2022

PHYSICS

(Honours)

Paper Code : IX - A & B

Full Marks : 90 | Time : Four Hours

Paper Code : IX - A

(Marks : 20)

Choose the corret answer.

Each question crries 2 marks.

1. The series limit of Balmer series is 3646Å. The wavelength of the first member of this series is —

   (A) 4861 Å (approximately)

   (B) 6563 Å (approximately)

   (C) 7015 Å (approximately)

   (D) 7500 Å (approximately)

2. The de Broglie wavelength of a moving electron and the wavelength of a photon are each 2.0 Å. Then, what is the correct conclusion for them ?

   (A) Their linear momenta are equal.

   (B) Their kinetic energies are eaual.

   (C) Their linear momenta and also their kinetic energies are equal.

   (D) Their linear momenta as well as their kinetic energies are different.

3. In quantum mechanics, the dimension of the wavefunction $\psi(\vec{r},t)$ is —

(A) $L^{3/2}$

(B) $L^{1/2}$

(C) $L^{-1/2}$

(D) $L^{-3/2}$

4. A wavefunction is given by $\psi(x)=\begin{cases} e^{ikx}+Be^{-ikx} & \text{for} \quad x<-L \\ Ae^{ikx} & \text{for} \quad x>L \end{cases}$. The relation satisfied by the constants A and B is —

(A) $A+B=1$

(B) $|A|+|B|=1$

(C) $|A|^2+|B|^2=1$

(D) $|A|=|B|$

5. For the atomic state ${}^3P_1$, the value of the Lande's g-factor will be —

(A) 1

(B) 2

(C) $\frac{3}{2}$

(D) $\frac{5}{2}$

6. The stable nucleus having a radius equal to one-third of the radius of Os^{189} is —

(A) Li^{7}

(B) Ne^{20}

(C) Fe^{56}

(D) Cu^{63}

7. The radioactive sample Sr^{90} undergoes β-decay, having a decay constant $(\lambda)\, 7.83 \times 10^{-10} S^{-1}$. Taking Avogadro number $N_A = 6.02 \times 10^{23}$ per mole, the activity of 1.0 gm of Sr^{90} would be —

(A) 14.1 curie

(B) 141 curie

(C) 12690 curie

(D) 14.1×10^{4} curie

8. Given below a *K*-capture reaction in which the daughter nucleus is formed directly in the ground state.

$${}_{55}Cs^{131} + {}_{-1}e^{0} \rightarrow {}_{54}Xe^{131} + \nu$$

If the total energy released in the process is 350 *keV* and the binding energy of *K*-electron in Xe^{131} is 35 *keV*, the energy of the neutrino would be —

(A) 385 *keV*

(B) 350 *keV*

(C) 315 *keV*

(D) none of the above

9. The quark composition of a proton and its strangeness number are given by —

   (A) ddu; zero

   (B) ddu; one

   (C) uud; one

   (D) uud; zero

10. Which of the following are magic numbers ? 2, 6, 8, 16, 20, 30, 46 —

   (A) 2, 8 and 20

   (B) 8, 20 and 30

   (C) 8, 16 and 30

   (D) 8, 16 and 46

Paper Code : IX - B

(Marks : 70)

The figures in the margin indicate full marks. Candidates are required to give their answers in their own words as far as practicable.

Answer ***five*** questions, taking at least ***one*** from each of group.

Group A

(Atomic Physics)

1. (a) What do you mean by 'space quantisation' ? 2

   (b) Prove that the D-state of an alkali atom is always a doublet. Give the spectroscopic representation of the atomic states. 2+1

   (c) Describe briefly Franck-Hertz experiment. What conclusion can be drawn from this experiment ? 5+1

   (d) The velocity of the electron in the k-shell of H-atom is given by $v_1 = \frac{\hbar}{ma_0}$, where m = electronic mass = 9.1×10^{-31} kg ; a_0 = radius of k-shell (first Bohr orbit) of H-atom = 0.53Å and h = Planck's constant = 6.62×10^{-34} J.S. Calculate the value of $\frac{v_1}{c}$, where c = speed of light in vacuum. What is the name of this ratio ? 2+1

2. (a) Describe briefly with a schematic diagram, the construction and the principle of operation of an Aston's mass spectrography (no mathematical details is required). Why is it known as velocity focussing mass spectrograph ? 5+1

   (b) Explain the origin of continuous X-ray spectra and the characteristic line spectra. State Moseley's law. 1+2+1

   (c) If the electron in a hydrogen atom rotates in a circular orbit, obtain an expression for the orbital magnetic moment of the atom. Hence, introduce 'Bohr magneton'. 3+1

3. (a) A 2-electron atomic state is given by $^3F_4$. Obtain the S, L and J-values for the state. There are two other atomic states for the obtained values of S and L. Write down those two states. 2+2

