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Elastic Scattering of ^{16}O on ^{9}Be

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Using the tandem Van de Graaff in Kyoto University, excitation functions of the elastic scattering of ^{16}O on ^{9}Be at 73.7, 90.0 and 148.6 degrees in the center of mass system have been measured in the energy range $E_{lab}=11.0-34.0$ MeV. The excitation functions are compared with the optical model calculation using the shallow potential values and or the deeper potential values. Those in the lower energy region are fairly well reproduced with the deeper potential calculation. However, the anomalous structures in the higher energy region could not be explained with our optical model calculation. More complex reactions related to the nuclear structure of the projectile and the target nucleus seems to occur in the higher energy region.

INTRODUCTION

Recently, heavy ions accelerated by tandem Van de Graaff are frequently used in studies on nuclear reactions. Especially, measurements of excitation functions have been actively pursued for elastic scattering and nuclear reactions between light nuclei in the mass region up to sd-shell nuclei. From these studies some special phenomena related to the character of interaction between nuclei have been recognized. At the energy far above Coulomb barrier energy, existence of the gross structure which can not be attributed to black nucleus scattering in excitation function of the elastic scattering was found for the cases of $^{16}O-^{16}O$, *etc.*[1] At the energy near by Coulomb barrier energy, existence of quasi molecular state in $^{12}C-^{12}C$ system was reported.[2]

However, at the medium energy, above the Coulomb barrier but under the energy of gross structure region, excitation function shows very complicated feature. The excitation function of elastic scattering has quite different feature depended on combinations of nuclei, for example, in $^{12}C-^{12}C$ system it shows complicated resonance-like structure, while in $^{14}N-^{14}N$ system has monotonically decreasing character, and in $^{12}C-^{16}O$ system seems to have an intermediate feature between above two cases.[3] In this energy region, nuclear reactions also seems to have complicated feature. Examples are the reactions, (^{7}Li, t), (^{7}Li, α), (^{6}Li, d), and (^{6}Li, α) on some states of light nuclei, where the angular distributions show forward peaking as if the direct-reaction process, conversely the excitation functions have resonance-like features.[4] The other example is $^{12}C(^{12}C, \alpha)^{20}Ne^{*}$ reaction leading to so-called "2α-state" of ^{20}Ne, which shows the similar feature as in the cases of Li-induced reactions.[5] From these examples it seems that in this medium energy region the process of elastic scat-

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tering and reaction depends strongly on the structure of nuclei concerned. Some experimental researches on heavy ion nuclear reactions in the medium energy region are undertaken by authors to make clear the dependence of heavy ion interactions nuclear structure.

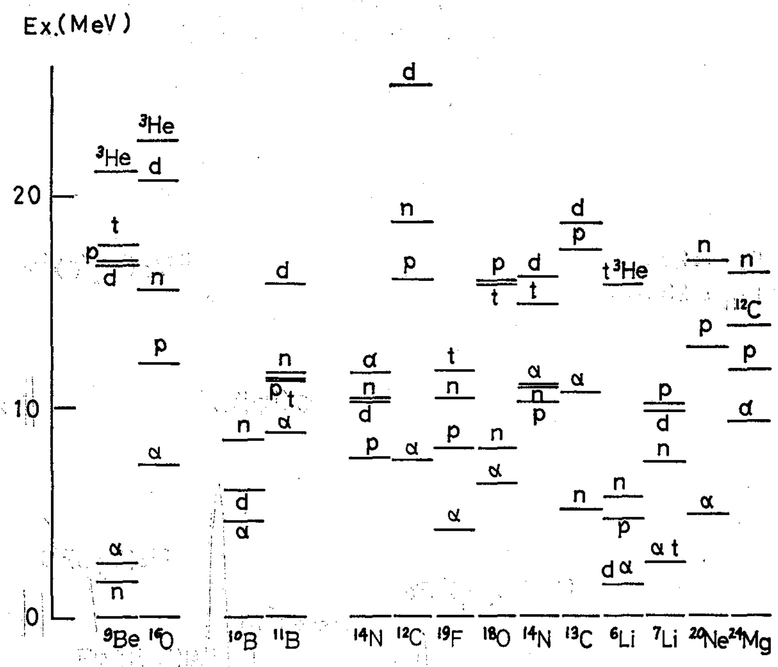

Fig. 1. Particle-decay threshold energies of some light nuclei.

