SHORT COMMUNICATIONS

INELASTIC SCATTERING OF PROTONS ON ^{12}C†

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During the recent Variable Energy Cyclotron experiment involving the elastic scattering of protons on ^{12}C, the complete energy spectrum of the scattered protons was obtained by means of a 100-channel analyser (McKenna, Baxter, and Shute 1961, henceforth referred to as I). Two prominent peaks were obtained: the higher energy one corresponding to elastic scattering and the lower energy one to inelastic scattering with the residual carbon nucleus being left in its first excited state, 4·43 MeV. In I the elastic scattering results were reported briefly. The purpose of this short communication is to discuss the main features of the inelastic scattering.

Angular distributions for this inelastic process have been determined at approximately 5° intervals, between 170° and 25° scattering angles, over the energy range $11\frac{1}{2}$–8 MeV in 100 keV steps. Moreover, complete angular distributions were made, in 25 keV steps, over the known resonance region at 9·2 MeV, while runs at nine preferred angles, with 40 keV spacing, were later made over the 7·6, 8·2, and 10·5 MeV resonance regions. Below 8 MeV only fragmentary angular distributions were obtained. This was due to the low energy of the inelastic peak, especially at backward angles, which prevented correct reproduction by the kick-sorter. From 8 to 7 MeV, angular distributions were obtained only for angles less than 100°. Below 7 MeV no useful data were obtained, both because of the low proton energy at all angles, and because the inelastic cross section had become too small for the peak to be observed above the background.

None of the angular distributions exhibit any information between 55° and 25°. This is due to the masking of the inelastic peak, at these angles, by protons elastically scattered from the hydrogen content of the polythene target. This process has a relatively high cross section, and the energy of the scattered proton is a $\cos^2$ function of the detection angle. In order to keep the analyser counting rate low without using excessively small beam currents, the display of the non-elastic region was biased out; thus only elastic distributions are available between these angles. However, at 25° a separate run was made, using a reduced beam and no analyser bias, so that inelastic scattering information is available at this angle. This 25° point is of low accuracy ($\simeq$10%), due to poor statistics and high dead-time counting losses, but was persisted with because information at this forward angle is of assistance in judging the possible direct interaction contribution to the inelastic scattering process.

† Manuscript received May 4, 1961.

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In estimating the differential cross section from the spectrum displayed on the analyser, the background contribution of elastically scattered protons under the inelastic peak was allowed for. This reached a maximum value of 10% when there was a very large elastic cross section without a correspondingly large inelastic cross section. This elastic " tail ", due to slit scattering, inelastic reactions in the scintillator, etc., is discussed by the Minnesota group (Stovall and Lee 1960).

Some of the angular distributions obtained are shown in Figure 1. Figure 1 (*a*) shows a rapid variation as the 9·2 MeV resonance is crossed. Figure 1 (*b*) shows the complete change of shape that occurs between 10·67 and 10·37 MeV, indicating the complexity of the level structure in this region.

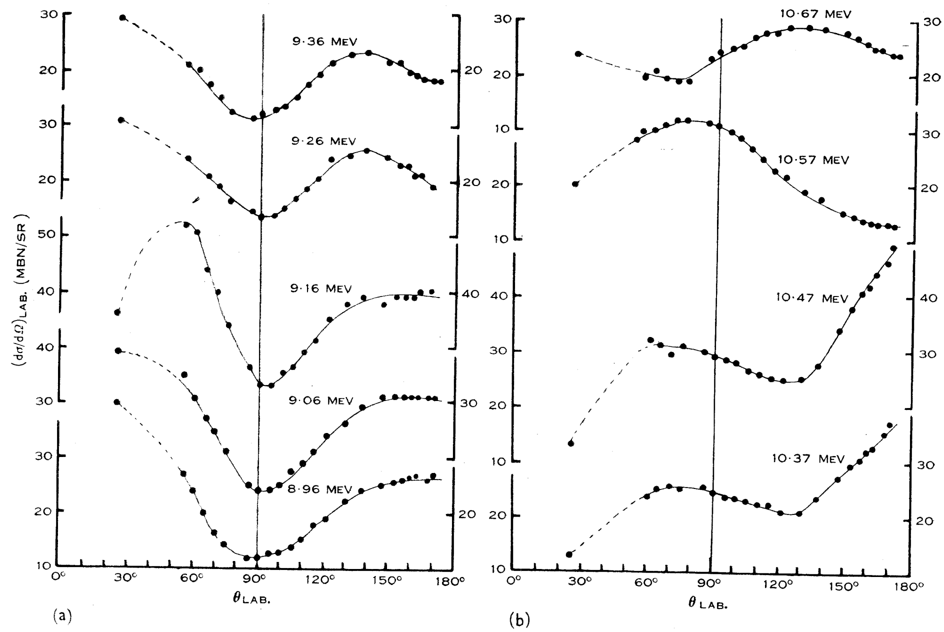

Fig. 1.—Angular distributions for $^{12}C(p,p')^{12}C^*$ 4·43 MeV, (*a*) in the region of 9·2 MeV incident proton energy ; (*b*) in the region of 10·5 MeV incident proton energy. The smooth line indicates the trend of the experimental points. Relative accuracy of points : ±2% ; absolute value of differential cross section : ±10%. All units in the laboratory system.

