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QUASI-ELASTIC INTERACTION OF 155-Mev PROTONS WITH PROTONS IN Li^6 AND Li^7

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We have studied the reactions $Li^6(p,2p)He^5$ and $Li^7(p,2p)He^6$ by detecting the product protons in coincidence. The 155-Mev proton beam of the Orsay synchrocyclotron had a 10-20% duty cycle.[1] The experimental apparatus has been used for a similar study in carbon.[2] It consists of two telescopes, each with (1) two plastic scintillation counters to define the scattered beams and (2) one NaI counter to measure the energy of each product proton. The two telescopes are used to study the angular distribution of two protons emitted in coincidence in a plane which includes the incident beam and at angles θ_1 and θ_2 with the incident beam and arranged symmetrically around it. The angular resolution in the scattering plane is ±2.5°. At each angle, the summed energy of the two coincident protons is displayed on a pulse-height analyzer when the energy of one of the two protons lies between 62 and 82 Mev for Li^6 and 60 and 80 Mev for Li^7. This limits the events studied to an energy ratio, $x^2=E_1/E_2$, of $0.7<x^2<1.0$ for low-binding-energy protons and $0.6<x^2<1.0$ for high-binding-energy protons. The energy calibration is carried out with free p-p scattering events from a CH_2 target. The targets were prepared from material supplied by Oak Ridge National Laboratory and had a purity of 95.6% (Li^6) and 99.9% (Li^7).

The summed energy spectra at $\theta_1=\theta_2=40°$ displayed in Fig. 1 are typical. Two peaks are observed for each target, corresponding to binding energies of the target proton of 23.5 ± 0.7 Mev and 10.0 ± 1.4 Mev for Li^7 and 20.0 ± 0.7 Mev and 4 ± 1.4 Mev for Li^6.[3] The position and width of the low-binding-energy peaks correspond to the residual nuclei He^6 and He^5 being left in their ground state, although excitation of the 1.71-Mev level[4] in He^6 cannot be excluded. The binding energies involved

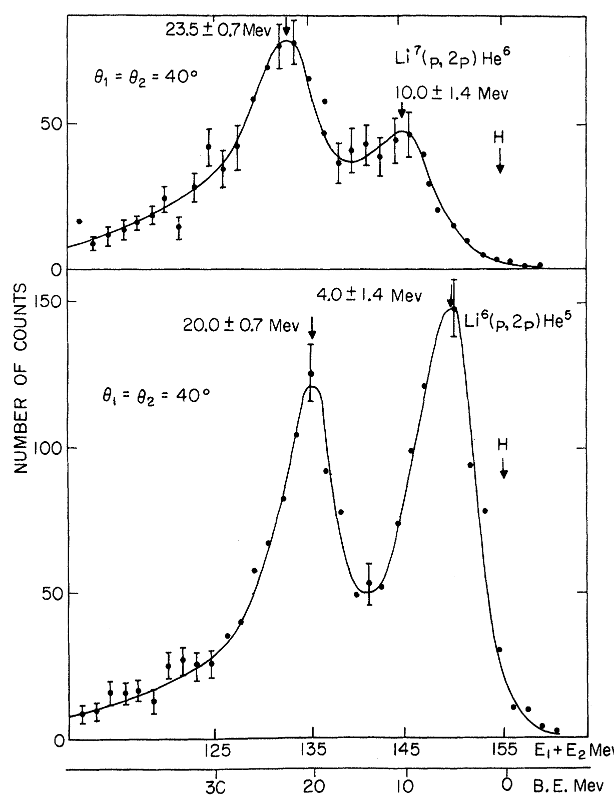

FIG. 1. Summed energy spectra of Li^6 and Li^7 at $\theta_1=\theta_2=40°$. The abscissa also indicates the binding energy of the target protons.

