PHY/VI/CC/18 **Student's Copy**

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(CBCS)

(6th Semester)

PHYSICS

ELEVENTH PAPER

(Thermal and Statistical Physics)

Full Marks : 75

Time : 3 hours

(PART : A—OBJECTIVE)

(*Marks* : 25)

The figures in the margin indicate full marks for the questions

SECTION—A

(*Marks* : 10)

Tick (✓) the correct answer in the brackets provided : 1×10=10

1. According to kinetic theory of gases, energy associated with one gram molecule of a diatomic gas is

(a) $\frac{3}{2}K_BT$ ( )

(b) $\frac{3}{2}RT$ ( )

(c) $\frac{5}{2}K_BT$ ( )

(d) $\frac{5}{2}RT$ ( )

2. If C_p 29 08 J mole ^{1}K ^{1} and C_v 20 77 J mole ^{1}K ^{1}, then the gas molecule is

(a) monoatomic ( )

(b) diatomic ( )

(c) triatomic ( )

(d) Atomicity cannot be determined from the given data ( )

3. Viscosity of a gas is due to transport of

(a) momentum ( )

(b) energy ( )

(c) mass ( )

(d) temperature ( )

4. The change in specific volume when 1 kg of water freezes is 91 10 ^{6} m^{3} and Latent heat of ice L 3 36 10^{5} J kg ^{1}. Then the pressure required to freeze ice at 272 K is

(a) 134·2 atm. ( )

(b) 135·2 atm. ( )

(c) 136·2 atm. ( )

(d) 137·2 atm. ( )

5. The thermodynamic probability of a system at equilibrium is

(a) maximum ( )

(b) minimum ( )

(c) 1 ( )

(d) 0 ( )

6. The probability of occurrence of two independent events is equal to the _____ of their probability.

(a) sum ( )

(b) difference ( )

(c) product ( )

(d) ratio ( )

7. The internal energy U of a system is given by

(a) $NK_BT \frac{}{T}(\log Z)$ ( )

(b) $NK_BT^2 \frac{}{T}(\log Z)$ ( )

(c) $NK_BT^3 \frac{}{T}(\log Z)$ ( )

(d) $NK_BT^4 \frac{}{T}(\log Z)$ ( )

8. In canonical ensemble, the partition function is expressed as

(a) $_r e^{E_r/K_BT}$ ( )

(b) $_r e^{K_BTE_r}$ ( )

(c) $_r e^{E_r/K_BT^2}$ ( )

(d) $_r e^{K_BT^2E_r}$ ( )

9. Pauli's exclusion principle applies to

(a) M-B statistics ( )

(b) F-D statistics ( )

(c) B-E statistics ( )

(d) All of the above ( )

10. The number of different arrangements of six indistinguishable particles among four cells of equal a priori probability if there is no restrictions on the number of particles entering into a cell is

(a) 24 ( )

(b) 30 ( )

(c) 17280 ( )

(d) 84 ( )

SECTION—B

(*Marks* : 15)

Answer the following questions : 3×5=15

1. Calculate the Avogadro's number if the mean kinetic energy of a molecule of a hydrogen gas at 0 °C is 5 62 10 ^{23} J.

OR

2. Using Maxwell's law of distribution of velocities, show that the most probable velocity of gas molecules is given by $\sqrt{\frac{2K_B T}{m}}$, where K_B is the Boltzmann's constant.

3. Show that $C_P \quad C_V \quad TE \quad ^2V$, where E is the bulk modulus of isothermal elasticity and is the coefficient of volume expansion.

OR

4. State Gibb's phase rule. Show that at triple point, the three phases of water can coexist in equilibrium at a fixed temperature and a fixed pressure only and neither can be varied arbitrarily.

5. Discuss the postulates of 'Equal a priori Probability'.

OR

6. Show that the number of phase cells in the given energy range for a free particle is given by $\frac{4 \quad V}{3h^3}(2mE)^{3/2}$.

