

$^{209}\text{Bi}(p,x)^{211}\text{At}$ cross section? – Secondary particle induced reaction

(N. Otsuka, 2023-03-07, Memo CP-D/1072)

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 $^{209}\text{Bi}(p,x)^{211}\text{At}$ cross sections. $^{209}\text{Bi}(p,\pi^-)^{210}\text{At}$, $^{209}\text{Bi}(p,\pi^-n)^{209}\text{At}$ etc. are possible at high energy, but $^{209}\text{Bi}(p,x)^{211}\text{At}$ is still impossible. I this has been interpreted as production due to a secondary reaction such as $^{209}\text{Bi}(p,\alpha+x)$ then $^{209}\text{Bi}(\alpha,2n)^{211}\text{At}$.

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

1. ^{211}At production is always due to $^{209}\text{Bi}(\alpha,2n)^{211}\text{At}$.
2. $^{210,209}\text{At}$ production is due to $^{209}\text{Bi}(\alpha,xn)^{213-x}\text{At}$ and $^{209}\text{Bi}(p,\pi^-xn)^{210-x}\text{At}$.
3. $^{208,206}\text{At}$ production is due to $^{209}\text{Bi}(p,\pi^-xn)^{210-x}\text{At}$.

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 ^{210}At production The last figure shows the $^{209}\text{Bi}(p,x)^{210}\text{At}$ cross sections in EXFOR other than Clark et al. look ~ 10 times too high.

