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A Systematics of Optical Model Compound Nucleus Formation Cross Sections for Neutron,Proton,Deuteron,^{3}He and Alpha Particle Incidents

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Simple formulae to reproduce the optical model compound nucleus formation cross sections for neutron,proton,deuteron,triton,^{3}He and alpha particles are presented for target nuclei of light to medium weight mass region.

Many nuclear reaction calculation codes utilize optical model compound nucleus formation cross sections repetitiously many times to obtain nuclear reaction behavior. For ordinary personal computers, the cross section calculation is quite heavy work. So, simple fitting formula or simple systematics of the cross sections over many target nucleus are useful for the nuclear reaction calculation. As an example, in the statistical multi-step reaction code EXIFON /1/, the cross sections for neutron, proton and alpha particle incidents are reproduced with several tenth of fitting parameters, over target nucleus mass number A>20 in the incident energy region below 100MeV. Modification of the EXIFON code were made /2/ to apply it to light nucleus and to include deuteron, triton and ^{3}He emission, and fitting parameters for these particles were also determined to reproduce the cross sections in the target nucleus mass region A<=16.

In the present study, target nucleus are extended to the medium weight nuclei, and the cross sections are calculated with optical potential parameters given in the ref./3/. Incident energy dependence of the cross section ratio R(E): charged particle (p,d,t,^{3}He and alpha-particle) to neutron are well reproduced with the following formulae. Incident energy region was divided into two region, using a Coulomb barrier related parameter E_0:

$E_0 = Q_b * R_C$, $Q_b = E_{qb} * R_q$,

where E_{qb} is Coulomb barrier and given by $E_{qb} = 1.4399 * Z_p * Z_T / R$ (MeV) using the interaction radius: $R = R_0 * (A_T^{1/3} + A_p^{1/3})$ and $R_0 = 1.3$ fm.

In the incident energy region: $E <= E_0$, R(E) is given by approximated Coulomb barrier penetration factor and

$R(E) = Exp[-2*G/A_g]$

$G = \{Arccos(E_b^{1/2}) - E_b^{1/2}*(1-E_b)^{1/2}\}*Q_b/Z_p/E_b^{1/2})$

In the incident energy region: $E > E_0$

$R(E) = R(E_0)+\{1-Exp(-A_0*(E-E_0))\}*\{A_1+A_2*(E-E_0)^{1/2}\}$

where, $R_c, R_q, A_g, A_0, A_1, A_2$ are fitting parameters.

Examples of the fitting are shown in Fig.1 for ^{12}C and ^{90}Zr. The fitting parameters dependence on target nucleus atomic number is shown in Fig.2.

Neutron incident compound nucleus formation cross section was reproduced by, in the incident energy region: $E_1 =< E < E_2$,

$\sigma_n(E) = A_l*E+A_m+A_n/E$,

in $E < E_1$,

$\sigma_n(E) = B_l*(E-E_1)+\sigma_n(E_1)+B_n*(1/E-1/E_1)$,

and in $E > E_2$,

$\sigma_n(E) = \sigma_n(E_2)*(E/E_2)^{A0}$,

where $A_l, A_m, A_n, B_l, B_n, E_1$, and E_2 are fitting parameters.

Examples of the cross section fitting are shown in Fig.3 and values of the fitting parameters are given in Table 1.

As is shown in Figures, the cross section ratios and the neutron incident cross sections are reproduced well with the present simple formulae.

[References]

/1/ Kalka,H.: Z.Phys.A341,289(1992), /2/ Murata,T.: JAERI-Conf 97-005, p.286

/3/neutron: Wilmore,D.,hodgson,P.E.: Nucl.Phys.32,353(1962), proton: Perey,F.G.:Phys. Rev.131,745(1963), deuteron:P erey,C.M.,Perey.F.G.:Phys.Rev.132,755(1963), triton& ^{3}He:Becchetti,F.D.,Greenlees,G.W.:"Polarization Phenomena in Nuclear Reaction" ,p.628, alpha: Arthur,E.D.,Young,P.G.:LA-8636-MS(ENDF-304)

