2003080104020001
EXAMINATION APRIL 2024
MASTER OF SCIENCE (PHYSICS) (FOURTH SEMESTER)
ATOMIC AND MOLECULAR PHYSICS

[**Time: Three Hours]** **[Max. Marks: 70]**

Instructions:
1. Fill up strictly the following details on your answer book
   a. Name of the Examination: **MASTER OF SCIENCE (PHYSICS) (FOURTH SEMESTER)**
   b. Name of the Subject: **ATOMIC AND MOLECULAR PHYSICS**
   c. Subject Code No: **2003080104020001**
2. Sketch neat and labelled diagram wherever necessary.
3. Figures to the right indicate full marks of the question.
4. All questions are compulsory.
5. Assume the data if required.
6. Attempt any two of each question

Seat No:

Student's Signature

Q.1 a) What is an isotope shift? Describe the factors responsible for it. Derive the expression for first order energy shift (ΔE) and error (δE). **6**

b) What do you mean of structure multiplet? Draw the fine structure splitting of the energy levels of the hydrogen atom and explain it. **6**

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

Q.2 a) Consider an atom consisting of a nucleus of charge Ze, mass M and two electrons of mass m. Write the Schrodinger equation for spatial part of the wave function. Show that $\Psi(\overrightarrow{r_2}, \overrightarrow{r_1}) = \pm \Psi(\overrightarrow{r_1}, \overrightarrow{r_2})$. What are para and ortho states? **6**

b) Write the Hamiltonian with respect to independent particle model. Derive the expression for the zero-order spatial wave function and the corresponding energy for ground state of two electron atoms. **6**

c) (i) Explain the level scheme of two electron atoms. **4**
(ii) Draw the spectrum for the three-body system of the He^{++} nucleus and two electrons and explain it. Also draw the spectrum of two electrons with Z > 2. Deduce the value of ionization potential. **2**

Q.3 a) Explain electron states in a central field, Configurations, shells and subshells. **6**

b) Write the Hamiltonian of an atom containing a nucleus of charge Ze and N-electrons in the absence of external fields. Derive the expression of Hamiltonian corresponding to central field approximation. **6**

c) (i) Discuss the problem of Fermi electron gas by imposing periodic boundary conditions on the wave functions of electrons. Find out the energy on the surface of Fermi sphere and write the relation between Fermi momentum, Fermi velocity and Fermi temperature. **4**

(ii) How are electrons distributed in various subshells for n = 3? **2**

Q.4 a) Discuss the rotational and vibrational motion of diatomic molecules and obtain the expression of radial equation. **6**

b) (i) Explain the following Hund's case for electronic spin of the molecules $|\Delta E| >> B >> |A|$. **5**

(ii) Explain spin uncoupling. **1**

c) Explain the concept of non-localized bonds in benzene. Using a Variational method, show that the coefficient **6**

$C_j^{\mu} = exp\left(\frac{i\pi\mu j}{3}\right)$

Q.5 a) (i) How the electronic spectra of molecules are generated? Explain the features of it with the help of fine structure of Bel molecule. **4**

(ii) Explain how the oxygen isotopes distinguish with respect to nuclear spin. **2**

b) (i) Discuss the gerade and ungerade state pertaining to rotational structure of diatomic molecule. Draw the Fortate diagram for transition between two $\sum$ states and explain it. **5**

(ii) Why the electric dipole operator vanishes in homonuclear diatomic molecule? **1**

c) (i) Discuss the vibrational structure of electronic spectra. Write the Deslandres formula. Explain the terms progression and band sequence. **4**

(ii) The zero-point energy of the ground state of N_2 is $1176\ cm^{-1}$ and that of its lowest excited state is $727\ cm^{-1}$. The energy difference between the minima of the potential energy curves is $50206\ cm^{-1}$. What is the energy of the $v' = 0\ to\ v'' = 0$ transition in cm^{-1}. What is the corresponding wavelength? **2**

Q.6 a) What do you mean by atom mirrors? Draw the schematic diagram of an atom mirror using an evanescent wave and explain it. Explain the use of it in building atom cavities. **5**

b) Explain the paramagnetic resonance in bulk samples. Derive the expression of net magnetic moment per unit volume. Draw the schematic diagram of a paramagnetic resonance apparatus and explain it. **5**

c) How is the NMR spectrum studied? Also explain the concept of spin-lattice relaxation 5 time and the spin-spin relaxation time. **5**

Use the following data if required:

$K_B = 1.38 \times 10^{-23} J/°K$

$h = 6.62 \times 10^{-34} J.sec$

Electron mass $= 9.1 \times 10^{-31} Kg$

$C = 3 \times 10^8 m/sec$

$1\, eV = 1.6 \times 10^{-19} Joule$

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