**Nuclear Data Section**

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**Memo CP-D/1072**

**Date:** 2023-03-07

**To:** Distribution

**From:** N. Otsuka

**Subject: 209Bi(p,x)211At cross section? – secondary particle induced reaction**

**Reference:** Memo CP-D/0737

I extracted REACTION codes violating charge or mass conservation in April 2012 and all errors listed in the summary (Memo CP-D/0737) have been fixed. I repeated this checking again by using X4Pro distributed from the NDS website (Ver. 2022-12-22). Charge conservation was checked for datasets below 150 MeV. All cases for corrections without further discussion are summarized in Table 1 appended to this memo.

I found some entries compiling 209Bi(p,x)211At cross sections. 209Bi(p,π-)210At, 209Bi(p,π- n)209At etc. are possible at high energy, but 209Bi(p,x)211At is still impossible. I this has been interpreted as production due to a secondary reaction such as 209Bi(p,α+x) then 209Bi(α,2n)211At.

The figure in the next page shows the target thickness T dependence of 211,210,209,208,206,205At yields relative to 207At yield at Ep=200 MeV (reproduction of Fig.6 of J.L.Clark et al., Phys.Rev.C26(1982)2073 EXFOR C2113). The authors considered 207At is always produced by 209Bi(p,π- 3n)207At reaction and choose the 207At as a reference. A larger 211,210,209At/207At ratio with a thicker sample is interpreted due to increase of 209Bi(α,xn)213-xAt events while constant 208,206At/207At up to a certain thickness.is interpreted due to absence of the secondary α contribution. Namely, they interpret

1. 211At production is always due to 209Bi(α,2n)211At.
2. 210,209At production is due to 209Bi(α,xn) 213-xAt and 209Bi(p,π- xn)210-xAt.
3. 208,206At production is due to 209Bi(p,π- xn)210-xAt.

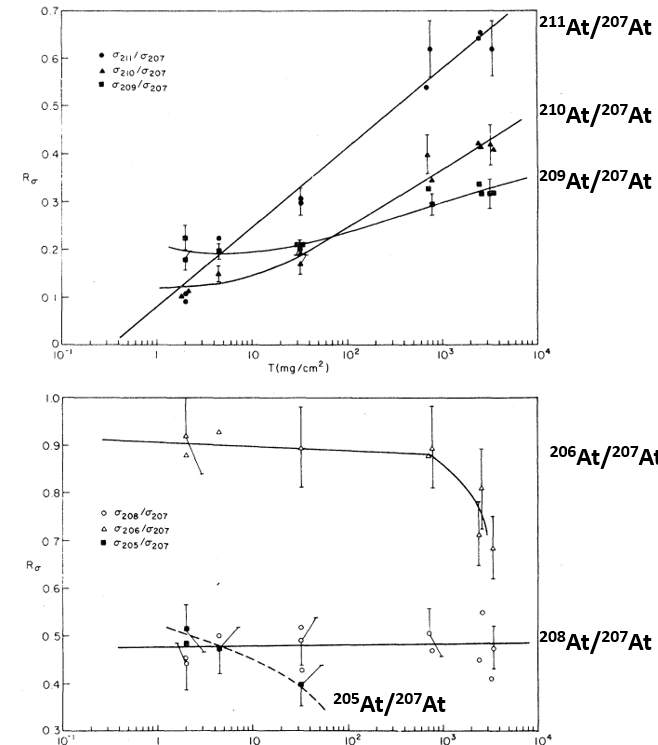
I think

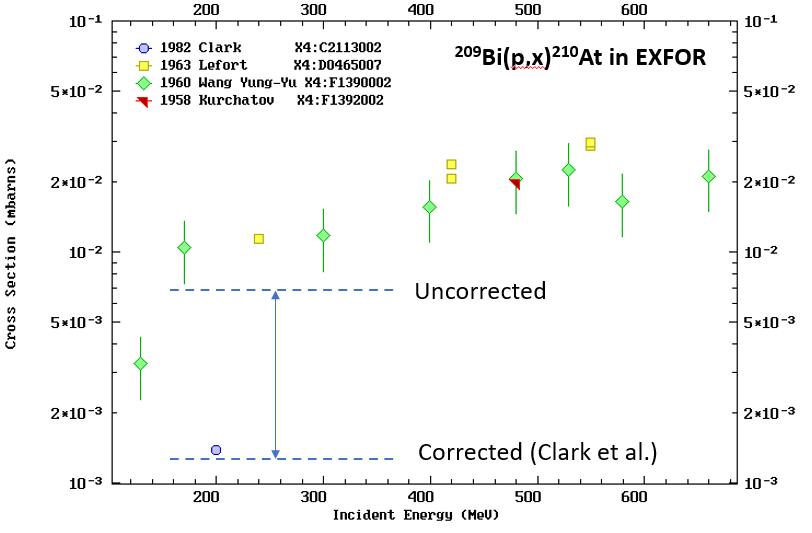
* we should not do compilation for production caused by a secondary particle induced reaction *only*. (1st case above)
* we may do compilation for production which could be partly due to a secondary particle induced reaction (2nd case above). Information on presence/correction for secondary particle induced reaction is useful.

