Resonances in $^{12}C(^{18}O,\alpha)^{26}Mg$

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An excitation function for the reaction $^{12}C(^{18}O,\alpha)^{26}Mg$ was measured at $\vartheta=7°$ (lab) in the energy range 10–15 MeV (c.m.). Resonancelike structures are observed for the ground state at $E=11.5$, 12.8, and 14.3 MeV (c.m.). For the summed group of states $E_x=0.00$–5.71 MeV, structures are correlated with the ground-state excitation function and, to some extent, with $^{12}C(^{18}O,^{18}O(2^+))^{12}C$ inelastic-scattering data. Angular distributions have been measured in the energy range $E_{c.m.}=10.8$–12.2 MeV. An angular distribution for the ground state at $E_{c.m.}=11.6$ MeV is dominated by $l=10$. Legendre polynomial expansion coefficients for $E_{c.m.}=10.8$–12.2 MeV are presented.

Excitation functions for the α channel in the systems $^{12}C+{}^{12}C$ and $^{12}C+{}^{16}O$ have been measured in detail[1,2] and show correlated intermediate resonance structures for many states of the residual nuclei ^{20}Ne and ^{24}Mg, respectively. Dramatic resonances dominated by partial waves greater than the grazing partial wave have been observed in the $^{12}C(^{16}O,\alpha)^{24}Mg$ reaction in the energy range $E_{c.m.}=9$–15 MeV.[3] This motivated us to investigate the $^{12}C(^{18}O,\alpha)^{26}Mg$ reaction in the same energy region. The nucleus ^{18}O, of course, has the same Z as ^{16}O and likewise has a 0^+ ground state, but has two extra neutrons. The Q value for the ^{16}O reaction is 6.8 MeV, while that of the ^{18}O reaction is 13.0 MeV. Thus, the α particle can carry away more angular momentum from the ^{18}O reaction than for the same center-of-mass energy in the ^{16}O reaction. The ratio of the number of open channels for the ^{18}O reaction to the ^{16}O reaction is about 100 in this energy region.[4] Thus, we expected the cross section to be reduced in the ^{18}O case, in both the resonant and nonresonant contributions. However, we might expect the resonant to nonresonant ratio to be similar to that for $^{12}C(^{16}O,\alpha)^{24}Mg$. Intermediate structure has been observed in $^{12}C+{}^{18}O$ elastic scattering at back angles in the range $E_{c.m.}=15$–25 MeV, with angular distributions dominated by odd partial waves.[5] However, little or no correlation is seen in the α and ^{8}Be channels at these energies.[6] No structure was observed in the elastic scattering below 15 MeV.[7] We have investigated the $^{12}C(^{18}O,\alpha)^{26}Mg$ reaction in the energy range $E_{c.m.}=10$–15 MeV.

Data were taken using the University of Pennsylvania Universal Negative Ion Source (UNIS) for the ^{18}O beam, accelerated through the FN tandem Van de Graaff accelerator. The targets were self-supporting foils of isotopically enriched (99.99%) ^{12}C of areal density 30 $\mu g/cm^2$ [100 keV (c.m.)], positioned at an angle of 45° with respect to the beam. Nickel absorbers were used to stop the elastically-scattered ^{18}O ions.

An excitation function for the energy range 10–15 MeV (c.m.) was measured at $\vartheta=6.3°$ (lab). A graph of the differential cross section $d\sigma/d\Omega$(lab) vs energy (c.m.) is shown in Fig. 1. The cross section is, in fact, greatly reduced from that of the $^{12}C+{}^{16}O$ reaction. The ground-state excitation function clearly exhibits three resonancelike structures at $E_{c.m.}=11.5$, 12.8, and 14.3 MeV, with a full width at half maximum (FWHM) of approximately 500 keV (c.m.) for each. Cross sections leading to final states with $E_x=0.00$–5.71 MeV were summed for this energy region. These results are also shown in Fig. 1. The peaks in this excitation function are somewhat correlated with those for the ground state; there is strong correlation at 11.5 and 12.8 MeV, but less so near 14.3 MeV. This was a preliminary investigation into the possibility of intermediate structure in this energy region, and the results were encouraging. Inelastic scattering data have been measured for the $^{12}C+{}^{18}O$ system for energies from 10.0 to 23.6 MeV (c.m.).[8] Periodic structures were observed in the ^{18}O (2^+) yield. Those results, along with our summed excitation function, are shown in Fig. 2. The presence of structure in this channel was a further encouraging sign.

