Comment on $^{12}C(^{12}C,\alpha)^{20}Ne$ Excitation Functions*

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The excitation function for the $^{12}C(^{12}C,\alpha)^{20}Ne$ reaction leading to the 2^+ state at 7.83 MeV possesses oscillations similar in width to those observed for the low-lying states. For the 7.83-MeV state, the oscillations are considerably damped in magnitude and are superimposed on a large underlying cross section that varies much more slowly with energy.

In a recent study[1] of the $^{12}C(^{12}C,\alpha)^{20}Ne$ reaction, certain states were observed to be selectively populated. These included the 0^+ state at 7.20 MeV and the 2^+ state at 7.83 MeV. Angular distributions for those states were similar to what one might expect for a direct mechanism. On the other hand, excitation functions showed strong oscillations. Exhaustive studies of angular distributions and excitation functions for the reaction $^{12}C(^{12}C,\alpha)^{20}Ne$ leading to the low-lying states of ^{20}Ne had been performed previously.[2] Those data were successfully interpreted in terms of a compound-nucleus reaction mechanism. The question naturally arises: Are the excitation functions for the selectively populated states qualitatively different from those of the low-lying states?

Previous data[1,3] indicated that there were qualitative differences, e.g., the prominent structure in the excitation function measured for the 7.83-MeV state appeared to be much broader than that measured for the low-lying states. These results, however, were not conclusive, since data[1,3] were taken only in 500-keV (lab) steps. We have investigated the excitation function for this state in smaller steps [50 keV (lab)], in order to make a direct comparison with the low-lying states.

In Ref. 1, the most prominent structure in the excitation function for the 7.83-MeV state was a relatively broad peak near 26.5-MeV bombarding energy. This peak appeared to have a width of about 2 MeV, whereas the structure observed earlier[2] for the low-lying states was about 100–200 keV in width. We have measured excitation functions in the bombarding energy range 25–27 MeV in 50-keV steps for the 7.83-MeV 2^+ state and for the low-lying states.

The data were obtained with the $^{12}C^{4+}$ beam from the University of Pennsylvania tandem. Targets were 7-$\mu g/cm^2$ self-supporting foils of isotopically enriched (99.99%) ^{12}C. This thickness corresponds to an energy loss of ~30 keV for 25-MeV ^{12}C ions. Outgoing α particles were detected in a Si surface-barrier detector of depletion depth 1000 μ. A Ta foil placed in front of the detector stopped the ^{12}C ions without seriously affecting the energy resolution for the α particles. Tests for carbon buildup during the course of the experiment were made by frequent measurements of repeat points. A small buildup was observed and has been corrected for.

An α-particle spectrum obtained at a bombarding energy of 25.0 MeV and a lab angle of 20° is displayed in Fig. 1. Particle groups of interest are those leading to the 0^+ ground state (g.s.), the 2^+ 1.63-MeV, 4^+ 4.25-MeV, 2^- 4.97-MeV, and 2^+ 7.83-MeV states.

Excitation functions measured at 20° (lab) for those states are displayed in Fig. 2. Also displayed are the earlier data[3] for the 7.83-MeV state measured at $\theta(\text{lab})=18.75°$, in 500 keV steps. The general features of the present data are similar to those previously[2] measured for the ground and 1.63-MeV states. Rapid oscillations are observed, with peak-to-valley ratios of 10 : 1, and widths of ~250 keV. Structure of similar width is observed in the data for the 7.83-MeV state, but the peak-to-valley ratios are considerably smaller.

The average cross section measured in this energy interval for the 7.83-MeV state is 9.1 mb/sr, whereas for the 1.63-MeV 2^+ state, the average

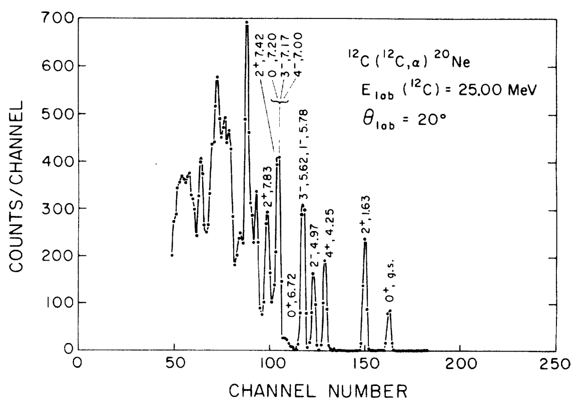

FIG. 1. α spectrum obtained at 20° for the $^{12}C(^{12}C,\alpha)^{20}Ne$ reaction at 25.0 MeV.

