The Production of Radium E and Radium F (Polonium) from Bismuth

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It is shown that when bismuth is bombarded with 10-Mev deuterons both radium E and radium F are formed. The former corresponds to a neutron capture and the latter to the capture of a proton. The yield of each product is found as a function of the exciting energy. At 10 Mev the yield of radium F is less than one-fourth of that of radium E. Since the possibility of a neutron and a proton leaving the nucleus should be almost equally probable, this is evidence that the deuteron as a whole has a low probability of entering the nucleus but rather obeys an Oppenheimer-Phillips process. The cross sections for the formation of radium E and radium F at 10 Mev are 4×10^{-28} cm^2 and 9×10^{-29} cm^2, respectively.

STABLE bismuth consists of a single isotope of mass 109. It was shown by J. Livingood[1] that bismuth bombardment by deuterons of 5.2 Mev resulted in a capture of the neutron giving radium E. At the higher deuteron energies now available it is shown that the bombardment also forms radium F. This process corresponds to the capture of a proton. The arrangement of these isotopes is shown in Fig. 1. Radium E with a half-life of five days disintegrates into radium F by a beta-transition, and radium F with a half-life of 136 days decays to lead (206) by the emission of an alpha-particle.

It is apparent that a knowledge of the intensities of each of these radioactive products as produced by incident deuterons, when the energy of the deuterons is set at various particular values, should be of value. These quantities can be definitely determined. To reduce the energy of the bombarding deuterons the bismuth sample was covered with an aluminum foil of suitable stopping power. Identical exposures in terms of microampere minutes were given to various bismuth samples at energies from ten to six million electron volts, approximately.

The amount of radium F made is obtained directly by placing the specimen immediately after bombardment close to an ionization chamber connected to a linear amplifier. Adjustment could be made to count pulses of any desired magnitude and the bias was usually set such that only alpha-particles originating in a thickness of the bismuth, equivalent to two centimeters of air were counted. Since 10-Mev deuterons penetrated the bismuth to a depth, equivalent to sixty-four centimeters of air, the yield of alpha-particles recorded is that from the thin surface layer and is essentially due to deuterons of the maximum energy.

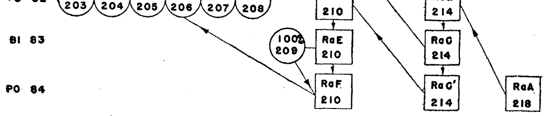

FIG. 1. Arrangement of isotopes.

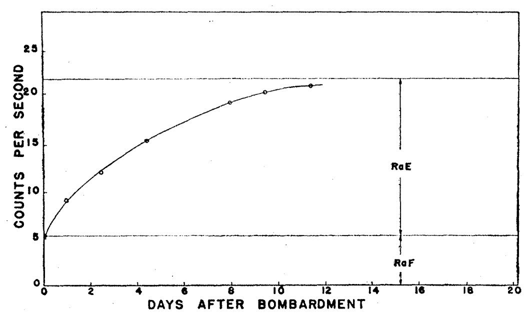

FIG. 2. Counts from sample after bombardment by deuterons.

The atoms of radium E in this same layer will emit beta-rays, thus becoming radium F and consequently be able to give alpha-particles and be counted. Fig. 2 shows the actual counts observed from such a bombarded sample at various times after bombardment. Since the half-lives of each product are known, every observation of the activity (N) at a time (t) after bombardment is sufficient to allow the calculation of the total

[1] J. Livingood, Phys. Rev. **49**, 876 (1936).

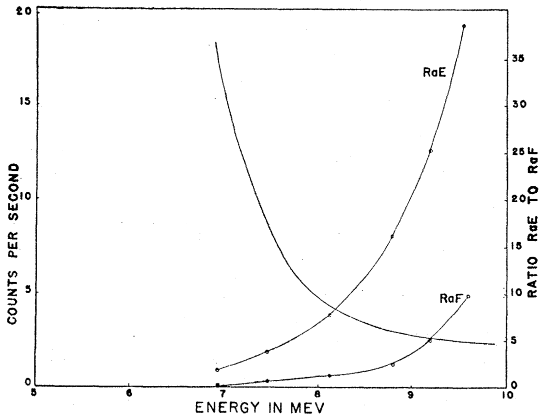

FIG. 3. Activity of targets for various energies of bombarding particles.

number (N_0) of radium E atoms formed. Thus

$$N_0 = N \bigg/ \frac{\lambda_1}{\lambda_2 - \lambda_1}[e^{-\lambda_1 t} - e^{-\lambda_2 t}],$$

where λ_1 and λ_2 are the decay constants for the parent and daughter substances, respectively. The maximum activity is attained twenty-five days after bombardment.

The results obtained from the bismuth targets bombarded by deuterons of various energies are shown collectively in Fig. 3. A practical threshold appears for the formation of radium F at about 6.5 Mev. The ratio of the radium E to radium F is shown by the scale on the right side of the figure. At 10 Mev the yield of radium E is still almost five times that of radium F. If the deuteron in every case entered the nucleus then this ratio should be slightly less than unity since it should be easier for the neutron to leave than for the proton. It thus seems that at these energies the deuteron has a low probability of entering the nucleus as a whole. It must obey an Oppenheimer-Phillips[2] process, in which the deuteron in the external field of the nucleus yields a neutron and a proton and only the neutron enters. The entrance barrier for the deuteron must be considerably above 10 Mev. The cross section (σ) for each process may be calculated. At 10 Mev these values are 9×10^{-29} cm^2 and 4×10^{-28} cm^2 for radium F and radium E, respectively.

This investigation is made possible by the support of the Horace H. Rackham Fund.

[2] J. R. Oppenheimer and M. Phillips, Phys. Rev. **48**, 500 (1935).

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The Distribution in Energy of the Fragments from Uranium Fission

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The ionization produced by the fragments from uranium fission was measured. The number-energy curve shows two peaks corresponding to 65 and 98 Mev. The ionization produced by the two fragments simultaneously was measured by using a thin foil coated with U. The number-energy curve has one peak at 159 Mev and a half-width of 30 Mev.

I. INTRODUCTION

SHORTLY after the discovery of the fission of uranium by Hahn and Strassmann[1] a number of experiments[2–5] were performed in which the kinetic energy liberated in the process was measured. The method used in these experiments was the comparison of the ionization produced by the single fission fragments with that produced by α-particles of known energy. The agreement between these experiments was not very good. In each of the above experiments at least two maxima in the number-ionization curve were found, and the sum of the energies corresponding to these maxima was about 125 Mev according to v. Droste, Haxel, and Booth,

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[2] W. Jentschke and F. Prankl, Naturwiss. **27**, 134 (1939).
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[5] E. T. Booth, J. R. Dunning and F. G. Slack, Phys. Rev. **55**, 981 (1939).