Safety Analysis for FY2016 Th Target at BLIP

Internal Dose Analysis

This document includes estimates of internal dose to workers as well as members of the public who could be accidentally exposed to inhalation of radionuclides from the irradiated Th target. Specifically, this analysis covers irradiation of the 12 g Th foil at 200 MeV, and for transport from BLIP to TPL where it will be prepared for shipment to ORNL during FY2016. The internal dose estimates in an accident are based on review of accidents at both NRC-licensed and DOE-owned facilities. Experience in accidents (1, 2, 3, 4, 5, 6) has been such that workers who are closest to the point of release receive the highest internal radiation exposure.

In accidents involving the release of radioactive materials, experience has been that the magnitude of the maximum inhalation intake is on the order of one-millionth, 1E-6, of the amount of unsealed material being processed (7, 8). This fractional value for intake is useful for determining if additional Credited Controls, other controls or response plans are necessary. This empirical approach is applicable for processes which confine radioactive material within an enclosure. Accidents reviewed include a glovebox (9), hood, ion exchange column (10), and pelletizer within a glovebox (11). This analysis uses an approach which is applicable to accidental inhalation intakes of tritium (12, 13) or radioiodine compounds (14, 15), although the probability or frequency of release in those cases may be greater when compared to actinides resulting from irradiation of Th, which are largely alpha emitters. It is important to note that the fraction 1E-6 applies to inhalation intakes only, and that this is the likely mode of intake for trained and qualified employees (7).

While fractional intakes for workers have been limited to 1E-6, the fractional intakes by members of the "public" will be much less (1). In this analysis, the "public" are any non-C-AD employees in nearby areas or BNL buildings on-site. The material released from BLIP Building or Building 801 will be a small fraction of the amount released from the initial vessel containing the radioactivity. This was true for the Three Mile Island accident (18), except for the inert gas radionuclides which are not internal emitters. Even under adverse meteorological conditions, diffusion dilutes concentrations so that any member of the "public" will not likely receive more than a small fraction, less than one millionth, of the material released from a building (1, 8). Thus, the need for Credited Controls to protect the "public" near BLIP or Building 801 is based partly on the fraction 1E-12 of the amount in process. A factor of 100 is used, for a combined factor of 1E-10, in order to account for differences in dose limits, body size, metabolism, and chemical form in the environment.

Intakes through skin contact with materials such as HTO or KI, which are compounds that are easily transported through the epithelium, have been considerably greater than 1E-6 in accident cases (13), but skin absorption of compounds associated with alpha-emitters is poor. On-the-other-hand, safety review and training of BLIP and Building 801 workers should preclude any significant intake through the skin or by ingestion following an accident.

For the objective of producing Ac-225 by irradiation of this Th foil, the MCNPX calculated spectrum of all radionuclides produced and their activity at end of bombardment with 192 MeV

(200 MeV LINAC) protons is presented in Table 1 (Attachment 1). Irradiation was assumed to be for a total of approximately 25,000 μA-h (~8 days). The data for radioactivity in Table 1 is from the Tgt_16_03 Canning Record by Leonard Mausner that is posted on the C-AD RSC web page. The Th target is cut into 3 pie-shaped pieces; each piece is about 4 g. Thus, Table 1 represents the radioactivity for 1/3 of the target. With the exception of the target Th-232, output in the Table below is truncated below 10 μCi (1E-5 Ci). The truncated radionuclides would add no significant dose in the event of an accidental release.

Radionuclides that are not listed with an internal dose per unit intake are either inert gas or there was no evaluated internal dose data available. The elements Xe, Kr and Rn are inert gases and would not be internally retained; they would be exhaled. Where dosimetric data was lacking, it was assumed these radionuclides would not contribute significantly to internal dose in an accident. The cases where internal dose per unit intake was not available primarily involved radionuclides that are beta emitters or the nuclear transformations occurred via IT or EC.

Internal dose per unit intake from the maximum inhalation class was taken from Reference 16. Any daughters produced after the intake of any specific radionuclide were accounted for in the tabulated estimates of the committed effective dose equivalent to a worker or to a non C-AD person outside the building where the accident occurred. The values used for internal dose per unit intake are current and have been evaluated by NRC with regard to accident analyses. See Reference 17.

Following an accident, the maximum unmitigated internal dose to a C-AD worker near the target is approximately 8 rem and the internal dose to a person in a nearby non-C-AD building is about 0.8 mrem according to the experienced-based model.

For this estimate of accident dose, no credit was taken for release fractions, or for engineered safeguards such as a shielded hot-cell enclosure maintained under negative pressure. Nor was credit was taken for decay in the BLIP tank or BLIP Hot Cell. Credit was not taken for holdup of released materials on the charcoal and HEPA filtered exhaust from the BLIP or Building 801 stacks.

The following tables are subsets of information in Table 1 and they illustrate the potential accident dose from the two main radiological hazards, which are alpha-emitting radionuclides (Table 2) and gaseous radionuclides (Table 3).

