ANGULAR DISTRIBUTION OF α PARTICLES FROM THE $Li^7(p, \alpha)He^4$ *REACTION*

A. M. PETROV

Leningrad Physico-technical Institute, Academy of Sciences, U.S.S.R.

Submitted to JETP editor March 6, 1962

J. Exptl. Theoret. Phys. (U.S.S.R.) **43**, 66-69 (July, 1962)

Experimental results are presented on the relative yield of α particles as a function of the cosine of the emission angle in the c.m.s., for proton energies in the range 1.12—3.58 MeV. The proton-energy dependence of the coefficients A and B in the α-particle angular distribution [Eq. (1)] is given. The curve A(E) is different from the theoretical one.

INTRODUCTION

ALTHOUGH the $Li^7(p, \alpha)He^4$ reaction was the first nuclear reaction achieved by means of an accelerator, it still continues to attract the attention of researchers.[1-8] The reason for this is its simplicity, which permits a relatively easy theoretical interpretation.

The angular distribution in the c.m.s. of the α particles produced in the reaction is given by the equation

$$I(\theta_{cms}) = I(90°)\,[1 + A(E)\cos^2\theta_{cms} + B(E)\cos^4\theta_{cms}] \quad (1)$$

where θ_{cms} is the angle of emission. Equation (1) is consistent with the assumption that the reaction is due to protons with orbital angular momenta $l = 1$ and $l = 3$.

The energy dependence of the coefficients A and B indicates that the reaction involves at least two states of the intermediate nucleus Be^8 with total angular momenta J = 0 and J = 2. This assumption served as a basis of calculations of the angular distribution using the dispersion theory, first with only the p-waves taken into account ($l = 1$)[9] and then extended to include the f-waves ($l = 3$) of the bombarding protons.[10]

The majority of the experiments on the angular distribution of α particles from the $Li^7(p, \alpha)He^4$ reaction were carried out at proton energies below 1 MeV. Only in two experiments, carried out in the same laboratory, were protons with energy up to 3.5 MeV used.[2] In the present experiment, the angular distribution was investigated in the energy range from 1.12 to 3.58 MeV. The purpose of the experiment was to explain the role of the states of the intermediate nucleus Be^8, which take part in the reaction at relatively high energies of the bombarding protons.

EXPERIMENT

The beam from the cyclotron of the Physico-technical Institute of the U.S.S.R. Academy of Sciences was focused by two quadrupole lenses on a target placed in the center of a vacuum chamber 500 mm in diameter. A slit collimator, which determined the beam geometry, was placed in front of the chamber. A Faraday cylinder behind the chamber measured the beam intensity. A special plane attachment with willemite screen, placed at the exit from the chamber between the poles of an electromagnet, permitted us to determine the beam energy from its deflection in the magnetic field.

Cassettes with nuclear emulsions of the T-2 type were placed on the periphery of the chamber.

The photographic plates, 3 cm × 6 cm, were placed in the cassettes at an angle of 10° to the direction towards the target. The positions of the cassettes in the chamber enabled us to detect α particles emitted in the range of angles from 10 to 170°, in steps of 10°.

In first experiments we used metallic lithium targets 15—20 μ thick obtained by rolling the metal in an atmosphere of dry CO_2. Later the target consisted of aluminum foil 0.6 μ thick with metallic lithium evaporated on it in vacuum. The target was transferred into the chamber in an atmosphere of CO_2.

The thickness of the targets was determined after the exposure by means of potentiometric titration of a solution of the lithium from the target in distilled water. The energy losses in the target were not greater than 60 keV.

In a large number of cases, the range in the emulsion of α particles from the reaction and of scattered protons is of the same magnitude. A

