Radioactive Isotopes of Indium from Alpha-Bombardment of Silver

Further investigation[1] of the radioactivity produced in silver when it is bombarded with 16-Mev alpha-particles shows that the activity consists primarily of two periods having half-lives of 20 minutes and 65 minutes. These two periods decay by positron emission and have been chemically identified as indium. The possible radioactive indium isotopes are In^{110} and In^{112}. Cadmium isotopes which might be produced are stable.

The 20-minute period is undoubtedly the same as that first reported by Lawson and Cork[2] who used $\mathrm{Cd}+\mathrm{d}$ and assigned it to In^{111}. A definite assignment of this period was difficult at the time because of several possible indium isotopes and the lack of experimental data. Barnes[3] produced the same activity by $\mathrm{Cd}+p$ but had no reason for changing its assignment. The fact that the 20-minute indium period is produced by $\mathrm{Ag}+\alpha$ definitely assigns it to In^{112} formed by the reaction $\mathrm{Ag}^{109}(\alpha, n)\ \mathrm{In}^{112}$.

The 72-second period has been observed from In+fast neutrons[2] and $\mathrm{In}+\gamma$[4] and assigned to In^{112}. We have looked for such a period produced by $\mathrm{Ag}+\alpha$ and could not find it. To check the possibility that this period might be due to In^{114} we have bombarded Cd with α-particles where In^{114} would be produced in the reaction $\mathrm{Cd}^{111}\ (\alpha, p)\ \mathrm{In}^{114}$. The chemical separation required only two minutes, but no activity was observed. The 72-second period is not produced by slow neutrons[2] on indium which is further evidence that it cannot be due to In^{114}. There remains the possibility that this period is due to In^{111} produced by an $n-3n$ or $\gamma-2n$ reaction. In^{111} would be allowed by the proton and deuteron reactions in which the 72-second period has been observed.

The 65-minute indium period has also been observed by Barnes[3] in $\mathrm{Cd}+p$ and assigned tentatively to In^{110}. Our alpha-particle data from the reaction $\mathrm{Ag}^{107}\ (\alpha, n)\ \mathrm{In}^{110}$ verifies his assignment. The absence of the 65-minute period with the reaction $\mathrm{Cd}+d$ also indicates that In^{110} produces this period.

Two other weaker activities were observed in the reaction $\mathrm{Ag}+\alpha$; one of about 9 hours and another weaker one of 2–3 days. A 9.4-hour period is characteristic of gallium produced by $\mathrm{Cu}^{63}\ (\alpha, n)\ \mathrm{Ga}^{66}$. The intensity observed was consistent with the copper impurity in the fine silver (99.95 percent). In the chemical procedure some gallium was added to the solution and the gallium and indium precipitated as hydroxides. This precipitate was dissolved in $6n$ HCl and the gallium separated from the indium by extraction with ether. The gallium fraction showed half-lives of 60 minutes and 9.4 hours characteristic of $\mathrm{Cu}+\alpha$ and the indium precipitate had activities of 65 minutes and a 9.4-hour period greatly reduced in intensity indicating that the separation by the ether extraction was not complete. By comparing the relative intensities from pure copper and that of our silver, it was evident that one could detect less than 1 part in 10,000 of copper in silver.

A long bombardment of Ag by α-particles gives an additional weak period of 2–3 days half-life. This has not been chemically identified and since the intensity of this period is less than that of any of the other activities observed, it also may be due to an impurity. However, it may be identical with the 2.7-day indium period found by Barnes[3] and Cork[5] and assigned by the former to an isomeric state of In^{112}.

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[2] J. L. Lawson and J. M. Cork, Phys. Rev. **52**, 531 (1937).
[3] S. W. Barnes, Phys. Rev. **56**, 414 (1939).
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Air Mass Effect on Cosmic-Ray Intensity

Blackett[1] has suggested that the "temperature effect" of the cosmic rays is due to the vertical shift of the layer in which the mesotrons are formed and has further suggested that it may be possible to correlate cosmic-ray data with the structure of depressions. Data obtained with a Carnegie, Model C cosmic-ray meter loaned to us by A. H. Compton indicate a noticeable change in intensity at the fronts separating different air masses.

The data were obtained while the meter was on board the *M. S. Northland* traveling between Seattle and Juneau, Alaska, in the process of investigating the latitude effect. The location of the fronts was obtained from the Seattle airport office of the U. S. Weather Bureau. Of the twelve fronts investigated, three were cold fronts, one was warm, and eight were occlusions. The cold fronts gave changes of from 2.9 percent to 5 percent; the warm front gave a change of 2 percent, while the occlusions gave changes of from 1.7 percent to 2.5 percent. The changes took place over a space of from one to three hours. Two further cases of fluctuation were noticed, one accompanying an influx of warm moist air aloft, the other representing a zone of transition which contained no definite front.

The explanation of such an effect follows at once from Blackett's suggestion. If z is the height of mesotron formation and L the mean range, then the fractional change in intensity is given by:

$$dI=-\frac{dz}{L}.$$

In a private communication from A. H. Compton, we learn that recent experiments of Rossi and of Schein show that $L\sim 9$ km whereas z is not less than 20 km. Using the value of $L=9$ km and the observed values for dI, we find that dz is from 200 m to 400 m.

If we connect the formation of the mesotrons with a layer of given density, then the vertical shift of this layer at the passage of a front will be given by:

$$dz=\frac{RT}{Mg}\ln\left(\frac{PT_0}{P_0T}\right),$$

where T_0 is the absolute temperature of the layer before passage of the front and T the temperature after, P_0 and P are the corresponding pressures, M the molecular weight of air, R the gas constant, and g the acceleration of gravity. Unfortunately there were no data available at heights as great as 20 km. However, data by J. Bjerknes[2] and J.