## **Research Notes**

Brief reports of new ideas, short notes, and comments on papers appeared in this journal may be submitted with a condensed form to this secton.

Contributions should in general not exceed 800 words in length.

## Investigation of the $^{32}S(n,\alpha)^{29}Si$ Reaction at 14.1 MeV

CHUNG- CHAUR PERNG (彭忠朝), SONG-YUNG LIN (林松雲), MUH-CHUEN CHOU (周木春), YI-CHUAN HSU (許玉釧), and YUIN-CHI HSU (許雲基)

Department of Physics, National Taiwan University, Taipei, Taiwan (Received 5 January 1976)

Energy spectra and angular distributions of the alpha particles from the  $^{32}\mathrm{Si}(n,\alpha)^{29}\mathrm{Si}$  reaction have been studied at an incident energy of 14.1 MeV. The results indicate that the reaction proceeds mainly through the compound nucleus process. The nuclear temperature and spin cut-off parameter for  $^{29}\mathrm{Si}$  are obtained to be  $1.65\pm0.13\,\mathrm{MeV}$  and  $2.39\pm0.24$  respectively.

The obvious forward peaks, however, in the anguar distributions of alpha particles leading to the ground and 2.03+2.43 MeV states are found. By treating the observed cross section of the ground state transition as an incoherent sum of the DI and CN processes, the, contribution of the compound nucleus process is estimated to be 48%. The contribution of the direct-interaction to the cross section of the first excited state is negligible.

The study of the  ${}^{40}\text{Ca}(n,\alpha){}^{37}\text{Ar}$  reaction at 14MeV in our previous report<sup>(1)</sup> has shown that the dominant reaction mechanism is compound nucleus process and has also indicated that the contribution from the direct-interaction process is important for the low-lying states. However, most of the experimental results<sup>(2~6)</sup> obtained in the mass region of medium weight indicate almost complete predominance of the compound nucleus process. In view of the inconsistent experimental results, the investigation of the  ${}^{32}\text{S}(n,\alpha){}^{23}\text{Si}$  is undertaken to obtain more accurate information on these situations involved, especially in the interesting low-lying states of the residual nucleus.

The  $^{32}$ S target used in the  $(n, \alpha)$  reaction was made by vaccum evaporation of natural sulphur on a gold foil with 2.0 cm diameter and 1.32 mg/cm<sup>2</sup> thickness. The abundance of  $^{32}$ S in natural sulphur is 95%.

The energy spectra of the alpha particles were obtained by using counter telescope technique at neutron energy of 14.1 MeV. Details of the experimental apparatus and procedures have been described elsewhere<sup>(1,7)</sup>.

<sup>(1)</sup> C. C. Perng, S.Y. Lin, M. C. Chou, Y.C. Hsu, J.C. Hwang and Y.C. Hsu, Chinese J. Phys. 11, 119 (1973).

<sup>(2)</sup> I.M. Turkiewicz, N. Cindro, P. Kulišič, P. Strobal and D. Veselič, Nuclear Physics 77, 276 (1966).

<sup>(3)</sup> C. Spira and J. M. Robson, Nuclear Physics A127, 81 (1969).

<sup>(4)</sup> S. Kardonsky, H. L. Finston and E. T. Williams, Phys. Rev. C4, 840 (1971).

<sup>(5)</sup> M. Bormann, W. Schmidt, V. Schröder, W. Scobel and U. Seebeck, Nuclear Physics A187, 65 (1972).

<sup>(6)</sup> N. A. Khan, S. Mubarakmand and Mahmud Ahmad, Nuclear Physics A202, 123 (1973).

<sup>(7)</sup> C. C. Perng, S. Y. Lin, Y. C. Hsu and Y. C. Hsu, Chinese J. Phys. 13, 26 (1975).

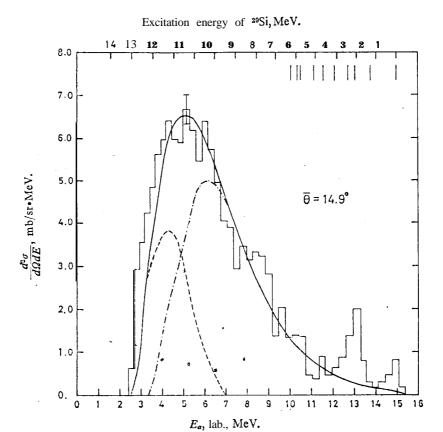


Fig. 1. Energy spectrum of the alpha particles emitted from the  $^{32}S(n,\alpha)^{29}Si$  reaction. Dashdotted and dashed curves represent the contributions from the (n, a) and  $(n, n'\alpha)$  spectra predicted by the statistical theory.

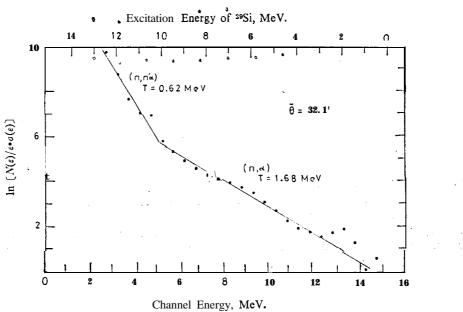


Fig. 2. Constant nuclear temperature plots for alpha particle spectrum.

