Serial No. 5202

[This question paper contains 3 printed pages]

a) Name of Department: Physics

b) Name of Course: B.Sc. Hons. – (Physics) – NEP: UGCF-2022

c) Name of the Paper: Atomic and Molecular Physics (GE Paper)

d) Semester: VIII

e) Unique Paper Code: 2224002011

f) Medium of setting the Question paper: English Language

g) Question paper set number: I

Duration: **3 Hours** Maximum Marks: 90

Instructions for Candidates

Write your Roll No. on the top immediately on receipt of this question paper.

Attempt five questions in all. All questions carry equal marks.

Question No. **1** is compulsory.

Non-programmable calculator is allowed.

1. Attempt any six of the following: **(6 × 3 = 18)**

(a) Write a short note on paramagnetic molecular orbitals and fractional bond order using the O_2 molecule as an example.

(b) Discuss the difference between σ (sigma) and π (pi) molecular orbitals with suitable diagrams.

(c) Explain whether the ground state level $^2S_{1/2}$ can exhibit Zeeman splitting in a weak magnetic field.

(d) State the Born-Oppenheimer approximation and briefly explain its significance in molecular spectroscopy.

(e) Distinguish between Stokes and anti-Stokes lines observed in Raman scattering.

(f) Briefly discuss the physical conditions necessary for a linear combination of atomic orbitals (LCAO) to form stable molecular orbitals.

(g) Estimate the orbital magnetic dipole moment of an electron moving in the ground state ($n=1$) of a hydrogen atom.

2. (a) Describe the anomalous Zeeman effect. Derive the expression for the energy shift of an atomic state in a weak external magnetic field and trace the splitting transitions for the Sodium D_1 line. **(10 Marks)**

(b) In a Stern-Gerlach experiment, a beam of silver atoms $(\mu = 1\mu_B)$ passes through a non-uniform magnetic field gradient of 1.5×10^3 T/m over a length of 4 cm. Calculate the transverse deflection of the two split beams on a screen placed at the edge of the magnetic field. **(5 Marks)**

(c) Explain why homonuclear diatomic molecular orbitals do not possess a permanent electric dipole moment and discuss how this affects their pure rotational spectra. **(3 Marks)**

3. (a) State and explain the Franck–Condon principle. Discuss its quantum mechanical interpretation regarding the intensity distribution in electronic–vibrational transitions using potential energy curves. **(10 Marks)**

(b) Discuss the difference between radiative relaxation (fluorescence/phosphorescence) and non-radiative relaxation of an excited molecular state. **(5 Marks)**

(c) What is zero-point energy? If the fundamental vibrational wave number of an HCl molecule is $2886\ cm^{-1}$, determine its zero-point energy in Joules. **(3 Marks)**

4. (a) Compare Infrared (IR) spectroscopy and Raman spectroscopy. Discuss their selection rules, the respective electromagnetic energy regions utilized, and their complementary nature in structural analysis. **(10 Marks)**

(b) The ground state electronic configuration of Carbon is $1s^2 2s^2 2p^2$. Find all the possible standard spectroscopic term symbols for this equivalent electron configuration using L-S coupling. **(5 Marks)**

(c) Define the Paschen-Back effect and discuss its importance when an atom is placed in a very strong magnetic field. **(3 Marks)**

5. (a) What is meant by the fine structure of alkali spectra? How is it explained based on spin-orbit interaction, and explain why the screening constant causes alkali levels to be deeper than corresponding hydrogen levels? **(10 Marks)**

(b) Explain the isotope effect in vibrational spectroscopy. Show how the vibrational frequency shifts when an atom in a diatomic molecule is substituted by its heavier isotope. **(5 Marks)**

(c) Write a short note on the physical mechanisms behind the production of Continuous and Characteristic X-rays. **(3 Marks)**

6. (a) What are pure vibrational Raman lines? Discuss the selection rules and derive the expressions for the Raman shift values of the Stokes and anti-Stokes lines for a diatomic molecule. **(10 Marks)**

(b) State Landé's interval rule and discuss its relevance in verifying the validity of Russell-Saunders (L-S) coupling in multi-electron atoms. **(5 Marks)**

(c) Calculate the Landé's g-factor for the atomic states corresponding to the $^3P_1$ and $^3D_1$ terms. **(3 Marks)**

Given:

Planck's Constant: 6.63×10^{-34} Joule sec

Electronic charge: 1.6×10^{-19} C

Rydberg's Constant: 1.097×10^{7} m^{-1}

Bohr magneton: 9.274×10^{-24} J/T

Mass of H-atom: 1.674×10^{-27} Kg

Mass of Chlorine atom: 5.81×10^{-26} Kg

Mass of Carbon atom: 1.99×10^{-26} Kg

Mass of oxygen atom: 2.66×10^{-26} Kg

Mass of electron: 9.1×10^{-31} Kg