parts, the half of the track near the star has 10 gaps while the other half of the track has 18 gaps. This variation in the gap density further indicates that the particle which produced the track traveled toward the star. Aside from the characteristics of the track itself, the observable energy release in the star cannot be explained if track 4 is assumed to be due to a slow negative π-meson. The gap density, δ-rays and multiple scattering along track 4 make it quite certain that the track was produced by a slow meson whose mass was less than that of a proton and which traveled toward the star; therefore, it seems probable that the meson was a negatively charged τ- or κ-meson, of which several examples of the positively charged mesons have been observed recently.[1-6] From the grain density and the point scattering along the track, it would seem reasonable to assume that track 1 is due to a π-meson with a kinetic energy of the order of the rest energy. Assuming that track 1 was produced by such a π-meson, track 2 by a π-meson and track 3 by a proton, the vector sum of the momentum of the charged particles from the star is 160 Mev/c, which corresponds to the momentum of a neutron of about 11 Mev energy. The total kinetic energy of all the charged particles observed plus the rest energy of the two mesons is less than the rest energy of a τ-meson or κ-meson It is then concluded that the event is an example of the nuclear capture of a negative τ- or κ-meson where two mesons and one heavy particle are ejected plus one or more neutral particles and possibly a recoil or a low energy electron.

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† AEC Postdoctoral Fellow.
[1] Brown, Camerini, Fowler, Muirhead, Powell, and Ritson, Nature **163**, 82 (1949).
[2] J. B. Harding, Phil. Mag. **41**, 405 (1950).
[3] C. O'Ceallaigh, Phil. Mag. **42**, 1032 (1951).
[4] Fowler, Menon, Powell, and Rochat, Phil. Mag. **42**, 1040 (1951).
[5] P. E. Hodgson, Phil. Mag. **42**, 1060 (1951).
[6] L. LePrince-Ringuet, Revs. Modern Phys. **21**, 42 (1949), and private communications.

Angular Distributions of the Be^9+D Neutrons†

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NEUTRONS from $Be^9(d, n)B^{10}$, B^{10*} were observed at six angles between 15° and 140°, by means of recoil proton tracks in 100-micron Ilford C-2 nuclear plates. A thin Be target (0.1 mg/cm²), supported by 1/64-inch copper backing, was bombarded by 0.94-Mev deuterons focused on a target spot 1/8-inch in diameter. The nuclear plates were mounted 5 cm from the target inside a large paraffin-lined target chamber, with the target spot in the plane of each emulsion.

Recoil proton tracks were measured under oil immersion (40× objective, N.A. 1.00), using acceptance criteria similar to those adopted by others.[1] Angular distributions obtained for five neutron groups are shown in Fig. 1. Using a standard range-energy curve[2] the ground state Q was calculated to be 4.44 Mev, and excitation energies in B^{10} for the other groups are 0.76, 1.78, 2.22, and 3.68 Mev. It is estimated that these numbers are good ±0.05 Mev, aside from possible errors in the range-energy relation. The agreement with neutron data of Ajzenberg[3] and gamma-ray data of Rasmussen *et al.*[4] is satisfactory.

As shown in Fig. 1, each angular distribution shows some evidence for a forward peak, suggestive of the stripping process. In particular, the lowest energy neutron group ($E_x=3.68$ Mev) can be fitted remarkably well by a curve calculated from the theory of Butler[5] for $l_p=1$. Curves for $l_p=0$ and 2 are included for comparison. The effect of the low deuteron energy in broadening and separating the peaks corresponding to different values of l_p is quite evident.

The other four distributions show an increasing yield in the backward quadrant, similar to distributions observed in the $Be^9(d, p)Be^{10}$, Be^{10*} reaction.[6] At higher bombarding energies,