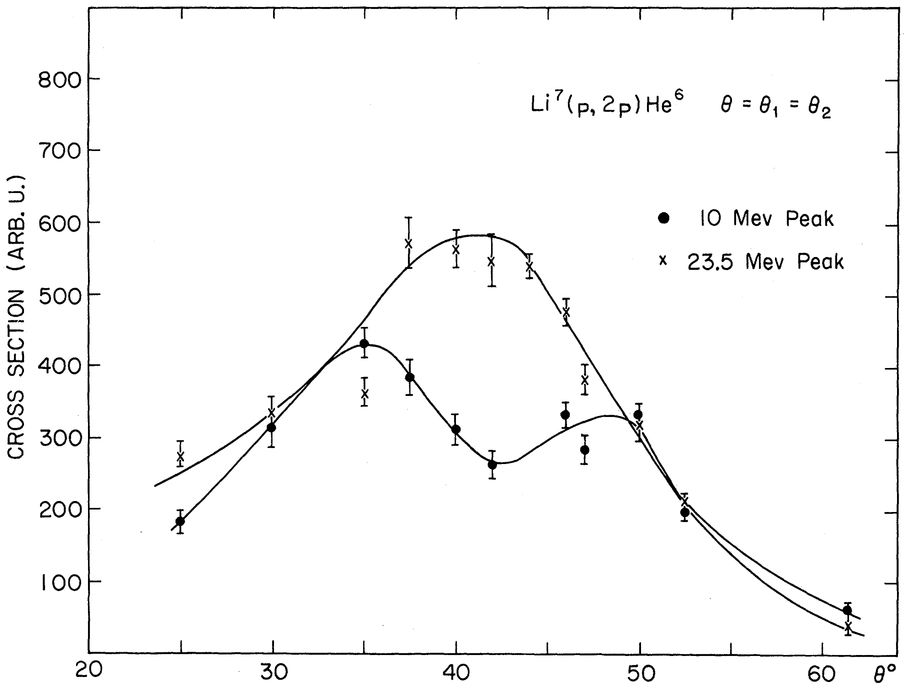

FIG. 2. Angular correlation distributions for Li^7.

suggest that the higher binding energy peaks are produced by the interaction of the incident protons with "inner core" protons in the target nuclei while the lower binding energy peaks are produced by the interaction with "outer shell" protons. This conclusion is based on the fact that the interaction time in the $(p, 2p)$ reaction is much smaller than the rearrangement time of the residual nucleus. Even for the ground state of He^5, these two times differ by a factor of 30 as calculated from the level width of 0.5 Mev reported in reference 4. The binding energies for the inner core protons are similar to those for He^4.

We have obtained angular correlation distributions from energy spectra measured at several angles $\theta = \theta_1 = \theta_2$ by integrating the number of events observed in a fixed summed energy interval of 15 Mev centered around each peak. For the higher binding energy protons this method yields only an upper limit to the cross section at small and large angles ($\theta < 30°$, $\theta > 50°$) since the corresponding peaks ride on a continuum which becomes appreciable. The results are presented in Figs. 2 and 3. The cross-section scale is in arbitrary units, but the same units are used for all curves. The errors shown are of statistical origin. The results for Li^7 are in agreement with previous studies[5] with ordinary targets in the regions where comparison is possible.

The angular correlation distributions for Li^7 (Fig. 2) have characteristic features previously observed with C^{12}.[2,5,6] The high-binding-energy peak has a maximum at about 41° as expected for s-shell protons, and the low-binding-energy peak has a minimum at about 42°, characteristic of p-shell protons. At small and large angles the cross sections fall off much more rapidly than for C^{12}. On the usual Born approximation interpretation, this observation means that the wave functions of the target protons in Li^7 have fewer high-momentum components than in C^{12}. The same conclusion has been reached from a study of the energy-sharing[7] in the same reaction.

