Radioactivity Due to Neutron Ejection Produced by Fast Neutrons

The disintegration of beryllium[1] and deuterium[2] by gamma-ray bombardment has been reported by Szilard and Chalmers and by Chadwick and Goldhaber. Bothe and Gentner[3] and Heyn[4] have more recently reported similar activation of heavier elements. Since the cyclotron yields intense gamma-radiation as well as fast neutrons this subject is investigated further. Deuterons of 6.3 Mev were allowed to fall on various targets and the radiation from these targets in turn made to activate other elements shielded completely from the deuteron beam. It was at once observed that these secondary targets were strongly activated in a quite different way than when activated directly by deuterons or by slow neutrons. Elements which in the usual way by neutron capture yield a certain number of radioactive isotopes as revealed by the half-life periods, now have one of the ordinary periods either completely lacking or suppressed. In addition there appears a new period which is radio-positive. This is as expected if, in this disintegration, neutrons are ejected from, rather than added to the nuclei by the exciting radiation. The question then arises whether the fast neutrons or the gamma-rays or both are the exciting agents.

To answer this question experiments of two types have been carried out. In one method the secondary target was placed 4.5 cm from the primary target and bricks of lead or paraffin could be interposed between the two and the change in activation of the secondary target observed. In another the activation of a given secondary target was observed as the primary target was changed so as to give neutrons and gamma-rays of different known energies. From both of these experiments the conclusion is that for the most part, if not completely, the activation of the secondary target is due to fast neutrons. Table I shows in resumé the results when secondary targets of nitrogen, oxygen, silver and copper are each used with primary targets of lithium, boron, beryllium and copper. Secondary oxygen targets of several forms were employed, namely as metallic oxides, ammonium nitrate and water. The energies of the neutrons emitted from lithium, boron and beryllium under deuteron bombardment have been measured and have values reaching up to 14, 13 and 4.6 Mev, respectively.[5] The energies of the neutrons from copper are not known. To these energy values must be added a large portion of the impinging 6.3 Mev deuteron energy.

The neutron radiation from the beryllium and copper primary targets appears to be inadequate to activate the 10 min. period of copper and the 26 min. period of silver, yet adequate to activate the oxygen period. This is perhaps surprising since from the energy balance an incident energy of about 15 Mev or more should be necessary.

TABLE I. *Relative activation (approximate I_0) of secondary targets under high energy neutron bombardment.*

Neutrons from	N^{13} 11 min.	O^{15} 2.1 min.	Ag^{106} 26 min.	Ag^{108} 2.3 min.	Cu^{62} 10 min.	Cu^{64} 12 hr.	Cu^{66} 5 min.
Li	100	60	100	50	100	6	0
B	27	15	42	43	73	4	0
Be	0	72	0	28	0	3	14
Cu	18	100	0	3	0	2	4

As is evident from the table high energy neutrons form Cu^{62} and Cu^{64} from the two stable Cu^{63} and Cu^{65} isotopes. For slow neutrons Cu^{64} and Cu^{66} are formed from the same two stable isotopes. A similar relation holds for the two stable Ag^{107} and Ag^{109} isotopes.

Investigation of other elements is being continued. Most all the elements, so far bombarded with these high energy neutrons, have yielded new or previously known artificial radioactive periods. Br, Sn, In, Zn and Cd have been found to be particularly easy to activate. For slow neutron bombardment, as was shown by Fermi, the bombarded nucleus most frequently increases in mass number by one. For high energy neutron bombardment the bombarded nucleus, in every case so far investigated, apparently decreases in mass number. It is therefore apparent that for elements with two or more isotopes the assignment of radioactive periods may now in many cases be made more easily and certain.

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Critical Frequencies of Low Ionosphere Layers[*]

The comparatively well-known layers of the ionosphere which have been studied by the pulse method lie between virtual heights of approximately 100 and 500 kilometers. Layers much below 100 kilometers have been reported by several observers[1–3] during the past two years. In all of these cases such high frequencies were used that the low layers were penetrated by the same emissions for which reflections are reported to have been obtained. Therefore these experimenters have not determined the critical frequencies or maximum ionization densities of the lower layers, and have offered no means of studying variations of these properties. It would seem that the low layer reflections reported may have been of the nature of "sporadic"[4] or partial reflections from a sharp boundary, but were certainly not total reflections such as are obtained from the normal E, F_1 and F_2 layers for frequencies below the critical frequencies. The mechanism producing the partial reflections can hardly be that envisaged by the Eccles-Larmor theory of refraction.

The critical frequency of at least one of these lower layers has been observed by us by the method of continuous automatic field intensity recording, and this layer has