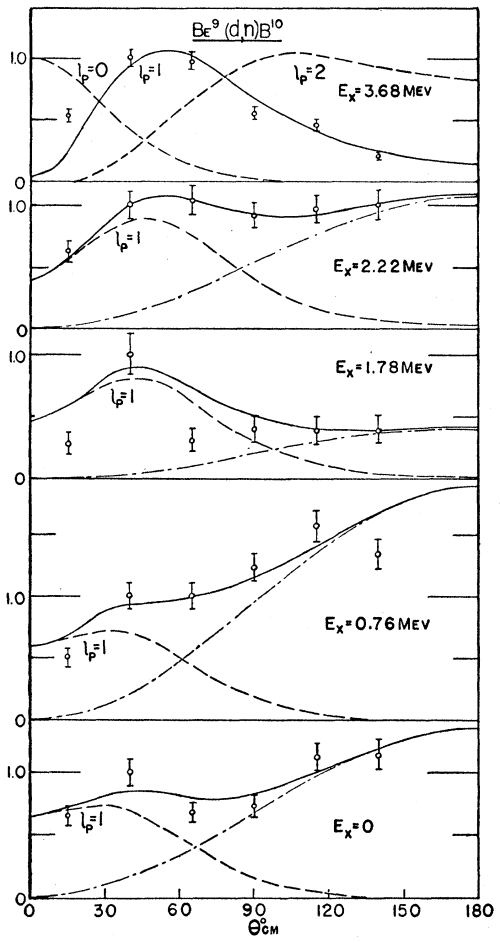

FIG. 1. Angular distributions in the center-of-mass system of neutrons from $Be^9(d, n)B^{10}$, B^{10*}. E_x=excitation energy of B^{10}. Dashed curve=stripping curve for the value of l_p shown. Dash-dot curve=$(1-\cos\theta)$. Solid curve=sum.

departures from the theoretical stripping curves have generally been attributed to compound nucleus formation. At low bombarding energies, the compound nucleus undoubtedly plays an important if not a predominant role. Accordingly, we have attempted to analyze the observed distributions into two parts: one attributed to the stripping process, the other to compound nucleus formation. In view of the uncertainties in the measurements and the fact that the theory used[5] does not take into account the Coulomb barrier, which is certainly important at low bombarding energy, we have not attempted a detailed analysis. A simple $(1-\cos\theta)$ curve added to the $l_p=1$ stripping curve gives a reasonable fit to most of the data. (It should be mentioned that statistics were extremely poor for the group at $E_x=1.78$ Mev.) Such a distribution is typical of strong interference between waves of opposite parity and low angular momenta in the compound nucleus process.

Diesendruck[7] has made a similar analysis of the distribution of long-range protons from $Be^9(d, p)Be^{10}$ for deuteron energies of 1 to 3 Mev. The assignment of $l=1$ in these (d, n) and (d, p) reactions is confirmed by observations[8] at higher bombarding energies where the stripping process is well substantiated. This assignment fixes the parities of the final states as even, if Be^9 is odd, and limits the angular momenta to 0, 1, 2 or 3.

Table I shows the relative "neutron weights" of the 5 states of B^{10} from our thin target data. Also shown for comparison are the "gamma-ray weights" of the excited states from the thick target intensity data of Rasmussen[4] at $E_d=1.2$ Mev, assuming the level

TABLE I. Relative weights of B^{10} states.

E_x	Neutron weight	Gamma-ray weight A	Gamma-ray weight B
3.68 Mev	26	21	21
2.22	24	31	23
1.78	7	17	25
0.76	43	31	31
Total, excited states	100	100	100
0.00 (ground state)	38	—	—

scheme suggested by Ajzenberg.[3] In "A" the 410-kev gamma is assigned to a transition between the 2.22- and the 1.78-Mev states; in "B" the 410-kev gamma is omitted from the scheme. The agreement is somewhat better under assumption "A."

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[1] Johnson, Laubenstein, and Richards, Phys. Rev. **77**, 413 (1950).
[2] Lattes, Fowler, and Cuer, Proc. Phys. Soc. (London) **A59**, 883 (1947); N. Nereson and F. Reines, Rev. Sci. Instr. **21**, 534 (1950).
[3] F. Ajzenberg, Phys. Rev. **82**, 43 (1951).
[4] Rasmussen, Hornyak, and Lauritsen, Phys. Rev. **76**, 581 (1949); V. K. Rasmussen (private communication).
[5] S. T. Butler, Proc. Roy. Soc. (London) **A208**, 559 (1951).
[6] I. Resnick and S. S. Hanna, Phys. Rev. **82**, 463 (1951); F. L. Canavan (to be published).
[7] L. Diesendruck (private communication).
[8] F. A. El-Bedewi, Proc. Phys. Soc. (London) **A65**, 64 (1952); F. Ajzenberg, Phys. Rev. **87**, 205 (1952); C. F. Black, Phys. Rev. **87**, 205 (1952).

Thermoluminescence and Changes of Color Centers in LiF

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PRINGSHEIM and Yuster[1] have reported that on warming LiF, x-rayed at low temperature the emission of a blue glow peak and disappearance of an absorption band, 3400A both take place at −135°C. They have observed that the x-rayed sample left at room temperature shows a blue color due to an absorption band at 6200A. In the course of time, this band gives place to an absorption band at 4450A. In the present work their observations with a single crystal have been confirmed by using powdered LiF colored with 10-kv cathode-rays at liquid oxygen temperature. The sample was prepared by double decomposition of LiCl (Merck) and NH_4F in the laboratory.

