ORDRE DES INGÉNIEURS DU QUÉBEC

NOVEMBER 2014 SESSION

Open-book examination
Calculators : only authorized models
Duration : 3 hours

14-PH-B1 PHYSIQUE DU RAYONNEMENT

NB : USE THE DATA OF SECTION «USEFUL INFORMATION » AT THE END OF THE QUESTION SHEET

Problem 1. (15%)

Carbon 14, at a rate of 1.4×10^{15} Bq/year, is produced naturally by the interaction of cosmic rays with atmospheric nitrogen, with the reaction $^{14}N + n \rightarrow p + {}^{14}C$. The half-life of ^{14}C being 5700 years, what is the global inventory of ^{14}C ?

Problem 2. (20%)

Given that the microscopic cross section of Boron-10 is $\sigma_0 = 4050$ barns at the reference speed v_0, what is the sensitivity of a neutron detector whose volume is 100 cm^3, and is filled with $B^{10}F_3$ enriched to 96% as a function of Hg pressure in cm for the range $40 \leq p \leq 100$?

Suppose that the thermal neutrons have a Maxwell-Boltzman energy distribution for which the speed ratio is $\frac{\bar{v}}{v_0} = \frac{2}{\sqrt{\pi}} = 1.128$ and that the Boron-10 cross section varies as $\sigma(v) = \frac{1}{v}\sigma_0$.

Problem 3. (20%)

It is determined that the thyroid uptake of Iodine to the thyroid of a thyroid cancer patient is 50%. What quantity of ^{131}I in Bq (half life of 13 hours) must be inected to deliver 15 grays in 3 days to his thyroid, whose mass is 30g ?

Problem 4. (20%)

A first sample of water from a river is taken at the discharge of a radio-isotope laboratory, while a second sample is taken upriver from the discharge. Each sample is counted during 10 minutes, and it is found that the first sample reads 225 cpm, and 210 cpm for the second. At the confidence level of 99%, is the water of the first sample more radio-active than the second sample ?

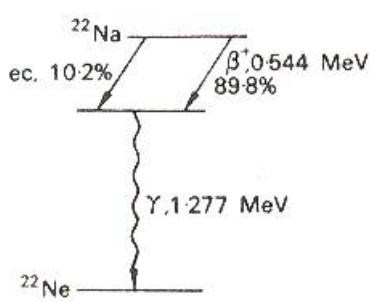
Problem 5. (25%)

A worker weighting 70kg ingests accidentally some Iodine-131. Two days later, his thyroid gland contains 2×10^4 Bq. His body burden is measured during two months. Use the following ICRP retention function: $R(t) = 0.7\exp(-\frac{0.693}{0.35}t) + 0.3\exp(-\frac{0.693}{100.}t)$ MBq.

Calculate :

a) the amount of activity originally deposited in the thyroid

b) the dose commitment to the thyroid as a result of the accident

Useful Information

1 eV = 1.6×10^{-19} Joule.
Masse of neutron = 939.5653 MeV
Speed of light = 299,792,458 m/sec
I-131 : beta-gamma, 0.23MeV/transformation, $T_{1/2}^{R}$ = 8 days.