B.Sc. 3rd Semester (Honours) Examination, 2023 (CBCS)

Subject : Physics

Course : CC-VI

(Thermal Physics)

Time: 2 Hours **Full Marks: 40**

The figures in the margin indicate full marks.

*Candidates are required to give their answers in their own words
as far as practicable.*

1. Answer *any five* questions from the following: 2×5=10

   (a) The number density of molecules of a gas is $2 \cdot 5 \times 10^{18}$/c.c. at N.T.P. Calculate the number of molecules per c.c. of the gas at 0°C and 10^{-5} mm pressure of mercury.

   (b) A certain amount of gas is allowed to expand (i) isothermally, (ii) isobarically, and (iii) adiabatically. In which case the work done is (A) maximum and (B) minimum? Explain your answer using P-V diagram.

   (c) Write down the van der Waals' equation for the oxygen of mass 4g.

   (d) "All reversible processes are quasi-static but all quasi-static processes are not reversible" — Justify the statement.

   (e) A motor car tyre has a pressure of 3 atmospheres at room temperature (27°C). If the tyre suddenly bursts, what will be the resulting temperature?

   (f) Find the enthalpy H in terms of the Gibbs free energy G and its derivatives.

   (g) Distinguish between the cooling by J-T effect and the same by adiabatic expansion.

   (h) A piece of ice of mass 50g taken at 0°C is thrown into a pond of temperature 32°C. Assuming that the temperature of the pond remains unchanged after melting of the ice, calculate the total change in entropy of the system.

2. Answer *any two* questions from the following: 5×2=10

   (a) (i) What do you mean by 'collision probability'? Find the probability that a gas molecule will traverse a distance x without suffering any collision.

   (ii) Calculate the percentage of gas molecules having free paths lying between λ and 2λ; where λ is the mean free path of a molecule. 3+2

   (b) (i) Expand the van der Waals' equation of state in the virial form $PV = RT \left[1 + \frac{B}{V} + \frac{C}{V^2} + \cdots\right]$ and determine the Boyle temperature. What is the significance of Boyle temperature?

   (ii) The critical pressure and critical density of helium are $2 \cdot 26$ atm. and $0 \cdot 069$ g cm^{-3} respectively. Find its critical temperature. 3+2

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(c) An ideal gas expands according to law $PT^2 = $ constant.

    (i) What is the amount of work done by the gas?

    (ii) Find out an expression of the molar heat capacity.

    (iii) Obtain an expression of the coefficient of volume expansion of the gas.   5
(Given $\frac{C_P}{C_V} = \gamma$, where the symbols have their usual meaning).

(d) State the effect of a change in temperature on viscosity. Show that the coefficient of viscosity of an ideal gas is independent of pressure and directly proportional to the square root of the absolute temperature.

    5

3. Answer *any two* questions from the following: 10×2=20

  (a) (i) Derive an expression for the most probable speed of the molecules of a Maxwellian gas. Calculate the fraction of molecules of a gas within 1% of the most probable speed at S.T.P. Will it be the same for all gases at all temperatures?

    (ii) Calculate $\left(\frac{\overline{1}}{v}\right)$ and compare this with $\frac{1}{\overline{v}}$.   6+4

  (b) (i) What is the Gibbs potential? How is it related with the first order phase transition? Deduce the Clausius-Clapeyron equation $\left(\frac{dp}{dT}\right)\text{Sat} = \frac{L}{T(v_2 - v_1)}$, where symbols have their usual meaning.

    (ii) An ideal gas expands isothermally from an initial volume v_1 at a pressure p_1 to a final volume v_2 at a pressure p_2. Calculate the change in entropy and enthalpy. What will be the values of these parameters when the gas expands adiabatically from temperature T_1 to T_2?   6+4

  (c) (i) A Carnot engine operates between the temperatures T_1 and T_2, with a gas as working substance. The equation of state is given by $P(V - b) = RT$. Calculate the heat absorbed, amount of work done in each part of the cycle and the efficiency of the cycle.

    (ii) 1 kg of water is heated from 0°C to 100°C and converted into steam at the same temperature. Calculate the increase in entropy and draw its T–S diagram. In the T–S diagram, indicate the amount of heat absorbed by 1 kg of water for its transformation from water at 0°C into steam at 100°C.   6+4

  (d) (i) State Nernst heat theorem. Establish the equivalence of third law of thermodynamics and Nernst heat theorem. Show that the specific heats of a thermodynamic system approaches to zero as $T \to 0$.

    (ii) Taking internal energy and volume of a system as a function of T and P, show that $\left(\frac{\partial U}{\partial T}\right)_P = C_P - TV\beta_P$ and $\frac{dV}{V} = \beta_P\, dT - \frac{dP}{K_T}$; where β_P is the coefficient of volume expansion at constant pressure and K_T is the isothermal bulk modulus.   6+4

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