(b) An inventor claims to have designed a flow device, which gives equal amounts of cold air at 250 K and hot air at 350 K at 1 bar pressure when the device is fed with air at 30 bar and 300 K. He further claims that the device does not require any energy input to operate. Treat the air is an ideal gas with γ = 1.4. Judge whether such device is thermodynamically possible or not.

7 + 5=12

7. (a) It is desired to produce 5000 kg/h of ice at 273 K from water at 273 K, while the ambient temperature is 313 K. It is planned to supply power from a heat engine to run the refrigerator. The heat engine operates between a source at 373 K and the ambient atmosphere. Calculate i) the minimum power required to run the refrigerator, ii) the maximum efficiency of the heat engine and iii) the ratio of heat rejected by both the devices to the ambient atmosphere to the energy absorbed by the refrigerator from the water at 273 K.

(b) Data given: the latent heat of fusion of water at 273 K is 6.002 kJ/mol.
Establish the following relation, $C_P - C_V = \frac{\alpha^2 VT}{\beta}$ where, α is the isobaric thermal expansion coefficient, β is the isothermal compressibility coefficient and all other symbols bear the usual significance

6+6=12

Group – E

8. (a) Draw a schematic representation of vapour compression refrigeration cycle and discuss the process with a T - S diagram. Determine an expression of COP of the process.

(b) A vapor compression cycle using ammonia as refrigerant is employed in an industry. Cooling water at 288 K enters the condenser at a rate of 0.25 kg/s and leaves at 300 K. Ammonia at 294 K condenses at a rate of 0.5 kg/min. Enthalpy of liquid ammonia at 294K is 281.5 kJ/kg. The compressor efficiency is 90%. Saturated ammonia vapour at 258 K and enthalpy of 1426 kJ/kg enters the compressor. Find out the power required by the compressor and also the refrigeration capacity in tons.

5 + 7=12

9. (a) Draw a schematic representation of re-heat Rankine cycle and discuss the process with a T-S diagram. Determine an expression of efficiency of the process.

(b) In a thermal power plant operating on a Rankine cycle, superheated steam at 50 bar and 500°C enters a turbine, the isentropic efficiency of which is 80%. The condenser which is operating at 0.05 bar delivers saturated liquid to a feed pump, the isentropic efficiency of which is 70%. Determine the thermal efficiency of the power plant and the power generation from the plant if mass flow rate of steam is 180 tons/h.
(Steam table may be allowed to use)

5 + 7 = 12

B.TECH/CHE/3RD SEM/CHEN 2104/2019

THERMODYNAMICS – I
(CHEN 2104)

Time Allotted : 3 hrs **Full Marks : 70**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 5 (five) from Group B to E, taking at least one from each group.

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

Group – A
(Multiple Choice Type Questions)

1. Choose the correct alternative for the following: **10 × 1 = 10**

(i) For negligible change in kinetic and potential energy, the enthalpy change in an adiabatic open system
(a) Heat transferred out from control volume
(b) Work done on system
(c) Zero
(d) None of above.

(ii) Entropy change in a reversible adiabatic process
(a) Minimum (b) zero (c) maximum (d) infinity.

(iii) In a throttling process, the pressure of a ideal gas reduces by 50%. The specific volume will change by a factor of (γ is specific heat capacity ratio)
(a) 2 (b) $2^{1/\gamma}$ (c) $2^{(\gamma-1)/\gamma}$ (d) 0.5.

(iv) The change in Gibbs free energy when a real gas undergoes an isothermal change in state is
(a) RT ln(P_2/P_1) (b) RT ln(V_1/V_2) (c) RT ln(Z_1/Z_2) (d) RT ln(f_2/f_1)
(Symbols bear usual significance)

(v) Irreversibility is associated with a process is due to
(a) mechanical and fluid friction
(b) unrestricted expansion
(c) transfer of species due to concentration difference
(d) all of the above.

(vi) Free expansion is a good example of
(a) static process (b) equilibrium process
(c) non-equilibrium process (d) isothermal process.

(vii) As pressure approaches zero, fugacity coefficient value tends to
(a) pressure (b) unity (c) zero (d) infinity.

