

# MODELLING RADIOACTIVE DECAY

National Power (D D Apsley) and CERC

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*In this document 'ADMS' refers to ADMS 5.2.*

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## 1. Introduction

ADMS models three plume depletion processes: dry deposition, wet deposition and radioactive decay. This paper describes the radioactive decay module. All three processes lead to a variation with downwind distance, or travel time, of the plume strength  $Q$ :

$$Q(x) = \int_{-\infty}^{\infty} dy \int_0^{\infty} C(x, y, z) U dz \quad (1)$$

where  $U$  is the mean wind speed and  $C$  is the concentration.

It is assumed that:

- (i) Removal processes act independently;
- (ii) Removal processes are irreversible

The first assumption implies that plume strength can be written as a product of source strength and depletion factors corresponding to each removal process. Where species with significantly different deposition parameters are present in the release a separate calculation must be performed for each. Variation of deposition parameters with the formation of new isotopes following radioactive decay cannot, however, be modelled and the values of dry deposition velocity and washout coefficient specified by the user should reflect the contents of the initial isotope inventory. Deposition of daughter isotopes could alternatively be estimated by post-processing the model output using the expression  $D(x, y) = v_d C(x, y, z = 0)$ , where  $D$  is the deposition flux and  $v_d$  the dry deposition velocity, see technical specification P17/13 for more details.

Removal processes are integrated into the dispersion model as follows. Let  $C_1(x, y, z)$  be the mean activity *per unit source strength* in the absence of deposition or radioactive decay. The activity of the  $i$ th isotope in the inventory,  $C_i(x, y, z)$ , is then given by

$$C_i(x, y, z) = Q_i C_1(x, y, z) \quad (2)$$

The amount of each radioisotope is given as a fraction of the total mass release. Thus, if  $q_i$  is the amount of isotope  $i$  in the release in  $\text{mol kg}^{-1}$  and  $Q$  the total activity, the total plume strength for isotope  $i$  is:

$$Q_i = q_i Q \quad (3)$$

The variation of  $q_i$  with travel time is computed by the Radioactive Decay Module, which is described in the next section.

## 2. Modelling Radioactive Decay

Radioactive decay is calculated for a set of isotopes given their parent isotopes and decay constants (or half-lives). The main parameters used are given in Table 1.

Process	Parameters
Radioactive decay	{ $\lambda_i$ } - decay constants { $f_{ij}$ } - decay fraction $i \rightarrow j$

**Table 1:** Modelling parameters

The sources of radioactive decay data are described in paper P17/06.

The Radioactive Decay Module solves the coupled ordinary differential equations governing the transformation of radioactive isotopes [1]:

$$\frac{dq_i}{dt} = -\lambda_i q_i + \sum_{j \neq i} f_{ji} \lambda_j q_j \quad (4)$$

where:

$q_i$  = number fraction (mol kg<sup>-1</sup>) of isotope  $i$  in the emission;

$\lambda_i$  = decay constant of isotope  $i$ ;

$f_{ji}$  = fraction of isotope  $j$  decaying into  $i$ .

For plumes i.e. continuous releases, the “age” of the material at a downstream position  $x$ , is given by:

$$t = \int_0^x \frac{dx}{U(z_m)} \quad (5)$$

where  $z_m$  is the mean plume height.

The decay constant  $\lambda_i$  is related to the half-life  $T_{1/2}$  by:

$$T_{1/2} = \frac{\ln 2}{\lambda} \quad (6)$$

and the number fraction is related to the activity  $A$  in Bequerels per kg (Bq kg<sup>-1</sup>) of that isotope by:

$$A_i = \lambda_i q_i \quad (7)$$

Up to 50 parent and daughter isotopes can be considered. Appendix A gives a list of the isotopes included in ADMS with their half-lives and decay products [2].

Calculation of gamma dose is described in ADMS Technical Specification P20/01.

### 3. Finite Releases

Radioactive decay from finite (puff) releases can be calculated by the model for short term averages as time integrated or time dependent activity output. The coupled ordinary differential equations governing the transformation of radioactive isotopes are solved as for plumes, see §2.

For time dependent puff output, equation (5) which gives the “age” of the material at a downstream position  $x$ , is replaced by the expression in equation (8):

$$t = \int_0^x \frac{dx}{U(z_s)} - t_{start} \quad (8)$$

where  $t_{start}$  is the start time of the puff and  $z_s$  is the original source height.  $z_s$  is used in place of  $z_m$  as the mean plume height varies at each downstream position with each puff output time and is poorly defined outside the plateau region of the puff.

### 4. Nomenclature

$A_i$	isotope activity in Becquerels per kg
$f_{ji}$	fraction of isotope j decaying into i
$Q$	plume strength
$q_i$	number fraction of isotope i in the emission
$Q_s$	source strength
$t$	travel time
$t_{start}$	start time of puff release
$T_{1/2}$	half-life
$U(z)$	wind speed at height z
$z_m$	mean plume height
$z_s$	plume height
$\lambda_i$	decay constant of isotope i

#### **Subscripts**

i	isotope index
s	source
1	per unit plume strength

## 5. References

- [1] Jones, J.A. (1983), Models to allow for the effects of coastal sites, plume rise and buildings on dispersion of radionuclides and guidance on the value of deposition velocity and washout coefficients, *NRPB-R157*, Harwell (London, HMSO)
- [2] Jylha, K. (1991), Empirical scavenging coefficients of radioactive substances released from Chernobyl, *Atmospheric Environment*, **25A**, 263-270

## Appendix A

### List of Isotopes with Half Lives and Decay Chains

The sources of radioactive decay data are described in paper P17/06.

Parent	Half life (s)	Daughter 1	Daughter 2	Daughter 3
HT (tritium gas)	3.8940E+08	HE-3 (1.000)		
H-3 (tritiated water)	3.8940E+08	HE-3 (1.000)		
OBT (organically bound tritium)	3.8940E+08	HE-3 (1.000)		
BE-7	4.6070E+06	LI-7 (1.000)		
BE-10	5.0450E+13	B-10 (1.000)		
C-11	1.2230E+03	B-11 (1.000)		
N-13	5.9770E+02	C-13 (1.000)		
C-14	1.8070E+11	N-14 (1.000)		
C-14(O2) (carbon dioxide)	1.8070E+11	N-14 (1.000)		
O-15	1.2220E+02	N-15 (1.000)		
F-18	6.5860E+03	O-18 (1.000)		
NE-19	1.7220E+01	F-19 (1.000)		
NA-22	8.2060E+07	NE-22 (1.000)		
NA-24	5.4000E+04	MG-24 (1.000)		
AL-26	2.2580E+13	MG-26 (1.000)		
MG-28	7.5270E+04	AL-28 (1.000)		
AL-28	1.3440E+02	SI-28 (1.000)		
P-30	1.4990E+02	SI-30 (1.000)		
SI-31	9.4390E+03	P-31 (1.000)		
SI-32	1.4190E+10	P-32 (1.000)		
P-32	1.2350E+06	S-32 (1.000)		
P-33	2.1950E+06	S-33 (1.000)		
S-35(H) (hydrogen sulphide)	7.5550E+06	CL-35 (1.000)		