As shown in Table 2, only 5.7% of the radioactivity is from alpha-emitting radionuclides or radionuclides with alpha-emitting progeny, and these nuclides have high melting and boiling points (see Table 2A). On the other hand, these radionuclides represent 98% of an unmitigated internal dose in an accident. These nuclides are moderately long-lived; days, weeks and months. At Building 801, each 1/3 target will be separately packaged and shipped to ORNL. Again, in these tables, the total activity and accident dose is for 1/3 of the target and should be multiplied by 3 if the full target is involved in an accident.

The last column in Table 2 shows the accident dose at 100 m using the inhalation and cloud shine model described in a DOE model in References 18 and 19. The main difference between

the DOE model and the model based on experience reported in the literature is the assumption of release fraction values in an accident defined in the DOE model as listed below:
1. Gases 1.0 (such as tritium, krypton, xenon, argon, radon, chlorine, etc.)
2. Highly volatile/combustible 0.5 (phosphorus, sulfur, potassium, iodine, sodium, bromine)
3. Semi-volatile 0.01 (selenium, mercury, cesium, polonium, tellurium, ruthenium, carbon)
4. Solid/Powder/Liquid 0.001 (all materials not listed above)

Table 2 Activities of Alpha-Emitters or Radionuclides that Decay to Alpha-Emitters at End of Bombardment in One Third Segment of the Th Target; Internal Dose in an Accident Assumes No Engineered Safeguards

Half-life, h	Isotope of	Mass Number	Activity, Ci	rem/μCi Inhaled	Inhalation Dose to C-AD Worker Dose, rem	Inhalation Dose to Non C-AD On-Site Person, rem	Inhalation Dose and Cloud Shine Dose at 100 m; References 18, 19), rem
1.67E+04	Th	228	3.20E-03	3.10E+02	9.92E-01	9.92E-05	3.48E-05
4.49E+02	Th	227	4.13E-02	1.60E+01	6.61E-01	6.61E-05	2.32E-05
2.40E+02	Ac	225	5.98E-02	8.00E+00	4.78E-01	4.78E-05	2.06E-05
8.71E+01	Ra	224	7.15E-02	2.90E+00	2.07E-01	2.07E-05	7.22E-06
2.94E+01	Ac	226	9.20E-02	1.30E+00	1.20E-01	1.20E-05	5.16E-06
1.14E+01	Ra	223	1.31E-02	7.50E+00	9.83E-02	9.83E-06	3.45E-06
4.18E+02	Pa	230	2.26E-02	1.50E+00	3.39E-02	3.39E-06	4.11E-04
6.13E+00	Ac	228	7.60E-02	2.90E-01	2.20E-02	2.20E-06	9.50E-07
3.58E+02	Ra	225	2.60E-03	7.60E+00	1.98E-02	1.98E-06	6.84E-07
3.32E+03	Po	210	1.73E-03	8.10E+00	1.40E-02	1.40E-06	4.94E-06
2.20E+01	Pa	228	3.24E-02	4.10E-01	1.33E-02	1.33E-06	5.89E-04
1.06E+01	Pb	212	7.15E-02	1.60E-01	1.14E-02	1.14E-06	1.66E-07
2.78E+00	Ac	224	8.71E-02	1.30E-01	1.13E-02	1.13E-06	4.88E-07
	Sum		5.75E-01		2.68E+00	2.68E-04	1.10E-03

Table 2A Elemental Properties of Radionuclides Listed in Table 2

Boiling Point, ^{o}C	Melting Point, ^{o}C	Element
4788	1842	Th
3198	1050	Ac
1737	700	Ra
4027	1568	Pa
962	254	Po
1749	327	Pb

As shown in Table 3 for the experienced based model, the potential internal dose from volatile gaseous radioactivity in an accidental release from this target is about 12 mrem to a worker or to any nearby on-site person if an accidental release occurs during transit between BLIP and Building 801. The iodine and bromine isotopes are assumed to be volatile and may more easily be dispersed in an accident involving an unmitigated release from the irradiated target.

External dose rate from a release of radioactive gas in a 1000 m^3 room with radioactive isotopes of Xe, Kr and Rn plus radioactive isotopes of I and Br (see Table 3) would initially be about 20 mrem per minute to workers in an accident. While the alpha-gamma-emitting Rn isotopes in Table 3 are short lived, they are in equilibrium with their long-lived parent or grandparent and they will be decaying with the half-lives of the parent or grandparent, which are typically long-lived. Again, it is assumed there is unmitigated release of gaseous radionuclides from the irradiated Th target. However, much of the gas may be retained in the solid Th metal unless it is heated and gases are driven out in the accident. This has occurred at AGS and J-Park where high-mass-number metal targets (Au or Pt) were momentarily heated to about 1000 ^oC by the unintentional "short" pulses of beam and radio-gases were driven out.

In the case of BLIP, beam irradiations occur in a closed environment that has filtered exhaust. If radiation levels suddenly rise in the BLIP or Building 801 work areas, workers would likely leave the room immediately. The radioactive gas in this accident would quickly dissipate if it reached outside the building and external dose rates would be less by many orders of magnitude. External dose rate from a cloud of gas released during transit between BLIP and Building 801 would likely dissipate within a few minutes, but this time period would be dependent upon local weather.

