values of the isotopic spin and the total charge (see reference 2). However, for comparison with experiment, the distribution of particles according to charge is essential. Such a distribution can often be found on the basis of the conservation of isotopic spin in utilizing the methods of group theory[6].

By carrying out the respective calculations, it is possible to find the statistical weights for the end states with different distributions of charge between the particles. The data for the end states $(pp\,-)$, $(pn\,+\,-)$, $(pn\,-\,0)$, which are of interest to us, are compiled in the Table.

From the above Table it follows that the ratios $(pp\,-)$: $(pn\,+\,-)$: $(pp\,-\,0)$ at an energy of 1.75 bev are equal to 2.1 : 5.7 : 1 and at an energy of 1.46 bev these are 3.5 : 6.3 : 1. As is shown by the calculation , at 2.2 bev these ratios are 1.4 : 5 : 1. The experimental value of these ratios, as has already been pointed out, is 1 : 3.2 : 1. However, the authors[1] themselves stress that even the ratios 2.4 : 7.6 : 1 do not contradict experiment. In our calculation the probability of the production of five-prong stars was found to be negligibly small.

Thus, the calculation of the multiple production of mesons at energies of the order of 2 bev by the statistical theory, but taking into account the isobaric states gives an entirely satisfactory agreement with experiment. We are postponing the discussion of the angular and energy distributions until the subsequent communication.

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A Study of the Energy Levels of the Lithium Nucleus by the Method of Magnetic Analysis

L. M. Khromchenko and V. A. Blinov
Radio Institute of the Academy of Sciences, USSR

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In this work the energy spectrum of the lithium nucleus was investigated by the method of magnetic analysis of the products of nuclear reactions, which has been described previously[1]. The method used gave the possibility of obtaining lines visible to the eye on a photoplate, at the position of the localization of discrete groups of particles. Such a spectrogram was then studied with the aid of a microphotometer. The length of the whole photoplate and half of its width was covered with a filter of aluminum foil, whose thickness could be varied. Its thickness was calculated to be such that protons would pass through, but that particles having a shorter path would be completely filtered out. When the type of particles, the value of the magnetic field and the geometry of the instrument are known, it is possible to determine definitely the energy of the particles of the group under investigation from the position of the line on the photoplate.

In our experiments a layer of lithium oxide, (obtained by burning metallic lithium in air) was deposited on a copper foil having a thickness of approximately 0.5 μ. The target was bombarded with a monoenergetic beam of deuterons with an energy up to 4.7 mev. The experiments were carried out at three energies of the bombarding deuterons, from 3.7 to 4.7 mev. As in the previous experiments[1,2] carried out by this method, the total spectrum of the element studied was obtained at the same time on one and the same photoplate. The energy of the primary deuterons was determined by the elastic recoil from the nuclei present in the target.

The reproductions of the photoplates obtained during the irradiation of the lithium oxide with deuterons are given in Fig. 1. The microphotograms of these plates are shown in Figs. 2 and 3. In Fig. 2 the upper curve was obtained on the half of the plate without the filter, and the lower curve on the filtered half. As is evident from the Figures, in addition to the deuterons elastically recoiled from Cu^{64}, O^{16}, C^{12}, and Li^7, we have

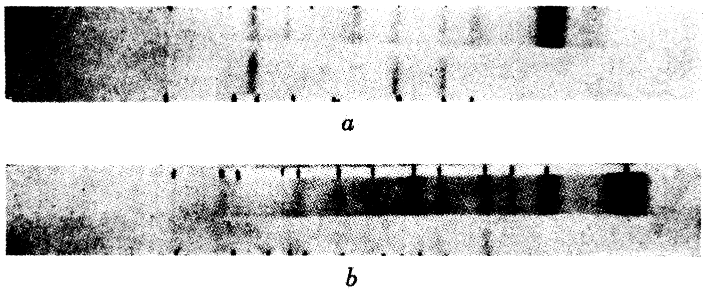

FIG. 1. The energy spectrum of lithium.
a. $E_d = 3.76$ mev; *b.* $E_d = 4.69$ mev.

