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SUPERVISOR LABORATORY RECORDS
ORNL
10-5-54

# ERRATA

CL 574 (3)

On page 2, omit factor 4 in expression for $A_{mn}$.

On page 2, omit "cos" in front of n(x, y) under integral.

On page 3, $\overline{\cos\theta}$ means average value of the cos $\theta$.

On page 3, $\varphi$ = angle in center of gravity system (this did not print clearly on some sheets).

On page 3, the value under the radical is $\sqrt{3\sigma\sigma_a}$

On page 4, omit square root in expression for D, $\lambda$ :

$$\text{i.e.,} \quad D = \frac{\lambda v}{3}\left(1 - \overline{\cos\theta}\right)^{-1} ,$$

$$\text{transport m.f.p.} = \lambda\left(1 - \overline{\cos\theta}\right)^{-1} = \lambda_f$$

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PILE THEORY LECTURE NOTES

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A. M. Weinberg

May 6, 1943

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## III. Diffusion and slowing down in a multiplying medium

### A. Definition of k and preliminary discussion of its calculations

Consider an infinite multiplying medium consisting of a mixture of moderator and metal. Suppose that a number of thermal neutrons are absorbed in the medium. (If the medium is infinite in size, this is the only possible fate of a neutron; otherwise it may leak out.) What is the life history of these neutrons through one generation?

A fraction f ($\sim$85%) will be absorbed in the metal, 1 - f will be absorbed in the moderator. f is called the thermal utilization; it is defined as the number of thermals absorbed in metal per second/number of thermals produced per second.

Each thermal absorbed gives rise to $\eta$ ($\sim$1.32) fast neutrons by thermal fission; $\eta \equiv$ no. of fast neutrons produced by thermal fission per thermal neutron absorbed. Hence there are f $\eta$ fast neutrons produced by absorption of f thermal neutrons.

Each fast neutron gives rise to $\epsilon$ ($\sim$1.05) fast neutrons by fast fission in 238 where $\epsilon \equiv$ no. of fast neutrons produced by fast fission per fast neutron produced by thermal neutron fission. Hence, after fast fission there are f $\eta\epsilon$ fast neutrons per thermal neutron originally absorbed.

These f $\eta\epsilon$ fast neutrons are slowed down through the resonance absorption region; however, only the fraction p ($\sim$85%) escape resonance capture, p being defined as the probability of a fast neutron escaping resonance capture. Consequently of an original slow neutron absorbed,

$$k = f \eta p \epsilon$$

neutrons are present after one complete generation. k, which is defined as the number of slow neutrons produced per generation per slow

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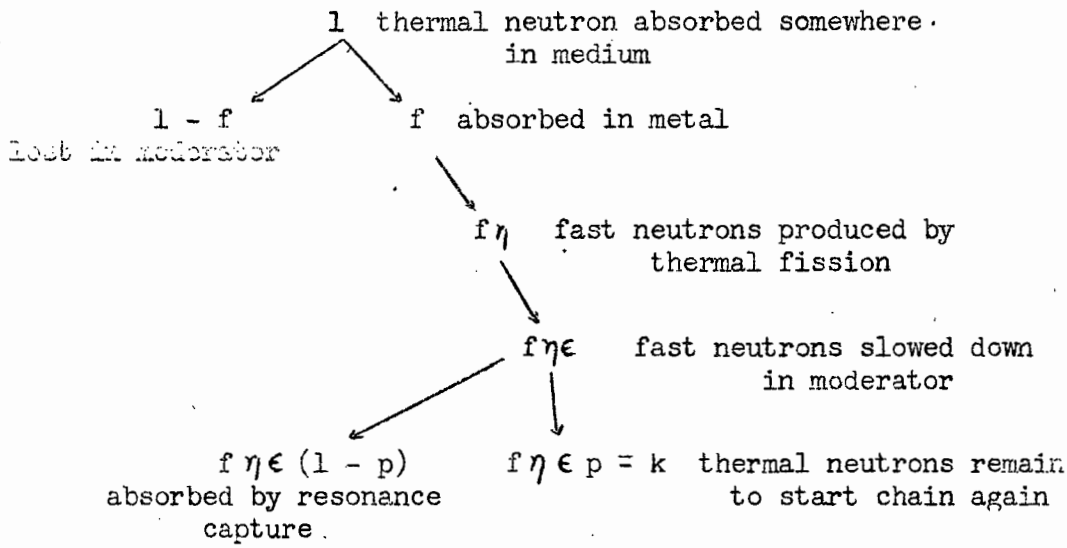
neutron absorbed anywhere in an infinite medium, is called the <u>multiplication factor</u>. It is also the no. of fast neutrons escaping resonance capture produced per thermal neutron absorbed. If $k < 1$, the original neutrons will disappear by absorption; if $k > 1$, the original neutrons will multiply indefinitely in an infinite medium.

