Systematical Analysis of Fast Neutron Induced Alpha Particle Emission Reaction Cross Sections

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Overview

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- **The Comparison of Theoretical and Experimental (n,a) Cross Sections**
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Introduction

Investigation of the fast neutron induced alpha particle emission reaction is important for both:

nuclear reactor technology

the understanding of nuclear reaction mechanisms.

Systematic study of reaction cross sections is important:

to estimate radiation damage due to helium production nuclear heating and transmutations in the structural materials of reactors.

in practice to evaluate the neutron cross sections of the nuclides, for which no experimental data are available.

Formula for The Reaction Cross Section

For fast neutrons using the evaporation and constant nuclear temperature models and semi-classical approach for an inverse reaction cross section we can obtain the following general formula:

$$\sigma_{n\alpha}^{com} = 2\pi(R + \lambda\!\!\!^{-})^2 e^{\frac{Q_{n\alpha} - V_{\alpha}}{\Theta}}$$

← G.Khuukhenkhuu, G.Unenbat Scientific Transactions, National University of Mongolia, 7(159), 2000, p.72

where:

R – radius of target nuclei

λ- wavelength of incident neutrons

$Q_{n\alpha}$ – reaction energy

V_{α} - coulomb potential for alpha particle

Θ - thermodynamic temperature of nuclei

Thermodynamic temperature

$$\Theta = \sqrt{\frac{13.5\left(E_n + Q_{n\alpha}\right)}{A-3}}$$

⟸ J.M.Blatt and V.F.Weisskopf Theoretical Nuclear Physics, John Wiley and Sons, New York, 1952.

where:

E_n – neutron energy

A – mass number of target nuclei

Coulomb potential

$$V_\alpha = 2.058\frac{Z-2}{(A-3)^{1/3} + 4^{1/3}}$$

⟸ D.G.Gardner and Yu-Wen Yu Nucl. Phys., v.60, N1, 1964, p.49

where:

Z – proton number of target nuclei

Reaction energy (used Weizsacker formula)

$$Q_{n\alpha} = \varepsilon(A-3, Z-2) + B_\alpha - \varepsilon(A,Z) = B_\alpha - 3\alpha + \beta\left(A^{2/3} - (A-3)^{2/3}\right) +$$

$$+\gamma\left(\frac{Z^2}{A^{1/3}} - \frac{(Z-2)^2}{(A-3)^{1/3}}\right) + \xi\left(\frac{(N-Z)^2}{A} - \frac{(N-Z+1)^2}{A-3}\right) + \frac{\delta_i}{A^{3/4}} - \frac{\delta_f}{(A-3)^{3/4}}$$

Where:
B_α – the binding energy of alpha particle,
N – neutron number of target nuclei,
α=15.7 MeV, β=17.8 MeV, γ=0.71 MeV, ξ=23.7 MeV and
for even-even nuclei δ=11.8 MeV,
for odd-odd nuclei δ=-11.8 MeV,
for even-odd or o-even nuclei δ=0.

