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A COMPILATION OF ACCURATELY MEASURED 2200 MS^{-1} CROSS-SECTIONS FOR 101 (n,γ) REACTIONS OF INTEREST IN ACTIVATION ANALYSIS ; A CRITICAL COMPARISON WITH LITERATURE

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Abstract : 2200 ms^{-1} Cross-sections were determined, according to the activation meth- od, for 101 (n,γ) reactions of interest in activation analysis. The results are averages of independent measurements at Gent and Budapest. The literature data for the input parameters were carefully selected. For some noteworthy cases, a comparison is made with the data of recent evaluated nuclear data files and with the results of other experimentalists.

(cross section ; n,gamma ; activation)

Introduction

2200 ms^{-1} (n,γ) Cross-sections [σ_0] are essential parameters in absolutely standardized (parametric) reactor neutron activation analysis. The usefulness of several recent evaluation works on σ_0-data - as major sources of information - is unquestionable. The quality of evaluated σ_0's depends, above all things, on the available experimental results, which are, however, often scarce or conflicting. Therefore, the present work was undertaken with the aim to contribute significantly to the experimental basis of σ_0-evaluation.

Experimental

The here presented σ_0-values were obtained according to the activation method.

For 83 (n,γ) reactions, the experiments were carried out independently at the Institute for Nuclear Sciences (INW,Gent) and the Central Research Institute for Physics (KFKI,Budapest) [occasionally at the Risø National Laboratory, Denmark]. Different experimental setups and techniques allowed to detect and to eliminate systematic experimental errors :

- use was made of targets with different chemical and physical characteristics. E.g. for Ag-110m (formed isotope) the basic materials were Ag or $AgNO_3$ (μg to mg amounts on W41-paper or Al-foil), or 1 mm diam. Al-0.2% Ag wire; for I-128 : $KH(IO_3)_2$, KI or KIO_3 (20-200 μg on W41-paper, with no iodine losses detected); for Au-198 (the ultimate standard) : 0.2-1 mm diam. Al-~0.1% Au wires of different origin, the compositions of which were checked meticulously ;
- 3-5 runs were carried out in at least 2 channels of both the THETIS reactor/INW and the WWR-M reactor/KFKI (and 1 channel of the DR-3 reactor/ Risø). The contribution of epithermal activation was corrected for via careful determination of the thermal-to-epithermal neutron flux ratio (ranging from 15 to 320) and of the $1/E^{1+\alpha}$ epithermal neutron flux distribution (α from -0.03 to +0.17) ;
- gamma's were counted with at least 3 Ge-detectors, the sources being positioned at 15-20 cm distance, for which the detection efficiency curve was determined with 1-2% accuracy. Different methods for peak area integration and for correction for dead-time and random coincidence were applied.

For 18 (n,γ) reactions, the determinations were performed in only one of the Institutes.

Input Parameters

A careful selection was made of literature data for the input parameters, the most crucial ones being the absolute gamma-intensity, the isotopic abundance and the half-life. The selected values are listed in Table 1, together with evaluated data for I_0/σ_0 (I_0 = resonance integral) /1/ and $\bar{E}_r$ (effective resonance energy)/2/ - introduced to correct for epithermal activation. In case of complex activation and decay, selected data for other relevant parameters (branching ratios, etc.) are also given.

Results

The σ_0's (relative to Au-198), listed in Table 1, are usually the averages of 3-5 runs x 2 channels x 2 reactors (and involving several Ge-detectors). The total uncertainties were obtained by quadratic combination of random (experimental) ones - not exceeding 2% - with uncertainties originating from the input data. The latter are sometimes surprisingly large, e.g. 24% on the value for the Cu-66 1039.2 keV gamma-intensity, and 50% on the value for the Os-184 isotopic abundance.

"Tentative" results, between square brackets, are obtained from 3-5 runs x 2 channels x 1 reactor.

Comparison with Evaluated Data

It is reassuring that a complete consistency is obtained for such "standards" as Mn-56 [13.3b (± 1.5%)/3/], Co-60 [37.13b(± 0.2%)/3/] and U-239 [2.68b(± 0.7%)/4/].

For some cases, however, significant discrepancies are observed, the most noteworthy of which are mentioned below (formed isotope indicated). Note that "(recent) evaluations" refer to Refs /3-7/, and that values with* are normalized to the same input data as in this work (which is not always possible).

