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CAPTURE CROSS SECTIONS FOR 240 KEV NEUTRONS OF GOLD, RHENIUM AND URANIUM

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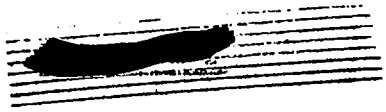
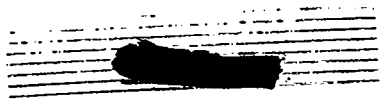


ABSTRACT

The capture cross section of gold, rhenium and urenium for 240 Kev neutrons is measured. We obtain $\sigma_{Au} = 0.7 10^{-24}$ cm^2, $\sigma_{Re185} = 1.2 10^{-24}$ cm^2, $\sigma_{Re187} = 1.3 10^{-24}$ cm^2 and $\sigma_c(28) = 0.165 10^{-24}$ cm^2, on the basis of $\sigma_f(25) = 2.5 10^{-24}$ cm^2.



CAPTURE CROSS SECTIONS FOR 240 KEV NEUTRONS OF GOLD, RHENIUM AND URANIUM

The capture cross sections of several elements for 240 Kev neutrons have been measured by using Y+Be photoneutrons and detecting the β radioactivity formed in the samples irradiated.

EXPERIMENTAL METHOD

The general experimental procedure is a very simple one: the yttrium source is embedded in a cube of beryllium having a 4 cm side. This cube is put in contact with an enriched uranium sample of known 25 content and the fissions produced are measured in an ionization chamber connected with a linear amplifier. In this way, knowing the cross section of 25, one can calculate the neutron flux through a sample having the geometry of the 25 sample.

The 25 sample is then replaced by the substance to be studied, care being taken that no changes are introduced in the geometry, and the new substance is irradiated to saturation. Afterwards its beta activity is measured. Obviously we have

$$\sigma_c = \sigma_{25} \frac{R\, N_{25}}{R_f\, N}$$

in which σ_c is the capture cross section of the substance under investigation, σ_{25} is the fission cross section of 25, R is the number of disintegrations per unit time in our sample, which contains N atoms and R_f is the fission rate in the 25 sample which contains N_{25} atoms.

CORRECTIONS APPLIED

In calculating R from the counting rate in a Geiger-Müller counter many corrections are needed. We shall not describe all the obvious ones, like the correction for a finite time of irradiation. A few words are

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in order, however, on some other corrections, such as the estimate of the counter efficiency, and the self-absorption of the sample and the counter-window absorption. Our counters have a flat mica window of about 3 mg/cm^2 thickness and 2 cm diameter. The sample is located at a fixed position a few millimeters under the window and a weighed sample of U_3O_8 is occasionally located in the same position. The U_3O_8, which weighs about 15 mg, is spread on a thin mica foil as a disc having the same diameter as our samples, fixed with a trace of Duco cement and covered with another thin mica window. We assume that such a sample emits 734 betas per minute per milligram. These betas are due to UX_2; we have neglected the betas of UX, and of UY because they are so soft that they do not pass the various windows. This is shown also by investigation of the absorption of the beta rays of our uranium standards.

Using such a standard we find the efficiency of our counters for UX_2 beta rays; it turns out to be approximately 0.3.

The correction for self-absorption is made by using the formula

$$A = A' \frac{\mu t}{1 - e^{-\mu t}} ,$$

in which A is the corrected counting rate, A' the observed counting rate, μ "the absorption coefficient" of the beta rays and t the thickness of the samples.

In the Re experiment μ/ρ was measured for Al and then calculated from the empirical relation

$$(\mu/\rho)_{Re} = (\mu/\rho)_{Al} \frac{(150 + Z_{Re})}{(150 + Z_{Al})} .$$

This procedure was tested in the case of gold by hammering into a thin foil a portion of the sample and measuring μ/ρ directly. The results are consistent within the experimental errors.

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The window absorption is calculated from the absorption coefficient of the beta rays.

Finally it is important to ascertain whether more than one electron is emitted per disintegration. This last point, as is well known, is especially important for 93^{239}. In the case of gold, data are found in the literature*

* J. R. Richardson, Phys. Rev. 55, 609 (1939)
Also A. F. Clark, Phys. Rev. 61, 232 (1942).

showing that there is only a weak line of conversion electrons occuring at about 400 Kev. of such an intensity as to indicate less than 0.1 internal conversion electron per disintegration.

