## The Disintegration of Nitrogen by Slow Neutrons

The disintegration of nitrogen by slow neutrons was attributed independently by Chadwick and Goldhaber[1] and by ourselves[2] to the reaction

$$_7N^{14}+{}_0n^1\rightarrow{}_5B^{11}+{}_2He^4+Q_1. \qquad (1)$$

However, the value of $Q_1$ obtained by Chadwick and Goldhaber by an ionization method was 0.5 MEV, while we deduced the value 2.33 MEV from our range measurements of tracks observed in a cloud chamber. Our value was calculated from the 1.06-cm range of the disintegration particles by assuming that the disintegration particles were $B^{11}$ nuclei and alpha-particles. In a private communication Dr. Goldhaber has suggested that this apparent disagreement can be eliminated if we interpret the disintegration in a different way as postulated in the reaction

$$_7N^{14}+{}_0n^1\rightarrow{}_6C^{14}+{}_1H^1+Q_2. \qquad (2)$$

The energy of the disintegration $Q_2$ calculated from our range measurements then becomes $0.58\pm0.03$ MEV which agrees with Chadwick and Goldhaber's ionization value. We have now found another reason why the former interpretation is impossible. We have just measured the energy released in the reaction

$$_5B^{11}+{}_1H^2\rightarrow{}_6C^{12}+{}_0n^1+Q_3 \qquad (3)$$

and found $Q_3$ to be $13.5\pm0.3$ MEV.[3] Combining this result with that of Cockcroft and Lewis[4] in their investigation of the reaction

$$_7N^{14}+{}_1H^2\rightarrow{}_6C^{12}+{}_2He^4+Q_4 \qquad (4)$$

one obtains $Q_1=Q_4-Q_3=-0.28\pm0.3$ MEV.

This is quite different from the value 1.5 MEV which was calculated from Bethe's masses and which appeared to agree fairly well with the value 2.33 MEV. However, our value of $Q_1=-0.28$ MEV agrees quite well with the respective values $Q_1=-0.3$ and $Q_1=-0.2$, calculated from the recent list of masses given by Oliphant[5] and by Cockcroft and Lewis.[4] This new value of $Q_1$ necessarily eliminates reaction (1) from further consideration in regard to the 1.06 cm particles resulting from the disintegration of nitrogen by slow neutrons.

Recently McMillan[6] has obtained evidence of a radioactive $C^{14}$ with a half-life of about 3 months and a maximum beta-ray energy of about 0.2 MEV. From reactions (2) and (5)

$$_6C^{14}\rightarrow{}_7N^{14}+e^-+Q_5 \qquad (5)$$

we see that $_0n^1-{}_1H^1=Q_2+Q_5$; hence from these data the mass difference between a neutron and a hydrogen atom appears to be 0.8 MEV. This is in good agreement with Aston's new masses of $_1H^1$ and $_1H^2$, and Feather's binding energy of the deuteron (2.26 MEV).

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[3] To be published in Phys. Rev.
[4] Cockcroft and Lewis, Proc. Roy. Soc. **A154**, 261 (1936).
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## Isotopic Constitution of Strontium, Barium, and Indium

Mass spectrograph analyses have been made of the ions of strontium, barium, and indium, emitted when oxides of these elements are heated on tungsten filaments. Evidence has been obtained for two new isotopes, one of strontium and one of barium. No new indium isotopes were found. The observations reported below have been checked on two different instruments.

In the case of strontium, a peak was observed at mass 84 whose height corresponded to 0.5 percent of the total strontium emission. The masses of the known isotopes of strontium are all greater than 84 so the possibility is excluded that the effect is due to a strontium compound. Since the only known isotope of mass 84 belongs to krypton and the other krypton isotopes do not appear, we believe that this peak is due to a new isotope of strontium. A small impurity of rubidium was present initially but disappeared with continued heating of the filament. The relative abundance of the known strontium isotopes was found to be 9.6 percent of mass 86, 7.5 percent of mass 87, and 82.4 percent of mass 88, differing slightly from the rough values given by Aston.[1] Assuming a packing fraction of −8.2 this gives 87.62 for the atomic weight of strontium, in good agreement with the chemical value of 87.63. A search for other isotopes revealed that masses 82, 83, 85, 89, and 90 were present to less than 1 in 2000, 1 in 1000, 1 in 2000, 1 in 500 and 1 in 2000, respectively.

The curves for barium showed a peak at mass 134 making up 1.8 percent of the total emission. The same considerations which applied in the case of strontium lead us to believe that this is due to a new isotope of barium. Accepting Aston's relative abundance for the known isotopes 135, 136, 137, and 138, and assuming packing fractions of −6.1 we deduce an atomic weight for barium of 137.36 in exact agreement with the international atomic weight. Barium isotopes of masses 132, 133, 139, and 140 were shown to be present to less than 1 in 2000, 1 in 1000, 1 in 400, and 1 in 1000, respectively.

Evidence for the possible existence of a third isotope of indium is given by the observation[2] of three artificially radioactive periods induced in indium by neutron bombardment. However, only two of these periods are water sensitive. Mass spectrograph analyses revealed only the two known isotopes. A search over the mass range from 110 to 119 showed that masses 110, 111, 112, 114, 116, 117, 118, and 119 were present to less than 1 in 5000, 1 in 10,000, 1 in 5000, 1 in 200, 1 in 5000, 1 in 10,000, 1 in 8000, and 1 in 30,000, respectively. The ratio of the abundance of mass 115 to that of mass 113 was found to be $21\pm1$ in agreement with Aston's observation.[3] If we assume a packing fraction of −6 we obtain for indium an atomic weight of 114.81 in agreement with Aston's value. The international atomic weight for indium is 114.76.

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[1] Aston, *Mass Spectra and Isotopes* (Arnold, 1933).
[2] Szilard and Chalmers, Nature **135**, 98 (1935).
[3] Aston, Proc. Roy. Soc. **A149**, 403 (1935).