Typical energy spectrum of the emitted alpha particles is shown in Fig. 1, where two peaks corresponding to the ground and  $2.03 + 2.43 \,\text{MeV}$  states of <sup>29</sup>Si are observed. If the constant nuclear temperature formula is used for the level density  $(W(E) \propto \exp(E/T))$ , the temperature T can be obtained from the slope of the logarithmic plots (Fig. 2). The values of T are found to be 1.65f.O.13 MeV and  $0.56 \pm 0.18 \,\text{MeV}$ , which are corresponding to the reactions  $^{32}\text{S}(n,\alpha)^{29}\text{Si}(Q=1.52 \,\text{MeV})$  and  $^{32}\text{S}(n,n'\alpha)^{29}\text{Si}(Q=-6.95 \,\text{MeV})$  respectively. The combination from the (n,a) and  $(n,n'\alpha)$  spectra is also shown in Fig. 1.

The measured angular distributions are indicated in Fig. 3. It is obviously seen that these distributions appear to be approximately symmetric around 90°, except the lower excitation parts (Fig. 2-a and 2-c), where predominant forward peaks are found. The features are very agreeable with the results of Turkiewicz et al.<sup>(2)</sup>.

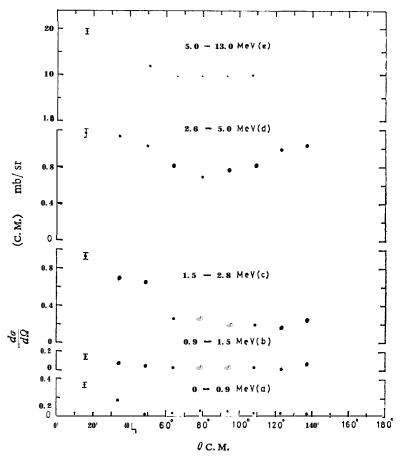


Fig. 3. Angular distributions of alpha particles leading to various excitation energies of 29Si.

In the analysis of the angular distribution of the low-lying states, the DWBA method (for DI process) and the Hauser-Feshbach theory (for **CN** process) are used. The details of the calculations are described in our previous report<sup>(1)</sup>.

The optical potential parameters used in the DWBA calculation are listed in Table I. The parameters for alpha particles are obtained from the results of Satchler *et al.*(6), except that the well depths are modified(9)

Hodgson(10).

<sup>)</sup> Bynne McFadden and G. R. Satchler, Nuclear Physics 84, 177 (1966).

<sup>(9)</sup> J.E. McQueen, J. M. Joyce and E. J. Ludwing, Nuclear Physics A147, 81(1970).

<sup>(10)</sup> P. E. Hodgson, Direct Interactions and Nuclear Reaction Mechanisms. (Gordon and, Breach, Science Publishers, Inc. New York, 1963) p. 103.

Table I. Optical-model parameters used in DWBA analysis

Channel	V (MeV)	<i>r<sub>R</sub></i> (fm)	$a_R$ (fm)	W (MeV)	<i>r<sub>I</sub></i> (fm)	(fm)	<i>r<sub>c</sub></i> (fm)
n+32S	43.8	1.25	0.65	11.3	1.25	0.98	1.25
$\alpha + ^{29}Si$	112.8	1.80	0.54	13.0	1.80	0.54	1.20

Table II. Optical-model parameters used in compound nucleus calculation

Channel	V (MeV)	(fm)	$a_R$ (fm)	W (MeV)	<i>r<sub>I</sub></i> (fm)	<i>a<sub>I</sub></i> (fm)	(fm)
n+32S	48.0-0.3 <i>E</i>	1.25	0.65	$3.0E^{1/2}$	1.25	0.98	1.25
P+32P	, 58.0-0.3 E	1.25	0.65	$3.0 E^{1/2}$	1.25	0.98	1.25
$\alpha+^{29}Si$	112.8	1.80	0.54	13.0	1.80	0.54	1.20

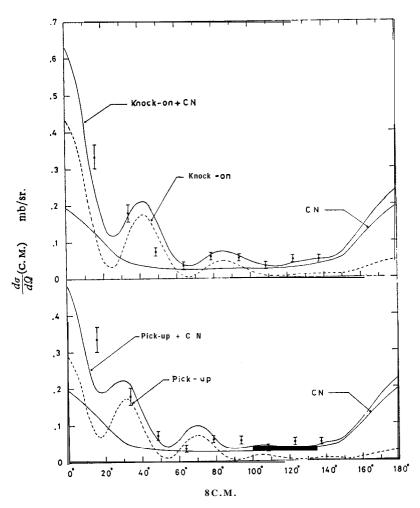


Fig. 4. Angular distribution of the ground state transition in **comparision** with the theoretical predictions. For DI process, the DWBA-3 code is used and the interaction range  $\boldsymbol{\xi}$  is 1.6 fm.

For the compound nucleus calculation, about fifty neutron, proton and alpha particle exit channels are incorporated and the employing optical potential parameters appropriate to the entrance and exit channels are listed in Table II.

In the DI calculation, two possible mechanisms, pick-up and knock-on, are considered. However, the incoherent combinations of pick-up+CN and knock-on+CN are all in good agreement with the experimental result of the ground state transition (Fig. 4). The CN contribution accounts for approximately 48% of the observed cross section and is about 30% of the entire Hauser-Feshbach prediction. For the first excited state the DI contribution to the cross section is negligible and the observed result is quite well agreeable with the CN calculation.

The spin cut-off parameter  $\sigma$  is extracted to be 2.39f0.24 by fitting to the angular distribution of the energy region 2.8-5.0 MeV of <sup>29</sup>Si, since in this region the contributions from the direct-interaction and the (n,  $n'\alpha$ ) reaction could be negligible.

This work is supported by the National Science Council of the Republic of China.