

Time: 3 Hrs

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.1. Attempt any **two**:---

- (a) Set up steady state Schrodinger's equation for H-atom in spherical polar coordinates. Solve it by the method of separation of variables. Explain how magnetic quantum numbers m_l arises in solving ϕ equation. **10**
- (b) State Pauli's exclusion principle. Show that particles obeying Pauli's exclusion principle are described by antisymmetric wave functions. **10**
- (c) Explain with neat diagrams, Stern-Gerlach experiment to demonstrate space quantization of electron spin. **10**

2. Attempt any **two**:---

- (a) If an electron undergoes a transition from a higher energy level E_m to a lower energy level E_n , prove quantum mechanically that it emits a radiation of frequency, **10**
- $$\nu = \frac{(E_m - E_n)}{h}$$
- (b) Derive an expression for Lande's 'g' factor and obtain its value for 5D state. **10**
- (c) Explain with neat diagrams, L-S and J-J coupling schemes for two electron atoms. **10**

3. Attempt any **two**:---

- (a) Derive an expression for the vibrational frequency of a diatomic molecule in terms of its reduced mass and force constant. Show that the vibrational energy levels are equally spaced assuming that the molecule performs a linear harmonic motion. **10**
- (b) Write expression for rotational energy of a rigid diatomic molecule. Explain in detail, how energy levels get modified if effect of bond elongation is taken into consideration. Draw appropriate energy level diagram. **10**
- (c) Draw the block diagram of a double beam infrared spectrophotometer and explain each block in detail. **10**

4. Attempt any **two**:---
- (a) Discuss quantum theory of Raman effect in detail. **10**
- (b) Explain pure rotational Raman spectra of a linear diatomic molecule. **10**
Show graphical representation of energy levels and spectral lines.
- (c) What is the basic principle of Nuclear Magnetic Resonance (NMR)? **10**
Explain NMR spectrometer with a neat diagram.
5. Attempt any **four**:---
- (i) Write note on radial probability density of electron in H-atom. **05**
- (ii) Show that **05**

$$\Theta_{20} = \frac{\sqrt{10}}{4} [3\cos^2\theta - 1]$$
 is a solution of Θ equation:

$$\frac{1}{\sin\theta} \frac{d}{d\theta} \left(\sin\theta \frac{d\Theta_{lm}}{d\theta} \right) + [\ell(\ell+1) - \frac{m_l^2}{\sin^2\theta}] \Theta_{lm} = 0$$
- (iii) Calculate the angle between \vec{J} and \vec{L} in ${}^2P_{3/2}$ state. **05**
- (iv) A sample of certain element is placed in a magnetic field of intensity 0.3 T. How far apart Zeeman components of wavelength 4500 Å will be? **05**
Given : $e/m = 1.7588 \times 10^{11} \text{C/kg}$ $c = 3 \times 10^8 \text{ m/s}$
- (v) The lowest rotational energy of CO molecule is $4.76 \times 10^{-4} \text{ eV}$ **05**
corresponding to a transition from $J = 0$ to $J = 1$. Calculate the bondlength of CO molecule whose reduced mass is $1.138 \times 10^{-26} \text{ Kg}$.
Given : $h = 1.054 \times 10^{-34} \text{ Js}$ $1 \text{ eV} = 1.6 \times 10^{-19} \text{ J}$
- (vi) Determine the force constant of HCl molecule if its vibrational frequency is $9 \times 10^{13} \text{ Hz}$. Given : $M(\text{H}) = 1.67 \times 10^{-27} \text{ Kg}$, $M(\text{Cl}) = 5.81 \times 10^{-26} \text{ Kg}$ **05**
- (vii) If bondlength of H_2 is 0.07417 nm , what would be the position of the first rotational Raman line in the spectrum? **05**
Given : $M(\text{H}) = 1.673 \times 10^{-27} \text{ Kg}$, $h = 6.63 \times 10^{-34} \text{ Js}$, $c = 3 \times 10^8 \text{ m/s}$
- (viii) Calculate the magnetic field strength required to get a transition frequency of 60 MHz for fluorine. **05**
Given : $g_n = 5.255$, $h = 6.63 \times 10^{-34} \text{ Js}$, $\mu_N = 5.051 \times 10^{-27} \text{ J/T}$