The behaviour of the cross section at fixed scattering angles for differing incident energies is obtainable from the above data. These excitation functions show resonance structure at energies corresponding to the recently discovered levels in ^{13}N discussed in I. Similar resonances have also been observed when the de-excitation gamma ray is detected in coincidence with the inelastic proton (Adams *et al.* 1960).

Some of the excitation functions obtained are shown in Figure 2, for scattering angles of 65°, 85·3°, 137·6°, and 168°. In all cases differential cross section, angle, and incident energy are given in the laboratory system. The 7·6, 8·2, and 9·2 MeV resonances are clearly indicated; between 10 and 11 MeV there appear to be at least 3 resonances, namely, 10·3, 10·5, and 11·0 MeV.

These inelastic scattering results are presented here in order to confirm the resonance structure reported in I. This additional information will be of assistance in the analysis of the elastic scattering, which is proceeding by means of a tentative two-channel multilevel type analysis.

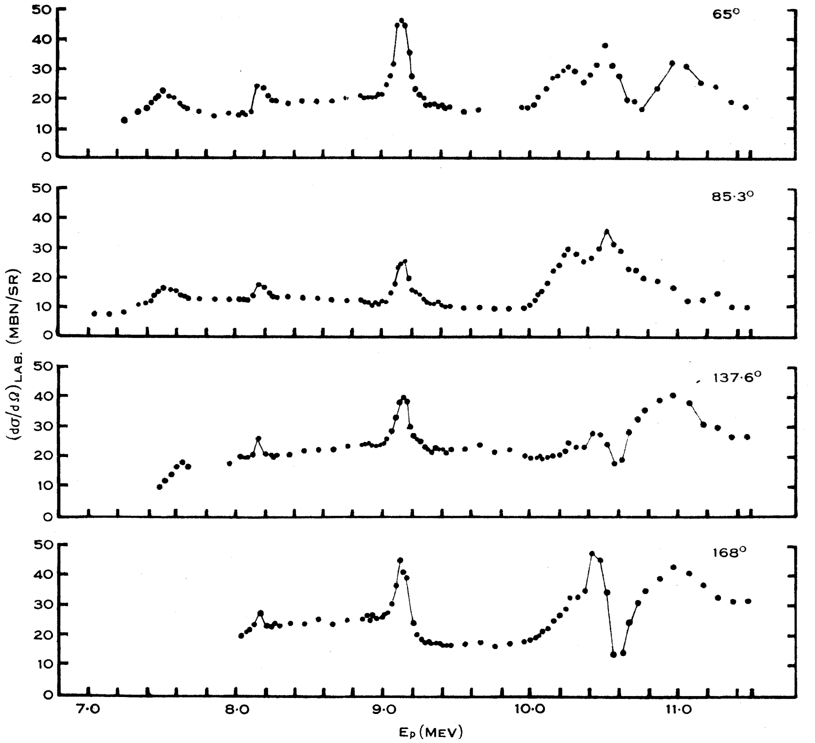

Fig. 2.—$^{12}C(p,p')^{12}C^*$ 4·43 MeV: differential cross section *v.* bombarding energy at four representative angles, showing resonance structure at 7·6, 8·2, 9·2, 10·3, 10·5, and 11·0 MeV. Absolute value of cross sections accurate to $\pm 10\%$. All units in the laboratory system.

As in I, we acknowledge the assistance of the cyclotron group, led by Professor Caro.

Note added in Proof

The preliminary phase shift analysis which we have carried out on the elastic data below 8 MeV, confirms that the 5·38 MeV resonance in ^{13}N is $3/2^+$, $\Gamma \simeq 110$ keV. It shows, moreover, that the broad resonance at $6\frac{1}{2}$ MeV is also $3/2^+$, $\Gamma \simeq 2$ MeV. Confirmation of these assigned j^π values has been given in a personal communication from the Wisconsin group where analysis of polarization measurements produced similar level parameters.

In a recent article (INS34), Okai and Tamura of the Institute of Nuclear Study, Tokyo, indicate that the 8·2 MeV resonance, as seen in our elastic and inelastic data, could be due to an F-wave contribution on the grounds of the strong coupling between the competing elastic and inelastic channels. Phase contributions up to $l=3$ have been included in our analysis scheme, but as yet there is no confirmation of this possible assignment at $8 \cdot 2$ MeV.

We wish to thank Drs. W. Haeberli and S. Okai for the communications referred to here.

References

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