INVESTIGATION OF HIGH-ENERGY PROTONS EMITTED IN THE PHOTODISINTEGRATION OF Li^6

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Protons with energies of 16 Mev and above are studied. Data relating to the excitation functions, angular distributions, and n-p coincidences suggest a rather high probability for the formation of highly excited states in He^5 and Li^5 nuclei as a result of a single-particle reaction with the Li^6 nucleus.

We have investigated photodisintegrations of the Li^6 nucleus, leading to the formation of protons with energies above 16 Mev, with the synchrotron of the U.S.S.R. Academy of Sciences Physico-Technical Institute operating at 100 Mev. A 100-mg/cm² target consisting of 90% Li^6 and 10% Li^7 was employed. The protons were registered with the aid of the previously described[1] scintillation-counter telescopes.

1. We obtained curves of the photoproton yield as a function of the gamma-ray energy for the energy interval E = 35 to 87 Mev, and simultaneously for five proton groups with mean energies $\bar{E}_p$ of 16, 20, 25, 30, and 35 Mev. The width of the energy interval for each group was 20 - 25% of the mean energy of the corresponding group. The excitation function for protons with a mean energy $\bar{E}_p = 20$ Mev, obtained from the experimental yield curve by the method of Penhold and Leiss,[2] is shown in Fig. 1. For the other proton groups the yield and cross-section curves have the same general outlines but are displaced on the energy scale in accordance with the change in the proton energy. The measurements were carried out for angles $\theta = 57.5$ and 102.5°, but no substantial difference in the yield curves was noted.

A characteristic feature of the cross-section curves, practically in the whole of the investigated interval, is the comparatively slow change of the cross section with the gamma-ray energy. If it is assumed that the protons are the product of the $Li^6(\gamma,p)He^5$ reaction, then on the basis of the level scheme of the He^5 nucleus[3] it is possible to say that, for instance, for $\bar{E}_p = 20$ Mev, quanta with a mean energy of 29 - 34 Mev should take part in the process if the He^5 nucleus remains in the ground or first excited state at an energy of about 3 — 6 Mev, or quanta with an energy ≥ 45 Mev if the excitation energy of the final He^5 nucleus is 16.7 Mev or higher. The excitation function would depend much more strongly on the energy of the quanta, if (as was found for C^{12}, reference 4) the probabilities for the formation of highly excited states of He^5 and (or) for the simultaneous breakup of Li^6 into three particles were not comparable with the probability for the formation of a He^5 nucleus in the ground or in a weakly excited state. The decay into three particles would explain naturally the fact that protons belonging to a narrow energy interval are produced by quanta of arbitrary energy with an insignificant change in cross section.

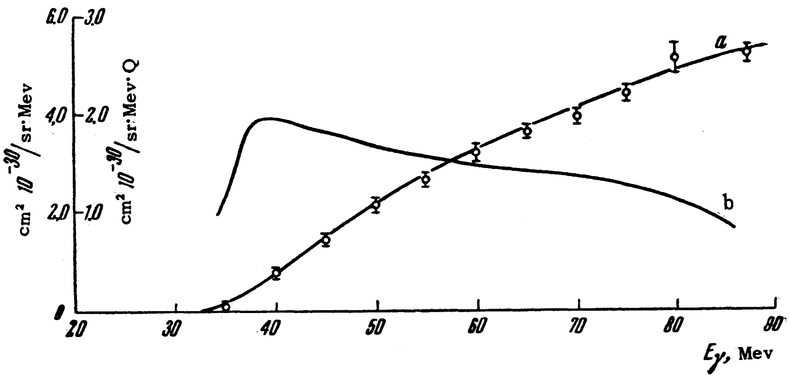

FIG. 1. Yield curve (a) and cross section curve (b) for protons with $\bar{E}_p = 20$ Mev from the Li^6 nucleus at an angle of 57.5°. The left-hand ordinate scale is for curve b, and the right-hand for curve a. The errors are statistical.

2. For the purpose of obtaining additional information, measurements of n-p coincidences were undertaken for the bremsstrahlung of gamma quanta with a maximum energy of 87 Mev. A scintillation counter with a volume of 6.3×10^3 cm^3, filled with a 5 g/l solution of p-terphenyl in xylene was employed to register the neutrons. The proton telescope was set at an angle of 78° and the neutron telescope at an angle of 90° to the direction of the gamma-ray beam. The counting efficiency of n-p coincidences, determined by the $D_2O - H_2O$ method, that is under conditions of 100-percent correlation of the emission angles of the neutron and the proton in the photodisintegration of deuterium, was 0.104 ± 0.039.

