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[illegible] ALPHA-INDUCED THICK-TARGET [illegible] [illegible]

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DISCLAIMER

[illegible]

[illegible] Alamos National Laboratory [illegible]

CALCULATED α-INDUCED THICK-TARGET NEUTRON AND RADIONUCLIDE YIELDS FOR E_α < 50 MEV

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ABSTRACT

Thick target yields for αs incident on elements $1 < Z < 15$ and Z [illegible] 17 have been [illegible] culated using the α stopping data of Ziegler with radionuclide production cross sections calculated with the GNASH code. Comparisons are made of the calculated [illegible] with sparse measured data. Radionuclide production yields are tabulated at [illegible] 40 and 50 MeV.

INTRODUCTION

Thick target α-induced yield calculations have been performed by two [illegible] (RTP & WBW) at Los Alamos for nearly a decade. These calculations have [illegible] on the production of neutrons and nuclides by actinide decay αs interacting with [illegible] having thresholds below a few MeV. In a recent paper[illegible] we described the [illegible] and calculations of spontaneous fission and α-induced thick target [illegible] SOURCES code. The SOURCES data library contains the following:

- [illegible] cross section data for isotopes of Be, B, C, N, O, F, Ne, Na, Mg, [illegible] [illegible]
- radioactive decay data [illegible]
- α stopping [illegible] Ziegler [illegible]

[illegible]

where $N_{Z,m}$ is the atom density of element Z within the material. The stopping cross section $\epsilon_Z(E)$ for a pure element Z with atom density N_Z is defined by

$$\epsilon_Z(E) = -\frac{dE}{N_Z dx}$$

Eq. [illegible] may be written in terms of its elemental constituents and the [illegible] isotopes of each element as

$$Y_m(E) = \sum_{Z=1}^{n} \frac{N_{Z,m}}{N_m} \sum_{i}^{I_Z} \frac{N_{i,m}}{N_{Z,m}} \int^{E} \frac{\sigma_i(E)}{\epsilon_m(E)} dE \qquad [illegible]$$

where $N_{i,m}$ is the atom density of element Z within the material. Since the ratio of [illegible] atoms to all element Z atoms within the material is the same as in the pure [illegible]

$$Y_m(E) = \sum_{Z} \frac{N_{Z,m}}{N_m} \sum_{i} \frac{N_{i,Z}}{N_Z} \int^{E} \frac{\sigma_i(E)}{\epsilon_m(E)} dE$$

[illegible] energy dependence [illegible] approximation [illegible]

$$\epsilon_m(E) = \sum [illegible] \epsilon_Z(E)$$

[illegible]

$$Y_m(E) = \sum \frac{N}{N} [illegible] \sum \frac{N}{N} \int [illegible] \frac{\sigma}{\epsilon} dE$$

[illegible]

$$[illegible]$$

[illegible]

of product nuclides within a range of $-6 \le \delta Z \le 0$ and $-7 \le \delta N \le 0$ relative to the compound system formed by the incident α and the target nuclide. These calculations were made for all 25 stable isotopes of the 11 elements given above.

There exist little measured data for energetic αs incident on these targets, leading to the production of radionuclides, with which comparisons can be made. Figure 1 compares the calculated ^{9}Be(α,2n)^{11}C cross section with the measured data of Anders, Herges and Scobel. Figure 2 compares the calculated ^{27}Al(α,x)^{3}H cross section with the data extracted by Moss and Manzel from their thick target yield measurements. Figure 3 compares the calculated ^{27}Al(α,x)^{22}Na cross section with the data of Martens and Schweimer and Gruetter. These comparisons suggest an uncertainty in calculated cross section data of about a factor [illegible]

RESULTS

The cross sections calculated with GNASH were grouped by target element and [illegible] target yields were calculated for each element using the natural abundances of the stable isotopes. In all, yields for some 100 combinations of elemental target and product particle or nuclide were calculated on a grid of α energies. For the purpose [illegible] yields for all particles other than neutrons and all stable product nuclides were removed [illegible] the tabulated yields; however, yields of other particles and stable products [illegible] retained and are available upon request.