Table 3 Gaseous Radionuclide Activities at End of Bombardment in One Third Segment of the Th Target; Internal Dose in an Accident Assumes No Engineered Safeguards

Isotope of	Mass Number	Activity, Ci	rem/μCi Inhaled	Inhalation Dose to C-AD Worker Dose, rem	Inhalation Dose to Non C-AD On-Site Person, rem	Inhalation Dose Plus Cloud Shine Dose at 100 m; DOE-STD-1027-92 Model, rem
Rn	218	1.73E-01				2.13E-09
I	133	1.26E-01	5.40E-03	6.80E-04	6.80E-08	1.18E-05
Xe	133	1.20E-01				6.67E-08
I	132	1.18E-01	3.30E-04	3.89E-05	3.89E-09	6.76E-07
Xe	135	1.12E-01				4.42E-07
I	131	8.37E-02	3.20E-02	2.68E-03	2.68E-07	4.65E-05
Kr	85m	7.71E-02				8.74E-08
Rn	220	7.15E-02				6.45E-10
I	135	6.91E-02	1.10E-03	7.60E-05	7.60E-09	1.32E-06
I	130	4.83E-02	2.50E-03	1.21E-04	1.21E-08	2.10E-06
Rn	217	3.11E-02				
Rn	219	1.31E-02				1.21E-08
Xe	135m	1.09E-02				7.29E-08
I	123	9.79E-03	2.70E-04	2.64E-06	2.64E-10	4.59E-08
I	124	8.98E-03	1.92E-02	1.72E-04	1.72E-08	2.99E-06
Xe	125	6.75E-03				2.64E-08
Kr	79	5.67E-03				9.84E-09
I	126	5.62E-03	4.30E-02	2.42E-04	2.42E-08	4.20E-06
I	122	5.40E-03				
Xe	127	4.77E-03				1.96E-08
Xe	133m	3.43E-03				1.68E-09
I	125	2.44E-03	2.40E-02	5.86E-05	5.86E-09	1.02E-06
Xe	122	1.69E-03				1.58E-09
Xe	131m	2.29E-04				3.38E-11
Br	82	3.36E-02	1.30E-03	4.37E-05	4.37E-09	7.58E-07
Br	77	4.09E-03	2.60E-04	1.06E-06	1.06E-10	1.85E-08
Br	76	2.03E-03	1.20E-03	2.44E-06	2.44E-10	4.23E-08
Sum		1.15E+00		4.12E-03	4.12E-07	7.22E-05

Accident-Specific Assumptions

Engineered safeguards help ensure an unplanned dose to a worker is less than 100 mrem in a day, which is a C-AD limit, and to a non-C-AD person less than 25 mrem in a year, which is a BNL limit. Engineered safeguards include trained and qualified personnel, handling the target with manipulators in shielded hot-cells maintained under negative pressure, and requiring hot-cell exhaust pass through HEPA and charcoal filters prior to release from stacks. From Table 2, allowing the target to decay prior to removing it from the BLIP Hot Cell before transfer to Building 801 will not reduce significantly the internal dose in an accident. Table 2 shows most of the half-lives to be long relative to a practicable decay period. However, external gamma-dose rate from all the target radionuclides in Table 1 is expected to drop significantly within a reasonable decay period of 8 hours to one day.

Movement of the Th target to Building 801 after a few hours of decay in order to package and ship requires the Th target-can be visually intact. Following visual inspection from the BLIP Hot Cell window, the irradiated Th target-can should be placed in a secondary sealed container so as to capture leaking radio-gases should they leak from the target-can during transit to Building 801. The target-can and secondary container would be placed in a shielded transfer pig which reduces gamma-radiation from the target–can inside the transport pig to acceptable transport levels. Transfer to Building 801 requires Radiological Control Technicians with survey instruments to be present with the pig during the move.

There are no natural gas lines or combustible fuels stored at BLIP or TPL. Safeguards include actively preventing gasoline and other highly combustible materials in these areas. The temperature of a gasoline fire ranges between 900 ^{o}C to 1250 ^{o}C. The temperature of the target's radioactivity would also depend on the combustibility of the target shielding that could be burned by the flames; shielding in this case is concrete, steel and lead. Heat from a fire outside the transport pig would be largely absorbed by the shielded pig. The same would be true for shielding from a fire outside a hot cell. Very little heat is generated from radioactive decay in the target, and decay heat does not significantly add to the temperature of the irradiated target.

In the Building 801 Hot Cell, the target can is opened and any radio-gas released would be trapped on filters in the hot-cell exhaust system. If gases are released during packaging, gamma-shine from the possible capture of several Ci of radio-gases captured in the acid scrubber at Building 801 would be evaluated by locally installed monitoring equipment. Each 1/3 target piece will be sealed in a glass vial with snap-on cap, and then placed individually in existing Type A shipping containers as successfully used previously. Packages will be shipped to ORNL for processing when the external radiation dose rate on the exterior of the package drops below the DOT requirements for a Type A package.

