GROUND STATE OF THE Be^6 NUCLEUS

M. GULYAMOV, B. V. RYBAKOV, and V. A. SIDOROV

Submitted to JETP editor January 15, 1963

J. Exptl. Theoret. Phys. (U.S.S.R.) **44**, 1829-1831 (June, 1963)

The neutron spectrum from the $Li^6(p, n)Be^6$ reaction is investigated by the time-of-flight method for 9.96-MeV protons. A more exact value of the reaction energy ($Q = -5.08 \pm 0.04$ MeV) and of the width of the ground state of Be^6 ($\Gamma = 0.14 \pm 0.04$ MeV) is obtained.

THE Be^6 nucleus has been observed in our laboratory with the aid of a single-channel fast-neutron spectrometer by the time-of-flight method.[1] The energy of the reaction $Li^6(p, n)Be^6$ (ground state) turned out to be -5.2 ± 0.2 MeV. An estimate of $\Gamma < 0.3$ MeV was obtained for the width of the ground state.

Measurements of the neutron spectrum from the $Li^6(p, n)Be^6$ reaction by means of the recoil protons in the nuclear emulsion carried out by Ajzenberg-Selove et al.[2] confirmed these data, but did not make it possible to refine them. Meanwhile the exact energy values and the width of the ground state of the Be^6 nucleus are of great interest, since this nucleus is part of the lightest isobar triplet He^6–Li^6–Be^6. The development of fast-neutron spectrometry[3] makes it possible to increase considerably the accuracy of the measurements. In the present work the neutron spectrum from the $Li^6(p, n)Be^6$ reaction was investigated with the aid of a multichannel fast-neutron spectrometer by the time-of-flight method in the cyclotron laboratory of the Atomic Energy Institute of the U.S.S.R. Academy of Sciences.[4]

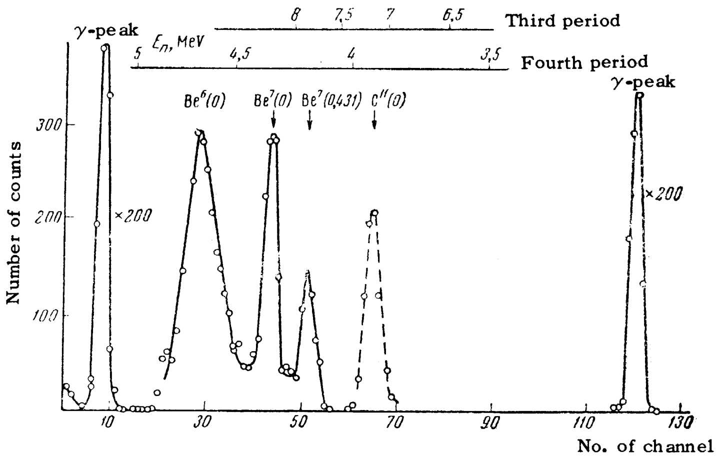
The spectrometer is based on the use of the natural modulation of the cyclotron beam. The multichannel time analyzer operates on the vernier principle.[5] The resolving time of the spectrometer is better than 3 nanosec; the width of the time analyzer channel is about 0.85 nanosec. The registration system has 256 channels with a capacity of 2^{16} pulses per channel. The data are displayed by a print-out perforating device based on telegraphic apparatus.[6]

The measurements were carried out with a lithium target enriched with the Li^6 isotope; the target thickness corresponded to a 65-keV loss for 10-MeV protons. The metallic lithium was pressed onto a tungsten backing by rolling between steel rollers. The scintillation counter with a tolan crystal and a FÉU-36 photomultiplier was set at an angle of 7.5° to the proton beam at a distance of up to 10 m from the target.

The exact determination of the energy of the protons in the cyclotron beam was carried out by measuring their time of flight from a slotted graphite diaphragm, specially mounted in the ion channel, to the target. The base distance used amounted to 551.8 ± 0.2 cm. The measurements were carried out with the aid of a neutron spectrometer from the relative position on its scale of the peaks corresponding to the gamma rays produced in the diaphragm and in the target. The proton energy was measured after each measurement of the neutron spectrum. The proton energy at the center of the target averaged over all the measurements was $E_p = 9.96 \pm 0.03$ MeV. The spread of the values obtained in different measurements does not exceed the limits of the indicated error.

