

Activation cross sections for production of ^{166}Ho , ^{180}Ta , ^{186}Re and ^{210}Bi

(N. Otsuka, 2025-04-29, Memo CP-D/1132)

We expect to see -G in REACTION SF4 for activation cross sections when the metastable state has a very long half-life.

Four nuclides have metastable states with half-lives longer than 1000 years –

- $^{166\text{m}}\text{Ho}$ (1200 years)
- $^{180\text{m}}\text{Ta}$ ($>7.1 \times 10^{15}$ years)
- $^{186\text{m}}\text{Re}$ (2.0×10^{15})
- $^{210\text{m}}\text{Bi}$ (3.04×10^6 years).

We expect to see -G in REACTION SF4 for the production cross section of these nuclides measured by the activation method. But I found 72 datasets coded without -G in REACTION SF4, and I think we should add -G with a few exceptions. Note that some ^{186}Re and ^{210}Bi datasets were measured before discovery of the metastable states (1972 for $^{186\text{m}}\text{Re}$ and 1953 for $^{210\text{m}}\text{Bi}$).

List of datasets for 67-HO-166, 73-TA-180, 75-RE-186 and 83-BI-210 in REACTION SF4 coded with ACTIV in METHOD

EXFOR #	REACTION	Year	Remark	Additional correction
10218.008	(67-HO-165(N,G)67-HO-166,,SIG,,SPA)/ (79-AU-197(N,G)79-AU-198,,SIG,,SPA)	1972	Table 1 of C,71KNOX,1,113,1971 report the cross section is for 166gHo.	
12866.160	67-HO-165(N,G)67-HO-166,,SIG,,SPA	1978	1379 keV gamma used, free from interference from 166mHo decay	Remove SF8=SPA.
12866.161	67-HO-165(N,G)67-HO-166,,RI	1978	1379 keV gamma used, free from interference from 166mHo decay	
20188.024	67-HO-165(N,G)67-HO-166,,RI	1972	Table 1 of J,IIN,34,2699,1972 mentions "both isomers".	
20561.013	67-HO-165(N,G)67-HO-166,,RI	1974	The measured thermal cross section is compiled with -G in 20561.012.	
20635.009	67-HO-165(N,G)67-HO-166,,RI	1975	81 keV gamma used. See remark of 20188.024.	
20645.030	67-HO-165(N,G)67-HO-166,,RI	1974	81 keV gamma used. $\sigma_0=62$ mb taken from Holden (1968) is partial for 166gHo.	
22612.003	67-HO-165(N,G)67-HO-166,,SIG	1971		
23266.140.1	(67-HO-165(N,G)67-HO-166,,RI,,AV)// (67-HO-165(N,G)67-HO-166,,SIG,,AV)	2013	Add -G. Except for one line (80.6 keV), the measured gamma lines are irrelevant to metastable state production. (Farina Arbocco, 2025-04-23)	
23266.140.2	(67-HO-165(N,G)67-HO-166,,RI)// (67-HO-165(N,G)67-HO-166,,SIG)	2013	Add -G. Except for one line (80.6 keV), the measured gamma lines are irrelevant to metastable state production. (Farina Arbocco, 2025-04-23)	
23266.141	(67-HO-165(N,G)67-HO-166,,RI)// (67-HO-165(N,G)67-HO-166,,SIG)	2013	Add -G. Except for one line (80.6 keV), the measured gamma lines are irrelevant to metastable state production. (Farina Arbocco, 2025-04-23)	
23266.142	67-HO-165(N,G)67-HO-166,,SIG,,AV	2013	Add -G. Except for one line (80.6 keV), the measured gamma lines are irrelevant to metastable state production. (Farina Arbocco, 2025-04-23)	
23266.143	67-HO-165(N,G)67-HO-166,,SIG	2013	Add -G. Except for one line (80.6 keV), the measured gamma lines are irrelevant to metastable state production. (Farina Arbocco, 2025-04-23)	
30368.025	67-HO-165(N,G)67-HO-166,,RI	1969		

32233.022	68-ER-166(N,P)67-HO-166,,SIG	2012	Add -G (Ihor Kadenko via Olena Gritzay, 2025-04-28)	
C0372.002	(92-U-238(P,X)ELEM/MASS,,SIG)/ (92-U-238(P,X)56-BA-140,CUM,SIG)	1955		
D4285.004	67-HO-165(D,P)67-HO-166,,SIG	2013	Table 3 of J,NIM/B,311,102,2013 report the cross sections are for 166gHo.	
E1241.003	73-TA-0(P,X)ELEM/MASS,CUM,SIG	1985		
G4107.008	73-TA-181(G,N)73-TA-180,,SIG,,BRA,DERIV		(Ok. Isomeric ratio taken from theoretical model.)	
M0273.011	73-TA-181(G,N)73-TA-180,,SIG,,BRS		(Corrected in PRELIM.M136)	
10221.047	75-RE-185(N,G)75-RE-186,,SIG	1976		
11343.031	75-RE-185(N,G)75-RE-186,,RI	1950		
11447.116	75-RE-185(N,G)75-RE-186,,SIG,,MXW	1947		
11507.095	75-RE-185(N,G)75-RE-186,,SIG,,MXW	1952	(Ok. Pile oscilation method.)	Remove METHOD=ACTIV.
11625.033	75-RE-185(N,G)75-RE-186,,SIG,,MXW	1960		
11830.003	75-RE-185(N,G)75-RE-186,,RI	1962		
12165.003	75-RE-185(N,G)75-RE-186,,RI	1968		
12194.002	75-RE-185(N,G)75-RE-186,,RI	1966		
12194.003	75-RE-185(N,G)75-RE-186,,RI	1966		
12866.184	75-RE-185(N,G)75-RE-186,,SIG,,SPA	1978		Remove SF8=SPA.
12866.185	75-RE-185(N,G)75-RE-186,,RI	1978		
14388.054	75-RE-185(N,G)75-RE-186,,RI	1955		
20645.045	75-RE-185(N,G)75-RE-186,,RI	1974		
23266.144.1	(75-RE-185(N,G)75-RE-186,,RI,,AV)// (75-RE-185(N,G)75-RE-186,,SIG,,AV)	2013	Add -G. Measurement was done quit immediately after short irradiation (Farina Arbocco, 2025-04-22)	
23266.144.2	(75-RE-185(N,G)75-RE-186,,RI)// (75-RE-185(N,G)75-RE-186,,SIG)	2013	Add -G. Measurement was done quit immediately after short irradiation (Farina Arbocco, 2025-04-22)	