- As-76; evaluations : 4.48-4.5b (from /8/: 4.48b); our result agrees with 3.96b* /9/ and 4.12b/10/;
- Rb-88; evaluations : 0.12b (from /11/: 0.122b); our result agrees with 0.106b* /9/ ;
- Ag-110m; evaluations : 4.6-4.7b (from some 4 consistent experimental results); our result agrees with 4.05b* /9/ ;

- Sn-113 (0.911m+g); evaluations : 0.97-0.98b ; our result agrees with 0.51b* /12/, 0.562b* /9/ and 0.558b* /13/ ;
- I-128 ; evaluations : 6.2b (from some 6 consistent experimental results) ; our result is still ∿10% lower than 4.45b* /14/ ;
- Ba-131(m+g) ; evaluations : 11.3-11.5b ; our result agrees with 8.8b /15/, to which evaluators unduly added 2.5b /16/ for m-formation ;
- Er-171 ; evaluations : 5.7-5.8b (from some 3 consistent experimental results) ; our result only agrees with 8.72b /17/ ;
- Yb-175(m+g) ; evaluations : 65-69.4b (from /18/: 65b) ; our result agrees with 130b* /19/ and 116b* /9/ ;
- Os-193 ; evaluations : 1.97-2.0b (from /20/ : 2.0b) ; sole experimental value : 1.9b* /20/.

The interpretation of these and other cases is left to the discretion of the evaluators.

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REFERENCES

1. F.De Corte : Agregé Thesis, Gent (1987); to be published
2. S.Jovanovic, F.De Corte, A.Simonits, L.Moens, P.Vukotic, J.Hoste : J.Radioanal.Nucl.Chem. 113, 177 (1987)
3. S.F.Mughabghab, M.Divadeenam, N.E.Holden : Neutron Cross Sections, Vol.1, part A, Acad. Press, N.Y. (1981)
4. S.F.Mughabghab : Neutron Cross Sections, Vol.1, part B, Acad.Press, N.Y. (1984)
5. F.W.Walker, D.G.Miller, F.Feiner : Chart of the Nuclides, 13th ed., G.E.C. (1984)
6. Computope Chart (Z=0-65, Z=60-109), NNDC-BNL (March 1985)
7. E.Gryntakis, D.E.Cullen, G.Mundy : in Handbook on Nuclear Activation Data, Techn.Repts Ser. no. 273, IAEA, Vienna (1987)
8. T.B.Ryves : J.Nucl.Energy 25, 129 (1971)
9. R.E.Heft : Proceed.Am.Nucl.Soc.Topical Conf., Mayaguez, CONF-780421, 1 (1979)
10. L.Koester, W.Knopf, W.Waschkowski, A.Kluver : Z.Phys. A318, 347 (1984)
11. L.Seren, E.N.Friedlander, S.H.Turkel : Phys. Rev. 72, 888 (1947)
12. W.Maenhaut, F.Adams, J.Hoste : J.Radioanal. Chem. 16, 39 (1973)
13. P.Nikolow, S.Niese : Isotopenpraxis 1, 31 (1980)
14. L.Friedmann, D.C.Aumann : Radiochim.Acta 33, 183 (1983)
15. W.S.Lyon : Nucl.Sci.Eng. 8, 278 (1960)
16. R.S.Tilbury, H.H.Kramer : Nucl.Sci.Eng. 31, 545 (1968)
17. R.F.Barnes : Rept. ANL-5287 (1954)
18. S.F.Mughabghab, R.E.Chrien : Phys.Rev. 174, 1400 (1968)
19. G.H.E.Sims, D.G.Juhnke : J.Inorg.Nucl.Chem. 32, 2839 (1970)
20. J.I.Kim, F.Adams : Radiochim.Acta 9, 61 (1968)

Table 1. Compilation of 2200 ms^{-1} (n,γ) cross-sections (together with input data) determined at the INW (Gent) and the KFKI (Budapest)

