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Differential Cross Sections for Elastic Scattering of Low-Energy Protons from ^{24}Mg and ^{26}Mg*

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The ^{24,26}Mg(p, p)^{24,26}Mg differential cross sections have been measured at E_p=1.5-3.0 MeV by using targets of high enrichment in ^{24}Mg and ^{26}Mg respectively. Excitation functions for the elastic scattering of protons have been obtained at center-of-mass scattering angles near 130° and 150° for proton energies between 1.5 and 3.0 MeV. Scattering angular distributions were measured at three energies in this range. The elastic scattering excitation functions exhibit conspicuous resonances at E_p=1.63 MeV for the ^{24}Mg(p, p) case and at E_p=2.03 MeV for the ^{26}Mg(p,p) case. The measured angular distributions show a characteristic of symmetry about 90° at resonance and a characteristic of Coulomb scattering at non-resonant energies. Differential cross sections for elastic scattering of protons from ^{26}Mg were found to be somewhat larger than those from ^{24}Mg in the energy range investigated.

1. INTRODUCTION

THE elastic scattering of protons has been studied rather extensively in the last decade. A large volume of data has been accumulated at variously high energies. However, the low-energies experiment has been performed over limited energies at few scattering angles. The investigation of elastic proton scattering on even-even nuclei at low energies is well known to be a useful tool for studying nuclear energy levels at high excitation. Measurement of the angular distributions and excitation functions would serve to give a knowledge of the resonant energies and widths of compound nuclei. From phase-shift analysis of elastic scattering data, it is possible to determine definite values for the momenta and parities of the excited states form in the compound nucleus.

The Tsing Hua Van de Graaff accelerator provides a variable-energy source Of protons at low energies for such scattering studies. A program was planned at this laboratory for investigation on proton resonance reactions for a series of target nuclei and bombarding energies, with the aim of studying high-lying levels in compound nuclei. The present experiment was underaken to measure the differential cross sections for the elastically scattered protons from ^{24}Mg and ^{26}Mg at the bombarding energies below 3 MeV. This paper describes the experi-

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mentand presents the data obtained. The continuation work in deal with the analysis is in progress.

Previous works on ^{24}Mg(p,p)^{24}Mg and ^{26}Mg(p,p)^{26}Mg reactions at low energies have been reported in refs. 1 and 2 and refs. 3 and 4 respectively. Many resonances in the energy region of $E_p=1-4$ MeV have been reported.

2. EXPERIMENTAL

The proton beam at energies between 1.5 and 3.0 MeV from the Tsing Hua Van de Graaff accelerator was used to bombard targets of ^{24}Mg and ^{26}Mg. The. elastically scattered protons were analyzed by two ORTEC surface-barrier detectors The detection system was adjusted to select and count only the desired elastically scattered protons. The accumulation of beam was performed by using a current integrator and a monitor. The monitor was employed as a check on the beam integrator system and on the uniformity of the target for the angular distribution. The total number of protons scattered elastically at a given angle was determined from the sum of two runs. A more extensive description of the experimental arrangement has been given previously" ‘.

The targets of ^{24}Mg and ^{26}Mg were prepared by the vacuum evaporation " ’ of magnesium in high enrichment (-99%) and were deposited onto a thin carbon backing (-10 μg/cm^2). The targets used in this experiment is of -30 μg/cm^2 thick. The thickness was determined by assuming that the scattering was Rutherford near 1 MeV and was checked by comparing the data taken from the (d,p) reaction with values obtained in the previous experiment in this laboratory for studies of the Mg(d,p) reactions@ ‘ ·

Data were collected at laboratory angles of 130" and 150" in steps of 15 keV from $E_p=1.5$ MeV to 3.0 MeV to obtain energy excitation functions; the proton energies range investigated corresponds to excitation energies of 3.73 MeV to 5.17 MeV and 9.71 MeV to 11.25 MeV in the compound nuclei ^{25}Al and ^{27}Al respectively. In addition, data were also taken at three different energies and angle ranges of 50" to 160° to get angular distributions.

3. RESULTS AND DISCUSSION

In Figs. 1 and 2 are shown the yield curves for protons scattered elastically from ^{24}Mg and ^{26}Mg, respectively, at the laboratory angles of 130" and 150" · The full line is drawn through the data points. For comparison, the calculated Rutherford cross section is also shown in Figs. 1 and 2 by the dash line. The

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(2) E. K. Lin, G. C. Kiang and H.S. Tzeng. Chin. J. Phys. 6, 67 (1968).
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experimental uncertainty in the measured absolute cross sections is of the order of 10%. The principal sources of uncertainty were the nonuniformity of the target and the beam integration.

