1) has obtained written attestation that the individual has satisfactorily completed the requirements in this item and subpart 2 and has achieved a level of competency sufficient to function independently as an authorized medical physicist for each type of therapeutic medical unit for which the individual is requesting authorized medical physicist status. The written attestation must be signed by a preceptor authorized medical physicist who meets the requirements in this part or equivalent agreement state requirements for an authorized medical physicist for each type of therapeutic medical unit for which the individual is requesting authorized medical physicist status; and

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(2) has training for the types of use for which authorization is sought that includes hands-on device operation, safety procedures, clinical use, and the operation of a treatment planning system. This training requirement may be satisfied by satisfactorily completing either a training program provided by the vendor or by training supervised by an authorized medical physicist authorized for the types of use for which the individual is seeking authorization; or

B. (1) holds a master's or doctor's degree in physics, medical physics, other physical science, engineering, or applied mathematics from an accredited college or university, and:

(a) has completed one year of full-time training in medical physics;

(b) has completed an additional year of full-time work experience under the supervision of an individual who meets the requirements for an authorized medical physicist for the types of use for which the individual is seeking authorization. This training and work experience must be conducted in clinical radiation facilities that provide high-energy, external beam therapy (photons and electrons with energies greater than or equal to 1,000,000 electron volts) and brachytherapy services and must include:

i. performing sealed source leak tests and inventories;

ii. performing decay corrections;

iii. performing full calibration and periodic spot checks of external beam treatment units,

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stereotactic radiosurgery units, and remote afterloading units as applicable; and

iv. conducting radiation surveys around external beam treatment units, stereotactic radiosurgery units, and remote afterloading units as applicable;

(2) has obtained written attestation that the individual has satisfactorily completed the requirements in this item and has achieved a level of competency sufficient to function independently as an authorized medical physicist for each type of therapeutic medical unit for which the individual is requesting authorized medical physicist status. The written attestation must be signed by a preceptor authorized medical physicist who meets the requirements in this part or equivalent NRC or agreement state requirements for an authorized medical physicist for each type of therapeutic medical unit for which the individual is requesting authorized medical physicist status; and

(3) has training for the types of use for which authorization is sought that includes hands-on device operation, safety procedures, clinical use, and the operation of a treatment planning system. This training requirement may be satisfied by satisfactorily completing either a training program provided by the vendor or by training supervised by an authorized medical physicist authorized for the types of use for which the individual is seeking authorization.

Subp. 2. **Certification requirements.** A specialty board under subpart 1, item A, shall require all candidates for

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certification to:

A. hold a master's or doctor's degree in physics, medical physics, or other physical science, engineering, or applied mathematics from an accredited college or university; and

B. have two years of full-time practical training or supervised experience in medical physics:

(1) under the supervision of a medical physicist who is certified in medical physics by a specialty board recognized by the commissioner, the NRC, or an agreement state; or

(2) in clinical radiation facilities providing high-energy, external beam therapy (photons and electrons with energies greater than or equal to 1,000,000 electron volts) and brachytherapy services under the direction of physicians who meet the requirements for authorized users in part 4731.4458 or 4731.4479; and

C. pass an examination, administered by diplomates of the specialty board, that assesses knowledge and competence in clinical radiation therapy, radiation safety, calibration, quality assurance, and treatment planning for external beam therapy, brachytherapy, and stereotactic radiosurgery.

4731.4413 AUTHORIZED NUCLEAR PHARMACIST TRAINING.

Subpart 1. **Training and education requirements.** Except as provided in part 4731.4414, a licensee must require an authorized nuclear pharmacist to be a pharmacist who:

A. is certified by a specialty board whose

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certification process has been recognized by the NRC or an agreement state and has obtained written attestation signed by a preceptor authorized nuclear pharmacist, that the individual has satisfactorily completed the requirements in subpart 2 and has achieved a level of competency sufficient to function independently as an authorized nuclear pharmacist; or

B. (1) has completed 700 hours in a structured educational program consisting of both:

(a) 200 hours of classroom and laboratory training in the following areas:

i. radiation physics and instrumentation;

ii. radiation protection;

iii. mathematics pertaining to the use and measurement of radioactivity;

iv. chemistry of radioactive material for medical use; and

v. radiation biology; and

(b) supervised practical experience in a nuclear pharmacy involving:

i. shipping, receiving, and performing related radiation surveys;

ii. using and performing checks for proper operation of instruments used to determine the activity of dosages, survey meters, and, if appropriate, instruments used to measure alpha- or beta-emitting radionuclides;

iii. calculating, assaying, and safely

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preparing dosages for patients or human research subjects;

iv. using administrative controls to avoid medical events in the administration of radioactive material; and

v. using procedures to prevent or minimize radioactive contamination and using proper decontamination procedures; and

(2) has obtained written attestation signed by a preceptor authorized nuclear pharmacist, that the individual has satisfactorily completed the requirements in this item and has achieved a level of competency sufficient to function independently as an authorized nuclear pharmacist.

