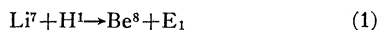


### The Masses of Be<sup>8</sup>, Be<sup>9</sup> and B<sup>11</sup>, as Determined from Transmutation Data

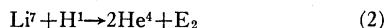
We<sup>1</sup> have investigated the gamma-ray spectrum resulting from the bombardment of Li by H<sup>1</sup>. The spectrum is complicated but has a definite maximum at 16 mev = 0.0172 mass units. The intensity of the gamma-radiation increases rather suddenly when the bombarding voltage reaches 600 kv,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

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



and that the proton is captured on a level, presumably the ground level, in Be<sup>8</sup>. It is not likely that any reaction involving Li<sup>9</sup> could yield sufficient energy.

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



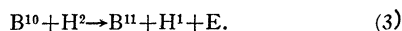
and solve for the mass of Be<sup>8</sup>. From the data given by Oliphant<sup>2</sup> we find E<sub>2</sub> = 17.5 mev = 0.0188 mass unit at 600 kv. This gives

$$\text{Be}^8 = 2\text{He}^4 + \text{E}_2 - \text{E}_1 = 8.0043 + 0.0188 - 0.0172 = 8.0059,$$

which is 0.0016 greater than the mass of two alpha-particles. It is, therefore, to be expected that Be<sup>8</sup> 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.

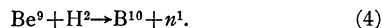
The first evidence for the existence of Be<sup>8</sup> was obtained by Kirchner<sup>3</sup> who gives 8.0074 for the mass. This determination depends, however, on the value 11.0110 ± 0.0015 for the mass of B<sup>11</sup> as given by Aston. If, on the other hand, we use our value for the mass of Be<sup>8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

Almost the same value for B<sup>11</sup> is obtained from the reaction



Cockroft<sup>4</sup> has measured four groups of protons and we<sup>5</sup> 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<sup>10</sup>, H<sup>2</sup> and H<sup>1</sup>, we get B<sup>11</sup> = 11.0093, in good agreement with the above value.

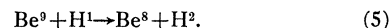
Using the above mass values we may calculate the mass of Be<sup>9</sup> from several well-known reactions. Bonner and Brubaker<sup>6</sup> have recently investigated the energy spectrum of neutrons produced when Be is bombarded by H<sup>2</sup>, and have shown that the maximum energy of these neutrons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



Using the above values and n<sup>1</sup> = 1.0080 (Chadwick), 0.0007 for the kinetic energy of the H<sup>2</sup> and 0.0005 for the kinetic energy of B<sup>10</sup>, we find

$$\text{Be}^9 = 10.0135 + 1.0080 + 0.0048 + 0.0005 - 2.0136 - 0.0007 = 9.0125.$$

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

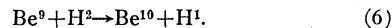


Using Oliphant's<sup>2</sup> data for the kinetic energy of the H<sup>2</sup> particle and taking the mass of Be<sup>8</sup> to be 8.0059, we obtain

$$\text{Be}^9 = 8.0059 + 2.0136 + 0.0008 - 1.0078 - 0.0001 = 9.0124.$$

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

Oliphant<sup>2</sup> has observed 26 cm protons when Be is bombarded by H<sup>2</sup>. We may assume that the reaction is

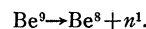


We obtain the mass of Be<sup>10</sup> from Meitner's<sup>8</sup> observation that Be<sup>10</sup> is radioactive, changing into B<sup>10</sup> and a negative electron with 0.3 mev energy. From this we obtain for the mass of Be<sup>9</sup>

$$\text{Be}^9 = 10.0135 + 1.0078 + 0.0047 + 0.0003 - 2.0136 - 0.0002 = 9.0125$$

The excellent agreement among these three determinations of the mass of Be<sup>9</sup> 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<sup>9</sup> 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<sup>9</sup> may be disrupted by gamma-rays from radium, as found by Szilard and Chalmers.<sup>9</sup> Our masses of Be<sup>8</sup> and Be<sup>9</sup> lead us to predict that the lowest energy gamma-ray capable of disrupting Be<sup>9</sup> is 1.4 mev, which is the minimum required to produce the reaction



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,<sup>10</sup> but not in agreement with those of Gentner.<sup>11</sup>

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California Institute of Technology,  
February 14, 1935.

<sup>1</sup> Crane, Delsasso, Fowler and Lauritsen, to be published soon.

<sup>2</sup> Oliphant, Inter. Conf. of Physics, London, Oct. 1934.

<sup>3</sup> Kirchner and Neuert, Physik. Zeits. 35, 292 (1934).

<sup>4</sup> Cockroft, Inter. Conf. on Physics, London, Oct. 1934.

<sup>5</sup> Crane, Delsasso, Fowler and Lauritsen, Phys. Rev. 46, 1109 (1934).

<sup>6</sup> Bonner and Brubaker, L. A. Meeting, Am. Phys. Soc., Dec. 1934; Phys. Rev. 47, 254A (1935).

<sup>7</sup> See reference 2.

<sup>8</sup> Meitner, Naturwiss. 22, 420 (1934).

<sup>9</sup> Szilard and Chalmers, Nature 134, 494 (1934).

<sup>10</sup> Ridenour, Shinohara and Yost, Phys. Rev. 47, 318 (1935).

<sup>11</sup> Gentner, Comptes rendus 199, 1211 (1934).