B.Sc. 3rd Semester (Honours) Examination, 2022 (CBCS)

Subject : Physics

Course : CC-VI

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.
Symbols have their usual meaning.

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

(a) What do you mean by thermodynamic equilibrium? How is it related with the concept of reversible process?

(b) Show that when an ideal gas having f degrees of freedom expands adiabatically, the temperature and pressure are related by the differential equation $\frac{dT}{dP} = \frac{2}{f+2}\frac{T}{P}$.

(c) Why does Maxwell-Boltzmann speed distribution curve broaden with the increase of temperature?

(d) What is Brownian motion? What are its essential characteristics?

(e) What is enthalpy? Show that an isothermal curve drawn on P-V diagram is also isoenthalpic for an ideal gas.

(f) Find out the change of Gibb's free energy, when one mole of an ideal gas expands in reversible isothermal process until its volume is doubled.

(g) Why do we observe heating effect whenever a rubber wire is stretched adiabatically?

(h) If heat rises, why does the temperature decrease at higher elevations?

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

(a) (i) 1g. of water at 100°C changes into steam occupying a volume of 1760 cc. at a pressure of 1 atm. Calculate the change of internal energy. [Given, latent heat of steam = 540 cal/gm]

(ii) Show that the change of entropy between two states from (P_1, V_1, T_1) to (P_2, V_2, T_2) for one mole of ideal gas is $S_2 - S_1 = C_p ln\frac{T_2}{T_1} - Rln\frac{P_2}{P_1}$. If these two states are the same adiabatic system, show that this change is zero. 2+3

(b) (i) Using Maxwell's thermodynamic relations, prove that $C_P - C_V = T\left(\frac{\partial P}{\partial T}\right)_V\left(\frac{\partial V}{\partial T}\right)_P$, and show that this difference is zero in case of water at 4°C.

(ii) Considering volume V as a function of pressure P and temperature T, Prove that $\left(\frac{\partial \alpha}{\partial p}\right)_T + \left(\frac{\partial \beta}{\partial T}\right)_P = 0$, where α is the volume expansivity and β is the isothermal compressibility. 3+2

(c) (i) What is second-order phase transition? How can one differentiate between the orders of phase transition based on Ehrenfest classification?

(ii) Calculate how much pressure in atm. is required to make ice freeze at –1°C. Specific volume of water increases by 9·1% on freezing and the latent heat of fusion of ice is 80 cal/gm at normal atm. pressure. 3+2

(d) (i) What do you mean by critical temperature of gas? On which properties of the gas does it depend?

(ii) Obtain the value of critical temperature of gas obeying Berthelot's equation of state $\left(P+\frac{a}{TV^2}\right)(V-b)=RT$, in terms of constants a and b. 2+3

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

(a) (i) For a two-dimensional gas, the Maxwell-Boltzmann speed distribution function is given by

$$F(c)=\frac{m}{K_BT}c\exp\left(-\frac{mc^2}{2K_BT}\right),$$

where symbols have their usual meanings. Derive the expression of average speed, root mean square speed and most probable speed of such distribution.

(ii) Find out an expression for the mean translational energy per degree of freedom for the molecules of Maxwellian gas. Show that the result is consistent with the principle of equipartition of energy. 6+4

(b) (i) Which phenomena arise due to transport of mass from one region to another inside the gas due to concentration gradient? Show that in case of self diffusion, the number of molecules crossing per unit area per unit time for unit concentration gradient is $\frac{1}{3}\lambda\bar{c}$, where λ is the mean free path and $\bar{c}$ is the root mean square speed of the gas molecules.

(ii) Consider molecules in a gas of mean number density n having collision cross section α moving with speed V. What is the probability $P(t)$ for a molecule to experience no collision up to time t? Therefore, what is the mean time between collisions? 6+4

(c) (i) State Carnot theorem. Prove Clausius inequality from Carnot theorem.

(ii) Two identical finite bodies of equal and constant thermal capacity and at temperatures T_1 and T_2 respectively ($T_1 > T_2$), are allowed to attain the same final temperature T_F by the action of reversible heat engine, show that work done by the engine will be maximum when final temperature is $T_F=\sqrt{T_1T_2}$.

(iii) One kg of water at 0°C is brought into contact with a heat reservoir at 100°C. When the water has reached 100°C, calculate the change of entropy of the water, the heat reservoir and the universe. Explain how the water might be heated from 0°C to 100°C with almost no change in entropy of the universe. 3+3+4

(d) (i) What is Joule-Thomson effect? Obtain a general expression for Joule-Thomson coefficient and show that the effect is due to deviation from Joule's law and Boyle's law.

(ii) State third law of thermodynamics in terms of change in entropy.

"All expansion coefficients must tend to zero as temperature tends to absolute zero." Justify the statement. 6+4

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