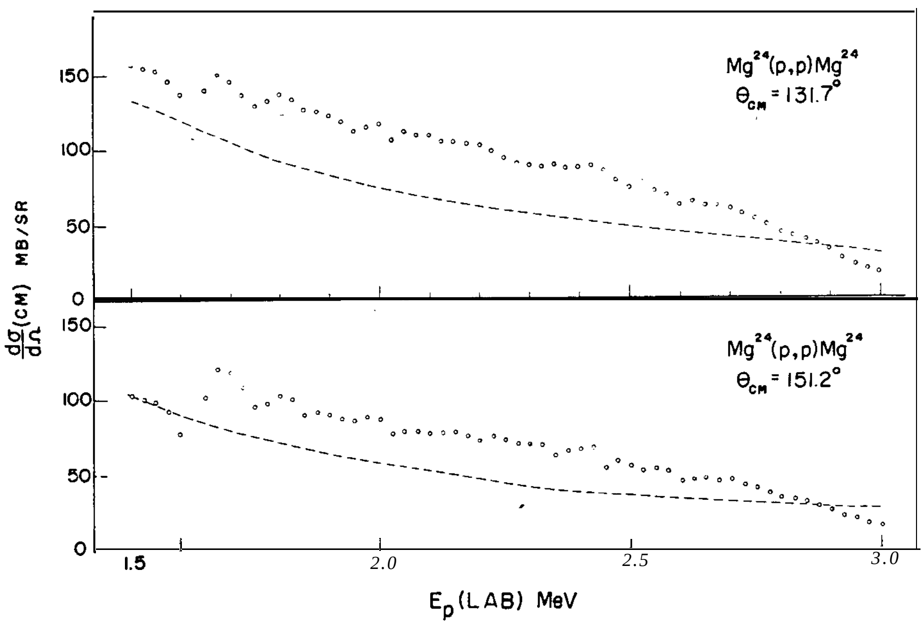

Fig. 1. Differential cross section for protons scattered elastically from ^{24}Mg as a function of incident proton energy. The dash line represents the theoretical Rutherford cross section.

For ^{24}Mg, the only resonance type structure appearing in the yield curves was observed at E_p=1.5—1.9 MeV. In this region there is a pronounced resonance at E_p=1.63 MeV, corresponding to ^{25}Al level with excitation energy 3.55 MeV. This characteristic is similar to the yield curve of Mooring et *al*[4] measured at an angle of 164°, which shows the striking resonance at E_p= 1.63 MeV. Valter *et al*[5] have assigned this level to have odd parity and $\frac{1}{2}$ unit of angular momentum. The other significant feature of the measured yield curves is that both cross sections at θ_{lab}=130° and θ_{lab}=150° tend to decrease gradually as E_p increase and a minimum appears near E_p=3.0 MeV. It has been shown[5] that there is a resonance at E_p=3.14 MeV. In general, the observed cross sections are about 30% higher than the Rutherford scattering cross sections.

The differential cross sections as a functon of angle for the elastically scattered protons from ^{24}Mg are shown in Fig. 3. The data were recorded in 10° step from 50" to 160"· The angular distributions vary smoothly as a function of energy. The differential cross section decreases with increasing bombarding energy. The trend follows closely with the Rutherford curve at off-resonance

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(5) A. K. Valter. V. E. Storizhko and A. I. Popov. Soviet Physics JETP 1'7, 39 (1963).

