Decay Data and Isotopic Abundances for Dosimetry Applications

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The International Reactor Dosimetry File IRDF-2002 was released in 2004 and fully documented in 2006 [1]. This file contains cross-section data for 66 dosimetry reactions and, for the first time, decay data information for all radioactive nuclides that may be produced by these reactions.

In the last few years, new cross-section evaluations have become available that re-define some of these dosimetry reactions and therefore justify an update and an extension of the 2002 version of the library [2]. During the same period, more recent decay data information were made available through the continuous evolution of the ENSDF library [3]. The decay data part of the IRDF was also updated and this note describes the main steps of this updating procedure.

1. Decay Data

For each radionuclide present in the IRDF file and their possible descendants, the evaluated decay data sets were collected from the most recent ENSDF mass-chain evaluations (as of December 2011). The decay data part of the IRDF file contains 64 nuclides in their ground state (of which 8 have a double decay mode), 34 nuclides in their first isomeric state (of which 9 have a double decay mode) and 3 nuclides in their second isomeric state.

All decay data schemes have been checked from the point of view of their physical quality and consistency, prior to being converted to the ENDF-6 format [4].

These two steps have been carried out by means of the SDF2NDF code [5], which was derived from RADLST Version 5.5 [6] – through extensive recoding and translation into double precision – and was enhanced with several new features. Radiation emitted from the electron cloud (X rays, Auger electrons, etc.) are also calculated. Several auxiliary output files were added in order to make data checking easier.

SDF2NDF performs several physical checks, for example:

a) The overall energy balance between the decay *Q*-value and the sum of the energies of all emitted particles (including recoils);
b) The sum of the transition intensities depopulating an excited level must be equal to the feeding of this level;
c) The transition intensity between two excited levels has to be equal to the sum of the gamma intensity and the converted electron intensities;
d) The total conversion coefficient must be close to the sum of the partial coefficients for the different electron shells.

The ENDF file produced by SDF2NDF is finally checked using the conventional STANEF, CHECKR and FIZCON processing codes [7] and is available from the IAEA Nuclear Data Section website: http://www-nds.iaea.org/.

2. Isotopic Abundances

The IRDF-2002 file contained the isotopic abundances of the 287 stable isotopes as evaluated in 1997 by Rosman and Taylor [8]. A more recent evaluation of the abundances is given in [9] and these new values are recommended.

Most values have changed only slightly or are identical between the two evaluations, with significant differences to be observed in only a few cases (+1.8 % for ^{70}Zn, +2.9 % for ^{76}Ge, +5.8 % for ^{124}Xe, -7.0 % for ^{156}Dy, -5.0 % for ^{158}Dy), but they remain consistent with the error bars.

Table 1 shows the relevant abundances taken from [9].

Table 1: Abundances of the stable isotopes (following [9])

