

Chapter HFS 157

APPENDIX O

DETERMINATION OF A₁ AND A₂

- I. Values of A₁ and A₂ for individual radionuclides, which are the bases for many activity limits elsewhere in these regulations, are given in TABLE VI. The curie (Ci) values specified are obtained by converting from the Terabecquerel (TBq) figure. The curie values are expressed to 3 significant figures to assure that the difference in the TBq and Ci quantities is one tenth of one percent or less. Where values of A₁ or A₂ are unlimited, it is for radiation control purposes only. For nuclear criticality safety, some materials are subject to controls placed on fissile material.
- II. For individual radionuclides whose identities are known, but which are not listed in TABLE VI, the determination of the values of A₁ and A₂ requires department approval, except that the values of A₁ and A₂ in TABLE VII may be used without obtaining department approval.
- III. In the calculations of A₁ and A₂ for a radionuclide not in TABLE VI, 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 either longer than 10 days, or longer than that of the parent nuclide, shall be considered as a single radionuclide, and the activity to be taken into account, and the A₁ or A₂ value to be applied shall be those corresponding to the parent nuclide of that chain. In the case of radioactive decay chains in which any daughter nuclide has a half-life either longer than 10 days, or greater than that of the parent nuclide, the parent and those daughter nuclides shall be considered as mixtures of different nuclides.
- IV. 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:

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

- (b) For normal form radioactive material, the maximum quantity transported in a Type A package:

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

where B(i) is the activity of radionuclide i and A₁(i) and A₂(i) are the A₁ and A₂ values for radionuclide respectively.

Alternatively, an A₁ value for mixtures of special form material may be determined as follows:

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

where f(i) is the fraction of activity of nuclide i in the mixture and A₁(i) is the appropriate A₁ value for nuclide i.

An A_2 value for mixtures of normal form material may be determined as follows:

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

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

- V. 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 paragraph IV. 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.

TABLE VI
A₁ AND A₂ VALUES FOR RADIONUCLIDES

Symbol of RadioNuclide	Element and Atomic No.	A1	A1	A2	A2	Specific Activity	
		(TBq)	(Ci)	(TBq)	(Ci)	(TBq/g)	(Ci/g)
Ac-225	Actinium (89)	0.6	16.2	1x10 ⁻²	0.270	2.1x10 ³	5.8x10 ⁴
Ac-227		40	1080	2x10 ⁻⁵	5.41x10 ⁻⁴	2.7	7.2x10 ¹
Ac-228		0.6	16.2	0.4	10.8	8.4x10 ⁴	2.2x10 ⁶
Ag-105	Silver (47)	2	54.1	2	54.1	1.1x10 ³	3.0x10 ⁴
Ag-108m		0.6	16.2	0.6	16.2	9.7x10 ⁻¹	2.6x10 ¹
Ag-110m		0.4	10.8	0.4	10.8	1.8x10 ²	4.7x10 ³
Ag-111		0.6	16.2	0.5	13.5	5.8x10 ³	1.6x10 ⁵
Al-26	Aluminum (13)	0.4	10.8	0.4	10.8	7.0x10 ⁻⁴	1.9x10 ⁻²
Am-241	Americium (95)	2	54.1	2x10 ⁻⁴	5.41x10 ⁻³	1.3x10 ⁻¹	3.4
Am-242m		2	54.1	2x10 ⁻⁴	5.41x10 ⁻³	3.6x10 ⁻¹	1.0x10 ¹
Am-243		2	54.1	2x10 ⁻⁴	5.41x10 ⁻³	7.4x10 ⁻³	2.0x10 ¹
Ar-37	Argon (18)	40	1080	40	1080	3.7x10 ³	9.9x10 ⁴
Ar-39		20	541	20	541	1.3	3.4x10 ¹
Ar-41		0.6	16.2	0.6	16.2	1.5x10 ⁶	4.2x10 ⁷
Ar-42		0.2	5.41	0.2	5.41	9.6	2.6x10 ²
As-72	Arsenic (33)	0.2	5.41	0.2	5.41	6.2x10 ⁴	1.7x10 ⁶
As-73		40	1080	40	1080	8.2x10 ²	2.2x10 ⁴
As-74		1	27.0	0.5	13.5	3.7x10 ³	9.9x10 ⁴
As-76		0.2	5.41	0.2	5.41	5.8x10 ⁴	1.6x10 ⁶
As-77		20	541	0.5	13.5	3.9x10 ⁴	1.0x10 ⁶
At-211	Astatine (85)	30	811	2	54.1	7.6x10 ⁴	2.1x10 ⁶
Au-193	Gold (79)	6	162	6	162	3.4x10 ⁴	9.2x10 ⁵
Au-194		1	27.0	1	27.0	1.5x10 ⁴	4.1x10 ⁵
Au-195		10	270	10	270	1.4x10 ²	3.7x10 ³
Au-196		2	54.1	2	54.1	4.0x10 ³	1.1x10 ⁵
Au-198		3	81.1	0.5	13.5	9.0x10 ³	2.4x10 ⁵
Au-199		10	270	0.9	24.3	7.7x10 ³	2.1x10 ⁵
Ba-131	Barium (56)	2	54.1	2	54.1	3.1x10 ³	8.4x10 ⁴
Ba-133m		10	270	0.9	24.3	2.2x10 ⁴	6.1x10 ⁵
Ba-133		3	81.1	3	81.1	9.4	2.6x10 ²
Ba-140		0.4	10.8	0.4	10.8	2.7x10 ³	7.3x10 ⁴
Be-7	Beryllium (4)	20	541	20	541	1.3x10 ⁴	3.5x10 ⁵
Be-10		20	541	0.5	13.5	8.3x10 ⁻⁴	2.2x10 ⁻²
Bi-205	Bismuth (83)	0.6	16.2	0.6	16.2	1.5x10 ⁻³	4.2x10 ⁴
Bi-206		0.3	8.11	0.3	8.11	3.8x10 ³	1.0x10 ⁵
Bi-207		0.7	18.9	0.7	18.9	1.9	5.2x10 ¹

TABLE VI
A₁ AND A₂ VALUES FOR RADIONUCLIDES (Continued)

