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SEAT No._____ **No. of Printed Papers: 02**

SARDAR PATEL UNIVERSITY

M.Sc. (Physics) 1st Semester Examination

Friday, 22th March, 2019

Subject: PS01CPHY22

(Atomic and Molecular Spectroscopy and Statistical Mechanics)

Time: 02:00 pm to 05:00 pm **Total Marks: 70**

Q-1 Eight multiple choice questions. (MCQ) **[01 mark each]**

1. Fine structure of H-atom is obtained as a result of _____ correction to Hamiltonian.
   (a) Non-relativistic (b) Relativistic (c) Darwin (d) None
2. Identify the pair of meta-stable states of Helium atom.
   (a) 2S and 2P (b) 1S and 2S (c) 2^3S and 2^3P (d) 2^3S and 2^1S
3. In Co_2 laser the gas proportion of Co_2, N_2 and He is _____
   (a) 1:2:3 (b) 10:1:2 (c) 3:2:1 (d) 1:3:2
4. A metastable state has a much longer life time ~ __ than that of the normal excited states ~ __
   (a) 10^{-3}s (b) 10^{-2}s (c) 10^{-10}s (d) 10^{-8}s
5. Which of the following gives the normalization condition in quantum statistical mechanics in density matrix formalism?
   (a) $Tr(\hat{\rho}\hat{G}) = 1$ (b) $Tr(\hat{\rho}) = 1$ (c) $\hat{\rho}\hat{G} = 1$ (d) $\hat{\rho} = 1$
6. Which of the following is correct for Bose-Einstein condensation?
   (a) a large number of particles accumulates in a single quantum state.
   (b) it is purely of a quantum mechanical origin.
   (c) it takes place at the best in momentum space and not in coordinate space
   (d) All of the above are correct.
7. Which of the following would show a discontinuous change during a second-order phase transition?
   (a) specific heat (b) energy (c) entropy (d) volume
8. According to the theory of Brownian motion, the mean-square displacement of a particle $\langle x^2 \rangle$ in a fluid is proportional to (η being the viscosity of the fluid)
   (a) η (b) η^2 (c) $1/\eta$ (d) $1/\eta^2$

Q -2 Attempt any 7 of the following 9 question briefly. **[02 marks each]**

1. Write Schrodinger equation for two-electron atoms and explain each term of equation with necessary diagram.
2. Calculate the ionization energy of the Li^{2+} ion with the electron in its ground state, first excited state and second excited state.
3. Define Lamb shift and in H-atom energy level diagram with lamb shift.
4. Explain different vibration modes of CO_2 molecules
5. Explain in brief CARS

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6. For the canonical ensemble, write the density matrix in energy representation and derive the expression for the density operator $\hat{\rho} = e^{-\beta\hat{H}}/Tr(e^{-\beta\hat{H}})$.
7. Define the fugacity of a physical system described using statistical mechanics. Explain the range of values it can attain for Fermi systems and Bose systems.
8. What are critical exponents? Write the relationship between the critical exponents α, β, γ and, the corresponding quantities specific heat, order parameter and correlation radius respectively.
9. Give a brief description of the Ising model.

Q-3

(a) Obtain time independent three dimensional Schrödinger equation for Hydrogen atom. **[06]**

(b) How many degenerate states are possible for n= 1, 2, 3 and 4 in Hydrogen atom? Draw H- atom energy level diagram with all degenerate states up to n=4. A H-atom undergoes a quantum jump from n=2 to n=1, what is the energy of the photon emitted by the atom in this process? In which region of the electromagnetic spectrum does this transition appears? **[06]**

OR

(b) Derive Thomas Fermi equation for many electron system **[06]**

Q-4

(a) Derive threshold pump power for three level laser systems. **[06]**

(b) Write a detail note on Semiconductor Laser. **[06]**

OR

(b) Explain construction, working and energy level diagram of He-Ne Laser. **[06]**

Q-5

(a) For a free particle in a box, derive the expression for the density matrix in coordinate representation. Also, prove that the expectation value of the Hamiltonian $\langle H \rangle = \frac{3}{2}kT$. **[06]**

(b) Explain how the statistical equilibrium of white dwarf stars can be explained using Fermi-Dirac statistics. Write the mass-radius relationship for these stars and discuss the Chandrasekhar limit. **[06]**

OR

(b) Describe and discuss Mayer's cluster expansion for a real gas. **[06]**

Q-6

(a) Discuss in detail the classification of phase transitions. **[06]**

(b) Derive the Boltzmann transport equation. **[06]**

OR

(b) Describe the theory of Brownian motion in a fluid and derive the expression for the mean-square displacement of particles in terms of the diameter of the particles and the viscosity of the fluid. **[06]**