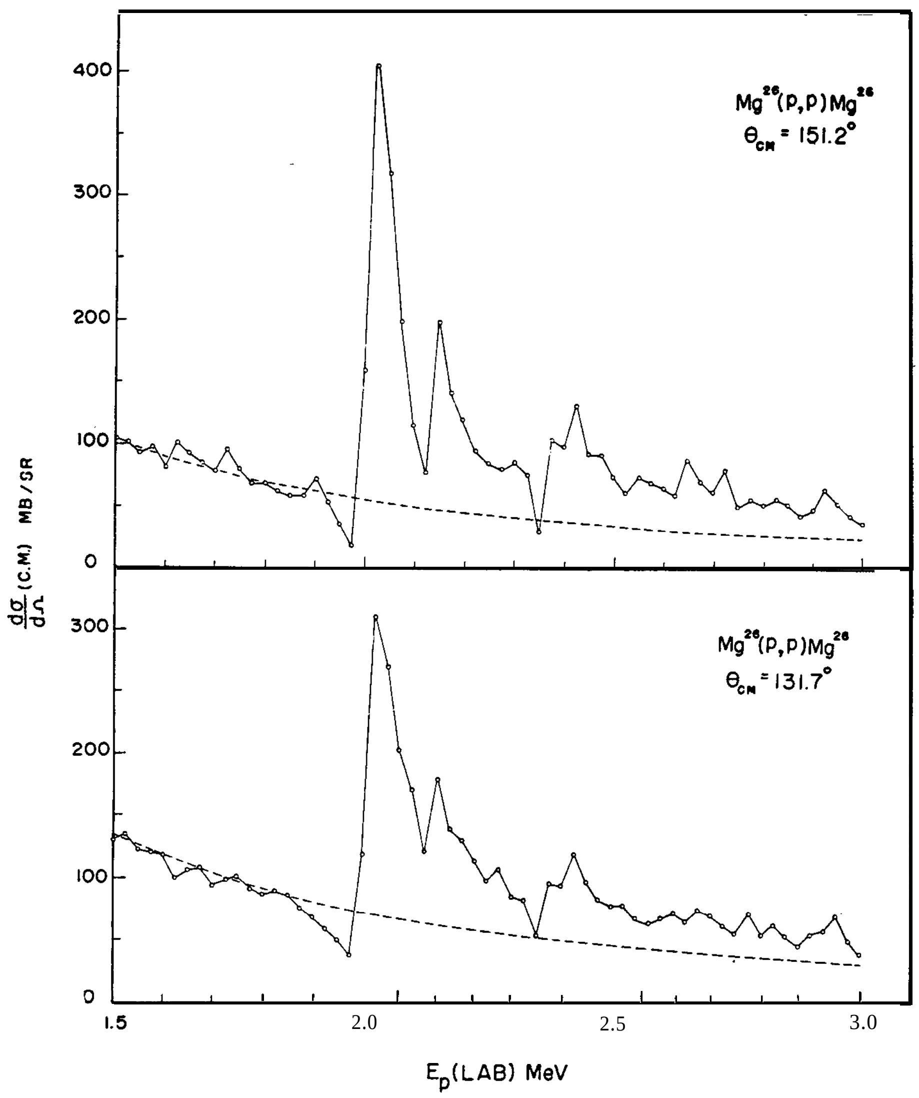

Fig. 2. Differential cross section for proton scattered elastically from ^{26}Mg as a function of incident proton energy. The dash line represents the theoretical Rutherford cross section.

region. Significant deviation from Rutherford scattering was observed in the angular distribution at E_p=3.0 MeV. All data points at angles larger than 90" are lower than the Rutherfored curve.

For ^{26}Mg, the measured exciation functions as shown in Fig. 2 indicate some resonances appearing at E_p between 2.1 MeV and 2.5 MeV and a conspicuous anomaly at E_p=2.03 MeV in the elastic proton yield. This corresponds to a doublet with resonance energies at E_p=2.025 MeV and 2.050 MeV with widths Γ=40 keV and 70 keV, respectively, as observed in ref. 4. Our data gives Γ= 50 keV for the 2.03 MeV resonance. The corresponding energies of excited states in the compound nucleus ^{27}Al are 10.222 MeV and 10.245 MeV. These two resonance

