**Nuclear Data Section**

**International Atomic Energy Agency**

**P.O.Box 100, A-1400 Vienna, Austria**

**Memo CP-D/1132**

**Date:** 29 April 2025

**To:** Distribution

**From:** N. Otsuka

**Subject: Activation cross sections for production of 166Ho, 180Ta, 186Re and 210Bi**

Four nuclides have metastable states with half-lives longer than 1000 years – 166mHo (1200 years), 180mTa (>7.1×1015 years), 186mRe (2.0×1015) and 210mBi (3.04×106 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 186Re and 210Bi datasets were measured before discovery of the metastable states (1972 for 186mRe and 1953 for 210mBi).

**Distribution:**

[nrdc.memo-distribution@iaea.org](mailto:nrdc.memo-distribution@iaea.org)

**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,JIN,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. σ0=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 irrelenvant 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 irrelenvant 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 irrelenvant 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 irrelenvant 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 irrelenvant 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 osccilation 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** |  |  |