Symbol of RadioNuclide	Element and Atomic No.	A1	A1	A2	A2	Specific Activity	
		(TBq)	(Ci)	(TBq)	(Ci)	(TBq/g)	(Ci/g)
Bi-210m		0.3	8.11	3×10^{-2}	0.811	2.1×10^{-5}	5.7×10^{-4}
Bi-210		0.6	16.2	0.5	13.5	4.6×10^3	1.2×10^5
Bi-212		0.3	8.11	0.3	8.11	5.4×10^5	1.5×10^7
Bk-247	Berkelium (97)	2	54.1	2×10^{-4}	5.41×10^{-3}	3.8×10^{-2}	1.0
Bk-249		40	1080	8×10^{-2}	2.16	6.1×10^1	1.6×10^3
Br-76	Bromine (35)	0.3	8.11	0.3	8.11	9.4×10^4	2.5×10^6
Br-77		3	81.1	3	81.1	2.6×10^4	7.1×10^5
Br-82		0.4	10.8	0.4	10.8	4.0×10^4	1.1×10^6
C-11	Carbon (6)	1	27	0.5	13.5	3.1×10^7	8.4×10^8
C-14		40	1080	2	54.1	1.6×10^{-1}	4.5
Ca-41	Calcium (20)	40	1080	40	1080	3.1×10^{-3}	8.5×10^{-2}
Ca-45		40	1080	0.9	24.3	6.6×10^2	1.8×10^4
Ca-47		0.9	24.3	0.5	13.5	2.3×10^4	6.1×10^5
Cd-109	Cadmium (48)	40	1080	1	27.0	9.6×10^1	2.6×10^3
Cd-113m		20	541	9×10^{-2}	2.43	8.3	2.2×10^2
Cd-115m		0.3	8.11	0.3	8.11	9.4×10^2	2.5×10^4
Cd-115		4	108	0.5	13.5	1.9×10^4	5.1×10^5
Ce-139	Cerium (58)	6	162	6	162	2.5×10^2	6.8×10^3
Ce-141		10	270	0.5	13.5	1.1×10^3	2.8×10^4
Ce-143		0.6	16.2	0.5	13.5	2.5×10^4	6.6×10^5
Ce-144		0.2	5.41	0.2	5.41	1.2×10^2	3.2×10^3
Cf-248	Californium (98)	30	811	3×10^{-3}	8.11×10^{-2}	5.8×10^1	1.6×10^3
Cf-249		2	54.1	2×10^{-4}	2×10^{-4}	5.41×10^{-3}	1.5×10^{-1}
Cf-250		5	135	5×10^{-4}	1.35×10^{-2}	4.0	1.1×10^2
Cf-251		2	54.1	2×10^{-4}	5.41×10^{-3}	5.9×10^{-2}	1.6
Cf-252		0.1	2.70	1×10^{-3}	2.70×10^{-2}	2.0×10^1	5.4×10^2
Cf-253		40	1080	6×10^{-2}	1.62	1.1×10^3	2.9×10^4
Cf-254		3×10^{-3}	8.11×10^{-2}	6×10^{-4}	1.62×10^{-2}	3.1×10^2	8.5×10^3
Cl-36	Chlorine (17)	20	541	0.5	13.5	1.2×10^{-3}	3.3×10^{-2}
Cl-38		0.2	5.41	0.2	5.41	4.9×10^6	1.3×10^8
Cm-240	Curium (96)	40	1080	2×10^{-2}	0.541	7.5×10^2	2.0×10^4
Cm-241		2	54.1	0.9	24.3	6.1×10^2	1.7×10^4
Cm-242		40	1080	1×10^{-2}	0.270	1.2×10^2	3.3×10^3
Cm-243		3	81.1	3×10^{-4}	8.11×10^{-3}	1.9	5.2×10^1
Cm-244		4	108	4×10^{-4}	1.08×10^{-2}	3.0	8.1×10^1
Cm-245		2	54.1	2×10^{-4}	5.41×10^{-3}	6.4×10^{-3}	1.7×10^{-1}

TABLE VI
A₁ AND A₂ VALUES FOR RADIONUCLIDES (Continued)

Symbol of RadioNuclide	Element and Atomic No.	A ₁	A ₁	A ₂	A ₂	Specific Activity	
		(TBq)	(Ci)	(TBq)	(Ci)	(TBq/g)	(Ci/g)
Cm-246		2	54.1	2x10 ⁻⁴	5.41x10 ⁻³	1.1x10 ⁻²	3.1x10 ⁻¹
Cm-247		2	54.1	2x10 ⁻⁴	5.41x10 ⁻³	3.4x10 ⁻⁶	9.3x10 ⁻⁵
Cm-248		4x10 ⁻²	1.08	5x10 ⁻⁵	1.35x10 ⁻³	1.6x10 ⁻⁴	4.2x10 ³
Co-55	Cobalt (27)	0.5	13.5	0.5	13.5	1.1x10 ⁵	3.1x10 ⁶
Co-56		0.3	8.11	0.3	8.11	1.1x10 ³	3.0x10 ⁴
Co-57		8	216	8	216	3.1x10 ²	8.4x10 ³
Co-58m		40	1080	40	1080	2.2x10 ⁵	5.9x10 ⁶
Co-58		1	27.0	1	27.0	1.2x10 ³	3.2x10 ⁴
Co-60		0.4	10.8	0.4	10.8	4.2x10 ¹	1.1x10 ³
Cr-51	Chromium (24)	30	811	30	811	3.4x10 ³	9.2x10 ⁴
Cs-129	Cesium (55)	4	108	4	108	2.8x10 ⁴	7.6x10 ⁵
Cs-131		40	1080	40	1080	3.8x10 ³	1.0x10 ⁵
Cs-132		1	27.0	1	27.0	5.7x10 ³	1.5x10 ⁵
Cs-134m		40	1080	9	243	3.0x10 ⁵	8.0x10 ⁶
Cs-134		0.6	16.2	0.5	13.5	4.8x10 ¹	1.3x10 ³
Cs-135		40	1080	0.9	24.3	4.3x10 ⁻⁵	1.2x10 ⁻³
Cs-136		0.5	13.5	0.5	13.5	2.7x10 ³	7.3x10 ⁴
Cs-137		2	54.1	0.5	13.5	3.2	8.7x10 ¹
Cu-64	Copper (29)	5	135	0.9	24.3	1.4x10 ⁵	3.9x10 ⁶
Cu-67		9	243	0.9	24.3	2.8x10 ⁴	7.6x10 ⁵
Dy-159	Dysprosium (66)	20	541	20	541	2.1x10 ²	5.7x10 ³
Dy-165		0.6	16.2	0.5	13.5	3.0x10 ⁵	8.2x10 ⁶
Dy-166		0.3	8.11	0.3	8.11	8.6x10 ³	2.3x10 ⁵
Er-169	Erbium (68)	40	1080	0.9	24.3	3.1x10 ³	8.3x10 ⁴
Er-171		0.6	16.2	0.5	13.5	9.0x10 ⁴	2.4x10 ⁶
Es-253	Einsteinium (99) ^{a/}	200	5400	2.1x10 ⁻²	5.4x10 ⁻¹	—	—
Es-254		30	811	3x10 ⁻³	8.11x10 ⁻²	—	—
Es-254m		0.6	16.2	0.4	10.8	—	—
Es-255		—	—	—	—	—	—
Eu-147	Europium (63)	2	54.1	2	54.1	1.4x10 ³	3.7x10 ⁴
Eu-148		0.5	13.5	0.5	13.5	6.0x10 ²	1.6x10 ⁴
Eu-149		20	541	20	541	3.5x10 ²	9.4x10 ³
Eu-150		0.7	18.9	0.7	18.9	6.1x10 ⁴	1.6x10 ⁶
Eu-152m		0.6	16.2	0.5	13.5	8.2x10 ⁴	2.2x10 ⁶
Eu-152		0.9	24.3	0.9	24.3	6.5	1.8x10 ²
Eu-154		0.8	21.6	0.5	13.5	9.8	2.6x10 ²

