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Proton-induced Reactions with ^{9}Be Between 6·5 and 9·5 MeV

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Abstract

Excitation functions for the reactions ^{9}Be(p, p$_0$)^{9}Be, ^{9}Be(p, p$_2$)^{9}Be*(2·43 MeV), ^{9}Be(p, d$_0$)^{8}Be and ^{9}Be(p, α_0)^{6}Li have been measured at 60°, 105° and 140°. With the exception of a resonance observed in the elastic scattering channel at 6·5 MeV, no resonant structure was found in any excitation function.

Introduction

In a previous paper (Hudson *et al.* 1972) angular distribution measurements of the ^{9}Be(p, d$_0$)^{8}Be reaction were reported for proton energies between 5 and 11 MeV, together with an analysis employing both the DWBA theory (Tobocman 1954) and the BHMM theory of stripping reactions (Butler *et al.* 1967). The fitting quality of these theories was measured by two quantities, χ^2 the parameter usually calculated by searching optical model codes, and χ_p^2 which weights the larger cross sections of the stripping peak (Hudson *et al.* 1972), where spectroscopic factors are usually determined. For all parameter sets used (Hudson *et al.* 1972), a peak occurred in the values of χ^2, but not χ_p^2, near a proton energy of 8 MeV (Fig. 1), indicating that the phenomenon producing the variation was located at backward angles. This is just the region where compound nucleus reactions will have their greatest effect, since the direct reaction component is relatively smaller there.

For resonances in ^{10}B (formed in a compound nucleus type reaction), the cross section σ_{pd} for the ^{9}Be(p, d$_0$)^{8}Be reaction is related to the partial widths by

$$\sigma_{pd} \propto \Gamma_p \Gamma_d . \qquad (1)$$

Thus a resonance in the (p, d) reaction should appear in the (p, p$_0$), (p, p$_1$), (p, α) and similar reactions, unless Γ_p is only a small component of the total width Γ. In this event Γ_d will be dominant, and the resonance should be observed mainly in the (p, d) reaction.

Bingham *et al.* (1964) have reported a broad resonance in the total cross section of the ^{9}Be(p,p$_2$)^{9}Be*(2·43 MeV) reaction near 8 MeV incident proton energy (corresponding to about 14 MeV excitation in ^{10}B). Results from a study of the ^{11}B(p, d$_0$)^{10}B reaction by Bachelier *et al.* (1969) showed a level at about 14 MeV in ^{10}B, while a previous measurement of the ^{9}Be(p, d$_0$)^{8}Be differential cross section at 90° (lab.) by Blieden *et al.* (1963) indicated a change in trend in this region.

The above data, and the apparent inadequacy of direct reaction theories in predicting ^{9}Be(p, d$_0$)^{8}Be angular distribution shapes, appear to indicate a significant compound nucleus component in the reaction mechanism for bombarding energies near 8 MeV.

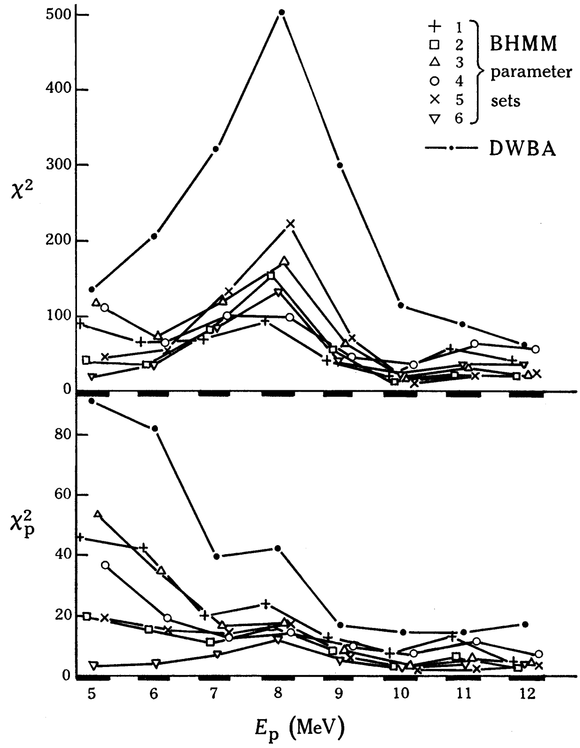

Fig. 1. Values of χ^2 and χ_p^2 obtained from BHMM and DWBA analyses of the ^{9}Be(p, d$_0$)^{8}Be reaction (from Hudson *et al.* 1972).

Experimental Method and Results

In the present experiment, measurements were made of the excitation functions for the reactions ^{9}Be(p, p$_0$)^{9}Be, ^{9}Be(p, p$_2$)^{9}Be*, ^{9}Be(p, d$_0$)^{8}Be and ^{9}Be(p, α_0)^{6}Li from 6·5 to 9·5 MeV proton incident energy at 60°, 105° and 140° (lab.) using the proton beam of the variable energy cyclotron at the Melbourne University. The experimental arrangement and particle identification system used have been reported elsewhere (Hudson 1970; Hudson *et al.* 1972).