Determination of Additional Credited Controls

Based on this analysis, a suitable secondary container for the irradiated Th target should be fabricated or devised to contain gaseous radioactivity potentially released from the target during transit from BLIP to Building 801. Such containment would likely prevent internal and external

exposure to any person from gaseous radioactivity that exceeded 25 mrem if an accidental release occurred.

Measurements of radio-gas exposure rate from the charcoal filters in Building 801 filter bank should be evaluated following target-can opening in the hot-cell.

The target-can could break during irradiation at BLIP, and a handling and clean-up plan for BLIP should be documented beforehand. The BLIP cooling water may contain alpha emitters after a target-can breach, and handling alpha-emitter contaminated water safely should be addressed in the plan.

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Attachment 1 – Table 1 Activities at End of Bombardment for Radionuclides in One Third Segment of the Th Target; Internal Dose in an Accident Assumes No Engineered Safeguards

Half-life	Isotope of	Mass Number	Activity, Ci	rem/μCi Inhaled	C-AD Worker Dose, rem	Dose to Non C-AD On-Site, rem
	Th	231	4.93E-01	8.10E-04	3.99E-04	3.99E-08
5.37 h	Ag	113	3.65E-01		0.00E+00	0.00E+00
	Ag	112	3.45E-01	6.20E-04	2.14E-04	2.14E-08
	In	115m	3.28E-01	1.20E-04	3.94E-05	3.94E-09
	Cd	115	3.28E-01	3.80E-03	1.25E-03	1.25E-07
21 h	Pd	112	3.12E-01		0.00E+00	0.00E+00
	Sn	121	3.03E-01	4.70E-04	1.42E-04	1.42E-08
	In	117m	2.55E-01	1.50E-04	3.83E-05	3.83E-09
36 s	In	117	2.31E-01	3.00E-05	6.93E-06	6.93E-10
	Ag	111	2.03E-01	5.90E-03	1.20E-03	1.20E-07
0.000164 s	Ag	109m	1.80E-01		0.00E+00	0.00E+00
	Pd	109	1.80E-01	1.10E-03	1.98E-04	1.98E-08
38 s	Po	214	1.73E-01		0.00E+00	0.00E+00
35 ms	Rn	218	1.73E-01		0.00E+00	0.00E+00
38 s	Ra	222	1.73E-01		0.00E+00	0.00E+00
	Th	226	1.70E-01	3.50E-02	5.95E-03	5.95E-07
	Rh	105	1.70E-01	8.90E-04	1.51E-04	1.51E-08
	Nb	97	1.65E-01	7.10E-05	1.17E-05	1.17E-09
	Y	92	1.53E-01	6.20E-04	9.49E-05	9.49E-09
	Rb	88	1.50E-01	8.00E-05	1.20E-05	1.20E-09
	Te	129	1.41E-01	7.70E-05	1.09E-05	1.09E-09
	Y	93	1.40E-01	2.10E-03	2.94E-04	2.94E-08
	Ru	105	1.38E-01	4.10E-04	5.66E-05	5.66E-09
	Sr	91	1.32E-01	1.40E-03	1.85E-04	1.85E-08
	Mo	99	1.26E-01	3.60E-03	4.54E-04	4.54E-08
	I	133	1.26E-01	5.40E-03	6.80E-04	6.80E-08
	Pa	233	1.26E-01	8.60E-03	1.08E-03	1.08E-07
	Te	127	1.23E-01	2.90E-04	3.57E-05	3.57E-09
5.25 d	Xe	133	1.20E-01		0.00E+00	0.00E+00
	Sb	129	1.20E-01	5.70E-04	6.84E-05	6.84E-09
	I	132	1.18E-01	3.30E-04	3.89E-05	3.89E-09
	Te	131	1.17E-01	9.90E-05	1.16E-05	1.16E-09
	Zr	97	1.15E-01	4.00E-03	4.60E-04	4.60E-08
9.1 h	Xe	135	1.12E-01		0.00E+00	0.00E+00
	Tc	99m	1.11E-01	3.20E-05	3.55E-06	3.55E-10
	Nb	97m	1.09E-01	7.10E-05	7.74E-06	7.74E-10
2.14 m	Bi	211	1.01E-01		0.00E+00	0.00E+00
4.77 m	Tl	207	1.01E-01		0.00E+00	0.00E+00
	Sb	127	9.51E-02	5.40E-03	5.14E-04	5.14E-08
	Ac	226	9.20E-02	1.30E+00	1.20E-01	1.20E-05
	Pb	209	9.09E-02	9.00E-05	8.18E-06	8.18E-10
0.00000365 s	Po	213	8.97E-02		0.00E+00	0.00E+00
	Ac	224	8.71E-02	1.30E-01	1.13E-02	1.13E-06
	I	131	8.37E-02	3.20E-02	2.68E-03	2.68E-07

