**B.TECH/CHE/4TH SEM/CHEN 2203/2019**

**CHEMICAL ENGINEERING THERMODYNAMICS**

**(CHEN 2203)**

**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) If the temperature of saturated water is increased infinitesimally at constant entropy, the resulting state of water will be

(a) liquid (b) saturated vapour

(c) liquid-vapour coexistence (d) solid.

(ii) The temperature at which real gas behaves like an ideal gas at low pressure is called

(a) Boyle temperature (b) critical temperature

(c) triple point temperature (d) inversion point.

(iii) During throttling process

(a) internal energy does not change

(b) enthalpy does not change

(c) Helmholtz free energy does not change

(d) Gibbs free energy does not change.

(iv) The latent heat of vaporization at critical point is

(a) negative (b) positive

(c) zero (d) not possible to determine.

(v) The boiling points of two liquids A and B are 80°C and 60°C respectively. The two liquids are immiscible. The boiling point of an equimolar emulsion of A and B is

(a) greater than 80°C (b) less than 60°C

(c) equal to 70°C (d) less than 80°C but greater than 60°C.

(vi) Which of the following statements is true with reference to minimum boiling azeotrope?

(a) The solution behaves like an ideal solution

(b) The solution exhibits positive deviation from ideality

(c) The solution exhibits negative deviation from ideality

(d) The activity coefficient is unity at azeotropic mixture.

(vii) The change in Gibbs free energy when a real gas undergoes an isothermal change in state is

(a) RT ln(P2/P1) (b) RT ln(V1/V2)

(c) RT ln(Z1/Z2) (d) RT ln(f2/f1)

[Symbols bear usual significance]

(viii) The units of the isothermal compressibility is

(a) m-3 (b) m-3 Pa-1 (c) m3 Pa-1 (d) Pa-1.

(ix) Which of the following is true for excess property *M E*? [*Mig* thermodynamic property of ideal gas, *Mid* thermodynamic property of ideal solution]

(a)  (b) 

(c)  (d) 

[Symbols bear usual significance]

(x) A gas mixture of three components is brought in contact with a dispersion of an organic phase in water. The degrees of freedom of the system is/are

(a) 1 (b) 2 (c) 3 (d) 4.

**Group – B**

2. (a) One kg of an ideal gas (mol.wt. 44) contained in a closed system undergoes a reversible isobaric process. During the process 48 kJ of internal energy is decreased. Determine the work done during the process. Given cp = 840 J/kgK.

(b) A boiler produces steam at 1 MPa and 300°C. The steam from the boiler is used to operate a turbine. The turbine exhausts steam into an evacuated tank of volume 150 m3. The turbine operated till the pressure in the tank rises to 1 MPa and 200°C. Assuming that the turbine and the tank are adiabatic, determine the work delivered by the turbine during filling up of the tank. [Steam Table may be allowed to use].

**5 + 7 = 12**

3. (a) Calculate the pressure developed by 1kmol of ammonia gas contained in a vessel of 0.6 m3 volume at a constant temperature of 200°C by using the following equation of state (EOS):

(i) Ideal gas EOS (ii) Van Der Waals EOS

(iii) Redlich-Kwong EOS

Given, Pc = 112.8 bar and Tc = 405.5K.

(b) Show that the compressibility factor at critical point of a real gas as per van der Waals equation of state is 0.375.

**7 + 5 = 12**

**Group – C**

4. (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.

[Data given: the latent heat of fusion of water at 273 K is 6.002 kJ/mol.]

(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.

**6 + 6 = 12**

5. (a) Establish the following relation, where, α is the isobaric thermal expansion coefficient, β is the isothermal compressibility coefficient and all other symbols bear the usual significance. Also show that, for ideal gas.

(b) In a process industry one unit delivers a gas A at 1 bar and 1000 K at a rate of 2 kmol/s and the second unit delivers a gas B at 1 bar and 800 K at a rate of 3 kmol/s. The ambient atmosphere is at 300 K. If the hot gas is considered source and the ambient atmosphere as sink, then calculate the maximum power obtainable from a heat engine if

(i) A and B gases are used as separate source

(ii) A and B gases are mixed and the mixture is used as source

[Assume both gases are ideal gas with γ = 1.4.]

**(4 + 2) + 6 = 12**

**Group – D**

6. (a) Given ln= x22(0.5 + 2x1) and ln= x12(1.5 – 2x2). Show that the system follows Gibbs Duhem equation.

(b) You are given some lab alcohol containing 96 mass % alcohol and 4 mass % water. You are asked to convert 2 dm3 of the supplied lab alcohol to a new solution containing 56 mass % ethanol and 44 mass % water. The experiment is carried out at 250C and 1 atm at which the following data are known

|  |  |  |
| --- | --- | --- |
| Partial mass volume of water (dm3/kg) | 0.816 (in 96 % alcohol) | 0.953 (in 56 % alcohol) |
| Partial mass volume of ethanol (dm3/kg) | 0.1273(in 96 % alcohol) | 1.243 (in 56 % alcohol) |

Also given that for pure water at the above P and T, mass volume = 1.003 dm3/kg. What dm3 of water are to be added to the 2 dm3 of lab alcohol to get the new solution and how much of it?

**6 + 6 = 12**

7. (a) Under atmospheric condition the acetone-chloroform azeotope boils at 64.50C and contains 33.5 mole% acetone. The vapour pressures of acetone and chloroform at this temperature are 995 mm Hg and 855 mm Hg respectively. Calculate the composition of the vapour at this temperature in equilibrium with a liquid analyzing 11.1 mole% acetone.

(b) At 300 K and 1 bar, the volumetric data for a liquid mixture of benzene and cyclohexane are represented by V = 109.4 x 10-6 – 16.8 x 10-6 x – 2.64 x 10-6 x2, where x is the mole fraction of benzene and V has the units of m3 / mole. Find the partial molar volume of benzene for its 30 mole% solution in cyclohexane. Find also the partial molar volume of benzene at infinite dilution.

**6 + 6 = 12**

**Group – E**

8. (a) For the vapour phase reaction P4  2P2 carried out at 2000K, the equilibrium reaction mixture contains 80 mole% P2. Find the total pressure of the system. Stoichiometric quantity of reactant was fed to the reactor.

[Data: = 225400 + 7.90 T lnT – 209.4T J/mol]

(b) An equimolar mixture of CO (g) and H2O(g) enters a reactor, which is maintained at 10 bar and 1000 K. Given that the equilibrium constant for the reaction at 1000 K is 1.5.

Reaction: CO (g) + H2O (g) = CO2 (g) + H2 (g)

Estimate the composition of the gas that leaves the reactor. Assume that the reaction mixture behaves like an ideal gas.

**5 + 7 = 12**

9. (a) Derive the functional relation between temperature with equilibrium constant of chemical reaction.

(b) Estimate the maximum conversion of ethylene to ethanol by vapour phase hydration at 2500C and 35 bars for an initial steam to ethylene ratio of 5.

[Data: The equilibrium constant (K) = 9.841 x 10-3]

|  |  |
| --- | --- |
| Material | Fugacity coefficient |
| Ethylene | 0.977 |
| Water vapour | 0.896 |
| Ethanol | 0.837 |

The reaction is: C2H4(g) + H2O(g) = C2H5OH(g)

**5 + 7 = 12**