Subp. 2. **Certification requirements.** A specialty board under subpart 1, item A, shall require all candidates for certification to:

A. have graduated from a pharmacy program accredited by the American Council on Pharmaceutical Education (ACPE) or have passed the Foreign Pharmacy Graduate Examination Committee (FPGEC) examination;

B. hold a current, active license to practice pharmacy;

C. provide evidence of having acquired at least 4,000 hours of training or experience in nuclear pharmacy practice. Academic training may be substituted for no more than 2,000 hours of the required training and experience; and

D. pass an examination in nuclear pharmacy, administered by diplomates of the specialty board, that assesses

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knowledge and competency in procurement, compounding, quality assurance, dispensing, distribution, health and safety, radiation safety, provision of information and consultation, monitoring patient outcomes, research, and development.

4731.4414 TRAINING; EXPERIENCED RADIATION SAFETY OFFICER, TELETHERAPY OR MEDICAL PHYSICIST, AUTHORIZED USER, AND NUCLEAR PHARMACIST.

[For text of item A, see M.R.]

B. An individual identified as a radiation safety officer, an authorized medical physicist, or an authorized nuclear pharmacist on an NRC or agreement state license; a permit issued by an NRC or agreement state broad scope licensee; an NRC or agreement state master material license permit; or a permit issued by a master material license permittee of broad scope between October 24, 2002, and April 29, 2005, need not comply with the training requirements of part 4731.4411, 4731.4412, or 4731.4413.

C. Physicians, dentists, or podiatrists identified as authorized users for the medical use of radioactive material on a license issued by the NRC or an agreement state; a permit issued by an NRC master material licensee; a permit issued by an NRC or agreement state broad scope licensee; or a permit issued by an NRC master material license broad scope permittee before October 24, 2002, who perform only those medical uses for which they were authorized on that date, need not comply with the training requirements of parts 4731.4432 to 4731.4479.

D. Physicians, dentists, or podiatrists identified as

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authorized users for the medical use of radioactive material on a license issued by the commissioner, the NRC, or an agreement state; a permit issued by an NRC master material licensee; a permit issued by an NRC or agreement state broad scope licensee; or a permit issued by an NRC master material license broad scope permittee who perform only those medical uses for which they were authorized between October 24, 2002, and April 29, 2005, need not comply with the training requirements of parts 4731.4432 to 4731.4479.

4731.4423 AUTHORIZATION FOR CALIBRATION, TRANSMISSION, AND REFERENCE USE.

A person authorized under part 4731.4403, subpart 1, for medical use of radioactive material may receive, possess, and use the following radioactive material for check, calibration, transmission, and reference use:

[For text of items A to C, see M.R.]

D. any radioactive material with a half-life longer than 120 days in individual amounts not to exceed the smaller of 200 microcuries (7.4 MBq) or 1,000 times the quantities in part 4731.3160; and

E. technetium-99m in amounts as needed.

4731.4427 RELEASE OF INDIVIDUALS CONTAINING UNSEALED RADIOACTIVE MATERIAL OR IMPLANTS.

A. A licensee may authorize release from licensee control of an individual who has been administered unsealed radioactive material or implants containing radioactive material

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if the total effective dose equivalent to any other individual from exposure to the released individual is not likely to exceed 0.5 rem (5 mSv).

[For text of items B to D, see M.R.]

4731.4432 UNSEALED RADIOACTIVE MATERIAL; UPTAKE, DILUTION, AND EXCRETION STUDIES; WRITTEN DIRECTIVE NOT REQUIRED.

Except for quantities that require a written directive under part 4731.4408 or 4731.4409, a licensee may use any unsealed radioactive material prepared for medical use for uptake, dilution, or excretion studies that is:

[For text of item A, see M.R.]

B. prepared by:

(1) an authorized nuclear pharmacist;

(2) a physician who is an authorized user and who meets the requirements of part 4731.4436 or parts 4731.4436, subpart 1, item C, subitem (1), unit (b), subunit vii, and 4731.4443; or

(3) an individual under the supervision, according to part 4731.4407, of the authorized nuclear pharmacist in subitem (1) or the physician who is an authorized user in subitem (2);

[For text of items C and D, see M.R.]