	La	141	8.09E-02	5.40E-04	4.37E-05	4.37E-09
	Bi	212	8.02E-02	2.10E-02	1.68E-03	1.68E-07
	Kr	85m	7.71E-02		0.00E+00	0.00E+00
	Y	91m	7.68E-02	3.10E-05	2.38E-06	2.38E-10
	Ac	228	7.60E-02	2.90E-01	2.20E-02	2.20E-06
	Pb	212	7.15E-02	1.60E-01	1.14E-02	1.14E-06
0.145 s	Po	216	7.15E-02		0.00E+00	0.00E+00
55.6 s	Rn	220	7.15E-02		0.00E+00	0.00E+00
	Ra	224	7.15E-02	2.90E+00	2.07E-01	2.07E-05
	Ce	143	7.13E-02	3.20E-03	2.28E-04	2.28E-08
	I	135	6.91E-02	1.10E-03	7.60E-05	7.60E-09
	Pr	145	6.71E-02	6.40E-04	4.29E-05	4.29E-09
299 ns	Po	212	6.43E-02		0.00E+00	0.00E+00
	Te	132	6.36E-02	7.70E-03	4.90E-04	4.90E-08
1.5 d	Pa	229	6.31E-02		0.00E+00	0.00E+00
	Ac	225	5.98E-02	8.00E+00	4.78E-01	4.78E-05
32.3 ms	At	217	5.98E-02		0.00E+00	0.00E+00
4.9 m	Fr	221	5.98E-02		0.00E+00	0.00E+00
	Bi	213	5.98E-02	1.70E-02	1.02E-03	1.02E-07
	As	77	5.56E-02	9.90E-04	5.50E-05	5.50E-09
	I	130	4.83E-02	2.50E-03	1.21E-04	1.21E-08
	Rh	106	4.69E-02	2.00E-04	9.38E-06	9.38E-10
	Bi	210	4.50E-02	1.90E-01	8.55E-03	8.55E-07
	Sb	128	4.46E-02	1.60E-03	7.14E-05	7.14E-09
	La	140	4.46E-02	4.40E-03	1.96E-04	1.96E-08
	Th	227	4.13E-02	1.60E+01	6.61E-01	6.61E-05
	Rh	105m	3.91E-02	2.00E-04	7.82E-06	7.82E-10
	Cd	117m	3.76E-02	4.10E-04	1.54E-05	1.54E-09
	Ga	73	3.54E-02	3.30E-04	1.17E-05	1.17E-09
0.499 s	Ge	73m	3.49E-02		0.00E+00	0.00E+00
	Ba	140	3.41E-02	3.60E-03	1.23E-04	1.23E-08
	Sb	122	3.39E-02	4.70E-03	1.59E-04	1.59E-08
	Br	82	3.36E-02	1.30E-03	4.37E-05	4.37E-09
	Pa	228	3.24E-02	4.10E-01	1.33E-02	1.33E-06
	Y	90	3.16E-02	8.20E-03	2.59E-04	2.59E-08
	Ce	137	3.14E-02	3.90E-05	1.22E-06	1.22E-10
	Sb	126	3.14E-02	1.00E-02	3.14E-04	3.14E-08
0.54 ms	Rn	217	3.11E-02		0.00E+00	0.00E+00
	Pm	149	3.08E-02	2.80E-03	8.62E-05	8.62E-09
3.05 m	Tl	208	2.88E-02		0.00E+00	0.00E+00
	Ge	77	2.85E-02	8.90E-04	2.54E-05	2.54E-09
	Rh	103m	2.83E-02	4.60E-06	1.30E-07	1.30E-11
	Pa	232	2.82E-02	8.90E-02	2.51E-03	2.51E-07
	Nb	96	2.76E-02	2.00E-03	5.52E-05	5.52E-09
	Pr	143	2.76E-02	7.30E-03	2.01E-04	2.01E-08
	Y	87	2.73E-02	1.60E-03	4.37E-05	4.37E-09
	Ru	103	2.64E-02	7.80E-03	2.06E-04	2.06E-08
	Pr	144	2.58E-02	4.20E-05	1.08E-06	1.08E-10
	Pr	142	2.57E-02	2.70E-03	6.94E-05	6.94E-09