Angular distributions were measured at many energies in the range $E_{c.m.}=10.8$–12.2 MeV to investigate in de-

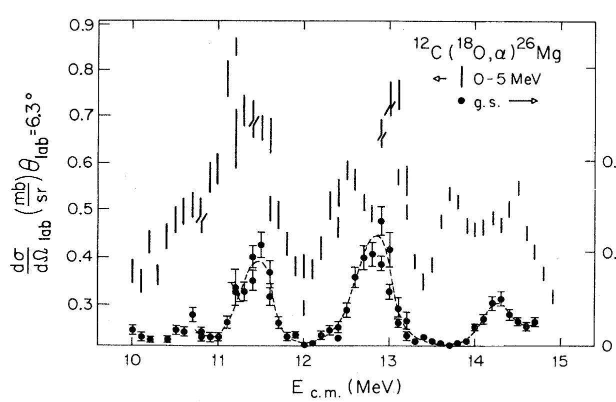

FIG. 1. Excitation function for $^{12}C(^{18}O,\alpha)^{26}Mg$ for the ground state and summed group of states 0.0–5.7 MeV.

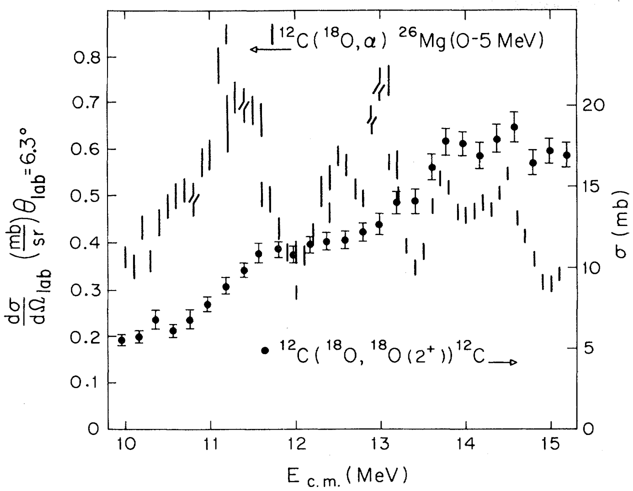

FIG. 2. Excitation function for the summed group from Fig. 1 along with $^{12}C(^{18}O,{}^{18}O(2^+))^{12}C$ inelastic-scattering data of Freeman and Haas (Ref. 8).

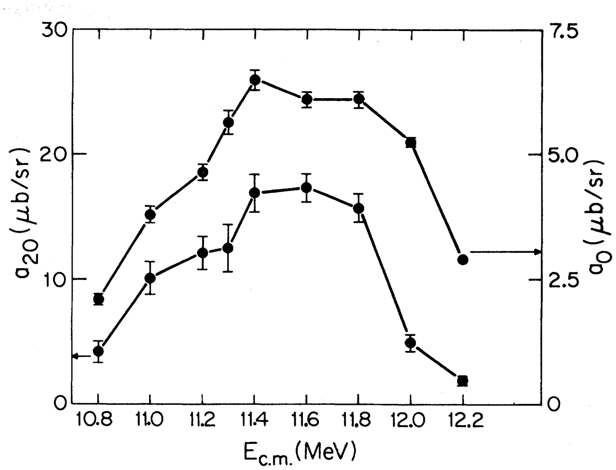

FIG. 4. Legendre polynomial expansion coefficients a_0 and a_{20} as a function of energy (c.m.).

