**Nuclear Data Section**

**International Atomic Energy Agency**

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**Memo CP-D/1018**

**Date:** 31 July 2021

**To:** Distribution

**From:** N. Otsuka

**Subject: Na-24 isomer production data**

Only the ground state is the isomeric state of 24Na (*i.e.,* states having half-life longer than 0.1 msec). Its first excitation level at 472 keV is a quasi-isomer (T1/2=20 msec). The isomeric transition probability of 99.95%, and production of the quasi-isomer can be identified by detection of the 427 keV prompt gamma (*e.g.*, online prompt gamma detection, cyclic activation). Its measurement technique is different from detection of the ground state (usual activation), and presence of 11-NA-24-G in REACTION SF4 (*i.e.*, 24Na production cross section *excluding* the quasi-isomer production) would be questionable.

I was asked by an EXFOR user if EXFOR C0700.005 (a dataset compiled with SF4=11-NA-24-G) excludes production of the short-lived state. As I (and maybe some of you) know “11-NA-24**-G**” is often seen in EXFOR Master, I extracted all 99 datasets coded with REACTION SF4=11-NA-24-G or 11-NA-24-M from EXFOR Master 2021-06-28, and quickly checked each dataset against the source article. They are mainly charged-particle induced data, and typically -G appeared when the entries were created or revised in 1997-2003.

In some datasets, originally -G or ISOMER=0 was added during revision of the entry.

***Examples***

* 20735.002: 11-NA-24-G+M,,SIG/SUM was revised to 11-NA-24-G,M+,SIG.
* B0073.020: 11-NA-24,M+,SIG was revised to 11-NA-24-G,CUM,SIG.
* M0152.002: ISOMER=0 was added to all data lines unless ISOMER=1 is given (!), then ISOMER=0 was deleted for many data lines (but kept for 24Na).
* T0131.019: 11-NA-24,CUM,SIG (B0096.040) was revised to 11-NA-24-G,CUM,SIG.

My conclusions after the assessment are

* **11-NA-24-G in REACTION SF4 must be 11-NA-24** (but see also my remark on 22012.003).
* **11-NA-24-M in REACTION must be 11-NA-24-L**

EXFOR 22012 is only the entry compiling the production cross section with 11-NA-24-G and 11-NA-24-M in REACTION SF4 together, which are tabulated and plotted as “(n,α**0**)” and “(n,α1)” cross sections in the source article (See next page). The former one is compared with the 27Al(n,α)24Na cross sections (important dosimetry cross section) evaluated by Tagesen & Vonach. The article figure shows the evaluated cross section agree with the (n,α0) cross section, and I believe EXFOR 22012.003 includes the 20 msec state production.

