Date:

Registration number:

ST. JOSEPH'S COLLEGE (AUTONOMOUS), BENGALURU-27
M.Sc. PHYSICS - II SEMESTER
SEMESTER EXAMINATION: APRIL 2022
(Examination conducted in July 2022)

**PH8218 – ATOMIC AND MOLECULAR PHYSICS**

(For supplementary candidates)

Time- 2 ½ hrs Max Marks-70

This question paper contains Two printed pages and Two parts

**Part A**

**Answer any FIVE questions. Each question carries 10 marks**

**[5 x 10 = 50]**

1. a). Describe the phenomenon of the normal Zeeman effect with a suitable schematic.
   b). Sketch out the spectral patterns of sodium lines. **[7+3]**
2. a). with a suitable diagram, explain the Paschen-Back effect.
   b). Represent in a diagram the electronic, rotational and vibrational energy levels. **[7+3]**
3. a). Describe the principle of nuclear magnetic resonance and obtain the expression for the resonance condition.
   b). How many $^1H$ NMR signals will arise for the given compounds. Justify your answer.
   (i). $ClCH_2CH_2Cl$, (ii). $ClCH_2CH_2CH_2Br$ **[7+3]**
4. (a). With a suitable diagram, explain the principle of electron spin resonance (ESR).
   (b). Display the Laue diffraction patterns for single crystal, polycrystal and amorphous nature. **[6+4]**
5. (a). Explain the electric quadrupole moment of a nucleus.
   (b). With a neat sketch, explain the recoilless emission and absorption of gamma rays**.**
   **[5+5]**
6. (a). Describe the quantum theory of Raman effect with the help of an energy level diagram.
   (b). Distinguish between symmetric top (prolate and oblate), spherical top and symmetric top molecules. **[6+4]**
7. (a). Explain the Frank-Condon Principle.
   (b). Explain the following vibrational modes of $CO_2$ molecules with a necessary diagram.
   (i). symmetric stretch, (ii). asymmetric stretch and (iii). bending modes.
   **[5+5]**

## Part B

**Answer any Four questions. Each question carries 5 marks**

**[4 x 5 = 20]**

8. How many hyperfine components will there be in the ESR spectrum of a system having an unpaired electron interacting with two equivalent protons?
9. The fundamental and first overtone transitions of $^{14}N^{16}O$ are centred at 1876.06 $cm^{-1}$ and 3724.20 $cm^{-1}$ respectively. Evaluate the equilibrium vibrational frequency, the anharmonicity constant, and zero-point energy.
10. Obtain the frequencies of the quadrupolar transition for an axial field gradient (spin of the nucleus is 5/2).
11. Define the Larmor Precession and obtain the expression for Larmor frequency.
12. A Mossbauer nucleus $^{57}Fe$ makes the transition from the excited state of energy 14.4 keV to the ground state. Calculate the recoil velocity.
13. Determine the geometric structure factor for body centred cubic system.

## List of Physics Constants

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