LETTER TO THE EDITOR

Measurement of Epithermal Neutron Spectra by Resonance Detectors*

A simple resonance activation method was adopted to investigate the neutron energy spectrum in the graphite moderator, where 6 detectors (In, Au, I, Co, Mn, Na) were used to cover the epithermal energy range. Neutrons were produced by the $Be^9(x, n)Be^8$ reaction having a threshold of 1.666 ± 0.002 Mev for x-rays. X-rays were generated by the bombardment of a specially designed gold target with the electron beam from a Van de Graaff accelerator. The energy of the electron beam was maintained at 3 Mev and the beam current at 1000 μA. The thickness, t, of the gold target was designed according to the relation

$$t = R(3 \text{ Mev}) - R(1.67 \text{ Mev})$$

where $R(3 \text{ Mev})$ and $R(1.67 \text{ Mev})$ are ranges of the 3 Mev and 1.67 Mev electrons in gold, respectively. The expected energy range of the effective gamma rays was from 3 to 1.67 Mev and that of the neutrons from 1.18 Mev to thermal. Detectors, enclosed in small packets of mirror paper carefully tailored so as to have the same geometry, were placed in the moderator assembly of CS grade graphite bars. Finally, a NMC PCC-11 proportional counter, calibrated with U_3O_8 standards, was used to furnish absolute counting data.

The determination of thermal and epithermal flux was obtained from the data taken on saturated activity of the detectors. The close agreement of the thermal flux data calculated from five of the detectors gave further evidence of the accuracy of this experiment.

To evaluate the epithermal flux, the method of successive approximations was used. The processing of data began with the use of the empirical equation

$$\phi(E) = (B/E^n)(0 < n \leq 1) \tag{1}$$

where B and n are parameters depending on the distance from the source. As this source distance increases, the expression eventually becomes the asymptotic $1/E$ flux as it should be in a nonabsorbing infinite isotropic medium. To determine the parameters B and n, a plot of $\overline{\phi(E)}$, the mean flux averaged over the sharp resonance peak, versus the resonance energy E_R, in log–log scale was used. The experimental value of $\overline{\phi(E)}$ was determined from

$$A_{\text{Res}} = N\overline{\phi(E)} \int_{E_1}^{E_2} \sigma_{\text{Res}}(E)\, dE \tag{2}$$

where A_{Res} is the saturation activity of a detector contributed by resonance absorption only and σ_{Res} the resonance absorption cross section given by the Breit-Wigner formula. If the total absorption cross σ is considered to be the composition of both the resonance cross section σ_{Res} and the $1/v$ cross section $\sigma_{1/v}$ as shown in Fig. 1, A_{Res} can be obtained by defining a separation factor K

$$K = \frac{A_{\text{Res}}}{A_{\text{Res}} + A_{1/v}} = \frac{N \int_{E_1}^{E_2} \sigma_{\text{Res}}(E)\phi(E)\, dE}{N \int_{E_1}^{E_2} \sigma_{\text{Res}}(E)\phi(E)\, dE + N \int_{0.4 \text{ ev}}^{1.18 \text{ Mev}} \sigma_{\text{th}} \sqrt{\frac{E_{\text{th}}}{E}}\, \phi(E)\, dE} \tag{3}$$

$$A_{\text{Res}} = K \cdot A_\infty$$

and A_∞ is the measured saturated activity of the Cd-covered resonance detectors.

According to the above considerations, the epithermal flux was calculated as follows:

(1) *First approximation.* It was assumed that $\phi(E) = C/E$, the integral in (3) could be evaluated, and henceforth, K and A_{Res}. Finally $\overline{\phi(E)}$ corresponding to the resonance peaks of the 6 detectors were determined by means of (2). The result so obtained is shown in Fig. 2; n and B were determined as indicated in the table.

(2) *Second approximation.* $\phi(E) = B/E^n$ was assumed to be true with n given by the first approximation. The integrals in (3) were recalculated so that the more correct values of $\overline{\phi(E)}$ were obtained through the use of better values of A_{Res}. The result, so obtained, is also given in Fig. 2.

