Tutorial Problems: Nuclear Physics
PH:504

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1. The radius R of a nucleus with mass umber A is given by the formula $R = r_0 A^{1/3}$ with $r_0 \simeq 1.2fm$. Using the Fermi-gas model show that the energy E_F of the Fermi level in a nucleus with equal numbers of protons and neutrons is given by : $E_F = \frac{\hbar^2}{2M_p r_0^2}(\frac{9\pi}{8})^{2/3}$. Hence, estimate the total kinetic energy of the nucleons the nucleus ^{16}O. [Marks : 5]
2. By considering the conservation of energy and momentum show that a free electron cannot absorb a photon. Why can absorption occur if the electron is initially bound ? [Marks : 3]
3. The principal source of energy produced in the Sun is nuclear fusion via the pp chain :
   (a) $p + p \rightarrow p + {}^2_1H + e^+ + \nu + 0.42MeV$
   (b) $p + + {}^2_1H \rightarrow {}^3_2He + \gamma + \nu + 5.49MeV$
   (c) ${}^3_2He + {}^3_2He \rightarrow {}^4_2He + p + p + 12.86MeV$

   On average the neutrinos each take away 0.26 MeV. The flux of radiant energy at the distance of the Earth from the Sun is $1.37kWm^{-2}$. Calculate the flux of solar neutrinos at the Earth. [Marks : 5]
4. A beam of 1.5 MeV neutrons, of intensity $I_0 = 5 \times 10^{14} cm^{-2}s^{-1}$ is incident on a slab of copper of thickness d = 0.75 cm. The emergent beam has intensity $I = 0.23I_0$. Calculate the total cross-section of neutrons on copper at this energy. [Hints : $\sigma = \frac{\mu}{n_t}, n_t = \rho N_A/A$, density of copper, $\rho_{Cu} = 8.96gcm^{-3}$, atomic weight of natural copper, A = 63.5.] [5 Marks][Ref : Lilley, Nuclear Physics]
5. In the decay of ^{64}Cu both neutrinos and antineutrinos are observed. a) What are the two possible beta-decay processes and products ? b) Calculate the Q values for both decay modes. [Marks : 1+4=5]
6. Give a brief description of the reactions involved in the prinmordeal nucleosynthesis. List the nuclides that play major roles in the primordeal nucleosynthesis. [5+2 Marks]
7. What are the major challenges in the computation of reaction rates involved in primordeal nucleosynthesis ? What do you mean by Astrophysical S-factor. How can you connect it the the probability of tunnelng through the mutual Columb barrier of interactiong nuclei ? Hence indicate the importance of S-factor in the computation of Nuclear reaction rate. [Ref : Nuclear Atrophysics- A Course of Lectures ; Journal Ref : Nuclear Physicsa A, Volume 986, June 2019, Pages 98-106] [3+2+3+2 Marks]
8. Discuss the role of nuclear fusion reactions in the energy production in the stars. Give an account of the major reactions involved in the CNO-cycle. [5+3 Marks]
9. What do you mean by r- and s-processes ? How the heavy elements (elements beyond iron) are produced in the stars. Explain with suitable block diagram [2+4 Marks]

10. What are the main components of a nuclear reactor? Discuss the role of moderators in the reactors. What are the main criterion for sustained operation of a nuclear reactor? [2+2+1 marks]
11. With suitable example explain the origin of odd-parity levels in addition to the 0+, 2+, 4+, etc levels in the energy spectrum of even-even nuclei. [Hints : Class work] [3 Marks]
12. Explain why quadrupole mode of osccilation is considered most important in the collective model of nuclei. State the conditions under which prolate and oblate shape of deformed nuclei are observed. [2+2 Marks]
13. Define Clebesch-Gordon coefficient. What are the symmetry rules obeyed by these coefficients? List all the CGC's appearing in the expression for |J=1, M=1> for two fermionic system with $j_1 = 1/2, j_2 = 3/2$. [5 Marks]