M. Sc. Physics Examination, 2023

(2nd Year, 1st Semester)

Atomic and Molecular Physics

Paper –PG/SC/CORE/PHY/TH/109/2023

Time : Two hours   Full Marks : 40

Answer any FOUR questions choosing <u>two</u> from Qs. Nos. 1 to 3 and the <u>rest</u> from Qs. Nos. 4 to 6.

1. (a) Deduce the term value expression for *prolate* symmetric top molecule in terms of various rotational constants. (b) Anti-Stokes lines are less intense than Stokes lines – Explain. (c) In the infrared spectra of CO the fundamental and the first overtone transitions are observed at 2143.3 cm^{-1} and 4260.0 cm^{-1} respectively. Calculate the equilibrium oscillation frequency and the anharmonicity constant.   4½+2½+3

2. (a) How the expression for energy states of asymmetric top molecules is generally obtained? (b) The rotational and centrifugal distortion constants of HCl are 10.593 cm^{-1} and 5.3×10^{-4} cm^{-1} respectively. Obtain an estimate for vibrational frequency. The observed frequency is 2991 cm^{-1}; explain the discrepancy. (c) Obtain an expression for Raman shift of rotating molecules following classical theory.   3+3+4

3. (a) State the salient features of *Morse curve*. (b) Discuss the role of Franck-Condon principle in explaining the intensity of vibrational-electronic spectral lines. (c) The $J = 1 \leftarrow 0$ transition in HCl occurs at 20.68 cm^{-1}. Regarding the molecule to be a rigid rotator, calculate the wavelength of the transition $J = 10 \leftarrow 9$.   3+4+3

4. (a) Write down an expression for the transition probability of stimulated emission from one electron atom and show that under equilibrium with the external radiation field the transition probability from states a to b is the same as that from b to a where a and b are any pair of distinct energy states.

(b) What do you understand by electric dipole approximations and dipole matrix for the transition between different atomic energy levels?

                                                                      5+5

5. (a) Explain why Dirac theory could not interpret the experimentally overserved separation of the fine structure of H$_\alpha$ line for atomic transition in Hydrogen between n=3 to n=2 state? How is this discrepancy resolved?

(b) If the hyperfine interaction in an atom is given by $H = b\vec{S_e} \cdot \vec{S_p}$ where $\vec{S_e}$ and $\vec{S_p}$ denote the electron and proton spins, respectively, calculate the splitting of energy levels between the $^3S_1$ and $^1S_0$ states.

(3+2)+5

6. (a) A spectral line due to a transition from an electronic state p to an s state splits into three Zeeman lines for an atom in the presence of a strong magnetic field. Calculate the number of spectral lines of the atom to split when interacting with the intermediate field strengths.

(b) Explain how the Pauli exclusion principle introduces the coupling between the space and spin variables while describing the atomic states in a two electron systems.

(c) Explain why the ground state of an atom is always a singlet state.

5+3+2