

(3 Hours)

[Total Marks: 100]

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

**Q1.** Attempt any **two**:---

- (i) Starting with the three dimensional Schrodinger's equation in spherical polar coordinates for Hydrogen atom, obtain three ordinary differential equations that describe the hydrogen atom. **10**
- (ii) Explain space & magnitude quantization in hydrogen atom in Schrodinger's hydrogen model. **10**
- (iii) What are symmetric and anti-symmetric wave functions? Show that system of electrons is described by antisymmetric wave functions. **10**
- (iv) a) State the rule of maximum multiplicity and explain it with one example. **10**  
 b) Find set of all four quantum numbers for all the electrons in  $n = 2$  (L – shell) using Pauli's exclusion principle.

**Q2.** Attempt any **two**:---

- (i) Explain Vector atom model with *LS* coupling and *JJ* coupling schemes. **10**
- (ii) Explain quantum theory of radiative transition. Also show that when the electron jumps from higher energy level  $E_m$  to a lower energy level  $E_n$  the frequency of photon emitted is  $\nu = \frac{E_m - E_n}{h}$  **10**
- (iii) Discuss the quantum theory of normal Zeeman effect and obtain an expression for Zeeman shift. **10**
- (iv) Derive the expression for Lande g-factor. **10**

**Q3.** Attempt any **two**:---

- (i) Considering the diatomic molecule as a rigid rotator, derive an expression for rotational energy  $E_J$  and show that the rotational energy levels are not equally spaced. **10**
- (ii) Write the expression for vibration-rotation energy levels of a rigid diatomic molecule (neglect anharmonicity). Discuss features of P- branch and R-branch using suitable energy level diagram. **10**
- (iii) What is Born Oppenheimer approximation? What is meant by coarse structure of an electronic spectrum of a diatomic molecule? Discuss it by drawing a suitable energy level diagram. **10**
- (iv) State the principle of microwave spectrometer. Draw its labeled schematic diagram and explain the functions of its various parts. **10**

- Q4** Attempt any **two**:---
- (i) Give classification of molecules based on rotational behavior. **10**
  - (ii) Explain the Raman activity of vibrations of Carbon Dioxide molecules by considering different modes of vibration. **10**
  - (iii) Discuss pure rotational Raman spectra of linear molecules. **10**
  - (iv) Explain the Electron Spin Resonance (ESR) in materials. Why paramagnetic materials exhibit ESR? **10**
- Q5.** Attempt any **four**:---
- (i) Solve the  $\Phi$  – equation and normalize the wave function. Name the quantum number introduced. **05**
  - (ii) Using  $R = \frac{2}{a^{3/2}} e^{-r/a}$  calculate the radial probability density of electron beyond Bohr radius 'a'. **05**
  - (iii) Calculate the angle between  $\vec{J}$  and  $\vec{L}$  in  $^2P_{3/2}$  state. **05**
  - (iv) Explain Anomalous Zeeman Effect **05**
  - (v) Calculate the moment of inertia and energy of rotational  $J = 2$  level in HCl molecules. Given:  $M(H) = 1.66 \times 10^{-27} \text{ Kg}$ ,  $M(Cl) = 5.81 \times 10^{-26} \text{ Kg}$ , bond length = 2.1 AU,  $h = 6.63 \times 10^{-34} \text{ joule-sec}$ . **05**
  - (vi) State the principle involved in IR spectroscopy. Also draw block diagram for Absorption IR Spectrometer. **05**
  - (vii) In pure rotational Raman spectrum of CO gas, the Raman shift for the first stokes line is observed to be  $0.35 \times 10^{12} \text{ Hz}$ . Use this information to calculate the bond length of CO molecule. **05**  
Given : Reduced mass of CO molecule is  $1.14 \times 10^{-26} \text{ kg}$ ,  $h = 6.63 \times 10^{-34} \text{ joule-sec}$ .
  - (viii) A particular NMR instrument operates at 30.256MHz; what magnetic field is required to bring  $^{13}\text{C}$  nuclei to resonance? g-factor for  $^{13}\text{C}$  nucleus = 1.404 **05**  
Given :  $\mu_N = 5.05 \times 10^{-27} \text{ J/T}$
-