Cross sections (μb) of each At isotope production (c.f. Tables III and V of Clark’s article)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Thickness | 211 | 210 | 209 | 208 | 207 | 206 | 205 |
| 32.77 mg/m2 | 3.8 | 2.4 | 3.0 | 7.4 | 14 | 13 | 9 |
| 2.0 mg/cm2 | 1.5 | 1.8 | 3.7 | 8 | 17 | 15 | 16 |
| **Corrected** | **N/A** | **<1.4** | 3.0 | 7.4 | 14 | 13 | 9 |

This table shows secondary particle induced reaction effect is large for 210At production The last figure shows the 209Bi(p,x)210At cross sections in EXFOR other than Clark et al. look ~10 times too high.





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Table 1: REACTION codes requiring corrections

(Z/A: charge/mass conservation is broken. E/M: ELEM/MASS is coded in SF4)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Dataset #** | **REACTION** | **Z/A** | **E/M** | **Items** | **Suggested correction** |
| 40299.004 | 55-CS-133(N,X)56-BA-134,,SPC | Z |  | REACTION | ? (I cannot identify the origin of these gamma lines.) |
| 40299.005 | 55-CS-133(N,X)56-BA-134,,SPC | Z |  | REACTION | ? (I cannot identify the origin of these gamma lines.) |
| C2469.012 | 92-U-235(A,F)126-??-53,IND,FY,,FRC | Z | \* | Heading | Swap heading MASS and ELEMENT. |
| C2469.012 | 92-U-235(A,F)128-??-53,IND,FY,,FRC | Z | \* | Heading | Swap heading MASS and ELEMENT. |
| C2469.012 | 92-U-235(A,F)129-??-54,IND,FY,,FRC | Z | \* | Heading | Swap heading MASS and ELEMENT. |
| C2469.012 | 92-U-235(A,F)130-??-53,IND,FY,,FRC | Z | \* | Heading | Swap heading MASS and ELEMENT. |
| F1217.008 | 83-BI-203(D,X)83-BI-206,CUM,SIG | A | \* | REACTION | SF1: 83-BI-203 -> 83-BI-209 |
| M0795.007 | 83-BI-209(G,N)83-BI-203,,INT,,BRS | A | \* | REACTION | SF3: N -> X |
| M0795.007 | 83-BI-209(G,N)83-BI-204,,INT,,BRS | A | \* | REACTION | SF3: N -> X |
| M0795.007 | 83-BI-209(G,N)83-BI-205,,INT,,BRS | A | \* | REACTION | SF3: N -> X |
| M0795.007 | 83-BI-209(G,N)83-BI-206,,INT,,BRS | A | \* | REACTION | SF3: N -> X |
| M0795.007 | 83-BI-209(G,N)83-BI-207,,INT,,BRS | A | \* | REACTION | SF3: N -> X |
| O1508.003 | 30-ZN-64(D,X)30-ZN-69,,TTY,,PHY/MSC | A | \* | Data | Impurity in target? Delete this dataset. |
| O1508.003 | 30-ZN-64(D,X)31-GA-67,,TTY,,PHY/MSC | A | \* | Data | Impurity in target? Delete this dataset. |
| O1665.003.2 | 90-TH-232(P,X)92-U-230,,TTY,,(PHY),DERIV | Z |  | Data | Delete. Decay product - 232Th(p,x)230Pa -> 230U. |
| O2015.028 | 20-CA-40(P,X)18-AR-42,,SIG | A |  | REACTION | SF1: 20-CA-40 -> 20-CA-0 |
| O2315.018 | 28-NI-0(P,X)30-ZN-62,,SIG | Z |  | REACTION | SF1: 28-NI-0 -> 29-CU-0 |