S-35(C) (carbonyl sulphide)	7.5550E+06	CL-35 (1.000)		
CL-36	9.4920E+12	AR-36 (0.981)	S-36 (0.019)	
AR-37	3.0260E+06	CL-37 (1.000)		
CL-38	2.2330E+03	AR-38 (1.000)		
K-38	4.5820E+02	AR-38 (1.000)		
CL-39	3.3360E+03	AR-39 (1.000)		
AR-39	8.4830E+09	K-39 (1.000)		
K-40	4.0360E+16	CA-40 (0.890)	AR-40 (0.110)	
AR-41	6.5770E+03	K-41 (1.000)		
CA-41	4.4170E+12	K-41 (1.000)		
K-42	4.4490E+04	CA-42 (1.000)		
K-43	8.1360E+04	CA-43 (1.000)		
SC-43	1.4010E+04	CA-43 (1.000)		
K-44	1.3280E+03	CA-44 (1.000)		
SC-44M	2.1090E+05	SC-44 (0.986)	CA-44 (0.014)	
SC-44	1.4140E+04	CA-44 (1.000)		
TI-44	1.4920E+09	SC-44 (1.000)		
K-45	1.2000E+03	CA-45 (1.000)		
CA-45	1.4080E+07	SC-45 (1.000)		
TI-45	1.1090E+04	SC-45 (1.000)		
SC-46	7.2430E+06	TI-46 (1.000)		
CA-47	3.9140E+05	SC-47 (1.000)		
SC-47	2.8960E+05	TI-47 (1.000)		
V-47	1.9560E+03	TI-47 (1.000)		
SC-48	1.5730E+05	TI-48 (1.000)		
V-48	1.4030E+06	TI-48 (1.000)		
CR-48	8.2660E+04	V-48 (1.000)		
CA-49	5.2300E+02	SC-49 (1.000)		
SC-49	3.4440E+03	TI-49 (1.000)		
V-49	2.8520E+07	TI-49 (1.000)		
CR-49	2.5260E+03	V-49 (1.000)		
CR-51	2.3940E+06	V-51 (1.000)		
MN-51	2.7730E+03	CR-51 (1.000)		
MN-52M	1.2660E+03	CR-52 (0.980)	MN-52 (0.020)	
MN-52	4.8300E+05	CR-52 (1.000)		
FE-52	2.9790E+04	MN-52M (1.000)		
MN-53	1.1670E+14	CR-53 (1.000)		
MN-54	2.7000E+07	CR-54 (1.000)		

FE-55	8.5150E+07	MN-55 (1.000)		
CO-55	6.3150E+04	FE-55 (1.000)		
MN-56	9.2820E+03	FE-56 (1.000)		
CO-56	6.8050E+06	FE-56 (1.000)		
NI-56	5.2720E+05	CO-56 (1.000)		
CO-57	2.3400E+07	FE-57 (1.000)		
NI-57	1.2990E+05	CO-57 (1.000)		
CO-58M	3.2940E+04	CO-58 (1.000)		
CO-58	6.1170E+06	FE-58 (1.000)		
FE-59	3.8460E+06	CO-59 (1.000)		
NI-59	2.3650E+12	CO-59 (1.000)		
FE-60	3.1540E+12	CO-60M (1.000)		
CO-60M	6.2820E+02	NI-60 (0.0025)	CO-60 (0.9975)	
CO-60	1.6620E+08	NI-60 (1.000)		
CU-60	1.3920E+03	NI-60 (1.000)		
CO-61	5.9410E+03	NI-61 (1.000)		
CU-61	1.2270E+04	NI-61 (1.000)		
CO-62M	8.3460E+02	NI-62 (1.000)		
CO-62	9.3000E+01	NI-62 (1.000)		
CU-62	5.8430E+02	NI-62 (1.000)		
ZN-62	3.3350E+04	CU-62 (1.000)		
NI-63	3.0280E+09	CU-63 (1.000)		
ZN-63	2.2860E+03	CU-63 (1.000)		
CU-64	4.5720E+04	NI-64 (0.620)	ZN-64 (0.380)	
NI-65	9.0730E+03	CU-65 (1.000)		
ZN-65	2.1070E+07	CU-65 (1.000)		
GA-65	9.1200E+02	ZN-65 (1.000)		
NI-66	1.9650E+05	CU-66 (1.000)		
CU-66	3.0600E+02	ZN-66 (1.000)		
GA-66	3.3830E+04	ZN-66 (1.000)		
GE-66	8.1720E+03	GA-66 (1.000)		
CU-67	2.2270E+05	ZN-67 (1.000)		
GA-67	2.8170E+05	ZN-67 (1.000)		
GE-67	1.1220E+03	GA-67 (1.000)		
GA-68	4.0800E+03	ZN-68 (1.000)		
GE-68	2.4880E+07	GA-68 (1.000)		
ZN-69M	4.9540E+04	ZN-69 (1.000)		
ZN-69	3.4200E+03	GA-69 (1.000)		
GE-69	1.4060E+05	GA-69 (1.000)		
AS-69	9.1200E+02	GE-69 (1.000)		



GA-70	1.2690E+03	GE-70 (1.000)		
AS-70	3.1550E+03	GE-70 (1.000)		
SE-70	2.4600E+03	AS-70 (1.000)		
ZN-71M	1.4110E+04	GA-71 (1.000)		
ZN-71	1.4400E+02	GA-71 (1.000)		
GE-71	1.0200E+06	GA-71 (1.000)		
AS-71	2.3330E+05	GE-71 (1.000)		
ZN-72	1.6740E+05	GA-72 (1.000)		
GA-72	5.0750E+04	GE-72 (1.000)		
AS-72	9.3600E+04	GE-72 (1.000)		
GA-73	1.7680E+04	GE-73 (1.000)		
AS-73	6.9380E+06	GE-73 (1.000)		
SE-73M	2.3400E+03	AS-73 (1.000)		
SE-73	2.5740E+04	AS-73 (1.000)		
AS-74	1.5340E+06	GE-74 (0.680)	SE-74 (0.320)	
BR-74M	2.4900E+03	SE-74 (1.000)		
BR-74	1.5180E+03	SE-74 (1.000)		
KR-74	6.9000E+02	BR-74 (1.000)		
GE-75	4.9660E+03	AS-75 (1.000)		
SE-75	1.0350E+07	AS-75 (1.000)		
BR-75	5.8770E+03	SE-75 (1.000)		
AS-76	9.4760E+04	SE-76 (1.000)		
BR-76	5.8310E+04	SE-76 (1.000)		
KR-76	5.3280E+04	BR-76 (1.000)		
GE-77	4.0680E+04	AS-77 (1.000)		
AS-77	1.3970E+05	SE-77 (1.000)		
SE-77M	1.7450E+01	SE-77 (1.000)		
BR-77	2.0160E+05	SE-77 (0.810)	SE-77M (0.190)	
KR-77	4.4830E+03	BR-77 (1.000)		
GE-78	5.2210E+03	AS-78 (1.000)		
AS-78	5.4440E+03	SE-78 (1.000)		
SE-79	2.0500E+12	BR-79 (1.000)		
KR-79	1.2610E+05	BR-79 (1.000)		
RB-79	1.3740E+03	KR-79 (1.000)		
BR-80M	1.5910E+04	BR-80 (1.000)		
BR-80	1.0440E+03	KR-80 (0.915)	SE-80 (0.085)	
RB-80	3.4010E+01	KR-80 (1.000)		
SR-80	6.0000E+03	RB-80 (1.000)		
SE-81M	3.4360E+03	SE-81 (1.000)		
SE-81	1.1100E+03	BR-81 (1.000)		

