Artificial Radioactivity Produced by Alpha-Particles

Continuing our survey[1,2] of radioactivity produced by an alpha-particle beam accelerated in a cyclotron, we have replaced the thin platinum window through which the alpha-particles emerged by a gate valve assembly. This change permits targets to be bombarded by the direct beam inside the cyclotron vacuum tank, and removed in about 30 seconds without impairing the vacuum in the tank proper. A four- to ten-fold enhancement of the activities we have already studied has resulted. The present beam has an energy of about 8 Mev, and the currents to the target are of the order of 0.03 to 0.05 microampere.

We have tentatively identified the following activities:

Cr: A rather weak activity of two periods is observed in this element after alpha-particle bombardment. A chemical separation of Cr, Mn, and Fe was made, and it was found that the short period activity, having a half-life of about 8.9 minutes, is due to an isotope of iron. It emits positrons. We suggest that the active isotope is Fe^{55}, formed by the reaction Cr^{52} (α, n) Fe^{55}. The long period radioelement is isotopic with Mn, and emits negative electrons, decaying with a period of about 160 minutes. This makes it seem likely that the activity is due to Mn^{56}, found by Fermi[3] to be produced in the bombardment of Mn with slow neutrons, and of Fe and Co with fast neutrons. The half-life of Mn^{56} is given by Fermi as 2.5 hours. The thick-target intensities of the activities, corrected to infinite bombarding time, are approximately in the ratio $Mn^{56} : Fe^{55} = 3 : 10$. Mn^{56} is produced in our work by the reaction Cr^{53} (α, p) Mn^{56}. The relative abundance of the Cr isotopes involved in these two reactions is Cr^{53}; $Cr^{52} = 10$ percent; 82 percent.[4]

Co: A great enhancement in the yield of Cu^{62} from the reaction Co^{59} (α, n) Cu^{62}, produced by the elimination of the alpha-particle energy loss in the cyclotron exit window, has enabled us to make a better measurement of the period than the one reported in our last communication.[2] Our present value of the half-life is 10.0 minutes, in agreement with that given by Pool, Cork, and Thornton[5] for the same isotope formed from Cu^{63} by the $(n, 2n)$ reaction.

Cu: We reported[2] the formation of Ga^{68} from Cu by the reaction Cu^{65} (α, n) Ga^{68}. The greater intensity now available shows the presence of a longer lived radioelement produced from Cu by alpha-particle bombardment, and has enabled us to make a more reliable measurement of the period of Ga^{68} than that already reported. A chemical separation of Cu, Zn, and Ga showed that both the radioelements produced in Cu are isotopic with Ga. Both emit positrons. The short period, measured in a sample of Cu bombarded for 15 minutes and measured immediately is 68 minutes, and is to be identified with Ga^{68}. The long period, measured in a Cu target bombarded for 3.5 hours and allowed to decay for 14 hours before being transferred to the electroscope, is 9.4 hours. We suggest that this latter activity is due to Ga^{66}, formed in the reaction Cu^{63} (α, n) Ga^{66}. The relative initial intensities are about $Ga^{68} : Ga^{66} = 10 : 4$, corrected to infinite bombarding time. We have studied the absorption in aluminum of the positrons from Ga^{68}, and find that the half-value thickness is about 0.12 g/cm², indicating a maximum energy of about 2.2 Mev.

As: In agreement with Snell,[6] we find a radioelement of half-life 6.3 minutes formed in As by alpha-particle bombardment. Snell has identified this activity as being due to Br^{78}.

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Ionic Recombination in the Ionosphere

In a personal communication E. V. Appleton of the Cavendish Laboratory has called my attention to a point that was overlooked in my recent Letter to the Editor on the "Coefficient of Recombination of Gaseous Ions over an Extended Pressure Range."[1] In the letter I failed to consider the validity of the Thomson equation at extremely low pressures such as might apply to the ionosphere. There is nothing in the derivation of the Thomson equation which invalidates its applicability at lower pressures.[2] There is, however, a pressure below which the assumptions made in deducing the theory lead to values of the coefficient which are lower than the coefficient resulting from a process which is neglected in Thomson's theory. Thomson's theory assumes that ions will recombine if they come within the sphere of active attraction, $d = 2e^2/3kT$, of each other, and if when in that sphere one of the ions suffer a collision with a neutral molecule. At low pressures the chance of this molecular collision may be extremely remote for the coefficient ϵ giving this chance becomes very small. It is furthermore certain that if ions of opposite sign come within a distance r_0 of each other electron transfer will occur *without the added molecular impact*. Thus the Thomson mechanism for which $\alpha = \pi d^2 \epsilon (c_+^2 + c_-^2)^{\frac{1}{2}}$ must give way to another mechanism at pressures where $\pi d^2 \epsilon$ becomes comparable with πr_0^2.

While the mechanism of electron transfer characterizing ion recombination and defining r_0 has not been attacked by wave mechanics the process may be outlined as follows. The electron occupies a position of reduced potential energy in the molecule to which it is attached. On the approach of a positive ion there must exist at each distance of separation r between ions a finite chance of a transition of the electron over its small potential barrier into the vacant orbit of the positive ion. The overlapping electrostatic fields of the ions will materially facilitate this transfer, which in itself is rather high since the electron capture by the positive ion can proceed in a nonradiative manner the energy going to kinetic energy of separation of the resulting neutral molecules. Thus at each distance of