tail the dependence of differential cross section on angle and energy over the lowest of the three resonances shown in Fig. 1. For these measurements, a 50-slice position-sensitive detector[9] was used at forward angles, and a ΔE-E telescope consisting of a gas ΔE detector[9] and a 25-slice E detector was used at backward angles. The small cross section of this reaction necessitated the use of these large-solid-angle detectors to measure angular distributions, while proton interference at back angles required the use of the ΔE detector for particle identification. An angular distribution requires 12—24 h for completion with these detectors; with some other experimental setup, such as an array of single detectors, the same amount of data would have required tenfold the time. Clearly, without these detectors, this investigation would not have been possible. An angular distribution for the ground state at 11.6 MeV, near the peak of the resonance, is displayed in Fig. 3. The solid curve is a fit of the form

$$\sigma(\vartheta)=\sum_{l=0}^{L} a_l P_l(\cos\vartheta) ,$$

with $L=22$. The dashed curve is $P_{10}^2(\cos\vartheta)$. Clearly, the angular distribution is dominated by $l=10$. Figure 4 shows the expansion coefficients a_0 and a_{20} as a function of energy. The total cross section is $4\pi a_0$, and a_{20} is related to the contribution to the total cross section of the $l=10$ partial wave. It is remarkable how closely the two curves follow each other. The coefficients for $0<l<20$ all exhibit a similar energy dependence, with an enhancement at or near 11.6 MeV. Figure 5 shows how the goodness of the fit for 11.6 MeV changes with L, the maximum l value used. It is clear that $L=22$ is sufficient at this energy, and indeed it was sufficient for all energies in the range $E_{c.m.}=10.8$—12.2 MeV.

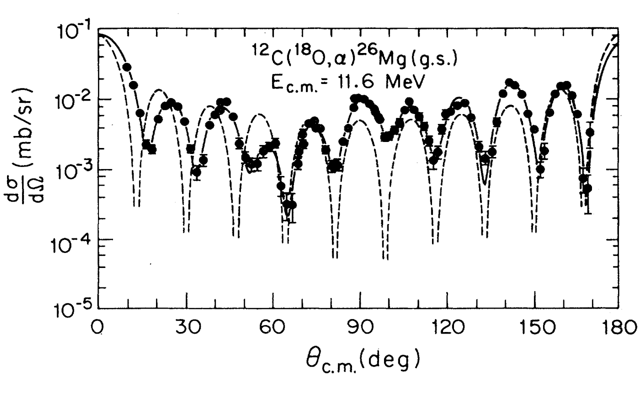

FIG. 3. Angular distribution for $^{12}C(^{18}O,\alpha)^{26}Mg$(g.s.), compared with P_l fit up to $l=22$ (solid curve) and a pure $P_{10}^2(\cos\vartheta)$ (dashed curve).

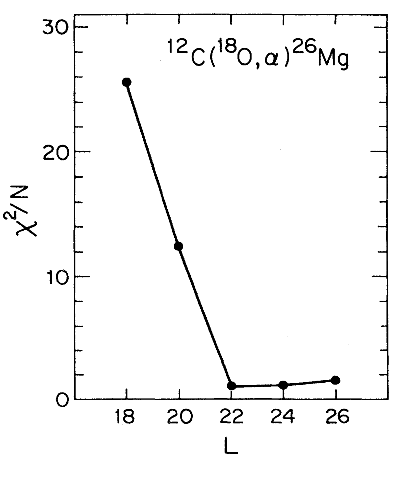

FIG. 5. Plot of χ^2/N vs L, where N is the number of degrees of freedom and L is the upper limit of the Legendre polynomial expansion used to fit the data of Fig. 3.

It appears that we are observing a 10^+ resonance in ^{30}Si. The grazing partial wave in the incident $^{12}C+{}^{18}O$ channel is about 8 calculated from a Yale-type optical model potential[10] and about 10 from the Seattle potential.[6] However, because of the large positive Q value for the $\alpha+{}^{26}$Mg final channel, the outgoing grazing partial wave is about 12. It is probably this feature that allows a 10^+ resonance to be observed.

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