2023

PHYSICS

Paper : PHYHC3066

(Thermal Physics)

Full Marks : 60
Pass Marks : 24

Time : 3 hours

The figures in the margin indicate full marks for the questions

1. Choose the correct answer for the following questions (any *five*) : 1×5=5

(a) Which one of the following is an intensive variable?

(i) Entropy

(ii) Specific volume

(iii) Enthalpy

(iv) Internal energy

(b) Entropy change in a Carnot cycle is

(i) $\frac{Q_1}{T_1}$ (ii) $\frac{Q_2}{T_2}$

(iii) $\frac{Q_1 - Q_2}{T_2}$ (iv) zero

(c) If S and V denote entropy and volume respectively, a second order phase transition involves

(i) $\Delta S = 0, \Delta V \neq 0$

(ii) $\Delta S = 0, \Delta V = 0$

(iii) $\Delta S \neq 0, \Delta V = 0$

(iv) $\Delta S \neq 0, \Delta V \neq 0$

(d) The mathematical form of Clausius-Clapeyron equation is

(i) $\left(\frac{dP}{dT}\right) = \frac{L}{T(V_2 - V_1)}$

(ii) $\left(\frac{dP}{dT}\right) = \frac{T}{L(V_2 - V_1)}$

(iii) $\left(\frac{dT}{dP}\right) = \frac{L}{T(V_2 - V_1)}$

(iv) $\left(\frac{dT}{dP}\right) = \frac{T}{L(V_2 - V_1)}$

(e) The molecular translational kinetic energy for one mole of a gas at 0 °C is

(i) $8{\cdot}31 \times 10^3$ J

(ii) $1{\cdot}38 \times 10^{-23}$ J

(iii) $6{\cdot}02 \times 10^{23}$ J

(iv) $3{\cdot}4 \times 10^3$ J

(f) The efficiency of a Carnot engine is 0·4. If the temperature of the sink is 27 °C, the temperature of the source is

(i) 127 °C (ii) 500 K

(iii) 500 °C (iv) 600 K

(g) At a given temperature, viscosity of a gas

(i) decreases with decrease of pressure

(ii) increases with decrease of pressure

(iii) is equal to pressure applied to the gas

(iv) is independent of pressure

(h) "The entropy of any system at absolute zero is a universal constant, which may be taken to be zero." This statement is known as

(i) Temperature-entropy theorem

(ii) Nernst heat theorem

(iii) Clausius theorem

(iv) Planck-Clausius theorem

(i) As per kinetic theory of gases, at constant temperature, which of the following statements is true? [M=molecular mass of the gas]

(i) $v_{rms} \propto M$

(ii) $v_{rms} \propto \sqrt{M}$

(iii) $v_{rms} \propto M^2$

(iv) $v_{rms} \propto \frac{1}{\sqrt{M}}$

(j) The critical temperature of a real gas is 40 K. In Joule-Thomson effect, its temperature of inversion will be

(i) 270 K (ii) 6·5 K
(iii) 270 °C (iv) 400 K

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

(a) State Zeroth law of thermodynamics and explain how it is used to define temperature.

(b) Define Helmholtz Free Energy and Gibb's Free Energy. 1+1=2

(c) Using Maxwell's thermodynamic relations, establish the TdS equation,

$$TdS = C_V dT + T\left(\frac{\partial P}{\partial T}\right)_V dV$$

(Continued)

(d) How does temperature afeect mean free path of a molecule?

(e) Define 'diffusion' and 'diffusion coefficient' in gaseous systems. 1+1=2

(f) 50 g of water is heated from 10 °C to 20 °C. If specific heat of water is 1 in the CGS system, calculate the entropy change.

(g) The Joule-Thomson coefficient μ is given by

$$\mu = -\frac{1}{C_P}\left[V - T\left(\frac{\partial V}{\partial T}\right)_P\right]$$

Find the value of μ for an ideal gas using the above relation.

3. Answer any *five* of the following questions : 5×5=25

(a) Obtain the equation of state for an adiabatic expansion of an ideal gas. Hence deduce that, $TV^{\gamma-1}$ = constant. 4+1=5

(b) An ideal gas undergoes reversible isothermal expansion from an initial volume V_i to a final volume V_f. Obtain an expression for change in entropy of the system. What is the corresponding change in entropy of the universe in this case? 4+1=5

(Turn Over)

(c) Define internal energy. Mention two points of difference between internal energy and enthalpy. Obtain the relation connecting enthalpy and specific heat at constant pressure. 1+2+2=5

(d) Using Maxwell's thermodynamic relations, show that $C_P - C_V = R$ for one mole of a perfect gas.

(e) Calculate the r.m.s. speed and the most probable speed of a hydrogen molecule at N. T. P. 2½+2½=5

(f) Show that entropy increases in an irreversible process. Explain what is referred to as 'heat death of the universe'. How is entropy related to disorder? 2+1+2=5

(g) Draw the P–V diagram of a Carnot engine and obtain an expression for its efficiency. 1+4=5

(h) Obtain an expression for fall in temperature obtained during an adiabatic demagnetization process.

(i) Mention two reasons of deviation of the behaviour of real gases from ideal gases. Calculate the critical temperature and Boyle temperature for CO_2. The van der Waal's constants are given as $a = 0{\cdot}0072$ and $b = 0{\cdot}002$. The unit of pressure is atmosphere and the unit of volume is that of a gm mol of the gas at NTP. 2+2+1=5

4. Answer any *two* of *(a)*, *(b)*, *(c)* and *(d)* : 10×2=20

(a) (i) Find an expression for coefficient of performance of a refrigerator. 5

(ii) Prove that the ratio of any two temperatures on the absolute scale is equal to the ratio of the quantities of heat taken in and given out by a Carnot's reversible engine working between these temperatures. 5

(b) Draw the experimental set up of a Joule-Thomson Porous Plug Experiment. Explain briefly the experimental procedure. How does this Joule-Thomson expansion differ from adiabatic expansion? Show that Joule-Thomson effect is iso-enthalpic. 2+3+2+3=10

(c) (i) Show that work done during isothermal expansion of an ideal gas is

$$W = nRT \ln \frac{V_2}{V_1}$$

2 moles of oxygen at 0 °C are compressed until the volume becomes one fourth of the initial value at the same temperature. Calculate the work done. 3+2=5

(ii) What is degree of freedom? State the law of equipartition of energy. If γ represents the ratio of specific heats of a gas then establish that,

$$\gamma = 1 + \frac{2}{f}$$

where f represents the degree of freedom. What will be the value of γ for a triatomic gas as per the above relation? 1+1+2+1=5

(d) (i) Prove from the laws of thermodynamics

$$\left(\frac{\partial U}{\partial V}\right)_T = T\left(\frac{\partial P}{\partial T}\right)_V - P$$

Hence show that internal energy of an ideal gas is independent of its volume at constant temperature. 4+1=5

(ii) Write a short note on Brownian motion with its significance. 5

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