S. Sipilä

Aalto University, School of Science
Department of Applied Physics

PHYS-E0460 Introduction to Reactor Physics, 1st mid-term exam 18 October 2023

You are allowed to use an unprogrammed calculator and the document "Mathematical Tools for Reactor Physics".

1. Give a concise explanation of the following:
   a) mass defect b) fertile isotope c) delayed neutron
   d) η_T e) Fermi age τ_T f) Wigner-Seitz cell

2. The β emitter ^{28}Al can be produced by the radiative capture of neutrons by ^{27}Al. The 0.0253 eV cross section for this reaction is 0.23 b. Suppose that a small, 0.01 g ^{27}Al target is placed in a beam of 0.0253 eV neutrons ($I = 3.5 \times 10^8$ 1/cm^{2}s) which strikes the entire target. The half-life of ^{28}Al is 2.24 minutes, and the neutron capture rate of ^{27}Al can be assumed small compared to the number of original nuclei in the target. ^{27}Al is also practically stable. Avogadro's number is 6.022×10^{23}, neutron mass is 1.6749×10^{-27} kg, and the target atom's molar mass [g/mol] is close to its number of nucleons.
   a) What is the neutron density in the beam?
   b) At what rate is ^{28}Al is produced?
   c) What is the maximum activity than can be produced in this experiment?

3. Consider a homogeneous medium of volume V that absorbs neutrons and has a neutron source density s. Formulate the continuity equation describing the neutron population and derive from it the steady-state one-group diffusion equation. Under what general conditions is the diffusion model applicable to describing the neutron population?

4. In a certain thermal reactor fuelled by slightly enriched uranium, 13% of fission neutrons are absorbed by ^{238}U in resonances and 3% leak out while still fast. 5% of the thermalized neutrons leak out, and of those that remain inside 82% are absorbed by fuel heavy metal. Out of these, 74% are absorbed by ^{235}U. For ^{235}U ($\eta_T = 2.068$). You may assume that there are no fast fissions ($\epsilon = 1$), and no absorptions to other materials. a) What is the multiplication factor k? b) What is the conversion ratio C?

5. Describe the fission process on a general level based on Gamow's liquid drop model of the nucleus. Elaborate on how fission can be induced and in what different kinds of nuclei. Describe also the process of producing nuclei that can be used as reactor fuel from nuclei that are not suitable for that purpose.