Radioactive Isotopes of Zinc and Cobalt

Professor E. O. Lawrence gave to one of us some copper filings of the Berkeley cyclotron's tank. The filings came from the deflecting plate which is submitted to strong deuteron and neutron bombardment and showed an intense radioactivity. Three months at least elapsed between the ending of the bombardment and the beginning of the measurements. In spite of this the filings showed a strong activity due to P^{32} which is an ever-present surface contamination of the samples we received from Berkeley. This isotope was chemically separated and used in some biological investigations.[1]

The copper filings were carefully analyzed. Even commercial copper is generally very pure and we assume that any activity, but for surface contaminations, is due to transmutation of Cu into radioactive isotopes.

The analysis was carried on with standard methods[2] and the following elements were definitely tested by addition to the original solution of the radioactive copper and subsequent separation: (1) arsenic, cadmium, aluminum, iron, manganese, lithium, gallium, carbon, nickel, calcium, copper, barium, sulphur; (2) sodium, cobalt, zinc, phosphorus.

The elements of the first group were found to be inactive, also many other elements which are not mentioned can be ruled out as carriers of any activity. To take into account surface contaminations we made a test by combustion of carbon with negative result, whereas P^{32} was separated as we have already pointed out. A weak radioactivity was found in sodium. This is possibly due to Na^{22},[3] but on account of its smallness we did not follow this activity. The elements enumerated above were chosen partially for chemical reasons in order to rule out as many elements as possible, and partially because they were suspected of being active.

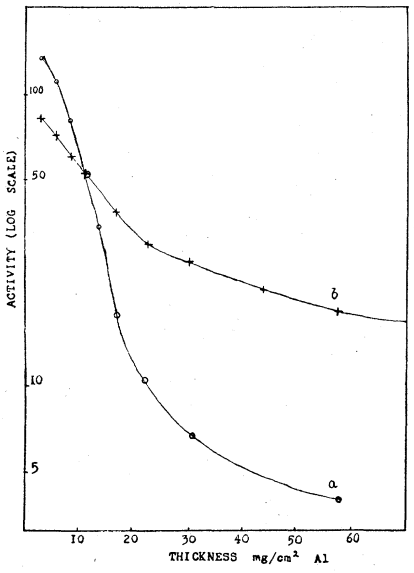

FIG. 1. Absorption curves of cobalt (a) and zinc radiation.

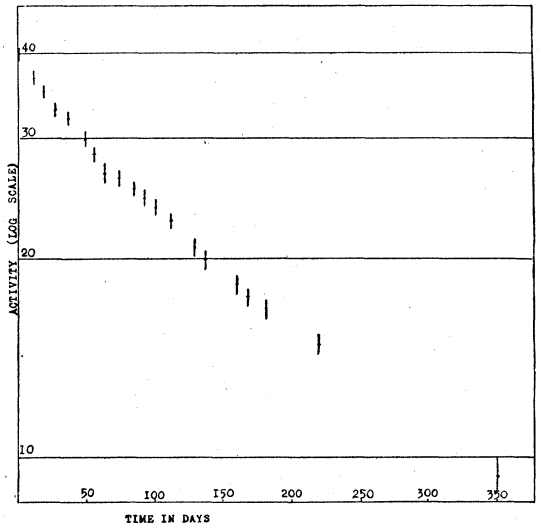

FIG. 2. Decay curve of cobalt.

Fairly strong activities were found in cobalt and zinc precipitates.

Cobalt and zinc, nickel and manganese were precipitated together in the ammonium sulphide group after having been added to the original solution.

Nickel and cobalt were separated by diacetylglioxime and α-nitroso-β-naphthol, or first by precipitation of nickel with diacetylglioxime and subsequent precipitation of cobalt with sulphuretted hydrogen.

Zinc and cobalt were separated by the method of Cl. Zimmermann[2] and by the method of Smith and Brunner.

Manganese was separated from nickel and cobalt with sulphuretted hydrogen in acetic solution. Zinc sulphide was also dissolved and reprecipitated as ammonium zinc phosphate.

From the pure precipitates we deposited zinc electrolytically from a sodic solution according to Spitzer, and cobalt from an ammoniacal solution according to Gibbs.

Zinc. The activity of zinc was measured on a thin electrolytic deposit and on zinc sulphide; the decay curves agree within the limits of experimental error. They were taken both on an ionization chamber closed by an aluminum foil of 0.1 mm thickness filled with CO_2 at three atmospheres pressure and on an ionization chamber closed by two aluminum foils of 0.001 mm thickness.

As a result of four of such curves measured for about 300 days a half-value period of 245 days was found. The decay curves are simple exponentials within experimental error.

The absorption curve of the radiation is given in Fig. 1, curve *b*.

Copper has two stable isotopes Cu^{63} and Cu^{65}. By the usual (D, n) reaction these isotopes would give rise to Zn^{64} and Zn^{66} both of which are stable. With the rather unusual (D, γ) reaction one would get Zn^{65} or Zn^{67}. The latter is known as a stable isotope; Zn^{65} according to Livingood[4] is radioactive with a period of one hour. It does not seem

possible to explain the existence of our radioactive zinc without assuming that it is isomeric with some nucleus already known. With this assumption all masses 64, 65, 66, 67 become possible. The possibility that the activity is due to neutron bombardment must also be borne in mind, though no zinc could be formed from copper by the usual primary neutron processes.

