effect for such molecules. Unfortunately the measurement and reduction of the plates cannot be begun immediately, but a few qualitative facts may be mentioned which are apparent from an inspection of the plates and enlargements.

In the spectrum of NH_3 reported by the writer in this issue of the *Physical Review*, four v' progressions in different electronic states were found. It appears that the analogs of three of these are present in the ND_3 spectrum. The three 0,0 bands of ND_3 almost coincide with the corresponding bands of NH_3, as would be expected. This may be regarded as additional evidence for the correctness of assignment of the 0,0 bands in NH_3. The fact that none of the other strong band heads and subbands of ND_3 coincide with those of NH_3 is additional confirmation of the high purity of the ND_3. The identification of all the weaker absorption requires, of course, a detailed examination, and some of it may prove to be due to NH_2D and ND_2H or even NH_3.

The strong bands in progressions II and III of ND_3 show differences of about 780 and 760. These were very crudely estimated, but appear to be upper state modifications of $\nu_1(745,748)$.[1] The predissociation in progression I appears to start at about the same point in ND_3 as in NH_3.[2] The bands in progressions II and III are very sharp in ND_3 as in NH_3. The rotational fine structure visible in NH_3 is not apparent in ND_3. If the moments of inertia are much larger in ND_3, this may be due to a lack of resolving power. The presence of NH_2D and ND_2H may cause a continuous background also, obscuring the lines of ND_3. This latter effect, if present, does not affect the sharpness of the heads. The subbands are all shaded to the red, as was observed in NH_3.

I am greatly indebted to Professor H. S. Taylor for furnishing the sample of ND_3 which made this work possible.

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May 15, 1935.

[1] E. F. Barker and Marcel Migeotte, Phys. Rev. **47**, 702 (1935).
[2] The measurements of Dr. W. S. Benedict (Phys. Rev. **47**, 641 (1935)) in this region, which were not available to the writer, will no doubt provide a more accurate value of the predissociation limit.

The Emission of Negative Electrons from Boron Bombarded by Deuterons

In March, 1935, Professor E. O. Lawrence and Dr. R. L. Thornton informed us, in conversation, that they had obtained some evidence indicating the emission of negative electrons of very high energy from boron bombarded with deuterons, and suggested that they might arise from the reaction

$$B^{11}+H^2 \rightarrow B^{12}+H^1 \rightarrow C^{12}+e^-+H^1. \quad (1)$$

We have since carried out an investigation of this question, by means of a cloud chamber, and have found such beta-ray emission. Because of the fact that the beta-ray emission does not persist for an appreciable length of time after bombardment, it was necessary to make the observations during bombardment. The experiment was performed in the following way.

A thin walled tube containing the boron (metal) target was constructed so as to project into the cloud chamber through the glass top plate, near one side of the chamber. Of the useful 180° of the target tube, a section extending around 90° was made thin enough to allow the escape of the protons belonging to the 92-cm group, which is known to result from boron bombarded with deuterons.[1] The other 90° section was about three times that thickness, and allowed only electrons to pass. Ample intensity was obtained by running at 550 kv and about ½ microampere deuteron current to the target. The electron tracks were curved by a magnetic field of 1500 gauss, to determine their energy.

Electron Spectrum

In Fig. 1 is shown the energy spectrum obtained from the measurement of 1773 electron tracks. As is evident from the plot, the spectrum is continuous, and similar in form to the usual beta-ray spectrum. The upper energy limit, after adding 0.65 MEV to compensate for the stopping power of the tube surrounding the target, is

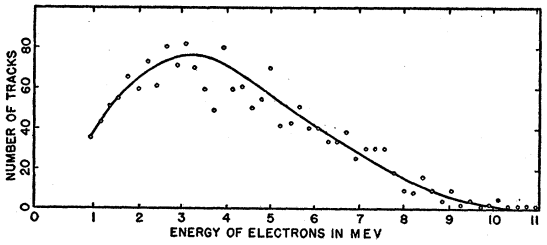

FIG. 1. Energy spectrum of negative electrons from the radioactive isotope B^{12}. To obtain the true energy, 0.65 MEV must be added to compensate for the stopping power of the wall surrounding active substance.

about 11 MEV. The position of the maximum in the curve is not to be taken seriously, since the geometrical conditions of the experimental set-up were such as to favor, to some extent, the lower energy electrons.

Protons

In order to compare the intensity of beta-ray emission with that of some other particle emitted under the same conditions we made a relative count of electrons and 92-cm protons, which were seen to emerge from the thin portion of the target tube. About 20 electrons were observed per proton of the 92-cm group. If we suppose that the beta-rays arise from reaction (1), the proton group associated with the beta-ray emission must necessarily be about 20 times as intense as the 92-cm group. Further, it is known from Cockroft's work that no group of that intensity exists above 10 cm range (2.5 MEV). We may therefore place an upper limit of 2.5 MEV on the energy of the proton in reaction (1).