(viii) The degrees of freedom in a system containing a solution of alcohol in water in equilibrium with its vapour
(a) 2 (b) 0 (c) 1 (d) None of (a), (b), (c).

(ix) The heat gained in a constant pressure process due to increase in temperature can be determined from
(a) Change in enthalpy of the system
(b) Change in internal energy
(c) Change in pressure
(d) None of (a), (b), (c).

(x) An ideal gas at temperature T_1 and pressure P_1 is compressed isothermally to a pressure P_2 ($>P_1$) in a closed system. Which of the following is true of the gas at two states?
(a) $U_1 = U_2$, $G_1>G_2$ (b) $H_1=H_2$, $G_1<G_2$
(c) $U_1 > U_2$, $G_1=G_2$ (d) $H_1<H_2$, $G_1=G_2$

Group – B

2. (a) Steam enters a heat exchanger at a pressure of 0.5 MPa and temperature of 250°C, and a mass flow rate of 1 Kg/s, the steam exits as a saturated vapor at 151.8°C. Cooling water enters the heat exchanger at a temperature of 285K and exits at an increased temperature. What is the temperature in water if its flowrate is 2 kg/s? Specific heat capacity of water is 4.2 kJ/(kg K).

(b) Carbon dioxide gas enters a water cooled compressor at 10 psia and 20°C. It is being discharged at 500 psia and 93°C. The mass flow rate of carbon dioxide is 78 gm/s. The gas enters the compressor through a 4 inch pipe and is discharged through 1 inch pipe. Shaft work supplied to the compressor 127 J/kg and the heat extracted from the compressor is 40000 kJ/kg. If the inlet enthalpy of carbon dioxide is 714 kJ/kg, what is the outlet enthalpy of gas. Specific volume of inlet carbon dioxide is 0.6 m^3/kg and at outlet it is 0.02 m^3/kg.

6 + 6 = 12

3. (a) Steam flows through a converging insulated nozzle of length 15 cm and an inlet diameter of 5cm. At the nozzle entry, temperature is 325°C and

pressure is 700 kPa and the velocity is 30 m/s. At the exit of the nozzle, steam temperature and pressure are 240°C and 350 kPa respectively. Use enthalpy values from steam tables and calculate velocity and diameter of nozzle.

(b) Describe Joule-Thomson porous plug experiment with a diagram and what inference can be made from it.

7 + 5 = 12

Group – C

4. (a) What is triple point of a substance?

(b) The Berthelot equation of state is given by

$$\left(P + \frac{a}{Tv^2}\right)(v - b) = RT$$

Develop necessary relation to determine the parameter 'a' and 'b' in terms of critical constant T_c and P_c and then convert the equation in reduced form where compressibility factor, Z is only function of reduced pressure, P_r and reduced temperature, T_r.

2 + 10 = 12

5. (a) A mass of 1 kg gaseous ammonia (T_c = 405.6K, P_c = 111.3 bar) is contained in a 50 L container immersed in a constant temperature bath at 30°C. Calculate the pressure of the gas in cylinder using any real gas equation of state. (ω =0.25)

(b) A gas obeying the Clausius equation of state is isothermally compressed from 5 MPa to 15 MPa in a closed system at 400K. The Clausius equation of state is $P = \frac{RT}{v - b(T)}$ where *P* is the pressure, *T* is the temperature, *v* is the molar volume and R is the universal gas constant. The parameter b in the above equation varies with temperature as $b(T) = b_0 + b_1 T$ with $b_0 = 4\times10^{-5} m^3 mol^{-1}$ and $b_1 = 1.35\times10^{-7} m^3 mol^{-1} K^{-1}$. Determine the change in molar enthalpy for this process.

(4 + 2)+ 6 = 12

Group – D

6. (a) A rigid insulated tank of volume 4m^3 is divided into two equal compartments by a removable partition of negligible volume. One compartment of volume contains Oxygen at 500K and 10 bar while 2nd one contains Nitrogen at 800K and 20 bar. The partition is removed and the gas is allowed to mix. After mixing calculate total change of entropy of the process. Assume both gases to be ideal with γ = 1.4