Available online at www.sciencedirect.com
SCIENCE DIRECT
Progress in Nuclear Energy 48 (2006) 173–180
PROGRESS IN NUCLEAR ENERGY
An International Review Journal
www.elsevier.com/locate/pnucene

A simple model for the neutron slowing down calculations

A. Jehouani *, A. Elmorabiti, A. Sabir, A. Aboubakr

Nuclear Physics and Techniques laboratory, Faculty of Sciences, University Cadi Ayyad, Semlalia, B. P2390, Marrakech, Morocco

Abstract

In general, nuclear reactors contain several heavy nuclides. That makes the neutron slowing down calculations more expensive in computation time and in computer memory especially when the heavy nuclides number is large. This paper presents a simple model to do these calculations with a significant reduction of both the computation time and the required computer memory. Basically only one fictitious heavy nuclide: the 'Equivalent Nuclide' is used by the model instead of all the heavy actual nuclides. The equivalent nuclide characteristics are directly obtained from those of the actual ones. The model.qualification has been done for the continous-energy neutron slowing down in the energy interval ($10^{-}5$ eV–2 MeV) at different temperatures 600, 900 and 1200 K. The model results are in good agreement with those obtained by direct calculations.

We have found that our model calculates the reactions rates with a high accuracy and save 50% of the computation time in the case of 2 resonant nuclides and 90% for 8 resonant nuclides. The major advantage is the huge reduction of the required computation memory.

Keywords: neutron; neutron slowing down calculation; equivalent nuclide model

1. Introduction

A growing interest has been noticed for the neutron resonance absorption (Jehouani et al., 1992a; Reuss and Coste-delacaux, 2003; Tellier et al., 1993) in reactor physics. The neutron slowing down calculation needs large computation time and large computing memory when media contain many heavy nuclides. In fact more programming effort and large machine memory are required to solve the neutron slowing down equation when the medium contains many heavy nuclides. That is the case for all the practical cases where we are interested in estimating the mutual shielding effect or in evaluating the group constants taking account of the shielding effects due to the presence of other multiple resonance nuclides (Reuss, 1986). We propose here a simple model to do these calculations with a high accuracy and a large reduction of a computation time. Basically only one fictitious resonant nuclide 'Equivalent nuclide' is used to do the calculations instead of all actual resonant nuclides. The characteristics of this Equivalent Nuclide are obtained from those of the heavy nuclides in medium.

The verification of the Equivalent Nuclide Model (ENM) is achieved by calculating the effective integral and average cross section for absorption.

First we briefly present the Livolant–Jeanpierre formalism (Livolant and Jeanpierre, 1973) and the iterative method (Jehouani et al., 1992b) to solve the neutron slowing down equation. Then we display the model, its verification and applications for the neutron resonance absorption.

* Corresponding author. Tel.: +212 4 43 74 10.
E-mail address: jehouani@ucam.ac.ma (A. Jehouani).

0149-1970/$ - see front matter © 2005 Elsevier Ltd. All rights reserved.
doi:10.1016/j.pnucene.2005.09.003

2. Livolant–Jeanpierre formalism (Livolant and Jeanpierre, 1973)

For an infinite homogeneous media containing a heavy resonant nuclide (0) and a non-resonant light nuclide (1), the neutron slowing down equation at the energy E is given by:

$$[\Sigma_1(E) + \Sigma_0(E)]\Phi(E) = R_0\Phi(E) + R_1\Phi(E) \tag{1}$$

where:

R_i is the slowing down operator for nuclide i:

$$R_i\Phi(E) = \int_E^{E/\alpha_i} \Sigma_{si}(E' \to E)\Phi(E')\mathrm{d}E'; \quad i = 0; 1 \tag{2}$$

and:

$\Sigma_0(E_1)$, Sigma;$_1(E)$ are the total macroscopic cross sections.
Sigma;$_{s0}(E)$, Sigma;$_{s1}(E)$ are the scattering macroscopic cross sections.
$\Phi(E)$ is the neutron flux
$\alpha_0 = ((A_0 - 1)/(A_0 + 1))^2$ and A_0 is the mass number of resonant nuclide.

We assume that the flux $\Phi(E)$ may be factorized as:

$$\Phi(E) = \varphi(E)\Psi(E) \tag{3}$$

Where $\phi(E)$ is the fine flux structure and $\Psi(E)$ is the macroscopic flux which is defined as:

$$\Psi(E) = \frac{R_1\Phi(E)}{\Sigma_{s1}(E)} \tag{4}$$

Since nuclide (0) has a short slowing down range, one can use the following approximation:

$$R_0\Phi(E) = \Psi(E)R_0\varphi(E) \tag{5}$$

substituting Eqs. (3) and (5) in Eq. (1) we obtain the fine structure equation:

$$[\sigma_e(E) + \sigma_0(E)]\varphi(E) = \gamma_1(E)\sigma_e(E) + \frac{R_0}{N_0}\varphi(E) \tag{6}$$

where:

$\sigma_0(E) = \sum_0(E)/N_0$
$\sigma_0(E) = \sum_1(E)/N_0$ is the equivalent cross section
$\gamma_1(E) = \sum_{s1}(E)/\sum_1(E)$
N_0 is the resonant nuclide concentration

This formalism was generalized to include many resonant nuclides (Reuss, 1986).

3. Iterative method (Jehouani et al., 1992b)

The fine structure Eq. (6) may be written as:

$$[\sigma_e(E) + \sigma_0(E)]\varphi(E) = \gamma_1(E)\sigma_e(E) + \int_E^{E/\alpha_0} \sigma_{s0}(E' \to E)\varphi(E')\mathrm{d}E' \tag{7}$$

In order to solve this equation we evaluate the integral term, which is due to the slowed down neutrons by the resonant nuclide. The iterative method estimates this quantity by using the following iterative process.

We put:

$$\lambda_0(E) = \int_E^{E/\alpha_0} \sigma_{s0}(E')\varphi(E')\frac{1}{(1-\alpha_0)E'}\mathrm{d}E' \tag{8}$$