Target isotope	θ,% HOLDEN84 *	$\frac{I_0}{\sigma_0}$ ($\bar{E}_r$,eV)	Formed isotope	T	Measured E_γ,keV (absol.intens.,%) ; REF.*	σ_0,barn (s,% rand.;tot.)
Na-23	100.	0.59(3380)	Na-24(m+g)	14.959h	1368.6(99.994);2754.0(99.881);YOSHIZAWA85	0.513(.5;.8)
Mg-26	11.01	0.64(25700)	Mg-27	9.458min	170.7(0.84);843.8(71.8);1014.4(28.0);KOCHER81	0.0372(.4;.9)
Al-27	100.	0.71(11800)	Al-28	2.240min	1778.9(100.);KOCHER81	0.226(.8;1.)
S-36	0.02	1.12(-)	S-37	5.05min	3103.8(94.1);ENDT78	0.16(1.8;50.)
Cl-37	24.23	0.69(13700)	Cl-38(m+g)	37.21min	1642.4(32.5);2167.5(44.0);KOCHER81	0.423(1.;1.5)
K-41	6.7302	0.97(2960)	K-42	12.36h	312.7(0.319);1524.7(17.9);KOCHER81	1.45(.6;2.5)
Ca-46	0.004	1.3(-)	Ca-47	4.536d	489.2(6.51);807.9(6.51);1297.1(74.0);NDS86	0.61(.6;76.)
			↓ 1.00			
			Sc-47	3.345d	159.4(67.9);NDS86	
Ca-48	0.187	0.45(133000)	Ca-49	8.715min	3084.4(92.1);NDS86	1.12(.9;2.2)
Sc-45	100.	0.43(5130)	Sc-46(m+g)	83.810d	889.3(99.984);1120.5(99.987);NDS86	26.3(.6;.7)
Ti-50	5.4	0.67(63200)	Ti-51	5.76min	320.1(93.1);928.6(6.9);NDS86	0.170(.8;2.2)
V-51	99.750	0.55(7230)	V-52	3.75min	1434.0(100.);KOCHER81	4.79(1.2;1.7)
Cr-50	4.345	0.53(7530)	Cr-51	27.702d	320.1(10.08);NDS86	14.9(.5;2.4)
Mn-55	100.	1.053(468)	Mn-56	2.5785h	846.8(98.9);1810.7(27.2);2113.1(14.3);NDS87	13.2(.3;1.)
Fe-58	0.28	0.975(637)	Fe-59	44.496d	142.6(0.98);1099.2(56.1);1291.6(43.6);LMRI80	1.31(.3;4.)
Co-59	100.	1.993(136)	Co-60(F_2m+g)	5.2714y	1173.2(99.90);1332.5(99.982);NDS86	37.2$_5$(.4;.7)
Ni-64	0.91	0.67(14200)	Ni-65	2.520h	336.3(4.61);1115.5(14.8);1481.8(23.5);NDS86	1.67(.4;2.2)
Cu-63	69.17	1.14(1040)	Cu-64	12.701h	511.0(35.74);1345.9(0.49);KOCHER81	4.28(.5;4.3)
Cu-65	30.83	1.06(766)	Cu-66	5.10min	1039.2(7.4);NDS83	2.48(.5;24.)
Zn-64	48.6	1.908(2560)	Zn-65	243.9d	1115.5(50.70);NDS86	0.726(.4;1.)
Zn-68	18.8	3.19(590)	Zn-69m	13.76h	438.6(94.8);NDS82	0.0699(.6;2.3)
Ga-71	39.9	6.63(154)	Ga-72(m+g)	14.1h	834.0(95.65);894.2(9.85);1050.8(6.93); 2201.7(26.1);2491.0(7.48);2507.8(12.8); 2515.4(0.253);KOCHER81	4.61(.4;1.)
As-75	100.	13.6(106)	As-76	26.32h	559.1(45.0);563.2(1.2);657.1(6.17);1212.9+ 1216.1(4.86);NDS84	3.86(.6;4.5)
Se-74	0.9	10.0(29.4)	Se-75	119.770d	121.1(17.17);136.0(58.5);264.7(58.6);279.5 (24.94);400.7(11.44);YOSHIZAWA85	51.2(.4;11.)
Br-79	50.69	13.2(69.3)	Br-80m	4.42h		[2.04]
			↓ 1.00			[m/g=0.26]
Br-79	50.69	11.(69.3)	Br-80	17.68min	616.3(6.7);665.8(1.08);NDS82	[7.81]
Br-81	49.31	19.3(152)	Br-32(F_2m+g)	35.30h	554.3(70.8);619.1(43.4);698.4(28.5);776.5 (83.5);827.8(24.0);1044.0(27.2);1317.5(26.5); 1474.9(16.3);NDS87	2.59(.3;1.2)
Rb-85	72.165	14.8(839)	Rb-86(m+g)	18.66d	1076.6(8.78);KOCHER81	0.494(1.;1.5)
Rb-87	27.83$_5$	23.3(364)	Rb-88	17.8min	898.0(14.7);1836.0(22.4);LMRI80	0.102(.9;4.)
Sr-84	0.56	14.5(469)	Sr-85m	67.66min	231.7(84.72);KOCHER81	[0.61]
			↓ F_2			
Sr-84	0.56	13.2$_5$(469)	Sr-85(F_2m+g)	64.84d	514.0(99.270);KOCHER81	0.690(.9;2.1)
Sr-86	9.86	4.11(795)	Sr-87m	2.805h	388.4(82.3);KOCHER81	0.770(.5;.9)
Y-89	100.	5.93(4300)	Y-90m	3.19h	202.5(96.6);479.5(90.99);KOCHER81	0.00104(.95;1.)