[illegible]

REFERENCES

[illegible]

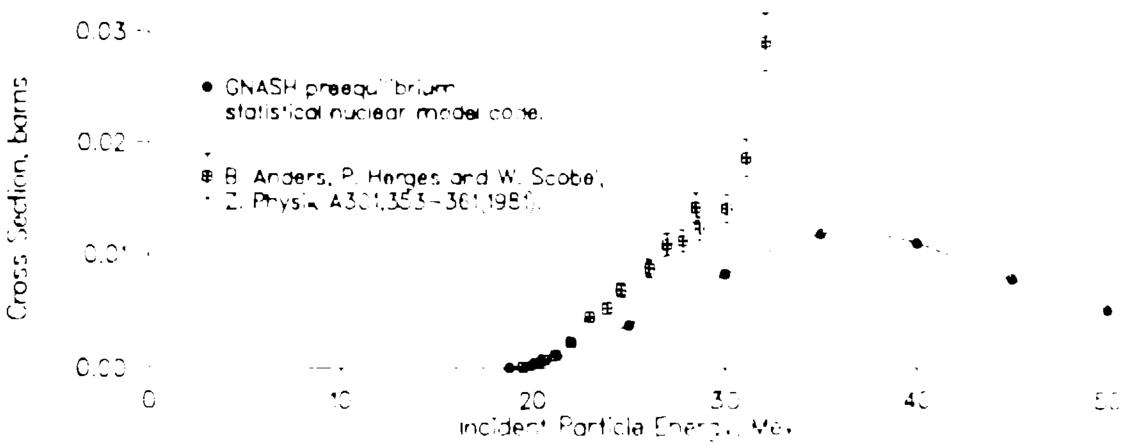


Fig. 1 Comparison of measured and GNASH calculated ^{9}Be [illegible] cross section

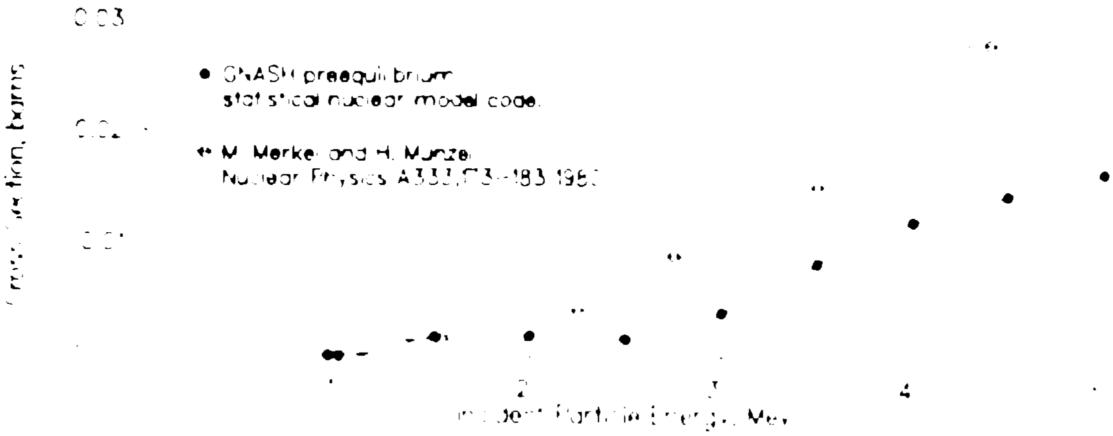
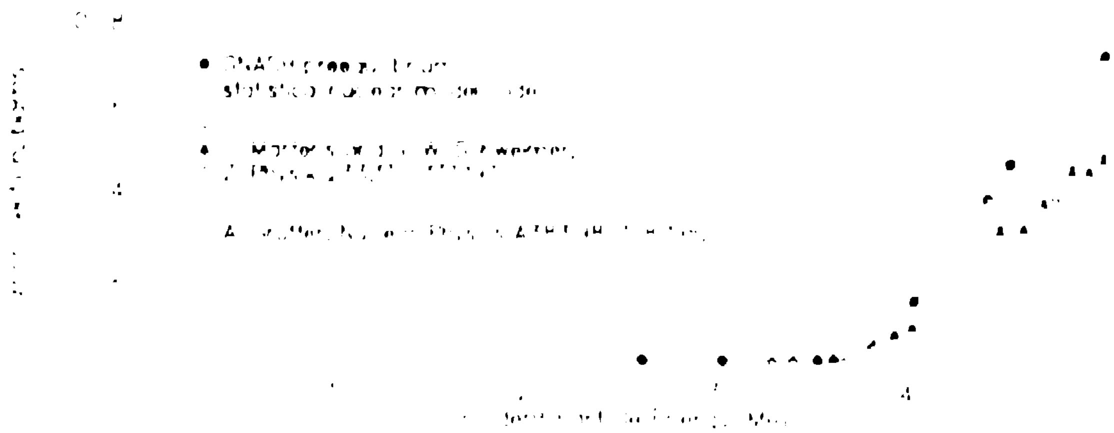


