Possible Production of Radioactive Isotopes of Element 85

We have previously reported[1] the production of artificial alpha-particle emitters from the bombardment of bismuth with 32 Mev alpha-particles. We wish to make a preliminary report at this time on our attempts to establish the chemical identity of this substance.

Two ranges of alpha-particles are emitted, one of approximately 6.1 cm and the other of approximately 4.2 cm. Both groups decay with the same half-life, 7.5 hours. About 60 percent of the total number of alpha-particles is in the long range group and about 40 percent is in the short range group. We have been unable to find a genetic relationship between these groups. Associated with the alpha-particle activity is a beta-ray activity and an x-ray or gamma-ray activity both of 7.5 hours half-life. The x-ray or gamma-ray has an energy of roughly 90 kev, as determined by absorption measurements.

In attempting to identify the alpha-emitter chemically we have succeeded in eliminating thallium, lead, bismuth and polonium by the experiments which are listed below. In all cases the bombarded bismuth was dissolved in nitric acid and brought to a 0.25 normal concentration in nitric acid. We precipitated lead and thallium as chlorides with hydrochloric acid and found no activity in the precipitates. We tested for bismuth in several ways. We precipitated bismuth with stannous chloride in alkaline solution and found no activity. We also made a fractional precipitation of bismuth with hydrogen sulphide in an acid solution. Starting with 6 normal hydrochloric acid concentration and diluting progressively we found a higher specific activity in the first fractions. We also made a fractional hydrolysis of bismuth again finding a decreasing specific activity in the last samples.

The chemical properties of the unknown substance are very close to those of polonium. However, we have established that it is not polonium by using polonium as a tracer. We prepared the tracer polonium by bombarding bismuth with deuterons. The bismuth containing the polonium (radium F) was dissolved in the same way as the bismuth containing the unknown activity. We then mixed a known amount of the standard polonium solution with each sample of the unknown. The experiments which eliminate polonium are as follows: In a 0.25 normal nitric acid solution the polonium deposited on a piece of metallic bismuth placed in the solution, but the unknown activity did not. In the fractional sulphide precipitates mentioned above the ratio of unknown activity to polonium activity was different in each sample. The same was true of the fractional hydrolysis. We then took a sample of the nitric acid solution containing both the unknown activity and the polonium, added potassium iodide and extracted the iodine with carbon tetrachloride. The iodine was reduced with sulphite and precipitated with silver nitrate. The precipitate contained only the 7.5-hour activity—the polonium having been left behind. The extraction of the unknown activity was not complete, however. We also added potassium iodide to a sample and distilled off the iodine. In this case some of the unknown activity followed the iodine, while all the polonium stayed behind. However, we have not yet found the condition for reproducing the distillation quantitatively, though the polonium never distills over.

Thus it seems definite that the unknown alpha-emitter is not thallium, lead, bismuth, polonium or any of the known elements up to uranium. So if it is an element in this region of the periodic table it must be element 85 (eka-iodine). However, its chemical properties are much closer to those of polonium than they are to those of iodine: it precipitates as a sulphide and it is precipitated by zinc in sulphuric acid solution, both reactions being characteristic of a metal and not of iodine; it precipitates incompletely with silver nitrate under conditions in which halogens precipitate quantitatively.

The possibility of fission is not eliminated since we have not ruled out all the elements below thallium. Fission seems unlikely, however, since no alpha-emitters are found in the known fission products. Furthermore the complex decay periods characteristic of fission products are missing.

At the suggestion of Dr. J. G. Hamilton and with his aid we have injected known amounts of the supposed eka-iodine into two hyperthyroid guinea pigs, on the chance that it might behave like iodine and be concentrated in the thyroid. The guinea pigs were killed about 4.5 hours after administration of the radioactive material and various portions of the bodies were examined for activity. In one animal the thyroid contained roughly 100 times as much activity as equal masses of other portions of the body. The concentration was somewhat less in the case of the second animal. This experiment has not been performed with polonium, however.

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Energy Losses of Fast Mesotrons and Electrons in Condensed Materials

Cross sections for energy losses by collision of fast charged particles are according to Fermi[1] not independent of the physical state of the material traversed but are larger in gases than in condensed materials. This effect was calculated as arising from the induced electromagnetic field and found to be characterized by the dielectric properties of the material. The result obtained from the model of a single type of dispersion electrons, was reported to be essentially independent of special assumptions as to the dielectric properties of the substance.

On learning about these deliberations we did not feel satisfied as to the relationship of this effect to the dielectric properties of the material. We have therefore carried out a more detailed investigation of this essentially classical phenomenon and also studied more general models for the dispersing system including the case of conductors.

We confirm the existence of a density-dependence of the collision cross section; but this interesting effect cannot in our opinion be in general related to the dielectric constant of the material for relevant velocities.

The effect can best be described by discussing certain limiting cases for a model containing two dispersion frequencies:

(*a*) Velocities so near the velocity of light that

$$1-(v^2/c^2)\ll(ne^2/\pi m\nu_2^2),$$

where n is number of electrons per unit volume and ν_2 the *larger* frequency in the atoms of the absorber. In this case the reduction in loss is found to be

$$\frac{2\pi ne^4}{mv^2}\left[\log\frac{ne^2/\pi m\nu_m^2}{1-v^2/c^2}-1\right], \qquad (1)$$

where ν_m is the *geometric mean* of the atomic frequencies[2]

$$(\nu_m=13.5Z\text{ ev}=3.5Z10^{15}\text{ sec.}^{-1})$$

(*b*) $1-(v^2/c^2)\ll(ne^2/\pi m\nu_1^2)$; $\quad 1-(v^2/c^2)\gg(ne^2/\pi m\nu_2^2)$.

Reduction in loss:

$$\frac{2\pi ne^4}{mv^2}\left[\log\frac{\alpha}{\nu_1[2(1-v^2/c^2)]^{\frac{1}{2}}}-\frac{1}{2}\right], \qquad (2)$$

where

$$\alpha^2=ne^2/\pi m.$$

Expressions (1) and (2) have been extended to cover more general dispersion- and conduction-models.

In applying these results to the passage of mesotrons we find that they afford no possibility of explaining away the surmised radioactivity. In particular, evaluation of the data given by Rossi, Hilberry, and Hoag[3] seems to show that the correction due to (1) would probably affect the value for the lifetime not much more than the inherent inaccuracy due to lack of precise knowledge of the mesotron velocities.

The observations of Pomerantz and Johnson[4] on the relative stopping power for mesotrons in water and lead agree well with our formulae for a reasonable choice of the frequencies involved.

The experiment of Crane, Oleson, and Chao[5] on the energy loss of 10 Mev electrons in carbon give according to the authors the following values:

Observed	1.86 Mev
Correction for radiative loss	0.13
Theoretical (Bloch-Bethe)	1.93
Theoretical Fermi	1.40
Theoretical (our formula (1))	1.72.

The details of the calculations and the comparisons with experiments will be given in a subsequent paper.

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[2] W. Heitler, *Theory of Radiation* (Oxford, 1936), p. 218.
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[5] Crane, Oleson and Chao, Bull. Am. Phys. Soc., New York Meeting, Feb. 1940, No. 3.