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The ^{26}Mg(d, α)^{24}Na Reaction at Low Energies(*)

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The reaction ^{26}Mg(d, α)^{24}Na was investigated in the incident deuteron energies, ranging from 2.5 to 3.0 MeV. A total of seven alpha-particle groups, corresponding to levels in ^{24}Na up to 1.88 MeV excitation, were observed. Data were taken at thirteen angles from 40" to 160' at E_d=2.5, 2.7, 2.8, 2.9 and 3.0 MeV to obtain angular distributions. Excition functions in 25 keV steps between 2.5 and 3.0 MeV were measured at θ=140° lab. The measured angular distributions of all alpha-particle groups were found to be nearly isotropic, and the measured excitation functions indicate the predominance of the compoud nucleus mechanism in the investigated region of deuteron energies.

1. INTRODUCTION

THE level structure of ^{24}Na has been studied extensively" ' from deuteron stripping reaction and decay-scheme work. A level scheme of the low-lying levels derived from the measurement of the ^{23}Na(d, p)^{24}Na reaction[2-5] and from the ^{23}Na(n,γ) thermal-neutron capture gamma rays[6,7] is given in fig. 1.

Recently Jahr et *al*[8] reported a new level at 1.51 MeV in ^{24}Na, which was not seen in the above mentioned works, from magnetic analysis of alpha particles from the ^{26}Mg(d,α)^{24}Na reaction at E_d=11.8 MeV. This level was observed to be rather strongly excited and the peak appeared in the spectrum is about equally prominent as the ground state transition. A high spin value ($e\geq4$) has been suggested[8] to this level, since the excitation of a high-spin state is probably enhanced in the (d, a) reaction[9].

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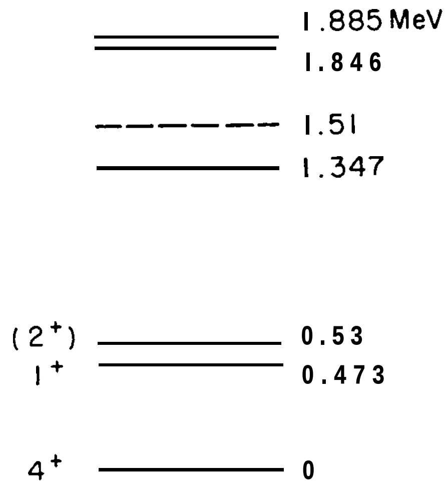

Fig. 1. Level diagram for low-lying levels of ^{24}Na. The dashed line indicates the new level at 1.51 MeV observed from the ^{26}Mg(d, α)^{24}Na reaction at E_d=11.8 MeV (see ref. 8).

The ^{26}Mg$(d,\alpha)^{24}$Na reaction at other energies has been very little investigated. Previously we have made a series measurement of the $(d$, a) reactions on ^{24}Mg, ^{25}Mg and ^{27}Al in the deuteron energy region 2.0–3.0 MeV (refs. 10-12). The results shown that the investigated reactions in this range of low energies proceed mainly via a compound nucleus, and the integrated cross sections can be described by the statistical theory(13). The (d, a) reaction on ^{26}Mg is expected to have some features in common with the (d,α) reaction in the neighboring even-A isotope ^{24}Mg. In present work, we have carried out the measurement of the ^{26}Mg$(d,\alpha)^{24}$Na reaction in the bombarding deuteron energy range from 2.5 to 3.0 MeV. An attempt is made to find the evidence for existence of a new level at 1.51 MeV in ^{24}Na. Preliminary results on the angular distributions and the excitation functions for the ^{26}Mg$(d,\alpha)^{24}$Na reaction are given in this report.

2. EXPERIMENTAL

A deuteron beam from the 3 MeV Van de Graaff accelerator of the Tsing Hua University was used to bombard a target of ^{26}Mg. To prepare the targets, MgO powder enriched in ^{26}Mg was evaporated under vacuum onto thin carbon foils, and a ^{26}Mg thickness of about **100** μg/cm^2 was obtained. Monitoring was done with a beam current integrator. The alpha particles produced in the reaction were detected in a pair of the semiconductor surface barrier detector. A detailed description of the experimental method has been given elsewhere.(10-12)

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Runs were performed for thirteen values of the laboratory angles in the interval from 40" to 160" to obtain angular distributions at E_d=2.5, 2.7, 2.8, 2.9 and 3.0 MeV. The excitation functions were measured in steps of 25 keV between 2.5 and 3.0 MeV at an angle of 140"·