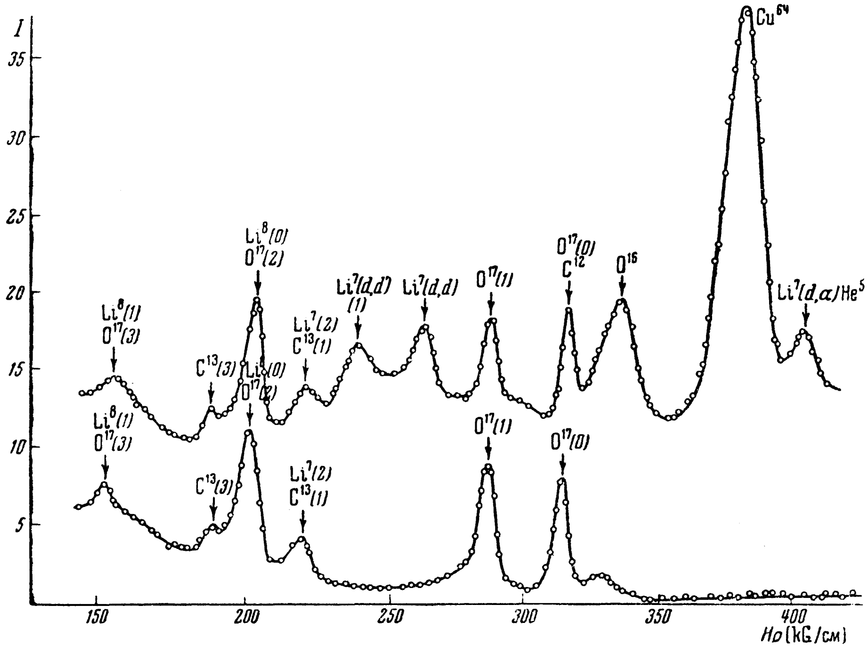

FIG. 2. The energy spectrum of lithium. $E_d = 3.76$ mev. Microphotogram of the half plate: above — irradiated without the filter; below — irradiated with the filter.

registered a series of groups of protons produced as a result of the reaction (d, p) on Li^6, Li^7, O^{16} and C^{12}.

Our data for the excitation levels of the Li^{7*} nucleus obtained from the investigation of six plates containing the lithium spectrum are compiled in Table I. These are compared with the data of a number of authors who obtained the above levels from the reaction $Li^6(d, p)$, as well as from other nuclear reactions.

No groups of protons corresponding to the transition of the Li^{7*} nucleus to the ground-state and to the first excitation level were observed in our experiments. This can be explained by the low propagation of the Li^6 isotope and, apparently, by the rather small cross section of the reaction (d,p) for these transitions. Therefore, for the calculation of the energy of the excitation levels of the Li^{7*} nucleus we have taken $Q_0 = 5.020$ mev, measured for this reaction by Strait, Van Patter et al[3].

In addition to the proton groups and the elastically recoiled deuterons, we have observed on all the plates a group of deuterons corresponding to the inelastic recoils from the main Li^7 isotope (propagation 92.48%). This group corresponded to the first excitation level of Li^{7*} with the $E^* = 0.476$ mev. The intensity of this group is large; it is comparable with the elastic recoil of deuterons from lithium. The level of Li^{7*} (3) with an excitation energy of 6.53 mev was previously obtained only