TABLE VI
A₁ AND A₂ VALUES FOR RADIONUCLIDES (Continued)

Symbol of RadioNuclide	Element and Atomic No.	A ₁ (TBq)	A ₁ (Ci)	A ₂ (TBq)	A ₂ (Ci)	Specific Activity (TBq/g)	Specific Activity (Ci/g)
Eu-155		20	541	2	54.1	1.8x10 ¹	4.9x10 ²
Eu-156		0.6	16.2	0.5	13.5	2.0x10 ³	5.5x10 ⁴
F-18	Fluorine (9)	1	27.0	0.5	13.5	3.5x10 ⁶	9.5x10 ⁷
Fe-52	Iron (26)	0.2	5.41	0.2	5.41	2.7x10 ⁵	7.3x10 ⁶
Fe-55		40	1080	40	1080	8.8x10 ¹	2.4x10 ³
Fe-59		0.8	21.6	0.8	21.6	1.8x10 ³	5.0x10 ⁴
Fe-60		40	1080	0.2	5.41	7.4x10 ⁻⁴	2.0x10 ⁻²
Fm-255	Fermium (100) ^{b/}	40	1080	0.8	21.6	—	—
Fm-257		10	270	8x10 ⁻³	21.6x10 ⁻¹	—	—
Ga-67	Gallium (31)	6	162	6	162	2.2x10 ⁴	6.0x10 ⁵
Ga-68		0.3	8.11	0.3	8.11	1.5x10 ⁶	4.1x10 ⁷
Ga-72		0.4	10.8	0.4	10.8	1.1x10 ⁵	3.1x10 ⁶
Gd-146	Gadolinium (64)	0.4	10.8	0.4	10.8	6.9x10 ²	1.9x10 ⁴
Gd-148		3	81.1	3x10 ⁻⁴	8.11x10 ⁻³	1.2	3.2x10 ¹
Gd-153		10	270	5	135	1.3x10 ²	3.5x10 ³
Gd-159		4	108	0.5	13.5	3.9x10 ⁴	1.1x10 ⁶
Ge-68	Germanium (32)	0.3	8.11	0.3	8.11	2.6x10 ²	7.1x10 ³
Ge-71		40	1080	40	1080	5.8x10 ³	1.6x10 ⁵
Ge-77		0.3	8.11	0.3	8.11	1.3x10 ⁵	3.6x10 ⁶
H-3	Hydrogen (1) See T-Tritium						
Hf-172	Hafnium (72)	0.5	13.5	0.3	8.11	4.1x10 ¹	1.1x10 ³
Hf-175		3	81.1	3	81.1	3.9x10 ²	1.1x10 ⁴
Hf-181		2	54.1	0.9	24.3	6.3x10 ²	1.7x10 ⁴
Hf-182		4	108	3x10 ⁻²	0.811	8.1x10 ⁻⁶	2.2x10 ⁻⁴
Hg-194	Mercury (80)	1	27.0	1	27.0	1.3x10 ⁻¹	3.5
Hg-195m		5	135	5	135	1.5x10 ⁴	4.0x10 ⁵
Hg-197m		10	270	0.9	24.3	2.5x10 ⁴	6.7x10 ⁵
Hg-197		10	270	10	270	9.2x10 ³	2.5x10 ⁵
Hg-203		4	108	0.9	24.3	5.1x10 ²	1.4x10 ⁴
Ho-163	Holmium (67)	40	1080	40	1080	2.7	7.6x10 ¹
Ho-166m		0.6	16.2	0.3	8.11	6.6x10 ⁻²	1.8
Ho-166		0.3	8.11	0.3	8.11	2.6x10 ⁴	7.0x10 ⁵
I-123	Iodine (53)	6	162	6	162	7.1x10 ⁴	1.9x10 ⁶
I-124		0.9	24.3	0.9	24.3	9.3x10 ³	2.5x10 ⁵
I-125		20	541	2	54.1	6.4x10 ²	1.7x10 ⁴
I-126		2	54.1	0.9	24.3	2.9x10 ³	8.0x10 ⁴

TABLE VI
A₁ AND A₂ VALUES FOR RADIONUCLIDES (Continued)