4731.4433 UPTAKE, DILUTION, AND EXCRETION STUDIES; TRAINING.

Subpart 1. **Training and education requirements.** Except as provided under part 4731.4414, a licensee must require the authorized user of unsealed radioactive material for the uses

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authorized under part 4731.4432 to be a physician who:

A. is certified by a medical specialty board whose certification process has been recognized by the NRC or an agreement state and has obtained written attestation, signed by a preceptor authorized user who meets the requirements of this part, part 4731.4436 or 4731.4443, or equivalent requirements of the NRC or an agreement state, that the individual has satisfactorily completed the requirements in subpart 2 and has achieved a level of competency sufficient to function independently as an authorized user for the medical uses authorized under part 4731.4432;

B. is an authorized user under part 4731.4436 or 4731.4443 or under equivalent requirements of the NRC or an agreement state; or

C. has:

(1) completed 60 hours of training and experience, including a minimum of eight hours of classroom and laboratory training, in basic radionuclide handling techniques applicable to the medical use of unsealed radioactive material for uptake, dilution, and excretion studies. The training and experience must include:

[For text of unit (a), see M.R.]

(b) work experience, under the supervision of an authorized user who meets the requirements under this part, part 4731.4436 or 4731.4443, or equivalent requirements of the NRC or an agreement state, involving:

i. ordering, receiving, and unpacking

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radioactive materials safely and performing the related radiation surveys;

ii. performing quality control procedures on instruments used to determine the activity of dosages and performing checks for proper operation of survey meters;

iii. calculating, measuring, and safely preparing patient or human research subject dosages;

iv. using administrative controls to prevent a medical event involving the use of unsealed radioactive material;

v. using procedures to safely contain spilled radioactive material and using proper decontamination procedures; and

vi. administering dosages of radioactive drugs to patients or human research subjects; and

(2) obtained written attestation, signed by a preceptor authorized user who meets the requirements of this part, part 4731.4436 or 4731.4443, or equivalent requirements of the NRC or an agreement state, that the individual has satisfactorily completed the requirements in this item and has achieved a level of competency sufficient to function independently as an authorized user for the medical uses authorized under part 4731.4432.

Subp. 2. **Certification requirements.** A specialty board under subpart 1, item A, shall require all candidates for certification to:

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A. complete 60 hours of training and experience in basic radionuclide handling techniques and radiation safety applicable to the medical use of unsealed radioactive material for uptake, dilution, and excretion studies that include the topics listed in subpart 1, item C, subitem (1), units (a) and (b); and

B. pass an examination, administered by diplomates of the specialty board, that assesses knowledge and competence in radiation safety, radionuclide handling, and quality control.

4731.4434 UNSEALED RADIOACTIVE MATERIAL; IMAGING AND LOCALIZATION STUDIES; WRITTEN DIRECTIVE NOT REQUIRED.

Except for quantities that require a written directive under part 4731.4408, a licensee may use any unsealed radioactive material prepared for medical use for imaging and localization studies that is:

A. obtained from a manufacturer or preparer licensed under part 4731.3395 or equivalent requirements of the NRC or an agreement state;

B. prepared by:

(1) an authorized nuclear pharmacist;

(2) a physician who is an authorized user and meets the requirements specified in part 4731.4436; or parts 4731.4436, subpart 1, item C, subitem (1), unit (b), subunit vii, and 4731.4443; or

(3) an individual under the supervision, according to part 4731.4407, of the authorized nuclear pharmacist in subitem (1) or the physician who is an authorized

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user in subitem (2);

C. obtained from and prepared by an NRC or agreement state licensee for use in research according to a radioactive drug research committee-approved protocol or an investigational new drug protocol accepted by the Food and Drug Administration; or

[For text of item D, see M.R.]

4731.4436 IMAGING AND LOCALIZATION STUDIES; TRAINING.

Subpart 1. **Training and education requirements.** Except as provided under part 4731.4414, a licensee must require an authorized user of unsealed radioactive material for the uses authorized under part 4731.4434 to be a physician who:

A. is certified by a medical specialty board whose certification process has been recognized by the NRC or an agreement state and has obtained written attestation, signed by a preceptor authorized user who meets the requirements in this part; or in item C, subitem (1), unit (b), subunit vii, and part 4731.4443; or equivalent requirements of the NRC or an agreement state, that the individual has satisfactorily completed the requirements in subpart 2 and has achieved a level of competency sufficient to function independently as an authorized user for the medical uses authorized under parts 4731.4432 and 4731.4434;

B. is an authorized user under part 4731.4443 and meets the requirements in item C, subitem (1), unit (b), subunit vii, or equivalent requirements of the NRC or an agreement state; or

C. has:

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(1) completed 700 hours of training and experience, including a minimum of 80 hours of classroom and laboratory training, in basic radionuclide handling techniques applicable to the medical use of unsealed radioactive material for imaging and localization studies. The training and experience must include, at a minimum:

[For text of unit (a), see M.R.]