Z	A	E	Iso	Z	A	E	Iso	Z	A	E	Iso	Z	A	E	Iso
1	1	H	99.9885 70	19	39	K	93.2581 44	32	70	Ge	20.38 18	44	100	Ru	12.60 7
	2	H	0.0115 70		40	K	0.0117 1		72	Ge	27.31 26		101	Ru	17.06 2
					41	K	6.7302 44		73	Ge	7.76 8		102	Ru	31.55 14
2	3	He	0.000134 3						74	Ge	36.72 15		104	Ru	18.62 27
	4	He	99.999866 3	20	40	Ca	96.941 156		76	Ge	7.83 7				
					42	Ca	0.647 23					45	103	Rh	100.
3	6	Li	7.59 4		43	Ca	0.135 10	33	75	As	100.				
	7	Li	92.41 4		44	Ca	2.086 110					46	102	Pd	1.02 1
					46	Ca	0.004 3	34	74	Se	0.89 4		104	Pd	11.14 8
4	9	Be	100.		48	Ca	0.187 21		76	Se	9.37 29		105	Pd	22.33 8
									77	Se	7.63 16		106	Pd	27.33 3
5	10	B	19.9 7	21	45	Sc	100.		78	Se	23.77 28		108	Pd	26.46 9
	11	B	80.1 7						80	Se	49.61 41		110	Pd	11.72 9
				22	46	Ti	8.25 3		82	Se	8.73 22				
6	12	C	98.93 8		47	Ti	7.44 2					47	107	Ag	51.839 8
	13	C	1.07 8		48	Ti	73.72 3	35	79	Br	50.69 7		109	Ag	48.161 8
					49	Ti	5.41 2		81	Br	49.31 7				
7	14	N	99.636 20		50	Ti	5.18 2					48	106	Cd	1.25 6
	15	N	0.364 20					36	78	Kr	0.355 3		108	Cd	0.89 3
				23	50	V	0.250 4		80	Kr	2.286 10		110	Cd	12.49 18
8	16	O	99.757 16		51	V	99.750 4		82	Kr	11.593 31		111	Cd	12.80 12
	17	O	0.038 1						83	Kr	11.500 19		112	Cd	24.13 21
	18	O	0.205 14	24	50	Cr	4.345 13		84	Kr	56.987 15		113	Cd	12.22 12
					52	Cr	83.789 18		86	Kr	17.279 41		114	Cd	28.73 42
9	19	F	100.		53	Cr	9.501 17						116	Cd	7.49 18
					54	Cr	2.365 7	37	85	Rb	72.17 2				
10	20	Ne	90.48 3						87	Rb	27.83 2	49	113	In	4.29 5
	21	Ne	0.27 1	25	55	Mn	100.						115	In	95.71 5
	22	Ne	9.25 3					38	84	Sr	0.56 1				
				26	54	Fe	5.845 35		86	Sr	9.86 1	50	112	Sn	0.97 1
11	23	Na	100.		56	Fe	91.754 36		87	Sr	7.00 1		114	Sn	0.66 1
					57	Fe	2.119 10		88	Sr	82.58 1		115	Sn	0.34 1
12	24	Mg	78.99 4		58	Fe	0.282 4						116	Sn	14.54 9
	25	Mg	10.00 1					39	89	Y	100.		117	Sn	7.68 7
	26	Mg	11.01 3	27	59	Co	100.						118	Sn	24.22 9
								40	90	Zr	51.45 40		119	Sn	8.59 4
13	27	Al	100.	28	58	Ni	68.0769 89		91	Zr	11.22 5		120	Sn	32.58 9
					60	Ni	26.2231 77		92	Zr	17.15 8		122	Sn	4.63 3
14	28	Si	92.223 19		61	Ni	1.1399 6		94	Zr	17.38 28		124	Sn	5.79 5
	29	Si	4.685 8		62	Ni	3.6345 17		96	Zr	2.80 9				
	30	Si	3.092 11		64	Ni	0.9256 9					51	121	Sb	57.21 5
								41	93	Nb	100.		123	Sb	42.79 5
15	31	P	100.	29	63	Cu	69.17 3								
					65	Cu	30.83 3	42	92	Mo	14.77 31	52	120	Te	0.09 1
16	32	S	94.99 26						94	Mo	9.23 10		122	Te	2.55 12
	33	S	0.75 2	30	64	Zn	48.268 321		95	Mo	15.90 9		123	Te	0.89 3
	34	S	4.25 24		66	Zn	27.975 77		96	Mo	16.68 1		124	Te	4.74 14
	36	S	0.01 1		67	Zn	4.102 21		97	Mo	9.56 5		125	Te	7.07 15
					68	Zn	19.024 123		98	Mo	24.19 26		126	Te	18.84 25
17	35	Cl	75.76 10		70	Zn	0.631 9		100	Mo	9.67 20		128	Te	31.74 8
	37	Cl	24.24 10										130	Te	34.08 62
				31	69	Ga	60.108 9	44	96	Ru	5.54 14				
18	36	Ar	0.3365 30		71	Ga	39.892 9		98	Ru	1.87 3	53	127	I	100.
	38	Ar	0.0632 5						99	Ru	12.76 14				
	40	Ar	99.6003 30												