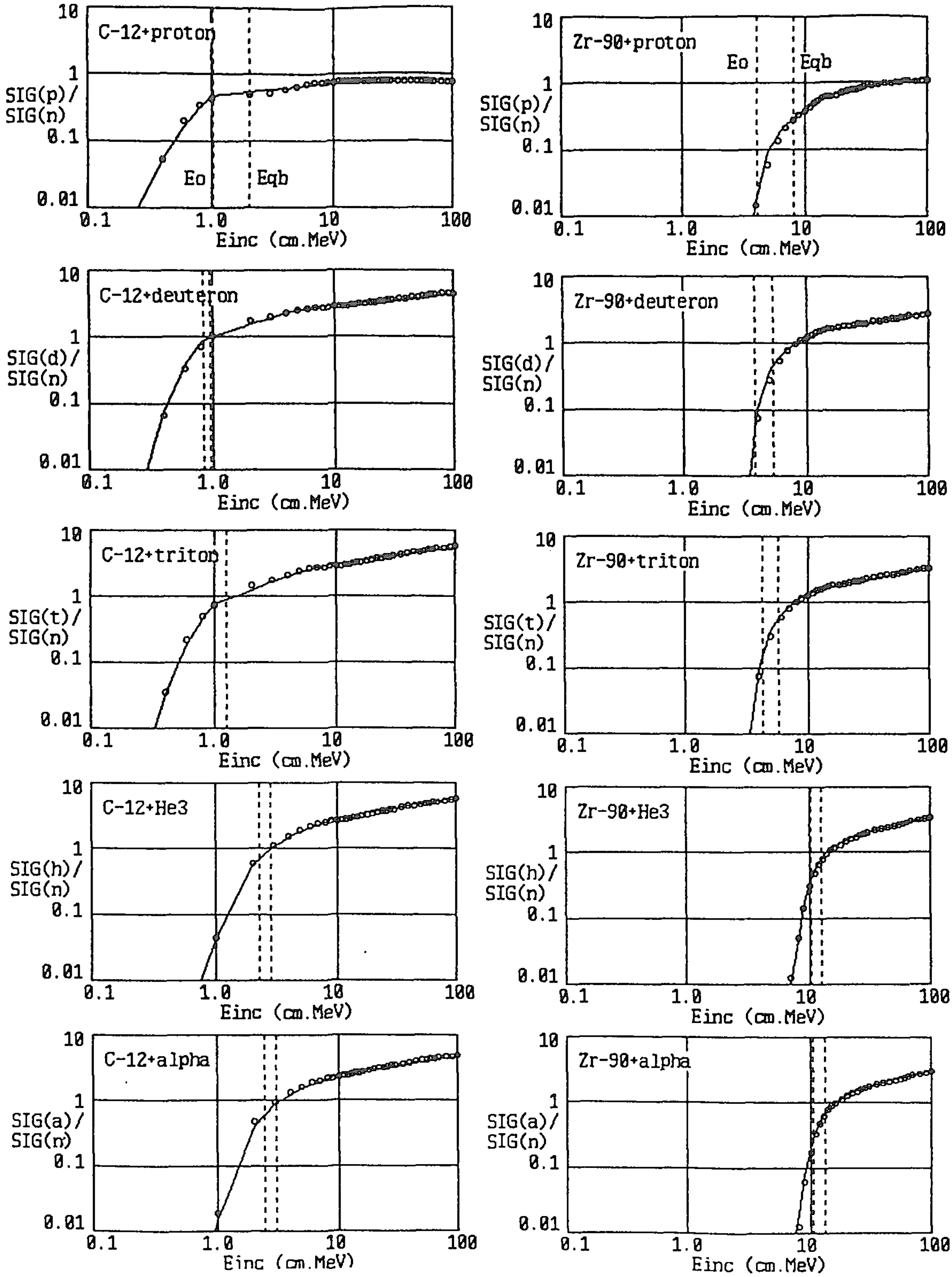

Fig.1 Ratio of charged particle incident compound nucleus formation cross section to that of neutron incident on ^{12}C and ^{90}Zr. Optical model calculation ratios are shown by circles and reproduced ratios using present formulae are shown by solid lines.