KR-81M	1.3000E+01	KR-81 (1.000)		
KR-81	6.6230E+12	BR-81 (1.000)		
RB-81M	1.9200E+03	KR-81 (0.500)	RB-81 (0.500)	
RB-81	1.6490E+04	KR-81 (1.000)		
SR-81	1.5300E+03	RB-81 (1.000)		
BR-82	1.2710E+05	KR-82 (1.000)		
RB-82M	2.2320E+04	KR-82 (1.000)		
RB-82	7.8000E+01	KR-82 (1.000)		
SR-82	2.1600E+06	RB-82 (1.000)		
SE-83	1.3500E+03	BR-83 (1.000)		
BR-83	8.6050E+03	KR-83M (1.000)		
KR-83M	6.5880E+03	KR-83 (1.000)		
RB-83	7.4480E+06	KR-83M (0.770)	KR-83 (0.230)	
SR-83	1.1660E+05	RB-83 (1.000)		
BR-84	1.9080E+03	KR-84 (1.000)		
RB-84	2.8320E+06	KR-84 (0.970)	SR-84 (0.030)	
KR-85M	1.6130E+04	RB-85 (0.770)	KR-85 (0.230)	
KR-85	3.3820E+08	RB-85 (1.000)		
SR-85M	4.1700E+03	SR-85 (0.860)	RB-85 (0.140)	
SR-85	5.6020E+06	RB-85 (1.000)		
RB-86	1.6120E+06	SR-86 (1.000)		
Y-86M	2.8810E+03	Y-86 (1.000)		
Y-86	5.3050E+04	SR-86 (1.000)		
ZR-86	5.9410E+04	Y-86 (1.000)		
KR-87	4.5790E+03	RB-87 (1.000)		
RB-87	1.4820E+18	SR-87 (1.000)		
SR-87M	1.0100E+04	SR-87 (0.990)	RB-87 (0.010)	
Y-87	2.8900E+05	SR-87M (1.000)		
KR-88	1.0220E+04	RB-88 (1.000)		
RB-88	1.0680E+03	SR-88 (1.000)		
Y-88	9.2140E+06	SR-88 (1.000)		
ZR-88	7.2060E+06	Y-88 (1.000)		
NB-88	8.5800E+02	ZR-88 (1.000)		
RB-89	9.1200E+02	SR-89 (1.000)		
SR-89	4.3620E+06	Y-89 (1.000)		
ZR-89	2.8240E+05	Y-89 (1.000)		
NB-89S	3.9610E+03	ZR-89 (1.000)		
NB-89L	7.3200E+03	ZR-89 (1.000)		
SR-90	9.1840E+08	Y-90 (1.000)		
Y-90M	1.1480E+04	Y-90 (0.996)	ZR-90 (0.004)	

Y-90	2.3040E+05	ZR-90 (1.000)		
NB-90	5.2580E+04	ZR-90 (1.000)		
MO-90	2.0410E+04	NB-90 (1.000)		
SR-91	3.4200E+04	Y-91M (0.590)	Y-91 (0.410)	
Y-91M	2.9820E+03	Y-91 (1.000)		
Y-91	5.0540E+06	ZR-91 (1.000)		
SR-92	9.7550E+03	Y-92 (1.000)		
Y-92	1.2740E+04	ZR-92 (1.000)		
Y-93	3.6360E+04	ZR-93 (1.000)		
ZR-93	4.8260E+13	NB-93M (0.950)	NB-93 (0.050)	
NB-93M	4.2900E+08	NB-93 (1.000)		
MO-93M	2.4660E+04	MO-93 (1.000)		
MO-93	1.1040E+11	NB-93 (1.000)		
TC-93M	2.6090E+03	TC-93 (0.820)	MO-93 (0.180)	
TC-93	9.9000E+03	MO-93 (1.000)		
Y-94	1.1460E+03	ZR-94 (1.000)		
NB-94	6.4020E+11	MO-94 (1.000)		
TC-94M	3.1210E+03	MO-94 (1.000)		
TC-94	1.7580E+04	MO-94 (1.000)		
RU-94	3.1080E+03	TC-94 (1.000)		
Y-95	6.4200E+02	ZR-95 (1.000)		
ZR-95	5.5300E+06	NB-95 (0.980)	NB-95M (0.020)	
NB-95M	3.1180E+05	NB-95 (1.000)		
NB-95	3.0370E+06	MO-95 (1.000)		
TC-95M	5.2720E+06	MO-95 (0.960)	TC-95 (0.040)	
TC-95	7.2000E+04	MO-95 (1.000)		
NB-96	8.4070E+04	MO-96 (1.000)		
TC-96M	3.0900E+03	TC-96 (1.000)		
TC-96	3.6970E+05	MO-96 (1.000)		
ZR-97	6.0840E+04	NB-97M (1.000)		
NB-97M	6.0000E+01	NB-97 (1.000)		
NB-97	4.3270E+03	MO-97 (1.000)		
TC-97M	7.5170E+06	TC-97 (1.000)		
TC-97	8.1990E+13	MO-97 (1.000)		
RU-97	2.5060E+05	TC-97 (1.000)*	TC-97M (4E-4)	
NB-98	3.0900E+03	MO-98 (1.000)		
TC-98	1.3250E+14	RU-98 (1.000)		
MO-99	2.3760E+05	TC-99M (0.880)	TC-99 (0.120)	
TC-99M	2.1670E+04	TC-99 (1.000)		
TC-99	6.7170E+12	RU-99 (1.000)		

RH-99M	1.6920E+04	RU-99 (1.000)		
RH-99	1.3820E+06	RU-99 (1.000)		
RH-100	7.4880E+04	RU-100 (1.000)		
PD-100	3.1370E+05	RH-100 (1.000)		
MO-101	8.7720E+02	TC-101 (1.000)		
TC-101	8.5200E+02	RU-101 (1.000)		
RH-101M	3.7500E+05	RU-101 (0.900)	RH-101 (0.100)	
RH-101	1.0090E+08	RU-101 (1.000)		
PD-101	2.9770E+04	RH-101M (1.000)		
RH-102M	1.7880E+07	RU-102 (0.840)	PD-102 (0.160)	
RH-102	9.1460E+07	RU-102 (1.000)		
AG-102	7.7400E+02	PD-102 (1.000)		
RU-103	3.3930E+06	RH-103M (1.000)		
RH-103M	3.3660E+03	RH-103 (1.000)		
PD-103	1.4650E+06	RH-103M (1.000)		
AG-103	3.9430E+03	PD-103 (1.000)		
TC-104	1.0920E+03	RU-104 (1.000)		
AG-104M	2.0100E+03	PD-104 (0.700)	AG-104 (0.300)	
AG-104	4.1530E+03	PD-104 (1.000)		
CD-104	3.4620E+03	AG-104M (1.000)		
RU-105	1.5980E+04	RH-105 (1.000)		
RH-105	1.2730E+05	PD-105 (1.000)		
AG-105	3.5420E+06	PD-105 (1.000)		
RU-106	3.1800E+07	RH-106 (1.000)		
RH-106M	7.9200E+03	PD-106 (1.000)		
RH-106	2.9900E+01	PD-106 (1.000)		
AG-106M	7.2660E+05	PD-106 (1.000)		
AG-106	1.4380E+03	PD-106 (1.000)		
RH-107	1.3020E+03	PD-107 (1.000)		
PD-107	2.0500E+14	AG-107 (1.000)		
CD-107	2.3370E+04	AG-107 (1.000)		
AG-108M	4.0060E+09	PD-108 (0.900)	AG-108 (0.100)	
AG-108	1.4220E+02	CD-108 (0.978)	PD-108 (0.022)	
PD-109	4.8340E+04	AG-109M (1.000)		
AG-109M	3.9610E+01	AG-109 (1.000)		
CD-109	4.0090E+07	AG-109 (1.000)		
IN-109	1.5120E+04	CD-109 (1.000)		
AG-110M	2.1590E+07	CD-110 (0.987)	AG-110 (0.013)	
AG-110	2.4600E+01	CD-110 (0.997)	PD-110 (0.003)	
IN-110L	1.7640E+04	CD-110 (1.000)		