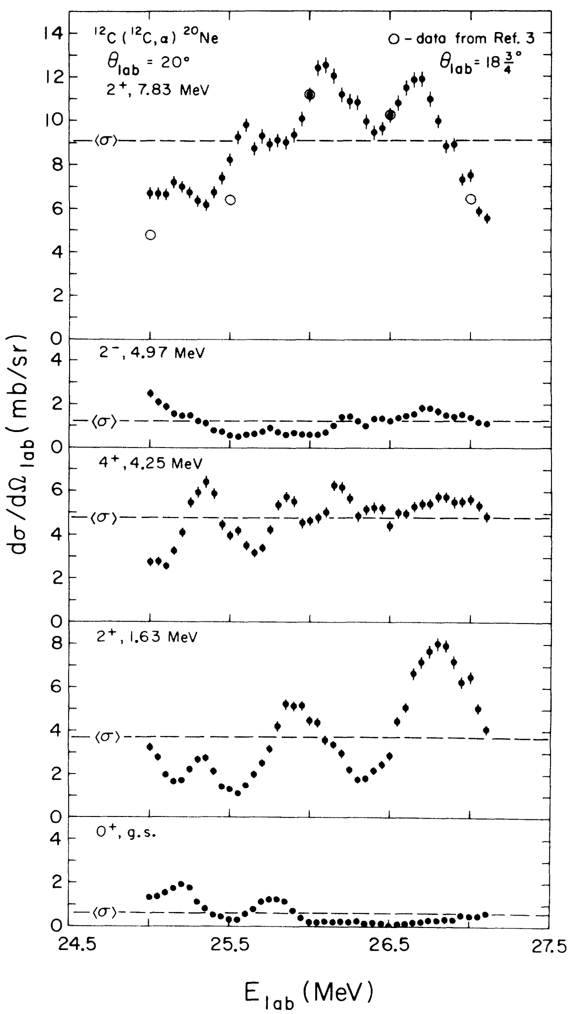

FIG. 2. Excitation functions measured at 20° (lab) for the $^{12}C(^{12}C,\alpha)^{20}Ne$ reaction at low-lying states.

cross section is only 3.7 mb/sr. Calculations[4] based on a purely statistical process predict that the 7.83-MeV 2^+ state will be only $\frac{1}{4}$ as strong as the 1.63-MeV 2^+ state.

It thus appears that the rapid oscillations observed for the low-lying states is also present in the 7.83-MeV data. However, for the 7.83-MeV state, these oscillations appear to be superimposed on a large background having a width much larger than that of the rapid oscillations. There is no indication of such an underlying background for the low-lying states – neither in the present data nor in the much more exhaustive data of Ref. 2.

The excitation function data for the 7.83-MeV state is thus qualitatively different from that of the other states. What, then, is the reaction mechanism responsible for population of the 7.83-MeV state? It was suggested in Ref. 1 that a large direct component was present, in which two α particles were transferred to the ^{12}C target, and thus that the 7.83-MeV state had a large parentage of a ^{12}C core plus two α particles.

Noble[5] has calculated the excitation functions expected from such a reaction. He finds that inclusion of the momentum transfer dependence at both vertices ($^{12}C \rightarrow$ "^{8}Be" $+ \alpha$ and $^{12}C +$ "^{8}Be" $\rightarrow {}^{20}Ne$) produces oscillations in the excitation functions with a width of a few MeV. It thus appears that, at least for the 7.83-MeV state, the data are consistent with the presence of such a reaction mechanism, but with the usual compound-nucleus oscillations superimposed on this direct background. Measurements to further elucidate the $^{12}C(^{12}C,\alpha)$-^{20}Ne reaction mechanism are underway at this laboratory.

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