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U^{239} FISSION CROSS SECTION

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U^{239} FISSION CROSS SECTION

by

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In the course of calculating probabilities of repeated neutron capture of U^{238} in a high density fast neutron flux, we made a crude estimate of the U^{239} fission cross section. This report gives that estimate and its basis.

We think of the process of neutron-induced fission as taking place following the capture of a neutron and the subsequent sharing of the excitation among many neutrons, from which collective modes may lead to fission itself. Ignoring all but the main features in the above concept, we recognize two gross functional forms of the fission cross section:

1. The exponential rise of the fission width as the top of the fission barrier is approached.
2. The inverse velocity dependence of the average compound nucleus cross section.

We therefore look for a crude cross section dependence below the fission barrier of the form

$$\sigma_F \propto \sigma_{FCN} \cdot \Gamma_F$$

where σ_F is the fission cross section, σ_{FCN} is the cross section for formation of the compound nucleus, E_n is the neutron energy, and Γ_F is the fission width. We shall expect $\sigma_{FCN} \propto E_n^{-1/2}$ and Γ_F to be an exponential.

The following considerations were, therefore, incorporated in Fig. 1:

A. The well-known fact that for given element, both even mass numbered isotopes and the odd mass numbered isotopes separately show a decrease in "threshold" energy with increasing mass number.[1-4] We therefore estimate that U^{239} has a sharp positive rise in the fission cross section at about 0.47 Mev.

B. The empirical variation of the "plateau" value of the fission cross section with $Z^{4/3}/A$ as put forward by Barschall and Henkel.[5] Our estimate from this work is that U^{239} has a "plateau" value of about 0.25 barn.

C. The simplest exponential law for Γ_F is $e^{a(E-E_o)}$. We estimate a by comparison with an extrapolation from the thresholds[6,7] of U^{234}, U^{236}, U^{238}, Np^{237}, and Am^{241}, using the more complete form of D below to arrive at $a = 8.3$ Mev^{-1}. Compare Seaborg.[3]

D. Putting in the thermal average value[7] of 15 barns at 0.0253×10^{-6} Mev and ignoring resonance structure, we estimate E_o from the formula

$$\langle \sigma_F \rangle = 0.25 \sqrt{\frac{E_o}{E}} \, \ell^{8.3(E-E_o)}$$

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1. Philip Morrison in Experimental Nuclear Physics, E. Segrè, editor, Vol. II, page 136, John Wiley & Sons, Inc., New York (1953). Not used quantitatively. Values too high for U^{235}.

2. Neutron binding energies, etc., were taken from A. G. W. Cameron, Atomic Energy of Canada Limited, Chalk River Project Report CRP-690 (March, 1957).

3. G. T. Seaborg, Phys. Rev. 88, 1429 (1952).

4. Alex E. S. Green, Nuclear Physics, International Series of Physics, McGraw-Hill Book Company, Inc., New York (1955).

5. H. H. Barschall as reported in R. L. Henkel, Los Alamos Scientific Laboratory Report LA-2122 (June, 1957).

6. R. L. Henkel, Los Alamos Scientific Laboratory Report LA-2122 (June, 1957), and private communications (1956-57).

7. Donald J. Hughes and Robert B. Schwartz, "Neutron Cross Sections," Brookhaven National Laboratory Report BNL-325, Supplement I, (January, 1957).

and we find E_o = 0.521 Mev. This result is in good agreement with the independent estimate of A which gives a "threshold" of the order of 0.47 Mev. Figure 1 shows that the above formula is in fortuitously good agreement.

E. The graph, therefore, incorporates the formula

$$\langle \sigma_F \rangle \text{ (barns)} = 0.25\ [0.521/E(\text{Mev})]^{1/2} \exp[8.3\ (E - 0.521)]$$

below E = 0.38 Mev with a plateau of 0.25 barn at about 2 to 4 Mev, the two being joined by a smooth curve of no physical significance whatever.