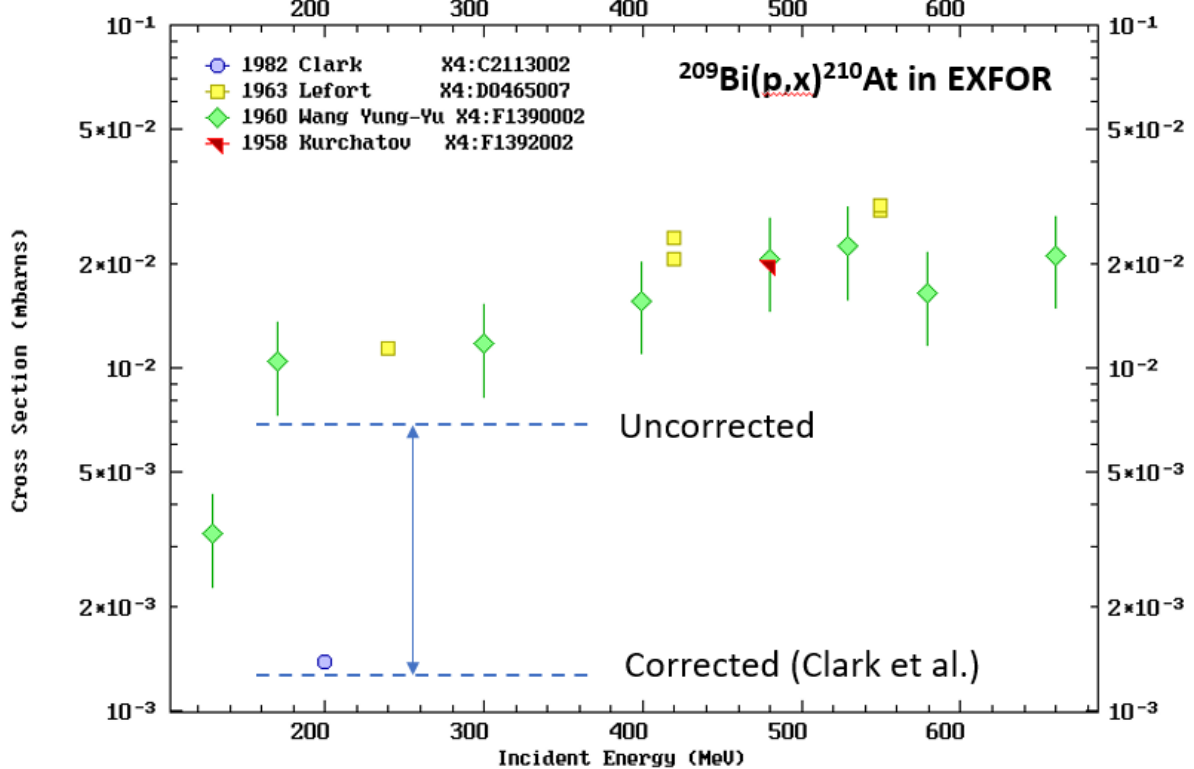
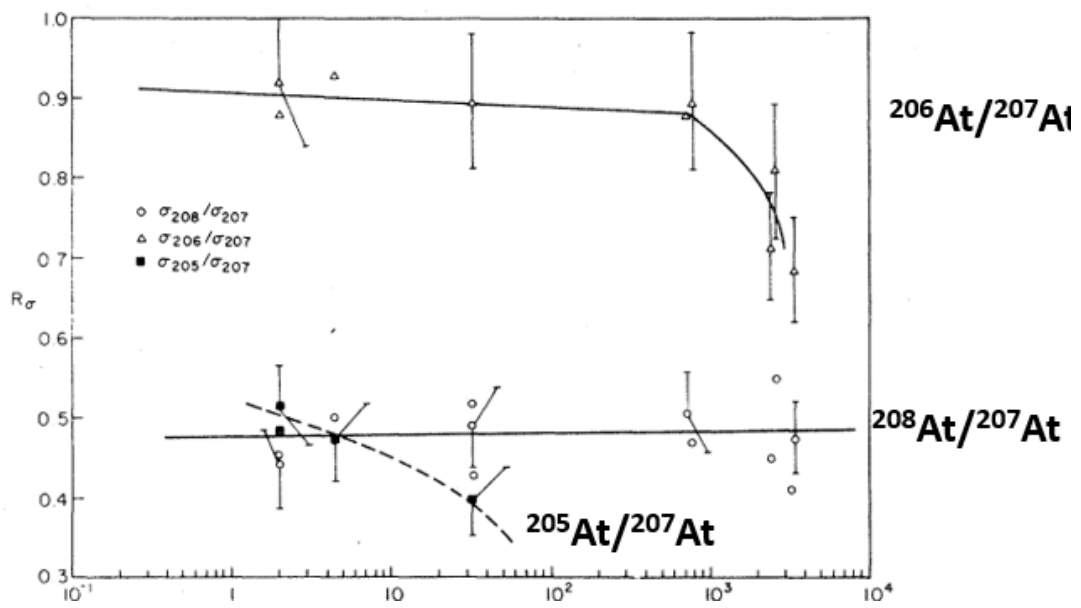
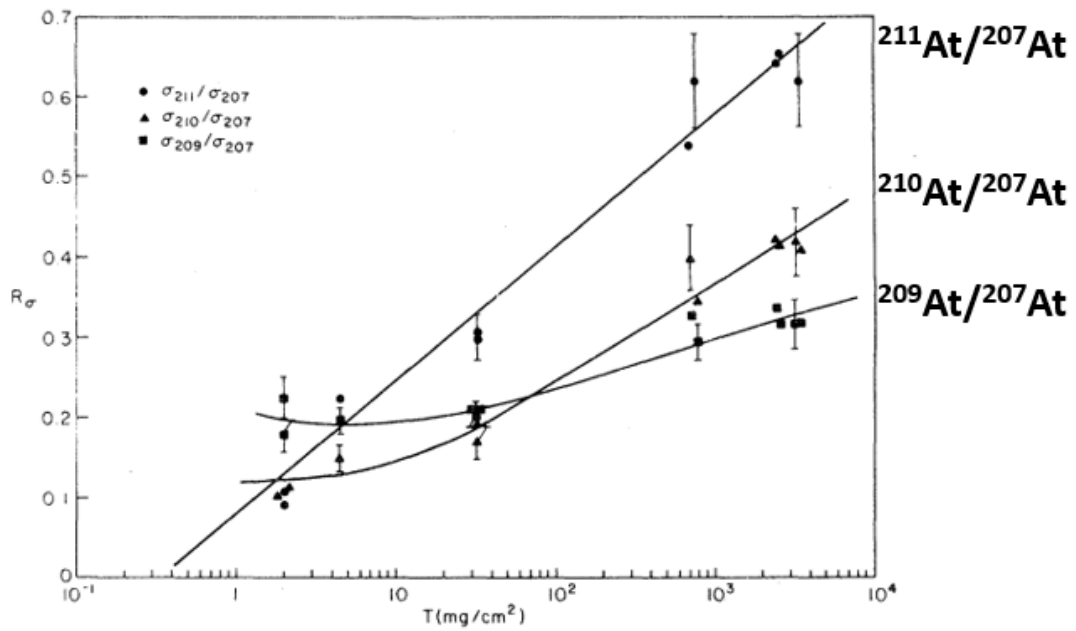


Table 1: REACTION codes requiring corrections
(Z/A: charge/mass conservation is broken. E/M: ELEM/MASS is coded in SF4)

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)