**Table 1 and Figure 5 of W.Enz et al., Ann. Phys. (Leipzig) 42(1985) 283**





**Datasets coded with SF4=11-NA-24-G or 11-NA-24-M in EXFOR Master 2021-06-28**“Detected” gives the radiation detected. 0.47, 1.37 and 2.76 gives the gamma energies in MeV.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Subentry** | **REACTION** | **Proposal** | **Detected** | **Additional comment** |
| 10186.002 | (13-AL-27(N,A)11-NA-24-M,,SIG) | Replace -M with -L. | 0.47 | Cyclic activation |
| 10186.003 | (12-MG-24(N,P)11-NA-24-M,,SIG) | Replace -M with -L. | 0.47 | Cyclic activation |
| 11365.002 | (11-NA-23(N,G)11-NA-24-G,,SIG,,SPA) | Remove -G.? | ? | The source (report) not available. |
| 20191.002 | (13-AL-27(N,A)11-NA-24-G,,SIG,,FIS) | Remove -G. | B- |   |
| 20735.002 | (12-MG-24(N,P)11-NA-24-G,M+,SIG,,FIS) | Remove -G. | B | Originally compiled with -G+M,,SIG/SUM |
| 20735.003 | (13-AL-27(N,A)11-NA-24-G,M+,SIG,,FIS) | Remove -G. | B | Originally compiled with -G+M,,SIG/SUM |
| 22012.003 | (13-AL-27(N,A)11-NA-24-G,,SIG) | Remove -G. | 0.47 | See the remark on the article table and figure in this memo. |
| 22012.004 | (13-AL-27(N,A)11-NA-24-M,,SIG) | Replace -M with -L. | 1.37 |   |
| 22201.002 | ((26-FE-56(N,P)25-MN-56,,SIG)/(13-AL-27(N,A)11-NA-24-G,,SIG)) | Remove -G. | ? |   |
| 22201.003 | ((28-NI-58(N,P)27-CO-58,,SIG)/(13-AL-27(N,A)11-NA-24-G,,SIG)) | Remove -G. | ? |   |
| 31528.010 | (13-AL-27(N,A)11-NA-24-M,,SIG) | Replace -M with -L. | 0.47 | SF7=G -> DG for some points of 002 and 003. |
| 40589.002 | (11-NA-23(N,G)11-NA-24-M,,SIG,,MXW) | Replace -M with -L. | ? |   |
| 40784.003 | (12-MG-0(N,X)11-NA-24-M,,SIG) | Replace -M with -L. | 0.47 |   |
| 40784.004 | (13-AL-27(N,A)11-NA-24-M,,SIG) | Replace -M with -L. | 0.47 |   |
| A0438.003 | (26-FE-0(6-C-12,X)ELEM/MASS,CUM,SIG) | Remove ISOMER=0 for 11-NA-24. | DG |   |
| A0438.005 | (26-FE-0(8-O-16,X)ELEM/MASS,CUM,SIG) | Remove ISOMER=0 for 11-NA-24. | DG |   |
| A0439.003 | (41-NB-93(6-C-12,X)ELEM/MASS,CUM,SIG) | Remove ISOMER=0 for 11-NA-24. | DG |   |
| A0439.005 | (73-TA-181(6-C-12,X)ELEM/MASS,CUM,SIG) | Remove ISOMER=0 for 11-NA-24. | DG |   |
| A0463.002 | (29-CU-0(3-LI-7,X)ELEM/MASS,CUM,SIG) | Remove ISOMER=0 for 11-NA-24. | DG |   |
| A0486.005 | (82-PB-0(3-LI-7,X)ELEM/MASS,CUM,SIG) | Remove ISOMER=0 for 11-NA-24. | DG |   |
| A0611.008 | (50-SN-118(P,X)11-NA-24-G,CUM,SIG) | Remove -G. | DG |   |
| B0016.003.1 | (13-AL-27(P,X)11-NA-24-G,M+,SIG,,,EXP) | Remove -G. | B- | The source (thesis) not available. |
| B0016.003.2 | (13-AL-27(P,X)11-NA-24-G,M+,SIG,,,EXP) | Remove -G. | DG | The source (thesis) not available. |
| B0022.003 | (13-AL-27(P,X)11-NA-24-G,CUM,SIG,,,EVAL) | Remove -G. | B-,1.37,2.76 |   |
| B0022.004 | ((13-AL-27(P,X)11-NA-24-G,CUM,SIG,,,EVAL)/(6-C-12(P,X)6-C-11,,SIG,,,EVAL)) | Remove -G. |   |   |
| B0049.004 | (12-MG-25(P,2P)11-NA-24-G,M+,SIG,,,EXP) | Remove -G. | B? |   |
| B0073.020 | (13-AL-27(P,X)11-NA-24-G,CUM,SIG,,,EXP) | Remove -G. | 1.37 |   |
| B0076.003 | (13-AL-27(P,X)11-NA-24-G,CUM,SIG,,,EXP) | Remove -G. | B |   |