It can be shown, from the energy balance of the reaction, that the contribution of the reactions

$$\mathrm{Li}^6(\gamma p)\,\mathrm{He}^5, \quad \mathrm{He}^5 \rightarrow \mathrm{He}^4 + n;$$
$$\mathrm{Li}^6(\gamma n)\,\mathrm{Li}^5, \quad \mathrm{Li}^5 \rightarrow \mathrm{He}^4 + p$$

to the n-p coincidences should be small, on account of the quite high thresholds for proton ($E_p \geq 16$ Mev) and neutron ($E_n \geq 9$ Mev) registration; this can, however, only be shown for cases when the He^5 and Li^5 nuclei remain in the ground or first excited states. The contribution from these reactions is possible if the second (E_{exc} = 16.7 Mev) or even higher levels of the He^5 and Li^5 are excited; the $Li^6(\gamma pn)He^4$ reaction should also make a definite contribution. If in addition the quantum interacts with quasideuteron formations in the Li^6 nucleus, then a correlation between the emission angle of the neutron and proton can be expected. Experimentally the following results were obtained:

The observed ratio of coincidences and the number of registered protons	0.0102 ± 0.0035
The same, assuming a 100-percent correlation between the emission angles of the neutron and proton	0.098 ± 0.074
The same, assuming an isotropic distribution of the emitted neutrons	0.3 - 0.4

(the calculated efficiency of the neutron counter, assuming an isotropic neutron distribution, is 2.5 - 3.5%).

Taking into account the large dimensions of the neutron counter, it seems improbable that the contribution of correlated n-p coincidences exceeded substantially 10% of the total number of registered protons. The fact that 30 - 40% of these protons can be accompanied by neutrons speaks in favor of the assumption of a considerable probability for the formation of He^5 and Li^5 nuclei in strongly excited states. A considerable contribution of these states could explain the observed shape of the cross-section curves. The possibility that strongly excited He^5 and Li^5 nuclei are produced was previously expressed by Komar and Yavor[5] in connection with the photodisintegration of Ne^{20}. At present we are making attempts to measure the angular correlation of emitted neutrons and protons.

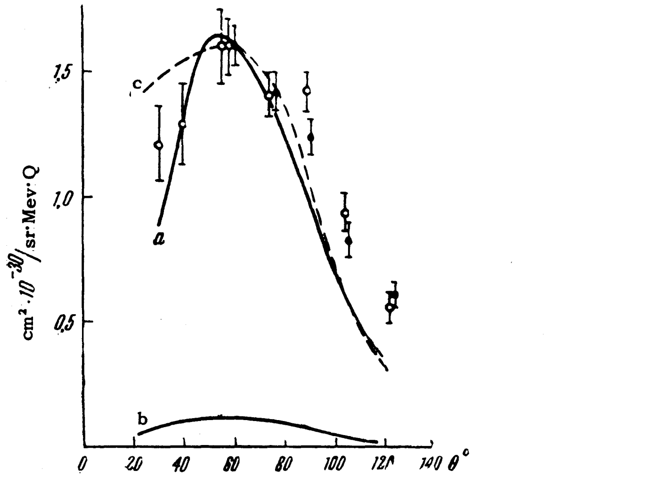

FIG. 2. Angular proton distribution for $\bar{E}_p$ = 25 Mev. The ordinate scale is given for the experimental points and for curve b. The errors are statistical.

3. The investigations of the angular photoproton distributions for $E_{\gamma max}$ = 87 Mev are in better qualitative agreement with the concepts of a single-nucleon interaction mechanism between the gamma quanta and the Li^6 nucleus. Figure 2 shows the angular distribution of 20- to 31-Mev protons. Curve a is calculated from Shklyarevskiĭ's formulas, obtained on the basis of the shell model for the single-nucleon interaction mechanism and normalized according to the experimental data for $\theta = 60°$. However, the quantitative agreement with theory (curve b) is unsatisfactory. Curve c is obtained from ideas about the quasideuteron interaction mechanism, as previously,[1] and is also normalized for $\theta = 60°$. It is obvious that at small angles (smaller than 60°) curve c lies considerably above the experimental points, while the shape of the angular proton distribution for a single-nucleon interaction mechanism (curve a) is in better agreement with the experimental data.

In conclusion, the authors wish to express their gratitude to Prof. A. P. Komar and the laboratory co-workers for their attention and interest in the work, and also to the synchrotron crew headed by N. N. Chernov.

Note added in proof (May 3, 1960): The results of the investigation of the correlation of the emission angles of neutrons and protons show that while a weakly expressed correlation apparently exists for the C^{12} nucleus, no such correlation for Li^6 is observed. The isotropic yield of neutrons, registered in coincidence with protons, confirms the assumption of a single-nucleon mechanism in the photodisintegration of Li^6.

[1] Bazhanov, Volkov, and Kul'chitskiĭ, JETP **35**, 322 (1958), Soviet Phys. JETP **8**, 224 (1959).

[2] A. S. Penhold and J. E. Leiss, Phys. Rev. **114**, 1332 (1959).

[3] F. Ajzenberg-Selove and T. Lauritsen, Nucl. Phys. **11**, 1 (1959).

[4] E. B. Bazhanov, JETP **38**, 267 (1960), Soviet Phys. JETP **11**, 193 (1960).

[5] Bazhanov, Volkov, Komar, Kul'chitskiĭ, Chizhov, and Yavor, Тр. Всесоюзной конф. по ядерным реакциям при малых и средних энергиях, Trans. of the All-Union Conference on Nuclear Reactions at Low and Medium Energies, Acad. of Sci. Press, p. 463, 1958.

[6] G. M. Shklyarevskiĭ, JETP **36**, 1492 (1959), Soviet Phys. JETP **9**, 1057 (1959).

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