Fig. 2 [illegible] of measured and GNASH calculated [illegible] cross section



[illegible]

Table 1

Alphas on Be Thick-Target [illegible]

Product		Incident Alpha Energy 5 MeV	10 MeV	[illegible] MeV	[illegible] MeV	[illegible] MeV	[illegible] MeV
Neutrons		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
H	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
He	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Be	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Be	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Be	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
B	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
B	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table 2

Alphas on B Thick-Target [illegible]

Product		Incident Alpha Energy 5 MeV	10 MeV	[illegible] MeV	[illegible] MeV	[illegible] MeV	[illegible] MeV
Neutrons		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
H	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
He	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Be	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Be	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Be	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Be	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
B	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table [illegible]

Alphas [illegible] Thick-Target [illegible]

Product		Incident Alpha Energy [illegible] MeV	[illegible] MeV	[illegible] MeV	[illegible] MeV	[illegible] MeV	[illegible] MeV
Neutrons		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
He	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

[illegible]	[illegible] MeV	[illegible] MeV	[illegible] MeV	[illegible] MeV	[illegible] MeV	[illegible] MeV
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table 4 (Continued)

Product	Incident Alpha Energy 5 MeV	10 MeV	20 MeV	30 MeV	40 MeV	50 MeV
B 13	0	0	0	0	0	1.6[illegible]
C 10	0	0	0	0	0	1.44E-12
C 11	0	0	0	7.73E-14	2.59E-06	1.94E-05
C 14	0	0	3.05E-08	1.79E-07	8.[illegible]	1.04E-05
N 1[illegible]	0	0	0	0	0	3.00E-[illegible]
N 13	0	0	3.64E-06	2.91E-05	6.74E-05	7.80E-05
N 16	0	0	0	6.3[illegible]	3.[illegible]	1.[illegible]
O 14	0	0	0	0	3.25E-08	4.75E-07
O 15	0	0	5.68E-07	4.96E-06	2.1[illegible]	5.[illegible]
F 15	0	0	0	0	0	1.64E-[illegible]
F 16	0	0	0	0	0	6.10E-13
F 17	0	1.32E-05	4.54E-05	4.66E-05	4.89E-05	4.[illegible]
F 18	0	1.30E-08	4.07E-07	5.88E-07	6.0[illegible]E-07	6.[illegible]E-07

