Re-Measurement of the Energies Released in the Reactions Li^7 (p, α) He^4 and Li^6 (d, α) He^4

The energies released in the reactions Li^7 (p, α) He^4 and Li^6 (d, α) He^4 were measured in 1935 by Oliphant, Kempton, and Rutherford.[1] They used a variable pressure air absorption tube which was calibrated with the precisely measured natural alpha-particles from ThC'. They obtained 17.06 ± 0.06 Mev for the Li^7 reaction and 22.06 ± 0.07 Mev for the Li^6 reaction. These values, slightly revised by Livingston and Bethe,[2] have been used by Allison,[3] together with the precise results on the beryllium-proton reactions, obtained by electrostatic analysis,[4,5] to set up masses for several of the lightest atoms.

Recently Bethe[6] has reinterpreted the 1935 Cavendish result on Li^6, raising it to 22.21 Mev, and Oliphant[7] has stated that the correct value may well lie outside the limits specified in the Cavendish result.

We have therefore repeated the earlier work, using an absorption cell in much the same manner. The use of thin collodion windows on the cell instead of mica, the use of thin instead of thick targets, and the prevention of the formation of oil films on the targets differentiated our work from the earlier attempts. Also the higher voltage available for the bombarding beam gave higher yields of disintegration particles and made possible the use of smaller apertures through which they were counted. Several runs were made on different targets of LiF for a period extending over several weeks. In the case of Li^6 a separated target produced in the mass spectrograph by L. H. Rumbaugh was used and gave results no different from the LiF targets. We obtained 17.28 ± 0.03 Mev for the Li^7 reaction and 22.20 ± 0.04 for the Li^6 reaction.

These new values may now be used in connection with our electrostatic analyzer results to give $Li^6=6.01682\pm0.00011$, $Li^7=7.01784\pm9$, $Be^8=8.00766\pm15$, $Be^9=9.01486\pm13$. These are based on the usual values of H, D and He^4.

Our results confirm Bethe's revision of the Li^6 reaction energy release, and our masses agree closely with those of Bethe-Barkas.[8] The question of the stability of Be^8 is now undecided by these masses, but on the Gamow theory of alpha-particle decay we may predict a minimum lifetime of 10^{-16} second for this nucleus.[9]

A detailed account of this investigation is being submitted for publication by one of us. The progress of this work was greatly aided by a grant from the American Philosophical Society.

SAMUEL K. ALLISON
LESTER S. SKAGGS
NICHOLAS M. SMITH, JR.

Ryerson Physical Laboratory,
University of Chicago,
Chicago, Illinois,
July 13, 1939.

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Investigation of Boron by Slow Neutrons

A cloud chamber investigation[1] of the B^{10} (n, α) disintegration appeared to indicate an asymmetrical distribution with respect to the plane perpendicular to the incident neutron direction. In these preliminary observations only 75 disintegrations were observed, of which 45 occurred in the forward direction and 30 in the backward. A fuller investigation has now been made by means of an ionization chamber, and the results demonstrate that the distribution is symmetrical.

W. E. GOOD
R. D. HILL

Department of Physics,
University of Illinois,
Urbana, Illinois,
July 5, 1939.

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Disintegration of Deuterium by Protons and p-n Reactions in Light Gaseous Elements

Neither of the homologous reactions,

$$H^1+H^2\rightarrow 2H^1+n^1, \quad (1)$$

$$n^1+H^2\rightarrow H^1+2n^1, \quad (2)$$

have heretofore[1] been observed, in spite of the importance to be attached to such simple disintegrations which may be treated theoretically with considerable rigor, and consequently may provide additional information concerning nuclear interactions.

The binding energy of the deuteron[2] is 2.17 Mev and therefore the threshold of the reactions (1) and (2) should be reached with protons or neutrons of 3.25 Mev. The present report is to record an experiment designed to detect reaction (1).

A chamber was constructed so that gases could be used as targets for the proton beam from the Princeton cyclotron. The lead lining of the chamber was electrically insulated so that it could also be used as a Faraday collector for the protons which entered through a one-mil aluminum window. Steps were taken to minimize the neutron background caused by bombardment of internal parts of the cyclotron itself. Neutrons generated by disintegrations in the chamber were slowed down in paraffin and measured with a silver detector. Observations were taken when the target was deuterium under one atmosphere pressure, and also normal hydrogen under the same conditions. With the normal hydrogen in the chamber the average initial activity of the detector was 0.238 ± 0.004 div./sec. per microampere. When the chamber contained deuterium the activity was 0.623 ± 0.004 div./sec. per microampere.

With the same geometrical arrangement the neutrons produced in O_2, N_2, CO_2 and A, at one atmosphere pressure in each case, were also observed. Some experiments on the efficiency of the collector in the presence of the various gases indicated that in some cases the apparent proton current was affected somewhat by ionization in the gas. Except for the isotopes of hydrogen the comparison between gases can therefore be only semi-quantitative. Consequently it can only be said that from O_2, N_2 and C the neutron emission is

considerably less than from D_2, the neutrons presumably coming from p, n reactions in the rare isotopes. From argon the neutron emission is larger, about the same as from D_2, giving evidence for the reaction A^{40} (p, n) K^{40}.