IN-110S	4.1470E+03	CD-110 (1.000)		
SN-110	1.4400E+04	IN-110S (1.000)		
AG-111	6.4370E+05	CD-111 (1.000)		
IN-111	2.4450E+05	CD-111 (1.000)		
SN-111	2.1180E+03	IN-111 (1.000)		
AG-112	1.1230E+04	CD-112 (1.000)		
IN-112	8.6410E+02	CD-112 (0.560)	SN-112 (0.440)	
CD-113M	4.2900E+08	IN-113 (1.000)		
IN-113M	5.9710E+03	IN-113 (1.000)		
SN-113	9.9450E+06	IN-113 (1.000)		
IN-114M	4.2780E+06	IN-114 (0.965)	CD-114 (0.035)	
IN-114	7.1900E+01	SN-114 (0.980)	CD-114 (0.020)	
AG-115	1.2000E+03	CD-115 (1.000)		
CD-115M	3.8540E+06	IN-115 (0.970)	IN-115M (0.030)	
CD-115	1.9240E+05	IN-115M (1.000)		
IN-115M	1.6150E+04	IN-115 (0.950)	SN-115 (0.050)	
IN-115	1.6080E+23	SN-115 (1.000)		
SB-115	1.9080E+03	SN-115 (1.000)		
IN-116M	3.2490E+03	SN-116 (1.000)		
IN-116	1.4000E+00	SN-116 (1.000)		
SB-116M	3.6190E+03	SN-116 (1.000)		
SB-116	9.4800E+02	SN-116 (1.000)		
TE-116	8.9640E+03	SB-116 (1.000)		
CD-117M	1.2100E+04	IN-117 (1.000)		
CD-117	8.9640E+03	IN-117 (1.000)		
IN-117M	6.9900E+03	SN-117 (0.530)	IN-117 (0.470)	
IN-117	2.6280E+03	SN-117 (1.000)		
SN-117M	1.1760E+06	SN-117 (1.000)		
SB-117	1.0080E+04	SN-117 (1.000)		
SB-118M	1.8000E+04	SN-118 (1.000)		
SB-118	2.1000E+02	SN-118 (1.000)		
IN-119M	1.0800E+03	SN-119 (0.950)	IN-119 (0.050)	
IN-119	1.4400E+02	SN-119 (0.950)	SN-119M (0.050)	
SN-119M	2.5310E+07	SN-119 (1.000)		
SB-119	1.3720E+05	SN-119 (1.000)		
SB-120L	4.9780E+05	SN-120 (1.000)		
SB-120S	9.5330E+02	SN-120 (1.000)		
I-120M	3.1800E+03	TE-120 (1.000)		
I-120	4.8610E+03	TE-120 (1.000)		
I-120(P) <sup>#</sup>	4.8610E+03	TE-120 (1.000)		

I-120(ME) <sup>†</sup>	4.8610E+03	TE-120 (1.000)		
XE-120	2.4000E+03	I-120 (1.000)		
SN-121M	1.7340E+09	SB-121 (1.000)		
SN-121	9.7410E+04	SB-121 (1.000)		
TE-121M	1.3310E+07	TE-121 (0.900)	SB-121 (0.100)	
TE-121	1.4690E+06	SB-121 (1.000)		
I-121	7.6320E+03	TE-121 (1.000)		
I-121(P) <sup>#</sup>	7.6320E+03	TE-121 (1.000)		
I-121(ME) <sup>†</sup>	7.6320E+03	TE-121 (1.000)		
XE-121	2.4060E+03	I-121 (1.000)		
SB-122	2.3330E+05	TE-122 (0.970)	SN-122 (0.030)	
I-122	2.1720E+02	TE-122 (1.000)		
I-122(P) <sup>#</sup>	2.1720E+02	TE-122 (1.000)		
I-122(ME) <sup>†</sup>	2.1720E+02	TE-122 (1.000)		
XE-122	7.2360E+04	I-122 (1.000)		
SN-123M	2.4050E+03	SB-123 (1.000)		
SN-123	1.1160E+07	SB-123 (1.000)		
TE-123M	1.0340E+07	TE-123 (1.000)		
TE-123	3.1540E+20	SB-123 (1.000)		
I-123	4.7530E+04	TE-123 (1.000)		
I-123(P) <sup>#</sup>	4.7530E+04	TE-123 (1.000)		
I-123(ME) <sup>†</sup>	4.7530E+04	TE-123 (1.000)		
XE-123	7.4880E+03	I-123 (1.000)		
SB-124M2	1.2120E+03	SB-124 (1.000)		
SB-124M1	9.2990E+01	SB-124 (0.800)	TE-124 (0.200)	
SB-124	5.2030E+06	TE-124 (1.000)		
I-124	3.6120E+05	TE-124 (1.000)		
I-124(P) <sup>#</sup>	3.6120E+05	TE-124 (1.000)		
I-124(ME) <sup>†</sup>	3.6120E+05	TE-124 (1.000)		
SN-125	8.3290E+05	SB-125 (1.000)		
SB-125	8.7350E+07	TE-125 (0.800)	TE-125M (0.200)	
TE-125M	5.0120E+06	TE-125 (1.000)		
I-125	5.1940E+06	TE-125 (1.000)		
I-125(P) <sup>#</sup>	5.1940E+06	TE-125 (1.000)		
I-125(ME) <sup>†</sup>	5.1940E+06	TE-125 (1.000)		
XE-125	6.1200E+04	I-125 (1.000)		
CS-125	2.7000E+03	XE-125 (1.000)		
SN-126	3.1540E+12	SB-126M (1.000)		
SB-126M	1.1400E+03	TE-126 (1.000)		
SB-126	1.0710E+06	TE-126 (1.000)		

I-126	1.1250E+06	TE-126 (0.560)	XE-126 (0.440)	
I-126(P) <sup>#</sup>	1.1250E+06	TE-126 (0.560)	XE-126 (0.440)	
I-126(ME) <sup>†</sup>	1.1250E+06	TE-126 (0.560)	XE-126 (0.440)	
CS-126	9.8400E+01	XE-126 (1.000)		
BA-126	5.7920E+03	CS-126 (1.000)		
SN-127	7.5600E+03	SB-127 (1.000)		
SB-127	3.3270E+05	TE-127 (0.840)	TE-127M (0.160)	
TE-127M	9.4180E+06	TE-127 (0.992)	I-127 (0.008)	
TE-127	3.3660E+04	I-127 (1.000)		
XE-127	3.1450E+06	I-127 (1.000)		
CS-127	2.2500E+04	XE-127 (1.000)		
SN-128	3.5460E+03	SB-128S (0.970)	SB-128L (0.030)	
SB-128L	3.2440E+04	TE-128 (1.000)		
SB-128S	6.2400E+02	TE-128 (1.000)		
I-128	1.4990E+03	XE-128 (0.937)	TE-128 (0.063)	
I-128(P) <sup>#</sup>	1.4990E+03	XE-128 (0.937)	TE-128 (0.063)	
I-128(ME) <sup>†</sup>	1.4990E+03	XE-128 (0.937)	TE-128 (0.063)	
CS-128	2.3400E+02	XE-128 (1.000)		
BA-128	2.1000E+05	CS-128 (1.000)		
SB-129	1.5550E+04	TE-129 (1.000)		
TE-129M	2.9030E+06	TE-129 (0.640)	I-129 (0.360)	
TE-129	4.1760E+03	I-129 (1.000)		
I-129	4.9490E+14	XE-129 (1.000)		
I-129(P) <sup>#</sup>	4.9490E+14	XE-129 (1.000)		
I-129(ME) <sup>†</sup>	4.9490E+14	XE-129 (1.000)		
XE-129M	6.9120E+05	XE-129 (1.000)		
CS-129	1.1540E+05	XE-129 (1.000)		
SB-130	2.4000E+03	TE-130 (1.000)		
I-130	4.4490E+04	XE-130 (1.000)		
I-130(P) <sup>#</sup>	4.4490E+04	XE-130 (1.000)		
I-130(ME) <sup>†</sup>	4.4490E+04	XE-130 (1.000)		
CS-130	1.7940E+03	XE-130 (0.980)	BA-130 (0.020)	
SB-131	1.3800E+03	TE-131 (1.000)		
TE-131M	1.0800E+05	I-131 (0.820)	TE-131 (0.180)	
TE-131	1.5000E+03	I-131 (1.000)		
I-131	6.9470E+05	XE-131 (0.994)	XE-131M (0.006)	
I-131(P) <sup>#</sup>	6.9470E+05	XE-131 (0.994)	XE-131M (0.006)	
I-131(ME) <sup>†</sup>	6.9470E+05	XE-131 (0.994)	XE-131M (0.006)	
XE-131M	1.0280E+06	XE-131 (1.000)		
CS-131	8.3720E+05	XE-131 (1.000)		