By employing a high[2] rate of heating, some new glow peaks have been recorded [continuous curve (a)]; it is seen that the peak at −135°C is not single but consists of two peaks at −142°C and −130°C. If heating is not stopped at room temperature, a broad glow peak is given out at about 400°C, which to the naked eye appears to be richer in light of longer wavelengths (yellow-red). The blue color of the sample changes now to yellowish-brown, obviously due to a shift of the absorption band. The sample then becomes red luminescent under blue light irradiation. Klick[3] has assumed this to be due to absorption at the M-band, but Pringsheim[4] has assigned the red luminescence to the new band that develops from the 6200A band. The broken curve (b) of Fig. 1 shows the change in absorption centers taking place at about 400°C. To get it, LiF bombarded at room temperature was irradiated with faint blue light (tungsten lamp across glass filter transmitting shorter wavelengths than 5100A), and the scattered light was received by a photomultiplier tube. The sample was heated as in the thermoluminescence experiment. The curve gives a measure of the scattered blue light at different temperatures. As heating is increased, the sample begins to give a faint glow peak at 400°C or so, and the amount of scattered blue light is now diminished. This shows increased absorption of blue light due to a shift of the original absorption band.

The curve (c) shows similarly the appearance of red fluorescence at 400°C. A sample bombarded at liquid oxygen temperature was irradiated with blue light, and a photomultiplier (1P22) tube with red filter (transmitting between 6070A and the red end) in front

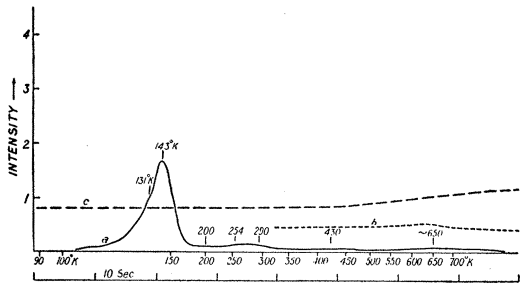

FIG. 1. The continuous curve (a) gives the thermoluminescence record of LiF excited with cathode rays at liquid oxygen temperature. The curve (b) gives a measure of the blue light scattered by LiF during heating of a sample colored at room temperature. The rise at 650°K in this curve indicates the last thermopeak, and thereafter the slight fall of the smooth curve indicates creation of an absorption band in the blue region. The curve (c) gives a measure of red light received from the sample when it was irradiated with blue light. The rise in the curve at 650°K shows that the sample at this temperature becomes red luminescent under blue light. The curve (c) was recorded simultaneously with the curve (a) in the same run of thermoluminescence experiment.

of its cathode received scattered light from the sample, passing through the filter. The sample was heated, and a record of the red light from the sample was made. The rise in the curve shows that at this temperature the sample has become red luminescent under blue light excitation.

If the coloration of the sample is done at low temperature, this change to red luminescence takes place at 400°C, but if the coloration is done at room or higher temperature the transition temperature becomes still higher.

During bombardment at low temperature the sample fluoresces blue under cathode-rays, but intense bombardment makes the sample red luminescent in a short time. Thus the red luminescence, which is excitable in the bombarded sample by blue light can also be developed to some extent, by intense bombardment at low temperature. Apparently this luminescent center is formed by an aggregate of primary centers.

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[1] P. Pringsheim and P. Yuster, Phys. Rev. **78**, 293 (1950).
[2] J. Sharma, Phys. Rev. **85**, 692 (1952).
[3] C. C. Klick, Phys. Rev. **79**, 894 (1950).
[4] See footnote 5 of reference 3.

A Theory of Contact Noise

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CURRENT flow across a contact difference of potential such as exists in rectifiers and transistors is of the form:

$$i=R(T, E, U)\exp(-E/kT)[1-\exp(-eU/kT)], \qquad (1)$$

where E is the height of the energy barrier that exists because of the equalization of the Fermi levels of the two "materials" making up the contact (the "materials" may be of the same bulk nature as in a $P-N$ junction in germanium), U is the applied potential, and R is a slowly varying function of T, E and U.

The physical basis for the exponential dependence of the current on E is that the current is determined primarily by the number of electrons in the "neighborhood" of the contact with thermal energy greater than E. This number is independent on the temperature of the lattice and electrons in the "neighborhood" of the contact. We will not in this note attempt to define the size of the "neighborhood" whose temperature determines the current flow except to say that it is certainly larger than the mean free path for electron-lattice scattering.