It can be shown that for a uniform distributed source

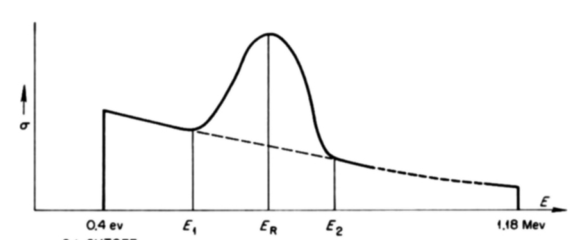
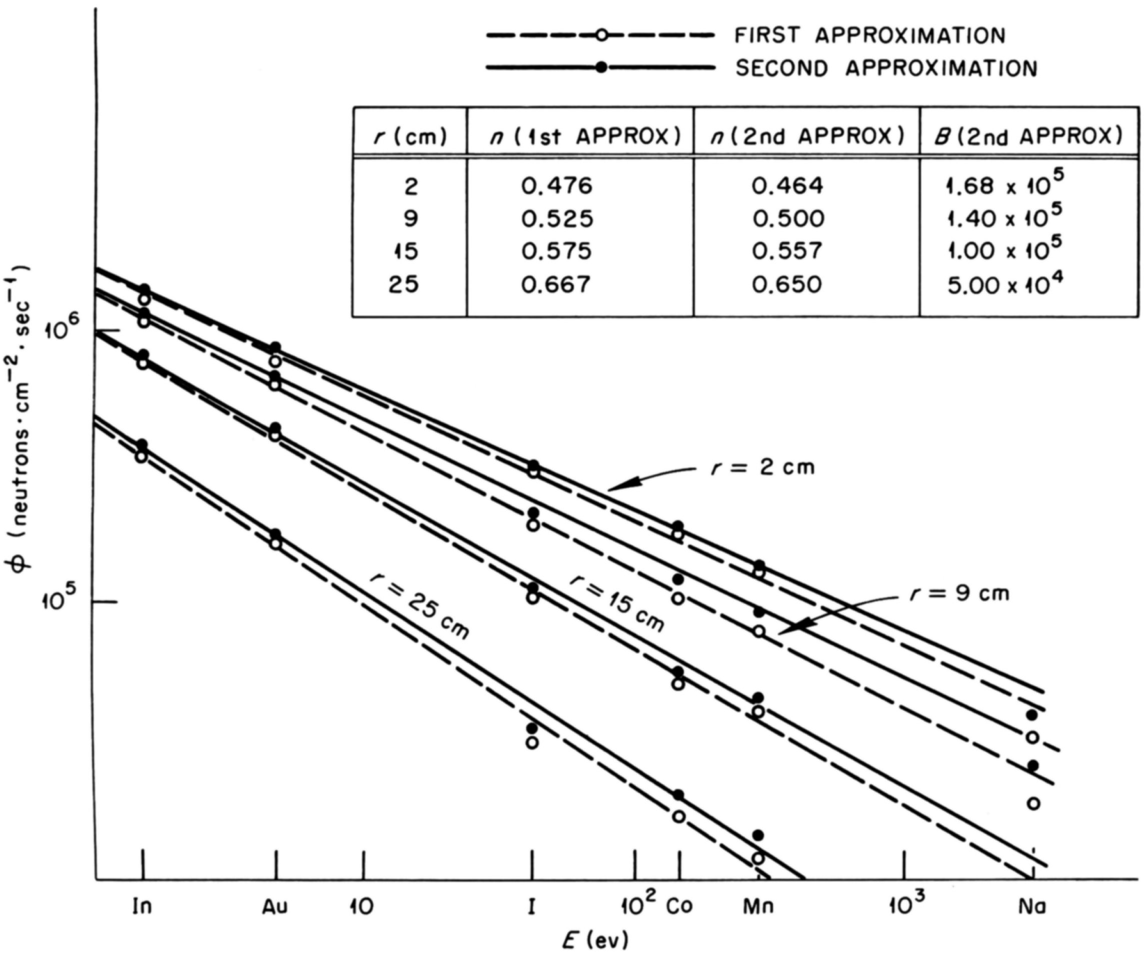


FIG. 1

* M.S. thesis in Tsing Hua University under the direction of Professor J. P. Chien.



r (cm)	n (1st APPROX)	n (2nd APPROX)	B (2nd APPROX)
2	0.476	0.464	1.68×10^5
9	0.525	0.500	1.40×10^5
15	0.575	0.557	1.00×10^5
25	0.667	0.650	5.00×10^4

FIG. 2

in a moderator with constant scattering cross section Σ_s, the neutron flux in asymptotic case is given by $\phi(E) = AE^m$

$$m = \frac{\Sigma_s(E)}{\Sigma(E)(1-\alpha)} \cdot \frac{1-\alpha^m}{\alpha^m}$$

$$\Sigma = \text{total cross section} \qquad (4)$$

$$\alpha = \left(\frac{A-1}{A+1}\right)^2$$

It happened that the m calculated from (4) for graphite was fairly close to the n obtained from this experiment.

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