BA-131M	8.7590E+02	BA-131 (1.000)		
BA-131	1.0200E+06	CS-131 (1.000)		
LA-131	3.5390E+03	BA-131 (1.000)		
TE-132	2.8160E+05	I-132 (1.000)		
I-132M	5.0160E+03	I-132 (0.860)	XE-132 (0.140)	
I-132	8.2800E+03	XE-132 (1.000)		
I-132(P) <sup>#</sup>	8.2800E+03	XE-132 (1.000)		
I-132(ME) <sup>†</sup>	8.2800E+03	XE-132 (1.000)		
CS-132	5.5970E+05	XE-132 (0.978)	BA-132 (0.022)	
LA-132	1.7280E+04	BA-132 (1.000)		
TE-133M	3.3230E+03	I-133 (0.870)	TE-133 (0.130)	
TE-133	7.4700E+02	I-133 (1.000)		
I-133	7.4880E+04	XE-133 (1.000)		
I-133(P) <sup>#</sup>	7.4880E+04	XE-133 (1.000)		
I-133(ME) <sup>†</sup>	7.4880E+04	XE-133 (1.000)		
XE-133M	1.8900E+05	XE-133 (1.000)		
XE-133	4.5300E+05	CS-133 (1.000)		
BA-133M	1.4010E+05	BA-133 (1.000)		
BA-133	3.3870E+08	CS-133 (1.000)		
TE-134	2.5080E+03	I-134 (1.000)		
I-134	3.1550E+03	XE-134 (1.000)		
I-134(P) <sup>#</sup>	3.1550E+03	XE-134 (1.000)		
I-134(ME) <sup>†</sup>	3.1550E+03	XE-134 (1.000)		
CS-134M	1.0440E+04	CS-134 (1.000)		
CS-134	6.5020E+07	BA-134 (1.000)		
LA-134	4.0030E+02	BA-134 (1.000)		
CE-134	2.5930E+05	LA-134 (1.000)		
I-135	2.3790E+04	XE-135 (1.000)		
I-135(P) <sup>#</sup>	2.3790E+04	XE-135 (1.000)		
I-135(ME) <sup>†</sup>	2.3790E+04	XE-135 (1.000)		
XE-135M	9.1740E+02	XE-135 (1.000)		
XE-135	3.2730E+04	CS-135 (1.000)		
CS-135M	3.1800E+03	CS-135 (1.000)		
CS-135	7.2530E+13	BA-135 (1.000)		
BA-135M	1.0330E+05	BA-135 (1.000)		
LA-135	7.0200E+04	BA-135 (1.000)		
CE-135	6.3360E+04	LA-135 (1.000)		
CS-136	1.1320E+06	BA-136 (1.000)		
PR-136	7.8600E+02	CE-136 (1.000)		
ND-136	3.0380E+03	PR-136 (1.000)		



CS-137	9.4610E+08	BA-137M (0.935)	BA-137 (0.065)	
BA-137M	1.5310E+02	BA-137 (1.000)		
LA-137	1.8920E+12	BA-137 (1.000)		
CE-137M	1.2380E+05	CE-137 (0.994)	LA-137 (0.006)	
CE-137	3.2410E+04	LA-137 (1.000)		
PR-137	4.5960E+03	CE-137 (1.000)		
XE-138	8.5020E+02	CS-138 (1.000)		
CS-138	1.9320E+03	BA-138 (1.000)		
LA-138	4.2560E+18	BA-138 (0.700)	CE-138 (0.300)	
PR-138M	7.5600E+03	CE-138 (1.000)		
PR-138	8.7000E+01	CE-138 (1.000)		
ND-138	1.8140E+04	PR-138M (1.000)		
BA-139	4.9620E+03	LA-139 (1.000)		
CE-139	1.1890E+07	LA-139 (1.000)		
PR-139	1.6230E+04	CE-139 (1.000)		
ND-139M	1.9800E+04	PR-139 (1.000)		
ND-139	1.7820E+03	PR-139 (1.000)		
BA-140	1.1010E+06	LA-140 (1.000)		
LA-140	1.4500E+05	CE-140 (1.000)		
BA-141	1.0960E+03	LA-141 (1.000)		
LA-141	1.4150E+04	CE-141 (1.000)		
CE-141	2.8080E+06	PR-141 (1.000)		
ND-141M	6.2400E+01	ND-141 (1.000)		
ND-141	8.9640E+03	PR-141 (1.000)		
PM-141	1.2540E+03	ND-141 (1.000)		
SM-141M	1.3560E+03	PM-141 (1.000)		
SM-141	6.1200E+02	PM-141 (1.000)		
BA-142	6.3600E+02	LA-142 (1.000)		
LA-142	5.5500E+03	CE-142 (1.000)		
PR-142M	8.7590E+02	ND-142 (1.000)		
PR-142	6.8870E+04	ND-142 (1.000)		
PM-142	4.0490E+01	ND-142 (1.000)		
SM-142	4.3490E+03	PM-142 (1.000)		
LA-143	8.5380E+02	CE-143 (1.000)		
CE-143	1.1880E+05	PR-143 (1.000)		
PR-143	1.1720E+06	ND-143 (1.000)		
PM-143	2.2890E+07	ND-143 (1.000)		
CE-144	2.4560E+07	PR-144 (1.000)		
PR-144M	4.3210E+02	ND-144 (1.000)		
PR-144	1.0370E+03	ND-144 (1.000)		

PM-144	3.1370E+07	ND-144 (1.000)		
PR-145	2.1530E+04	ND-145 (1.000)		
PM-145	5.5810E+08	ND-145 (1.000)		
SM-145	2.9370E+07	PM-145 (1.000)		
EU-145	5.1320E+05	SM-145 (1.000)		
GD-145	1.3740E+03	EU-145 (1.000)		
PM-146	1.7450E+08	ND-146 (0.650)	SM-146 (0.350)	
SM-146	3.2480E+15	ND-142 (1.000)		
EU-146	3.9820E+05	SM-146 (1.000)		
GD-146	4.1730E+06	EU-146 (1.000)		
PR-147	8.1600E+02	ND-147 (1.000)		
ND-147	9.4860E+05	PM-147 (1.000)		
PM-147	8.2730E+07	SM-147 (1.000)		
SM-147	3.3420E+18	ND-143 (1.000)		
EU-147	2.0740E+06	SM-147 (1.000)*	PM-143 (2E-6)	
GD-147	1.3720E+05	EU-147 (1.000)		
TB-147	5.9410E+03	GD-147 (1.000)		
PM-148M	3.5690E+06	SM-148 (0.930)	PM-148 (0.070)	
PM-148	4.6390E+05	SM-148 (1.000)		
EU-148	4.7080E+06	SM-148 (1.000)		
GD-148	2.9330E+09	SM-144 (1.000)		
ND-149	6.2280E+03	PM-149 (1.000)		
PM-149	1.9110E+05	SM-149 (1.000)		
EU-149	8.0440E+06	SM-149 (1.000)		
GD-149	8.1210E+05	EU-149 (1.000)		
TB-149	1.4940E+04	GD-149 (0.840)	GD-149 (0.160)	
PM-150	9.6480E+03	SM-150 (1.000)		
EU-150L	1.0780E+09	SM-150 (1.000)		
EU-150S	4.5440E+04	GD-150 (0.900)	SM-150 (0.100)	
TB-150	1.1770E+04	GD-150 (1.000)		
ND-151	7.4640E+02	PM-151 (1.000)		
PM-151	1.0220E+05	SM-151 (1.000)		
SM-151	2.8380E+09	EU-151 (1.000)		
GD-151	1.0370E+07	EU-151 (1.000)		
TB-151	6.3360E+04	GD-151 (1.000)*	EU-147 (5E-6)	
EU-152M	3.3550E+04	GD-152 (0.770)	SM-152 (0.230)	
EU-152	4.2030E+08	SM-152 (0.720)	GD-152 (0.280)	
GD-152	3.4070E+21	SM-148 (1.000)		
SM-153	1.6810E+05	EU-153 (1.000)		
GD-153	2.0910E+07	EU-153 (1.000)		