3. RESULTS AND DISCUSSION

Figs. 2-6 show some energy spectra of alpha particles at deuteron energies **2.5-3.0** MeV. We observed seven groups of alpha particles. Impuity groups were observed from the $^{12}C(d,\alpha)^{10}B$ and $^{16}O(d,\alpha)^{14}N$ reactions. The α_0 group corresponds to the ground state of ^{24}Na excited in the $^{26}Mg(d,\alpha)$ reaction. The doublet ($\alpha_{1,2}$ group), corresponding to the first and second excited states at 0.473 and 0.53 MeV respectively, was not resolved clearly, and at some angles the impurity group from the $^{16}O(d,\alpha)^{14}N$ reaction seriously obscured the $\alpha_{1,2}$ group. The α_3 group leads to the third excited state of ^{24}Na at 1.347 MeV. It is about equally excited at E_d=2.5, 2.7 and 2.8 MeV as the ground state, while the intensity becomes larger at E_d=2.9 and 3.0 MeV. The α_4 group corresponds to a new level of ^{24}Na at 1.51 MeV excited in the present reaction. It appears in the spectrum defintely at several forward angles. The observed intensity decreases approximately to the background as increasing angle to $\theta_{lab}\sim 90°$. At backward angles the peak appears to be rather weak. Checking from the kinematics of the α_4 group, the variation in energy with angles corresponds exactly to the kinematics calculated for a $^{26}Mg(d,\alpha)^{24}Na$ reaction. Also, the obtained energy of this level is in agreement with the value obtained by Jahr et *al*[8] from the same reaction at higher energy (E_d=11.8 MeV). However, its cross section in the case of our deuteron energies is relatively much smaller as compared to other alpha groups. Accordingly the excitation of this level from the $^{26}Mg(d,\alpha)^{24}Na$ reaction is seen to depend on the incident energy. The $\alpha_{5,6}$ group corresponds to a doublet of the fifth and sixth excited states at 1.846 and 1.885 MeV; it was not resolved in most cases.

The shape of the measured angular distributions is varying with the deuteron energies 2.5-3.0 MeV. From formation of a compound nucleus, the averaged cross sections over a sufficient interval of incident energy are expected to be generally symmetric about 90"· Fig. 7 shows the obtained angular distribution averaged over five deuteron energies 2,5, 2.7, 2.8, 2.9 and 3.0 MeV. It is observed that all excited states are somewhat characterized by an isotropic distribution, Not shown in Fig. 7 is the angular distribution for the 1.51 MeV state. Because statistics are meager for this state, no angular distribution was obtained.

The results of the measured excitation functions at θ=140° lab. for the present energies E_d =2.5−3.0 MeV are presented in Fig. 9. For all alpha **groups the**

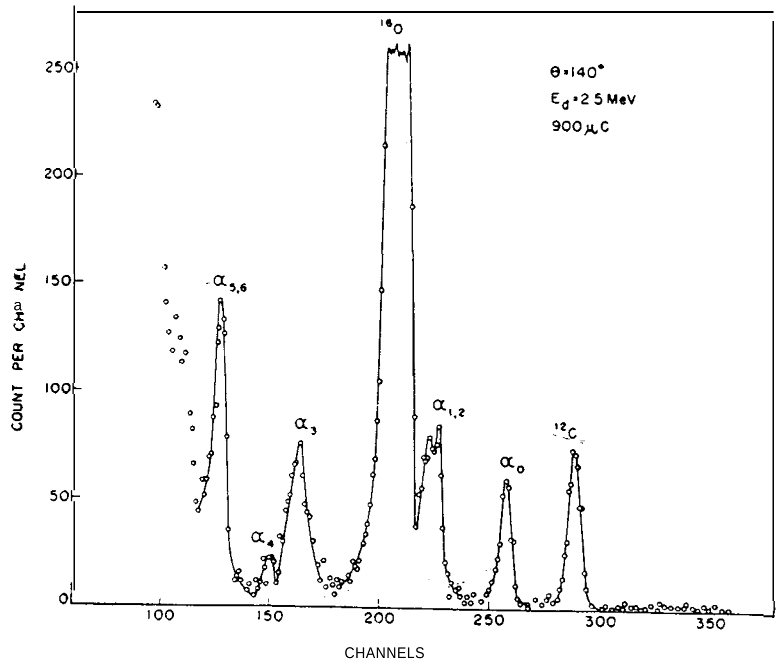

Fig. 2. Typical a-particle spectrum for the $^{26}Mg(d,\alpha)^{24}Na$ reaction at 2.50 MeV deuteron energy