| B0078.002.2 | (29-CU-0(P,X)11-NA-24-G,IND/M+,SIG,,,EXP) | Remove -G. | 1.37 |   |
| B0078.002.R | ((29-CU-0(P,X)10-NE-24,CUM,SIG,,,EXP)/(29-CU-0(P,X)11-NA-24-G,IND/M+,SIG,,,EXP)) | Remove -G. | 1.37 |   |
| B0078.003.1 | (47-AG-0(P,X)10-NE-24,CUM,SIG,,,EXP) | Remove -G. | 1.37 |   |
| B0078.003.2 | (47-AG-0(P,X)11-NA-24-G,IND/M+,SIG,,,EXP) | Remove -G. | 1.37 |   |
| B0078.003.R | ((47-AG-0(P,X)10-NE-24,CUM,SIG,,,EXP)/(47-AG-0(P,X)11-NA-24-G,IND/M+,SIG,,,EXP)) | Remove -G. | 1.37 |   |
| B0078.004.1 | (79-AU-197(P,X)10-NE-24,CUM,SIG,,,EXP) | Remove -G. | 1.37 |   |
| B0078.004.2 | (79-AU-197(P,X)11-NA-24-G,IND/M+,SIG,,,EXP) | Remove -G. | 1.37 |   |
| B0078.004.R | ((79-AU-197(P,X)10-NE-24,CUM,SIG,,,EXP)/(79-AU-197(P,X)11-NA-24-G,IND/M+,SIG,,,EXP)) | Remove -G. | 1.37 |   |
| B0078.005.2 | (92-U-0(P,X)11-NA-24-G,IND/M+,SIG,,,EXP) | Remove -G. | 1.37 |   |
| B0078.005.R | ((92-U-0(P,X)10-NE-24,CUM,SIG,,,EXP)/(92-U-0(P,X)11-NA-24-G,IND/M+,SIG,,,EXP)) | Remove -G. | 1.37 |   |
| B0147.003 | (79-AU-197(PIP,X)11-NA-24-G,CUM,SIG,,,EXP) | Remove -G. | DG |   |
| B0147.004 | (79-AU-197(PIN,X)11-NA-24-G,CUM,SIG,,,EXP) | Remove -G. | DG |   |
| C0700.005 | (13-AL-27(P,N+3P)11-NA-24-G,,SIG) | Remove -G. | B |   |
| M0152.002 | (29-CU-0(G,X)ELEM/MASS,,SIG,,BRA) | Remove ISOMER=0 for 11-NA-24. | 1.37 |   |
| M0152.003 | (29-CU-0(G,X)ELEM/MASS,,SIG,,BRA) | Remove ISOMER=0 for 11-NA-24. | 1.37 |   |
| M0152.004 | (29-CU-0(G,X)ELEM/MASS,,SIG,,BRA) | Remove ISOMER=0 for 11-NA-24. | 1.37 |   |
| M0152.005 | (29-CU-0(G,X)ELEM/MASS,,SIG,,BRA) | Remove ISOMER=0 for 11-NA-24. | 1.37 |   |
| M0152.006 | (25-MN-55(G,X)ELEM/MASS,,SIG,,BRA) | Remove ISOMER=0 for 11-NA-24. | 1.37 |   |
| M0152.007 | (25-MN-55(G,X)ELEM/MASS,,SIG,,BRA) | Remove ISOMER=0 for 11-NA-24. | 1.37 |   |
| M0152.008 | (25-MN-55(G,X)ELEM/MASS,,SIG,,BRA) | Remove ISOMER=0 for 11-NA-24. | 1.37 |   |
| M0152.009 | (25-MN-55(G,X)ELEM/MASS,,SIG,,BRA) | Remove ISOMER=0 for 11-NA-24. | 1.37 |   |
| M0152.010 | (23-V-51(G,X)ELEM/MASS,,SIG,,BRA) | Remove ISOMER=0 for 11-NA-24. | 1.37 |   |
| M0152.011 | (23-V-51(G,X)ELEM/MASS,,SIG,,BRA) | Remove ISOMER=0 for 11-NA-24. | 1.37 |   |
| M0152.012 | (23-V-51(G,X)ELEM/MASS,,SIG,,BRA) | Remove ISOMER=0 for 11-NA-24. | 1.37 |   |
| M0152.013 | (23-V-51(G,X)ELEM/MASS,,SIG,,BRA) | Remove ISOMER=0 for 11-NA-24. | 1.37 |   |
| M0152.014 | (29-CU-0(G,X)ELEM/MASS,,SIG,,BRA) | Remove ISOMER=0 for 11-NA-24. | 1.37 |   |
| M0152.015 | (25-MN-55(G,X)ELEM/MASS,,SIG,,BRA) | Remove ISOMER=0 for 11-NA-24. | 1.37 |   |
| M0152.016 | (23-V-51(G,X)ELEM/MASS,,SIG,,BRA) | Remove ISOMER=0 for 11-NA-24. | 1.37 |   |
| O0412.002 | (11-NA-23(P,PIP)11-NA-24-G,IND/M+,SIG) | Remove -G. | B,2.76 |   |
| O0412.003 | (12-MG-0(P,X)11-NA-24-G,CUM,SIG) | Remove -G. | B,2.76 |   |
| O0412.004 | (14-SI-0(P,X)11-NA-24-G,CUM,SIG) | Remove -G. | B,2.76 |   |
| O0412.006 | (16-S-0(P,X)11-NA-24-G,CUM,SIG) | Remove -G. | B,2.76 |   |
| O0412.007 | (17-CL-0(P,X)11-NA-24-G,CUM,SIG) | Remove -G. | B,2.76 |   |
| O0412.008 | (19-K-0(P,X)11-NA-24-G,CUM,SIG) | Remove -G. | B,2.76 |   |