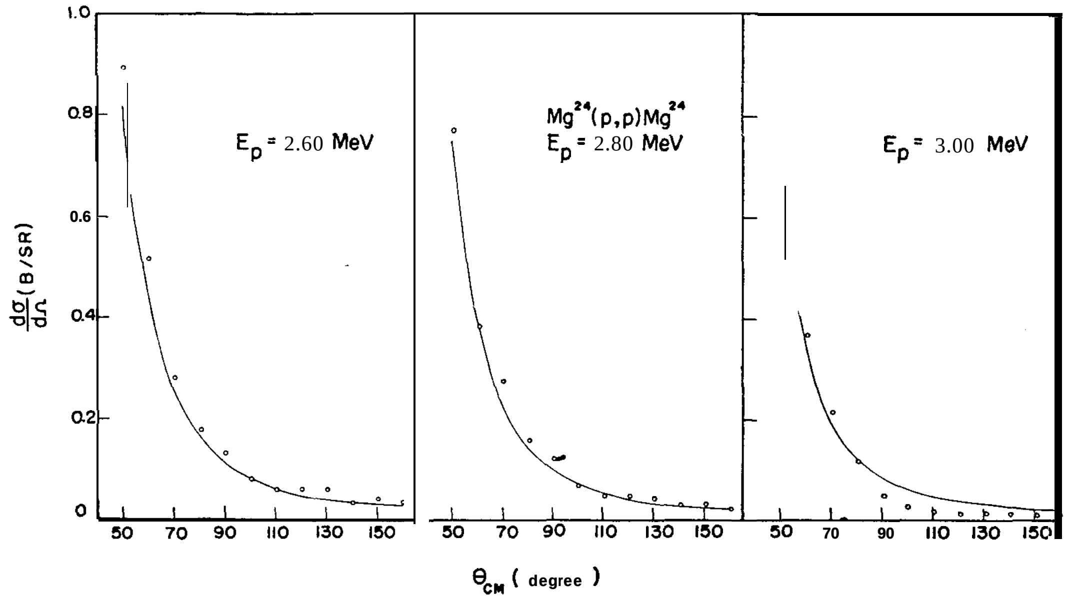

Fig. 3. Angular distributions of elastically scattered protons at different energies from ^{24}Mg.

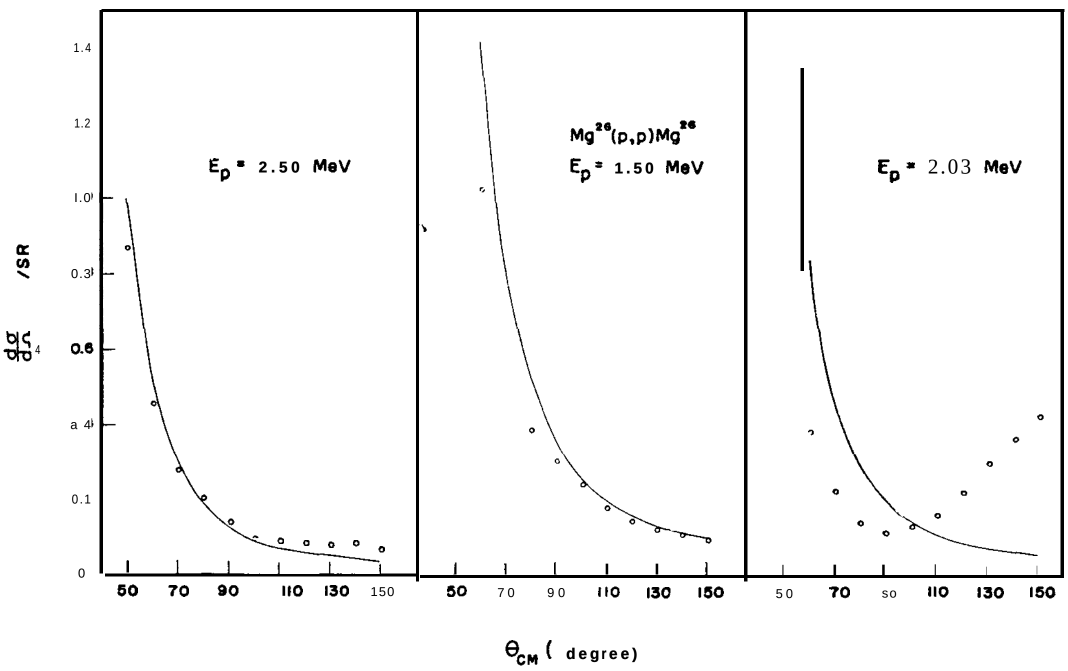

Fig. 4. Angular distributions of elastically scattered protons at d'fferent energies from ^{26}Mg.

states were found@* ') to be $3/2^-$ and $1/2^+$ respectively. As is seen from Fig. 4, the measured angular distribution for the 2.03 MeV resonance show a characteristic of symmetry about 90°, while the measured angular distributions at other

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(7) P. M. Endt and C. Van der Leun, Nucl. Phys. **A105**, 111 (1967).

energies in the off-resonance region follow the Rutherford curve. The results of measurements are in fairly agreeement with those of the earlier works.[8,6]

It is noticeable that there is somewhat change in the magnitude of the cross sections for elastic scattering of protons from ^{24}Mg and ^{26}Mg. The measured magnitudes of the differential cross sections for ^{26}Mg are somewhat larger than those for ^{24}Mg. The other noticeable change in the differential cross sections is the fluctuation as the energy of the incident proton changes. The ^{24}Mg data in the excitation functions show rather smooth curves except near $E_p=1.63$ MeV resonance. However, we have missed many very narrow resonances in this energy range. The large thickness of the target used and insufficient energy resolution made it difficult to study fine structure of narrow resonant levels in the compound nuclei ^{25}Al and ^{27}Al in the present experiment for the elastic proton scattering.

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