**Name of the Department: Physics**

**Name of the Course: B.Sc. (Hons.) Physics - CBCS_Core**

**Name of the Paper: Thermal Physics**

**Semester: III**

**Unique Paper Code: 32221302**

**Question paper Set number: A**

**Duration: 3 Hours** **Maximum Marks: 75**

**<u>Instructions for Candidates</u>**

1. Answer any **four** questions.
2. All Questions carry equal marks.



Q. 1 List the characteristics of first order phase transitions.

Derive Clausius Clapeyron latent heat equation. Discuss the effect of change in pressure on boiling and melting points.

Calculate the boiling point of a sample gas at a pressure of 80cm of Hg. The normal boiling point is 80°C, latent heat of vapourization is 380 joules/g, density of vapour at the boiling point is 4 g/litre and that of the liquid is 0.9 $gcm^{-3}$.

Which curve has a greater slope, representing an isothermal or adiabatic process. Jusity mathematically

Q. 2 Explain four thermodynamic potentials.

Obtain Maxwell's four thermodynamic relations using the exact differential nature of the thermodynamic potentials.

Show that for an ideal gas,

and for a dilute real gas,

$$C_p - C_v = R(1 + 2a/RTV^2)$$

Q3 Define intensive and extensive variables. Give their examples.

Explain the significance of Second Law of Thermodynamics.

Establish the equivalence between Kelvin-Planck and Clausius statements of Second Law of Thermodynamics.

Can a Carnot heat engine attain 100% efficiency? Justify your answer.

Calculate the increase in entropy of 1g of a gas when its temperature is raised from $0^{\circ}$C to $100^{\circ}$C at constant volume. $C_v$ for the given gas is 5.035 cal/deg.mole.

Q4 Obtain the general expression for Joule-Thomson(Kelvin) Coefficient. Hence find out its value for an ideal gas.

Obtain the reduced van der Waals equation of state for a gas.

Write down the salient features of results of Andrew's experiment on $CO_2$ gas.

Q.5 Using Maxwell's distribution function, obtain an expression for average speed ($v_{av}$), root means square speed ($v_{rms}$) and most probable speed ($v_{mps}$).

Calculate the relative magnitude of these speeds. How do these speeds vary with temperature?

Calculate the average energy of nitrogen molecules at $27^{\circ}$C.
Given, k = 1.38 x $10^{-23}$ J/K.

Show that,

$$\frac{T_i}{T_c} = \frac{27}{4}$$

Q6 Derive an expression for thermal conductivity (K) of a gas on the basis of kinetic theory of gases. Show that it is maximum for a hydrogen molecule and hydrogen atom.

Calculate mean free path and collision frequency for an ideal gas. Given,
molecular diameter is 2 A° at 20°C, 1 atm pressure equals 1.01 x $10^5$ N/$m^2$,
velocity of molecules is 511 m/s .

How does mean free path vary with temperature and pressure?

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## Instructions for Candidates

1. Answer any four questions.
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Q. 1 Explain the terms open system, closed system and isolated system. What is meant by an equation of state of a thermodynamic system?

Starting with V = V (p, T) and using the condition for an exact differential, prove that

$$\left(\frac{\partial \beta_T}{\partial T}\right)_p = -\left(\frac{\partial \alpha}{\partial p}\right)_T$$

where $\beta_T$ is the isothermal compressibility and $\alpha$ is coefficient of volume expansion.

Using the first law of thermodynamics and the equation of state for an ideal gas calculate the fraction of the heat supplied available for external work if a diatomic ideal gas near room temperature is expanded at constant pressure and at constant temperature.

Q. 2 mention the significance of the Second Law of Thermodynamics.

Draw a labelled PV diagram and the corresponding TS diagram for a Carnot engine and explain its working. Hence, obtain an expression for its efficiency.

If 20 kJ are added to a Carnot cycle at a temperature of 100°C and 14.6 kJ are rejected at 0°C, determine the location of absolute zero on the Celsius scale.

Q. 3 Prove that the slope on a TS diagram of an isochoric curve is T/ $C_V$ and that of an isobaric curve is T/$C_p$.

1 kg of ice at - 5°C is exposed to the atmosphere which is at 20°C. The ice melts and attains thermal equilibrium with the atmosphere. Determine the entropy increase of ice. Given that $C_p$ of ice is 2.093 kJ/kg-K and the latent heat of fusion of ice is 333.3 kJ/kg.

State Nernst-Simon Statement of the Third Law of Thermodynamics. Use it to prove that the volume expansion coefficient at constant pressure as well as the pressure expansion coefficient at constant volume vanish as T approaches 0 K.

Q. 4 Find the diffusion coefficient of hydrogen at STP if the free path of the molecule is $1.6 \times 10^{-7}$m.

Using Maxwell's thermodynamic relations, show that the ratio of adiabatic to isobaric volume expansivity is **1/(1-$\gamma$)**.

Discuss the principle of magnetic cooling by adiabatic demagnetisation. State the limitations of the method.

Q. 5 Depict graphically the Maxwell-Boltzmann law of distribution of molecular velocities of an ideal gas for two different temperatures. Discuss the salient features of the curves.

The melting point of lead under normal pressure is 600 K. What will be the change in its value when pressure is increased to 100 atm. The density of lead in solid and liquid phases is 11.01 g $cm^{-3}$ and 10.65 g $cm^{-3}$, respectively. The latent heat of fusion is 24.5 x $10^7$ erg $g^{-1}$.

A cathode-ray tube is working such that 90% of the electrons leaving the cathode reach the anode 20 cm away without making a collision. The diameter of an ion is 3.6 x $10^{-10}$ m and the electron temperature is 2000 K. Calculate the pressure inside the tube. Use the electronic mean free path $4/\sigma n$, where $\sigma$ is the cross-section of the ion.

Q. 6 Write the van der Waal's equation of state for n moles of a real gas. What were the modifications introduced in the properties of an ideal gas to obtain this equation and what do the terms involving the constants in this equation represent?

Compare the isotherms for $CO_2$ obtained experimentally by Andrews with the theoretical isotherms of van der Waal.

Show that in Joule-Thomson expansion process the enthalpy remains constant. Calculate the drop in temperature produced by the adiabatic throttling process in the case of oxygen when the pressure is reduced by 50 atm. and the initial temperature of the gas is 27℃. Given that the van der Waal's constants
$a = 1.32 \times 10^{12} cm^4 dynes\, mol^{-2}, b = 31.2 cm^3 mol^{-1}$ and $C_p = 7 cal\, mol^{-1} K^{-1}$.