Symbol of RadioNuclide	Element and Atomic No.	A ₁ (TBq)	A ₁ (Ci)	A ₂ (TBq)	A ₂ (Ci)	Specific Activity (TBq/g)	Specific Activity (Ci/g)
I-129		Unlimited	Unlimited	Unlimited	Unlimited	6.5x10 ⁻⁶	1.8x10 ⁻⁴
I-131		3	81.1	0.5	13.5	4.6x10 ³	1.2x10 ⁵
I-132		0.4	10.8	0.4	10.8	3.8x10 ⁵	1.0x10 ⁷
I-133		0.6	16.2	0.5	13.5	4.2x10 ⁴	1.1x10 ⁶
I-134		0.3	8.11	0.3	8.11	9.9x10 ⁵	2.7x10 ⁷
I-135		0.6	16.2	0.5	13.5	1.3x10 ⁵	3.5x10 ⁶
In-111	Indium (49)	2	54.1	2	54.1	1.5x10 ⁴	4.2x10 ⁵
In-113m		4	108	4	108	6.2x10 ⁵	1.7x10 ⁷
In-114m		0.3	8.11	0.3	8.11	8.6x10 ²	2.3x10 ⁴
In-115m		6	162	0.9	24.3	2.2x10 ⁵	6.1x10 ⁶
Ir-189	Iridium (77)	10	270	10	270	1.9x10 ³	5.2x10 ⁴
Ir-190		0.7	18.9	0.7	18.9	2.3x10 ³	6.2x10 ⁴
Ir-192		1	27.0	0.5	13.5	3.4x10 ²	9.2x10 ³
Ir-193m		10	270	10	270	2.4x10 ³	6.4x10 ⁴
Ir-194		0.2	5.41	0.2	5.41	3.1x10 ⁴	8.4x10 ⁵
K-40	Potassium (19)	0.6	16.2	0.6	16.2	2.4x10 ⁻⁷	6.4x10 ⁻⁶
K-42		0.2	5.41	0.2	5.41	2.2x10 ⁵	6.0x10 ⁶
K-43		1.0	27.0	0.5	13.5	1.2x10 ⁵	3.3x10 ⁶
Kr-81	Krypton (36)	40	1080	40	1080	7.8x10 ⁻⁴	2.1x10 ⁻²
Kr-85m		6	162	6	162	3.0x10 ⁵	8.2x10 ⁶
Kr-85		20	541	10	270	1.5x10 ¹	3.9x10 ²
Kr-87		0.2	5.41	0.2	5.41	1.0x10 ⁶	2.8x10 ⁷
La-137	Lanthanum (57)	40	1080	2	54.1	1.6x10 ⁻³	4.4x10 ⁻²
La-140		0.4	10.8	0.4	10.8	2.1x10 ⁴	5.6x10 ⁵
Lu-172	Lutetium (71)	0.5	13.5	0.5	13.5	4.2x10 ³	1.1x10 ⁵
Lu-173		8	216	8	216	5.6x10 ¹	1.5x10 ³
Lu-174m		20	541	8	216	2.0x10 ²	5.3x10 ³
Lu-174		8	216	4	108	2.3x10 ¹	6.2x10 ²
Lu-177		30	811	0.9	24.3	4.1x10 ³	1.1x10 ⁵
MFP	For mixed fission products, use formula for mixtures or TABLE VII.						
Mg-28	Magnesium (12)	0.2	5.41	0.2	5.41	2.0x10 ⁵	5.4x10 ⁶
Mn-52	Manganese (25)	0.3	8.11	0.3	8.11	1.6x10 ⁴	4.4x10 ⁵
Mn-53		Unlimited	Unlimited	Unlimited	Unlimited	6.8x10 ⁻⁵	1.8x10 ⁻³
Mn-54		1	27.0	1	27.0	2.9x10 ²	7.7x10 ³
Mn-56		0.2	5.41	0.2	5.41	8.0x10 ⁵	2.2x10 ⁷
Mo-93	Molybdenum (42)	40	1080	7	189	4.1x10 ⁻²	1.1

TABLE VI
A₁ AND A₂ VALUES FOR RADIONUCLIDES (Continued)

Symbol of RadioNuclide	Element and Atomic No.	A ₁ (TBq)	A ₁ (Ci)	A ₂ (TBq)	A ₂ (Ci)	Specific Activity (TBq/g)	Specific Activity (Ci/g)
Mo-99		0.6	16.2	0.5	13.5 ^{c/}	1.8x10 ⁴	4.8x10 ⁵
N-13	Nitrogen (7)	0.6	16.2	0.5	13.5	5.4x10 ⁷	1.5x10 ⁹
Na-22	Sodium (11)	0.5	13.5	0.5	13.5	2.3x10 ²	6.3x10 ³
Na-24		0.2	5.41	0.2	5.41	3.2x10 ⁵	8.7x10 ⁶
Nb-92m	Niobium (41)	0.7	18.9	0.7	18.9	5.2x10 ³	1.4x10 ⁵
Nb-93m		40	1080	6	162	8.8	2.4x10 ²
Nb-94		0.6	16.2	0.6	16.2	6.9x10 ⁻³	1.9x10 ⁻¹
Nb-95		1	27.0	1	27.0	1.5x10 ³	3.9x10 ⁴
Nb-97		0.6	16.2	0.5	13.5	9.9x10 ⁵	2.7x10 ⁷
Nd-147	Neodymium (60)	4	108	0.5	13.5	3.0x10 ³	8.1x10 ⁴
Nd-149		0.6	16.2	0.5	13.5	4.5x10 ⁵	1.2x10 ⁷
Ni-59	Nickel (28)	40	1080	40	1080	3.0x10 ⁻³	8.0x10 ⁻²
Ni-63		40	1080	30	811	2.1	5.7x10 ¹
Ni-65		0.3	8.11	0.3	8.11	7.1x10 ⁵	1.9x10 ⁷
Np-235	Neptunium (93)	40	1080	40	1080	5.2x10 ¹	1.4x10 ³
Np-236		7	189	1x10 ⁻³	2.70x10 ⁻²	4.7x10 ⁻⁴	1.3x10 ⁻²
Np-237		2	54.1	2x10 ⁻⁴	5.41x10 ⁻³	2.6x10 ⁻⁵	7.1x10 ⁻⁴
Np-239		6	162	0.5	13.5	8.6x10 ³	2.3x10 ⁵
Os-185	Osmium (76)	1	27.0	1	27.0	2.8x10 ²	7.5x10 ³
Os-191m		40	1080	40	1080	4.6x10 ⁴	1.3x10 ⁶
Os-191		10	270	0.9	24.3	1.6x10 ³	4.4x10 ⁴
Os-193		0.6	16.2	0.5	13.5	2.0x10 ⁴	5.3x10 ⁵
Os-194		0.2	5.41	0.2	5.41	1.1x10 ¹	3.1x10 ²
P-32	Phosphorus (15)	0.3	8.11	0.3	8.11	1.1x10 ⁴	2.9x10 ⁵
P-33		40	1080	0.9	24.3	5.8x10 ³	1.6x10 ⁵
Pa-230	Protactinium (91)	2	54.1	0.1	2.70	1.2x10 ³	3.3x10 ⁴
Pa-231		0.6	16.2	6x10 ⁻⁵	1.62x10 ⁻³	1.7x10 ⁻³	4.7x10 ⁻²
Pa-233		5	135	0.9	24.3	7.7x10 ²	2.1x10 ⁴
Pb-201	Lead (82)	1	27.0	1	27.0	6.2x10 ⁴	1.7x10 ⁶
Pb-202		40	1080	2	54.1	1.2x10 ⁻⁴	3.4x10 ⁻³
Pb-203		3	81.1	3	81.1	1.1x10 ⁴	3.0x10 ⁵
Pb-205		Unlimited	Unlimited	Unlimited	Unlimited	4.5x10 ⁻⁶	1.2x10 ⁻⁴
Pb-210		0.6	16.2	9x10 ⁻³	0.243	2.8	7.6x10 ¹
Pb-212		0.3	8.11	0.3	8.11	5.1x10 ⁴	1.4x10 ⁶
Pd-103	Palladium (46)	40	1080	40	1080	2.8x10 ³	7.5x10 ⁴
Pd-107		Unlimited	Unlimited	Unlimited	Unlimited	1.9x10 ⁻⁵	5.1x10 ⁻⁴

