Report

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Preliminary Report on the Capture of Neutrons by Uranium in the Energy Region of Photo Neutrons from Radium-Beryllium Sources

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The capture of neutrons by uranium which leads to the formation of uranium 239 plays an important role from the point of view of the chain reaction in a system in which a lattice of uranium spheres is embedded in graphite. If the cross-section for this process were known as a function of the energy, then this knowledge could be utilized in determining the most favorable arrangement in this system. While one may assume that this cross-section falls off inversely proportionally to the square root of the energy of the neutron in the region between a few hundred volts and a few ten thousands of volts, the absolute value of the cross-section is not known for any value of the energy. We have for this reason attempted to determine this cross-section for photo neutrons from a radium-beryllium source. A preliminary rough measurement gives a cross-section of about

As a source of neutrons we used a beryllium block 8 cm. high having a diameter of 8 cm. and an inside bore of 3 cm. diameter. A small box containing a uranium salt, from which the natural β-active components were removed before irradiation, was placed inside the bore of the beryllium block and two grams of radium were placed next to it inside the bore. While this uranium s ample was being irradiated, another identical uranium sample was placed in a flat container below a Geiger counter and the growth of its activity was observed. After irradiation (48 minutes) the non-irradiated sample was replaced by the irradiated sample and the activity of the latter was followed. The difference in initial activity between the two samples (taken at the time when the irradiation was stopped) amounted to 0.93 expressed in units of the activity which corresponds to one hour's growth of activity of the two samples (which is due to the growth of uranium X in the sample). This value has to be multiplied by 4/3 in order to correct for infinite time of irradiation. We may write for the capture cross-section σ of uranium leading to the formation of uranium 239

$$\sigma = .93 \times \frac{4}{3} \frac{\beta}{N\alpha} \frac{1}{852 \times 2.08 \times 10^{17}} \qquad (1)$$

In this formula N is the number of neutrons emitted by the photo source, α is the geometrical factor so defined that αN gives the number of neutrons going per cm.^{2} and second through the uranium sample. β is a factor which correlates the penetrating power of the β rays of uranium 239 to the β rays of uranium X; if these two β rays were equally penetrating, the factor β would have the value 1. In reality the β rays of uranium 239 are softer, and the value of β is roughly estimated to be about 3 for the case of our particular geometry. This value is a rough estimate which will be checked by later measurements. The above given formula would hold if the total initial activity of 0.93 growth units would be due to the 24-minute period of uranium 239. In reality a fraction of about .18 of this activity is due to fission, and a corresponding correction will be applied to the cross-section given by equation (1).

In order to determine the fraction of the initial activity which is due to fission, and in order to determine the value of the factor α, the following experiments have been carried out.

(a) A box filled with 3 grams of the above-mentioned uranium salt was irradiated by a fast neutron source (one gram of radium mixed with beryllium) at 7 cm. distance for 48 minutes, and the initial activity was observed by switching over from a non-irradiated sample to the irradiated sample at the end of the irradiation. This initial activity was observed to be 1.1 growth units on a 3 gram sample placed below the counter in the same geometry as used before.

(b) The number of fissions produced in an ionization chamber coated with a thick uranium oxide layer was compared for the photo neutron source and the radium-alpha-beryllium source. We obtained 5 fissions for the photo neutron source at a distance of 11 cm. between the center of the source and the center of the spherical ionization chamber. We obtained 124 fissions per minute for the radium-beryllium mixture at a distance of 15 cm. from the center of the spherical ionization chamber.

(c) We compared the activity obtained in iodine with photo neutrons for two positions, one being the same position in which the uranium was irradiated by photo neutrons in the first mentioned experiment, and the other being 10 cm. away from the center of the photo neutron source. We found the ratio of the activities to be 13.6.

From the accessory experiments a, b and c we may conclude that about 0.16 of the initial activity is due to fission, and 0.93-0.16 = 0.77 is due to the 24-minute period.

From the accessory experiment c we may conclude that the factor a has the value of $a = 13.6 \times \frac{1}{4\pi 10^2}$. The number of neutrons emitted by the photo source per second (N) was estimated sometime ago by Anderson and Fermi who compared this photo neutron source with a fast neutron source (radium mixed with beryllium) to be about 3.8×10^6. This value is now being re-measured by B. T. Feld under the supervision of E. Fermi. With the above value and the application of the above-mentioned correction of the initial activity observed after photo neutron irradiation for fission activity, we find a cross-section for the formation of uranium 239 of about

$$\sigma = 6.15 \times 10^{-25} \text{ cm}^2$$

Since this value appeared to be exceptionally high if compared with the capture cross-sections of elements other than uranium which were found by Halban and Griffiths, on the other hand, for photo neutrons from radiothorium-deuterium and radium-beryllium, respectively. We have, therefore, also tried to determine the capture cross-section for iodine for which Griffiths has reported a value of

questionable value. Again we find a very high value, about ten times as large as the value quoted by Griffiths, and in this particular case we have compared the activity of a thin sheet of iodine irradiated by photo neutrons in a fairly well defined geometry and compared this activity with the activity of uranium x and radium E standards. It should be noted that our measurement of the uranium cross-section is not finished and, therefore, more accurate determinations are being made at present.