Table 1. Continued

Target isotope	θ,% HOLDEN84 *	$\frac{I_0}{\sigma_0}$($\bar{E}_r$,eV)	Formed isotope	T	Measured E_γ,keV (absol.intens.,%) ; REF.*	σ_0,barn (s,% rand.;tot.)
Zr-94	17.38	5.05(6260)	Zr-95	64.03d	724.2(44.1$_5$);756.7(54.5);NDS83	0.0530(.3;1.)
			↓.0111			
			.989 ↓ Nb-95m	86.6h		
			↓.944			
			Nb-95	34.97d	765.8(99.79);NDS83	
Zr-96	2.80	248(338)	Zr-97	16.74h		0.0213(.6;1.)
			↓.968			
			.032 ↓ Nb-97m	60s	743.3(97.9);NDS85	
			↓1.00			
			Nb-97	72.1min	657.9(98.4);NDS85	
Nb-93	100.	7.35(574)	Nb-94m	6.26min	871.0(0.50);NDS85	0.863(1.6;12.)
Mo-98	24.13	53.1(241)	Mo-99	65.94h	181.1(6.08);739.5(12.1);778.0(4.34);NDS86	0.131(.4;.8)
			↓F_2=.880$_5$		[$\gamma_{140.5,Mo}/F_2\gamma_{140.5,Tc}$=0.0675]	
			Tc-99m	6.01h	140.5(89.06);NDS86	
Mo-100	9.63	18.84(672)	Mo-101	14.6min		0.200(.8;11.)
			↓1.00			
			Tc-101	14.2min	306.8(88.0);545.1(5.98);NDS85	
Ru-96	5.52	26.5(776)	Ru-97	2.9d	215.7(86.2);NDS85	0.229(.5;1.2)
Ru-102	31.6	3.63(181)	Ru-103	39.26d	497.1(90.9);610.3(5.73);NDS85	1.16(.3;2.3)
Ru-104	18.7	12.8(495)	Ru-105	4.44h	262.8(6.57);469.4+470.1(17.7);724.3(47.3); NDS86	0.491(.7;2.)
			↓.245			
			.755 ↓ Rh-105m	45s	129.7(20.0);NDS86	
			↓1.00			
			Rh-105	35.36h	306.1(5.13);319.2(19.2);NDS86	
Rh-103	100.	7.5(1.45)	Rh-104m	4.34min		[11.] [m/g=0.082]
			↓.9987			
Rh-103	100.	7.6(1.45)	Rh-104	42.3s	555.8(2.0);NDS84	[134.]
Pd-108	26.46	28.8(39.7)	Pd-109(m+g)	13.7h	309.1+311.4(0.0368);413.0+415.2(0.0173); 602.5(0.00798);636.3(0.00998);647.3(0.0244); 781.4(0.0112);NDS84	[8.77]
			↓1.00			
			Ag-109m	39.6s	88.0(3.61);NDS84	
Pd-110	11.72	20.(950)	Pd-111m	5.5h	172.1(33.0);NDS79	[0.012]
Ag-107	51.839	2.90(38.5)	Ag-108	2.37min	433.9(0.50);633.0(1.76);NDS82	33.1(1.3;5.)
Ag-109	48.161	17.5(6.08)	Ag-110m	249.76d	446.8(3.72);620.4(2.802);657.8(94.51);676.6+ 677.6(10.48);687.0(6.43);706.7+708.1(16.66); 744.3(4.73);763.9(22.29);818.0(7.33);884.7 (72.7);937.5(34.37);1384.3(24.34);1475.8 (3.990);1505.0(13.05);YOSHIZAWA85	3.90(.6;.8)
Cd-114	28.73	39.6(207)	Cd-115	53.46h	527.9(27.45);NDS87	[0.23]
			↓1.00			
			In-115m	4.486h	336.2(45.9);NDS87	
In-113	4.3	27.3(6.41)	In-114m(m2+m)	49.51d	190.3(15.4);558.4(4.39);725.2(4.33);NDS82	[8.2]
In-115	95.7	16.8(1.56)	In-116m(m$_2$+m)	54.15min	137.9(3.29);416.9(29.20);818.7(11.48);1097.2 (56.21);1293.5(84.40);1507.5(9.96);2112.2 (15.53);NDS81	157(.5;3.)
