Registration Number:
Date & Session:

ST. JOSEPH'S COLLEGE (AUTONOMOUS), BENGALURU -27

M.Sc. Physics – III SEMESTER

SEMESTER EXAMINATION: OCTOBER 2022

(Examination conducted in December 2022)

PH9222 – ATOMIC AND MOLECULAR PHYSICS

Time: 2 ½ Hours **Max Marks: 70**

This paper contains TWO printed pages and TWO parts

PART-A

Answer any FIVE questions. Each question carries TEN Marks.

[5 x 10 = 50]

1. (a). With suitable sketches, describe the Zeeman splitting under a low and strong magnetic field.
   (b). Illustrate, with an energy level diagram, the Paschen-Back effect for the D_2 line of sodium. $D_2\ line\ transition:\ 3\ ^2P_{\frac{3}{2}} \rightarrow\ 3\ ^2S_{\frac{1}{2}}$. [6+4]
2. (a). Describe the spin-orbit (L-S) coupling with a suitable example.
   (b). Compute the Hamiltonian expression for the Helium atom with a suitable diagram. [4+6]
3. (a). Compare the symmetric top, spherical top and asymmetric top molecules using the moment of inertia.
   (b). Explain different modes of vibration of CO_2 molecules, will their energy levels be same?
   (c). A diatomic molecule such as CO, HCl, and HF will show a vibrational spectrum, whereas N_2, O_2 & H_2 will not. Justify your answer. [4+4+2]
4. (a). Using the harmonic oscillator approximation, show that the energy levels of diatomic molecules are equally spaced.
   (b). Explain the Franck-Condon principle and using it how one can estimate the intensity. [6+4]
5. (a). Differentiate between Rayleigh and Raman Scattering.
   (b). With a neat sketch explain the concepts of stokes and anti-stokes lines using the quantum theory of the Raman effect. Why the anti-Stokes lines are less intense than Stokes lines? [6+4]
6. (a). Explain the physical principle of Nuclear Magnetic Resonance (NMR). Obtain an expression for resonance frequency.
   (b). Predict, how many spin-spin splitting will appear for a proton (H_a) interacting with (i). one equivalent proton (H_b), two equivalent protons (H_b) and three equivalent protons (H_b). . [5+5]
7. (a). Briefly describe the theory involved in UV-Visible Spectrometer.
   (b). Using the Jablonski diagram, explain the following process (i). Absorption, (ii). Fluorescence, (iii). Phosphorescence. [5+5]

PART-B

Answer any <u>FOUR</u> questions. Each question carries <u>FIVE</u> Marks.

[4 x 5 = 20]

8. Calculate the wavenumber for the longest wavelength transition in the Balmer series of atomic hydrogen.
9. Evaluate the average period of rotation of the HCl molecule if it is in the J=1 state. The internuclear distance of HCl is 0.1274 nm. The mass of the hydrogen and chlorine atoms are 1.673 x 10^{-27} Kg and 58.06 x 10^{-27} Kg, respectively.
10. Irradiation of carbon tetrachloride by 4.358 Å radiation gives Raman lines at 4400, 4419 and 4447 Å**.** Calculate the Raman shift for each of these lines in cm^{-1}.
11. A free electron is placed in a magnetic field of strength 1.3 Tesla. Find out the resonance frequency when g = 2.0023 and Bohr magneton μ_B = 9.274 x 10^{-24} J/T.
12. An unpaired electron couples with two equivalent nuclei of spin $I = 1/2$. Predict the Electron spin resonance spectrum.
13. Assuming an axial field gradient, compute an expression for frequencies of the quadrupolar transitions. Show the energy level transition for I = 3/2.

<u>List of Physics Constants</u>

Speed of light in vacuum (c)	2.997925 x 10^{8} ms^{-1}
Charge of electron (e)	1.6021 x 10^{-19} C
Rest mass of electron (m)	9.109 x 10^{-31} kg
Atomic mass unit (m_u)	1.6604 x 10^{-27} kg
Electron radius (r_e)	2.828 x 10^{-15} m
1 Angstrom unit (Å)	10^{-10} m
Avogadro's number (N_A)	6.02252 x 10^{26} $kmol^{-1}$
Boltzmann constant (k_B)	1.38054 x 10^{-23} jK^{-1}
Thermal energy at 300K (k_BT)	0.0258 J
Planck's constant (h)	6.626 x 10^{-34} Js
Permeability of free space (μ_o)	4π x 10^{-7} Hm^{-1}
Permittivity of free space (ε_o)	8.854 x 10^{-12} Fm^{-1}
Rydberg constant for Hydrogen (R_H)	1.0967758 x 10^{7} m^{-1}
Universal gas constant (Ru = N_Ak_B)	8.3143 x 10^{3} $Jkmol^{-1}K$
Bohr Magnetron (μ_B)	9.27 X 10^{-24} Am^{2}