thus

$$\frac{L}{d} < \frac{1+\cos n^{1/2}\pi}{n^{1/2}\sin n^{1/2}\pi}. \qquad (2)$$

For the radial motion the equations are the same, except that $n^{1/2}$ is replaced by $(1-n)^{1/2}$.

According to Dennison and Berlin, the allowable range of n values in the racetrack is between $n=0.56$ and $n=0.75$. The corresponding limits given by (2) are $L/d<0.56$ and $L/d<0.25$. These are not unduly restrictive conditions. However, the defocusing effect which leads to this instability will manifest itself, even when the limits are not exceeded, by an increased amplitude of the oscillations. For orbits crossing the equilibrium orbit at the same angle, the amplitude of oscillation in the racetrack will be larger than in a circular synchrotron by a factor $\sin n^{1/2}\pi/\sin \pi\mu$. For $n=\frac{2}{3}$, $L/d=0.3$, this is a factor 2.3. One thus pays a price for the convenience of having the straight legs: insofar as the yield of the machine is concerned, the gap width and all vertical clearances are effectively reduced in just this ratio.

This work was carried out under the auspices of the Manhattan District.

[1] H. R. Crane, Phys. Rev. **69**, 542 (1946).
[2] D. M. Dennison and T. H. Berlin, Phys. Rev. **69**, 542 (1946).
[3] For the method of calculating μ see Whittaker and Watson, *Modern Analysis*, Sec. 19.4. A very similar problem has been treated by B. van der Pol and M. J. O. Strutt, Phil. Mag. **5**, 18 (1928).

Radioactive Isotopes in the Columbium Region

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In addition to the well-known activities in columbium (i.e., Cb^{93*} 40 days, Cb^{92} 11 days, Cb^{94} 6.6 minutes, Cb^{95} 75 minutes), a series of isotopes has been reported of half-lives 4 minutes, 12 minutes, 38 minutes, 21 hours, and 96 hours. These have been found by the Rochester group[1] and were produced from zirconium by the p-n reaction.

Short bombardments of columbium metal foils with 10-Mev deuterons produced the 6.6-minute β^--activity in Cb^{94} as well as 18-minute and 6.5-hour[2] positron activities. The latter periods can be assigned to isomeric states of Mo^{93} produced in the Cb^{93} $(d, 2n)$ process. Deuteron bombardment of molybdenum also yielded the 18-minute and 6.5-hour β^+-activities along with the 15-minute and 68-hour β^--decay periods.

Prolonged irradiation of a stack of columbium metal foils by 10-Mev deuterons produced intense activities in the front layers but essentially none (less than 2 percent of that in first foil) in the foils which were not penetrated by the beam of deuterons. After the short-lived activities (including the intense 6.5-hour Mo^{93}) had decreased to a negligible value, the decay followed the curve shown in Fig. 1. It is seen that two long periods remain, Cb^{92} 11 days and one of 21.6 hours. The latter activity is presumably identical with that of 21 hours formed by Zr $(p$-$n)$.

Cloud-chamber observations indicated that negative beta-particles were emitted by the latter isotope. Absorption in aluminum foils gave a value of 1.2 Mev for the upper limit of the β-spectrum. Gamma-rays of energy 0.6 Mev (as determined by absorption in lead) were also emitted by this isotope.

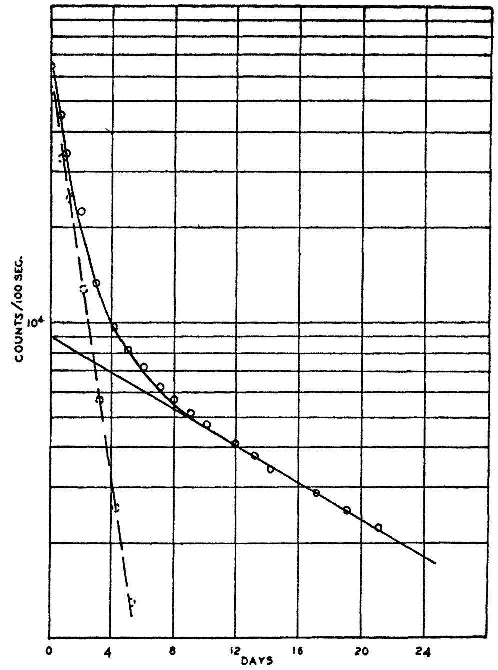

FIG. 1. Decay of long-period activities in columbium showing 21.6-hour and 11-day activities.

In studying the activities as a function of the average deuteron energy, it was found that the 11-day and 21.6-hour activities had similar excitation functions, the threshold for each being $\sim$5 to 6 Mev. The low value of the threshold energy indicated that Cb^{92} (11 days) is formed in the process Cb^{93} (d, H^3).

Slow neutron bombardment of columbium yielded the 6.6-minute activity but not the longer periods. The 21.6-hour period is therefore assigned to an isomeric state of Cb^{92} produced in the Cb^{93} (d, H^3) reaction.

[1] See G. T. Seaborg, Rev. Mod. Phys. **16**, 13 (1944).
[2] D. N. Kundu and M. L. Pool, Phys. Rev. **70**, 111 (1946).

Production of Heavily Ionizing Particles by X-Rays Generated by a 100-Mev Betatron[1,2]

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Cloud-chamber photographs of ionizing particles generated by x-rays of 100-Mev peak energy were taken in a magnetic field. It was found that in addition to numerous tracks due to electrons and positrons, tracks of heavily ionizing particles also occurred in the chamber. An attempt was made to obtain the masses of these particles from measurements of the range and curvature of their