Rohlf: *Modern Physics from a to Z0,* James William Rohlf, Wiley, 1994

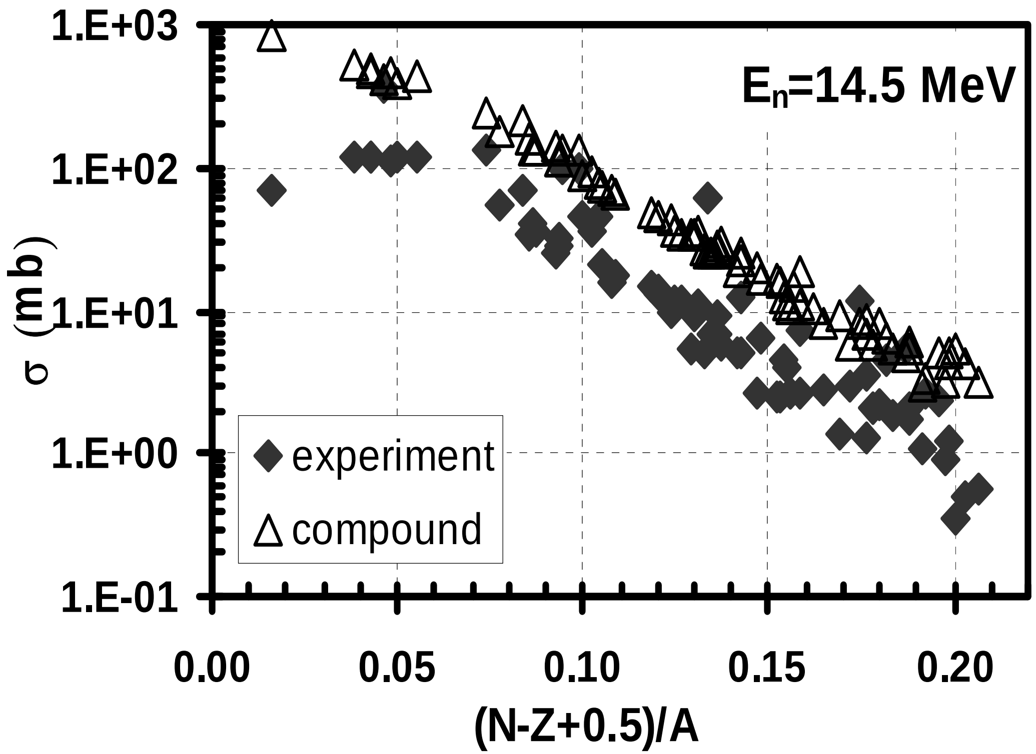
Simple Formula for the (n,a) cross section:

$$\sigma_{n\alpha}^{com} = C\pi(R + \lambda\!\!\!^{-})^2 e^{-K\frac{N-Z+0.5}{A}}$$

$$C = 2\exp\frac{1}{\Theta}\left\{-3\alpha + \beta\left(A^{2/3} - (A-3)^{2/3}\right) + \gamma\left(\frac{Z^2}{A^{1/3}} - \frac{(Z-2)^2}{(A-3)^{1/3}}\right) + \varepsilon_\alpha - V_\alpha\right\}$$

$$K = \frac{2\xi}{\Theta}$$

The Comparison of Theoretical and Experinmental (n,a) Cross Sections



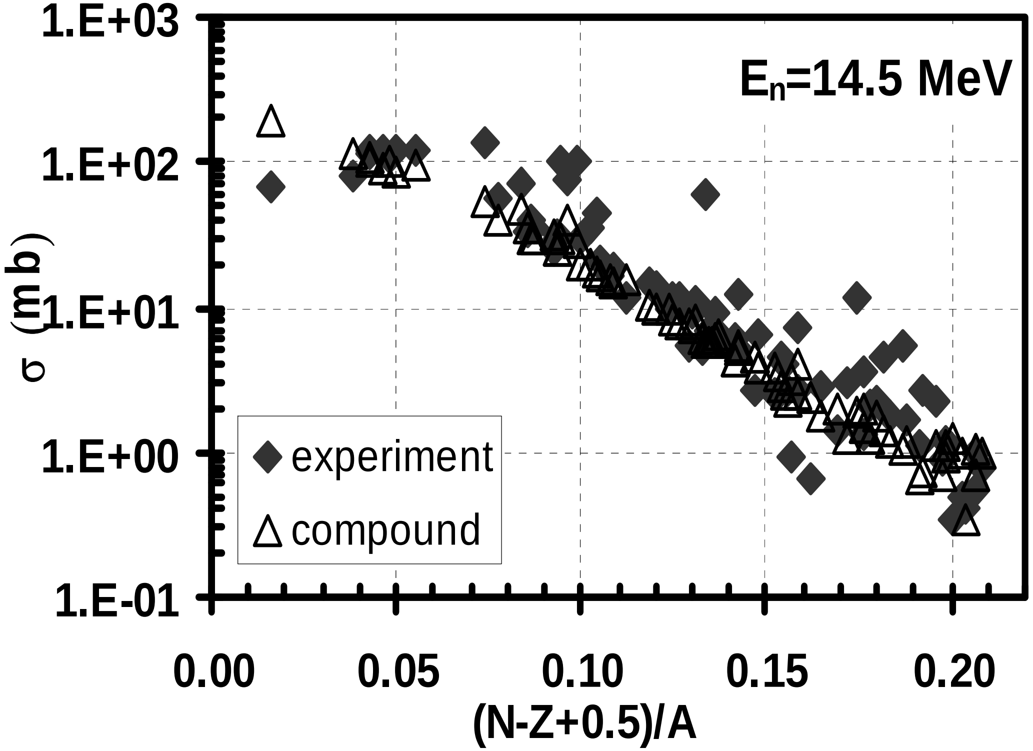
The comparisons of the absolute values for theoretical cross sections calculated by statistical model with known experimental data at neutron energies En=14.5 MeV is shown here.