| O0412.009 | (20-CA-0(P,X)11-NA-24-G,CUM,SIG) | Remove -G. | B,2.76 |   |
| O0412.011 | (22-TI-0(P,X)11-NA-24-G,CUM,SIG) | Remove -G. | B,2.76 |   |
| O0412.012 | (23-V-51(P,X)11-NA-24-G,CUM,SIG) | Remove -G. | B,2.76 |   |
| O0412.013 | (24-CR-0(P,X)11-NA-24-G,CUM,SIG) | Remove -G. | B,2.76 |   |
| O0412.014 | (25-MN-55(P,X)11-NA-24-G,CUM,SIG) | Remove -G. | B,2.76 |   |
| O0412.015 | (26-FE-0(P,X)11-NA-24-G,CUM,SIG) | Remove -G. | B,2.76 |   |
| O0412.016 | (27-CO-59(P,X)11-NA-24-G,CUM,SIG) | Remove -G. | B,2.76 |   |
| O0412.017 | (28-NI-0(P,X)11-NA-24-G,CUM,SIG) | Remove -G. | B,2.76 |   |
| O0412.018 | (29-CU-0(P,X)11-NA-24-G,CUM,SIG) | Remove -G. | B,2.76 |   |
| O0412.019 | (30-ZN-0(P,X)11-NA-24-G,CUM,SIG) | Remove -G. | B,2.76 |   |
| O0412.020 | (31-GA-0(P,X)11-NA-24-G,CUM,SIG) | Remove -G. | B,2.76 |   |
| O0412.021 | (32-GE-0(P,X)11-NA-24-G,CUM,SIG) | Remove -G. | B,2.76 |   |
| O0412.022 | (33-AS-75(P,X)11-NA-24-G,CUM,SIG) | Remove -G. | B,2.76 |   |
| O0412.023 | (34-SE-0(P,X)11-NA-24-G,CUM,SIG) | Remove -G. | B,2.76 |   |
| O0412.024 | (38-SR-0(P,X)11-NA-24-G,CUM,SIG) | Remove -G. | B,2.76 |   |
| O0412.025 | (39-Y-89(P,X)11-NA-24-G,CUM,SIG) | Remove -G. | B,2.76 |   |
| O0412.026 | (40-ZR-0(P,X)11-NA-24-G,CUM,SIG) | Remove -G. | B,2.76 |   |
| O0412.027 | (41-NB-93(P,X)11-NA-24-G,CUM,SIG) | Remove -G. | B,2.76 |   |
| O0412.028 | (42-MO-0(P,X)11-NA-24-G,CUM,SIG) | Remove -G. | B,2.76 |   |
| O0412.029 | (46-PD-0(P,X)11-NA-24-G,CUM,SIG) | Remove -G. | B,2.76 |   |
| O0412.030 | (47-AG-0(P,X)11-NA-24-G,CUM,SIG) | Remove -G. | B,2.76 |   |
| O0412.031 | (48-CD-0(P,X)11-NA-24-G,CUM,SIG) | Remove -G. | B,2.76 |   |
| O0412.032 | (49-IN-0(P,X)11-NA-24-G,CUM,SIG) | Remove -G. | B,2.76 |   |
| O0412.033 | (50-SN-0(P,X)11-NA-24-G,CUM,SIG) | Remove -G. | B,2.76 |   |
| O0412.034 | (73-TA-181(P,X)11-NA-24-G,CUM,SIG) | Remove -G. | B,2.76 |   |
| O0412.035 | (79-AU-197(P,X)11-NA-24-G,CUM,SIG) | Remove -G. | B,2.76 |   |
| O0412.036 | (82-PB-0(P,X)11-NA-24-G,CUM,SIG) | Remove -G. | B,2.76 |   |
| O0412.037 | (92-U-0(P,X)11-NA-24-G,CUM,SIG) | Remove -G. | B,2.76 |   |
| O0467.002 | (92-U-0(P,X)11-NA-24-G,CUM,SIG) | Remove -G. | 1.37,2.76 |   |
| O0500.004 | (82-PB-0(P,X)11-NA-24-G,CUM,SIG) | Remove -G. | 1.37? | Not clear if the decay data are from the authors. (Not seen in Gloris's thesis.) |
| P0067.005 | (13-AL-27(D,P+A)11-NA-24-G,,SIG) | Remove -G. | B |  -G in 002-004 removed in 2000. 005 overlooked? |
| P0124.002 | (13-AL-27(D,P+A)11-NA-24-G,,SIG) | Remove -G. | B |   |
| T0131.019 | (26-FE-0(P,X)11-NA-24-G,CUM,SIG) | Remove -G. | B |  -G was added when it was moved from B0096. |
| T0131.044 | (29-CU-0(P,X)11-NA-24-G,CUM,SIG) | Remove -G. | B |  -G was added when it was moved from B0096. |
| T0200.002 | (29-CU-0(6-C-12,X)ELEM/MASS,CUM,SIG) | Remove ISOMER=0 for 11-NA-24. | DG |   |
| T0200.003 | (29-CU-0(6-C-12,X)ELEM/MASS,CUM,SIG) | Remove ISOMER=0 for 11-NA-24. | DG |   |
| T0201.002 | (29-CU-0(6-C-12,X)ELEM/MASS,CUM,SIG) | Remove ISOMER=0 for 11-NA-24. | DG |   |

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