Radioactive Isotopes of Cobalt

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THE recent mass spectrographic investigation of the cobalt isotopes by Mitchell, Brown, and Fowler,[1] showing that Co^{59} is the only stable isotope of cobalt, taken together with our recently acquired transmutation data, now makes it possible for us to make isotopic assignments for all the cobalt radioactivities with almost complete certainty. Tentative assignments had been made, before all these facts were known, in our table.[2,3] The following paragraphs outline what we now believe to be the proper interpretation.

Co^{60}: *10.7 minutes and 5.3 years.* The long-lived activity has been produced by the reactions $Co^{59}(n, \gamma)Co^{60}$, $Co^{59}(d, p)Co^{60}$ and $Ni^{62}(d, \alpha)Co^{60}$. Negative beta-particles and gamma-rays are emitted and the absorption curves have already been published.[4] The short-lived activity has been produced by the reactions $Co^{59}(n, \gamma)Co^{60}$ and $Ni^{60}(n, p)Co^{60}$ and the radiation consists largely of conversion electrons. It is probable that the 10.7-minute activity constitutes an isomeric transition from an upper to a lower level in Co^{60}, and that the 5.3-year activity is due to beta-particle decay from the lower level to stable Ni^{60}.

Co^{58}: *72 days.* This activity has been produced by the reactions $Mn^{55}(\alpha, n)Co^{58}$, $Ni^{58}(n, p)Co^{58}$, $Fe^{57}(d, n)Co^{58}$, $Fe^{57}(p, \gamma)Co^{58}$, and probably also $Fe^{56}(\alpha, np)Co^{58}$. Magnetic deflection experiments have shown that the particles are mainly, if not entirely, positive beta-particles. Absorption curves have been obtained from samples made by all, except the last, of these reactions, and the common range is 0.12 g/cm² of aluminum which corresponds[5,6] to an upper energy limit of 0.4 Mev. The gamma-ray absorption has a half-thickness of 6.5 g/cm² of lead, corresponding[7] to an energy of 0.6 Mev.

Co^{57}: *270 days.* This isotope has been produced by the reactions $Fe^{56}(d, n)Co^{57}$ and $Fe^{56}(p, \gamma)Co^{57}$. The range of the positrons is 0.06 g/cm² of aluminum, corresponding[5,6] to an energy of 0.26 Mev. Conversion electrons are also present in the radiation from this activity.

Co^{56}: *72 days.* The half-life of this positron emitter is the same, within the errors of measurement, as that of Co^{58}, but the energy of the positrons is decidedly greater. The range is 0.5 g/cm² of aluminum which corresponds[8] to an upper energy limit of 1.2 Mev. The gamma-ray absorption has a half-thickness of 10 g/cm² of lead, corresponding[7] to an energy of 1.05 Mev. This isotope has been produced by the reactions $Fe^{56}(d, 2n)Co^{56}$, $Ni^{58}(d, \alpha)Co^{56}$ and $Fe^{54}(\alpha, np)Co^{56}$. Low energy (5.5 Mev) deuterons on iron produce Co^{58} by the d, n reaction, but do not produce Co^{56}, while 16-Mev deuterons on iron produce Co^{56} by the $d, 2n$ reaction.

Co^{55}: *18.0 hours.* This well-known activity is produced by the reactions $Fe^{54}(d, n)Co^{55}$ and $Fe^{54}(p, \gamma)Co^{55}$. It has been found to be the parent of Fe^{55}, and this is the basis for its assignment to Co^{55}.

We have not found any evidence for a radioactive Co^{54}, which might have been formed by the reaction $Fe^{54}(d, 2n)Co^{54}$.

Full details of this work, including decay and absorption curves and a bibliography of all the work that has been done on the radioactive isotopes of cobalt, will be published in *The Physical Review* at a later date. We are indebted to Mr. G. Friedlander for aid in some of the experiments. Our thanks are also due the Research Corporation and the Rockefeller Foundation for financial support.

[1] J. J. Mitchell, H. S. Brown, and R. D. Fowler, Phys. Rev. **60**, 359 (1941).
[2] J. J. Livingood and G. T. Seaborg, Rev. Mod. Phys. **12**, 30 (1940).
[3] G. T. Seaborg, Chem. Rev. **27**, 199 (1940).
[4] J. J. Livingood and G. T. Seaborg, Phys. Rev. **53**, 847 (1938).
[5] R. W. Varder, Phil. Mag. **29**, 726 (1915).
[6] C. E. Eddy, Proc. Camb. Phil. Soc. **25**, 50 (1929).
[7] W. Gentner, J. de phys. et rad. **6**, 274 (1935).
[8] Widdowson and Champion, Proc. Phys. Soc. **50**, 192 (1938).