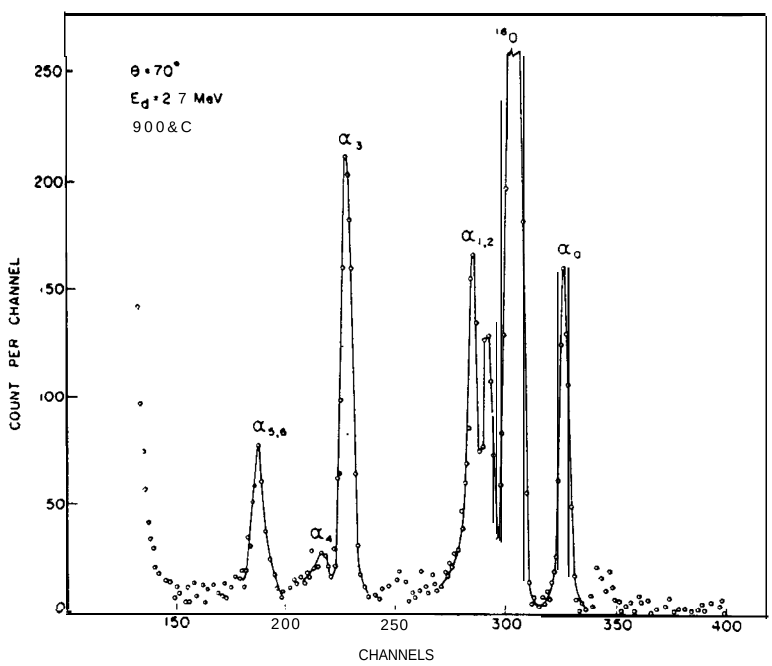

Fig. 3. Typical a-particle spectrum for the $^{26}Mg(d,\alpha)^{24}Na$ reaction at 2.70 MeV deuteron energy

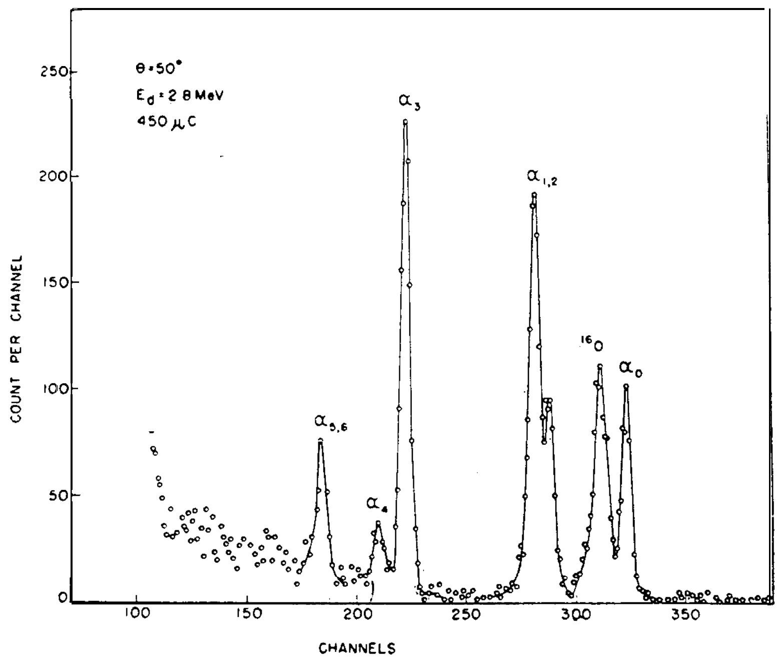

Fig. 4. Typical a-particle spectrum for the $^{26}Mg(d, \alpha)^{24}Na$ reaction at 2.80 MeV deuteron energy

