M.Sc. Examination, 2019

Semester - IV

Physics

Special Course: MPC-464

(Nuclear Physics-III)

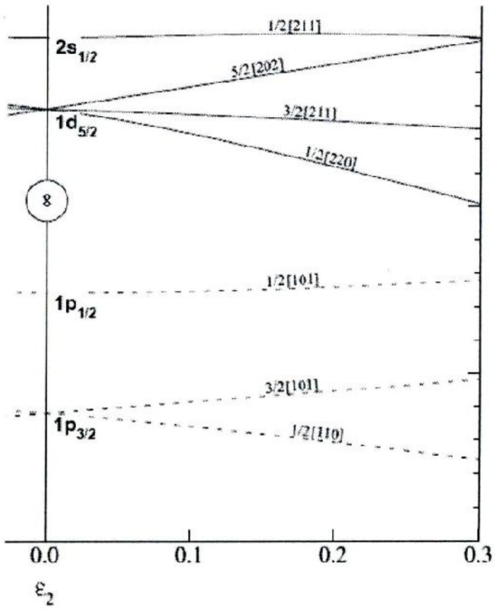
Time: Three Hours **Full Marks: 40**

Questions are of value as indicated in the margin.

Answer ***any four*** questions

1. (a) Give an experimental evidence to illustrate the existence of nuclear shell structure. 2
   (b) Distinguish the assumptions between spherical and deformed shell model. 2
   (c) Sketch the ordering of the single particle levels (on the basis of spherical shell model) up to N = 28 highlighting the role of spin-orbit coupling. 2
   (d) "To dissociate a proton from a heavy nucleus needs more energy than to dissociate a neutron" – Establish the statement with the necessary arguments on the basis of liquid drop model. 4

2. (a) Write down the ground state configurations and the ground state spin-parity for ^{13}C and ^{13}N on the basis of spherical shell model. Give your comments (on the basis of simplistic view point) related to the dominance of proton and neutron excitations in the lower-most excited states of the two nuclei. (0.5+0.5) + (0.5+0.5) + 1
   (b) Write down the Nilsson configuration for the single-particle state occupied by the even-Z deformed nucleus (having deformation parameter 0.2) with N = 14. Identify the various quantum number involved with. (2+1)



   (c) Distinguish the controlling factors that govern the emission of gamma-rays and internal conversion electrons. 2
   (d) "Internal conversion is not a two step process" – Justify with simple argument. 2

3. (a) What do you mean by Weisskopf single particle estimates? Write down the standard expressions for the reduced transition rates corresponding to Electric and Magnetic type of radiation on the basis of Weisskopf estimate. Do the necessary calculations to fill up the following:

$$B_W(\text{E2}) = \ldots\ldots\ldots\ldots\ e^2\text{fm}^4 \quad \text{and} \quad B_W(\text{M1}) = \ldots\ldots\ldots\ldots\ldots\ \mu_N^2$$

   where the symbols have their usual significance. 1+(1+1)+(1+1)

   (b) Calculate the Coulomb Barrier (in the lab frame) and the l_{max} value for the following fusion-evaporation reaction:

$$^{37}\textbf{Cl}(Z=17) + {}^{115}\textbf{In}(Z=49) \rightarrow {}^{152}\textbf{Dy}^*(Z=66) \rightarrow {}^{148}\textbf{Dy} + \textbf{4n}$$ 2+3

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4. (a) Write down the functional dependency of the intrinsic quadrupole moment of a nucleus with its deformation parameter. 1

   (b) Draw schematically the splitting of Nilsson orbits corresponding to $i_{13/2}$ single particle orbit (belonging to N = 6 oscillator shell) in the presence of prolate deformations. You have to label the splitted levels in terms of the appropriate Nilsson quantum numbers. 2+2

   (c) Consider the case of ^{92}Mo, which has a nanosecond isomer of mean-lifetime 2.22 ± 0.07 nsec corresponding to the γ-transition of energy 350-keV that decays from the level with 6^+ spin and feeds the low-lying level with 4^+ spin. Consider the branching ratio of the transition to be 85% and ICC = 0.017. Calculate the experimental B(E2) value (*in* e^2b^2 *unit*) for the transition. 3

   (d) What do you mean by spin-isomer? 2

5. (a) By tabulating the possible m-states of two quadrupole (l = 2) phonons, and their symmetrized combinations, obtain the possible 2-phonon states. Draw the level scheme of the nucleus undergoing two-phonon quadrupole modes of vibrations. Draw the possible γ-transitions between the states along with their corresponding dominant multipolarities. 2+2+2

   (b) Consider the following α-decay reaction:

$$^{251}\text{Fm}\ (Z = 100) \rightarrow {}^{247}\text{Cf}\ (Z = 98) + {}^{4}\text{He}\ (Z = 2)$$

   In this process, the α-particles with the following group of kinetic energies (in keV) are emitted:

   7304.705; 7250.581; 7183.665; 7105.924; 6927.808; 6884.50

   Do the necessary calculations (you have to deduce all the necessary expressions) to depict the α-decay scheme of ^{251}Fm. 4

6. (a) On the basis of statistical theory of nuclear reaction, deduce the necessary expression showing the dependency of nuclear level density on nuclear excitations. 3

   (b) Draw the necessary curve to illustrate the effect of neutron shell-closure on the level density parameter. 2

   (c) Assume that the nucleons inside a nucleus constitute Fermi gas. Estimate the depth of the nuclear potential. Given: $R_0 = 1.2 \times 10^{-15}$ metre; $h = 6.6 \times 10^{-34}$ J-sec; mass of one nucleon = 1.6×10^{-27} Kg. 4

   (d) What do you mean by the "critical size" of a fissile material? 1

7. (a) "Nuclear reaction is always accompanied by scattering, although scattering may and may not be accompanied by nuclear reaction" – Establish the statement on the basis of partial wave analysis of reaction cross-section. 6

   (b) Calculate the excitation energy of the ^{236}U [Z = 92 with m(^{236}U) = 236.0457 u] nucleus when a thermal neutron [m(n) = 1.0[illegible]7 u] (En = 0.025 eV) is absorbed by a ^{235}U [m(^{235}U) = 235[illegible]439 u] nucleus. 2

   (c) The neutron capture reaction of ^{197}Au at neutron energies upto a few hundred eV is characterized by a number of resonances. The most prominent one is at 4.906 eV and has $\Gamma_\gamma = 0.124$ eV and $\Gamma_n = 0.007\ E^{1/2}$ eV. The compound nucleus formed in this resonance absorption has spin 2. You have to use all the quantities and hence to show that the resonance cross-section for the concerned (n,γ) reaction is of the order of 10^4 barn. 2