Guru Jambheshwar University-2019
B.Sc (Third Semester)
Thermal Physics
CPL-302
Core Course-V

Time : 3 Hours *Maximum Marks: 80*

Note: *Attempt Five questions in all, selecting one question from each Unit. Q. No. 1 is compulsory.*

1. (*a*) Define Isothermal and Adiabatic Process. (2)
   (*b*) Write the statement of Second Law of Thermodynamics. (2)
   (*c*) Entropy of universe is always increasing. What is the implication of this fact? (2)
   (*d*) Define extensive and intensive variable with example. (2)
   (*e*) Write 4th Maxwell's equation. (2)
   (*f*) What is first order phase transformation? (2)
   (*g*) What is the critical point? (2)
   (*h*) State the zeroth law of thermodynamics. (2)

Unit-I

2. (*a*) Derive an expression for the efficiency of an ideal heat engine working between the temperature T_1 and $T_2 K$. Prove that efficiency of a reversible engine is maximum for the given source and sink. (12)
   (*b*) Find the efficiency of a Carnot's engine working between 127°C and 27°C. It absorbs 80 Cals of Heat. How much heat is rejected? (4)
3. (*a*) Define an adiabatic process and state two essential conditions for such a process to take place. Show that work down by one mole of an ideal gas during adiabatic expansion from temperature T_1 to T_2 is given by $W = \frac{R(T_1 - T_2)}{\gamma - 1}$. (10)
   (*b*) What is Internal Energy of a system? "Internal energy is state function and not a path function." Explain. (6)

Unit-II

4. (*a*) What do you mean by entropy? Show that entropy remains constant in reversible process but increases in irreversible process. (12)
   (*b*) 1 kg of water at 273 *K* is brought in contact with a heat reservoir at 373 *K*. What is the change in entropy of water as its temperature reaches 373 *K*? (10)

5. (*a*) Derive an expression for the entropy of a perfect gas in terms of volume and temperature. (10)

(*b*) Prove that for a complete reversible cycle of change in the state of substance $\oint dS = 0$ (6)

Unit-III

6. (*a*) Establish the Clausius-Clapeyron's equation:

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

from Maxwell's thermodynamical relations and explain the effect of pressure on boiling point of liquid and melting point of a solid.

(*b*) Calculate the depression of melting point of ice produced by one atmosphere increase of pressure. Given that latent heat of ice 80 cal/gm and specific volume of ice an water at 0°C are 1.091 cm^3 and 1.0 cm^3 respectively. (4)

7. (*a*) Define Helmholtz and Gibb's function. Derive from them corresponding Maxwell's thermodynamical relation. (8)

(*b*) From Maxwell's relation derive the relation between *Cp* and *Cv* for a gas which obey van der Waal's equation. (8)

Unit-IV

8. (*a*) Distinguish between a perfect gas and a real gas derive van der Waal's equation of state and use it to obtain the expression the critical constants in terms of the van der Waal equations. (12)

(*b*) Calculate critical temperature for CO^2, given that $a = 0.00874$ atoms cm^6 and $b = 0.0023\ cm^3$. (4)

9. (*a*) Define Boyle temperature and inversion temperature. Explain the behavior of real gases above and below the Boyle temperature. (8)

(*b*) What is Joule-Thomson effect? Distinguish between adiabatic expansion and Joule-Thomson effect. (5)

(*c*) Van der Waal's constants for a gas are $a = 6.9 \times 10^{-2}\ J M^3\ mole^{-2}$ and $b = 2.9 \times 10^{-9}\ m^3\ mole^{-1}$. The universal gas constant $R = 8.31\ J\ mol^{-1}\ K^{-1}$.

Calculate the critical temperature of the gas. (3)

SOLUTIONS

Ans. 1 (*e*) The system in which process is carried isobasically and isothermally from initial state to final state and the system evolve in the direction to minimize Gibb's free energy

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

Ans. 1 (*f*) First order phase transitions are those that involve a latent heat. During such transitions, a system either absorbs or release a fixed amount of energy per unit volume. In this derivative of Gibb's free energy changes discontinuously.

Ans. 1 (*g*) A critical point is the end point of a phase equilibrium defined by critical pressure (TP) and critical temperature (P_T)

Unit.(I)

Ans. 2 (*b*) The efficiency of cannot cycle is given by

$$\eta = 1 - \frac{T_2 \ (Temp\ of\ Sink)}{T_1 \ (Temp\ of\ Source)}$$

Given temperature of sources $= 127°C = (127 + 273)K$

$$= 400K$$

temperature of Sink $= 27°C = (27 + 273)K$

$$= 300K$$

So, efficiency, $\eta = 1 - \frac{300}{400} = 1 - 0.75$

$$= 0.25$$

Also efficiency, $\eta = 1 - \frac{Q_2 (\text{Heat released by system})}{Q_1 (\text{Heat obsorbed by system})}$

Given heat absorbed, $Q_1 = 80$ cals

$$0.25 = 1 - \frac{Q_2}{80}$$

$$\frac{Q_2}{80} = 1 - 0.25 = 0.75$$

$$Q_2 = 80 \times 0.75 = 60 \text{ cals.}$$

Ans. 4 (*b*) Heat absorbed, $Q = mc\,\Delta T$ ...(*i*)

where m = mass, c = specific heat

entropy, $s = \frac{dQ}{T} = mc\frac{dT}{T}$

$$s = mc \ln [T]_{T_1}^{T_2}$$

$$= mc \ln \frac{T_2}{T_1} = 2.303\, mc \log \frac{T_2}{T_1}$$

m = 1 kg,

c (specific heat of water) = 4200 J kg^{-1} k–1

final temp, T_2 = 373 K, initial temp, T_1 = 273 K

S = (2.303) (1kg) (4200 J kg^{-1} k^{-1}) $\log \frac{373}{273}$.

Ans. 8 (*b*) Critical Temp, $T_C = \frac{8a}{27Rb}$.

Ans. 9 (*c*) Critical Temp, $T_C = \frac{8a}{27Rb}$.

Q_2 = 80 × 0.75 = 60 cals.