The Masses of Be^8, Be^9 and B^{11}, as Determined from Transmutation Data

We[1] have investigated the gamma-ray spectrum resulting from the bombardment of Li by H^1. The spectrum is complicated but has a definite maximum at 16 mev = 0.0172 mass units. The intensity of the gamma-radiation increases rather suddenly when the bombarding voltage reaches 600 kv, and decreases again at higher voltage.

This suggests that a large part of the radiation is due to

$$Li^7+H^1\rightarrow Be^8+E_1 \qquad (1)$$

and that the proton is captured on a level, presumably the ground level, in Be^8. It is not likely that any reaction involving Li^6 could yield sufficient energy.

We may equate the right-hand side of this reaction to the right-hand side of the well-known reaction

$$Li^7+H^1\rightarrow 2He^4+E_2 \qquad (2)$$

and solve for the mass of Be^8. From the data given by Oliphant[2] we find $E_2=17.5$ mev = 0.0188 mass unit at 600 kv. This gives

$$Be^8=2He^4+E_2-E_1=8.0043+0.0188-0.0172=8.0059,$$

which is 0.0016 greater than the mass of two alpha-particles. It is, therefore, to be expected that Be^8 will have an extremely short lifetime, splitting up into two alpha-particles, each with an energy of 0.75 mev corresponding to a range of about 0.35 cm.

The first evidence for the existence of Be^8 was obtained by Kirchner[3] who gives 8.0074 for the mass. This determination depends, however, on the value 11.0110 ± 0.0015 for the mass of B^{11} as given by Aston. If, on the other hand, we use our value for the mass of Be^8 we find from Kirchner's data $B^{11}=11.0095$.

Almost the same value for B^{11} is obtained from the reaction

$$B^{10}+H^2\rightarrow B^{11}+H^1+E. \qquad (3)$$

Cockroft[4] has measured four groups of protons and we[5] have determined the gamma-ray spectrum. The agreement is satisfactory and the total energy in the reaction is 9.7 mev = 0.0104 mass unit. Using Bainbridge's value for B^{10}, H^2 and H^1, we get $B^{11}=11.0093$, in good agreement with the above value.

Using the above mass values we may calculate the mass of Be^9 from several well-known reactions. Bonner and Brubaker[6] have recently investigated the energy spectrum of neutrons produced when Be is bombarded by H^2, and have shown that the maximum energy of these neutrons is 4.5 mev$\pm$0.1 mev. Presumably the reaction is

$$Be^9+H^2\rightarrow B^{10}+n^1. \qquad (4)$$

Using the above values and $n^1=1.0080$ (Chadwick), 0.0007 for the kinetic energy of the H^2 and 0.0005 for the kinetic energy of B^{10}, we find

$$Be^9=10.0135+1.0080+0.0048+0.0005-2.0136-0.0007 =9.0125.$$

Dee[7] has observed a singly charged particle of short range from Be bombarded by protons. If we assume that this particle is H^2, the most probable reaction is

$$Be^9+H^1\rightarrow Be^8+H^2. \qquad (5)$$

Using Oliphant's[2] data for the kinetic energy of the H^2 particle and taking the mass of Be^8 to be 8.0059, we obtain

$$Be^9=8.0059+2.0136+0.0008-1.0078-0.0001=9.0124.$$

It should be noted that here the mass of B^{10} is not involved and the agreement therefore constitutes a check on the value 10.0135 for the mass of B^{10} as given by Bainbridge.

Oliphant[2] has observed 26 cm protons when Be is bombarded by H^2. We may assume that the reaction is

$$Be^9+H^2\rightarrow Be^{10}+H^1. \qquad (6)$$

We obtain the mass of Be^{10} from Meitner's[8] observation that Be^{10} is radioactive, changing into B^{10} and a negative electron with 0.3 mev energy. From this we obtain for the mass of Be^9

$$Be^9=10.0135+1.0078+0.0047+0.0003-2.0136-0.0002 =9.0125$$

The excellent agreement among these three determinations of the mass of Be^9 is no doubt to some extent fortuitous, for the probable error is in each case about 0.0005. Nevertheless, we may conclude that the mass of Be^9 is very nearly equal to the sum of the masses of two alpha-particles and a neutron, namely, $8.0043+1.0080=9.0123$.

It is, therefore, not surprising that Be^9 may be disrupted by gamma-rays from radium, as found by Szilard and Chalmers.[9] Our masses of Be^8 and Be^9 lead us to predict that the lowest energy gamma-ray capable of disrupting Be^9 is 1.4 mev, which is the minimum required to produce the reaction

$$Be^9\rightarrow Be^8+n^1.$$

Disintegration into two alpha-particles and a neutron would probably require more energy, because of the mutual potential barrier of two alpha-particles, which is about 2 mev. This is in agreement with the results of Ridenour, Shinohara and Yost,[10] but not in agreement with those of Gentner.[11]

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