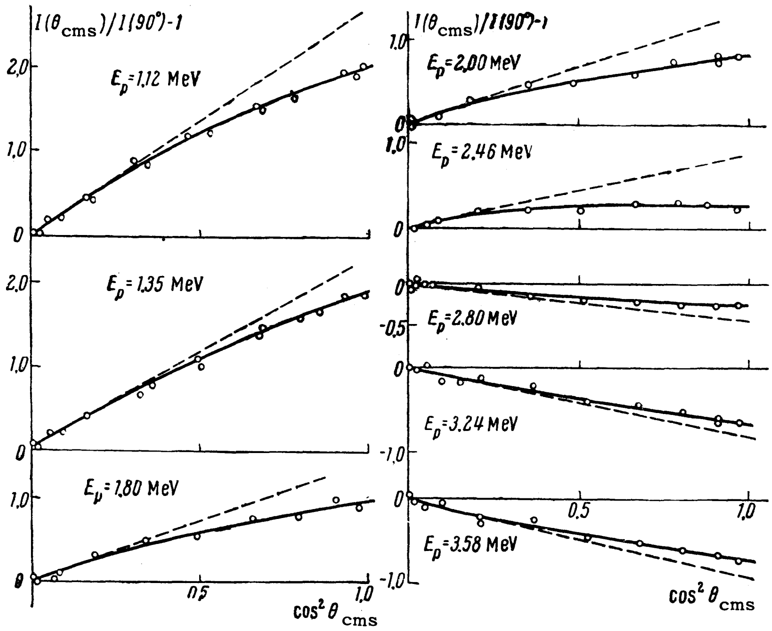

FIG. 1

E_p, MeV	A	B	E_p, MeV	A	B
1.12	2.75 ±0.13	—0.698±0.095	2.46	0.74±0.08	—0.516±0.076
1.35	2.267±0.085	—0.323±0.066	2.80	—0.41±0.03	+0.15 ±0.03
1.80	1.41 ±0.13	—0.45 ±0.12	3.24	—0.74±0.11	+0.093±0.100
2.00	1.29 ±0.10	—0.50 ±0.09	3.58	—1.00±0.12	+0.27 ±0.11

special method of development was therefore used, which permitted us to distinguish visually between the tracks of α particles and of scattered protons under the microscope.

The plates, placed at angles of 10 to 40° with respect to the direction of the proton beam were, in the majority of cases, inadequate for analysis because of a large background of scattered protons. However, since two identical particles are produced in the reaction and since their angular distribution in the c.m.s. is symmetrical with respect to the angle $\theta_{cms} = 90°$, the angular dependence of the α-particle yield can be constructed from measurements at angles greater than 80°.

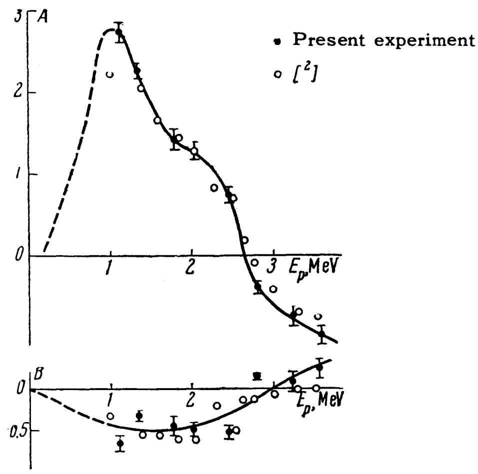

FIG. 2

RESULTS OF THE MEASUREMENTS

In each plate, 2500 to 3500 α particles were counted. The results of the measurements of the relative yield of α particles in the c.m.s. are shown in Fig. 1 as a function of $\cos^2 \theta_{cms}$ for different proton energies. The deviations from straight lines are due to the presence of a term proportional to $\cos^4 \theta_{cms}$ in the expression for the angular distribution.

The coefficients A and B in Eq. (1) were calculated using the least-squares method and are given in the table together with their probable errors. The dependence of the coefficients A and B on the energy of bombarding protons, obtained in our experiments, is compared with the results of [2] in Fig. 2. The dashed curves, referring to the energy range below 1 MeV were constructed by us from the results of [1,3-6]. One should note the very good agreement, in the energy range 1.2—2.6 MeV, between our data and those of [2] obtained by a different method. This leads us to the conclusion that the step on the descending branch of the curve A(E) around 2.2 MeV is not a result of statistical fluctuations.

The theoretical expression for the energy dependence of the coefficient A obtained, as mentioned above, taking two states of the intermediate nucleus into account, is of the form

$$A(E) = (C_0E^2 + C_1E + C_2) / (E^2 + C_3E + C_4)$$

(where C_i are constant factors), which represents a smooth curve without any steps.

The difference between the theoretical and experimental curves can be explained by the fact that the reaction involves a large number of states of the intermediate nucleus, rather than two as was assumed above. It is therefore desirable to extend the investigation of the angular distribution to the high-energy range, which might make it possible to establish the number of states of the intermediate nucleus which take part in the reaction.

[1] Rubin, Fowler, and Lauritsen, Phys. Rev. **71**, 212 (1947).

[2] Heydenburg, Hudson, Inglis, and Whitehead, Phys. Rev. **73**, 241 (1948); **74**, 405 (1948).

[3] Martin, Bower, Dunbar, and Hirst, Australian J. Sci. Research **A2**, 25 (1949).

[4] F. Hirst and R. Uebergang, Australian J. Sci. Research **A4**, 284 (1951).

[5] Talbott, Busala, and Weiffenbach, Phys. Rev. **82**, 1 (1951).

[6] Cartwright, Green, and Willmott, Phil. Mag. **44**, 1307 (1953).

[7] U. Timm, Naturwissenschaften **44**, 279 (1957).

[8] Conrad, König, and Timm, Naturwissenschaften **45**, 204 (1958).

[9] C. L. Critchfield and E. Teller, Phys. Rev. **60**, 10 (1941).

[10] R. Inglis, Phys. Rev. **74**, 21 (1948).

Translated by H. Kasha
12