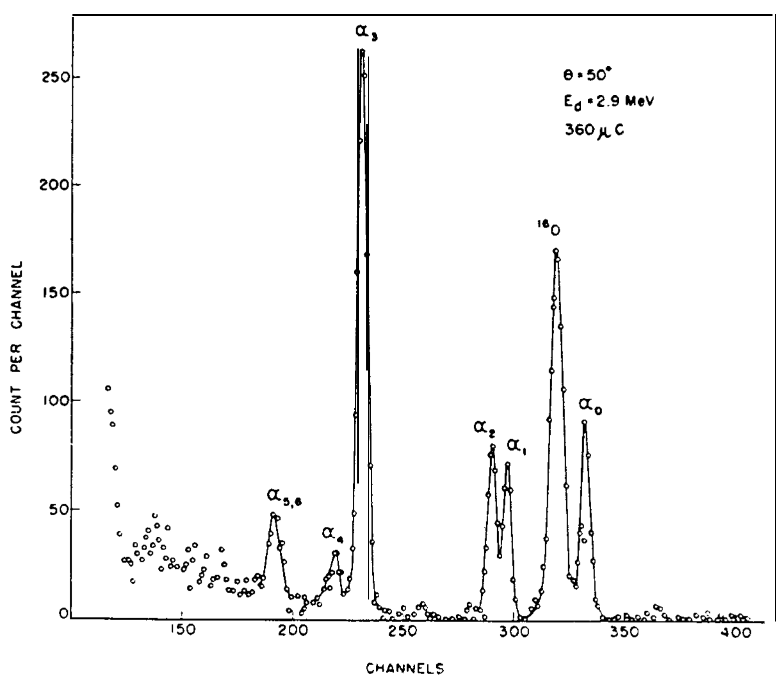

Fig. 5. Typical a-particle spectrum for the $^{26}Mg(d, \alpha)^{24}Na$ reaction at 2.90 MeV deuteron energy

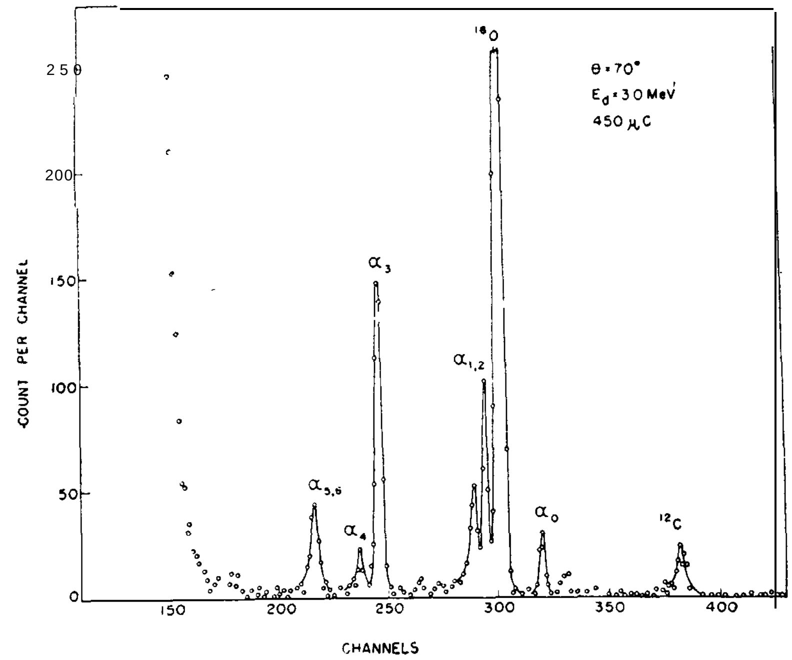

Fig. 6. Typical a-particle spectrum for the $^{26}Mg(d,\alpha)^{24}Na$ aeaction at 3.00 MeV deuteron energy