TB-153	2.0220E+05	GD-153 (1.000)		
EU-154	2.7750E+08	GD-154 (1.000)		
TB-154	7.7040E+04	GD-154 (1.000)		
SM-155	1.3260E+03	EU-155 (1.000)		
EU-155	1.5640E+08	GD-155 (1.000)		
TB-155	4.5960E+05	GD-155 (1.000)		
DY-155	3.5990E+04	TB-155 (1.000)		
HO-155	2.8810E+03	DY-155 (1.000)		
SM-156	3.3830E+04	EU-156 (1.000)		
EU-156	1.3120E+06	GD-156 (1.000)		
TB-156M2	8.7840E+04	TB-156 (1.000)		
TB-156M1	1.8000E+04	TB-156 (1.000)		
TB-156	4.6140E+05	GD-156 (1.000)		
EU-157	5.4540E+04	GD-157 (1.000)		
TB-157	4.7300E+09	GD-157 (1.000)		
DY-157	2.9160E+04	TB-157 (1.000)		
HO-157	7.5600E+02	DY-157 (1.000)		
EU-158	2.7530E+03	GD-158 (1.000)		
TB-158	4.7300E+09	GD-158 (1.000)		
GD-159	6.6820E+04	TB-159 (1.000)		
DY-159	1.2480E+07	TB-159 (1.000)		
HO-159	1.9800E+03	DY-159 (1.000)		
TB-160	6.2470E+06	DY-160 (1.000)		
TB-161	5.9710E+05	DY-161 (1.000)		
HO-161	9.0000E+03	DY-161 (1.000)		
ER-161	1.1660E+04	HO-161 (1.000)		
HO-162M	4.0800E+03	HO-162 (0.630)	DY-162 (0.370)	
HO-162	9.0000E+02	DY-162 (1.000)		
TM-162	1.3020E+03	ER-162 (1.000)		
YB-162	1.1340E+03	TM-162 (1.000)		
HO-164M	2.2500E+03	ER-164 (0.400)	DY-164 (0.400)	HO-164 (0.200)
HO-164	1.7400E+03	ER-164 (0.530)	DY-164 (0.470)	
DY-165	8.4030E+03	HO-165 (1.000)		
ER-165	3.7290E+04	HO-165 (1.000)		
DY-166	2.9370E+05	HO-166 (1.000)		
HO-166M	3.7830E+10	ER-166 (1.000)		
HO-166	9.6480E+04	ER-166 (1.000)		
TM-166	2.7730E+04	ER-166 (1.000)		
YB-166	2.0410E+05	TM-166 (1.000)		
HO-167	1.1160E+04	ER-167 (1.000)		

TM-167	7.9830E+05	ER-167 (1.000)		
YB-167	1.0500E+03	TM-167 (1.000)		
ER-169	8.0350E+05	TM-169 (1.000)		
YB-169	2.7660E+06	TM-169 (1.000)		
LU-169	1.2260E+05	YB-169 (1.000)		
TM-170	1.1110E+07	YB-170 (0.998)	ER-170 (0.002)	
LU-170	1.7280E+05	YB-170 (1.000)		
HF-170	5.7640E+04	LU-170 (1.000)		
ER-171	2.7070E+04	TM-171 (1.000)		
TM-171	6.0550E+07	YB-171 (1.000)		
LU-171	7.1020E+05	YB-171 (1.000)		
ER-172	1.7750E+05	TM-172 (1.000)		
TM-172	2.2890E+05	YB-172 (1.000)		
LU-172	5.7860E+05	YB-172 (1.000)		
HF-172	5.8940E+07	LU-172 (1.000)		
TA-172	2.2080E+03	HF-172 (1.000)		
TM-173	2.9660E+04	YB-173 (1.000)		
LU-173	4.3210E+07	YB-173 (1.000)		
HF-173	8.6410E+04	LU-173 (1.000)		
TA-173	1.3140E+04	HF-173 (1.000)		
LU-174M	1.2270E+07	YB-174 (0.800)	HF-174 (0.200)	
LU-174	1.0440E+08	YB-174 (1.000)		
TA-174	4.3210E+03	HF-174 (1.000)		
TM-175	9.1200E+02	YB-175 (1.000)		
YB-175	3.6210E+05	LU-175 (1.000)		
HF-175	6.0480E+06	LU-175 (1.000)		
TA-175	3.7810E+04	HF-175 (1.000)		
LU-176M	1.3250E+04	HF-176 (1.000)		
LU-176	1.1350E+18	HF-176 (1.000)		
TA-176	2.9090E+04	HF-176 (1.000)		
W-176	8.2800E+03	TA-176 (1.000)		
YB-177	6.8400E+03	LU-177 (1.000)		
LU-177M	1.3900E+07	HF-177 (0.780)	LU-177 (0.220)	
LU-177	5.7970E+05	HF-177 (1.000)		
HF-177M	3.0840E+03	HF-177 (1.000)		
TA-177	2.0380E+05	HF-177 (1.000)		
W-177	8.1000E+03	TA-177 (1.000)		
RE-177	8.3990E+02	W-177 (1.000)		
YB-178	4.4390E+03	LU-178 (1.000)		
LU-178M	1.3620E+03	HF-178 (1.000)		

LU-178	1.7040E+03	HF-178 (1.000)		
HF-178M	9.7760E+08	HF-178 (1.000)		
TA-178L	7.9200E+03	HF-178M (1.000)		
TA-178S	5.5870E+02	HF-178 (1.000)		
W-178	1.8750E+06	TA-178S (1.000)		
RE-178	7.9200E+02	W-178 (1.000)		
LU-179	1.6530E+04	HF-179 (1.000)		
HF-179M	2.1680E+06	HF-179 (1.000)		
TA-179	5.7470E+07	HF-179 (1.000)		
W-179	2.2500E+03	TA-179 (1.000)		
HF-180M	1.9800E+04	HF-180 (1.000)		
TA-180M	2.9160E+04	HF-180 (0.870)	W-180 (0.130)	
TA-180	3.1540E+20	W-180 (1.000)		
RE-180	1.4580E+02	W-180 (1.000)		
OS-180	1.3200E+03	RE-180 (1.000)		
HF-181	3.6630E+06	TA-181 (1.000)		
W-181	1.0470E+07	TA-181 (1.000)		
RE-181	7.2000E+04	W-181 (1.000)		
OS-181	6.3000E+03	RE-181 (1.000)		
HF-182M	3.6900E+03	TA-182 (0.540)	HF-182 (0.460)	
HF-182	2.8380E+14	TA-182 (1.000)		
TA-182M	9.5050E+02	TA-182 (1.000)		
TA-182	9.9370E+06	W-182 (1.000)		
RE-182L	2.3040E+05	W-182 (1.000)		
RE-182S	4.5720E+04	W-182 (1.000)		
OS-182	7.9200E+04	RE-182S (1.000)		
IR-182	9.0000E+02	OS-182 (1.000)		
HF-183	3.8390E+03	TA-183 (1.000)		
TA-183	4.4070E+05	W-183 (1.000)		
HF-184	1.4830E+04	TA-184 (1.000)		
TA-184	3.1320E+04	W-184 (1.000)		
RE-184M	1.4260E+07	RE-184 (0.700)	W-184 (0.300)	
RE-184	3.2830E+06	W-184 (1.000)		
IR-184	1.0870E+04	OS-184 (1.000)		
TA-185	2.9400E+03	W-185 (1.000)		
W-185	6.4880E+06	RE-185 (1.000)		
OS-185	8.1210E+06	RE-185 (1.000)		
IR-185	5.0410E+04	OS-185 (1.000)		
TA-186	6.3000E+02	W-186 (1.000)		
RE-186M	6.3070E+12	OS-186 (1.000)		