Sn-112	0.97		Sn-113m	21.4min		
			↓F_2=.911			
Sn-112	0.97	48.4(107)	Sn-113(F_2m+g)	115.09d		0.541(1.4;2.)
			↓1.00			
			In-113m	1.658h	391.7(64.9);NDS81	
Sn-116	14.53	56.3(128)	Sn-117m	13.60d	156.0+158.6(88.51);NDS87	0.00596(1.1;2.)
Sn-122	4.63	5.40(424)	Sn-123m	40.08min	160.3(85.6);NDS80	0.146(.5;2.5)
Sn-124	5.79	60.1(74.2)	Sn-125m	9.525min	331.9(99.57);NDS81	0.116(2.;3.)
Sn-124	5.79	60.(74.2)	Sn-125	9.64d	332.1(1.31);822.5(3.99);1067.1(9.04);1087.1 +1089.2(5.39);NDS81	[0.0042]
			1.00↓ ↓1.00			
			Sb-125	2.7617y	176.3(6.57);427.9(29.6);463.4(10.42);600.6 (17.61);606.6(5.02);635.9(11.23);YOSHIZAWA85	
Sb-121	57.3	33.0(13.1)	Sb-122(m+g)	2.70d	564.1(70.55);692.8(3.7);LMRI85	6.33(1.3;2.3)
Sb-123	42.7	28.8(28.2)	Sb-124 (F_3(m$_2$+m$_1$)+g)	60.20d	602.7(97.89);645.9(7.42);722.8(10.80);1691.0 (47.6);2090.9(5.48);LMRI85	4.08(.5;2.3)
I-127	100.	24.8(57.6)	I-128	24.99min	442.9(16.9);526.6(1.59);NDS83	4.04(1.1;10.)
Cs-133	100.	11.8(9.27)	Cs-134m	2.91h	127.5(12.7);NDS81	2.74(1.7;3.)
			↓1.00			
Cs-133	100.	12.7(9.27)	Cs-134(m+g)	2.062y	563.2(8.38);569.3(15.43);604.7(97.56);795.8 (85.44);801.9(8.73);NDS81	30.7(.8;1.)
Ba-130	0.106	24.8(69.9)	Ba-131(m+g)	11.8d	123.8(29.0);216.1(19.7);373.2(14.0);496.3 (46.8);KOCHER81	9.04(.7;3.)
Ba-132	0.101	5.6(143)	Ba-133m	38.9h	276.1(17.5);NDS86	[0.84]
Ba-138	71.70	0.88(15700)	Ba-139	83.06min	165.9(23.76);GEHRKE80	0.405(.7;1.4)
La-139	99.91	1.24(76.0)	La-140	40.27h	328.8(20.6);487.0(44.3);815.8(22.9);1596.5 (95.4);NDS87	9.43(.5;1.)
Ce-140	88.48	0.83(7200)	Ce-141	32.501d	145.4(48.2);NDS85	0.576(.9;1.2)
Ce-142	11.08	1.20(1540)	Ce-143	33.0h	231.6(2.05);293.3(42.8);350.6(3.23);664.5 (5.69);722.0(5.39);NDS86	0.974(.5;1.)
Pr-141	100.	1.51(296)	Pr-142(m+g)	19.12h	1575.6(3.7);NDS84	11.2(.6;14.)
Nd-146	17.19	2.00(874)	Nd-147	10.98d	91.1(28.1);275.4(0.77);319.4(1.91);439.9 (1.17);531.0(12.7);LMRI85	1.45(.8;3.)
Nd-148	5.76	5.08(236)	Nd-149	1.72h		2.36(1.1;6.7)
			↓1.00			
			Pm-149	53.08h	285.9(3.1);NDS85	
Nd-150	5.64	12.3(173)	Nd-151	12.4min	255.6(16.9);1180.6(15.3);LEDERER78	[0.91]
			↓1.00			
			Pm-151	28.40h	340.1(22.9);KOCHER81	
Sm-152	26.7	14.4(8.53)	Sm-153	46.7h	103.2(28.30); NDS82	220(.4;2.4)
Sm-154	22.7	4.30(142)	Sm-155	22.3min	141.2(2.00);246.0(3.70);NDS87	7.74(1.;6.)
Eu-153	52.2	5.66(5.80)	Eu-154(m+g)	8.561y	591.8(5.00);723.3(20.28);873.2(12.27);1274.4 (34.9);YOSHIZAWA85	307(.7;4.)