RESULTS FOR Au, AND Re [redacted]

By using the procedure outlined above it was found

$$\frac{\sigma_{Au}}{\sigma_{25}} = 0.28 \pm .06,$$

$$\frac{\sigma_{Re^{187}}}{\sigma_{25}} = 0.53 \pm 0.1,$$

$$\frac{\sigma_{Re^{185}}}{\sigma_{25}} = 0.47 \pm 0.1.$$

The assumption that $\sigma_{25} = 2.5 \times 10^{-24}$ cm^2 gives

$$\sigma_{Au} = 0.7 \times 10^{-24} \text{ cm}^2,$$

$$\sigma_{Re^{187}} = 1.3 \times 10^{-24} \text{cm}^2,$$

and $$\sigma_{Re^{185}} = 1.2 \times 10^{-24} \text{ cm}^2.$$

For the natural mixture of the Re isotopes $\sigma_{Re} = 0.51\sigma_{25} = 1.25 \times 10^{-24}$ cm^2; these values differ substantially from values found by H. v. Halban, Jr. and L. Kowarski (Nature, 142, 392-3 (1938)), for neutrons of approximately the same energy. The reason for the discrepancy is unexplained; also for other substances (silver, iodine) we found σ much larger than the values reported by v. Halban and Kowarski.

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MEASUREMENT OF σ_c of 28

Similar experiments were performed to determine σ_c of U^{238} for Y+Be neutrons. The principle of the experiment is the same as described above, except that instead of measuring the activity of the U^{239} formed, it was allowed to decay to 93^{239}, which was extracted chemically.

This procedure is indicated because the period of U^{239} (23 min.) is inconveniently short to work with, and because the activities of the fission products and of the uranium itself mask the 23 min. period. Also by using a chemical procedure one can operate with a sizable amount of uranium. In this case 59 grams of U_3O_8 located in a cylindrical box having 6 cm diameter were used. The neutron flux through the U_3O_8 box was measured by putting a known sample of enriched uranium in a median plane perpendicular to the axis and counting the fissions produced in it by our source.

We describe now the chemical procedures used: before irradiation the uranium was freed of UX_1 and UX_2 by water extraction of an ether solution of $UO_2(UO_3)_2 \cdot 6H_2O$. U_3O_8 was then prepared from the ether solution by further water extraction, precipitation with ammonium hydroxide, and ignition. The chemical treatment of the sample after irradiation was designed to give a reproducible extraction of 93, free of UX, the beta activity of which, if it were not removed, would grow sufficiently during the irradiation to mask completely the beta activity which was to be measured.

The irradiated oxide was dissolved with nitric acid; sulphur dioxide was added to insure the 93 being in the reduced fluoride-insoluble oxidation state; and a fluoride precipitate was taken out with cerium, lanthanum and zirconium present as carrier substances. The cerium and lanthanum carry the 93 in the precipitate; the zirconium keeps element 91 in solution. The precipitate was dissolved by fuming it with sulphuric acid; Th was added; and the 93 in this solution was oxidized with potassium bromate to the fluoride-

soluble state. The UX_1 was then precipitated as fluoride with its Th carrier. As the solution at this point still contained some beta besides that due to 93, it was fumed with sulphuric acid, rare earth carrier and potassium bromate were added, and another fluoride precipitate was removed. The solution from this operation was then fumed with sulphuric acid; a small amount of rare earth carrier and zirconium were added; and finally the 93, now in the reduced state, was precipitated as fluoride. This was the sample used in the measurements.

A blank experiment, consisting of treating according to the above scheme 60 grams of U_3O_8 which had been purified and then allowed to stand a few days, but which had not been irradiated, showed that only 90 counts per minute, small compared with the activity produced in irradiation, appeared in the final sample. This represents the amount of UX extracted together with 93 in our purification scheme. Two other check experiments were tried to determine the efficiency of extraction of 93 from a 60 gram sample of U_3O_8. These were done by dissolving another lot of U_3O_8 such as was used in the blank experiment and adding to it a known amount of 93. This mixture was put through the procedure, and the amount of 93 appearing in the final sample was measured. The yields from two such experiments were 78% and 82%.

The more difficult problem of passing from the counts measured in a Geiger-Müller counter to the number of disintegrations in the sample was solved by using data of Wahl (CN-266 and private communication) obtained with a very similar counter. These experiments do not seem absolutely final and it is planned to repeat them and check some possible although improbable loopholes. However the fact that Wahl obtained the correct half life of 94^{239} by using his method of reduction through 93^{239} counts to disintegration shows that this method is substantially correct.

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Using the number of disintegration in the 93^{239} sample, measured by the process described above, and the number of fissions produced in our standard, we obtain:

$$\frac{\sigma_c(28)}{\sigma_f(25)} = 0.066 \pm 0.001$$

or $\sigma_c(28) = 0.165 \times 10^{-24}$ cm^2 .

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