7. A monatomic gas is enclosed at a temperature T in a container of volume V. If the partition function of the gas is given by $\frac{V}{\ ^{\frac{3}{2}}}$, where is a constant and $\frac{1}{K_B T}$, then find the average energy of the molecule.

OR

8. Show that for a system in thermal equilibrium at absolute temperature T, the Boltzmann partition function in the energy state E_i is $Z \quad _i\, g_i e^{\ E_i / K_B T}$.

9. State three points to distinguish among M-B, B-E and F-D statistics.

OR

10. Calculate the Fermi energy of copper at T 0. Given; density of copper $9g/\text{cm}^3$ and atomic weight of copper 63 5g.

(PART : B—DESCRIPTIVE)

(*Marks* : 50)

The figures in the margin indicate full marks for the questions

1. *(a)* Define root mean square velocity. Using Maxwell-Boltzmann distribution law, find an expression for the root mean square velocity of the molecule. 1+4=5

(b) Calculate the probability that the speed of oxygen molecule lies between 100 and 101 m/s at 200 K. 3

(c) The average kinetic energy of a gas molecule at a certain temperature is $6\ 21\ 10^{21}$ joule. Find the temperature. 2

OR

2. *(a)* Define Brownian motion. State the essential features of Brownian motion. Discuss Einstein's theory of translational Brownian motion. 1+2+5=8

(b) Compute the average translational kinetic energy per molecule in a gas at room temperature (27 °C) and hence calculate the temperature needed to excite hydrogen atom. (Given : Excitation potential of hydrogen atom 10 2 eV) 2

3. *(a)* Deduce an expression for the viscosity of a gas in terms of mean free path of its molecules. Discuss the variation of viscosity with temperature and pressure. 5+2=7

(b) The viscosity of oxygen at 16 °C is $169\ 10^{7}$ decapoise, calculate the diameter of the oxygen molecule. 3

OR

4. *(a)* Using Maxwell's thermodynamical relations, show that for an isothermal process

$$\frac{U}{V}_{T} \quad T \; \frac{P}{T}_{V} \quad P$$

Hence discuss the variation of internal energy with volume during an isothermal process for *(i)* a perfect gas and *(ii)* a van der Waals' gas. 3+2+2=7

(b) Using Maxwell's relations, show that

$$T\,dS \quad C_p dT \quad T \; \frac{V}{T}_{P} \; dP$$

3

5. *(a)* What are the phase space and phase cells? Using the uncertainty principle, explain the meaning of a point in a phase space. 1+1+4=6

(b) Derive the relation $S \quad l \ln \; (E)$, where S = entropy and (E) thermodynamic probability. 4

OR

6. *(a)* Derive the Boltzmann's canonical distribution law. 6

(b) Show that for thermodynamical equilibrium of any two systems in contact, the parameter of the two systems must be identical. 4

7. *(a)* Explain micro-canonical, canonical and grand canonical ensembles with the help of necessary diagram. 6

(b) Show that the grand potential for a thermodynamic system is related to the grand partition function $\mathbb{Z}$ as $\quad ^{1} \ln \mathbb{Z}$. 4

OR

8. *(a)* Derive the probability distribution function in canonical ensemble. 5

(b) Derive the Stirling's formula for a collection of large number of particles. 5

9. *(a)* Using Maxwell-Boltzmann distribution law, show that the internal energy of an ideal monatomic gas depends only on its temperature. Hence show that $C_v \quad \frac{3}{2}R$. 4+1=5

(b) Using the Fermi-Dirac distribution law, obtain an expression for energy distribution of free electrons in a metal. 5

OR

10. *(a)* Find an expression for the most probable distribution of the particles among various energy levels for a system obeying Bose-Einstein statistics. 6

(b) Using Bose-Einstein statistics, deduce Planck's Radiation law. 4

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