Letters to the Editor

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Communications should not in general exceed 600 words in length.

Radioactive Rb from Deuteron Bombardment of Sr

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ONE of us[1] has reported the production in large quantities of a long-lived radioactive Y from the bombardment of Sr with 16-Mev deuterons. At this bombarding energy one would expect an appreciable amount of Rb to be produced by the (d, α) reaction. We have found a radioactive Rb of half-life 19.5 ± 1 days, produced from this reaction in sufficient quantities for tracer work and with the added advantage of high specific activity.

To prove that the activity was Rb the following procedure was adopted. The filtrate remaining after Y and Sr had been precipitated as $Y(OH)_3$ and $SrCO_3$ was evaporated to dryness and the ammonium salts driven off. Fe, as carrier for the Y, and Sr were again added along with 10 mg of K. Fe and Sr were precipitated in alkaline Na_2CO_3 solution. After filtration, K and Rb were precipitated from the filtrate with $Na_3Co(NO_2)_6$. If the active material had been Na it would have remained largely in solution, but over 99 percent was precipitated. The precipitate was dissolved in HCl, 4 mg of Rb added, and Rb_2SnCl_6 precipitated. All the activity came with the precipitate. Sn was then removed as sulfide, and the whole activity of, in this case, 400 μC remained in 4 mg of RbCl. Subsequent experiments showed that the activity could be separated quantitatively with Rb from equal molar mixtures of K, Sr, Ca and Mg. The activity must come from the Sr (d, α) Rb reaction since the Rb contamination of the target was negligible.

There are two "stable" isotopes of Rb, Rb^{85} and Rb^{87}. Snell[2] found an 18-min. and an 18-day period by the slow neutron bombardment of Rb. Our activity is undoubtedly his 18-day activity. The half-life of 19.5 days was obtained by following several samples over from one to four half-lives. However, there is some evidence for a weak longer period activity, so that the half-life may be somewhat shorter. Of the two slow neutron activities, only that of Rb^{86} can be produced by the Sr (d, α) Rb reaction, since Sr^{88} is the heaviest stable isotope of Sr. Therefore this 19.5-day period can definitely be assigned to Rb^{86}. This agrees with the assignment of the 18-min. period to Rb^{88} on the basis of Th fission experiments.[3,4]

Rb^{86} emits negative electrons and no strong γ-rays. From absorption measurements, the spectrum has an upper limit of 1.56 ± 0.05 Mev calculated from Feather's rule.

The yield of Rb^{86} from a 2000-microampere hour bombardment of Sr was 0.4 mC, as compared with 17 mC of the 55-day Sr^{89} from Sr^{88} (d, p) Sr^{89}, and 35 mC of the 100-day Y from Sr $(d, 2n)$ Y. The isotope responsible for the production of Y is uncertain, but if we assume that all the products come from Sr^{88}, the ratio of the cross sections for the $(d, 2n)$, (d, p), and (d, α) reactions at 16 Mev is 29 : 10 : 0.1. Dr. Martin Kamen has kindly supplied us with yield data for Fe and Mg bombarded with deuterons. In Fe the reactions are Fe^{56} $(d, 2n)$ Co^{56},[5] Fe^{58} (d, p) Fe^{59}, and Fe^{56} (d, α) Mn^{54}, and correcting for the reduced abundance of Fe^{58}, the ratio is 7 : 10 : 1.7. The Fe data are for 16-Mev deuterons. For Mg at 8 Mev the reactions are Mg^{26} (d, p) Mg^{27} and Mg^{24} (d, α) Na^{22}. The ratio here is ? : 10 : 200. We see that with increasing atomic number the (d, α) reaction drops off markedly as one would expect from the increase in the Coulomb barrier height. It is interesting to note that at 16 Mev, the $(d, 2n)$ reaction is one of the most probable, if not the most probable, reaction.

We wish to express our thanks to Professor E. O. Lawrence for his interest in this work and to the Research Corporation for financial support.

[1] Charles Pecher, Phys. Rev. **58**, 843 (1940).
[2] A. H. Snell, Phys. Rev. **52**, 1007 (1937).
[3] A. Langsdorf, Jr., Phys. Rev. **56**, 205 (1939).
[4] A. H. Aten, Jr., C. J. Bakker and F. A. Heyn, Nature **143**, 679 (1939).
[5] The measured Co consists of two long-life activities, and since the assignment of these activities is uncertain, our estimate of the yield may be in error by a factor of 2 or 3.

Showers of Penetrating Particles

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IN previous papers[1,2] a report was given of measurements which gave evidence for the existence of showers of at least two particles of a range not smaller than 17 cm of lead and the size of the penetrating core of which is of the order of 0.2 sq. m.

In this paper we report further measurements made with a sixfold coincidence set with a resolving time of 1.8×10^{-6} sec. and with the multivibrator circuit developed by one of us.[3] Some of the arrangements used (Fig. 1) were chosen in order to avoid knock-on showers and the secondary effects of the soft radiation which usually accompanies the penetrating rays.

