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## 14 MeV fission cross-sections of $^{232}$Th and $^{237}$Np*

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The only source of information about the fission cross-sections of $^{232}$Th and $^{237}$Np for 14 MeV neutrons is the compilation of neutron cross-sections by Hughes and Harvey.(1) However, these cross-sections have been taken from unpublished work and the experimental errors are not given. The purpose of the work reported here was to obtain more complete data on these cross-sections.

The source of fast neutrons in our experiments was the $T(d, n)^4$He reaction, in which 175 KeV deuterons bombarded a thick zirconium tritide target placed at an angle of 45° to the beam. The effective deuteron energy, after allowing for the energy loss of the deuterons in the target and the cross-section of the reaction as a function of energy, was 118 KeV.(2) The neutron output was monitored by using a proportional counter to count the α-particles emitted at 90° to the deuteron beam.

The fissile materials were electroplated upon platinum disks to form targets 20 mm in diameter which were placed in an ionization chamber at a distance of 6·2 cm from the neutron source. The energy of the neutrons inducing fissions in these targets was 14·6 MeV. In order to simplify the geometry and to obtain greater accuracy, the deuteron beam was defined by a diaphragm to give a beam spot on the tritium target less than 5 mm in diameter. The neutrons could therefore be regarded as originating from a point source. With this assumption, and allowing for the anisotropic angular distribution of the α-particles and neutrons in the laboratory system of co-ordinates,(2) the fission cross-section $\sigma$ can be calculated from the following formula:(3)

$$\sigma = \frac{4\pi r_0^2 k \omega_\alpha N_f}{\ln\left(1 + \frac{r_0^2}{R_0^2}\right) N N_\alpha} \tag{1}$$

where $r_0$ is the radius of the fissile deposit, $R_0$ is the distance from the neutron source to the deposit, $\omega_\alpha$ is the acceptance solid angle of the α-particles, $K$ is a coefficient which allows for the anisotropic angular distribution of the α-particles and neutrons, $N$ is the number of atoms of the fissile isotope in the deposit, $N_f$ is the number of fissions, and $N_\alpha$ is the number of α-particles recorded by the proportional counter.

Particular care was taken over the determination of the weight and purity of the fissile isotopes. To facilitate the determination of the weight of $^{232}$Th in the thorium target, the specific activity was increased by adding a trace amount of $^{230}$Th (decay period: $\tau = 8{\cdot}0 \times 10^4$ years). The chemical purity of the preparation was first examined spectrographically. It was then heated to a temperature of 1400°C to ensure the complete oxidation of the thorium to $ThO_2$, and weighed to an accuracy of 0·5 per cent. The oxide was then dissolved in distilled water and the solution successively diluted. This solution was also weighed very accurately. In order to determine the specific activity of the mixture of thorium isotopes (i.e. the number of α-particles counted per unit weight of thorium),

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samples from the solution were placed on platinum disks and weighed on an automatic balance. After drying, their activity was measured in an ionization chamber. The average specific activity of the thorium from six samples having various weights was 36·7 ± 0·3 counts/min/$\mu$g into $2\pi$ solid angle. The amount of thorium in the target was found by comparing its specific activity with that of some thorium electrolytically deposited from a solution of thorium nitrate in alcohol. It was found to be 248 ± 3 $\mu$g.

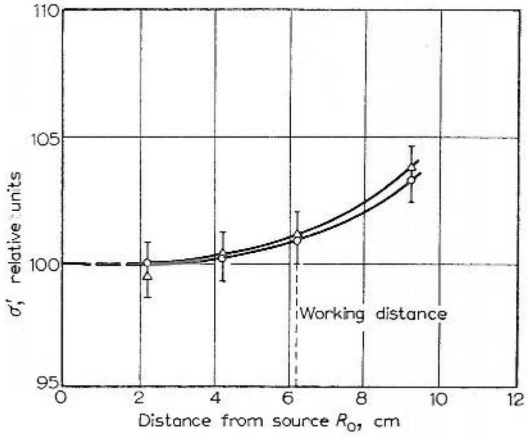

FIG. 1.—Scattered neutron background determination.

The weight of the $^{237}$Np in the neptunium target was obtained from its $\alpha$-activity, using the results of an earlier determination(4) of the $\alpha$-spectrum and decay period ($\tau = 2{\cdot}2 \pm 0{\cdot}1 \times 10^6$ yr) of this isotope. The number of neptunium atoms in the target deposit was $5{\cdot}57 \pm 0{\cdot}03 \times 10^{16}$.

