3.4 Averaging over material components

The above averaging referred, of course, to the process of averaging within one (or sometimes two) range(s) of neutron energy within a given material. However, a reactor core consists of many different physical components each of which may have different absorption and scattering properties. Thus in addition to the energy averaging described above, the simplest models homogenize this core by also averaging over these physical components as follows. The total reaction or absorption rate (per unit total core volume) in the homogenized core is clearly the sum of the reaction rates in each of the M materials present (denoted by the superscript $m = 1$ to $m = M$). The reaction rate in the material m per unit total core volume will be given by $\mathcal{N}^m \alpha^m \sigma^m \phi^m = \alpha^m \Sigma^m \phi^m$ where $\mathcal{N}^m$ is the number atoms of material m per unit volume of m, α^m is the volume of m per unit total core volume, σ^m is the reaction cross-section for the material m, Σ^m is the corresponding macroscopic cross-section (see section 2.3.3) and ϕ^m is the neutron flux in the material m. It follows that the average neutron flux, ϕ, and the average macroscopic absorption cross-section, Σ, will be related by

$$\Sigma\phi = \sum_{m=1}^{M} \mathcal{N}^m \alpha^m \sigma^m \phi^m \tag{1}$$

Note that in the special case in which the typical physical dimensions of the components are much smaller than the neutron mean free path then the neutron flux should be considered identical in all the materials ($\phi^m = \phi$) so that

$$\Sigma = \sum_{m=1}^{M} \mathcal{N}^m \alpha^m \sigma^m = \sum_{m=1}^{M} \alpha^m \Sigma^m \tag{2}$$

This allows evaluation of the effective cross-sections for a core with physically different components. Of course, each interaction or event will have its own effective cross-section so that there will be cross-sections for fission, Σ_f, for absorption, Σ_a, for scattering, Σ_s, etc.