Table 5

Alphas on [illegible]C Thick-Target Radionuclide Yields

Product	Incident Alpha Energy 5 MeV	10 MeV	20 MeV	30 MeV	40 MeV	50 MeV
Neutrons	4.30E-08	2.9[illegible]E-07	3.75E-06	3.32E-05	[illegible]E-04	[illegible]E-04
H 3	0	0	1.37E-09	1.95E-06	1.32E-05	4.82E-05
Be 8	0	0	0	1.52E-05	2.07E-04	4.60E-04
Be 10	0	0	0	2.43E-13	3.98E-[illegible]	4.[illegible]
B 9	0	0	0	0	0	3.5[illegible]
B 12	0	0	0	0	[illegible]	4.54E-[illegible]
B 13	0	0	0	0	[illegible]E-14	[illegible]
C 11	0	0	0	0	1.48E-[illegible]	1.39E-[illegible]
C 14	0	1.94E-[illegible]	1.09E-[illegible]	2.28E-[illegible]	1.09E-05	5.08E-05
C 15	0	0	0	0	3.[illegible]	[illegible]
N 13	0	0	0	0	5.3[illegible]	[illegible]
N 16	[illegible]	0	3.99E-[illegible]	6.4[illegible]E-08	[illegible]	[illegible]
N 17	[illegible]	0	0	6.[illegible]	6.[illegible]	4.[illegible]
N 18	[illegible]	0	0	[illegible]	0	[illegible]
O 14	[illegible]	0	[illegible]	[illegible]	2.54E-[illegible]	[illegible]
[illegible]	[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	0	[illegible]	[illegible]
F 17	[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]
F 18	[illegible]	0	[illegible]	[illegible]	6.[illegible]	[illegible]
F [illegible]	[illegible]	9.41E-[illegible]	3.44E-[illegible]	[illegible]	[illegible]	[illegible]
F [illegible]	[illegible]	4.95E-[illegible]	4.5[illegible]	[illegible]	5.54E-[illegible]	[illegible]
Ne 19	[illegible]	0	[illegible]	2.45E-[illegible]	7.36E-[illegible]	[illegible]
Ne [illegible]	[illegible]	0	[illegible]	7.48E-[illegible]	8.14E-[illegible]	8.18E-[illegible]

Table 6

Alphas on [illegible] Thick-Target Radionuclide Yields

Product	Incident Alpha Energy [illegible] MeV	[illegible] MeV	[illegible] MeV	[illegible] MeV	[illegible] MeV	[illegible] MeV
Neutrons	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
N [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
N [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
N [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Ne [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Ne [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table 7

Alphas on Ne Thick-Target Radionuclide Yields

Product	Incident Alpha Energy: 5 Mev	10 Mev	20 Mev	30 Mev	40 Mev	50 Mev
Neutrons	[illegible]9[illegible]-06	1.46E-05	1.19E-04	4.97E-04	1.29E-03	2.37E-03
H 3	0	0	2.00E-07	2.14E-06	1.[illegible]2E-05	3.60E-05
B 12	0	0	0	0	0	1.53E-11
B 13	0	0	0	0	0	1.83E-1[illegible]
C 14	0	0	0	1.6[illegible]E-07	1.5[illegible]E-06	1.21E-05
C 15	0	0	0	0	0	5.45E-1[illegible]
C 16	0	0	0	0	0	1.7[illegible]E-2[illegible]
N 13	0	0	0	0	6.96E-14	2.80E-08
N 16	0	0	0	9.81E-12	7.60E-08	2.04E-06
N 17	0	0	0	0	1.38E-10	1.33E-08
O 15	0	0	0	4.68E-10	8.11E-07	6.24E-06
O 19	0	0	0	0	3.53E-09	6.15E-08
F 17	0	0	0	7.47E-14	4.75E-07	5.05E-0[illegible]
F 18	0	0	0	3.68E-07	7.05E-05	2.23E-04
F 20	0	0	1.46E-09	1.06E-07	2.[illegible]E-06	1.19E-05
F 21	0	0	2.34E-12	3.13E-07	1.58E-06	6.89E-[illegible]
F 22	0	0	0	0	1.58E-11	1.44E-[illegible]
Ne 18	0	0	0	0	2.67E-11	2.26E-[illegible]
Ne 19	0	0	0	7.41E-07	5.21E-06	1.67E-0[illegible]
Ne 23	0	0	4.55E-09	1.21E-07	1.75E-06	6.18E-06
Ne 24	0	0	4.43E-09	1.30E-07	4.85E-07	1.41E-06
Na 20	0	0	0	0	0	3.94E-09
Na 21	0	0	0	6.13E-07	1.16E-05	3.79E-05
Na 22	0	0	1.37E-05	2.33E-04	3.79E-04	4.22E-04
Na 24	9.06E-09	1.32E-07	4.67E-06	2.72E-05	3.68E-05	3.81E-05
Na 25	1.72E-08	1.13E-06	7.39E-06	8.97E-06	9.06E-06	9.07E-06
Mg 21	0	0	0	0	0	1.33E-13
Mg 22	0	0	0	2.15E-08	1.91E-07	2.76E-07
Mg 23	0	5.69E-07	2.40E-05	3.50E-05	3.57E-05	3.61E-0[illegible]

