Neutrons from Deuteron Bombardment of Li^6

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THE number of neutrons from deuteron bombardment of Li^6 has been measured for deuterons of energy between 250 and 2200 kev. These neutrons are thought to come from the two reactions: $Li^6+H^2\rightarrow(^*Be^8)\rightarrow Be^7+n+3.3$ Mev, and $Li^6+H^2\rightarrow(^*Be^8)\rightarrow He^4+He^3+n+1.7$ Mev. Monoenergetic deuterons were obtained with the Rice Institute pressure Van de Graaff generator. Lithium enriched to 95 percent Li^6 was used as a target in the form of a thin film of Li_2SO_4 374 micrograms per sq. cm thick, which is equivalent to 124 kev for a 1-Mev deuteron.[1] The neutrons emitted in the direction of the deuteron beam were detected by means of the argon recoils in a proportional counter filled with argon at atmospheric pressure. The counter was biased to count neutrons of energy greater than 1 Mev. To correct for the Li^7 impurity in the target, the yield of neutrons from a normal Li_2SO_4 target of approximately the same thickness was measured under identical experimental conditions. Knowing the relative amounts of the two isotopes in each target, the contribution of each isotope alone can be determined. Plotted in Fig. 1 are the relative excitation curves for the two isotopes, corrected to indicate the yield of neutrons from targets of equal thickness of the pure isotopes. The units are arbitrary but are the same for both curves. The interval between successive points on the excitation curve is half the target thickness, and each point on the curve represents a count of at least 1280 on the neutron counter.

The angular distribution of the neutrons from lithium has been determined at several deuteron energies by counting the proton recoils from a number of polyethylene foils inside an argon-filled proportional counter. The counter subtended a solid angle of 0.025π at the target, and the neutrons were observed at 15-degree intervals between 0 and 150 degrees to the deuteron beam. The distribution of neutrons from Li^6 is essentially the same at 590, 1000, and 1700 kev, showing a maximum in the forward direction in the laboratory coordinates. The ratio of the counting rate at 0 degrees to that at 150 degrees is 7:4. The angular distribution of the Li^7 neutrons is practically spherical in laboratory coordinates at 605, 700, 820, and 1340 kev. At the 1020-kev resonance, the ratio of the counting rate at 0 and 150 degrees is approximately 2:1. This marked assymetry in the forward direction tends to exaggerate the effect of the 1020 resonance in observations made at 0 degrees.

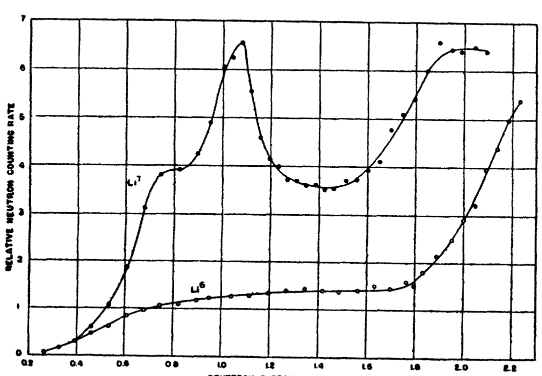

FIG. 1. Relative number of neutrons from separated isotopes of lithium, observed in the direction of the deuteron beam.

When allowance is made for the penetrability of the deuterons through the Coulomb barrier of the Li^6 nucleus, there appears to be a broad energy level in Be^8 excited by s-deuterons of about $\frac{1}{2}$ Mev energy, which corresponds to an excitation energy of 22.5 Mev in the Be^8 compound nucleus. The excitation curves have also been carried out for the two groups of protons from the competing reactions $Li^6+H^2\rightarrow(^*Be^8)\rightarrow Li^7+H^1+5.0$ Mev and $Li^6+H^2\rightarrow(^*Be^8)\rightarrow{}^*Li^7+H^1+4.5$ Mev, and for the alpha-particles from $Li^6+H^2\rightarrow(^*Be^8)\rightarrow He^4+He^4+22$ Mev. In both cases broad maxima in the cross section for disintegration were obtained, and after correcting for the Coulomb penetration, both sets of data indicate a resonance for deuterons of 0.4 Mev. The width of the resonance is about 0.5 Mev. It seems likely that the neutrons, protons, and alpha-particles all come from this same excited state of Be^8. The sharp rise in the neutron counting rate above 1.8 Mev seems to indicate an energy level in Be^8 excited by p-deuterons of energy between 2.5 and 3.0 Mev. The alpha-particle excitation curve does not show a resonance in this region,[2] which would be consistent with the assumption that deuterons with $l=1$ are responsible for this level.

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[1] The enriched Li^6 was kindly furnished by the AEC, Isotopes Branch, Oak Ridge, Tennessee.
[2] N. P. Heydenburg, C. M. Hudson, D. R. Inglis, and W. D. Whitehead, Phys. Rev. **74**, 405 (1948).

Note on the East-West Effect*

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IN a recent flight to Peru in a B-29, continuous measurements were made at 3.10 equivalent meters of water barometric pressure (approximately 30,000 feet) of the intensity of cosmic-ray particles at the zenith, 45° west and 45° east. In addition the azimuthal variation was measured over Peru (magnetic latitude zero) at 2.35 m of water (approximately 38,000 feet) for zenith angles of $22\frac{1}{2}°$, 45°, and $67\frac{1}{2}°$. These measurements were made with both 10 cm and 20 cm of lead placed between the counters as well as with *no lead* absorber.** Because of the important bearing that such measurements have on the nature of the primary radiation, some of the preliminary results at the equator are herein reported.

