LETTER TO THE EDITOR

Comments on "Neutron Lifetime, Fission Time and Generation Time"

It has been believed that the neutron lifetime is equal to the neutron generation time in a critical reactor. Lewins[1] presented the explanation to the equality in the simplest model. I would here prefer the names "generation time" and "fission time" to these by Lewins. I consider the one-group model of an infinite homogeneous reactor.

The definitions are

l = neutron lifetime

= mean time for one neutron to be removed from the reactor

$$= \frac{1}{v\Sigma_a}$$

Λ = mean generation time

= mean time for one neutron to produce the next-generation neutron

$$= \frac{1}{v\nu\Sigma_f}$$

τ = mean fission time

= mean time for one neutron to cause fission

$$= \frac{1}{v\Sigma_f}$$

k_∞ = multiplication factor

$$= \frac{\nu\Sigma_f}{\Sigma_a} = \frac{l}{\Lambda} .$$

These express that the mean generation time is equal to the neutron lifetime in a critical reactor. These generation and fission times are obtained by the mean free paths (mfp's) divided by neutron velocity. Here, the mfp's are formally defined as the reciprocal of the macroscopic cross section.[2] I will distinguish the mean reaction length from the mfp for the neutron generation and fission reactions.

Since the remaining neutrons after traveling the distance x cause a neutron reaction, the mean absorption length is

$$l_{abs} = \frac{\int_0^\infty x\Sigma_a e^{-\Sigma_a x}\,dx}{\int_0^\infty \Sigma_a e^{-\Sigma_a x}\,dx} = \frac{1}{\Sigma_a} . \tag{1}$$

Similarly, the mean generation length is

$$l_{gen} = \frac{\int_0^\infty x\nu\Sigma_f e^{-\Sigma_a x}\,dx}{\int_0^\infty \nu\Sigma_f e^{-\Sigma_a x}\,dx} = \frac{1}{\Sigma_a} . \tag{2}$$

Also, the mean fission length is

$$l_{fiss} = \frac{\int_0^\infty x\Sigma_f e^{-\Sigma_a x}\,dx}{\int_0^\infty \Sigma_f e^{-\Sigma_a x}\,dx} = \frac{1}{\Sigma_a} . \tag{3}$$

These three mean lengths have a same value in this model. Then, the mean reaction time is a unique value in this model. Not only is $1/v\Sigma_a$ the mean lifetime, but it also is the mean generation time. Therefore, the ratio of the mean lifetime and the mean generation time is always equal to 1. The ratio is independent of the multiplication factor.

The absorption reaction includes the fission reaction, and the ratio of the fission to the absorption is constant Σ_f/Σ_a everywhere a neutron will undergo a reaction. Also, the mean reaction length for a specific reaction can be viewed as the relaxation length that reduces the reaction probability by a factor of $1/e$.

Consider the neutron that was born by fission at position $x = 0$. The neutron moves interacting with a nucleus from the fission point. The neutron that survives up to x interacts in the next dx. The ratio of the fission to the absorption in the reaction at the distance x must be the same Σ_f/Σ_a on the average. Then, it is apparent that the mean path length traveled by the neutron before fission is the same as the mean path length before absorption. From Lewins's viewpoint, however, the mean path length before fission is not equal to the mean path length before absorption. His lengths are $1/\Sigma_f$ for the fission and $1/\Sigma_a$ for the absorption. Owing to $1/\Sigma_f > 1/\Sigma_a$, the ratio of the fission to the absorption becomes larger as x increases. It is wrong.

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REFERENCES

1. J. D. LEWINS, "Neutron Lifetime, Generation Time, and Reproduction Time," *Nucl. Sci. Eng.*, **78**, 105 (1981).

2. P. F. ZWEIFEL, *Reactor Physics*, p. 17, McGraw-Hill Book Company, New York (1973).