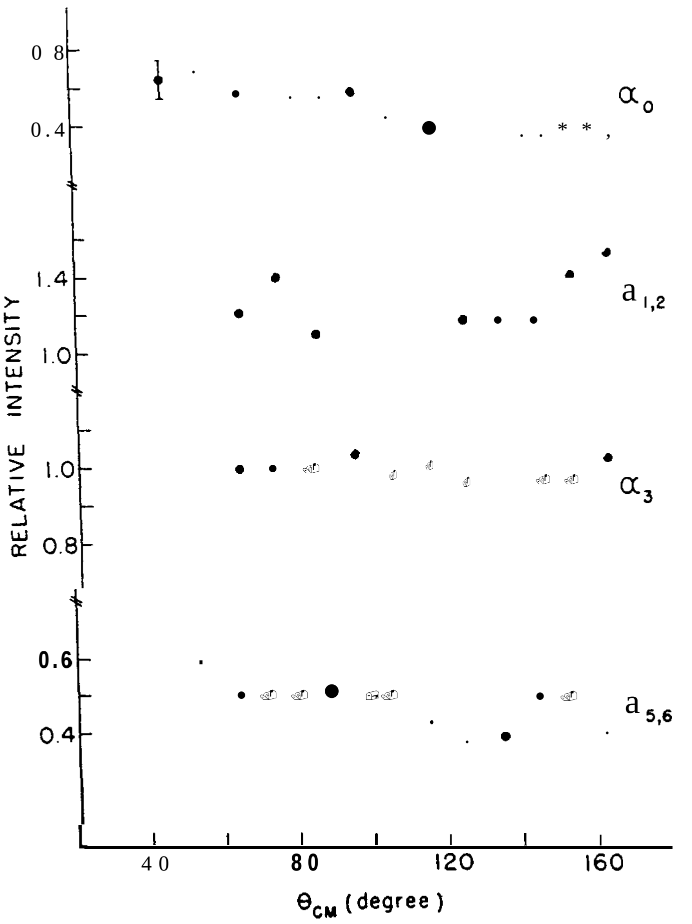

Fig. 7. Angular distributions of a-particles from the $^{26}Mg(d,\alpha)^{24}Na$ reaction averaged over five deuteron energies 2.5, 2.7, 2.8, 2.9 and 3.0 MeV. The error bar indicates the statistics error.

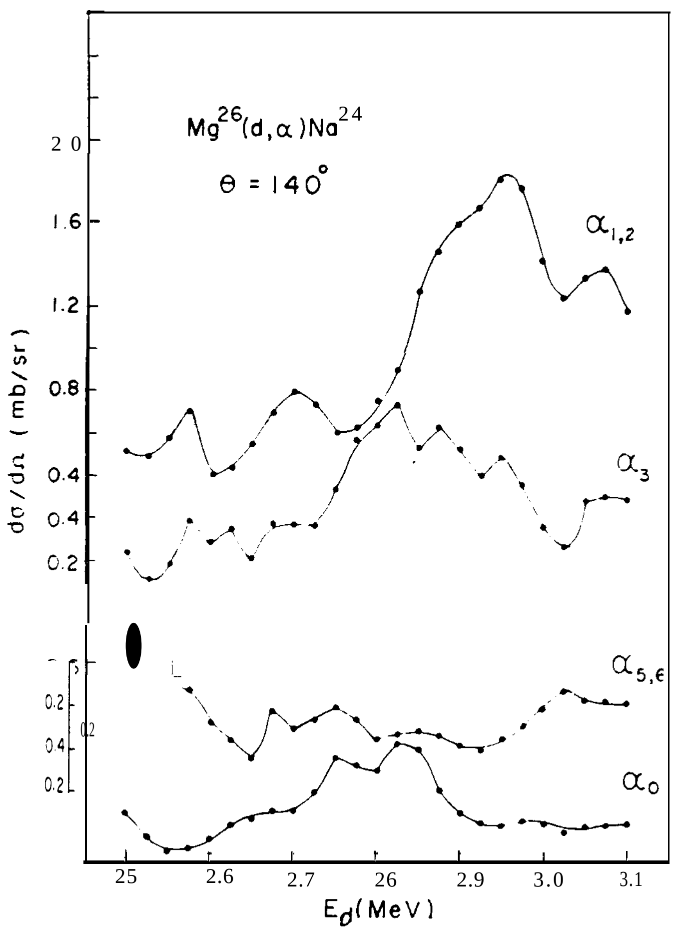

Fig. 8. Excitation functions of the a-paticle groups from the $^{26}Mg(d, \alpha)^{24}Na$ reaction at angle 140" lab

excitation functions show more or less marked fluctuations with energy. This behavior has been observed in the previously investigated $^{24}Mg(d, a)^{22}Na$ reaction " '), where a compound nucleus formation was found to be responsible for the reaction process.

Verification of the 2I+1 rule has been previously discussed for several (*d*, a) reactions[11,12]. A large amount of data has been accumulated on the (*d*, *a*) reaction on odd-A nuclei. It has been shown that the deviation from proportionality for the high spin values of the final nucleus is attributed to the insufficient energy of the deuterons and to the excitation of region of levels of the compound uncleus. It has been also shown that the cross section for high spin states are much depressed from the 2I+1 line. The ground state of ^{24}Na has a high spin value (I=4). The second and third excited states are known to have spin I=1 and 2, respectively. At higher excitation all spins of excited states are unknown. It is apparent that the $^{26}Mg(d, a)^{24}Na$ reaction is not favorable for an examination of the 2I+1 rule. From present data, it is not possible to draw some information and get suggestion on the spin of the excited states of ^{24}Na.

Finally we note that the isotropic angular distributions and the fluctuations of the excitation functions, and the analogy with the $^{24}Mg(d,\alpha)^{22}Na$ reaction investigated" "' previously allow us to conclude that the $^{26}Mg(d,$ a) ^{24}Na reaction in the investigated region of deuteron energies proceeds via a compound nucleus. In order to extract more information from experimental data, a detailed investigation of the $^{26}Mg(d,$ a) ^{24}Na reaction would be required.

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