

FIG. 1. Experimental build-up factors for transmission of a Co^{60} gamma-ray beam through concrete and lead.

regarded as the barrier thickness measured in mean free paths of the primary photons.

The build-up factor for lead is seen to be much lower than for concrete, a result caused by the appreciable photoelectric absorption in lead. The build-up curves show no tendency to flatten off, i.e., there is no evidence to suppose that an equilibrium between primary and secondary gamma-radiation is established. This is in accordance with the theoretical work. A quantitative comparison with many of the theoretical results, however, has been precluded by the amount of computation required. Calculations made by Solon, Wilkins, Oppenheim, and Goldstein,² based on a "root-mean-square angle" approximation, give build-up factors which are much smaller than our experimental values. Experimental build-up factors for a spherical geometry, reported by White,³ are larger than our values for the transmission of a beam through a barrier.

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¹Hirschfelder, Magee, and Hull, *Phys. Rev.* **73**, 852 (1948); J. O. Hirschfelder and E. N. Adams, II, *Phys. Rev.* **73**, 863 (1948); L. V. Spencer and U. Fano, *J. Research Natl. Bur. Standards* **46**, 446 (1951), and references given by these authors; L. L. Foldy, *Phys. Rev.* **81**, 395 (1951); L. L. Foldy and R. K. Osborn, *Phys. Rev.* **81**, 400 (1951); L. L. Foldy, *Phys. Rev.* **82**, 927 (1951); G. H. Peebles and M. S. Plesset, *Phys. Rev.* **81**, 430 (1951); Cave, Corner, and Liston, *Proc. Roy. Soc. (London)* **A204**, 223 (1950); Corner, Day, and Weir, *Proc. Roy. Soc. (London)* **A204**, 329 (1950).

²Solon, Wilkins, Oppenheim, and Goldstein, AEC Report No. NYO-637 (1951).

³G. R. White, *Phys. Rev.* **80**, 154 (1950).

Preparation of Ra^{229} and Ac^{229}

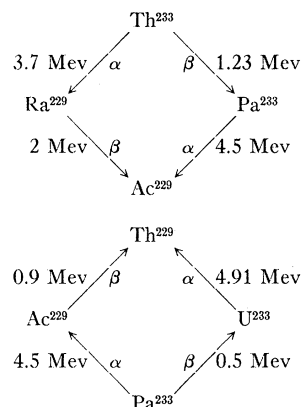
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BY the method of decay cycles^{1,2} it is possible to predict the disintegration energies of nuclides which have never been observed. In the present experiment, the β -disintegration energies

of Ra^{229} and Ac^{229} were calculated from the following cycles,



The α -disintegration energies of Th^{233} and Pa^{233} were obtained by extrapolation of the appropriate lines on an α -energy *vs* mass number plot (see reference 1, Fig. 1). In this way, the β -disintegration energies of Ra^{229} and Ac^{229} were calculated to be 2 Mev and 0.9 Mev, respectively. It was expected that these energies would lead to β -decay half-lives of about a minute and one hour, respectively.

Therefore it seemed possible that Ac^{229} could be obtained by a short irradiation of Ra^{228} (MsTh1) in a high neutron flux in the NRX pile, followed by a rapid chemical separation of Ac.

Ra^{228} was freed from 6.13-hr Ac^{228} (MsTh2) and rare earths by repeated extraction of its solution in a sodium acetate buffer of pH 6.0 with 0.25M thenoyltrifluoroacetone (T.T.A.) in benzene. The Ac-free aqueous radium solution was immediately evaporated to dryness in a silica tube, which was sealed and irradiated for