In seeking the dependence of the reaction process in medium energy region on the structure of projectile and target nuclei, it seems to be important fact that in the excitation energy corresponding to incident energy very few particle-decay channels are opened for the projectile or target nucleus (shown in Fig. 1). Among these decay channels, α-decay channels are situated at low energy, especially those of 4N-nuclei are the lowest channel far from other possible channels. The anomaly observed in reactions above mentioned occurs in the cases of these nuclei being the projectile or the target. When the nucleus as ^{16}O or ^{20}Ne which has the states formed by α+core interaction above α-threshold reacts on the other nucleus at the energy region where only α-channel is open, exchange process of α-particle is possible to have important influence upon the phenomenon.

From the point of view above mentioned, interaction between closed core nucleus and closed core+α nucleus are studied. As the former ^{16}O nucleus is used and as the latter ^{9}Be (because, in ^{9}Be nuclei intranuclear α would have a nature not so differing from that in ^{8}Be nuclei) or ^{20}Ne is used. In this report experimental results of elastic scattering of ^{16}O on ^{9}Be are described.

EXPERIMENTAL METHODS AND RESULTS

A self-supported ^{9}Be foil (30 $\mu g/cm^2$) was bombarded by ^{16}O ions of the energy from 11.0 MeV to 34.0 MeV accelerated by the Kyoto-University tandem Van de Graaff. ^{16}O ions and ^{9}Be ions emitted after scattering are measured by two 100 μ surface barrier solid state detectors respectively. To measure the intensity of incident ^{16}O ions, counts of elastically scattered ^{16}O on Ag which was slightly evaporated (2~3 $\mu g/cm^2$) on the ^{9}Be target was used. Since elastic scattering of ^{16}O on Ag in this energy region, is almost pure Coulomb scattering, this method gives easily absolute value of the elastic scattering cross sections for $^{16}O+^{9}Be$.

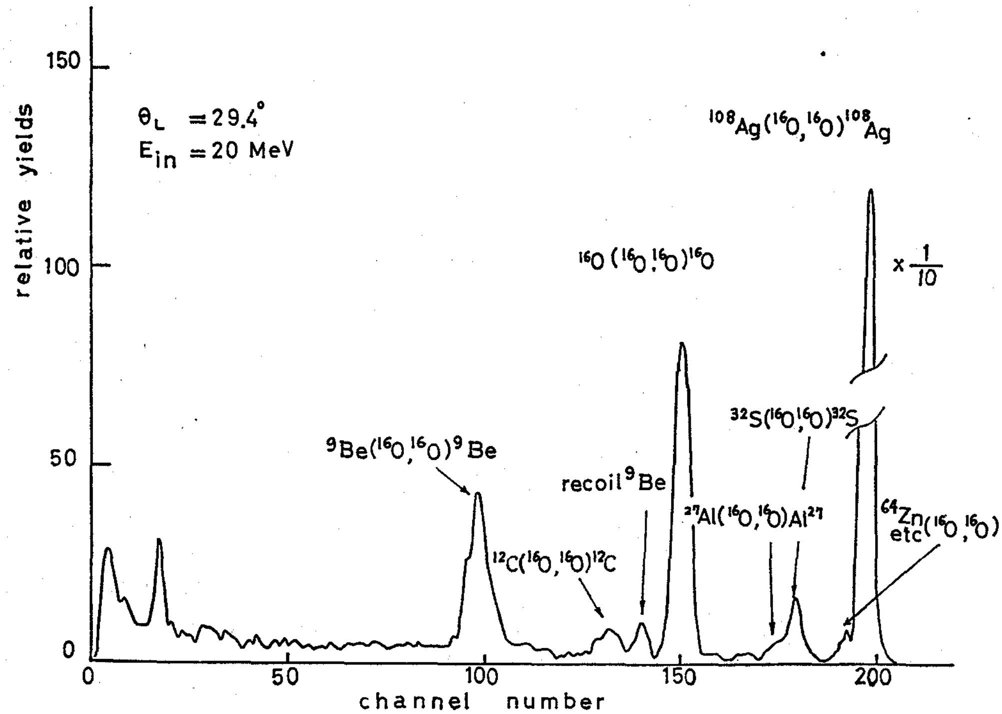

Fig. 2. An example of the energy spectrum of ^{16}O scattering on ^{9}Be.