RE-186	3.2640E+05	OS-186 (0.950)	W-186 (0.050)	
IR-186L	5.6870E+04	OS-186 (1.000)		
IR-186S	6.3000E+03	OS-186 (1.000)		
PT-186	7.2000E+03	IR-186L (1.000)		
W-187	8.6050E+04	RE-187 (1.000)		
RE-187	1.5770E+18	OS-187 (1.000)		
IR-187	3.7810E+04	OS-187 (1.000)		
W-188	5.9960E+06	RE-188 (1.000)		
RE-188M	1.1160E+03	RE-188 (1.000)		
RE-188	6.1130E+04	OS-188 (1.000)		
IR-188	1.4940E+05	OS-188 (1.000)		
PT-188	8.8120E+05	IR-188 (1.000)		
RE-189	8.7480E+04	OS-189 (1.000)		
OS-189M	2.1600E+04	OS-189 (1.000)		
IR-189	1.1490E+06	OS-189 (1.000)		
PT-189	3.9140E+04	IR-189 (1.000)		
OS-190M	5.9410E+02	OS-190 (1.000)		
IR-190M2	1.1160E+04	OS-190 (0.940)	IR-190 (0.060)	
IR-190M1	4.3210E+03	IR-190 (1.000)		
IR-190	1.0460E+06	OS-190 (1.000)		
OS-191M	4.6900E+04	OS-191 (1.000)		
OS-191	1.3310E+06	IR-191M (1.000)		
IR-191M	4.9410E+00	IR-191 (1.000)		
PT-191	2.4190E+05	IR-191 (1.000)		
IR-192M	7.6000E+09	IR-192 (1.000)		
IR-192	6.3960E+06	PT-192 (0.960)	OS-192 (0.040)	
OS-193	1.0800E+05	IR-193 (1.000)		
PT-193M	3.7410E+05	PT-193 (1.000)		
PT-193	1.5770E+09	IR-193 (1.000)		
AU-193	6.3540E+04	PT-193 (1.000)		
HG-193M	3.9950E+04	AU-193 (0.840)	HG-193 (0.160)	
HG-193	1.2600E+04	AU-193 (1.000)		
OS-194	1.8920E+08	IR-194 (1.000)		
IR-194M	1.4780E+07	PT-194 (1.000)		
IR-194	6.8940E+04	PT-194 (1.000)		
AU-194	1.4220E+05	PT-194 (1.000)		
HG-194	8.1990E+09	AU-194 (1.000)		
TL-194M	1.9680E+03	HG-194 (1.000)		
TL-194	1.9800E+03	HG-194 (1.000)		
IR-195M	1.3680E+04	IR-195 (1.000)		

IR-195	9.0000E+03	PT-195 (1.000)		
PT-195M	3.4740E+05	PT-195 (1.000)		
AU-195M	3.0490E+01	AU-195 (1.000)		
AU-195	1.5810E+07	PT-195 (1.000)		
HG-195M	1.4980E+05	AU-195M (0.500)	HG-195 (0.500)	
HG-195	3.5650E+04	AU-195 (1.000)		
TL-195	4.1760E+03	HG-195 (1.000)		
PB-195	9.4800E+02	TL-195 (1.000)		
PT-197M	5.6660E+03	PT-197 (0.970)	AU-197 (0.030)	
PT-197	6.5880E+04	AU-197 (1.000)		
HG-197M	8.5680E+04	HG-197 (0.940)	AU-197 (0.060)	
HG-197	2.3080E+05	AU-197 (1.000)		
TL-197	1.0220E+04	HG-197 (1.000)		
AU-198M	1.9870E+05	AU-198 (1.000)		
AU-198	2.3290E+05	HG-198 (1.000)		
TL-198M	6.7320E+03	TL-198 (0.550)	HG-198 (0.450)	
TL-198	1.9080E+04	HG-198 (1.000)		
PB-198	8.6410E+03	TL-198 (1.000)		
PT-199	1.8480E+03	AU-199 (1.000)		
AU-199	2.7120E+05	HG-199 (1.000)		
HG-199M	2.5560E+03	HG-199 (1.000)		
TL-199	2.6710E+04	HG-199 (1.000)		
PB-199	5.4000E+03	TL-199 (1.000)		
PT-200	4.4990E+04	AU-200 (1.000)		
AU-200M	6.7320E+04	AU-200 (0.830)	HG-200 (0.170)	
AU-200	2.9040E+03	HG-200 (1.000)		
TL-200	9.3960E+04	HG-200 (1.000)		
PB-200	7.7400E+04	TL-200 (1.000)		
BI-200	2.1840E+03	PB-200 (1.000)		
AU-201	1.5840E+03	HG-201 (1.000)		
TL-201	2.6300E+05	HG-201 (1.000)		
PB-201	3.3830E+04	TL-201 (1.000)		
BI-201	6.4800E+03	PB-201 (1.000)		
TL-202	1.0570E+06	HG-202 (1.000)		
PB-202M	1.3030E+04	PB-202 (0.910)	TL-202 (0.090)	
PB-202	9.4610E+12	TL-202 (1.000)		
BI-202	6.0120E+03	PB-202 (1.000)		
HG-203	4.0270E+06	TL-203 (1.000)		
PB-203	1.8740E+05	TL-203 (1.000)		
BI-203	4.2320E+04	PB-203 (1.000)		

PO-203	2.2020E+03	BI-203 (1.000)		
TL-204	1.1920E+08	PB-204 (0.979)	HG-204 (0.021)	
PB-205	4.5100E+14	TL-205 (1.000)		
BI-205	1.3230E+06	PB-205 (1.000)		
PO-205	6.4800E+03	BI-205 (1.000)*	PB-201 (0.00074)	
TL-206	2.5190E+02	PB-206 (1.000)		
BI-206	5.3950E+05	PB-206 (1.000)		
TL-207	2.8610E+02	PB-207 (1.000)		
BI-207	1.1980E+09	PB-207 (1.000)		
PO-207	2.1000E+04	BI-207 (1.000)		
AT-207	6.4800E+03	PO-207 (0.900)	BI-203 (0.100)	
TL-208	1.8420E+02	PB-208 (1.000)		
TL-209	1.3200E+02	PB-209 (1.000)		
PB-209	1.1710E+04	BI-209 (1.000)		
PB-210	7.0320E+08	BI-210 (1.000)		
BI-210M	9.4610E+13	TL-206 (0.996)	PO-210 (0.004)	
BI-210	4.3300E+05	PO-210 (1.000)		
PO-210	1.1960E+07	PB-206 (1.000)		
PB-211	2.1660E+03	BI-211 (1.000)		
BI-211	1.2840E+02	TL-207 (0.9972)	PO-211 (0.0028)	
PO-211	5.1580E-01	PB-207 (1.000)		
AT-211	2.5970E+04	PO-211 (0.590)	BI-207 (0.410)	
PB-212	3.8320E+04	BI-212 (1.000)		
BI-212	3.6340E+03	PO-212 (0.640)	TL-208 (0.360)	
PO-212	3.0490E-07	PB-208 (1.000)		
BI-213	2.7400E+03	PO-213 (0.978)	TL-209 (0.022)	
PO-213	4.2000E-06	PB-209 (1.000)		
PB-214	1.6080E+03	BI-214 (1.000)		
BI-214	1.1940E+03	PO-214 (1.000)		
PO-214	1.6430E-04	PB-210 (1.000)		
PO-215	1.7800E-03	PB-211 (1.000)*	AT-215 (2.3E-6)	
AT-215	1.0000E-04	BI-211 (1.000)		
PO-216	1.5000E-01	PB-212 (1.000)		
AT-216	3.0000E-04	BI-212 (1.000)		
AT-217	3.2300E-02	BI-213 (1.000)		
PO-218	1.8300E+02	PB-214 (1.000)*	AT-218 (1.9E-4)	
AT-218	2.0000E+00	BI-214 (0.999)	RN-218 (0.001)	
RN-218	3.5000E-02	PO-214 (1.000)		
RN-219	3.9610E+00	PO-215 (1.000)		
FR-219	2.1000E-02	AT-215 (1.000)		