Table 8

Alphas on Na Thick-Target Radionuclide Yields

Product	Incident Alpha Energy: 5 Mev	10 Mev	20 Mev	30 Mev	40 Mev	50 Mev
Neutrons	3.39E-06	8.5[illegible]E-05	6.65E-04	[illegible]	4.[illegible]	6.[illegible]
H 3	0	0	2.00E-06	7.[illegible]	2.[illegible]	5.8[illegible]
C 14	0	0	0	0	4.[illegible]8E-[illegible]	4.42E-[illegible]
N 16	0	0	0	0	0	2.79E-[illegible]
N 17	0	0	0	0	0	2.54E-[illegible]
F 18	0	0	0	3.32E-[illegible]	4.68E-06	8.61E-[illegible]
F 20	0	0	0	0	4.33E-15	1.35E-[illegible]
F 21	0	0	0	0	6.15E-09	3.92E-[illegible]
Ne 19	0	0	0	0	0	2.33E-[illegible]
Ne 23	0	0	0	0	1.14E-11	2.50E-[illegible]
Na 21	0	0	0	1.89E-[illegible]	7.10E-06	7.39E-[illegible]
Na 22	0	0	5.56E-06	[illegible]	1.[illegible]E-04	6.7[illegible]
Na 24	0	0	0	1.58E-[illegible]	4.75E-05	1.39E-[illegible]
Na 25	0	0	1.23E-07	5.15E-[illegible]	2.6[illegible]E-05	7.[illegible]
Mg [illegible]	[illegible]	0	0	0	[illegible]	7.9[illegible]
Mg [illegible]	[illegible]	0	0	[illegible]	[illegible]	[illegible]
Al 24	[illegible]	[illegible]	0	[illegible]	[illegible]	7.[illegible]
Al 25	[illegible]	[illegible]	1.94E-0[illegible]	[illegible]	[illegible]	[illegible]
Al 26	[illegible]	6.[illegible]	[illegible]E-04	[illegible]44E-[illegible]	[illegible]E-04	[illegible]

Table 9

Alphas on Mg Thick-Target Radionuclide Yields

Product	Incident Alpha Energy: [illegible] Mev	[illegible] Mev	[illegible] Mev	[illegible] Mev	[illegible] Mev	[illegible] Mev
Neutrons	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.7[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.64[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table [illegible] (continued)