An example of the measured single energy spectrum is shown in Fig. 2. In heavy ion reactions, background due to contamination in target is large. Especially, the contaminations of C and O are troublesome, because quantities of C and O in the target vary during the experimental runs. To avoid this background trouble, coincidence counting between the scattered ^{16}O and recoiled ^{9}Be was used. By this method spectra almost without background could be obtained.

Measurements were carried on the laboratory energy of ^{16}O between 11.1 MeV and 34.2 MeV (4.0 MeV and 12.3 MeV in the center of mass system respectively) at the center of mass angle 90.0°. Also the measurements were carried at the center of mass angles 73.7° and 148.6°. Excitation functions were obtained at the laboratory energy step of 100~500 KeV. These curves show complicated features over the c. m. energy of about 9 MeV beyond which energy α-channels of both ^{16}O and ^{9}Be are able to be opened.

DISCUSSIONS

The measured excitation function was compared with optical model calculation. An optical potential of usual volume type Woods-Saxon form:

$$U(r)=\frac{V}{1+\exp\left(\frac{r-R_R}{a_R}\right)}+i\frac{W}{1+\exp\left(\frac{r-R_R}{a_I}\right)}$$

was used. Actual calculation* was performed by 4 parameters postulating $R_R=R_I=R$ and $a_R=a_I=a$ as usual. Calculation was done with FACOM 230–60 computer facility in Kyoto University. Values of R and a used in the calculation were 6.4 fm and 0.49 fm respectively. Two sorts of potential value have been tried, one is a shallow potential which gives a fairly good explanation of the excitaiton function of $^{16}O-^{16}O$ elastic scattering,[6] and the other is a deep potential[7] which have frequently used so far for the calculation of angular distribution of heavy ion elastic scattering. Calculated excitation functions derived from the shallow potential are shown in Fig. 3 as well as Fig. 4 with experimental data.

