(2½ Hours) [Total Marks : 75

N. B. : (1) **All** questions are **compulsory**.
(2) **Figures** to the **right** indicate **full** marks.
(3) Draw neat diagrams wherever necessary.
(4) Symbols have their usual meaning unless otherwise stated.
(5) Use of log-table and nonprogrammable calculator is allowed.

1. (a) Attempt **any one.** **10**

(i) Write the Schrodinger equation for hydrogen atom in spherical polar coordinates. Using the method of separation of variables get the three differential equations for R, Θ and Φ. State the different quantum numbers and their permissible values.

(ii) Solve the Schrodinger equation for simple harmonic oscillator using operator method. Define the raising and lowering operator and hence get the lowest eigenfunction.

(b) Attempt **any one.** **5**

(i) Show that

$$\Theta_{20} = \frac{\sqrt{10}}{4}(3\cos^2\theta - 1)$$

is the solution of the equation,

$$\frac{1}{\sin\theta}\frac{d}{d\theta}\left(\sin\theta\frac{d\Theta_{lm_l}}{d\theta}\right)+\left[l(l+1)-\frac{m_l^{\,2}}{\sin\theta}\right]\Theta_{lm_l}=0$$

(ii) Show that the eigenvalue of the operator $\mathbf{L}^2$ is $l(l+1)\hbar^2$, when operated on hydrogen atom wavefunction.
Given :

$$\mathbf{L}^2 = -\hbar^2\left[\frac{1}{\sin\theta}\frac{\partial}{\partial\theta}\left(\sin\theta\frac{\partial}{\partial\theta}\right)+\frac{1}{\sin^2\theta}\frac{\partial^2}{\partial\phi^2}\right]$$

2. (a) Attempt **any one.** **10**

(i) Discuss LS coupling for two electron atom in detail. Find spectroscopic terms for an atom having s electron and p electron.

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(ii) Show, quantum mechanically, that an electron undergoing a transition from energy level E_m to a lower energy level E_n emits a radiation of frequency $\nu = \frac{E_m - E_n}{h}$

(b) Attempt **any one.** **5**

(i) Define symmetric and antisymmetric wavefunctions. Explain, why antisymmetric wavefunction obeys Pauli's exclusion principle.

(ii) Calculate angle between vectors **J** and **L** in $^2P_{1/2}$ state.

3. (a) Attempt **any one.** **10**

(i) What is Normal Zeeman Effect? Give quantum mechanical explanation of Normal Zeeman Effect.

(ii) What is Paschen-Back effect? Illustrate Paschen-Back effect considering a Principal series doublet.

(b) Attempt **any one.** **5**

(i) Draw vector atom model diagram showing relative orientations of vectors- **S**, **L**, **J**, μ_L, μ_S and μ_J.

(ii) What is anomalous Zeeman effect? Draw vector model diagram to represent it.

4. (a) Attempt **any one.** **10**

(i) State Franck-Condon principle. Using the principle, discuss the intensity pattern of electronic bands.

(ii) What is Raman effect? Explain it using the polarizability of molecules.

(b) Attempt **any one.** **5**

(i) Write a short note on vibration-rotation spectrum of a diatomic molecule.

(ii) In a CO molecule, the bond length is 1.13×10^{-10} m and the masses of C and O atoms are 1.99×10^{-26} kg and 2.66×10^{-26} kg respectively. Calculate the energy of the lowest rotational level.

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5. (a) Attempt **any one.** 4

(i) Normalise the wavefunction $\Phi = Ae^{im\phi}$ and hence find the value of A.

(ii) The natural frequency of CO molecule is 2×10^{13} Hz. Calculate the zero point energy. $h = 6.63 \times 10^{-34}$ Js.

(b) Attempt **any one.** 4

(i) State Hund's rule and show that $^{16}_{8}O$ has two unpaired electrons.

(ii) A beam of electrons enters a uniform magnetic field 1.8 wb/m^2. Find the energy difference between the electrons whose spins are parallel and antiparallel to the field.
Given : $\mu_B = 9.27 \times 10^{-24}$ joule/(wb/m^2)

(c) Attempt **any one.** 4

(i) A sample of certain element is placed in a magnetic field of 0.3 wb/m^2. How far apart are the normal Zeeman components of a spectral line of wavelength 4500 angstrom?
Given : e/m = 1.76×10^{11} C/kg.
c = 3×10^8 m/s.

(ii) Show that the Lande's g-factor has a value 1.5 when L = S. Illustrate it by giving two suitable examples along with their term symbols.

(d) Attempt **any one.** 3

(i) When a radiation of frequency 549.5×10^{12} Hz was scattered by a medium, the Raman spectrum showed a radiation of frequency 557.4×10^{12} Hz. Is it Stoke's line or antistoke's line? Determine the wavelength of Stoke's line.
c = 3×10^8 m/s.

(ii) Homonuclear diatomic molecules do not exhibit vibrational and rotational spectra but they exhibit Raman spectra. Explain.

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