(b) work experience, under the supervision of an authorized user who meets the requirements under this part; or in subunit vii and part 4731.4443; or equivalent requirements of the NRC or an agreement state, involving:

i. ordering, receiving, and unpacking radioactive materials safely and performing the related radiation surveys;

ii. performing quality control procedures on instruments used to determine the activity of dosages and performing checks for proper operation of survey meters;

[For text of subunits iii to vii, see M.R.]

(2) obtained written attestation, signed by a preceptor authorized user who meets the requirements in this part; or in subitem (1), unit (b), subunit vii, and part 4731.4443; or equivalent requirements of the NRC or an agreement state, that the individual has satisfactorily completed the requirements in this item and has achieved a level of competency sufficient to function independently as an authorized user for the medical uses authorized under parts 4731.4432 and 4731.4434.

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Subp. 2. **Certification requirements.** A specialty board shall require all candidates for certification to:

A. complete 700 hours of training and experience in basic radionuclide handling techniques and radiation safety applicable to the medical use of unsealed radioactive material for imaging and localization studies that include the topics listed in subpart 1, item C, subitem (1), units (a) and (b); and

B. pass an examination administered by diplomates of the specialty board, which assesses knowledge and competence in radiation safety, radionuclide handling, and quality control.

4731.4443 UNSEALED RADIOACTIVE MATERIAL; WRITTEN DIRECTIVE REQUIRED; TRAINING.

Subpart 1. **Training and education requirements.** Except as provided under part 4731.4414, a licensee must require an authorized user of unsealed radioactive material for the uses authorized under part 4731.4440 to be a physician who:

A. is certified by a medical specialty board whose certification process has been recognized by the NRC or an agreement state, meets the requirements in item B, subitem (1), unit (b), subunit vi, and has obtained written attestation that the individual has satisfactorily completed the requirements in this item and subpart 2 and has achieved a level of competency sufficient to function independently as an authorized user for the medical uses authorized under part 4731.4440. The written attestation must be signed by a preceptor authorized user who meets the requirements of this part or equivalent requirements of the NRC or an agreement state. A preceptor authorized user

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who meets the requirements in item B must also have experience in administering dosages in the same dosage category or categories under item B, subitem (1), unit (b), subunit vi, as the individual requesting authorized user status;

B. has:

(1) completed 700 hours of training and experience, including a minimum of 200 hours of classroom and laboratory training, in basic radionuclide handling techniques applicable to the medical use of unsealed radioactive material requiring a written directive. The training and experience must include:

[For text of unit (a), see M.R.]

(b) work experience, under the supervision of an authorized user who meets the requirements in this part or equivalent requirements of the NRC or an agreement state. A supervising authorized user who meets the requirements in this item must also have experience in administering dosages in the same dosage category or categories under subunit vi as the individual requesting authorized user status. The work experience must involve:

i. ordering, receiving, and unpacking radioactive materials safely and performing the related radiation surveys;

ii. performing quality control procedures on instruments used to determine the activity of dosages and performing checks for proper operation of survey meters;

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[For text of subunits iii to v, see M.R.]

vi. administering dosages of radioactive drugs to patients or human research subjects involving a minimum of three cases in each of the following categories for which the individual is requesting authorized user status: oral administration of less than or equal to 33 millicuries (1.22 GBq) of sodium iodide (I-131) for which a written directive is required; oral administration of greater than 33 millicuries (1.22 GBq) of sodium iodide (I-131) (experience with at least three cases also satisfies the requirement of oral administration of less than or equal to 33 millicuries of I-131); parenteral administration of any beta emitter, or a photon-emitting radionuclide with a photon energy less than 150 kilo electron volts for which a written directive is required; or parenteral administration of any other radionuclide for which a written directive is required; and

(2) obtained written attestation that the individual has satisfactorily completed the requirements in this item and has achieved a level of competency sufficient to function independently as an authorized user for the medical uses authorized under part 4731.4440. The written attestation must be signed by a preceptor authorized user who meets the requirements of this part or equivalent requirements of the NRC or an agreement state. A preceptor authorized user who meets the requirements in this item must also have experience in administering dosages in the same dosage category or categories under subitem (1), unit (b), subunit vi, as the individual

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requesting authorized user status.