RN-220	5.5610E+01	PO-216 (1.000)		
FR-220	2.7400E+01	AT-216 (1.000)		
FR-221	2.8810E+02	AT-217 (1.000)		
RN-222	3.3030E+05	PO-218 (1.000)		
FR-222	8.6410E+02	RA-222 (1.000)		
RA-222	3.8000E+01	RN-218 (1.000)		
FR-223	1.3080E+03	RA-223 (1.000)		
RA-223	9.8790E+05	RN-219 (1.000)		
AC-223	1.3200E+02	FR-219 (0.990)	RA-223 (0.010)	
RA-224	3.1620E+05	RN-220 (1.000)		
AC-224	1.0440E+04	RA-224 (0.900)	FR-220 (0.100)	
RA-225	1.2790E+06	AC-225 (1.000)		
AC-225	8.6410E+05	FR-221 (1.000)		
RA-226	5.0450E+10	RN-222 (1.000)		
AC-226	1.0440E+05	TH-226 (0.800)	RA-226 (0.200)	
TH-226	1.8540E+03	RA-222 (1.000)		
RA-227	2.5320E+03	AC-227 (1.000)		
AC-227	6.8660E+08	TH-227 (0.986)	FR-223 (0.014)	
TH-227	1.6170E+06	RA-223 (1.000)		
PA-227	2.2980E+03	AC-223 (0.850)	TH-227 (0.150)	
RA-228	1.8130E+08	AC-228 (1.000)		
AC-228	2.2070E+04	TH-228 (1.000)		
TH-228	6.0330E+07	RA-224 (1.000)		
PA-228	7.9200E+04	TH-228 (0.980)	AC-224 (0.020)	
TH-229	2.3150E+11	RA-225 (1.000)		
TH-230	2.4290E+12	RA-226 (1.000)		
PA-230	1.5030E+06	TH-230 (0.896)	U-230 (0.104)	AC-226 (3.2E-5)
U-230	1.7970E+06	TH-226 (1.000)		
TH-231	9.1870E+04	PA-231 (1.000)		
PA-231	1.0330E+12	AC-227 (1.000)		
U-231	3.6300E+05	PA-231 (1.000)*	TH-227 (5.5E-5)	
TH-232	4.4300E+17	RA-228 (1.000)		
PA-232	1.1320E+05	U-232 (1.000)		
U-232	2.2700E+09	TH-228 (1.000)		
NP-232	8.8200E+02	U-232 (1.000)		
PA-233	2.3330E+06	U-233 (1.000)		
U-233	4.9990E+12	TH-229 (1.000)		
NP-233	2.1720E+03	U-233 (1.000)		
TH-234	2.0820E+06	PA-234 (1.000)		
PA-234M	7.0200E+01	U-234 (0.9987)	PA-234 (0.0013)	

PA-234	2.4120E+04	U-234 (1.000)		
U-234	7.7110E+12	TH-230 (1.000)		
NP-234	3.8020E+05	U-234 (1.000)		
PU-234	3.1690E+04	NP-234 (0.940)	U-230 (0.060)	
U-235	2.2200E+16	TH-231 (1.000)		
NP-235	3.4220E+07	U-235 (1.000)*	PA-231 (1.6E-5)	
PU-235	1.5180E+03	NP-235 (1.000)*	U-231 (3E-5)	
U-236	7.3840E+14	TH-232 (1.000)		
NP-236L	3.6270E+12	PU-236 (1.000)		
NP-236S	8.1000E+04	PU-236 (0.570)	U-236 (0.430)	
PU-236	8.9910E+07	U-232 (1.000)		
U-237	5.8310E+05	NP-237 (1.000)		
NP-237	6.7490E+13	PA-233 (1.000)		
PU-237	3.9140E+06	NP-237 (1.000)*	U-233 (3.3E-5)	
AM-237	4.3810E+03	PU-237 (1.000)*	NP-233 (5E-5)	
U-238	1.4090E+17	TH-234 (1.000)		
NP-238	1.8290E+05	PU-238 (1.000)		
PU-238	2.7670E+09	U-234 (1.000)		
AM-238	5.8770E+03	PU-238 (1.000)		
CM-238	8.6410E+03	AM-238 (0.900)	PU-234 (0.100)	
U-239	1.4120E+03	NP-239 (1.000)		
NP-239	2.0350E+05	PU-239 (1.000)		
PU-239	7.5890E+11	U-235 (1.000)		
AM-239	4.2840E+04	PU-239 (1.000)*	NP-235 (5E-5)	
U-240	5.0750E+04	NP-240 (1.000)		
NP-240M	4.4390E+02	PU-240 (1.000)		
NP-240	3.8990E+03	PU-240 (1.000)		
PU-240	2.0620E+11	U-236 (1.000)		
AM-240	1.8290E+05	PU-240 (1.000)		
CM-240	2.3330E+06	PU-236 (1.000)		
PU-241	4.5400E+08	AM-241 (1.000)*	U-237 (2.3E-6)	
AM-241	1.3630E+10	NP-237 (1.000)		
CM-241	2.8340E+06	AM-241 (0.990)	PU-237 (0.010)	
PU-242	1.1870E+13	U-238 (1.000)		
AM-242M	4.7950E+09	AM-242 (0.9952)	NP-238 (0.0048)	
AM-242	5.7700E+04	CM-242 (0.840)	PU-242 (0.160)	
CM-242	1.4060E+07	PU-238 (1.000)		
PU-243	1.7840E+04	AM-243 (1.000)		
AM-243	2.3280E+11	NP-239 (1.000)		
CM-243	8.9880E+08	PU-239 (1.000)		

PU-244	2.6050E+15	U-240 (1.000)		
AM-244M	1.5600E+03	CM-244 (1.000)*	PU-244 (3.9E-4)	
AM-244	3.6360E+04	CM-244 (1.000)		
CM-244	5.7090E+08	PU-240 (1.000)		
CF-244	1.1640E+03	CM-240 (1.000)		
PU-245	3.7810E+04	AM-245 (1.000)		
AM-245	7.3800E+03	CM-245 (1.000)		
CM-245	2.6810E+11	PU-241 (1.000)		
BK-245	4.2690E+05	CM-245 (0.9989)	AM-241 (0.0011)	
PU-246	9.3750E+05	AM-246 (1.000)		
AM-246M	1.5000E+03	CM-246 (1.000)		
AM-246	2.3400E+03	CM-246 (1.000)		
CM-246	1.4920E+11	PU-242 (1.000)		
BK-246	1.5810E+05	CM-246 (1.000)		
CF-246	1.2850E+05	CM-242 (1.000)		
CM-247	4.9210E+14	PU-243 (1.000)		
BK-247	4.3520E+10	AM-243 (1.000)		
CM-248	1.0690E+13	PU-244 (1.000)		
CF-248	2.8820E+07	CM-244 (1.000)		
CM-249	3.8490E+03	BK-249 (1.000)		
BK-249	2.7650E+07	CF-249 (1.000)*	AM-245 (2.2E-5)	
CF-249	1.1060E+10	CM-245 (1.000)		
BK-250	1.1600E+04	CF-250 (1.000)		
CF-250	4.1250E+08	CM-246 (1.000)		
ES-250	7.5600E+03	CF-250 (1.000)		
CF-251	2.8320E+10	CM-247 (1.000)		
ES-251	1.1880E+05	CF-251 (0.9947)	BK-247 (0.0053)	
CF-252	8.3190E+07	CM-248 (1.000)		
FM-252	8.1720E+04	CF-248 (1.000)		
CF-253	1.5390E+06	ES-253 (0.9969)	CM-249 (0.0031)	
ES-253	1.7690E+06	BK-249 (1.000)		
FM-253	2.5930E+05	ES-253 (0.890)	CF-249 (0.110)	
ES-254M	1.4150E+05	FM-254 (1.000)		
ES-254	2.3820E+07	BK-250 (1.000)		
FM-254	1.1660E+04	CF-250 (1.000)		
FM-255	7.2250E+04	CF-251 (1.000)		
FM-257	8.6830E+06	CF-253 (1.000)		
MD-257	1.8720E+04	FM-257 (0.920)	ES-253 (0.080)	

\*This fraction rounds to 1.000 when shown to three decimal places, but is actually less than one.

# (P) denotes particulate isotope

† (ME) denotes iodine in the form of methyl iodide