Table 1. Continued

Target isotope	θ,% HOLDEN84 *	$\frac{I_0}{\sigma_0}(\bar{E}_r$,eV)	Formed isotope	T	Measured E_γ,keV (absol.intens.,%) ; REF*	σ_0,barn (s,% rand.;tot.)
Gd-158	24.84	31.0(48.2)	Gd-159	18.56h	363.3(8.);KOCHER81	[3.1]
Gd-160	21.86	3.83(480)	Gd-161	3.66min	165.2(2.58);283.6(5.95);314.9(22.7);360.9 (60.1);480.1(2.68);NDS84	[1.51]
Tb-159	100.	17.9(18.1)	Tb-160	72.1d	86.8(13.3);197.0(5.18);215.6(4.06);298.6 (26.64);879.4(30.35);962.3+966.2(34.78); 1178.0(14.97);1199.9(2.379);1271.9(7.505); 1312.1(2.838);YOSHIZAWA85,KOCHER81	23.8(.3;1.)
Dy-164	28.2	0.25(224)	Dy-165m	1.258min	108.2(3.01);515.5(1.527);NDS87	[1697]
			↓ F_2=.976			
Dy-164	28.2	0.19(224)	Dy-165(F_2m+g)	2.334h	94.7(3.58);279.8(0.498);361.7(0.84);633.4 (0.568);715.3(0.534);NDS87	2725(.5;13.)
Ho-165	100.	10.9_5(12.3)	Ho-166	26.80h	1379.4(0.93);1581.9(0.183);1662.4(0.121); NDS87	58.1(1.1;4.)
Er-170	14.9	4.42(129)	Er-171	7.52h	111.6(20.5);124.0(9.1);295.9(28.9);308.3 (64.4);NDS84	8.85(.6;3.)
Tm-169	100.	14.5(4.80)	Tm-170	128.6d	84.3(3.26);NDS87	[107]
Yb-174	31.8	0.46(602)	Yb-175(m+g)	4.19d	113.8(1.88);137.7(0.104);144.9(0.34);282.5 (3.0);396.3(6.5);KOCHER81	128(.4;6.5)
Yb-176	12.7	2.50(412)	Yb-177(m+g)	1.9h	121.6(3.41);138.6(1.33);150.4(20.0);899.2 (0.644);941.7(1.01);1028.0(0.633);1080.1 (5.5);1119.6(0.545);1149.7(0.643);1241.4 (3.36);LEDERER78	[3.11]
Lu-175	97.41	34.8(16.1)	Lu-176m	3.635h	88.4(8.90);LOWENTHAL81	16.7(1.5;3.8)
Hf-174	0.162	0.78(29.6)	Hf-175	70d	343.6(87.0);LEDERER78	549(1.;1.8)
Hf-179	13.629	14.4(16.2)	Hf-180m	5.5h	93.3(17.3);215.2(81.7);332.3(94.4);443.2 (83.3);500.7(14.7);NDS87	0.445(.4;1.2)
Hf-180	35.100	2.52(115)	Hf-181	42.39d	133.0(41.7);133.0+136.2+136.9(47.7);482.2 (82.8);KOCHER81	13.5(.5;1.3)
Ta-181	99.988	33.3(10.4)	Ta-182(m+g)	114.43d	152.4(6.95);222.1(7.50);1121.3(35.30);1189.0 (16.44);1221.4(27.17);1231.0(11.58);INDC83	20.4(.3;1.1)
W-186	28.6	13.7(20.5)	W-187	23.9h	134.2(9.5);479.6(23.4);551.5(5.44);618.3 (6.7);685.7(29.2);772.9(4.40);KOCHER81	38.7(.3;5.)
