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AN INTERPRETATION OF NUCLEAR CROSS SECTIONS FOR HIGH ENERGY NEUTRONS

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February 21, 1951

Berkeley, California

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Dejuren has recently extended the measurements of neutron cross sections to fill in the energy region up to 280 Mev[1] and finds two interesting features, illustrated by his data for aluminum in Figure 1:

1. The cross sections are constant at high energies, above 150 Mev;
2. The drop to these high energy levels occurs very sharply at intermediate energies.

The constancy of the cross sections at high energies is in contrast to the continued decrease with increasing energy which would be expected if the interaction between the neutron and the particles in the nucleus were weak. It suggests the presence of a singularity in the n-n and n-p interactions, presumably the same singularity for which evidence is provided in the p-p interaction by the nearly energy-independent p-p cross section at correspondingly high energies [2,3].

In order to test this interpretation of the energy-independent cross sections we have carried out calculations based on an optical model in which nuclear matter is described by an index of refraction and an absorption coefficient[4]. The cross section is then composed of an incoherent contribution depending only on the absorption coefficient and a coherent contribution depending on the index of refraction. The absorption coefficient is given by

$$K = \tfrac{1}{2}\rho\,(\sigma_{nn} \quad \sigma_{np}) \tag{1}$$

where ρ is the nucleon density, and the σ_{nn} and σ_{np} are the total n-n and n-p cross sections. For the index of refraction, n , we have (assuming equal numbers of protons and neutrons)

$$n = 1 + \frac{\pi \rho}{k^2} \left\{ f_{nn}(0) \quad f_{np}(0) \right\}, \tag{2}$$

where k is the neutron wave number and $f_{nn}(0)$ and $f_{np}(0)$ are the forward scattering amplitudes, all in the laboratory system.

If we assume that n-n and p-p forces are identical we may insert the measured n-p and p-p cross sections in (1). The forward scattering amplitudes occurring in (2), however, are not unambiguously determined by experiment, even under the assumption of identical n-n and p-p forces, but must be calculated from the particular nucleon-nucleon interaction assumed. We have substituted in (2) scattering amplitudes derived from potentials fitted to n-p and p-p scattering by Christian and Hart[5] and by Christian and Noyes[6] and obtained the cross section given by curve A of Figure 1. This result does not reproduce the rapid fall in Dejuren's measurements at intermediate energies.

Since the absorption coefficient and the incoherent cross section are fixed by experiment, the origin of the discrepancy must lie in the coherent contribution and, therefore, in the values used for the scattering amplitudes in (2). One sees that a description of the neutron cross sections requires a nucleon-nucleon potential such that f(0) decreases rapidly with increasing energy above 100 Mev. A potential consisting of a strong repulsion surrounded by an attractive well possesses this characteristic, owing to the circumstances that interference between the repulsion and the surrounding well causes the S phase shift, and hence its contribution to the scattering amplitude, to become negative at high energies.

An interaction of this type, containing a singlet central repulsion of

radius 0.60×10^{-13} cm., has already been suggested[3] in connection with high energy p-p scattering measurements. We have calculated the neutron cross sections using forward scattering amplitudes obtained from this potential, with results of aluminum given in curve B of Figure 1. We conclude from Figure 1 that if one is restricted to a simple model for the nucleon interaction, the sharp drop in the observed neutron cross sections at high energies requires that this model contain a strong central repulsion.

It is important to note that this argument sheds no light on the tensor component of the interaction, since tensor forces of any kind will make only small contributions to f(0).

A more detailed account is in preparation, including a discussion of the effect of the presence of other nucleons on the two-body nucleon cross sections.

This work was carried out under the auspices of the Atomic Energy Commission.

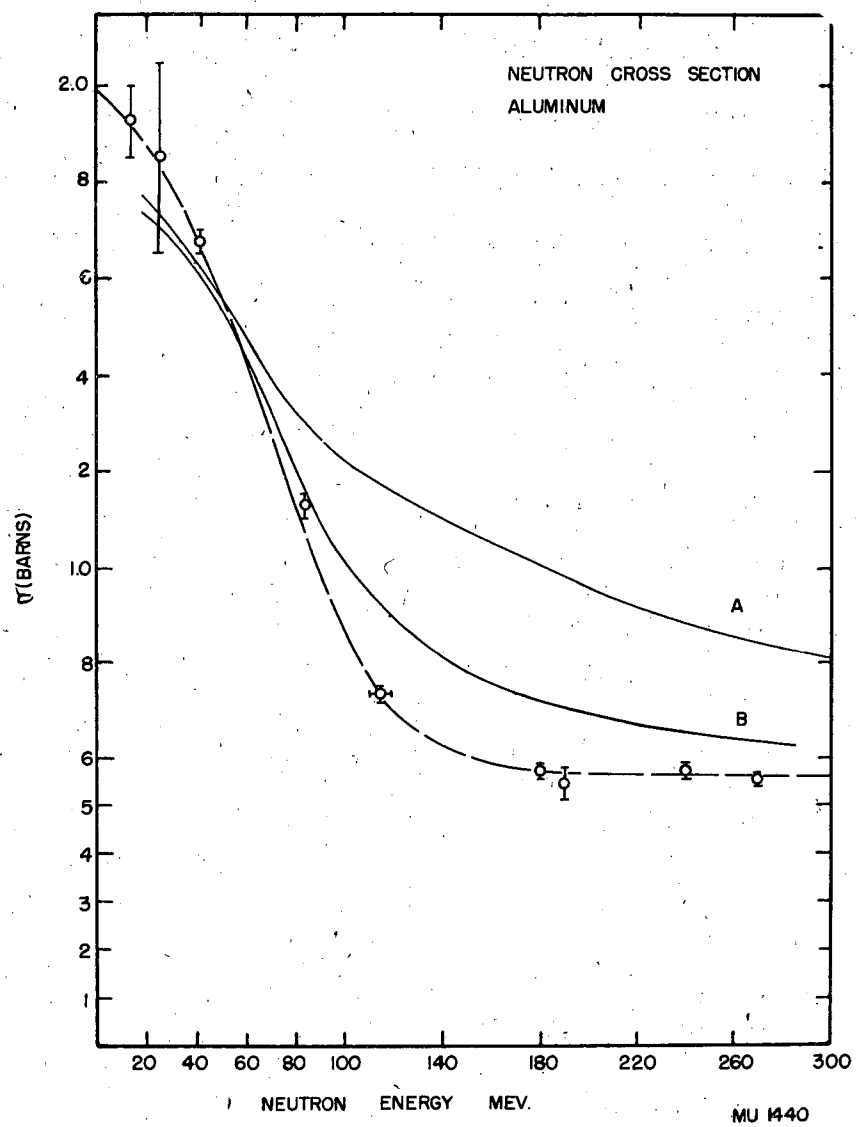
NEUTRON CROSS SECTION
ALUMINUM
σ (BARNS)
2.0
8
6
4
2
1.0
8
6
5
4
3
2
1
A
B
20
40
60
80
100
140
180
220
260
300
NEUTRON ENERGY MEV.
MU 1440

FIGURE 1

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6. R. S. Christian and H. P. Noyes, Phys. Rev. 79, 85 (1950).

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