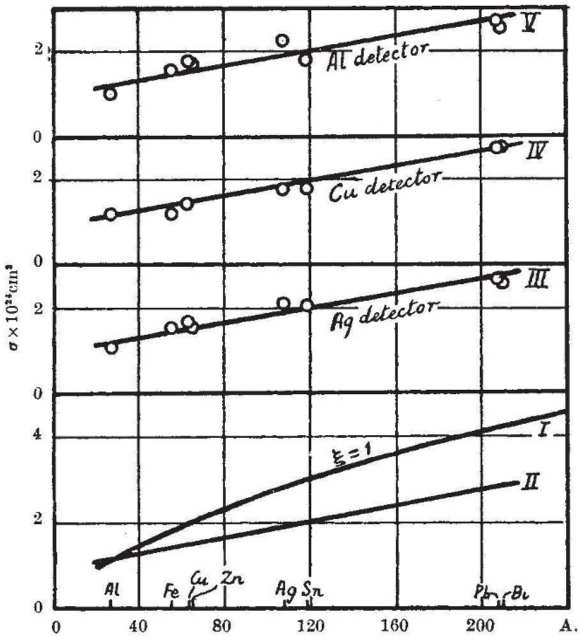
Interaction of Fast Neutrons with Atomic Nuclei

Neutrons may interact with nuclei in two different ways, namely: (*a*) formation of a compound nucleus, in a quasi-stationary state, with a subsequent emission of a corpuscular or electromagnetic radiation; (*b*) elastic (possibly also inelastic) collisions without sticking to the nucleus.

The decrease of intensity of a fast neutron beam when passing through matter, measured with a detector which responds only to neutrons above a certain energy, will be due to inelastic collisions (mostly process *a*) and elastic scattering (mostly process *b*).

The aim of this work was the study of the interaction of fast neutrons with nuclei through the measurement of the neutron absorption in different substances.



I produced the neutrons by deuteron bombardment of lithium (400 kv., about 100 μ amp.); as a measure of their intensity I used the activities induced by reactions of the type ($n - 2n$) and ($n - p$), that is, such reactions as ^{107}Ag-n-$2n$-^{106}Ag (24·5 min.), ^{63}Cu-n-$2n$-^{62}Cu (10·5 min.) and ^{27}Al-n-p-^{27}Mg (10·2 min.). The energy of the neutrons has in these conditions an upper limit of about 13·5 Mev.[1]. The detectors respond only to high-speed neutrons: silver and copper to neutrons of energies certainly above 8 Mev. and probably practically 12 Mev. (at least for copper[2]), aluminium above 4·5 Mev. Thus my measurements concern two energy regions of very different widths: 12–13·5 Mev. and 4·5–13·5 Mev.

The absorbing substances and the detectors were placed in the immediate neighbourhood of the neutron source; thus a great part of the scattered neutrons were reaching the detector and therefore the extinction of the beam was mostly due to effects other than scattering. If we suppose that every neutron that sticks to a nucleus and forms with it a compound nucleus cannot produce any of the above-mentioned reactions in the detector, then, in these conditions, the effective cross-section of the absorbing nucleus, as calculated from the intensity measurements, should not be smaller than $\sigma = \pi R^2 \xi$ where ξ is the sticking probability (process *a*) and R the nuclear radius. Curve I gives the calculated values of σ for different atomic weights A, assuming $\xi = 1$ and $R = 2 \times 10^{-13}\ A^{1/3}$ cm.

Measured cross-sections for silver, copper and aluminium detectors are plotted as Curves III, IV, V, and the average for all detectors as Curve II.

The discrepancy for heavy nuclei between the experimental Curve II and the theoretical Curve I can be explained by assuming that for these nuclei, ξ is less than 1, that is, a fast neutron may fall on a nucleus without sticking to it and without changing its direction by a great amount.

Another possible explanation would be to suppose that ξ equals 1, but to assume that compound nuclei are able to emit neutrons still of sufficient energy to activate the detectors; in this case we should be dealing either with elastic scattering or with scattering in which the neutron suffers quite a small loss of energy. However, due to the difference in the width of the sensitivity regions of the detectors, it is to be noted that this assumption would lead to a greater cross-section as detected with silver and copper than with aluminium. This is not the case and, on the other hand, an emission of very fast neutrons by compound nuclei, though highly excited, is very improbable, if we assume the liquid drop model.

The former assumption (ξ less than 1) seems to fit experimental data and theoretical expectations better. It is interesting to note that the experiments of Dunning, Pegram, Fink and Mitchell[3] in which, contrary to my experimental conditions, the authors measured the absorption including all processes mentioned above (*a* and *b*) the curve $\sigma(A)$ has a shape corresponding rather to the assumption that ξ equals 1.

After this work was completed, Grahame and Seaborg[4] published a paper on a similar subject. My results, though concerning neutrons of somewhat different energy regions, are in excellent agreement with theirs.

A detailed description of the apparatus and the experimental arrangement used will be published elsewhere.

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Band Spectrum of Helium

In the course of some investigations on the electrical properties of helium at fairly high pressures (about 25 mm. mercury), it was found that, if the gas was excited in such a way as to produce the line spectrum and the band spectrum of helium in comparable intensity, the rate of decrease in intensity of the band spectrum was much smaller than that of the line spectrum after the excitation was removed.

The accompanying reproduction shows three spectra of a discharge in helium at 27·5 mm. pressure taken under different conditions with a Bellingham and Stanley No. 2 glass spectrograph. Spectrum 1