Product	[illegible] MeV	[illegible] MeV	[illegible] MeV	[illegible] MeV	[illegible] MeV	[illegible] MeV
Na 22	[illegible]	[illegible]	0	[illegible]	[illegible]	[illegible]
Na 24	0	0	8.80E-09	3.6[illegible]E-0[illegible]	[illegible]	3.56E-0[illegible]
Na 25	0	[illegible]	1.89E-12	2.94E-07	[illegible]	6.04E-0[illegible]
Ne 2[illegible]	[illegible]	[illegible]	0	0	0	1.5[illegible]E-[illegible]
Mg 2[illegible]	[illegible]	0	1.47E-[illegible]	5.[illegible]	4.[illegible]	[illegible]
Mg 27	[illegible]	[illegible]	4.27E-06	[illegible]	[illegible]	[illegible]
Mg 28	[illegible]	[illegible]	6.4[illegible]	[illegible]	4.[illegible]	[illegible]
Al 24	[illegible]	[illegible]	0	0	[illegible]	[illegible]
Al 25	0	[illegible]	0	[illegible]	[illegible]	[illegible]
Al 2[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Al 28	4.76E-07	4.35E-06	2.54E-[illegible]	5.87E-0[illegible]	[illegible].88E-05	[illegible]
Al [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
S[illegible]	0	[illegible]	0	[illegible]	4.[illegible]	[illegible]
S[illegible]	[illegible]	1.80E-06	4.[illegible]E-05	[illegible]	[illegible]	[illegible]

Table [illegible]

Alphas on Al Thick-Target [illegible]

Product	[illegible] MeV	[illegible] MeV	[illegible] MeV	[illegible] MeV	[illegible] MeV	[illegible] MeV
			Incident Alpha Energy			
Neutrons	[illegible]	[illegible]	3.8[illegible]	[illegible]	[illegible]	4.[illegible]
H 3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4.[illegible]
F [illegible]	[illegible]	[illegible]	0	[illegible]	[illegible]	[illegible]
F [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4.[illegible]
Ne 2[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Na 22	[illegible]	[illegible]	0	[illegible]	[illegible]	[illegible]
Na 24	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Na 25	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Mg [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Mg [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Al [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Al [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table [illegible]

Alphas [illegible] Target [illegible]

Product	[illegible] MeV	[illegible] MeV	[illegible] MeV	[illegible] MeV	[illegible] MeV	[illegible] MeV
			Incident Alpha Energy			
Neutrons	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Ne [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Na 22	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Na 24	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
M[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Al [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Al [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Al [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Al [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Al	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table 12

Alphas on F Thick Target Radionuclide Yields

Product Nuclide	Incident Alpha Energy					
	10 MeV	15 MeV	20 MeV	30 MeV	40 MeV	50 MeV
Na [illegible]		1 [illegible]E-0[illegible]	1 [illegible]E-04	[illegible] 52E-04	1 44E-03	2 64E-03
[illegible]		[illegible]	1 40E-07	1 15E-06	6 49E-06	1 96E-05
Na 24		0	0	0	0	1 01E-18
Na 2[illegible]		0	0	0	0	5 75E-11
Mg 27		0	0	0	0	3 27E-15
Al 2[illegible]		0	0	2 5[illegible]E-14	2 70E-06	3 60E-05
Al 2[illegible]		0	0	0	3 [illegible]E-0[illegible]	9 57E-06
[illegible] 2[illegible]		0	0	1 1[illegible]E-11	7 83E-07	1 16E-05
[illegible]		0	0	0	9 96E-05	4 51E-06
[illegible]		0	0	7 90E-12	3 2[illegible]E-07	1 58E-06
[illegible]		0	1 6[illegible]E-1[illegible]	0 8[illegible]E-0[illegible]	2 [illegible]E-04	3 99E-04
[illegible]		0	0	4 57E-06	7 91E-05	2 18E-04
[illegible]		0	2 4[illegible]E-06	4 41E-05	1 91E-04	4 40E-04
S 3[illegible]		0	0	0	0	3 18E-12
[illegible]		0	0	3 45E-15	1 85E-07	2.66E-06
Cl 32		0	0	0	1 15E-1[illegible]	1 15E-08
[illegible]		0	3 55E-09	1 08E-06	1 61E-0[illegible]	1 68E-06
[illegible]		1 23E-05	8 [illegible]E-05	9 38E-0[illegible]	9 43E-05	9 43E-05

Table 13

[illegible] Thick Target Radionuclide Yields

[illegible]