Energy Balance

The energy release in the reaction

$$B^{11}+H^{2}\rightarrow C^{12}+n^{1} \qquad (2)$$

obtained from measurements of the maximum neutron energy,[2] is about 13 MEV. Eliminating between this and reaction (1), we see that

$$B^{12}\geq C^{12}+11 \text{ MEV}.$$

The conclusion to be drawn from this is that B^{12}, in disintegrating, loses an amount of mass not less than that corresponding to the *upper limit* of energy of the electron spectrum. The large energy involved in the electron spectrum and the fact that only the mass difference between n^1 and H^1 is made use of, place this conclusion well beyond the limits of experimental error, provided only that the reactions assumed are correct. This result has an important bearing on the neutrino hypothesis and the question of the validity of the principle of the conservation of energy in relation to beta-decay. A similar conclusion has already been reached by Henderson,[3] from a very precise, but less direct, experiment, namely a comparison of the change of energy around the two branches of the Th C to Th D sequence.

Comparison with Gamma-Ray Intensity

We have made a rough comparison of the intensities of beta-rays and of gamma-rays[4] by arranging the target and chamber so that enough paraffin could be interposed to absorb all the beta-rays. The number of beta-ray tracks was found to be about 10 times the number of tracks due to gamma-rays alone. Allowing for a factor of the order of magnitude 100 for the conversion of gamma-rays to recoil electrons in the chamber, we may conclude that the gamma-ray intensity is about 10 times the beta-ray intensity. From other observations[5] it appears that the rate of formation of B^{12} is somewhat greater than that of C^{11} (positron emitter of 20 min. half-life).

By means of an automatic timing device we were able to switch the ion current off a known length of time before each expansion of the chamber. Two runs of 100 pictures each were made, with the ion current stopped 1/25 and 2/25 seconds before the expansion. A total of about 1500 tracks was obtained in the first case, and about one-fourth that number in the second case, indicating a half-life of about 1/50 second for the active constituent.

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May 15, 1935.

[1] Cockroft and Walton, Proc. Roy. Soc. **A144**, 704 (1934).
[2] Bonner and Brubaker, unpublished.
[3] Henderson, Proc. Roy. Soc. **A147**, 572 (1934).
[4] Crane, Delsasso, Fowler and Lauritsen, Phys. Rev. **46**, 1109 (1934).
[5] Lauritsen and Crane, Phys. Rev. **45**, 493 (1934).

Thermal Equilibrium of Slow Neutrons

The question, first attacked by Fermi, of whether the "slow" neutrons, which are so effective in producing nuclear transformations and have such anomalous absorption coefficients, approximate ordinary thermal velocities is of fundamental importance. Following our earlier experiments[1] we have investigated further the effect on the properties of the slow neutrons of the temperature of the hydrogen containing material used to slow them down. Fig. 1 shows the general arrangement used. The Rn-Be

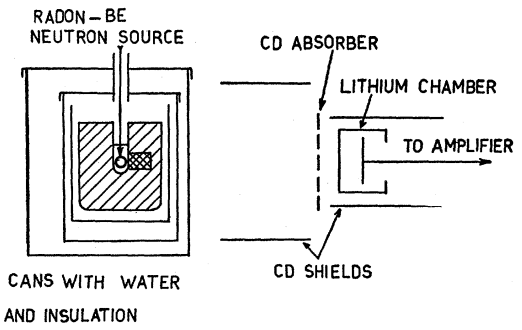

Fig. 1.

neutron source in a Pt container was placed in a cylindrical vessel of water which was inside several thin concentric polished cans to permit cooling to liquid air temperatures and also heating to the boiling point. The neutrons, after being slowed down by impacts with hydrogen nuclei, were detected through the ionizing particles ejected from Li, by means of an ionization chamber-amplifier system and thyratron recorder. In the first series of runs, the chamber had a Li front only; in the second series, runs 4 and 5, the chamber walls and collector were entirely of Li, resulting in much higher efficiency, and reducing the fraction of counts caused by high energy neutrons not highly absorbed by Cd from about 35 to 11 percent. In runs 1, 2 and 3, the Rn-Be bulb was at the same temperature as the water. Since it was found in a test that by cooling the bulb alone, the different modes of condensation of the radon at the low temperatures could produce increases in the number of recorded neutrons of the order of 3 to 8.6 percent, in the runs 4 and 5 the source with a thermocouple and heater was placed inside a soft glass Dewar and the bulb itself held at room temperature. In runs 1 and 2, the inner vessel was one of Cu containing 1100 g of H_2O. In runs 3, 4 and 5, a larger thin Al vessel containing 3400 g of H_2O was used, an amount sufficient to produce nearly the maximum number of slow neutrons. Cd shields were also introduced in the last two runs, as shown in Fig. 1, to reduce room scattering.

Table I shows the results of 5 runs in terms of the percentage change in the number of counts observed (chiefly from Li), and the percentage change in the absorption of Cd as the temperature was lowered from 373° to about 95°K in the first group, and 273° to about 95°K in the second