23266.145	(75-RE-185(N,G)75-RE-186,,RI)// (75-RE-185(N,G)75-RE-186,,SIG)	2013	Add -G. Measurement was done quit immediately after short irradiation (Farina Arbocco, 2025-04-22)
23266.146	75-RE-185(N,G)75-RE-186,,SIG,,AV	2013	Add -G. Measurement was done quit immediately after short irradiation (Farina Arbocco, 2025-04-22)
23266.147	75-RE-185(N,G)75-RE-186,,SIG	2013	Add -G. Measurement was done quit immediately after short irradiation (Farina Arbocco, 2025-04-22)
30079.036	75-RE-185(N,G)75-RE-186,,SIG	1966	
31247.021	75-RE-187(N,2N)75-RE-186,,SIG	1961	
31713.002	75-RE-185(N,G)75-RE-186,,SIG	2011	Add -G (Pham Ngoc Son, 2025-04-23)
40083.002	75-RE-185(N,G)75-RE-186,,SIG,,SPA	1967	
40083.007	75-RE-187(N,2N)75-RE-186,,SIG,,SPA	1967	
40083.008.1	75-RE-187(N,2N)75-RE-186,,SIG,,AV	1967	
40083.008.2	75-RE-187(N,2N)75-RE-186,,SIG	1967	
40083.008.3	75-RE-187(N,2N)75-RE-186,,SIG	1967	
41001.035	75-RE-185(N,G)75-RE-186,,SIG	1987	
A0212.045	74-W-186(D,2N)75-RE-186,,TTY,,PHY	1984	
C2242.002	74-W-186(D,2N)75-RE-186,,TTY,,SAT	2016	Table 2 of J,ARI,115,197,2016 report the yields are for 186gRe.
D0588.002	76-OS-192(P,X)75-RE-186,,SIG	2009	Add -G (Ferenc Szelecsenyi, 2025-04-24)
D0588.003	76-OS-192(P,X)75-RE- 186,,TTY,,(PHY),DERIV	2009	
D0665.002	74-W-0(P,X)75-RE-186,,TTY,,PHY	2010	Add -G (Mahdi Sadeghi, 2025-04-23)
D1050.009	74-W-0(D,X)75-RE-186,,SIG	2017	Question sent to Eva Simeckova (2025-04-22)
D7042.009	74-W-0(P,X)75-RE- 186,,TTY,,PHY,DERIV	2022	Add -G (Van Do Nguyen, 2025-04-23)
O2139.005	75-RE-0(P,X)75-RE-186,IND,SIG	2013	
R0053.007	75-RE-187(HE3,X)75-RE-186,,SIG	1968	
R0053.014	74-W-186(HE3,X)75-RE-186,,SIG	1968	
R0053.017	74-W-186(A,X)75-RE-186,,SIG	1968	
R0053.029	75-RE-185(HE3,2P)75-RE-186,,SIG	1968	
S0014.003	74-W-186(D,2N)75-RE-186,,SIG	1981	

11447.131	83-BI-209(N,G)83-BI-210,,SIG,,SPA	1947	
11450.040	83-BI-209(N,G)83-BI-210,,SIG,,FIS	1949	
21362.007	83-BI-209(N,G)83-BI-210,,SIG,,MXW	1950	
30067.018	83-BI-209(N,G)83-BI-210,,SIG	1967	
30249.005	(83-BI-209(N,A)81-TL-206,,SIG)/ (83-BI-209(N,G)83-BI-210,,SIG)	1973	
31849.002.3	83-BI-209(N,G)83-BI-210,,SIG	2022	(Ok, they measured the g.s. and m.s. activities separately.)
31849.004.3	83-BI-209(N,G)83-BI-210,,SIG,,EPI	2022	(Ok, they measured the g.s. and m.s. activities separately.)
31849.005	83-BI-209(N,G)83-BI-210,,RI,,,DERIV	2022	(Ok, they measured the g.s. and m.s. activities separately.)
41258.022	(83-BI-209(N,G)83-BI-210,,SIG)/ (23-V-51(N,G)23-V-52,,SIG)	1945	
41648.014	83-BI-209(N,G)83-BI-210,,SIG,,MXW	1956	
A0574.008	83-BI-209(D,P)83-BI-210,,SIG	1994	
C2124.004	83-BI-209(D,P)83-BI-210,,SIG	1947	