TABLE VI
A₁ AND A₂ VALUES FOR RADIONUCLIDES (Continued)

Symbol of RadioNuclide	Element and Atomic No.	A ₁	A ₁	A ₂	A ₂	Specific Activity	
		(TBq)	(Ci)	(TBq)	(Ci)	(TBq/g)	(Ci/g)
Pd-109		0.6	16.2	0.5	13.5	7.9x10 ⁴	2.1x10 ⁶
Pm-143	Promethium (61)	3	81.1	3	81.1	1.3x10 ²	3.4x10 ³
Pm-144		0.6	16.2	0.6	16.2	9.2x10 ¹	2.5x10 ³
Pm-145		30	811	7	189	5.2	1.4x10 ²
Pm-147		40	1080	0.9	24.3	3.4x10 ¹	9.3x10 ²
Pm-148m		0.5	13.5	0.5	13.5	7.9x10 ²	2.1x10 ⁴
Pm-149		0.6	16.2	0.5	13.5	1.5x10 ⁴	4.0x10 ⁵
Pm-151		3	81.1	0.5	13.5	2.7x10 ⁴	7.3x10 ⁵
Po-208	Polonium (84)	40	1080	2x10 ⁻²	0.541	2.2x10 ¹	5.9x10 ²
Po-209		40	1080	2x10 ⁻²	0.541	6.2x10 ⁻¹	1.7x10 ¹
Po-210		40	1080	2x10 ⁻²	0.541	1.7x10 ²	4.5x10 ³
Pr-142	Praseodymium (59)	0.2	5.41	0.2	5.41	4.3x10 ⁴	1.2x10 ⁶
Pr-143		4	108	0.5	13.5	2.5x10 ³	6.7x10 ⁴
Pt-188	Platinum (78)	0.6	16.2	0.6	16.2	2.5x10 ³	6.8x10 ⁴
Pt-191		3	81.1	3	81.1	8.7x10 ³	2.4x10 ⁵
Pt-193m		40	1080	9	243	5.8x10 ³	1.6x10 ⁵
Pt-193		40	1080	40	1080	1.4	3.7x10 ¹
Pt-195m		10	270	2	54.1	6.2x10 ³	1.7x10 ⁵
Pt-197m		10	270	0.9	24.3	3.7x10 ⁵	1.0x10 ⁷
Pt-197		20	541	0.5	13.5	3.2x10 ⁴	8.7x10 ⁵
Pu-236	Plutonium (94)	7	189	7x10 ⁻⁴	1.89x10 ⁻²	2.0x10 ¹	5.3x10 ²
Pu-237		20	541	20	541	4.5x10 ²	1.2x10 ⁴
Pu-238		2	54.1	2x10 ⁻⁴	5.41x10 ⁻³	6.3x10 ⁻¹	1.7x10 ¹
Pu-239		2	54.1	2x10 ⁻⁴	5.41x10 ⁻³	2.3x10 ⁻³	6.2x10 ⁻²
Pu-240		2	54.1	2x10 ⁻⁴	5.41x10 ⁻³	8.4x10 ⁻³	2.3x10 ⁻¹
Pu-241		40	1080	1x10 ⁻²	0.270	3.8	1.0x10 ²
Pu-242		2	54.1	2x10 ⁻⁴	5.41x10 ⁻³	1.5x10 ⁻⁴	3.9x10 ⁻³
Pu-244		0.3	8.11	2x10 ⁻⁴	5.41x10 ⁻³	6.7x10 ⁻⁷	1.8x10 ⁻⁵
Ra-223	Radium (88)	0.6	16.2	3x10 ⁻²	0.811	1.9x10 ³	5.1x10 ⁴
Ra-224		0.3	8.11	6x10 ⁻²	1.62	5.9x10 ³	1.6x10 ⁵
Ra-225		0.6	16.2	2x10 ⁻²	0.541	1.5x10 ³	3.9x10 ⁴
Ra-226		0.3	8.11	2x10 ⁻²	0.541	3.7x10 ⁻²	1.0
Ra-228		0.6	16.2	4x10 ⁻²	1.08	1.0x10 ¹	2.7x10 ²
Rb-81	Rubidium (37)	2	54.1	0.9	24.3	3.1x10 ⁵	8.4x10 ⁶
Rb-83		2	54.1	2	54.1	6.8x10 ²	1.8x10 ⁴
Rb-84		1	27.0	0.9	24.3	1.8x10 ³	4.7x10 ⁴