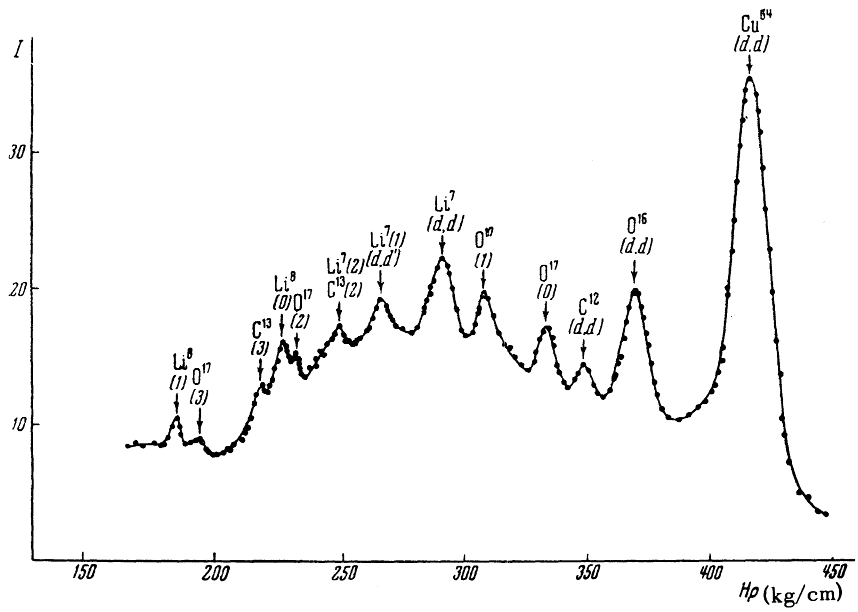

FIG. 3. The energy spectrum of lithium. $E_d = 4.69$ mev. Microphotogram of the half plate irradiated without the filter.

TABLE I. Excitation Levels of the Li^{7*} Nucleus

No. of Group	This Work		Data of Other Authors		
	Q, mev	E^*, mev	E^*, mev	Reactions	Authors
1	—	0.476 (from d,d')	0.483 0.477 0.478	(d, p) γ-rays (p,p') & (d,d')	Beuchner et al. Thomas and Lauritzen Williams et al.
2	(0.566)	(4 454) from (d,p)	4.56 4.61	(p, p') (d, p)	Frenzen and Likely Gelinas and Hanna
3	—1.510	6.530 from (d,p)	6.56	(p, p')	Frenzen and Likely

during the inelastic scattering of protons[4], but in the reaction (d, p) it was observed by us for the first time.

Table II describes the excitation levels of the Li^8 nucleus produced as a result of the reaction $Li^7(d, p)Li^8$. In our experiments the group of protons corresponding to the transition of the Li^8 nucleus into the ground-state is intense and fairly well defined. The value of $Q_0 = -0.183$ mev which we have obtained for this reaction is in very good agreement with the data obtained by a number of authors using very different methods.

In the review of Ajzenberg and Lauritsen[5], the first excitation level of Li^8 was considered doubtful, its energy was given only approximately (of the order of 1 mev). In our experiments the presence of such a level is confirmed quite definitely, the corresponding group of protons being fairly intense and clearly defined.

On all the plates containing the lithium spectrum obtained at $E_d \sim 3.7$ mev (Fig. 2), to the right of the peak of the deuterons which underwent

TABLE II. Excitation Levels of the Li^8 Nucleus

No. of Group	This Work		Data of Other Authors			
	Q, mev	E^*, mev	Q, mev	E^*, mev	Method	Author
0	—0.183	0	—0.187	0	Angular Threshold	Paul
			—0.188	0	Magnetic Spectrograph	Strait et al.
			—0.192	0	Electrostatic Analyzer	Williams et al.
1	—1.160	0.977	—	(1.0)	—	Gove and Harvey

an elastic recoil from the copper backing of the target there can be observed a fairly intense group of particles which did not go through the filter. Spectral analysis of the target substance established the absence of elements heavier than copper. Thus, this group could not be deuterons elastically recoiled from an element heavier than copper. There remained possible three reactions on the main lithium isotope: $Li^7(d,\alpha)He^5$, $Li^7(d, He^3)He^6$ and $Li^7(d, He^3)Li^6$. Special control experiments on thick-layer photoplates made it possible to measure the length of the tracks of the particles of the group under investigation and to establish that these were α-particles, and hence of all the possible reactions, the first takes place. The fact that the reaction (d, α) occurs precisely on the Li^7 isotope indicates a calculation of another variant: $Li^6(d, \alpha)He^4$. This gives a Q_0 value for the latter reaction which is incompatible with the known masses of the reacting particles.

From a study of five plates of the lithium spectrum at $E_d \sim 3.7$ mev we have determined the energy of the reaction to be $Q_0 = 13.719$ mev for the process $Li^7(d, \alpha)He^5$. The values for this quantity published up until now[6-8] vary within the range 13.43 - 14.43 mev. Since these values were measured by methods (ionization chamber, measuring the lengths of tracks, etc.) less accurate than the method of magnetic analysis (which we have used), the value of Q_0 obtained in our experiments may be considered as being more reliable and one which permits a more precise determination of the mass of the He^5 nucleus.