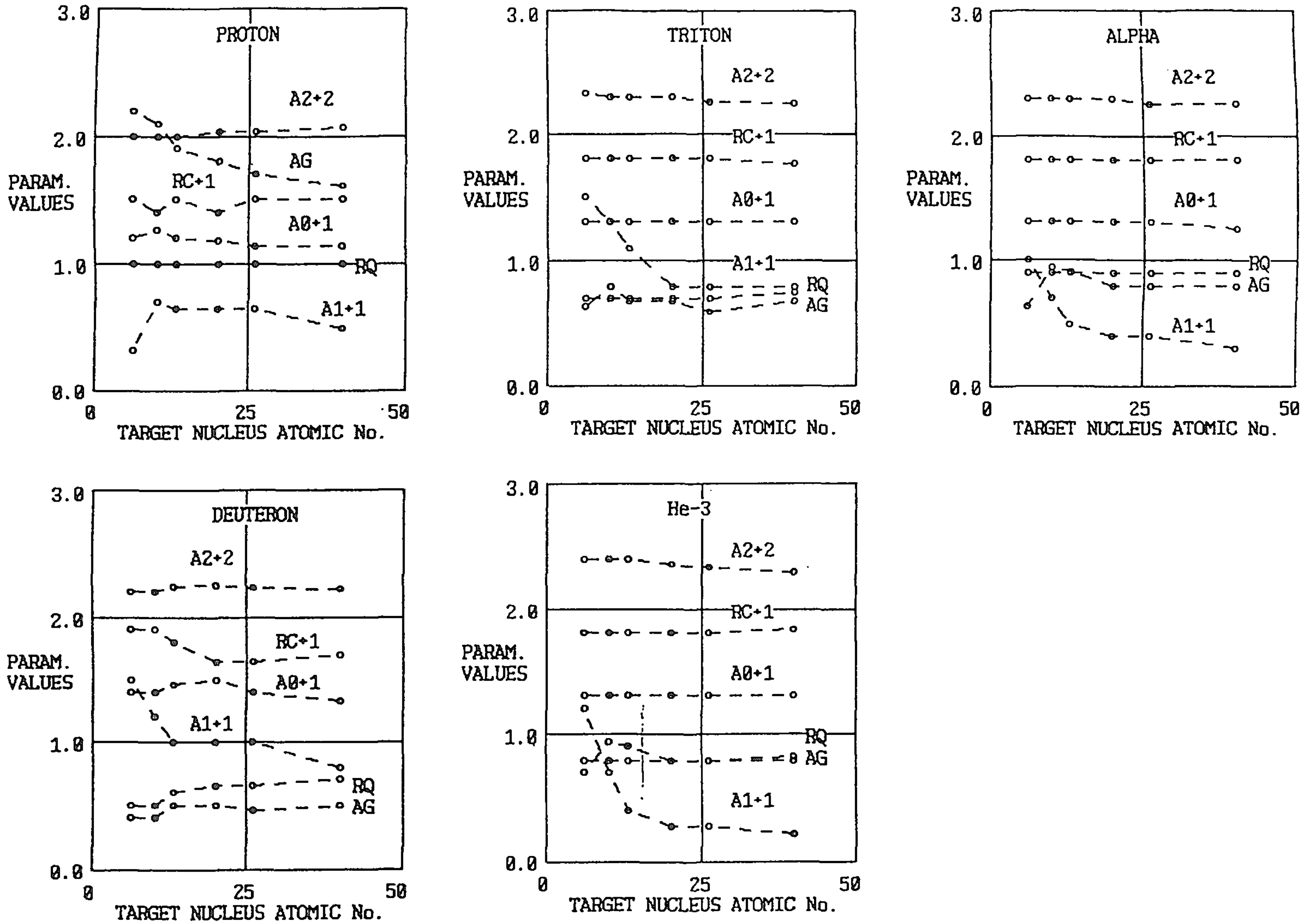

Fig.2 Target nucleus atomic number dependence of the parameters to reproduce the cross section ratios (See text). For distinction, some parameters are shifted by given value in the figure.