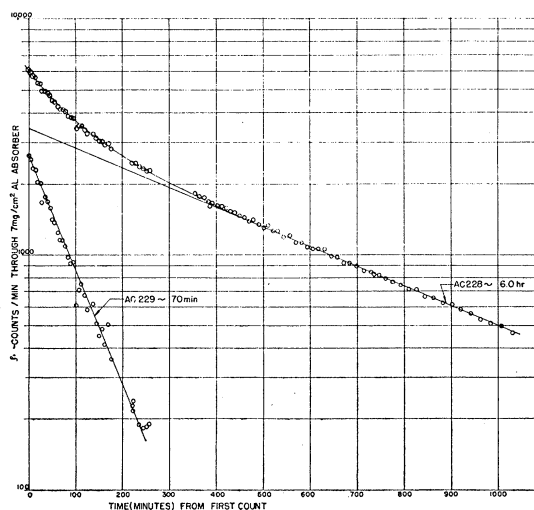


FIG. 1. Decay of Ac fraction from neutron-irradiated MsTh1 .

30–60 minutes in a thermal neutron flux of 5×10^{13} neutrons/cm² sec.

After the irradiation, the silica tube was smashed under sodium acetate buffer solution, and the Ac^{229} (plus the Ac^{228} which grew in during the irradiation) was extracted as before with T.T.A. The Ac was recovered into aqueous solution by agitating the benzene phase with 0.1M nitric acid. It was further purified by the method of Haissinsky³ and then by a second extraction with T.T.A. The benzene phase was washed twice with sodium acetate buffer

solution to remove adhering traces of the aqueous phase. Finally, the Ac was recovered in aqueous solution by extracting the benzene phase with 0.1M nitric acid. The nitric acid was evaporated on to a counting tray, and the decay of the β -activity was observed with an end-window Geiger tube counting through a 7 mg/cm² aluminum absorber. Counting began about 30 minutes after the end of the irradiation.

Periods of 66 ± 5 minutes and about 6.1 hours, attributed to Ac²²⁹ and Ac²²⁸, respectively, were observed. A typical decay curve is shown in Fig. 1.

The ratio of the 66-min activity to the Ac²²⁸ activity was not altered by precipitating BaSO₄ from a solution of the two, or by coprecipitating the activities with a carrier of lanthanum fluoride.

The possibility that the 66-min activity was the result of a fission product of uranium (which might be present as a trace impurity) was eliminated by showing that careful re-purification of the Ra²²⁸ from uranium did not alter the amount of Ac²²⁹ produced and also by showing that the main activity resulting from uranium (in samples which had not been coprecipitated with LaF₃) would be 23 minute U²³⁹, which was never observed in irradiations of Ra²²⁸. The 66-min activity does not correspond to any known rare earth activity which could be formed by (*n*, γ) reaction on rare earth impurities present in the Ra²²⁸. Finally, an irradiation under cadmium showed that the 66-min activity was produced by a thermal neutron reaction.

Since the 6.13-hr Ac²²⁸ could be used as a tracer for the Ac²²⁹, it was not necessary to know either the initial amount of Ra²²⁸ irradiated, or the yield of actinium in the chemical purification in order to calculate the (*n*, γ) cross section of Ra²²⁸. Values of 33 and 39 barns were obtained in two irradiations, but these results are not corrected for differences between Ac²²⁸ and Ac²²⁹ in back-scattering or counter window absorption. It is unlikely that the Ac²²⁹ was formed by (*n*, γ) reaction in the small amount of Ac²²⁸ present. The unusually large cross section of 2×10^6 barns would be required for this reaction in order to account for the amount of Ac²²⁹ produced.

A second extraction of Ac from the irradiated Ra²²⁸, carried out 10 minutes after the first, gave the expected amount of Ac²²⁸, but no Ac²²⁹. This observation is consistent with a short half-life for Ra²²⁹.

We wish to thank the NRX pile operating crews and Mr. P. B. Aitken for their cooperation in making fast irradiations possible.

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¹ Perlman, Ghiorso, and Seaborg, *Phys. Rev.* **77**, 26 (1950).

² S. G. Thompson, private communication.

