RAN-2403080104022001

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M. Sc. (Sem.-IV) Examination September - 2025

Physics : Atomic and Molecular Physics (PH-542)

Time: 3 Hours] **[Total Marks: 70**

સૂચના : / Instructions

(1) ઉપરોક્ત દર્શાવેલ વિગતો ઉત્તરવહી પર અવશ્ય લખવી.
Fill up strictly the above details on your answer book

(2) Assume the data if required.

(3) Figures to right hand side indicate marks of each question.

(4) Attempt any two of each question

Seat No.:

Student's Signature

1. (a) (i) Explain the fine structure splitting of the hydrogen atom. **(7)**

(ii) Draw the transitions contributing to the Balmer alpha line between the n = 3 and n=2 levels of atomic hydrogen and their relative intensities. **(2)**

(b) (i) Calculate the energy correction due to spin orbit term in theory of fine structure of hydrogenic atoms. **(6)**

(ii) Calculate the relativistic correction to the kinetic energy in theory of fine structure of hydrogenic atoms. **(3)**

(c) (i) What is Lamb Shift ? Draw the schematic diagram of Lamb-Retheford experiment and explain it. **(7)**

(ii) What is an isotope shift ? Describe the factors responsible for it. **(2)**

2. (a) (i) Derive the expression for the zero-order spatial wave function and the corresponding energy for which both electrons are in excited state with respect to independent particle model. **(6)**

(ii) Explain the role of the Pauli exclusion principle. Show that the para states are spin singlets while ortho states are spin triplets. **(3)**

(b) (i) Build the spin wave function χ (1,2) from the spin wave functions of the individual electrons. Show that the four spin states are the product of two individual spin functions and make the table for values of spin function χ, $S_z\chi$, and $S^2\chi$. **(3)**

(ii) Calculate the total degeneracy of the ground state configuration of carbon atom. **(2)**

(iii) Write the spin orbital and Slatter determinant for the two electrons of the ground state of helium. Also verify that H_c commutes with $\vec{L}$ and $\vec{S}$ of the electrons. **(4)**

(c) (i) Outline the theory of anomalous Zeeman effect. Also explain the Paschen-Back effect. **(7)**

(ii) Draw the spectrum for the three-body system of the He^{++} nucleus and two electrons and explain it. **(2)**

3. (a) (i) Describe the Hund's case in which electrostatic interaction is much larger than the spin orbit interaction and spin orbit interaction is greater than the rotational energy. **(6)**

(ii) Explain how the water molecule is formed? Write the full wave function for it. **(3)**

(b) (i) Derive nuclear wave equation for diatomic molecule using Born Oppenheimer approximation. **(8)**

(ii) Discuss the vibrational structure of polyatomic molecule. **(1)**

(c) (i) Explain the concept of non-localized bonds in benzene and derive the following expression of the π orbitals (ϕ_μ) of the benzene **(7)**

$$\phi_\mu(r) = N_\mu \sum_{j=1}^{6} \exp\left(\frac{i\pi\mu j}{3}\right) u_{2p_z}(\overline{r} - \overline{R}_j)$$

(ii) Explain spin uncoupling. What is A-doubling ? **(2)**

4. (a) (i) Discuss the rotational structure of electronic spectra. What is Fortrat diagram ? **(5)**

(ii) Discuss the vibrational structure of electronic spectra. Write the Deslandres formula. Explain the terms progression and band sequence. **(3)**

(b) (i) Identify the technique used to extract information about the constituents of a sample and explain it. **(5)**

(ii) Explain the follwing terms : **(3)**
(1) Dissociation
(2) Predissociation

(c) Explain the vibrational-rotational spectra of diatomic molecules. What is vibrational-rotational band ? Draw the energy level diagram of the lowest vibrational-rotational levels in a diatomic molecule and explain it. What is fundamental band ? **(8)**

Use the following data if required :
$K_B = 1.38 \times 10^{-23}$ J/^{0}K
$h = 6.62 \times 10^{-34}$J.sec
Electron mass = 9.1×10^{-31} Kg
C= 3×10^8 m/Sec
1 eV = 1.6×10^{-19} Joule