The thickness of the self-supporting ^{9}Be target (which was supplied by Penn-Spectra Tech. Inc., Wallingford, Pennsylvania) was determined from the energy loss of α-particles passing through it (Hudson *et al.* 1972), and was checked for consistency by comparison of absolute cross section values from the ^{9}Be(p, d$_0$)^{8}Be reaction with those of Hudson (1970), Votava *et al.* (1971) and Hudson *et al.* (1972) at 9 MeV proton energy.

Results from the ^{9}Be(p, p$_0$)^{9}Be, ^{9}Be(p, d$_0$)^{8}Be and ^{9}Be(p, p$_2$)^{9}Be* reaction measurements at 105° and 140° are shown in Figs 2*a*, 2*b* and 2*c* respectively. The resonance reported by Votava *et al.* (1971) in the elastic scattering channel is evident near 6·5 MeV at both angles (Fig. 2*a*). No other statistically significant resonant behaviour was observed in this or any other channel studied. However, there is a distinct change in the trend of the 140° data from the (p, d_0) reaction near 8 MeV, whereas the 105° data show a steady decline (Fig. 2*b*).

The excitation function of the $^9Be(p, p_2)^9Be^*$ reaction (Fig. 2*c*) showed no resonance of the kind previously reported by Bingham *et al.* (1964). Differential cross section values hardly varied over the energy range studied. Angular distributions of both the $^9Be(p, p_0)^9Be$ and $^9Be(p, p_2)^9Be^*$ reactions from 30° to 140° at 7 MeV were consistently 15% larger than those of Bingham *et al.*, whereas data compared at 8 and 9 MeV gave agreement to within the quoted errors.

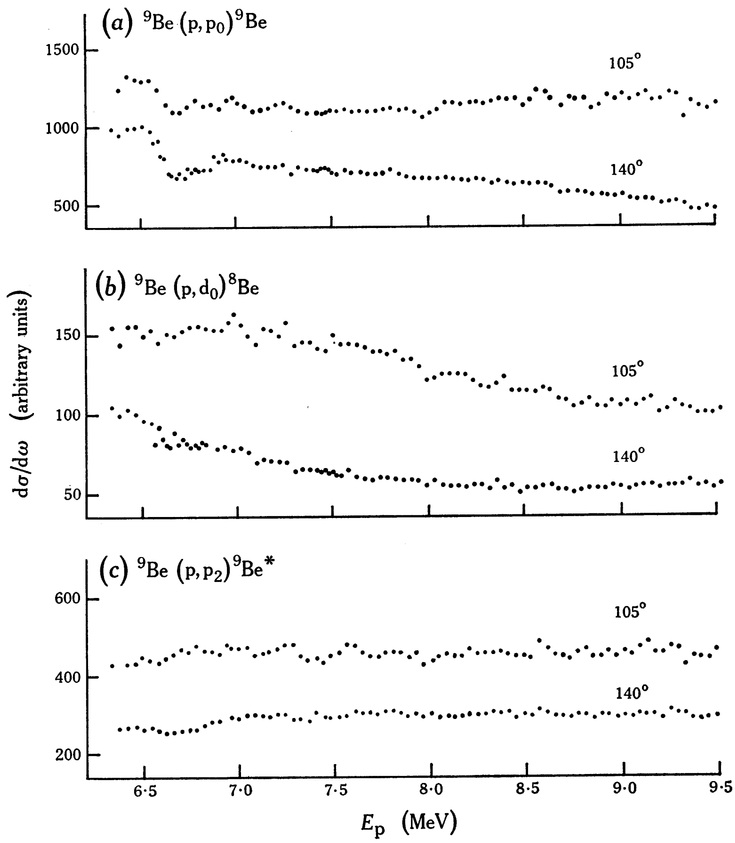

Fig. 2. Excitation functions for the $^9Be(p, p_0)^9Be$, $^9Be(p, d_0)^8Be$ and $^9Be(p, p_2)^9Be^*$ (2·43 MeV) reactions at laboratory angles of 105° and 140°.

Conclusions

Three conclusions may be drawn from this work:

Firstly, increased χ^2 values from both DWBA and BHMM predictions of cross sections for the $^9Be(p, d_0)^8Be$ reaction near 8 MeV incident proton energy, appear to be due to (unexplained) cross section changes at backward angles, rather than to any conventional resonance behaviour.

Secondly, the existence of a resonance in the $^9Be(p,p_0)^9Be$ reaction at about 6·5 MeV proton energy, previously reported by Votava *et al.* (1971), has been confirmed.

Finally, the 'resonance' reported by Bingham *et al.* (1964) in the $^9Be(p,p_2)^9Be^*$ (2·43 MeV) reaction at 8 MeV has been shown to be due to a cross section normalization error, possibly caused by incorrect determination of the thickness of the target used by these authors at 7 MeV incident proton energy.

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