(This Question paper contains 2 printed page) Roll No.....

Sr. No. of questions Paper : 8127

Name of Course	:	B.Sc. Prog.–Physical Sciences NEP: UGCF-2022
Semester	:	VIII- Semester (DSE Paper)
Name of the Paper:	:	Atomic and Molecular Physics
Unique Paper Code	:	2223510040

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

(Write your Roll No. on the top immediately on receipt of this question paper).
Attempt five questions in all.
Question No. 1 is compulsory.
Use of scientific calculators is allowed.

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

(a) What is meant by the lifetime of an excited state? Define the natural linewidth and explain its physical origin.

(b) State any three selection rules for electric dipole transitions in the LS coupling scheme.

(c) What are Stokes and Anti-Stokes lines in Raman effect? Which one is more intense?

(d)Distinguish between bonding and antibonding molecular orbitals. Explain their properties in terms of electron probability density.

(e) Explain the Pauli exclusion principle as applied to equivalent electrons. How does it restrict the possible term symbols for equivalent p electrons?

(f) The fundamental and first overtone vibrational transitions of HCl are observed at 2885.9 cm^{-1} and 5668.0 cm^{-1} respectively. Calculate the equilibrium oscillation frequency and the anharmonicity constant.

(g)State the basic principle of Nuclear Magnetic Resonance (NMR). How does the chemical shift arise?

2. **(a)** Explain the fine structure of the hydrogen atom arising from spin–orbit coupling. Using the Dirac relativistic theory, write down the expression for fine structure energy levels and explain the significance of the quantum number j. Show the splitting of the n = 3 level and the corresponding spectral lines.

(b) Discuss the Darwin term and its physical interpretation in the context of the hydrogen fine structure.

(14+4)

3. **(a)** Explain the Anomalous Zeeman effect. On the basis of quantum theory, derive expressions for the energy shifts of levels in a weak external magnetic field and explain the role of the Landé g-factor.

(b) Illustrate the splitting of spectral lines in the Anomalous Zeeman effect for the sodium D-lines ($^2S_{1/2} \rightarrow {}^2P_{1/2}$ and $^2S_{1/2} \rightarrow {}^2P_{3/2}$ transitions). Draw the energy-level diagram with all allowed transitions.

(12+6)

4. **(a)** Describe the LS (Russell–Saunders) coupling scheme for a two-electron system. For two electrons with $l_1 = 3$ and $l_2 = 2$, determine all possible values of L, S, and J, and list the resulting spectroscopic term symbols.

(b) Derive the expression for the rotational energy levels of a diatomic molecule treated as a symmetric-top (non-rigid) rotor. Show how centrifugal distortion modifies the rigid-rotor energy levels and discuss the effect on the rotational spectrum. (9+9)

5. **(a)** Explain the Valence Bond (VB) approach to molecular bonding. Compare the LCAO–MO and VB methods, highlighting their assumptions, applicability, and limitations.

(b) Construct the molecular orbital configuration for N_2 and O_2. Determine the bond order and predict the magnetic nature (paramagnetic or diamagnetic) for each.

(c) Explain the vibrational energy levels of a diatomic molecule using the anharmonic oscillator model. Discuss how the Morse potential curve accounts for dissociation and compare it with the harmonic oscillator.

(6+6+6)

6. **(a)** Explain the Raman effect on the basis of quantum theory. Describe the concept of virtual states and derive the selection rules for rotational and vibrational Raman spectra. Discuss the polarisation of Raman lines.

(b) Using an excitation source of 5000 Å, a Stokes Raman line is observed at 5765 Å. Calculate the Raman shift in cm^{-1} and predict the position (in Å) of the corresponding Anti-Stokes line.

(12+6)