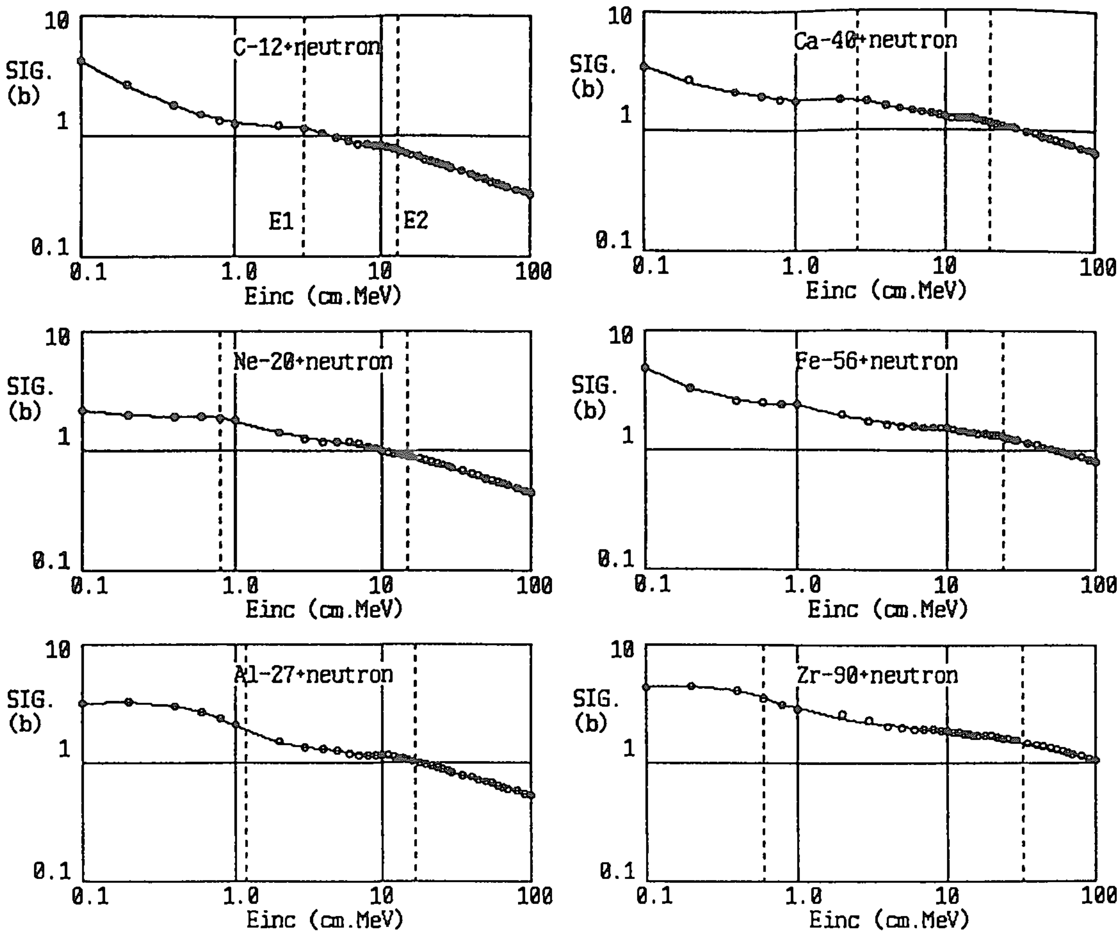

Fig.3 Examples of neutron incident compound nucleus cross sections reproduced by present formulae. Optical model calculated values are shown by circles and reproduced ones using present formulae are shown by solid lines.

Table 1 Values of fitting parameters for neutron incident compound nucleus formation cross sections (See text)

TARGET	AL	AM	AN	BL	BN	AO	E1	E2
C-12	-3.87E-01	6.66E+02	1.55E+03	3.72E+01	3.28E+02	-4.19E-01	3.00E+00	1.30E+01
Ne-20	-2.14E+01	1.18E+03	6.04E+02	9.74E+01	3.64E+01	-3.69E-01	8.00E-01	1.50E+01
Al-27	-9.28E+00	1.16E+03	7.17E+02	-1.69E+03	-4.00E+01	-3.74E-01	1.20E+00	1.68E+01
Ca-40	-7.43E+00	1.25E+03	1.56E+03	6.42E+01	1.89E+02	-3.53E-01	2.60E+00	2.00E+01
Fe-56	-9.87E+00	1.51E+03	9.32E+02	3.96E+02	3.06E+02	-3.41E-01	1.00E+00	2.40E+01
Zr-90	-1.39E+01	1.91E+03	1.01E+03	-2.99E+03	-8.11E+01	-2.99E-01	6.00E-01	3.25E+01