	Nd	147	2.56E-02	6.20E-03	1.59E-04	1.59E-08
	Pm	151	2.31E-02	1.60E-03	3.70E-05	3.70E-09
	Pa	230	2.26E-02	1.50E+00	3.39E-02	3.39E-06
	Sb	119	2.19E-02	1.90E-04	4.16E-06	4.16E-10
	Zr	89	2.14E-02	2.10E-03	4.49E-05	4.49E-09
15.7 s	Y	89m	2.14E-02		0.00E+00	0.00E+00
	In	110	2.13E-02	3.00E-04	6.39E-06	6.39E-10
	Sn	125	2.12E-02	1.40E-02	2.97E-04	2.97E-08
	Cs	129	1.97E-02	1.50E-04	2.96E-06	2.96E-10
	Ga	72	1.95E-02	1.70E-03	3.32E-05	3.32E-09
	Cs	136	1.92E-02	7.50E-03	1.44E-04	1.44E-08
	Y	91	1.85E-02	4.40E-02	8.14E-04	8.14E-08
	Sr	89	1.85E-02	3.70E-02	6.85E-04	6.85E-08
	Ce	141	1.78E-02	8.50E-03	1.51E-04	1.51E-08
	La	135	1.76E-02	5.20E-05	9.15E-07	9.15E-11
	Sm	153	1.65E-02	1.70E-03	2.81E-05	2.81E-09
	Pm	148	1.60E-02	1.00E-02	1.60E-04	1.60E-08
	Tc	96	1.57E-02	2.40E-03	3.77E-05	3.77E-09
	Sb	118	1.45E-02	2.60E-04	3.77E-06	3.77E-10
	Zn	72	1.41E-02	4.20E-03	5.92E-05	5.92E-09
	Zr	95	1.32E-02	1.90E-02	2.51E-04	2.51E-08
	Pb	211	1.31E-02	8.00E-03	1.05E-04	1.05E-08
1.78 ms	Po	215	1.31E-02		0.00E+00	0.00E+00
3.96 s	Rn	219	1.31E-02		0.00E+00	0.00E+00
	Ra	223	1.31E-02	7.50E+00	9.83E-02	9.83E-06
	Cs	131	1.25E-02	1.60E-04	2.00E-06	2.00E-10
0.56 s	Po	211	1.25E-02		0.00E+00	0.00E+00
	Rb	86	1.21E-02	6.60E-03	7.99E-05	7.99E-09
	Ba	131	1.11E-02	6.70E-04	7.44E-06	7.44E-10
15.29 m	Xe	135m	1.09E-02		0.00E+00	0.00E+00
	Te	121	9.82E-03	1.60E-03	1.57E-05	1.57E-09
	I	123	9.79E-03	2.70E-04	2.64E-06	2.64E-10
	I	124	8.98E-03	1.92E-02	1.72E-04	1.72E-08
	At	211	8.78E-03	9.30E-02	8.17E-04	8.17E-08
	Nb	95	8.74E-03	4.50E-03	3.93E-05	3.93E-09
0.3 ms	At	216	8.71E-03		0.00E+00	0.00E+00
27.4 s	Fr	220	8.71E-03		0.00E+00	0.00E+00
6.45 m	La	134	8.30E-03		0.00E+00	0.00E+00
	Sb	124	8.14E-03	2.10E-02	1.71E-04	1.71E-08
	Eu	157	7.67E-03	1.00E-03	7.67E-06	7.67E-10
	Cs	132	7.61E-03	1.20E-03	9.13E-06	9.13E-10
3.39 m	Pr	140	7.60E-03		0.00E+00	0.00E+00
	Rh	100	7.46E-03	1.40E-03	1.04E-05	1.04E-09
5.12 m	Cu	66	7.04E-03		0.00E+00	0.00E+00
	Cu	67	6.80E-03	1.10E-03	7.48E-06	7.48E-10
16.9 h	Xe	125	6.75E-03		0.00E+00	0.00E+00
	Ce	135	6.75E-03	1.40E-03	9.45E-06	9.45E-10
	Sm	156	6.50E-03	5.70E-04	3.71E-06	3.71E-10
	Nb	90	6.41E-03	2.10E-03	1.35E-05	1.35E-09