TABLE VI
A₁ AND A₂ VALUES FOR RADIONUCLIDES (Continued)

Symbol of RadioNuclide	Element and Atomic No.	A1	A1	A2	A2	Specific Activity	
		(TBq)	(Ci)	(TBq)	(Ci)	(TBq/g)	(Ci/g)
Rb-86		0.3	8.11	0.3	8.11	3.0x10 ³	8.1x10 ⁴
Rb-87		Unlimited	Unlimited	Unlimited	Unlimited	3.2x10 ⁻⁹	8.6x10 ⁻⁸
Rb (natural)		Unlimited	Unlimited	Unlimited	Unlimited	6.7x10 ⁶	1.8x10 ⁸
Re-183	Rhenium (75)	5	135	5	135	3.8x10 ²	1.0x10 ⁴
Re-184m		3	81.1	3	81.1	1.6x10 ²	4.3x10 ³
Re-184		1	27.0	1	27.0	6.9x10 ²	1.9x10 ⁴
Re-186		4	108	0.5	13.5	6.9x10 ³	1.9x10 ⁵
Re-187		Unlimited	Unlimited	Unlimited	Unlimited	1.4x10 ⁻⁹	3.8x10 ⁻⁸
Re-188		0.2	5.41	0.2	5.41	3.6x10 ⁴	9.8x10 ⁵
Re-189		4	108	0.5	13.5	2.5x10 ⁴	6.8x10 ⁵
Re (natural)		Unlimited	Unlimited	Unlimited	Unlimited	—	2.4x10 ⁻⁸
Rh-99	Rhodium (45)	2	54.1	2	54.1	3.0x10 ³	8.2x10 ⁴
Rh-101		4	108	4	108	4.1x10 ¹	1.1x10 ³
Rh-102m		2	54.1	0.9	24.3	2.3x10 ²	6.2x10 ³
Rh-102		0.5	13.5	0.5	13.5	4.5x10 ¹	1.2x10 ³
Rh-103m		40	1080	40	1080	1.2x10 ⁶	3.3x10 ⁷
Rh-105		10	270	0.9	24.3	3.1x10 ⁴	8.4x10 ⁵
Rn-222	Radon (86)	0.2	5.41	4x10 ⁻³	0.108	5.7x10 ³	1.5x10 ⁵
Ru-97	Ruthenium (44)	4	108	4	108	1.7x10 ⁴	4.6x10 ⁵
Ru-103		2	54.1	0.9	24.3	1.2x10 ³	3.2x10 ⁴
Ru-105		0.6	16.2	0.5	13.5	2.5x10 ⁵	6.7x10 ⁶
Ru-106		0.2	5.41	0.2	5.41	1.2x10 ²	3.3x10 ³
S-35	Sulfur (16)	40	1080	2	54.1	1.6x10 ³	4.3x10 ⁴
Sb-122	Antimony (51)	0.3	8.11	0.3	8.11	1.5x10 ⁴	4.0x10 ⁵
Sb-124		0.6	16.2	0.5	13.5	6.5x10 ²	1.7x10 ⁴
Sb-125		2	54.1	0.9	24.3	3.9x10 ¹	1.0x10 ³
Sb-126		0.4	10.8	0.4	10.8	3.1x10 ³	8.4x10 ⁴
Sc-44	Scandium (21)	0.5	13.5	0.5	13.5	6.7x10 ⁵	1.8x10 ⁷
Sc-46		0.5	13.5	0.5	13.5	1.3x10 ³	3.4x10 ⁴
Sc-47		9	243	0.9	24.3	3.1x10 ⁴	8.3x10 ⁵
Sc-48		0.3	8.11	0.3	8.11	5.5x10 ⁴	1.5x10 ⁶
Se-75	Selenium (34)	3	81.1	3	81.1	5.4x10 ²	1.5x10 ⁴
Se-79		40	1080	2	54.1	2.6x10 ⁻³	7.0x10 ⁻²
Si-31	Silicon (14)	0.6	16.2	0.5	13.5	1.4x10 ⁶	3.9x10 ⁷
Si-32		40	1080	0.2	5.41	3.9	1.1x10 ²
Sm-145	Samarium (62)	20	541	20	541	9.8x10 ¹	2.6x10 ³

TABLE VI
A₁ AND A₂ VALUES FOR RADIONUCLIDES (Continued)