It was observed that statistical model formulae give overestimated values for (n,a) cross sections at the 14,5 MeV energy of neutrons.

Our hypothesis: the difference is caused by the alpha-clusterization effect (alpha-particle formation probability) on the surface of nuclei.

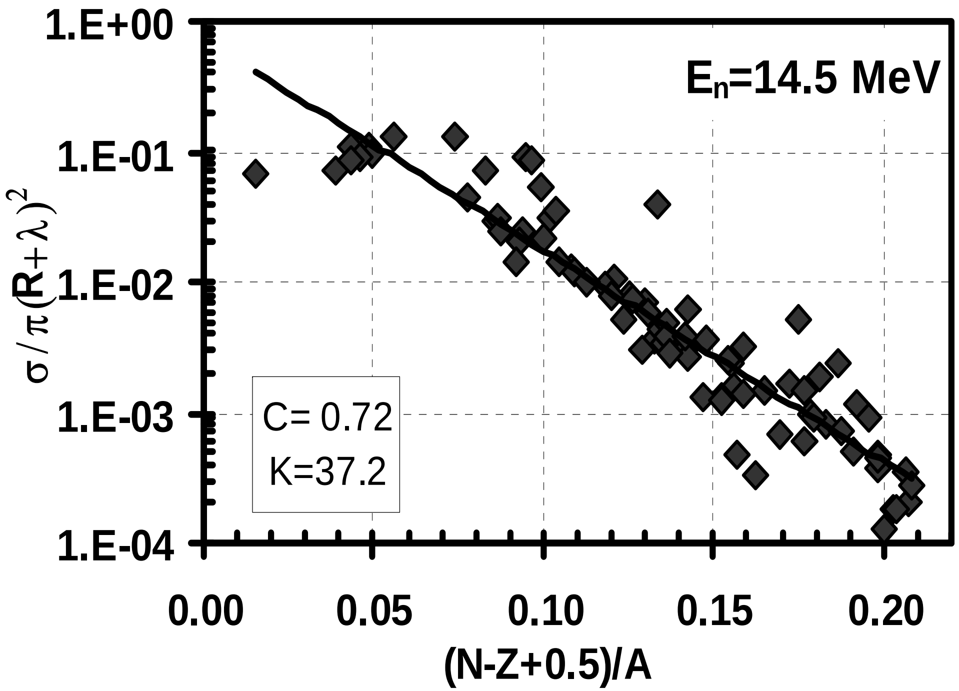
The ratio of neutron emission probability to alpha emission one from compound nucleus is 4.5

Yu.P.Popov and W.I.Furman III School on Neutron Physics, JINR, D3-11787, 1978, Dubna, p.390



In this case theoretical (n,a) cross sections are in agreement with experimental data

Systematic Analysis



E_n (MeV)	K	C
6	58.7	0.31
8	52.4	0.60
10	44.7	0.49
13	38.2	0.59
14.5	37.2	0.72
16	36.0	0.60

The values of parameters C and K fitted to experimental data are given in here.
And It is seen that theoretical line fitted to experimental data is in agreement with known experimental cross section data

The same as, C and K parameters for different neutron energies are fitted, and are given in Table.

Conclusion

- **Using the statistical model formula we performed the systematic analysis of fast neutron induced (n,a) reaction cross sections data.**
- **We have fitted the values of parameters C and K to experimental data for some energy of neutrons.**
- **When we take into account alpha particle emission probability the theoretical results agree well with the experimental data**


Thank you for your kind attention!