	Pr	139	6.24E-03	4.70E-05	2.93E-07	2.93E-11
16.05 h	Te	119	6.08E-03		0.00E+00	0.00E+00
3.91 h	La	133	6.08E-03		0.00E+00	0.00E+00
	Ni	66	6.02E-03	1.70E-03	1.02E-05	1.02E-09
	Rb	82	6.00E-03	2.80E-04	1.68E-06	1.68E-10
20 h	Tc	95	5.74E-03		0.00E+00	0.00E+00
	Y	86	5.74E-03	1.60E-03	9.18E-06	9.18E-10
	La	132	5.74E-03	5.10E-04	2.93E-06	2.93E-10
	Te	131m	5.68E-03	5.50E-03	3.12E-05	3.12E-09
	Kr	79	5.67E-03		0.00E+00	0.00E+00
	I	126	5.62E-03	4.30E-02	2.42E-04	2.42E-08
	Cs	128	5.57E-03	8.80E-05	4.90E-07	4.90E-11
	In	111	5.44E-03	7.70E-04	4.19E-06	4.19E-10
3.63 m	I	122	5.40E-03		0.00E+00	0.00E+00
	Gd	159	5.36E-03	8.90E-04	4.77E-06	4.77E-10
6 d	Te	118	5.08E-03		0.00E+00	0.00E+00
36 d	Xe	127	4.77E-03		0.00E+00	0.00E+00
	In	109	4.73E-03	1.10E-04	5.20E-07	5.20E-11
	As	76	4.38E-03	3.40E-03	1.49E-05	1.49E-09
	Sr	83	4.35E-03	1.40E-03	6.09E-06	6.09E-10
	Br	77	4.09E-03	2.60E-04	1.06E-06	1.06E-10
8.1 h	At	210	4.05E-03		0.00E+00	0.00E+00
	Te	129m	3.72E-03	2.00E-02	7.44E-05	7.44E-09
	Tb	154	3.71E-03	1.20E-03	4.45E-06	4.45E-10
	Ru	97	3.60E-03	4.20E-04	1.51E-06	1.51E-10
0.00000295	Xe	133m	3.43E-03		0.00E+00	0.00E+00
	Pd	101	3.38E-03	1.70E-04	5.75E-07	5.75E-11
	Rb	81	3.21E-03	1.00E-04	3.21E-07	3.21E-11
	Th	228	3.20E-03	3.10E+02	9.92E-01	9.92E-05
	Pd	100	3.07E-03	3.90E-03	1.20E-05	1.20E-09
	Cs	127	3.04E-03	5.20E-05	1.58E-07	1.58E-11
	Tc	94	3.04E-03	2.70E-04	8.21E-07	8.21E-11
	Eu	156	2.92E-03	1.10E-02	3.21E-05	3.21E-09
	Sr	85	2.75E-03	1.90E-03	5.23E-06	5.23E-10
48.5 m	Cd	111m	2.72E-03		0.00E+00	0.00E+00
	Cd	107	2.70E-03	1.00E-04	2.70E-07	2.70E-11
44.3 s	Ag	107m	2.70E-03		0.00E+00	0.00E+00
	Ru	106	2.61E-03	9.30E-02	2.43E-04	2.43E-08
	Ra	225	2.60E-03	7.6	1.98E-02	1.98E-06
	Sn	123	2.55E-03	3.00E-02	7.65E-05	7.65E-09
	Er	169	2.51E-03	2.00E-03	5.02E-06	5.02E-10
	I	125	2.44E-03	2.40E-02	5.86E-05	5.86E-09
	Se	73	2.36E-03	3.80E-04	8.97E-07	8.97E-11
97 m	Ce	133	2.36E-03		0.00E+00	0.00E+00
	Ba	128	2.19E-03	2.90E-03	6.35E-06	6.35E-10
	Cd	115m	2.18E-03	8.50E-02	1.85E-04	1.85E-08
308 ms	Ba	136m	2.15E-03		0.00E+00	0.00E+00
	Ho	166	2.07E-03	2.80E-03	5.80E-06	5.80E-10
17.5 h	Tb	152	2.03E-03		0.00E+00	0.00E+00

	Br	76	2.03E-03	1.20E-03	2.44E-06	2.44E-10
	Tm	173	2.03E-03	4.30E-04	8.73E-07	8.73E-11
	Pd	103	2.01E-03	1.40E-03	2.81E-06	2.81E-10
3.37 d	Nd	140	1.86E-03		0.00E+00	0.00E+00
	Re	182	1.84E-03	4.00E-04	7.36E-07	7.36E-11
	Ce	144	1.78E-03	3.50E-01	6.23E-04	6.23E-08
	Po	210	1.73E-03	8.10E+00	1.40E-02	1.40E-06
	Dy	166	1.72E-03	8.90E-03	1.53E-05	1.53E-09
20.1 h	Xe	122	1.69E-03		0.00E+00	0.00E+00
	Ce	139	1.64E-03	7.50E-03	1.23E-05	1.23E-09
	Tb	161	1.63E-03	3.10E-03	5.05E-06	5.05E-10
	Rb	84	1.55E-03	6.50E-03	1.01E-05	1.01E-09
	Ge	71	1.39E-03	1.20E-04	1.67E-07	1.67E-11
	Tm	172	1.38E-03	4.30E-03	5.93E-06	5.93E-10
2.16 m	Tl	209	1.26E-03		0.00E+00	0.00E+00
	Dy	157	1.18E-03	7.60E-05	8.97E-08	8.97E-12
	Tb	156	1.06E-03	3.60E-03	3.82E-06	3.82E-10
	Sc	47	1.03E-03	1.70E-03	1.75E-06	1.75E-10
	Er	171	1.01E-03	5.00E-04	5.05E-07	5.05E-11
	W	187	1.01E-03	5.30E-04	5.35E-07	5.35E-11
	Er	165	1.01E-03	2.70E-05	2.73E-08	2.73E-12
	Rh	99	9.94E-04	2.60E-03	2.58E-06	2.58E-10
	Er	172	9.67E-04	3.50E-03	3.38E-06	3.38E-10
	Tb	153	9.46E-04	7.00E-04	6.62E-07	6.62E-11
	Ce	134	8.78E-04	7.40E-03	6.50E-06	6.50E-10
	Rb	83	8.50E-04	4.90E-03	4.17E-06	4.17E-10
	Sb	125	7.23E-04	9.80E-03	7.09E-06	7.09E-10
	Ga	68	6.83E-04	1.20E-04	8.20E-08	8.20E-12
	Zr	86	6.75E-04	2.10E-03	1.42E-06	1.42E-10
	K	43	6.74E-04	5.60E-04	3.77E-07	3.77E-11
	As	72	6.73E-04	3.50E-03	2.36E-06	2.36E-10
5.4 h	At	209	6.71E-04		0.00E+00	0.00E+00
30 h	Tm	165	6.71E-04		0.00E+00	0.00E+00
	Te	127m	6.02E-04	1.90E-02	1.14E-05	1.14E-09
	Y	88	5.98E-04	2.10E-02	1.26E-05	1.26E-09
25.4 d	Sr	82	5.96E-04		0.00E+00	0.00E+00
	Gd	149	5.00E-04	2.00E-03	1.00E-06	1.00E-10
	Cs	134	4.07E-04	4.70E-02	1.91E-05	1.91E-09
	As	74	4.07E-04	6.50E-03	2.65E-06	2.65E-10
	Bi	206	3.87E-04	5.90E-03	2.28E-06	2.28E-10
	Ag	105	3.87E-04	4.70E-03	1.82E-06	1.82E-10
	Yb	169	3.66E-04	7.00E-03	2.56E-06	2.56E-10
	Zr	88	3.48E-04	2.20E-02	7.66E-06	7.66E-10
	Ga	66	3.38E-04	1.70E-03	5.75E-07	5.75E-11
	Ta	180	3.38E-04	2.10E-01	7.10E-05	7.10E-09
	Re	189	3.37E-04	1.10E-03	3.71E-07	3.71E-11
25.6 m	Ho	160	3.36E-04		0.00E+00	0.00E+00
28.6 h	Er	160	3.36E-04		0.00E+00	0.00E+00
	Ge	69	3.31E-04	6.20E-04	2.05E-07	2.05E-11