Re-185	37.40	15.4(3.40)	Re-186	90.64h	122.3(0.70);137.2(9.5);KOCHER81	106(.6;16.)
Re-187	62.60	4.57(14.1)	Re-188m	18.6min	92.5(5.15);106.0(10.8);NDS81	2.05(1.1;4.3) m/g=0.028
			↓ 1.00			
Re-187	62.60	4.34(14.1)	Re-188	16.98h	155.0(15.0);478.0(1.04);633.1+635.0(1.41); KOCHER81	73.2(.6;4.2)
Os-184	0.02	0.43(-)	Os-185	93.6d	646.1(81.0);NDS81	3613(1.5;50.)
Os-190	26.4	2.40(114)	Os-191m	13.03h		[9.2] [m/g=2.36]
			↓ 1.00			
Os-190	26.4	2.03(114)	Os-191	15.4d	129.4(25.9);KOCHER81	3.90(1.6;3.2)
Os-192	41.0	2.34(89.7)	Os-193	30.5h	280.4(1.24);321.6(1.28);387.5(1.26);460.5 (3.95);556.0+557.4+559.3+560.0(1.80);NDS81	3.12(.6;5.)
Ir-193	62.7	12.0(2.21)	Ir-194(m_1+g)	19.15h	293.5(2.6);328.4(13.1);KOCHER81	115(.8;13.)
Pt-198	7.2	17.0(106)	Pt-199(m+g)	30.8min		3.58(.9;4.)
			↓ 1.00			
			Au-199	3.139d	158.4(36.8);208.2(8.4);KOCHER81	
Au-197	100.	15.71(5.65)	Au-198	2.695d	411.8(95.56)	98.65 [ULTIM.STAND.]
Hg-196	0.14	0.49(93.5)	Hg-197m	23.8h	134.0(34.0);KOCHER81	101(1.;71.)
Hg-202	29.80	0.88(1960)	Hg-203	46.612d	279.2(81.46);NDS85	4.35(1.7;1.9)
Th-232	100.	11.53(54.4)	Th-233	22.3min		7.26(.3;1.1)
			↓ 1.00			
			Pa-233	27.0d	300.1(6.64);312.0(38.6);340.5(4.44);375.4 (0.676);ZIJP79	
U-238	99.2745	103.4(16.9)	U-239	23.50min		2.75(.4;2.)
			↓ 1.00			
			Np-239	2.355d	209.8(3.27);226.4+228.2(11.1);277.6(14.2); 315.9(1.61);334.3(2.05);NDS83	

* HOLDEN84=N.E.Holden et al.,Pure Appl.Chem. 56,675(1984);YOSHIZAWA85=Y.Yoshizawa et al.:Rept.ICRM3ND2/85(1985);KOCHER81=D.C. Kocher:Rept.DOE/TIC-11026(1981);ENDT78=P.M.Endt et al.:Nucl.Phys. A310,450(1978);NDSXY=Nuclear Data Sheets (19XY);LMRIXY= Table de Radionucléides, LMRI,CEA (19XY);GEHRKE80=R.J.Gehrke:IJARI 31,37(1980);LEDERER78=C.M.Lederer et al.:Table of Isotopes, 7th ed.(1978);LOWENTHAL81=G.C.Lowenthal et al.:J.Phys. G7,1557(1981);INDC83=A.Lorentz:Rept.INDC(NDS)-145/GEI(1983);ZIJP79= W.L.Zijp et al.:Rept.ECN-70(1979)