First, we have tried to get evidence of a possible association of the observed showers with the extensive showers discovered by Auger and his co-workers. A fivefold coincidence set was used: Four counters were arranged in two telescopes at a distance of 30 cm from each other and surrounded by lead (arrangement I of reference 1); the fifth counter being placed at a distance of 280 cm from the others. The observed frequency was of 8×10^{-4} min.$^{-1}$, showing that some soft radiation is associated with the penetrating core. We can therefore conclude that meson showers are responsible for some of the extensive showers.

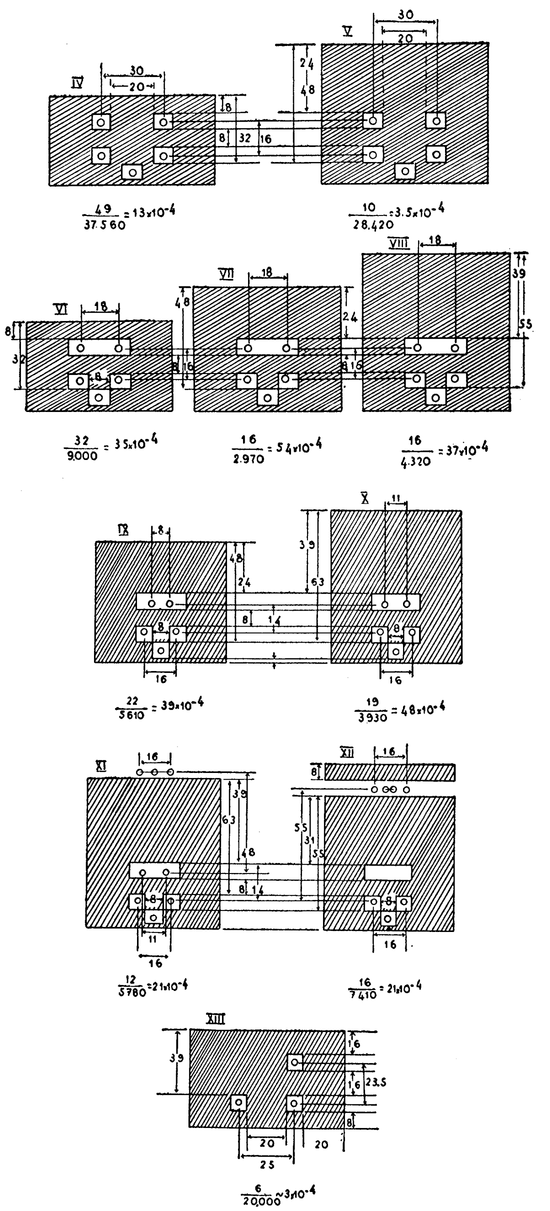

FIG. 1. Arrangements IV–XIII. The linear dimensions of the drawings are indicated in cm. The average frequency is given in min.$^{-1}$.

Other experiments on the nature of the penetrating showers are given in Fig. 1. The results of measurements IV and V show that a part of the rays responsible for the fivefold coincidences at a distance of 30 cm between the two telescopes, is absorbed by 24 cm of lead. By a narrower arrangement of type VI–X, there is no noticeable absorption and the observed frequency is about three times greater than the frequency of the fivefold coincidences in IV (and more than ten times greater than those in V) where 20 cm of Pb are placed between the telescopes. It might be objected that showers originated by a mesotron going through the lead sheet above the counters can produce such coincidences; especially if we take into account the experimentally established absorption coefficient of soft gamma-rays in lead [a sensible number of such rays are found in the cosmic rays][4] and the, experimentally as yet unverified, theoretical results of the meson theory[5] which predict high radiation losses for high energy mesons. We are very indebted to Professor G. Occhialini for having called our attention to this point. This assumption might also explain the differences in absorption effect observed in the arrangements IV–V and in VI–X. Such phenomena could be responsible for a part of the experimental results reported by Jánossy and Ingleby,[6] Froman, Josephson and Stearns[7] and Rossi and Regener.[8] Definite evidence for an association of at least two penetrating particles is given by arrangements of type V or of I, II, III of our previous paper, where the distance between two telescopes, each shielded from all the sides with at least 20 cm of lead, was increased to 120 cm.

It seems noteworthy that in experiments X, XI, XII the observed frequencies do not differ greatly, so that it is very probable that the observed showers are produced by vertical rays and contain several penetrating particles.

Other experiments are being carried out under 30 m of clay (about 50 m water equiv.). One of these is illustrated in Fig. 1—XIII. In a similar arrangement of threefold coincidences with a smaller distance between the two lower counters (only 8 cm Pb interposed) we have observed 13 coincidences in 14,500 min. We can therefore conclude that there is evidence for the existence underground (under 60 m water equiv.) of showers containing at least two particles penetrating more than 20 cm Pb. A simple calculation shows that it is highly improbable that soft radiation, which always accompanies the penetrating component underground, can be responsible for these showers. Further studies concerning the nature of the shower-producing rays is in progress.

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