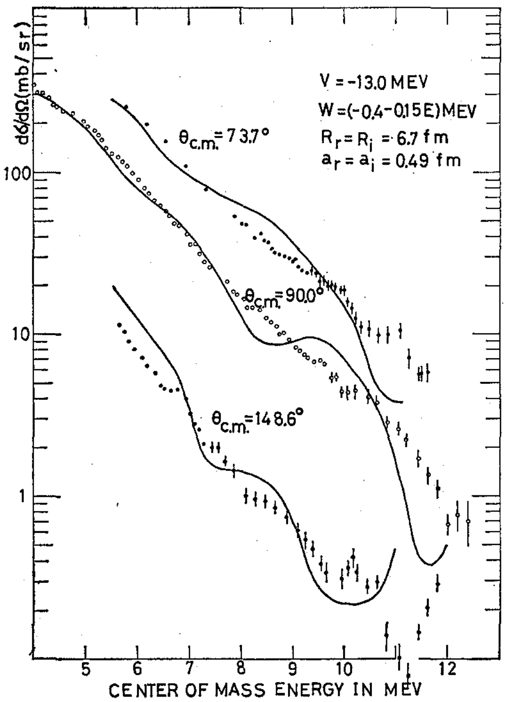

Fig. 3

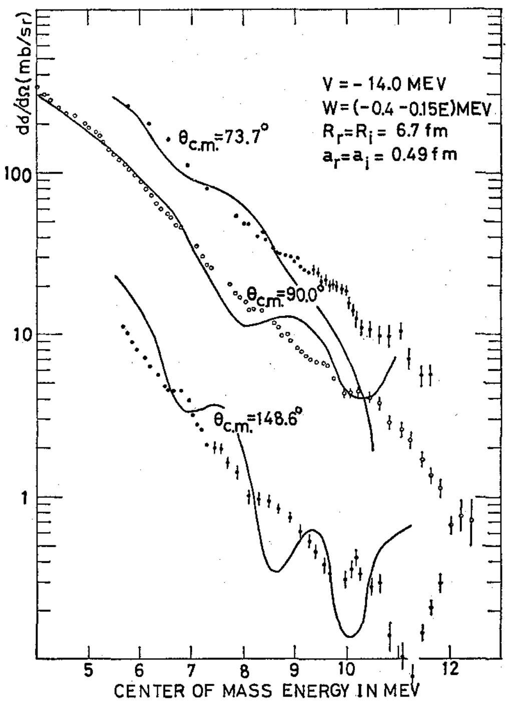

Fig. 4

Fig. 3, Fig. 4. Excitation functions of $^{9}Be+^{16}O$ elastic scattering at 73.7°, 90.0° and 148.6° in C. M. system. Comparison between the experimental values and the optical model calculation using the shallow potential.

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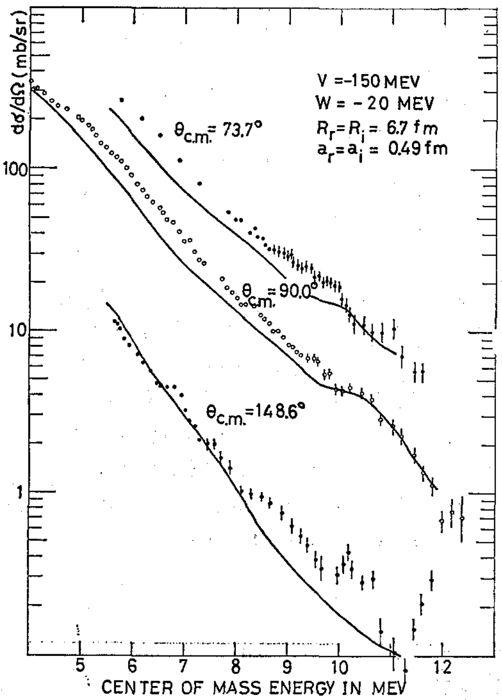

Fig. 5. Excitation functions of $^9Be+^{16}O$ elastic scattering at 73.7°, 90.0° and 148.6° in C.M. system. Comparison between the experimental values and the optical model calculation using the deeper potential.

Shallow potential seems to be able to reproduce the large bumpy structure in higher energy part in case of $\theta=148.6°$, but it gives a poor fitting for the smooth structure in lower energy part. On the other hand, deep potential reproduce fairly well the smooth structure in the lower energy part but can not reproduce the bumpy structure in the higher energy part at $\theta=148.6°$ (shown in Fig. 5). Beside this experimental data, an experiment on angular distribution of $^9Be+^{16}O$ scattering was reported by Krubasik *et al*[7] at an energy point of 30 MeV in laboratory system. Their angular distribution has no diffraction-like structure at backward angle. Therefore, it seems not to be reproduced by shallow potential.

In spite of the insufficient parameter search in our calculation, it could be said that the excitation function at the center of mass energy over 9 MeV suggests the possibility of the existence of somekinds of particular structure which can not be reproduced by a simple optical model calculation. This conclusion is supported by the other experimental results. That is, recently Middleton *et al*[8] have reported the existence of remarkable resonance-like structure in excitation function of $^{12}C(^{13}C, \alpha)^{21}Ne^*$ reaction at the energy corresponding to our experiments which gives the same compound nuclei as $^{16}O-^9Be$ system.

As far as this preliminary research is concerned, excitation function of elastic scattering of $^9Be+^{16}O$ seems to have a structure resulting from the openning of α-channels of the concerning nuclei.

Experimental research is now in progress on $^9Be+^{16}O$ system and on $^{20}Ne+^{16}O$ system for the purpose to make clear the characteristic feature of nuclear interactions between heavy ions.

This paper is dedicated to the late Professor Yoshiaki Uemura who had contributed to construct the Kyoto University tandem Van de Graaff.

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