2022

PHYSICS

(Theory Paper)

Paper Code : PHY 203

(Nuclear Physics-I)

Full Marks – 80

Time – Three hours

The figures in the margin indicate full marks for the questions.

1. Answer the following questions : 1×5=5

(a) The density of nucleus is

(i) larger for heavier nuclei

(ii) larger for lighter nuclei

(iii) independent of size of the nucleus

(iv) None of these

(b) The term Coulomb energy arises in the semi-empirical binding energy formula is due to

(i) nuclear attractive force between nucleons

(ii) electrostatic repulsive force between protons

(iii) the pairing of nucleons inside a nucleus

(iv) None of these

(c) The condition for β^- decay is

(i) $M_{at}(A, Z) > M_{at}(A, Z+1)$

(ii) $M_{at}(A, Z) > M_{at}(A, Z-1) + 2m_e$

(iii) $M_{at}(A, Z) > M_{at}(A, Z-1)$

(iv) $M_{at}(A, Z) > M_{at}(A, Z-1) - 2m_e$

(d) Choose the particle with zero Baryon number from the list given below :

(i) Pion (ii) Neutron

(iii) Proton (iv) Δ^+

(e) The isospin (I) and baryon number (B) of the up quark is

(i) I=1, B=1 (ii) I=1, B=1/3

(iii) 1=1/2, B=1 (iv) I=1/2, B=1/3

2. Answer any *five* of the following questions : 2×5=10

(a) Write down four general properties of nuclear force.

(b) Explain why a nucleus that can decay by positron emission may also undergo electron capture decay.

(c) Give two evidences to show that nuclear force is not purely central in nature.

(d) Draw a block diagram of the scintillation detector with proper labelling of different components.

(e) Name the crystals used as phosphor for efficient detection of alpha, beta and gama radiations in scintillation detectors.

(f) Find the strangeness of Λ° using Gell-Mann - Nishijima scheme.

3. Answer any *five* of the following questions : 5×5=25

(a) Draw a schematic diagram of the charge distribution inside a nucleus. What information regarding the nature of nuclear interaction one can gather from the nuclear density profile. Using Wood-Saxon function calculate the skin thickness of a nucleus. 1+1+3 =5

(b) (i) What is scattering length ? Discuss the significance of the sign of the scattering length. 1+1=2

(ii) In an electron-nucleus scattering experiment the first minimum in the angular distribution of the scattered electrons is found to be at 45°. Calculate the radius of the target nucleus. Given, energy of the incident electron is 420 MeV. 3

(c) Discuss the experimental evidences in favor of shell structure of atomic nucleus. 5

(d) Write down the expression for total mass energy of a nucleus using semi-empirical mass formula. Explain why pairing energy correction is incorporated in semi-empirical formula for binding energy. Using semi-empirical mass formula establish which of the isobars $^{108}_{47}Ag$ and $^{108}_{46}Pd$ decays into the other. What kind of decay occurs ? 4+1=5

(e) What do you mean by nuclear spin ? Using extreme single particle shell model, calculate the ground state spin and parity of $^{38}_{19}K$ nucleus. 1+4 = 5

(f) Apply conservation of charge, Baryon number, Lepton number, iso-spin, Z-component of isospin, strangeness quantum number to decide whether the following reactions are allowed or forbidden. If allowed, indicate the process of interaction. 1×5=5

(i) $\Sigma^+ \rightarrow n + e^+ + \nu_e$

(ii) $p + \pi^- \rightarrow n + \gamma$

(iii) $K^- + p \rightarrow \Xi^- + K^+$

(iv) $\pi^+ \rightarrow \mu^+ + \nu_\mu$

(v) $K^+ \rightarrow \pi^+ + \pi^+ + \pi^0 + \pi^-$.

4. Answer any *four* of the following questions : 10×4=40

(a) Assuming the attractive potential between the proton and neutron to be a finite square well type, estimate the normalized wave functions for deuteron. Hence, calculate the probability of finding the neutron and proton within the range of nuclear potential. Given, nuclear range $r_0 = 2.1$ fm, $\frac{\hbar^2}{m_p} = 41.3$ MeV fm^2, Binding energy of deuteron = 2.225 MeV. 7+3=10

(b) Discuss Fermi's theory of beta-decay to explain the continuous β-ray spectrum. Draw the rough experimental energy distribution plots of the decay of β^+ and β^- of $^{64}_{29}Cu$. Give an explanation for the observed difference between the distributions. Which additional factor takes care of the above behavior in the modified theoretical energy/momentum distribution obtained using Fermi theory.

7+1+1+1=10

(c) (i) Calculate the Q-value for the following reaction observed by Cockroft and Walton,

$$^{1}_{1}H + ^{7}_{3}Li \rightarrow ^{4}_{2}He + ^{4}_{2}He$$

The masses of $^{7}_{3}Li$, $^{4}_{2}He$ and protons are 7.016003 amu, 4.002602 amu, and 1.007825 amu respectively. State whether the reaction is exothermic or endothermic. Also, find the kinetic energy of the products if the incident protons have energy 600 KeV. 5

(ii) Discuss the compound nucleus hypothesis in the light of Ghoshal experiment. 5

(d) What is magic number ? Show that only three magic numbers can be explained if one assumes underlying nuclear interaction to be of harmonic oscillator potential type. Show that all the magic numbers can be reproduced by considering spin-orbit coupling. 1+5+4=10

(e) Draw the variation of current vs. applied voltage for a typical gas-filled detector and identify various regions of operation. Draw the block diagram and discuss the working principle of GM counter. What do you mean by dead-time of GM detector ? Why preamplifier is used in a gas-filled detector ? 2+5+2+1=10