Subp. 2. **Certification requirements.** A specialty board under subpart 1, item A, shall require all candidates for certification to:

A. successfully complete residency training in a radiation therapy or nuclear medicine training program or a program in a related medical specialty. These residency training programs must include 700 hours of training and experience as described in subpart 1, item B, subitem (1), units (a) and (b), subunits i to v. Eligible training programs must be approved by the Residency Review Committee of the Accreditation Council for Graduate Medical Education, the Royal College of Physicians and Surgeons of Canada, or the Committee on Postgraduate Training of the American Osteopathic Association; and

B. pass an examination, administered by diplomates of the specialty board, that tests knowledge and competence in radiation safety, radionuclide handling, quality assurance, and clinical use of unsealed radioactive material for which a written directive is required.

4731.4444 ORAL ADMINISTRATION OF SODIUM IODIDE I-131; QUANTITIES LESS THAN OR EQUAL TO 33 MILLICURIES (1.22 GBq); WRITTEN DIRECTIVE REQUIRED; TRAINING.

Except as provided under part 4731.4414, a licensee must require an authorized user for the oral administration of sodium iodide (I-131) requiring a written directive in quantities less than or equal to 33 millicuries (1.22 GBq) to be a physician who:

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A. is certified by a medical specialty board whose certification process has been recognized by the NRC or an agreement state and includes all of the requirements of item C, subitems (1) and (2), and who has obtained written attestation that the individual has satisfactorily completed the requirements of item C, subitems (1) and (2), and has achieved a level of competency sufficient to function independently as an authorized user for medical uses authorized under part 4731.4440. The written attestation must be signed by a preceptor authorized user who meets the requirements of this part, part 4731.4443 or 4731.4445, or equivalent requirements of the NRC or an agreement state. A preceptor authorized user who meets the requirement in part 4731.4443, subpart 1, item B, must also have experience in oral administration of less than or equal to 33 millicuries (1.22 GBq) of sodium iodide (I-131) for which a written directive is required or oral administration of greater than 33 millicuries (1.22 GBq) of sodium iodide (I-131) as specified in part 4731.4443, subpart 1, item B, subitem (1), unit (b), subunit vi;

B. is an authorized user under part 4731.4443, for oral administration of less than or equal to 33 millicuries (1.22 GBq) of sodium iodide (I-131) for which a written directive is required or oral administration of greater than 33 millicuries (1.22 GBq) of sodium iodide (I-131) under part 4731.4443 or 4731.4445, or under equivalent requirements of the NRC or an agreement state; or

C. has:

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(1) successfully completed 80 hours of classroom and laboratory training, applicable to the medical use of sodium iodide (I-131) for procedures requiring a written directive. The training must include:

[For text of units (a) to (e), see M.R.]

(2) work experience under the supervision of an authorized user who meets the requirements of this part, part 4731.4443 or 4731.4445, or equivalent requirements of the NRC or an agreement state. A supervising authorized user who meets the requirements in part 4731.4443, subpart 1, item B, must also have experience in oral administration of less than or equal to 33 millicuries (1.22 GBq) of sodium iodide (I-131) for which a written directive is required or oral administration of greater than 33 millicuries (1.22 GBq) of sodium iodide (I-131) as specified in part 4731.4443. The work experience must involve:

(a) ordering, receiving, and unpacking radioactive materials safely and performing the related radiation surveys;

(b) performing quality control procedures on instruments used to determine the activity of dosages and performing checks for the proper operation of survey meters;

[For text of units (c) to (f), see M.R.]

(3) obtained written attestation that the individual has satisfactorily completed the requirements of this item and has achieved a level of competency sufficient to function independently as an authorized user for medical uses authorized under part 4731.4440. The written attestation must

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be signed by a preceptor authorized user who meets the requirements of this part, part 4731.4443 or 4731.4445, or equivalent requirements of the NRC or an agreement state. A preceptor authorized user who meets the requirement in part 4731.4443, subpart 1, item B, must also have experience in oral administration of less than or equal to 33 millicuries (1.22 GBq) of sodium iodide (I-131) for which a written directive is required or oral administration of greater than 33 millicuries (1.22 GBq) of sodium iodide (I-131) as specified in part 4731.4443.

4731.4445 ORAL ADMINISTRATION OF SODIUM IODIDE; QUANTITIES GREATER THAN 33 MILLICURIES (1.22 GBq); WRITTEN DIRECTIVE REQUIRED; TRAINING.