Symbol of RadioNuclide	Element and Atomic No.	A ₁ (TBq)	A ₁ (Ci)	A ₂ (TBq)	A ₂ (Ci)	Specific Activity (TBq/g)	Specific Activity (Ci/g)
Sm-147		Unlimited	Unlimited	Unlimited	Unlimited	8.5x10 ⁻¹	2.3x10 ⁻⁸
Sm-151		40	1080	4	108	9.7x10 ⁻¹	2.6x10 ¹
Sm-153		4	108	0.5	13.5	1.6x10 ⁴	4.4x10 ⁵
Sn-113	Tin (50)	4	108	4	108	3.7x10 ²	1.0x10 ⁴
Sn-117m		6	162	2	54.1	3.0x10 ³	8.2x10 ⁴
Sn-119m		40	1080	40	1080	1.4x10 ²	3.7x10 ³
Sn-121m		40	1080	0.9	24.3	2.0	5.4x10 ¹
Sn-123		0.6	16.2	0.5	13.5	3.0x10 ²	8.2x10 ³
Sn-125		0.2	5.41	0.2	5.41	4.0x10 ³	1.1x10 ⁵
Sn-126		0.3	8.11	0.3	8.11	1.0x10 ⁻³	2.8x10 ⁻²
Sr-82	Strontium (38)	0.2	5.41	0.2	5.41	2.3x10 ³	6.2x10 ⁴
Sr-85m		5	135	5	135	1.2x10 ⁶	3.3x10 ⁷
Sr-85		2	54.1	2	54.1	8.8x10 ²	2.4x10 ⁴
Sr-87m		3	81.1	3	81.1	4.8x10 ⁵	1.3x10 ⁷
Sr-89		0.6	16.2	0.5	13.5	1.1x10 ³	2.9x10 ⁴
Sr-90		0.2	5.41	0.1	2.70	5.1	1.4x10 ²
Sr-91		0.3	8.11	0.3	8.11	1.3x10 ⁵	3.6x10 ⁶
Sr-92		0.8	21.6	0.5	13.5	4.7x10 ⁵	1.3x10 ⁷
T	Tritium (1)	40	1080	40	1080	3.6x10 ²	9.7x10 ³
Ta-178	Tantalum (73)	1	27.0	1	27.0	4.2x10 ⁶	1.1x10 ⁸
Ta-179		30	811	30	811	4.1x10 ¹	1.1x10 ³
Ta-182		0.8	21.6	0.5	13.5	2.3x10 ²	6.2x10 ³
Tb-157	Terbium (65)	40	1080	10	270	5.6x10 ⁻¹	1.5x10 ¹
Tb-158		1	27.0	0.7	18.9	5.6x10 ⁻¹	1.5x10 ¹
Tb-160		0.9	24.3	0.5	13.5	4.2x10 ²	1.1x10 ⁴
Tc-95m	Technetium (43)	2	54.1	2	54.1	8.3x10 ²	2.2x10 ⁴
Tc-96m		0.4	10.8	0.4	10.8	1.4x10 ⁶	3.8x10 ⁷
Tc-96		0.4	10.8	0.4	10.8	1.2x10 ⁴	3.2x10 ⁵
Tc-97m		40	1080	40	1080	5.6x10 ²	1.5x10 ⁴
Tc-97		Unlimited	Unlimited	Unlimited	Unlimited	5.2x10 ⁻⁵	1.4x10 ⁻³
Tc-98		0.7	18.9	0.7	18.9	3.2x10 ⁻⁵	8.7x10 ⁻⁴
Tc-99m		8	216	8	216	1.9x10 ⁵	5.3x10 ⁶
Tc-99		40	1080	0.9	24.3	6.3x10 ⁻⁴	1.7x10 ⁻²
Te-118	Tellurium (52)	0.2	5.41	0.2	5.41	6.8x10 ³	1.8x10 ⁵
Te-121m		5	135	5	135	2.6x10 ²	7.0x10 ³
Te-121		2	54.1	2	54.1	2.4x10 ³	6.4x10 ⁴

TABLE VI
A₁ AND A₂ VALUES FOR RADIONUCLIDES (Continued)

Symbol of RadioNuclide	Element and Atomic No.	A1	A1	A2	A2	Specific Activity	
		(TBq)	(Ci)	(TBq)	(Ci)	(TBq/g)	(Ci/g)
Te-123m		7	189	7	189	3.3x10 ²	8.9x10 ³
Te-125m		30	811	9	243	6.7x10 ²	1.8x10 ⁴
Te-127m		20	541	0.5	13.5	3.5x10 ²	9.4x10 ³
Te-127		20	541	0.5	13.5	9.8x10 ⁴	2.6x10 ⁶
Te-129m		0.6	16.2	0.5	13.5	1.1x10 ³	3.0x10 ⁴
Te-129		0.6	16.2	0.5	13.5	7.7x10 ⁵	2.1x10 ⁷
Te-131m		0.7	18.9	0.5	13.5	3.0x10 ⁴	8.0x10 ⁵
Te-132		0.4	10.8	0.4	10.8	1.1x10 ⁴	3.0x10 ⁵
Th-227	Thorium (90)	9	243	1x10 ⁻²	0.270	1.1x10 ³	3.1x10 ⁴
Th-228		0.3	8.11	4x10 ⁻⁴	1.08x10 ⁻²	3.0x10 ¹	8.2x10 ²
Th-229		0.3	8.11	3x10 ⁻⁵	8.11x10 ⁻⁴	7.9x10 ⁻³	2.1x10 ⁻¹
Th-230		2	54.1	2x10 ⁻⁴	5.41x10 ⁻³	7.6x10 ⁻⁴	2.1x10 ⁻²
Th-231		40	1080	0.9	24.3	2.0x10 ⁴	5.3x10 ⁵
Th-232		Unlimited	Unlimited	Unlimited	Unlimited	4.0x10 ⁻⁹	1.1x10 ⁻⁷
Th-234		0.2	5.41	0.2	5.41	8.6x10 ²	2.3x10 ⁴
Th (natural)		Unlimited	Unlimited	Unlimited	Unlimited	8.1x10 ⁻⁹	2.2x10 ⁻⁷
Ti-44	Titanium (22)	0.5	13.5	0.2	5.41	6.4	1.7x10 ²
Tl-200	Thallium (81.1)	0.8	21.6	0.8	21.6	2.2x10 ⁴	6.0x10 ⁵
Tl-201		10	270	10	270	7.9x10 ³	2.1x10 ⁵
Tl-202		2	54.1	2	54.1	2.0x10 ³	5.3x10 ⁴
Tl-204		4	108	0.5	13.5	1.7x10 ¹	4.6x10 ²
Tm-167	Thulium (69)	7	189	7	189	3.1x10 ³	8.5x10 ⁴
Tm-168		0.8	21.6	0.8	21.6	3.1x10 ²	8.3x10 ³
Tm-170		4	108	0.5	13.5	2.2x10 ²	6.0x10 ³
Tm-171		40	1080	10	270	4.0x10 ¹	1.1x10 ³
U-230	Uranium (92)	40	1080	1x10 ⁻²	0.270	1.0x10 ³	2.7x10 ⁴
U-232		3	81.1	3x10 ⁻⁴	8.11x10 ⁻³	8.3x10 ⁻¹	2.2x10 ¹
U-233		10	270	1x10 ⁻³	2.70x10 ⁻²	3.6x10 ⁻⁴	9.7x10 ⁻³
U-234		10	270	1x10 ⁻³	2.70x10 ⁻²	2.3x10 ⁻⁴	6.2x10 ⁻³
U-235		Unlimited	Unlimited	Unlimited	Unlimited	8.0x10 ⁻⁸	2.2x10 ⁻⁶
U-236		10	270	1x10 ⁻³	2.70x10 ⁻²	2.4x10 ⁻⁶	6.5x10 ⁻⁵
U-238		Unlimited	Unlimited	Unlimited	Unlimited	1.2x10 ⁻⁸	3.4x10 ⁻⁷
U (natural)		Unlimited	Unlimited	Unlimited	Unlimited	2.6x10 ⁻⁸	7.1x10 ⁻⁷
U (enriched 5 percent or less)		Unlimited	Unlimited	Unlimited	Unlimited	--- (TABLE VIII)	
U (enriched > 5 percent)		10	270	1x10 ⁻³	2.70x10 ⁻²	--- (TABLE VIII)	
U (depleted)		Unlimited	Unlimited	Unlimited	Unlimited	--- (TABLE VIII)	