³ M. Haissinsky, *Compt. rend.* **196**, 1778 (1933); C. K. McLane and S. Petersen, *National Nuclear Energy Series, Plutonium Project Record*, Vol. 14B, *The Transuranium Elements: Research Papers*, Paper No. 197 (McGraw-Hill Book Company, Inc., New York, 1949), p. 1388.

Distribution of Components of Ternary Isotopic Mixture along Clusius-Dickel Column*

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AN exploratory investigation was made into the distribution of the components of a ternary isotopic mixture along a Clusius-Dickel hot-wire thermal diffusion column during the approach to equilibrium.¹ Neon gas was chosen as the working substance because (a) it has a rather large thermal diffusion effect; (b) it has three stable isotopes, the rarest of which is sufficiently abundant in natural neon to be observed with the mass spectrograph available to us; (c) it is chemically inert, and requires no special handling techniques.

The details of construction of the three-meter glass Clusius-Dickel column are given in Fig. 1. It differs principally from

similar Pyrex columns used at Yale University² in that four additional sample tap-offs are provided at regular intervals along the length, to enable study of the distribution of components at various levels.

The samples were analyzed on a Consolidated model 21-102 recording mass spectrometer, made available to us by the U. S. Bureau of Mines Experimental Station in Laramie.

Spectroscopically pure neon, containing isotopes of masses 20, 21, and 22 in the percentages 89.90, 0.28, and 9.82, respectively, was introduced into the previously evacuated column by means

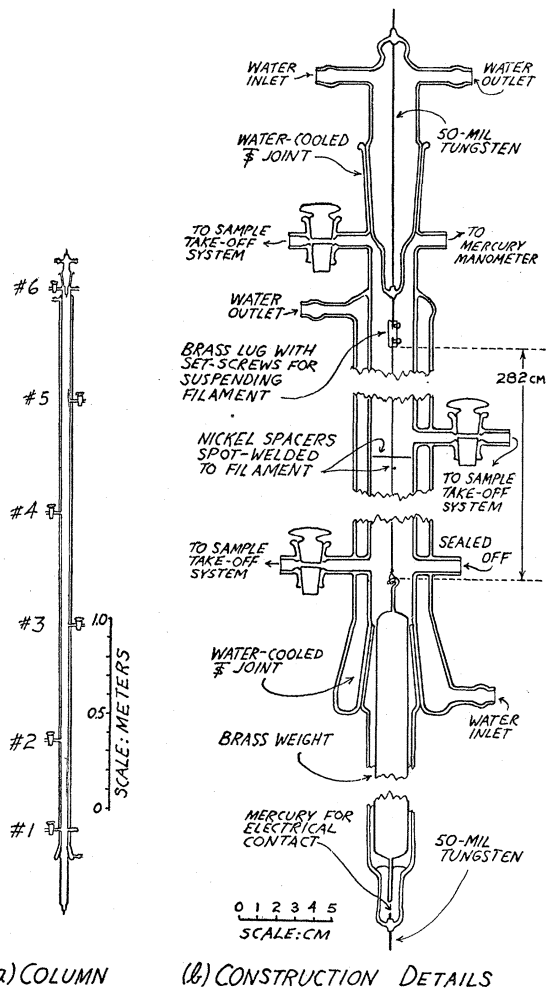


FIG. 1. Clusius-Dickel column for neon isotopes.

of a Toepler pump. When the electrically heated tungsten filament reached operating temperature, the neon was at a pressure of 61 cm Hg. (As the altitude of Laramie is 7200 ft, barometric pressure was only 58 cm Hg.) The ratio of cold-wall radius to hot-wire radius was 39.4:1, and the temperature ratio was approximately 1:4. The average temperature of the hot wire was determined from its thermal elongation. Equilibrium was essentially reached in about five hours of operation.

The results are summarized in Fig. 2. As the Ne²¹ constituted such a small fraction of the total throughout the run, the distributions of Ne²⁰ and Ne²² are effectively mirror images of each other. For these two isotopes there appears to exist in the column a pivot point, or point of constant concentration, at which the concentration never deviates from its initial value.