Except as provided under part 4731.4414, a licensee must require an authorized user for the oral administration of sodium iodide (I-131) requiring a written directive in quantities greater than 33 millicuries (1.22 GBq) to be a physician who:

A. is certified by a medical specialty board whose certification process has been recognized by the NRC or an agreement state and includes all the requirements in item C, subitems (1) and (2), and who has obtained written attestation that the individual has satisfactorily completed the requirements of this item and has achieved a level of competency sufficient to function independently as an authorized user for medical uses authorized under part 4731.4440. The written attestation must be signed by a preceptor authorized user who meets the requirements in this part, part 4731.4443, or

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equivalent requirements of the NRC or an agreement state. A preceptor authorized user who meets the requirements in part 4731.4443, subpart 1, item B, must also have experience in the oral administration of I-131 in quantities greater than 33 millicuries as specified in part 4731.4443, subpart 1, item B, subitem (1), unit (b), subunit vi;

B. is an authorized user under part 4731.4443, subpart 1, item A; 4731.4443, subpart 1, item B, for the oral administration of I-131 in quantities greater than 33 millicuries under part 4731.4443, subpart 1, item B, subitem (1), unit (b), subunit vi; or equivalent requirements of the NRC or an agreement state; or

C. has:

(1) successfully completed 80 hours of classroom and laboratory training, applicable to the medical use of I-131 for procedures requiring a written directive. The training must include:

[For text of units (a) to (e), see M.R.]

(2) has work experience, under the supervision of an authorized user who meets the requirements under this part, part 4731.4443, subpart 1, item A or B, or equivalent requirements of the NRC or an agreement state. A supervising authorized user who meets the requirements in part 4731.4443, subpart 1, item B, must also have experience in the oral administration of I-131 in quantities greater than 33 millicuries under part 4731.4443, subpart 1, item B, subitem (1), unit (b), subunit vi. The work experience must involve:

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(a) ordering, receiving, and unpacking radioactive materials safely and performing the related radiation surveys;

(b) performing quality control procedures on instruments used to determine the activity of dosages and performing checks for proper operation of survey meters;

[For text of units (c) to (f), see M.R.]

(3) obtained written attestation that the individual has satisfactorily completed the requirements of this item and has achieved a level of competency sufficient to function independently as an authorized user for medical uses authorized under part 4731.4440. The written attestation must be signed by a preceptor authorized user who meets the requirements in this part, part 4731.4443, or equivalent requirements of the NRC or an agreement state. A preceptor authorized user who meets the requirements in part 4731.4443, subpart 1, item B, must also have experience in the oral administration of I-131 in quantities greater than 33 millicuries under part 4731.4443, subpart 1, item B, subitem (1), unit (b), subunit vi.

4731.4446 PARENTERAL ADMINISTRATION OF UNSEALED RADIOACTIVE MATERIAL; WRITTEN DIRECTIVE REQUIRED; TRAINING.

A. Except as provided in part 4731.4414, the licensee must require an authorized user for the parenteral administration requiring a written directive to be a physician who is:

(1) an authorized user under part 4731.4443 or

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equivalent requirements of the NRC or an agreement state;

(2) an authorized user under part 4731.4458 or 4731.4479 or equivalent requirements of the NRC or an agreement state and meets the requirements in item B; or

(3) certified by a medical specialty board whose certification process has been recognized by the NRC or an agreement state under part 4731.4458 or 4731.4479 and meets the requirements in item B.

B. The physician under item A, subitems (2) and (3), must have:

(1) successfully completed 80 hours of classroom and laboratory training, applicable to parenteral administrations, for which a written directive is required, of any beta emitter, or any photon-emitting radionuclide with a photon energy less than 150 keV or parenteral administration of any other radionuclide for which a written directive is required. The training must include:

(a) radiation physics and instrumentation;

(b) radiation protection;

(c) mathematics pertaining to the use and measurement of radioactivity;

(d) chemistry of radioactive material for medical use; and

(e) radiation biology;

(2) work experience, under the supervision of an authorized user who meets the requirements in this part or part 4731.4443, or equivalent requirements of the NRC or agreement

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state, in the parenteral administration, for which a written directive is required, of any beta emitter, or any photon-emitting radionuclide with a photon energy less than 150 keV or parenteral administration of any other radionuclide for which a written directive is required. A supervising authorized user who meets the requirements in part 4731.4443 must have experience in parenteral administration of any beta emitter, or a photon-emitting radionuclide with a photon energy less than 150 kilo electron volts for which a written directive is required or parenteral administration of any other radionuclide for which a written directive is required as specified in part 4731.4443, subpart 1, item B, subitem (1), unit (b), subunit vi. The work experience must involve:

(a) ordering, receiving, and unpacking radioactive materials safely and performing the related radiation surveys;

(b) performing quality control procedures on instruments used to determine the activity of dosages and performing checks for proper operation of survey meters;

(c) calculating, measuring, and safely preparing patient or human research subject dosages;

(d) using administrative controls to prevent a medical event involving the use of unsealed radioactive materials;

(e) using procedures to contain spilled radioactive materials safely and using proper decontamination procedures; and

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(f) administering dosages to patients or human research subjects, that include at least three cases involving the parenteral administration, for which a written directive is required, of any beta emitter, or any photon-emitting radionuclide with a photon energy less than 150 keV or at least three cases involving the parenteral administration of any other radionuclide for which a written directive is required; and

(3) obtained written attestation that the individual has satisfactorily completed the requirements in this item and item A, subitem (2) or (3), and has achieved a level of competency sufficient to function independently as an authorized user for the parenteral administration of unsealed radioactive material requiring a written directive. The written attestation must be signed by a preceptor authorized user who meets the requirements in this part, part 4731.4443, or equivalent requirements of the NRC or agreement state. A preceptor authorized user who meets the requirements in part 4731.4443 must have experience in parenteral administration of any beta emitter, or a photon-emitting radionuclide with a photon energy less than 150 kilo electron volts for which a written directive is required or parenteral administration of any other radionuclide for which a written directive is required as specified in part 4731.4443, subpart 1, item B, subitem (1), unit (b), subunit vi.

4731.4458 MANUAL BRACHYTHERAPY TRAINING.

Subpart 1. **Training and education requirements.** Except as

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provided under part 4731.4414, a licensee must require an authorized user of a manual brachytherapy source for the uses authorized under part 4731.4450 to be a physician who:

A. is certified by a medical specialty board whose certification has been recognized by the NRC or an agreement state and has obtained written attestation, signed by a preceptor authorized user who meets the requirements of this part or equivalent requirements of the NRC or an agreement state, that the individual has satisfactorily completed the requirements of subpart 2 and has achieved a level of competency sufficient to function independently as an authorized user of manual brachytherapy sources for the medical uses authorized under part 4731.4450; or

B. has:

(1) completed a structured educational program in basic radionuclide handling techniques applicable to the use of manual brachytherapy sources that includes:

[For text of units (a) and (b), see M.R.]

(2) completed three years of supervised clinical experience in radiation oncology, under an authorized user who meets the requirements of this part or equivalent requirements of the NRC or an agreement state, as part of a formal training program approved by the Residency Review Committee for Radiation Oncology of the Accreditation Council for Graduate Medical Education, the Royal College of Physicians and Surgeons of Canada, or the Committee on Postgraduate Training of the American Osteopathic Association. This experience may be

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obtained concurrently with the supervised work experience required under subitem (1), unit (b); and

(3) obtained written attestation, signed by a preceptor authorized user who meets the requirements of this part or equivalent requirements of the NRC or an agreement state, that the individual has satisfactorily completed the requirements of this item and has achieved a level of competency sufficient to function independently as an authorized user of manual brachytherapy sources for the medical uses authorized under part 4731.4450.

Subp. 2. **Certification requirements.** A specialty board under subpart 1, item A, shall require all candidates for certification to:

A. successfully complete a minimum of three years of residency training in a radiation oncology program approved by the Residency Review Committee of the Accreditation Council for Graduate Medical Education, the Royal College of Physicians and Surgeons of Canada, or the Committee on Postgraduate Training of the American Osteopathic Association; and

B. pass an examination, administered by diplomates of the specialty board, that tests knowledge and competence in radiation safety, radionuclide handling, treatment planning, quality assurance, and clinical use of manual brachytherapy.

4731.4459 OPHTHALMIC USE OF STRONTIUM-90; TRAINING.

Except as provided under part 4731.4414, a licensee must require an authorized user of strontium-90 for ophthalmic radiotherapy to be a physician who:

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A. is an authorized user under part 4731.4458 or equivalent requirements of the NRC or an agreement state; or

B. has:

(1) completed 24 hours of classroom and laboratory training applicable to the medical use of strontium-90 for ophthalmic radiotherapy. The training must include:

[For text of units (a) to (d), see M.R.]

(2) had supervised clinical training in ophthalmic radiotherapy under the supervision of an authorized user at a medical institution, clinic, or private practice that includes the use of strontium-90 for the ophthalmic treatment of five individuals. The supervised clinical training must involve:

[For text of units (a) to (d), see M.R.]

