

# Chapter 1

## Neutron-Nucleus Interactions and Fission

The central problem in nuclear-reactor kinetics is to predict the evolution in time of the neutron population in a multiplying medium. Point kinetics allows the study of the global behaviour of the neutron population from the average properties of the medium. Before tackling, in the following chapters, the equations governing the time variation of the reactor power (proportional to the total neutron population), we shall discuss briefly the properties of a neutron-multiplying medium. After recalling a number of definitions, we shall give a qualitative description of the principal nuclear reactions at play in a self-sustaining chain reaction, and dwell on the source of fission neutrons. Since delayed neutrons play a crucial role in reactor kinetics, we shall describe in greater detail their production in a reactor.

### 1.1 Neutron-Nucleus Interactions

A neutron is an elementary particle. It is stable when bound to a nucleus by the nuclear force. In its free state, a neutron decays, with a time constant of 12 minutes, to a proton, accompanied by the emission of a  $\beta^-$  particle and an antineutrino. In view of the fact that free neutrons in a reactor either are absorbed in matter or escape, on a time scale of less than  $10^{-5}$  s, it is clear that neutron instability is completely negligible in reactor physics.

The power generated in a reactor comes from neutron-induced fissions. It results from the interaction between the neutrons and the nuclei of the physical medium. It is generally possible to neglect neutron-neutron interactions, because the density of neutrons is much smaller than that of nuclei. Free neutrons have a certain speed relative to nuclei. If one neglects the energy of thermal motion of the nuclei, the kinetic energy  $E$  of a neutron represents the energy available to a nuclear reaction between it and a nucleus. If we denote the relative speed of a neutron by  $v$  and its mass by  $m$ , then

$$E = \frac{1}{2}mv^2 \quad (1-1)$$

The energy is generally given in units of electron-volts ( $1 \text{ eV} = 1.6021 \times 10^{-19} \text{ J}$ ).

#### 1.1.1 Cross Sections

Interactions of neutrons with matter are described in terms of quantities called cross sections, which can be defined in the following fashion. Imagine a unidirectional neutron beam with a density of  $n$  neutrons per  $\text{cm}^2$ , of speed  $v$ , impinging perpendicularly on a thin slice of a target with a density of  $N$  identical nuclei per  $\text{cm}^2$ . Define the neutron flux  $\phi$  by

$$\phi = nv \quad (1-2)$$

<sup>1</sup> The speed of neutrons in a reactor is sufficiently low that one can neglect relativistic effects. Therefore  $m = m_0$ , the neutron rest mass ( $1.6748 \times 10^{-27} \text{ kg}$ ).

# Fundamentals Of Nuclear Reactor Physics Solution Manual

**David Halliday, Robert Resnick, Jearl Walker**



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