Johnson and Barry[1] measured a west excess at a zenith angle of 60° of only 7 percent above 5 cm of Hg at 20° geomagnetic latitude north. Since this could be accounted for in terms of the asymmetry in the penetrating component measured near sea level, it was concluded that there was no asymmetry in the soft component and hence that the soft component was due to equal numbers of primary positive and negative electrons. The penetrating component was identified as arising from primary protons.

Janossy and Nicolson[2] agree with this conclusion reached by Johnson, namely that the absence of a large east-west effect at high altitudes argues for two different kinds of primary particles at the equator.

The east-west effect in the penetrating component at intermediate latitudes and altitudes has recently been measured by Schein, Yngre, and Kraybill.[3] In the geomagnetic latitude range 27°–31° north, they report an asymmetry at 45° zenith angle of 0.46 ± 0.07, at a pressure altitude of 34,500 feet, in the particles that can penetrate 22 cm of lead.

In the experiment here reported the asymmetries in both the hard and soft components were measured. The telescopes were the same as used previously by us,[4] except the extreme angles were changed to include $\pm16°$ in zenith angle and $\pm20°$ in azimuth. Counting rates at the vertical with no absorber were about 500 per minute at the equator at an atmospheric pressure corresponding to 3.10 m of water (32,000 feet). The experiment was performed at approximately 0° geomagnetic latitude and 76° west geographic longitude.

Table I gives a summary of the results at 45° zenith angle. The counting rate has been corrected for dead time of the counters, accidental counts, and for side showers. An indication of the magnitude of the shower correction was obtained by displacing the center tray of counters out of line. A detailed account of these corrections will be published elsewhere.

The following conclusions are drawn from the data in Table I: (a) That at these altitudes the west excess in the total radiation is nearly as large as in the penetrating component. (b) That the percentage asymmetry is increasing with altitude. The fact that the percentage west excess is greater for the more penetrating radiation together with the fact that it decreases with decreasing altitude may be due to scattering suffered by the lower energy particles.

More complete data at the higher altitude were taken. The percentage west excess as a function of zenith angle with and without lead absorber is plotted in Fig. 1. This brings out quite clearly the near equality in the asymmetry of the penetrating and soft components.

The conclusion to be drawn is, that as far as these experiments are concerned, it is not necessary to assume a different primary particle to account for the penetrating and soft components at the equator and that it is quite likely that only one kind of incident, positively charged particle will suffice.

TABLE I. East-west asymmetry over Peru, zenith angle 45°.

M of water equivalent	Thickness of Pb absorber	West excess* (%)
3.1	0	23.3 ± 1.1
	10	27.6 ± 1.3
	20	30.4 ± 1.5
2.35	0	29.1 ± 1.4
	10	33.0 ± 1.6
	20	35.4 ± 1.7

* Computed from the difference between west and east divided by the average.

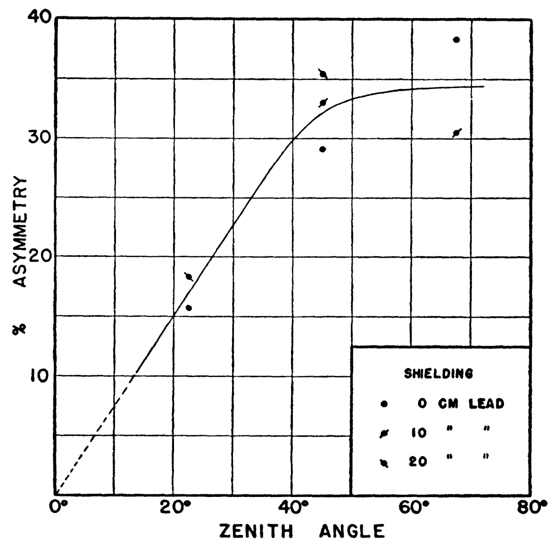

FIG. 1. The west excess in percent as a function of zenith angle with and without lead absorber.

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** Data of 2.35 m of water and zenith angle of $22\frac{1}{2}°$ are missing for 10 cm of Pb and at $67\frac{1}{2}°$ for 20 cm of Pb because of lack of time.

[1] T. H. Johnson and J. G. Barry, Phys. Rev. **56**, 219 (1939).
[2] L. Janossy and P. Nicolson, Proc. Roy. Soc. **192**, 99 (1947).
[3] M. Schein, V. H. Yngre, and H. L. Kraybill, Phys. Rev. **73**, 928 (1948).
[4] Biehl, Montgomery, Neher, Pickering, and Roesch, Rev. Mod. Phys. **20**, 353 (1948).

The Double-Surface Transistor

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IN a series of Letters to the Editor[1] appearing in a recent issue of this journal, there are described the physical construction and proposed theory of operation of a solid state semiconductor triode. This device, which is now called the type *A* transistor, comprises a block of high back-voltage germanium on one of the faces of which are two contacts, side by side with each other and close together. These contacts are called the emitter and collector, respectively. A large area contact to the opposite face of the semiconductor block is called the base contact.

The present communication describes another semiconductor triode, the double-surface transistor, in which the emitter and collector contacts bear on the two opposite faces of a thin wedge or slab of semiconductor. This slab is