Queen Mary University of London

PHYSICS department

Nuclear Physics & Astrophysics
Exercises – 6

Hand in on 1st floor by Friday 27th November 4pm

Hydrogen mass $^1H = 1.007825$ u **Avogadro's number $N_A = 6.022 \times 10^{23}$ mol^{-1}**
$e^2/4\pi\varepsilon_0 = 1.439976$ MeV fm
Use masses from Krane Appendix C

Assume the ordering of nuclear shells is:
$1s_{1/2}$; $1p_{3/2}$; $1p_{1/2}$; $1d_{5/2}$; $1d_{3/2}$; $2s_{1/2}$; $1f_{7/2}$; $2p_{3/2}$; $1f_{5/2}$; $2p_{1/2}$; $1g_{9/2}$; $1g_{7/2}$; $2d_{5/2}$

1. Cross sections are expressed in units of area. In nuclear physics a convenient unit for cross sections is the barn (b), where 1 b = 10^{-28} m^2. For ^{239}Pu the thermal fission cross section is 842 b. The cross section for other non-fission absorbtive processes is 276 b. Each fission produces on average 2.96 neutrons. What is the mean number of fission neutrons produced by ^{239}Pu per thermal neutron? [5]

2. In the pp cycle, helium nuclei are produced by the fusion of hydrogen nuclei and 6.55 MeV of electromagnetic energy (i.e. photons) is produced for every proton consumed. If the electromagnetic radiation energy measured at the surface of the earth is 9.4 Jcm^{-2}s^{-1} and is due to the pp cycle, what is the expected flux of neutrinos at the earth in cm^{-2}s^{-1} ? [6]

3. Give two reasons why earth-bound fusion reactors use the DT reaction. [4]
In a fusion reactor the reaction rate, R, of fusion reactions is given by

$$R = n_1 n_2 \langle\sigma v\rangle$$

where n_1 and n_2 are the number densities of D and T nuclei respectively, and $\langle\sigma v\rangle$ is the mean fusion reaction cross section x velocity, v, averaged over all particle velocities. The reaction Q is 17.6 MeV. Calculate the energy output per unit volume in a time t = 1s if $\langle\sigma v\rangle = 10^{-22}$ m^{3}s^{-1} and $n_1 = n_2 = 10^{20}$ m^{-3} [4]
For a plasma at a given temperature T consisting of D and T nuclei and an equal number density of electrons, n, give an expression for the thermal energy per unit volume of the plasma at temperate T. [2]
For a fusion reactor to be self-sustaining the fusion output energy density in a time t must exceed the thermal energy density of the plasma. Assuming that 80% of the fusion energy is lost by the escaping neutron give an expression for the minimum plasma confinement time t to achieve a self-sustaining reaction at a temperature equivalent of 10 keV. [4]

No need to turn over