M.Sc. Physics (Day) 2nd Year 1st Semester Examination, 2019

Atomic and Molecular Physics (PHY/TE/308)

Time: **Two hours** Full Marks: **40**

Answer question no. **1** and *any two* from the rest

1. Answer *any* **four:** 4×3

(a) Show that the relativistic kinematical correction for the energy of the electron in a hydrogenic atom goes as the fourth power of the fine structure constant.

(b) For a valence electron of an alkali atom excited to p-state, write the possible term symbols. Find the splitting when this atom is placed in a weak external uniform magnetic field applied in the z-direction.

(c) Show that for normal optical source under thermal equilibrium at $T \sim 10^3$ K with $\lambda \sim$ 6000 Å, the emission is predominantly spontaneous.

(d) What are Einstein's A and B coefficients? Show that Einstein's A coefficient is inversely related to the spontaneous lifetime associated with the transition.

(e) What are the consequences of breakdown of the Born-Oppenheimer approximation?

(f) Discuss the spectrum of a diatomic molecule treated as an anharmonic oscillator.

2. (a) Show by applying the uncertainty principle that the Bohr radius emerges as the only relevant length scale in a hydrogenic atom. Without solving the Schrödinger equation find the dependence of the energy E_n of the nth state on the principal quantum number n. (b) Homonuclear and spherical top molecules never show rotational spectrum – Justify. (c) Derive the selection rules that govern the transitions between the states of an oscillator.

(2+2)+4+6

3. (a) A hydrogen atom is placed in a weak uniform electric field directed in the z-direction. Consider the nine degenerate states with principal quantum number $n = 3$. Identify those pairs of states for which the matrix elements of the potential arising due to this electric field do not vanish. (b) In case of natural broadening, obtain the expression for *lineshape* function associated with the spontaneously emitted radiation. (c) Define normal coordinates. Discuss the classification of normal vibrations with an illustration. 5+4+5

4. (a) Write the full Hamiltonian for the electron of a hydrogenic atom that is placed in a uniform magnetic field applied in the z-direction. Show that when this field is comparable in magnitude with the strength of the spin-orbit coupling transitions between states with

different values of m_j $(= m_l + m_s)$ are not allowed. (b) Consider a collection of atoms and let a near-monochromatic radiation of energy density u of frequency ω passes through the medium. In such a condition, obtain the differential equation that governs the rate of change of intensity of the radiation as it passes through the medium bounded by two planes each of area S situated at z and $z+dz$, z being the direction of propagation of the radiation. Name the factor that decides the gain or attenuation in intensity of the beam as it leaves the medium. (c) What are the salient features of *Morse* function? The fundamental and first overtone transitions of $^{14}N^{16}O$ are found at 1876.06 cm^{-1} and 3724.20 cm^{-1} respectively. Evaluate the zero point energy and anharmonicity constant of the molecule. 4+5+(2+3)