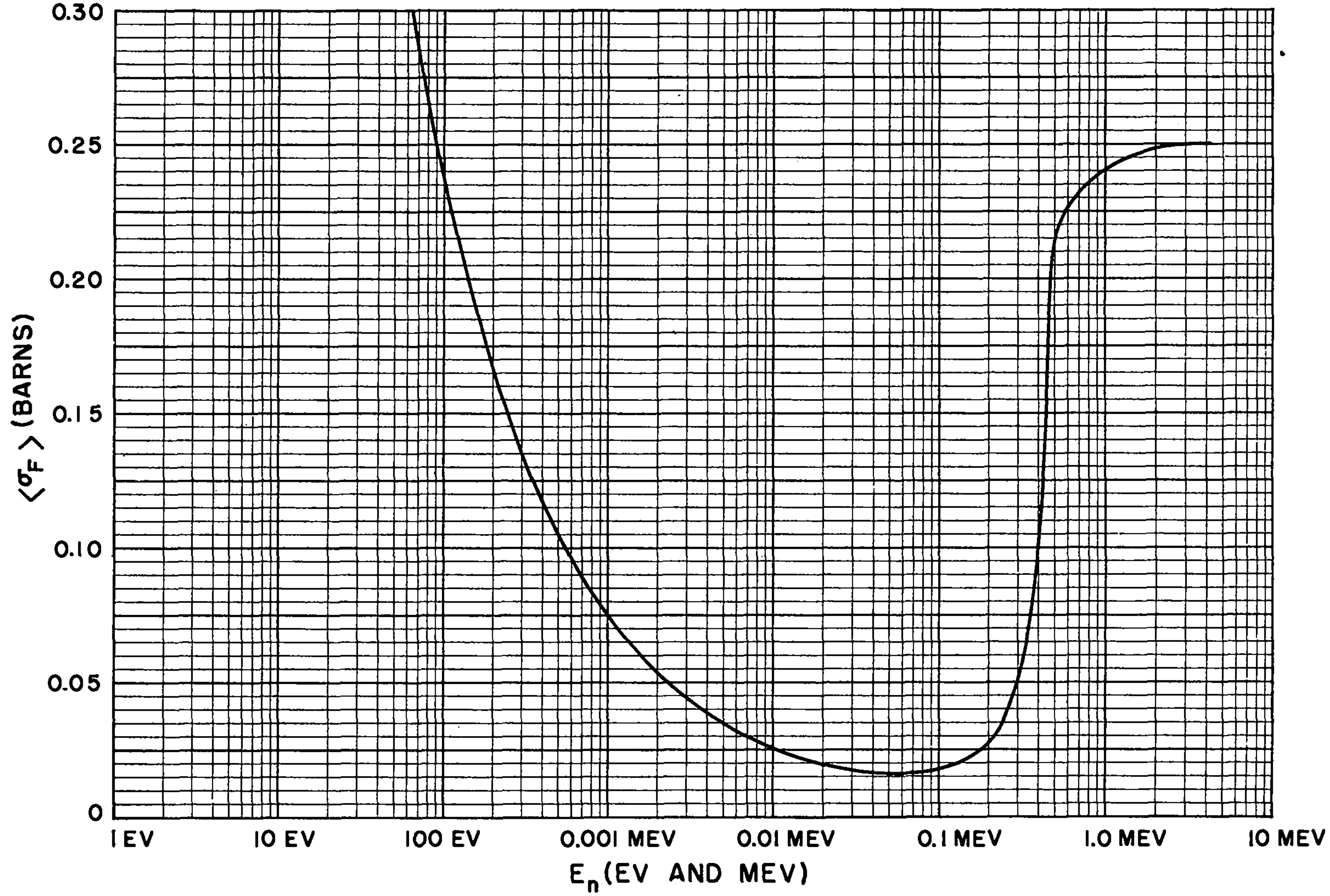

Fig. 1 σ_F of U^{239} vs neutron energy.