Taking for the mass of the particles participating in reaction, the values: $M_{H^2} = 2.0147411$, $M_{He^4} = 4.0038773$, $M_{Li^7} = 7.018225$[9], we obtain for the mass of He^5 the value $M_{He^5} = 5.014353$ A.M.U. For the values of the excitation energy determined from the well-defined peaks, the average error of measurements is of the order of 20 kev. The less clearly defined peaks give a larger error.

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The Formation of Charged П-Mesons by Nucleons

V. M. SIDOROV
Academy of Sciences of the USSR
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CHARGED π-mesons may be formed with free nucleons as a result of the following reactions:

$$p + p \to n + p + \pi^+ \text{ or } p + p \to d + \pi^+; \quad (1)$$

$$p + n \to n + n + \pi^+; \quad (2)$$

$$p + n \to p + p + \pi^-; \quad (3)$$

$$n + n \to n + p + \pi^- \text{ or } n + n \to d + \pi^-. \quad (4)$$

At the present time, the most complete experimental data exist from the study of the reaction (1). Some information concerning the interactions $(p - n)$ and $(n - n)$ can be obtained from the experimental study of collisions between nucleons and nuclei. Since even at 500 mev the wavelength of the bombarding particle is small compared with the distance between the nucleons, it can be assumed that at energies large compared with 500 mev, mesons are formed in complex nuclei mostly in individual collisions of nucleons.

On the basis of the hypothesis of charge independence of nuclear forces and symmetry of the properties of positive and negative mesons, it can be assumed that the cross sections of the processes of formation of π^+ and π^- mesons in $(p - n)$ collisions are equal.

If we assume also that charged mesons are formed in $(p - p)$ and $(p - n)$ collisions with equal probabilities, there more positive mesons should be formed than negative when complex nuclei are bombarded with protons, namely: $\sigma(\pi^+)/\sigma(\pi^-) = (A + Z)/A - Z)$. Thus when deuterium, carbon, and in general, nuclei having equal numbers of protons and neutrons are bombarded by protons, we can expect the ratio $\sigma(\pi^+)/\sigma(\pi^-)$ to be equal to 3. The ratio $\sigma(\pi^-)/\sigma(\pi^+)$ should be the same for the bombardment of complex nuclei with neutrons. Results of experimental work[1-3] indicate that when complex nuclei are radiated with protons of 340 to 380 mev, the ratio of the cross sections $\sigma(\pi^+)/\sigma(\pi^-)$ is considerably greater than $A + Z/A - Z$. Measurements of ouptuts of charged mesons at 90° to the beam resulting from bombardment of carbon with neutrons of 270 mev[4] showed that the output of π^- mesons in this case exceeds the output of π^+ mesons by a factor of approximately 15. It should be noted that these experiments were made using bombarding particles of energies close to the threshold of meson formation. If this case, in view of Pauli's principle, the ratio of cross sections $\sigma(\pi^+)/\sigma(\pi^-)$ can increase significantly when nuclei are bombarded with protons, and decrease in the case of bombardment with neutrons as noted by Chew and Steinberger[5].

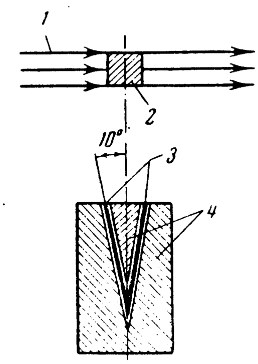

Fig. 1. Experimental arrangement
1. Proton beam. *2.* Target.
3. Photographic plate. *4.* Brass block.

The formation of charged mesons by the action of protons and neutrons on carbon and hydrogen was studied by us in experiments using the synchrocyclotron of the Institute for Nuclear Problems, Academy of Sciences, USSR.

1. *Formation of π^+ and π^- mesons by the action of protons on carbon and hydrogen.* A target of carbon or paraffin was placed in a narrowly collimated beam of protons of 657 ± 8.0 mev[6]. The charged mesons emitted from the target at an angle of 90° were recorded by means of nuclear emulsions. The experimental arrangement is shown in Fig. 1. The photographic plates were placed in the brass block at an angle of 10° to the direction of the incident mesons. The meson stopped within the emulsion was considered positive if it gave rise to a μ-meson trace and negative if it produced a "star".