Table 2: REACTION codes for production of At from irradiation of Bi or Pb by protons violating mass conservation

(Z/A: charge/mass conservation is broken. E/M: ELEM/MASS is coded in SF4)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Dataset #** | **REACTION** | **Z/A** | **E/M** | **Items** | **Suggested correction** |
| C1897.002 | 83-BI-209(P,X)85-AT-211,,SIG | A |  | Data | Delete this dataset. |
| C1897.003 | 83-BI-209(P,X)85-AT-211,,SIG | A |  | Data | Delete this dataset. |
| C1897.004 | 83-BI-209(P,X)85-AT-211,,SIG | A |  | Data | Delete this dataset. |
| C1897.005 | 83-BI-209(P,X)85-AT-211,,SIG | A |  | Data | Delete this dataset. |
| C1897.006 | 83-BI-209(P,X)85-AT-211,,SIG | A |  | Data | Delete this dataset. |
| C1897.007 | 83-BI-209(P,X)85-AT-211,,SIG | A |  | Data | Delete this dataset. |
| C1897.008 | 83-BI-209(P,X)85-AT-211,,SIG | A |  | Data | Delete this dataset. |
| C1897.009 | 83-BI-209(P,X)85-AT-211,,SIG | A |  | Data | Delete this dataset. |
| C1897.010 | 83-BI-209(P,X)85-AT-211,,SIG | A |  | Data | Delete this dataset. |
| D0465.006 | 83-BI-209(P,X)85-AT-211,,SIG | A |  | Data | Delete this dataset. |
| F1390.002.1 | 83-BI-209(P,X)85-AT-211,,SIG | A |  | Data | Delete this dataset. |
| F1390.003 | 83-BI-209(P,X)85-AT-211,,SIG | A |  | Data | Delete this dataset. |
| F1391.002.1 | 82-PB-208(P,X)85-AT-211,,SIG | A |  | Data | Delete this dataset. |
| F1391.002.2 | 82-PB-208(P,X)85-AT-210,,SIG | A |  | Data | Delete this dataset. |
| F1391.003 | 82-PB-208(P,X)85-AT-211,,SIG | A |  | Data | Delete this dataset. |
| F1391.004 | 82-PB-208(P,X)85-AT-210,,SIG,,AV | A |  | Data | Delete this dataset. |
| F1391.004 | 82-PB-208(P,X)85-AT-211,,SIG,,AV | A |  | Data | Delete this dataset. |
| F1391.006 | 82-PB-208(D,X)85-AT-211,,SIG | A |  | Data | Delete this dataset. |
| F1392.002.1 | 83-BI-209(P,X)85-AT-211,,SIG | A |  | Data | Delete this dataset. |
| F1392.003 | 83-BI-209(P,X)85-AT-211,,SIG | A |  | Data | Delete this dataset. |
| F1392.004.1 | 83-BI-209(P,X)85-AT-211,,SIG | A |  | Data | Delete this dataset. |
| F1392.004.2 | 83-BI-209(P,X)85-AT-211,,SIG | A |  | Data | Delete this dataset. |
| F1427.002 | 83-BI-208(P,X)85-AT-211,,SIG | A |  | Data | Delete this dataset. |
| F1427.003 | 82-PB-209(P,X)85-AT-211,,SIG | A |  | Data | Delete this dataset. |
| F1427.004 | 83-BI-208(P,X)85-AT-210,,SIG | A |  | Data | Delete this dataset. |
| F1427.004 | 83-BI-208(P,X)85-AT-211,,SIG | A |  | Data | Delete this dataset. |
| F1427.005 | 83-BI-208(P,X)85-AT-211,,SIG | A |  | Data | Delete this dataset. |
| F1427.006 | 83-BI-208(P,X)85-AT-211,,SIG | A |  | Data | Delete this dataset. |
| F1427.007 | 83-BI-208(P,X)85-AT-211,,SIG | A |  | Data | Delete this dataset. |
| F1427.008 | 82-PB-209(P,X)85-AT-211,,SIG | A |  | Data | Delete this dataset. |
| F1427.009 | 82-PB-209(P,X)85-AT-211,,SIG | A |  | Data | Delete this dataset. |
| O1906.002 | 83-BI-209(P,X)85-AT-211,,SIG | A | \* | Data | Delete the last data line (5+/-0.5 ub for 211At production) |