Cobalt. The activity of cobalt was examined by the same means as that of zinc. Electrolytic metallic cobalt, cobalt sulphide and the precipitate by α-nitroso-β-naphthol were examined. The decay curves show an indication of a bending; this bending seems to be present in all curves. Fig. 2 gives an example of such curves. The shape of the curve can be accounted for by admitting two radioactive cobalt isotopes. The longest period can be rather accurately determined and is of about 215 days. The shorter and, in our case, much weaker one is of the order of magnitude of one month. The absorption curve of the radiation is shown in Fig. 1, curve *a*. Two such curves were taken at about a six months interval. However, they do not show any remarkable difference in shape.

Magnetic deflection experiments show that the particles emitted are mostly electrons. There is also a γ-radiation.

We separated nickel from old cobalt preparations in order to see if cobalt decaying produced any radioactive nickel. No activity was found in nickel.

The formation of radioactive cobalt from copper under deuteron bombardment is not easily explained. Possibly radioactive cobalt is formed from copper under the bombardment of the neutrons always present in the cyclotron. In this case the processes would be $Cu^{63}(n, \alpha)\,Co^{60}$ or $Cu^{65}(n, \alpha)\,Co^{62}$.

If one of our activities is to be identified with an already known long period of cobalt[5] the mass 60 for the radioactive isotope seems to be most probable.

We have tried to find a radioactive cobalt by bombarding copper with neutrons of 500 mC of Rn+Be for several weeks and separating cobalt chemically. No activity was found in this way, but of course the neutron bombardment of the cyclotron is much more intense than ours can have been. Decisive evidence showing that the primary process is due to neutrons could be had by taking copper of a part of the tank which is not hit by deuterons.

Our warmest thanks are due to Professor E. O. Lawrence and to the Radiation Laboratory of the University of California (Berkeley) who by their invaluable gift made this investigation possible.

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[1] C. Artom, G. Sarzana, C. Perrier, M. Santangelo and E. Segrè, Nature **139**, 836, 1105 (1937)
[2] For all these methods see e.g. Treadwell's *Analytic Chemistry*.
[3] L. Jackson Laslett, Phys. Rev. **52**, 529 (1937).
[4] Livingood, Phys. Rev. **50**, 425 (1936).
[5] Sampson, Ridenour and Bleakney Phys. Rev. **50**, 382 (1936); Risser, ibid. **58**, 768 (1937).

Demagnetization Coefficient of Oblate Spheroids

The demagnetization coefficient N for an oblate (disk-like) spheroid in a direction normal to the axis of rotation is generally given in the form

$$N=2\pi\left[\frac{(1-e^2)^{\frac{1}{2}}}{e^3}\sin^{-1}e-\frac{1-e^2}{e^2}\right], \quad (1)$$

where e is the eccentricity. In terms of m, the ratio of the major to the minor axis, this becomes

$$N=\frac{2\pi}{m(1-1/m^2)}\left[\frac{1}{(1-1/m^2)^{\frac{1}{2}}}\sin^{-1}(1-1/m^2)^{\frac{1}{2}}-\frac{1}{m}\right]. \quad (2)$$

Neither form lends itself to rapid calculation, but it happens that an empirical equation can be used which is not only simple, but exceedingly accurate as well. A plot of $1/N$ against m results in a very straight line, except for values of m near 1. The equation of this line is

$$1/N=0.1013m+0.127. \quad (3)$$

An idea of its accuracy can be obtained from the following comparison:

m	$1/N$ (Eq. (1))	$1/N$ (Eq. (3))
1	0.239	0.228
5	0.638	0.634
10	1.143	1.140
20	2.153	2.153
50	5.200	5.192
100	10.26	10.26

This empirical equation should prove useful in connection with magnetization and torque measurements on oblate spheroids, and it is also applicable to a flat disk, insofar as a disk can be said to have a definite demagnetizing coefficient.

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The Zeeman Effect of the p^5d Configurations of Neon and Argon

We are just completing an investigation of the Zeeman effect in neon and argon, using a capillary discharge at high frequency in a field of about 28,000 gauss.

In the case of neon, a few members of the $2p^53d$, all of the $2p^54d$, and some of the members of $2p^55d$ and $2p^56d$ configurations are sufficiently resolved to allow the determination of the g factors. The agreement between the values thus found and the values calculated from Sampson's[1] and Shortley's[2] values is extremely satisfactory.

The results for argon also show very good agreement with the values computed from Sampson's parameters, although the agreement for the $3p^55d$ configuration is more satisfactory for $j=2$ than for $j=1$. Argon also shows an anomaly for the $j=2$ levels of the $3p^54d$ and $3p^55d$. While the levels called s_1'' and s_1'''' have practically identical g values ($g=1.00$) for the $3p^54d$, the values for $3p^55d$ are 1.2 and 0.8, showing that $5d$ is very much smaller for the $3p^54d$ than for the $3p^55d$.

Neon shows several interesting examples of the Paschen-Back effect in the p^5d configurations. The patterns have been calculated using the matrix mechanics and the computations are in good agreement with the observations.

A complete report will be published in the very near future.

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[1] Sampson, Phys. Rev. **52**, 1157 (1937).
[2] Shortley, Phys. Rev. **44**, 671 (1933).