In order to check the precision of the energy determination and in order to determine the width of the ground state of Be^6, measurements were made of the neutron spectra of the reactions $Li^7(p, n)Be^7$ (ground state and the level with an excitation energy of 0.431 MeV) and $B^{11}(p, n)C^{11}$ (ground state). The energies of these reactions are well known. The widths of the corresponding levels are extremely narrow.[7] The $Li^7(p, n)Be^7$ reaction was observed with the main target on the 4-percent admixture of the Li^7 isotope. For the $B^{11}(p, n)C^{11}$ reaction a borazon target (BN) was used, whose thickness corresponded to a 70-keV energy loss of 10-MeV protons.

The figure shows the experimentally obtained time distribution of the scintillation-counter pulses in the proton bombardment of lithium (Li^6 — 96.2%, Li^7 — 3.8%) and boron (dashed curve). The peak corresponding to the ground state of the Be^6 nucleus is clearly seen; its width is considerably larger than the instrumental width. The arrows indicate the tabulated values of the energies of the two lowest levels of the Be^7 nucleus and of the ground state of the C^{11} nucleus. As a result of processing several series of measurements we obtained the following value of the energy of the $Li^6(p, n)Be^6$ reaction: $Q = -5.08 \pm 0.04$ MeV. This corresponds



Time-of-flight distribution of neutrons produced in the bombardment of lithium with 9.96-MeV protons. The width of the channel is 0.848 nanosec. The pulse-height selector "window" corresponds to the registration of recoil protons with energy 3.5-4.5 MeV. The group of neutrons corresponding to the ground state of Be^6 is observed during the fourth period of the high-frequency cyclotron, and groups corresponding to the states $Be^7(0)$, $Be^7(0.431)$ and $C^{11}(0)$ – in the third period (the period is 95.24 nanosec).

Reaction	E^*, MeV	Reaction energy, MeV	
		our measurements	tabulated values[7]
$Li^7(p,n)Be^7$	0	-1.68 ± 0.05	-1.643
$Li^7(p,n)Be^7$	0,431	-2.09 ± 0.05	-2.074
$B^{11}(p,n)C^{11}$	0	-2.75 ± 0.04	-2.765

to a mass defect of the Be^6 nucleus of 20.16 ± 0.04 MeV.

The general precision of the method for determining reaction energies is illustrated by the table where the results of three of our measurements are compared with the known values.

The width of the ground state of the Be^6 nucleus was determined by quadratic subtraction of the instrumental width from the observed width. The instrumental width was found from the neutron lines from the reaction $B^{11}(p,n)C^{11}$ and $Li^7(p,n)Be^7$. In our previous work[1] and in the work of Ajzenberg-Selove et al[2] only the upper limit was determined of the width of the ground state of the Be^6 nucleus. The measurements carried out in the present work yield for the width of this level the value $\Gamma = 0.14 \pm 0.04$ MeV which corresponds to a lifetime $\tau = 4.7 \times 10^{-21}$ sec.

Wackman and Austern[8] in their work devoted to the three-particle model of the Li^6 nucleus calculated the binding energy of the He^6, Li^6, and Be^6 nuclei. Of greatest interest for comparison with experiment is the ratio of the differences of the Coulomb energies of Be^6–Li^{6*} and Li^{6*}–He^6, which is 1.50 under the assumption of identical charge distributions. Wackman and Austern obtained for this ratio under two different assumptions values of 1.63 and 1.73.

The experimental value of this ratio is 1.86 $\pm$ 0.05 which corresponds to a somewhat larger correlation of the two last protons in the Be^6 nucleus, not only compared with the assumption of homogeneous charge distribution, but also compared with the assumptions of Wackman and Austern.

The authors are grateful to O. D. Brill, V. V. Paramonov, and to all the cyclotron crew who assisted with this work.

[1] Bogdanov, Vlasov, Kalinin, Rybakov, and Sidorov, Atomnaya énergiya 3, 204 (1957).

[2] Ajzenberg-Selove, Osgood, and Backer, Phys. Rev. **116**, 1521 (1959).

[3] B. V. Bykov and V. A. Sidorov, Spectrometriya bystrykh neĭtronov (Fast-neutron Spectrometry), Atomizdat, 1958.

[4] Kurashov, Linev, Rybakov, and Sidorov, Atomnaya énergiya 5, 135 (1958).

[5] A. A. Kurashov and V. A. Sidorov, PTÉ No. 6, 60 (1961).

[6] Glukhov, Kurashov, Mel'nikov, and Sidorov, PTÉ No. 2, (1962).

[7] F. Ajzenberg-Selove and T. Lauritzen, Nucl. Phys. **10**, 1 (1952).

[8] P. H. Wackman and N. Austern, Nucl. Phys. **30**, 529 (1962).

Translated by Z. Barnea
290