We may estimate the absolute cross section for the reaction (1) using the observed ratio of neutrons from deuterium to those from oxygen. DuBridge *et al.*[3] have obtained the absolute cross section and excitation function for O^{18} (p, n) F^{18} at somewhat lower energies than those used in these experiments. We have obtained a rough excitation curve for the reaction at higher energies and have joined this smoothly to the curve obtained by the authors cited. We are thus able to obtain the absolute cross section by referring to this curve. For protons of 5.1 Mev the cross section is found to be about 1.4×10^{-26} cm^2. However, because of the uncertainties involved in the estimate, only the order of magnitude of the cross section can be said to be known with certainty.

This cross section is too large to be accounted for by a secondary process, *viz.* H^2 (H^2, n^1) He^3, which takes place when elastically recoiling deuterons traverse the deuterium gas.

Princeton University,
Princeton, New Jersey,
July 12, 1939.

WALTER H. BARKAS*
MILTON G. WHITE

* Member, The Institute for Advanced Study, Princeton, New Jersey.
[1] See, however, Lewis *et al.*, Phys. Rev. **45**, 242 (1934), **45**, 497 (1934).
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[3] DuBridge, Barnes, Buck and Strain, Phys. Rev. **53**, 450 (1938).

X-Ray Fluorescing Coefficient and the Orientation of a Zinc Crystal

The intensity of the diffuse scattering of x-rays from an anisotropic crystal such as zinc is a function of the orientation angle ψ, which is the angle that the line bisecting the angle between the forward direction of the scattered rays and the backward direction of the incident rays makes with the c axis. So also is the intensity of a Bragg reflection from zinc a function of this angle ψ. The variation in both cases is due (a) to the anisotropy in the thermal vibrations of the atoms in the crystal and (b) to the distortion of the electron cloud around the atom. It seemed worth while to test whether the fluorescence coefficient might also be a function of ψ.

Approximately monochromatic rays ($\lambda=0.71$A) were obtained by passing x-rays from a molybdenum target tube through a zirconium filter. These rays fell at a glancing angle θ on the surface of a zinc crystal and the intensity of the secondary rays was measured in the direction ϕ by means of an ionization chamber and electrometer. The secondary rays consisted of fluorescent and scattered rays, the former being much more intense than the latter. We tested the intensity from a (0002) face ($\psi=0°$) of a crystal and compared this with the intensity from a $(10\bar{1}0)$ face ($\psi=90°$) of a second crystal. With $\phi=60°$, θ was given values between 20° and 40°; with $\phi=40°$, θ was given values between 12° and 28°. In order to separate the fluorescent rays from the scattered rays (including a possible small Bragg reflection at $\theta=\phi/2$), a thickness 0.025 cm of aluminum was transferred from the primary beam to the secondary beam. When in the secondary beam, this thickness cuts out practically all of the fluorescent radiation. Subtraction of the intensity reading when the aluminum is in the secondary beam from that when it is in the primary beam gives the intensity due to the fluorescent rays. In all cases we found that $(I_\phi, \theta)_{\psi=0°} = (I_\phi, \theta)_{\psi=90°}$ to within one percent.

We next passed θ through the value 8°15′, which is the position for first-order reflection of $\lambda=0.71$A from the (0002) planes. We thought that, due to extinction coming into play, there perhaps would be a change in the intensity of the fluorescent rays at $\theta=8°15'$. We found no such change.

We finally conclude that the coefficient of x-ray fluorescence (K characteristic rays) is not a function of the orientation of an anisotropic crystal such as zinc.

O. J. BALTZER
G. E. M. JAUNCEY

Wayman Crow Hall of Physics,
Washington University,
St. Louis, Missouri,
July 3, 1939.

Superstructure in Fe Ni_3

In a paper just published Leech and Sykes[1] report the detection by x-rays of superstructure in Fe Ni_3 in specimens which had been heated at 490°C, for times from 50 to 150 hours, and cooled very slowly to 370°C. In some previous experiments[2] I was unable to find superstructure in this alloy after heating at 425°C for 100 hours. I have made another test in which a specimen containing 73.8 percent nickel was heated at 490°C for six days and then cooled to 440°C in fourteen days. This specimen gave superstructure lines with sixteen hours' exposure to x-rays, thus confirming the results of Leech and Sykes.

Sykes and Jones[3] have shown that, when a quenched specimen of the alloy Cu_3Au is heated, lowering of resistance first occurs at the same temperature at which ordering becomes sufficient to be detected by x-rays. It is interesting to point out that this is apparently not the case for Fe Ni_3; Dahl[4] has reported that with heat treatments of one hour duration the resistance of the quenched alloy begins to decrease at about 250°C and that of the hard-worked alloy at 100°C, both reaching a minimum resistance at 425°C. My first x-ray experiments upon Fe Ni_3 in which order was not detected were made upon specimens heated at 425°C, to coincide with this minimum point. The specific heat curve given by Leech and Sykes for quenched specimens of Fe Ni_3 begins to show its first dip due to partial ordering at about 360°C with a minimum at 425°C, and it is possible that slower heating might lower both of these temperatures considerably. These data indicate that most of the decrease of resistance upon heating is due to order over distances too short to be detected by x-rays, although it is not clear that the effect in the cold-worked alloy can be entirely accounted for in this manner.

F. E. HAWORTH

Bell Telephone Laboratories,
New York, New York,
June 30, 1939.

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