When determining fission cross-sections, it is necessary to make an allowance for the fact that fissions may be induced, not only by the direct neutrons, but also by those scattered from surrounding objects. The fraction of these background fissions depends upon the distance between the neutron source and the target and also upon the behaviour of the fission cross-section as a function of neutron energy. In the cases of $^{232}$Th and $^{237}$Np, fissions can be induced only by fast neutrons and the effect of room scattered neutrons is therefore expected to be small. A quantitative determination of the fraction of fissions induced by scattered neutrons was made by studying the variation with the distance

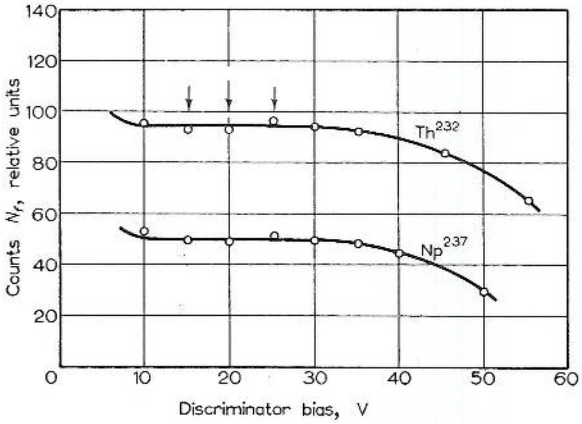

FIG. 2.—Ionization chamber characteristic. (The arrows indicate discriminator settings used.)

from the source of the term $\sigma'$ which occurs in equation (1):

$$\sigma' = \frac{N_f}{\ln\left(1 + \frac{r_0^2}{R_0^2}\right) N_\alpha} \tag{2}$$

Graphs of this quantity as a function of the distance $R_0$ are given in Fig. 1. For very small distances, the relative number of scattered neutrons becomes negligible and the curves have been extrapolated on the assumption that $\sigma'$ remains constant as $R_0$ approaches zero. The correction for the scattered neutrons was obtained from the difference between the value of $\sigma'$ at the distance used in the experiment ($R_0 = 6{\cdot}2$ cm) and that at $R_0 = 0$. This correction was (1 ± 1) per cent for both $^{232}$Th and $^{237}$Np.

Before each experiment, the counting characteristics of the $\alpha$-particle counter and the ionization chamber were checked. Fission counts were recorded at three different discriminator bias settings (Fig. 2). The good agreement obtained between the results showed that the plateau of the chamber did not change during the measurements. Repeat measurements made with both the thorium and the neptunium targets were in close agreement. The final results for the 14 MeV fission cross-sections are as follows:—

$^{232}$Th: $\sigma = 0{\cdot}35 \pm 0{\cdot}02$ barns

$^{237}$Np: $\sigma = 2{\cdot}4 \pm 0{\cdot}2$ barns.

These results agree well with those of HUGHES and HARVEY.(1) Should more accurate data on the decay period of $^{237}$Np become available, the weight of the neptunium target can be calculated more accurately and the error of the neptunium fission cross-section will be reduced correspondingly.

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## Inelastic neutron scattering cross-sections for some light nuclei at 14 MeV*

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IN the published literature, no information is available about the effective cross-section for inelastic scattering ($\sigma_{in}$) of 14 MeV neutrons by $^6$Li and $^7$Li. Moreover, the values given for the cross-sections $\sigma_{in}$ for the next three light nuclei are either unique (e.g. $^9$Be(1)) or do not agree with each other.(1–4)

In the work reported here, we have determined the cross-sections for the inelastic scattering of 14 MeV neutrons by isotopes of lithium ($^6$Li(90 per cent) and $^7$Li(99 per cent)) and by beryllium, boron, and carbon. The 14 MeV neutron source was a zirconium tritide target which was bombarded by 150 keV deuterons. A proportional counter, which counted the $\alpha$-particles from the $T(d, n)^4$He reaction, was used as a monitor. The cross-sections were determined by measuring the transmission of the primary neutron beam through slabs of the materials being studied. The thickness of the slabs, expressed as the number of nuclei per cm$^2$, varied between 2 and 3 × $10^{23}$. The neutrons were

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