OPTICAL MODEL ANALYSIS OF NEUTRON ELASTIC SCATTERING ON CARBON

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The calculation of the optical model of neutron scattering for C^{12} nucleus in the energy region of 4-14MeV has been carried out. To estimate a compound elastic scattering at low energies, the Hauser-Feschbach formalism has been used. A good agreement is obtained at higher energies.

In the present paper in order to explain the neutron scattering on the C^{12} nuclei, the prediction of optical model of nucleus has been investigated more thoroughly. The obtained results are in a good agreement with the experimental data in the neutron energy region of 6.5-14MeV.

Recently the estimation of sections of neutron interactions with nuclei by different model predictions is of great interest. For average neutron energies and for medium and heavy nuclei, the use of the nucleus optical model gives rather reasonable results [1, 2]. However, to estimate the neutron data for relatively light nuclei, the use of such a model needs additional investigations. This is attributed to different experimental data for supporting points on the one hand, and also to necessity for improvement of the optical potential on the other hand. In the present paper to determine the neutron energy region and to obtain the appropriate optical parameters, the estimation of the data on C^{12} by the nucleus optical model has been carried out.

For neutron energies lower than 4MeV, the optical parameters account the experimental data on light nuclei insufficiently indicating a low energy limit for the optical model. A good data agreement at neutron energies of 6.5-14MeV can be used to compensate for missing experimental data as the optical parameters in this energy region smoothly vary with energy. However, the obtained optical parameters are somewhat inaccurate due to a lack of the experimental data in the energy region considered.

The optical potential has been used in the following form [3]:

$$V(r) = -V_{CR}v_{cr}(r) - iV_{IM}v_{im}(r) - V_{SO}v_{so}(r)(\vec{\sigma}.\vec{e}) \qquad (1),$$

where

$$v_{cr}(r) = \frac{1}{1+exp\left[r - R_1/a\right]} \text{ (Woods-Saxon form)} \qquad (2)$$

and $v_{lm}(r)$ is the surface absorption form factor

$$v_{lm}(r) = exp\left\{-\left(\frac{r-R_2}{b}\right)^2\right\} \text{ (the Gaussian form)} \qquad (3)$$

The spin-orbit term is

$$v_{SO}(r) = -\left(\frac{h}{m_\pi C}\right)^2 \frac{1}{r}\frac{d}{dr}v_{cr}(r) \text{ (the Thomas form)} \qquad (4)$$

$$R_1 = r_{or}A^{1/3}; \quad R_2 = r_{oi}A^{1/3} \qquad (5)$$

where A is the mass number of the target nucleus.

In the present paper r_{or} and r_{oi} are equal to the value of r_0. The $R=r_0A^{1/3}$ is equated to the nuclear radius. Using the above potential (1), a following set of optical parameters i.e. V_{CR}, V_{IM}, V_{SO}, a, b and r_0, has been obtained.

The slight parameters changes are explained by different values of experimental cross-sections. However, to reveal the dependence of optical parameters on neutron energy is difficult due to interrelation between the optical parameters themselves. Moreover, at different neutron energies the change of optical parameters is not the same.

For calculation, a special computer programme was used. In this programme the search of parameters was realized by minimization of the following function:

$$\chi^2 = \sum_i \left(\frac{\sigma_i^{cal} - \sigma_i^{exp}}{\Delta\sigma_i^{exp}}\right)^2 + \frac{1}{N}\sum_{j=1}^{N}\left(\frac{\sigma(\theta_j)^{cal} - \sigma(\theta_j)^{exp}}{\Delta\sigma(\theta_j)^{exp}}\right)^2$$

where $\Delta\sigma$ is the experimental error of the σ value.

The given programme also contains the Hauser-Feschbach formalism where the cross-section data are assumption of compound neutron elastic scattering.

The fitting process for obtaining the optical parameters was carried out at neutron energies of 4.50; 7 and 13MeV. The data for the other energies were obtained at linear interpolation. The fact that for the carbon nuclei the experimental data on the total cross-section strongly vary at the neutron energies of 4.8; 5.3 and 8MeV indicates that the corresponding optical parameters should not be considered as absolute.

For neutron energies lower than 7MeV the Hauser-Feschbach formalism with the following energy levels for C^{12} was used [4].