TABLE VI
A₁ AND A₂ VALUES FOR RADIONUCLIDES (Continued)

Symbol of RadioNuclide	Element and Atomic No.	A ₁ (TBq)	A ₁ (Ci)	A ₂ (TBq)	A ₂ (Ci)	Specific Activity (TBq/g)	Specific Activity (Ci/g)
V-48	Vanadium (23)	0.3	8.11	0.3	8.11	6.3x10 ³	1.7x10 ⁵
V-49		40	1080	40	1080	3.0x10 ²	8.1x10 ³
W-178	Tungsten (74)	1	27.0	1	27.0	1.3x10 ³	3.4x10 ⁴
W-181		30	811	30	811	2.2x10 ²	6.0x10 ³
W-185		40	1080	0.9	24.3	3.5x10 ²	9.4x10 ³
W-187		2	54.1	0.5	13.5	2.6x10 ⁴	7.0x10 ⁵
W-188		0.2	5.41	0.2	5.41	3.7x10 ²	1.0x10 ⁴
Xe-122	Xenon (54)	0.2	5.41	0.2	5.41	4.8x10 ⁴	1.3x10 ⁶
Xe-123		0.2	5.41	0.2	5.41	4.4x10 ⁵	1.2x10 ⁷
Xe-127		4	108	4	108	1.0x10 ³	2.8x10 ⁴
Xe-131m		40	1080	40	1080	3.1x10 ³	8.4x10 ⁴
Xe-133		20	541	20	541	6.9x10 ³	1.9x10 ⁵
Xe-135		4	108	4	108	9.5x10 ⁴	2.6x10 ⁶
Y-87	Yttrium (39)	2	54.1	2	54.1	1.7x10 ⁴	4.5x10 ⁵
Y-88		0.4	10.8	0.4	10.8	5.2x10 ²	1.4x10 ⁴
Y-90		0.2	5.41	0.2	5.41	2.0x10 ⁴	5.4x10 ⁵
Y-91m		2	54.1	2	54.1	1.5x10 ⁶	4.2x10 ⁷
Y-91		0.3	8.11	0.3	8.11	9.1x10 ²	2.5x10 ⁴
Y-92		0.2	5.41	0.2	5.41	3.6x10 ⁵	9.6x10 ⁶
Y-93		0.2	5.41	0.2	5.41	1.2x10 ⁵	3.3x10 ⁶
Yb-169	Ytterbium (70)	3	81.1	3	81.1	8.9x10 ²	2.4x10 ⁴
Yb-175		30	811	0.9	24.3	6.6x10 ³	1.8x10 ⁵
Zn-65	Zinc (30)	2	54.1	2	54.1	3.0x10 ²	8.2x10 ³
Zn-69m		2	54.1	0.5	13.5	1.2x10 ⁵	3.3x10 ⁶
Zn-69		4	108	0.5	13.5	1.8x10 ⁶	4.9x10 ⁷
Zr-88	Zirconium (40)	3	81.1	3	81.1	6.6x10 ²	1.8x10 ⁴
Zr-93		40	1080	0.2	5.41	9.3x10 ⁻⁵	2.5x10 ⁻³
Zr-95		1	27.0	0.9	24.3	7.9x10 ²	2.1x10 ⁴
Zr-97		0.3	8.11	0.3	8.11	7.1x10 ⁴	1.9x10 ⁶

^{a/} International shipments of Einsteinium require multilateral approval of A₁ and A₂ values.

^{b/} International shipments of Fermium require multilateral approval of A₁ and A₂ values.

^{c/} 20 Ci for Mo⁹⁹ for domestic use

**TABLE VII
GENERAL VALUES FOR A₁ AND A₂**

Contents	A ₁		A ₂	
	TBq	Ci	TBq	Ci
Only beta- or gamma-emitting nuclides are known to be present.	0.2	5	0.02	0.5
Alpha-emitting nuclides are known to be present, or no relevant data are available.	0.10	2.70	2x10 ⁻⁵	5.4x10 ⁻⁴

**TABLE VIII
ACTIVITY-MASS RELATIONSHIPS FOR URANIUM**

Uranium Enrichment ^{*/} weight percent U-235 present	Specific Activity	
	Ci/g	TBq/g
0.45	1.8x10 ⁻⁸	5.0x10 ⁻⁷
0.72	2.6x10 ⁻⁸	7.1x10 ⁻⁷
1.0	2.8x10 ⁻⁸	7.6x10 ⁻⁷
1.5	3.7x10 ⁻⁸	1.0x10 ⁻⁶
5.0	1.0x10 ⁻⁷	2.7x10 ⁻⁶
10.0	1.8x10 ⁻⁷	4.8x10 ⁻⁶
20.0	3.7x10 ⁻⁷	1.0x10 ⁻⁵
35.0	7.4x10 ⁻⁷	2.0x10 ⁻⁵
50.0	9.3x10 ⁻⁷	2.5x10 ⁻⁵
90.0	2.2x10 ⁻⁶	5.8x10 ⁻⁵
93.0	2.6x10 ⁻⁶	7.0x10 ⁻⁵
95.0	3.4x10 ⁻⁶	9.1x10 ⁻⁵

^{*/} The figures for uranium include representative values for the activity of the uranium-235 that is concentrated during the enrichment process.