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)   For hydrogen atom, write down the differential equation for the radial part, **10**
       R(r), of the wave function $\Psi = R(r).\Theta(\theta).\Phi(\phi)$. Using this, show that
       the magnitude of angular momentum is quantized.

(b)   State Pauli's exclusion principle. Show that the system of electrons is **10**
       described by antisymmetric wave functions.

(c)   Discuss Stern-Gerlach experiment, which demonstrates the existence of **10**
       magnetic moment associated with electron spin.

2   Attempt any **two:---**
(a)   Explain with neat diagram, L-S and J-J coupling, for two electron atoms. **10**

(b)   What is normal Zeeman effect? Discuss the quantum theory of normal **10**
       Zeeman effect and obtain an expression for Zeeman shift.

(c)   Write expression for average position of electron and explain allowed and **10**
       forbidden transitions. State selection rules for allowed transitions and
       discuss whether following transitions are allowed or forbidden.
       (i) $\Psi_{200} \rightarrow \psi_{100}$ (ii) $\Psi_{320} \rightarrow \psi_{211}$

3.   Attempt any **two:---**
(a)   Write expression for vibration-rotation energy of a diatomic molecule. **10**
       Using appropriate selection rules, find the expression for the frequency of
       spectral lines in P and R branch of the spectrum. Draw energy level
       diagram.
(b)   Prove that the vibrating diatomic molecule is equivalent to a single particle **10**
       executing linear harmonic motion. Write quantum expression for its
       vibrational energy and also draw energy level diagram.

(c)   Draw a labeled schematic diagram of a microwave spectrometer and **10**
       explain function of its various parts.

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4.   Attempt any **two:**---

(a)   Explain pure rotational Raman spectra of a linear diatomic molecule.   **10**

(b)   What is Raman effect? With the help of neat diagram, describe the   **10**
experimental set up of Raman effect.

(c)   Explain the principle of Electron Spin Resonance (ESR). Describe the   **10**
ESR spectrometer set up with the help of labeled diagram.

5.   Attempt any **four:**---

(i)   For a d-electron, draw space quantization diagram. Also calculate cosine   **05**
of angle between each orientation of L and Z-axis.

(ii)   Show that the solution $R_{10}(r) = \dfrac{2}{a_0^{3/2}} e^{-r/a_0}$ **05**

of radial differential equation of hydrogen atom is normalized.

(iii)   Define Lande's 'g' factor and find its value $^2P_{3/2}$ state.   **05**

(iv)   A spectral line of 4000 A is subjected to 0.5 T of magnetic field. The   **05**
normal Zeeman shift is observed to be 0.03735 A. Determine the specific
charge of an electron (e/m). Given : $c = 3 \times 10^8$ m/s.

(v)   Determine rotational energy of $J = 2$ state in eV for HCl molecule having   **05**
bondlength 2.1 A. Given : Reduced mass of HCl = 0.162×10^{-26}Kg,
$\hbar = 1.054 \times 10^{-34}$Js, $1eV = 1.6 \times 10^{-19}$ J

(vi)   Calculate vibrational frequency of Hydrogen molecule if its force   **05**
constant is 480 n/m and mass of hydrogen atom is 1.67×10^{-27}Kg.

(vii)   If bondlength of H_2 is 0.07417nm, what would be the position of the first   **05**
rotational Raman line in the spectrum?
Given : $M(H) = 1.673 \times 10^{-27}$ Kg, $h = 6.63 \times 10^{-34}$Js, $c = 3 \times 10^8$m/s

(viii)   The ^{13}C NMR spectrum of a compound occurs at 10.705 MHz in a   **05**
magnetic field of 1 T. What is its resonance frequency if the applied field
is 3 T.

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