E (MeV)	J^π	MeV	J^π
0	0^+	-6.134	3^-
6.052	0^+	6.916	2^+
6.047	1^+	7.121	1^-

The calculated cross-section values and the experimental data are shown in Table 1. It is seen from the Table 1 that there is a good agreement for values at neutron energies more or equal to 6MeV.

A significant variation of near 8MeV indicated that the optical model prediction for this energy cannot be considered sufficient. However, as seen in table 1, the given data are in a good agreement.

Table 1.

E_n, MeV	σ_T^{exp}, δ	σ_T^{cal}, δ	σ_{el}^{exp}, δ	σ_{el}^{cal}, δ
4,50	1,43 ± 0,05	1,43	1,55	1,42
5,00	1,45 ± 0,07	1,45	1,12±015	1,18
5,50	1,50 ± 0,07	1,50	0,97	1,25
6,00	1,41	1,41	1,35	1,33
7,00	1,39 ±0,04	1,39	0,97	0,86
8,00	1,37 ±0,06	1,37	0,95	0,84
9,00	1,45 ±0.04	1,45	1,05	0,93
10,00	1,42 ±0,06	1,42	1,03	0,89
11,00	1,46 ±0,03	1,46	1,01	0,87
12,00	1,47 ± 0,05	1,47	0,97	0,83
13,00	1,51 ±0,07	1,51	0,89	0,87

For the purpose of calculation, the experimental data on inelastic cross-sections were obtained in the following form:

$$\sigma_{nonel} = \sigma_T - \int \sigma_{el}(\theta) d\Omega ,$$

These data, as compared to σ_t, are inaccurate due inaccuracy of the σ_{el} values.

The optical parameters obtained for different neutron energies are tabulated in table 2.

In calculation the interpretation of $R=r_0A^{1/3}$ as the nuclear radius is somewhat inaccurate the as r_0 value slightly changes for different neutron energies. It should be noted that if r_{oi} slightly differs from r_0, the obtained parameters values are practically unchangeable.

Table 2.

E_n, MeV	V_{CR}, MeV	V_{im}, MeV	V_{SO}, MeV	a, f	B, f	r_0, f
4,5	32,2	1,9	8,3	0,72	0,90	1,10
5,0	34,5	2,0	7,6	0,50	0,98	1,27
5,5	35,3	2,2	8,5	0,51	0,97	1,35
6	38,1	2,2	8,1	0,53	0,99	1,41
7	41,0	2,1	7,3	0,52	0,95	1,38
8	40,3	2,2	8,0	0,53	0,91	1,37
9	42,1	2,1	4,8	0,55	0,86	1,28
10	43,2	2,2	4,4	0,61	0,83	1,25
14	50,4	7,4	5,1	0,65	0,78	1,20

The neutron size as compared to that of nucleus can be neglected in the case of heavy nucleus nuclei, while for the light C^{12} nucleus it is unreasonable. Probably, this fact can explain the energy dependence of V_{CR} and r_0 parameters (table 2). It has been found that with increase of neutron size relative to the target nucleus the r_0 value also increases, while the value of V_{CR} decreases.

The increase of V_{IM} with neutron energy conforms with theoretical predictions, on the base of the exclusion principle.

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KARBON NÜVƏSİNDƏN NEYTRONLARIN SƏPİLMƏSİNİN OPTİK MODELƏ GÖRƏ TƏHLİLİ

C^{12} nüvəsi üçün neytronların səpilməsinin optik modelə görə hesablanması yerinə yetirilmişdir. 4-14 MeV energi intervalı götürülmüşdür. Aşağı enercilər üçün kompaund elastiki səpilməni qiymətləndirmək məqsədilə Hauzer-Feşbah formalizmindən istifadə olunmuşdur. Yaxşı uyğunluq halları yüksək enercilər üçün alınır.

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АНАЛИЗ УПРУГОГО РАССЕЯНИЯ НЕЙТРОНОВ НА АТОМАХ УГЛЕРОДА ПРИ ПОМОЩИ ОПТИЧЕСКОЙ МОДЕЛИ

Проведено вычисление по оптической модели рассеяния нейтронов для ядра C^{12}. Рассматривался энергетический интервал 4-14МеВ. При низких энергиях для оценки компаундного упругого рассеяния применялся формализм Хаузера-Фешбаха. Хорошее согласование получается при высоких энергиях.

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