Table 1 (cont'd): Abundances of the stable isotopes (following [9])

Z	A	E	Iso	Z	A	E	Iso	Z	A	E	Iso	Z	A	E	Iso
54	124	Xe	0.0952 3	62	144	Sm	3.07 7	69	169	Tm	100.	76	190	Os	26.26 2
	126	Xe	0.0890 2		147	Sm	14.99 18						192	Os	40.78 19
	128	Xe	1.9102 8		148	Sm	11.24 10	70	168	Yb	0.13 1				
	129	Xe	26.4006 82		149	Sm	13.82 7		170	Yb	3.04 15	77	191	Ir	37.3 2
	130	Xe	4.0710 13		150	Sm	7.38 1		171	Yb	14.28 57		193	Ir	62.7 2
	131	Xe	21.2324 30		152	Sm	26.75 16		172	Yb	21.83 67				
	132	Xe	26.9086 33		154	Sm	22.75 29		173	Yb	16.13 27	78	190	Pt	0.014 1
	134	Xe	10.4357 21						174	Yb	31.83 92		192	Pt	0.782 7
	136	Xe	8.8573 44	63	151	Eu	47.81 6		176	Yb	12.76 41		194	Pt	32.967 99
					153	Eu	52.19 6						195	Pt	33.832 10
55	133	Cs	100.					71	175	Lu	97.41 2		196	Pt	25.242 41
				64	152	Gd	0.20 1		176	Lu	2.59 2		198	Pt	7.163 55
56	130	Ba	0.106 1		154	Gd	2.18 3								
	132	Ba	0.101 1		155	Gd	14.80 12	72	174	Hf	0.16 1	79	197	Au	100.
	134	Ba	2.417 18		156	Gd	20.47 9		176	Hf	5.26 7				
	135	Ba	6.592 12		157	Gd	15.65 2		177	Hf	18.60 9	80	196	Hg	0.15 1
	136	Ba	7.854 24		158	Gd	24.84 7		178	Hf	27.28 7		198	Hg	9.97 20
	137	Ba	11.232 24		160	Gd	21.86 19		179	Hf	13.62 2		199	Hg	16.87 22
	138	Ba	71.698 42						180	Hf	35.08 16		200	Hg	23.10 19
				65	165	Tb	100.						201	Hg	13.18 9
57	138	La	0.090 1					73	180	Ta	0.012 2		202	Hg	29.86 26
	139	La	99.910 1	66	156	Dy	0.056 3		181	Ta	99.988 2		204	Hg	6.87 15
					158	Dy	0.095 3								
58	136	Ce	0.185 2		160	Dy	2.329 18	74	180	W	0.12 1	81	203	Tl	29.52 1
	138	Ce	0.251 2		161	Dy	18.889 42		182	W	26.50 16		205	Tl	70.48 1
	140	Ce	88.450 51		162	Dy	25.475 36		183	W	14.31 4				
	142	Ce	11.114 51		163	Dy	24.896 42		184	W	30.64 2	82	204	Pb	1.4 1
					164	Dy	24.896 42		186	W	28.43 19		206	Pb	24.1 1
59	141	Pr	100.										207	Pb	22.1 1
				67	165	Ho	100.	75	185	Re	37.40 2		208	Pb	52.4 1
60	142	Nd	27.2 5						187	Re	62.60 2				
	143	Nd	12.2 2	68	162	Er	0.139 5					83	209	Bi	100.
	144	Nd	23.8 3		164	Er	1.601 3	76	184	Os	0.02 1				
	145	Nd	8.3 1		166	Er	33.503 36		186	Os	1.59 3	90	232	Th	100.
	146	Nd	17.2 3		167	Er	22.869 9		187	Os	1.96 2				
	148	Nd	5.7 1		168	Er	26.978 18		188	Os	13.24 8	92	234	U	0.0054 5
	150	Nd	5.6 2		170	Er	14.910 36		189	Os	16.15 5		235	U	0.7204 6
													238	U	99.2742 10

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