A New Determination of the Range of the Alpha Particles of Uranium I and II.

—By George C. Laurence, M. Sc., Physics Laboratory, Dalhousie University, Halifax, N. S.*

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The ranges of nearly all the elements which emit alpha particles have now been determined accurately. The values for uranium I and II and thorium are less reliable because of experimental difficulties incident to their low activity. Considerable interest, however, is attached to these three, because the validity of Geiger and Nuttall's Law for elements of small decay constant is almost entirely dependent on them. Apparent disagreement, moreover, between their ranges, as measured by Geiger and Nuttall[1], and as calculated from pleochroic halo data[2], has led to a suggestion that there has been a gradual change in their ranges and decay constants throughout geological time. A new determination of the ranges of uranium I and II has therefore been undertaken, using the Wilson Cloud Chamber Method which appeared likely to yield higher accuracy than ionisation or scintillation methods. The extremely small activity of the radioactive material required that the method be modified by the use of a source of large area, the operation of the camera shutter by hand, and the abandonment of shutters to cut off the radiation before the completion of expansions.

Apparatus.—The expansion chamber had a diameter of 6 cm. and a maximum depth of 1 cm. Its piston was operated by a lever, cam and spring mechanism. A fine bore manometer connected to it provided for the measurement of the pressure inside, and a thermometer inserted between projecting flanges of the chamber indicated the temperature. The usual

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1 H. Geiger and J. M. Nuttall, Phil. May **23**, 439, 1912, and H. Geiger, Z S. f. Phys. **8**, 45, 1922.

2. J. Joly, Trans. Roy. Soc. of London, **A551**, 51, 1917, and B. Gudden, Z S. f. Phys. **26**, 110, 1924.

gelatin film kept the air in the chamber moist and served as a conducting electrode for an electric field of 200 volts across the chamber.

The chamber was lighted from the side by a 10 ampere d. c. arc with condensing lenses and an alum solution to absorb heat radiation.

The camera had a lens of 4.5 f. a. and focal length 7.5 cm. and was mounted 20 cm. above the chamber. Kodak Super Speed Motion Picture Film was used, being carried on reels in a box detachable from the back of the camera. Exposures of .4 to .6 seconds were required for sharp photographs.

Source.—The source was prepared by subliming uranium vapor on strips of mica. Small lumps of metallic uranium supported on the ends of tungsten wires formed the electrodes of an electric arc. The arc was struck in a pressure of a few millimeters of air, which was just sufficient to maintain it. The uranium, vaporised by the heat, deposited in a thin uniform film on the mica strips which formed a spiral about 4 cm. in diameter surrounding the arc. A current of 10 amperes for one minute produced a film of the required thickness; .5 mg. per sq. cm., equivalent in absorption to 1mm. of air. A strip thus prepared, 10 cm. long by .8 cm. wide, fastened to the side walls of the chamber with soft wax, served as the uranium source.

Method.—Some of the tracks are formed in the chamber before the expansions are completed and are a source of error. The usual method of stopping the radiation before the completion of expansions by shutters was not practical with so large a source. By making the expansions very rapid, however, the number of tracks formed before the completion of expansions was reduced to less than 2% of the total number, as estimated from the supposition that the number of tracks formed is proportional to the length of time the gas in the chamber is below the required supersaturation temperature. This source of error was therefore negligibly small.

Although provision was made for the automatic operation of the camera shutter, the fact that only one expansion in a

hundred produced a track suitable for photographing made it practically necessary to operate it by hand. It was found that the shutter could be opened by hand before the tracks diffused enough to measurably affect the length, so that small error resulted from this cause.

Preliminary Experiments with Polonium.—Thus modified, the method was applied as a check to the alpha particles of polonium. Small pieces of a glass tube that formerly contained radium emanation were used as a source. 400 photographs were taken. After discarding indistinct and doubtful tracks, about 300 were measured on the negatives. The range of polonium determined from these in the usual manner was found to be 3.84 cm. That this is somewhat smaller than the generally accepted value 3.92 cm., is partly accounted for by the penetration of the radium A, radium B and radium D into the glass by recoil.

Uranium Measurements.—About 600 photographs, requiring over 50,000 expansions, were taken. After discarding poor photographs about 370 measurements were obtained. These were corrected for temperature, pressure and vapor pressure. From these data a curve was plotted with range as abcissa and number of tracks of length greater than that range as ordinate. This curve fell off rapidly to zero as the end of the range of uranium II was reached, with no tracks longer than 3.32 cm. The range of uranium II was obtained in the customary manner by extending the slope at the end of the curve in a straight line to intersect the range axis. Superimposed on the curve representing the uranium II tracks is another similar curve corresponding to the shorter range uranium I. Producing the slope at the end of this curve to intersect the uranium II curve exterpolated back gave the range of uranium I.

From the distribution of the tracks about a mean value according to the error law, as found by Mlle. Curie[3], it was shown that corrections of .049 cm. and .055 cm., respectively,

3. Mlle. I, Currie, Ann. de Phys. **3**, 299, 1925.

should be added to the ranges so obtained to correct for the finite thickness of the source. .018 cm. and .016 cm. were also added to the ranges to correct for the obliquity of the tracks to the plane of the photographic film.

About 20% of the tracks hit the top or bottom of the chamber before reaching the end of their path. These affect the shape of the curve considerably but their distribution is such that they introduce an error of probably less than .005 cm. in the result as obtained above, as was shown by calculating the curve of their distribution from probability considerations.

Fully corrected, the ranges in dry air at 760 mm. pressure and 15°C are—

for uranium I, 2.72 cm.
for uranium II, 3.29 cm.

with an error of probably less than $1\frac{1}{2}\%$ and 1% respectively.

The value for uranium I falls on the Geiger and Nuttall Curve within the limits of experimental error and is quite close to Geiger and Nuttall's value 2.67 cm. The result for uranium II is considerably greater than Geiger and Nuttall's 3.07 cm. Both results appear to be still at variance with the pleochroic halos. Applying Geiger and Nuttall's law to the range 3.29 cm. gives for the decay constant of uranium II, which has never been measured, 2.1×10^{-11} sec.$^{-1}$, and for the half life, 1.0×10^{4} years.

The above values are to be considered as provisional pending the taking of more photographs. It is intended to apply the method also to thorium. A fuller discussion of the method will be given in a subsequent paper.

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