	Sc	48	3.27E-04	3.60E-03	1.18E-06	1.18E-10
	Fe	59	3.16E-04	1.50E-02	4.74E-06	4.74E-10
	U	230	3.15E-04	2.00E+01	6.30E-03	6.30E-07
	As	71	3.05E-04	1.10E-03	3.36E-07	3.36E-11
	Eu	148	2.98E-04	3.80E-03	1.13E-06	1.13E-10
	Ga	67	2.90E-04	4.80E-04	1.39E-07	1.39E-11
	Sn	117m	2.72E-04	3.40E-03	9.25E-07	9.25E-11
	Yb	175	2.64E-04	1.50E-03	3.96E-07	3.96E-11
	Ca	47	2.55E-04	5.50E-03	1.40E-06	1.40E-10
	Ta	183	2.43E-04	4.60E-03	1.12E-06	1.12E-10
	In	113m	2.37E-04	3.40E-05	8.06E-09	8.06E-13
	Sn	113	2.37E-04	8.90E-03	2.11E-06	2.11E-10
	Tb	155	2.36E-04	6.70E-04	1.58E-07	1.58E-11
11.93 d	Xe	131m	2.29E-04		0.00E+00	0.00E+00
	Eu	145	2.23E-04	2.60E-03	5.80E-07	5.80E-11
	As	73	1.80E-04	3.10E-03	5.58E-07	5.58E-11
	Tm	167	1.68E-04	2.60E-03	4.37E-07	4.37E-11
	Cd	109	1.66E-04	1.00E-01	1.66E-05	1.66E-09
	Rh	101	1.53E-04	3.20E-02	4.90E-06	4.90E-10
	Sc	46	1.48E-04	2.00E-02	2.96E-06	2.96E-10
	Dy	159	1.46E-04	2.10E-03	3.07E-07	3.07E-11
	Hf	181	1.41E-04	1.30E-02	1.83E-06	1.83E-10
	Dy	159	1.45E-04	2.10E-03	3.05E-07	3.05E-11
	Pm	147	1.45E-04	3.40E-02	4.93E-06	4.93E-10
	Hf	181	1.39E-04	1.30E-02	1.81E-06	1.81E-10
17.36 s	Se	77m	1.32E-04		0.00E+00	0.00E+00
	Pb	210	1.30E-04	1.30E+01	1.69E-03	1.69E-07
	Pm	147	1.27E-04	3.40E-02	4.32E-06	4.32E-10
	Pb	210	1.24E-04	1.30E+00	1.61E-04	1.61E-08
	Er	171	1.11E-04	5.00E-04	5.55E-08	5.55E-12
	Ta	182	1.09E-04	3.70E-02	4.03E-06	4.03E-10
	Eu	149	1.08E-04	1.60E-03	1.73E-07	1.73E-11
	Tc	94	1.03E-04	2.70E-04	2.78E-08	2.78E-12
	Sr	90	1.02E-04	1.30E+00	1.33E-04	1.33E-08
	Ra	228	2.15E-05	4.20E+00	9.03E-05	9.03E-09
	Sm	145	2.13E-05	1.00E-02	2.13E-07	2.13E-11
	W	181	1.73E-05	1.50E-04	2.60E-09	2.60E-13
	Tm	171	1.53E-05	8.60E-03	1.32E-07	1.32E-11
	V	49	1.26E-05	2.80E-04	3.53E-09	3.53E-13
5.2 s	W	183m	1.22E-05		0.00E+00	0.00E+00
	Cu	154	1.10E-05	2.60E-01	2.86E-06	2.86E-10
2.89 y	Po	208	1.01E-05		0.00E+00	0.00E+00
	Th nat	232	3.48E-06	1.60E+03	5.57E-03	5.57E-07
Sum			1.01E+01		2.74E+00	2.74E-04