Schematically, for an infinite medium,




Note that in this diagram the neutrons lost by leakage are not mentioned. Since in a finite medium there is always some loss by leakage, k must exceed 1 by an amount large enough to make up this leakage loss in order for a divergent chain reaction to be set up. The larger the medium, the less k need exceed 1 for critical condition to be met.

1) <u>f</u>, the thermal utilization

The fraction of neutrons absorbed by the metal depends only on the relative amount of metal and moderator and the ratio of their capture cross-sections; it increases as the density of metal per cell increases. In a homogeneous mixture,

$$f = \frac{N_o \sigma_{ao}}{N_o \sigma_{ao} + N_1 \sigma_{a1}}$$

where o refers to metal, 1 to moderator, N = average number of atoms/c.c. If the metal is lumped so that the average density of neutrons in moderator = d x average density in metal, then

$$f = \frac{N_o \sigma_{ao}}{N_o \sigma_{ao} + dN_1 \sigma_{al}}$$

where the N's are averages over the whole cell. d is called the <u>thermal disadvantage factor</u>. Its calculation is a straightforward problem in diffusion theory.

2) $\eta$, the no. of fast neutrons produced by thermal fission per thermal neutron absorbed in the metal.

Since the absorption is partly due to parasitic capture in 238 and partly due to fission in 235, the fraction of thermals absorbed in 235 is

$$\frac{\sigma_f}{\sigma_{ao}}$$

$\sigma_f$ = fission cross-section. If $\nu$ = number of fast neutrons per thermal fission, then

$$\eta = \frac{\sigma_f}{\sigma_{ao}} \nu \quad .$$

$\sigma_f = 4.6 \times 10^{-24}$, $\sigma_{ao} = 7.8 \times 10^{-24}$, $\nu = 2.2$, $\eta = 1.29$

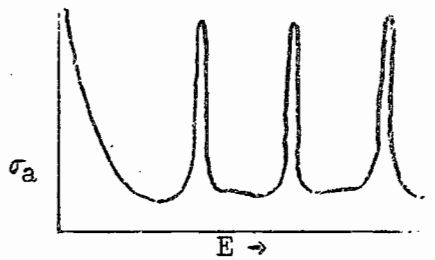
3) $\epsilon$, fast multiplication ~~constant~~ factor

$\epsilon$ is an essentially geometric quantity whose value depends on the size of the metal lump, and practically not at all on the moderator.

4) p, probability of escaping resonance capture

The resonance absorption is, as its name implies, a resonance process; it occurs at certain discrete energies. The lowest resonance level lies at about 10 eV, and higher levels appear at intervals of about 10 eV up to several thousand eV, where the levels merge into a continuum.

The resonance absorption is decreased if the metal is lumped because then the bulk of the slowing through the resonance region occurs in the moderator, away from the metal. For metal lumps of the same size the resonance absorption is therefore smallest when the ratio of moderator to metal is largest.




The fact that the resonance absorption is concentrated in lines causes the absorption to be partly a surface and partly a volume effect. The surface effect is a "sorting out" of the resonance energy neutrons from the continuum which strikes the metal surface; the volume effect is an absorption of the remaining neutrons after they have been thrown back into a resonance level by collisions. If the metal is thoroughly mixed with a scatterer of low atomic weight, its volume absorption will be increased very appreciably. The absorption in a lump is much less than the absorption of an equal mass in separate thin layers because of this culling of the neutrons having the correct energy. The ratio of the "bulk" absorptions and the "thin" layer absorption is called the "volume advantage" and is about 25 for metal.

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JUN 30 1943
M. D. WHITAKER