(b) What is Zeeman effect ? An alkali atom cannot exhibit normal Zeeman effect. Why ? 1+1

(c) Describe, in detail, a theory which explains the anomalous Zeeman effect. Illustrate with diagrams the Zeeman splitting of sodium D^1 and D^2 lines in the transverse view. Mention clearly the relevant selection rules. 4+4

Group B

(Quantum Mechanics)

4. (a) Deduce an expression for the 'Compton shift' of a high-frequency photon. Write down important dissimilarities between 'Compton effect' and 'Raman effect'. 4+3

(b) Explain why an electron of the scatterer cannot be scattered at an angle greater than 90° in compton effect. 3

(c) A beam of X-rays of wavelength 0.2 nm is incident on a free electron and gets scattered in a direction with respect to the direction of the incident radiation resulting in maximum wavelength shift. Prove that the percentage energy loss of the incident radiation is 2.36%.

Take λ_c (compton wavelength) = 0.002426 nm. 4

5. (a) Describe briefly Davisson-Germer's electron diffraction experiment. What important conclusion was obtained from it ? 5+1

(b) A moving particle mass 'm' is represented by the wavefunction $\psi(\vec{r},t) = Ae^{i(\vec{k}.\vec{r}-wt)}$, where A = constant. Show that the probability current density is $\vec{J} = \frac{\hbar k}{m}|A|^2$. 3

(c) The normalised wavefunction of a particle moving in a region $0 \le x \le L$ is given by $\psi(x) = \sqrt{\frac{2}{L}\sin\frac{n\pi x}{L}}$, where n is an integer. Find the expectation value of the momentum of the particle. 3

(d) If $\hat{A}$ and $\hat{B}$ are Hermitian, show that $i[\hat{A}, \hat{B}]$ is Hermitian, where $[\hat{A}, \hat{B}]$ is a commutator bracket. 2

6. (a) Write down the Schrödinger equation for the stationary state of a simple harmonic oscillator confined to the *x*-axis. What is the nature of the solution at $x \to \pm\infty$? 1+2

(b) The ground state wavefunction of a one-dimensional harmonic oscillator (of mass *m* and angular frequency ω) is $\psi_0 = \sqrt{\frac{\alpha}{\sqrt{\pi}}} e^{-\frac{\alpha^2 x^2}{2}}$, where $\alpha = \sqrt{\frac{m\omega}{\hbar}}$.

What is the energy corresponding to this state ? Is it an eigenfunction of momentum ? Justify analytically. 3+2

(c) The energy of a linear harmonic oscillator in the thrid excited state is 0.1 *eV*. Prove that the frequency of oscillation of the oscillator is $\gamma \sim 10^{12}\,\text{Hz}$.

Take $h = 6.626 \times 10^{-34}$ J.s. 3

(d) Heteronuclear molecules (like *HCl*, *Co* etc.) can exhibit vibrational spectra while homonuclear molecules (like H_2, O_2 etc.) cannot. Why ?

In which region of electromagnetic waves do these vibrational spectra belong ? 2+1

Group C

(Nuclear and Elementary Particle Physics)

7. (a) What is meant by 'range' of an α-particle ? What is straggling ? 1+2

(b) Explain nuclear fission on the basis of liquid drop model. 3

(c) U^{235} captures a thermal neutron and undergoes fission to release energy of 180 MeV. If the mass numbers of the fission fragments be 140 and 93, calculate the kinetic energy of the lighter fragment. 3

(d) Outline briefly Ghoshal's experiment in connection with the compound nuclear reaction. 4

(e) What is meant by cross-section of a nuclear reaction ? 1

8. (a) Show, from the semi-empirical mass formula, that $A \simeq 2z$ for light nuclei. Take $a_c / a_a = 0.030$. 3

(b) On the basis of extreme single particle shell model, find the ground state spin and parity of ${}_6C^{13}$. 2

(c) What do you mean by 'dead time' with reference to a G.M. counter ? How can this time be shortened ? 2+1

(d) Explain qualitatively how the neutrino hypothesis solves the apparent breakdown of conservation of angular momentum and energy in β-decay. 3

(e) What are Van Allen radiation belts ? How many belts are there ? 2+1

9. (a) Expalin the 'proton-proton cycle' and the 'carbon-nitrogen cycle' in connection with the production of stellar energy. 2+2

(b) Define electric quadrupole moment of a nucleus and explain its importance. 2+1

(c) A positron collides head on with an electron and both of them are annihilated. Each particle had initially a kinetic energy of 1.0 *MeV*. Show that the wavelength of each of the resulting γ-ray photons is approximately 0.0082Å. Take rest mass of an electron or a positron as 9.11×10^{-31} kg. 3

(d) Identify the unknown particle in each of the reactions given below, using the conservation laws.

(i) $\mu^- + p \rightarrow {}_0n^1 + ...$

(ii) $\pi^- + p \rightarrow k^0 + ...$ 2+2