The angular correlation distribution for the high-binding-energy protons in Li^6 (Fig. 3) is very similar to that of the corresponding protons in Li^7; the 23% difference in peak cross section can be explained by the difference in absorption. However, the angular correlation distributions of the low-binding-energy protons in Li^6 and Li^7 are very different, that for Li^6 being instead very similar to that of the high-binding-energy protons. The observation of the narrow peaks in the summed energy spectrum suggests that this difference is not the result of the difference in lifetime of the residual nuclei but rather due to differences in the properties of the low-binding-energy proton in Li^6 and Li^7. Using the impulse approximation interpretation, the wave function of the low-binding-energy proton in Li^6

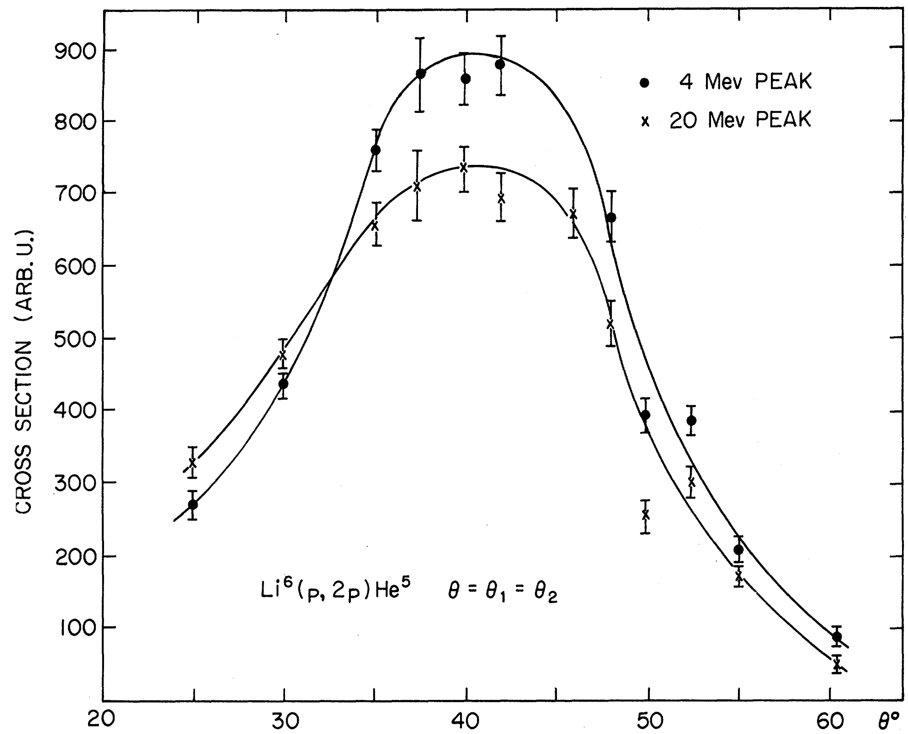

FIG. 3. Angular correlation distributions for Li^6.

contains many more low-momentum components than the corresponding proton in Li^7. In fact our Li^6 distribution is consistent with an s-proton interpretation, but we do not know whether a p proton with important low-momentum components might not yield a similar distribution.

The observed dip at about 41° in the angular correlation distribution for the low-binding-energy protons in Li^7 indicates that these protons have a pronounced minimum in their linear momentum distribution at zero momentum. Therefore the shell-model description of the low-binding-energy protons in Li^7 as p-shell protons is consistent with our observations. The results with the low-binding-energy protons in Li^6 are difficult to understand on the basis of the usual shell model, especially the large difference between the Li^6 and Li^7 distributions. Target protons with a maximum in their linear momentum distribution at zero momentum yield an angular correlation distribution with a maximum at about 41°. A model for Li^6 which yields such low-binding-energy s protons (a description consistent with our results) is the (alpha + deuteron) complex, in which the Li^6 spin is entirely due to the intrinsic spins of the neutron and proton in the deuteron.

The differences reported in this note seem to us to illustrate well the usefulness of studies of (p, $2p$) reactions at high energies in order to obtain information on nuclear structure. A complete report of similar studies with light elements will be published elsewhere.

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