(3) obtained written attestation, signed by a preceptor authorized user who meets the requirements of this part, part 4731.4458, or equivalent requirements of the NRC or an agreement state, that the individual has satisfactorily completed the requirements in this item and has achieved a level of competency sufficient to function independently as an authorized user of strontium-90 for ophthalmic use.

4731.4461 USE OF SEALED SOURCES FOR DIAGNOSIS; TRAINING.

Except as provided under part 4731.4414, a licensee must require an authorized user of a diagnostic sealed source for use in a device authorized under part 4731.4460 to be a physician, dentist, or podiatrist who:

[For text of item A, see M.R.]

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B. has:

(1) completed eight hours of classroom and laboratory training in basic radionuclide handling techniques specifically applicable to the use of the device. The training must include:

(a) radiation physics and instrumentation;

(b) radiation protection;

(c) mathematics pertaining to the use and measurement of radioactivity; and

(d) radiation biology; and

(2) completed training in the use of the device for the uses requested.

4731.4479 REMOTE AFTERLOADER UNITS, TELETHERAPY UNITS, AND GAMMA STEREOTACTIC RADIOSURGERY UNITS; TRAINING.

Subpart 1. **Training and education requirements.** Except as provided under part 4731.4414, a licensee must require an authorized user of a sealed source for a use authorized under part 4731.4463 to be a physician who:

A. is certified by a medical specialty board whose certification process has been recognized by the NRC or an agreement state, meets the requirements in item B, subitem (4), and has obtained written attestation that the individual has satisfactorily completed the requirements in this item and subpart 2 and has achieved a level of competency sufficient to function independently as an authorized user of each type of therapeutic medical unit for which the individual is requesting authorized user status. The written attestation must be signed

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by a preceptor authorized user who meets the requirements of this part or equivalent requirements of the NRC or an agreement state for an authorized user for each type of therapeutic medical unit for which the individual is requesting authorized user status; or

B. has:

(1) completed a structured educational program in basic radionuclide techniques applicable to the use of a sealed source in a therapeutic medical unit that includes:

[For text of units (a) and (b), see M.R.]

(2) completed three years of supervised clinical experience in radiation therapy, under an authorized user who meets the requirements of this part or equivalent requirements of the NRC or an agreement state, as part of a formal training program approved by the Residency Review Committee for Radiation Oncology of the Accreditation Council for Graduate Medical Education, the Royal College of Physicians and Surgeons of Canada, or the Committee on Postgraduate Training of the American Osteopathic Association. The experience may be obtained concurrently with the supervised work experience required under subitem (1), unit (b);

(3) obtained written attestation that the individual has satisfactorily completed the requirements in this item and has achieved a level of competency sufficient to function independently as an authorized user of each type of therapeutic medical unit for which the individual is requesting authorized user status. The written attestation must be signed

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by a preceptor authorized user who meets the requirements of this part or equivalent requirements of the NRC or an agreement state for an authorized user for each type of therapeutic medical unit for which the individual is requesting authorized user status; and

(4) received training in device operation, safety procedures, and clinical use for the types of use for which authorization is sought. This training requirement may be satisfied by satisfactory completion of a training program provided by the vendor for new users or by receiving training supervised by an authorized user or authorized medical physicist, as appropriate, who is authorized for the types of use for which the individual is seeking authorization.

Subp. 2. **Certification requirements.** A specialty board under subpart 1, item A, shall require all candidates for certification to:

A. successfully complete a minimum of three years of residency training in a radiation therapy program approved by the Residency Review Committee of the Accreditation Council for Graduate Medical Education, the Royal College of Physicians and Surgeons of Canada, or the Committee on Postgraduate Training of the American Osteopathic Association; and

B. pass an examination, administered by diplomates of the specialty board, that tests knowledge and competence in radiation safety, radionuclide handling, treatment planning, quality assurance, and clinical use of stereotactic radiosurgery, remote afterloaders, and external beam therapy.

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4731.7050 LABELS, SECURITY, AND TRANSPORTATION PRECAUTIONS.

Subpart 1. **Labeling.**

[For text of items A and B, see M.R.]

C. A licensee may not transport licensed material unless the material is packaged, labeled, marked, and accompanied with appropriate shipping papers according to parts 4731.0400 to 4731.0455.

[For text of subp 2, see M.R.]

REPEALER. Minnesota Rules, parts 4731.0405; 4731.0410, subparts 5 and 6; and 4731.0422, subpart 1, are repealed.

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