

TE - sem - V (CBSEs) chemical - CET - II  
 Chemical Engineering  
 Thermodynamics - II

13/12/16

Q.P. Code : 573902

(3 Hours)

[ Total Marks : 80

- N.B. : (1) Question no.1 is compulsory.  
 (2) Attempt any **THREE** of the remaining questions.  
 (3) **Figure** to the **right** indicates **full** marks.  
 (4) Assume suitable data wherever necessary.

1. a) Fill in the blanks 10
- i) At equilibrium the entropy of an isolated system \_\_\_\_\_
  - ii) For a reversible reaction the Gibbs Energy is \_\_\_\_\_ at equilibrium.
  - iii) For a system obeying Henry's law the product of the Henry's constant and the mole fraction of a component is equal to \_\_\_\_\_ of the component in vapour phase.
  - iv) For an ideal gas mixture the total pressure is equal to the sum of \_\_\_\_\_
  - v) When an ideal gas is mixed the entropy of mixing at constant temperature and pressure is \_\_\_\_\_
- b) 10
- i) For an ideal solution the activity coefficient is
    - a. 1
    - b. Greater than 1
    - c. Less than 1
    - d. Depends on the solution
  - ii) For an ideal gas mixture the partial fugacity is equal to the
    - a. Partial pressure of the component
    - b. Vapor pressure of the component
    - c. Partial volume of the component
    - d. cannot be determined
  - iii) The Raoult's law is valid when
    - a. Both vapour and liquid is ideal
    - b. Vapor is non ideal and liquid is ideal
    - c. Liquid is non ideal but vapour is ideal
    - d. Both vapour and liquid are non ideal.
  - iv) The fugacity coefficient for an ideal gas mixture is
    - a. 1
    - b. greater than 1
    - c. less than 1
    - d. depends on temperature and pressure
  - v) For a minimum boiling azeotrope the boiling temperature of the azeotrope
    - a. is less than the low boiler and the high boiler
    - b. less than the low boiler
    - c. Higher than the high boiler
    - d. Higher than the low boiler and the high boiler

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[TURN OVER]

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2. a) A and B are fed into a reactor. The reactor is operated isothermally at 400 K. 10  
The following reactions occur in the reactor.  
 $A + B \rightarrow 3C + 2D \quad \Delta H(298) = -300 \text{ kJ/mol (1)}$   
 And  
 $A \rightarrow E \quad \Delta H(298) = -200 \text{ kJ/mol (2)}$   
 A is fed into the reactor at 10 mol/s. A and B are fed in equimolar quantities. The reactions are in gas phase, and the overall conversion of A is 20%. The flow rate of E in the exit of the reactor is 1 mol/s.  $C_p$  is 3R, where R is the universal gas constant. Calculate the amount of heat to be supplied to the reactor.
- b) For the reaction  $A \rightarrow 2R$ , find the conversion at 450 K. The reaction is in gas 10  
phase, and the reactants and products are ideal gases. The specific heat at constant pressure ( $C_p$ ) for the reactant as well as product is 3R. The entropy of formation for the reactant and product are zero at 298 K. The heats of reaction for the reactant and product, at 298 K are -10 kJ/mol and -12 kJ/mol.
3. a) At dilute aqueous Sodium Carbonate solution of 4.76% (mol) is concentrated 10  
to 6.25% (mol), by adding crystals. The flow rate of the dilute solution is 10 mol/s. The mixing is carried out at 25°C. Calculate the amount of heat to be removed from the mixer?  
 Heats of formation for compound and solutions at 298 K  
 $\text{Na}_2\text{CO}_3(\text{c}) = -270.3 \text{ kcal/mol}$   
 $\text{Na}_2\text{CO}_3 \cdot \text{H}_2\text{O} = -341.8 \text{ kcal/mol}$   
 $\text{Na}_2\text{CO}_3 \cdot 15\text{H}_2\text{O} = -273.13 \text{ kcal/mol}$   
 $\text{Na}_2\text{CO}_3 \cdot 20\text{H}_2\text{O} = -277.91 \text{ kcal/mol}$
- b) 10 moles of Nitrogen is mixed with 10 moles of Oxygen. This process is 10  
carried out at atmospheric temperature and pressure. The gases can be assumed to be ideal. Find the Gibbs free energy of the resulting mixture? The value of  $C_p$  is 29.1 kJ/kmol-K.
4. a) A solution of acetone and chloroform has 47 mol% of Chloroform. The 10  
partial molar volumes of acetone and chloroform in this mixture in this mixture are 74.71 ml/mol, and 80.2 ml/mol, respectively. What is the volume of a solution of mass 100g.
- b) The boiling point estimation of n-octane is done by Joback group contribution 10  
method. The formula for this is  $T_b (\text{K}) = 198 + \sum_i \nu_i \Delta T_b$  where  $\nu_i$  is the number of groups and  $\Delta T_b$  is the boiling point contribution. Find the boiling point of n-octane given that the boiling point contribution of non ring  $\text{CH}_2$  group, non ring  $\text{CH}_3$  group, are 23.58 and 22.88, respectively.

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[ TURN OVER ]

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5. a) An ideal ammonia absorption refrigeration system is used to cool an enclosure to  $-15^{\circ}\text{C}$ . Heat is available in the generator at  $110^{\circ}\text{C}$ . Cooling water is available at  $30^{\circ}\text{C}$ . Assuming that cooling and heating are done isothermally, in all the exchangers, calculate the COP. The COP of absorption refrigeration system

is given by  $\text{COP} = \frac{T_R}{T_2 - T_R} \times \frac{T_1 - T_2}{T_1}$ .  $T_R$  is the temperature of the evaporator,

$T_1$  is the temperature of the generator,  $T_2$  is the temperature of the Absorber/Condenser. For 1 T refrigeration, what is the heat supplied in the generator, and heat to be removed from the absorber, if the heat removed from the condenser is 3 kW. Take 1 T refrigeration as 3.5 kW

- b) R 12 is condensed at  $30^{\circ}\text{C}$ . It is then throttled to  $-5^{\circ}\text{C}$ . Find out the Refrigerant flow rate that enters the compressor for 1 T of refrigeration. 10

$T_s$	$P_s$	$H_f$ kJ/kg	$H_g$ kJ/kg
$-5^{\circ}\text{C}$	0.2619 MPa	31.42	185.243
$30^{\circ}\text{C}$	0.7449 MPa	64.539	192.475

It is assumed that the compressor discharge is at the saturated vapour condition. Find the work done by the compressor? Also calculate the COP.

6. a) Prove that the fugacity of a liquid is equal to that of vapour at equilibrium. 20  
 b) With a neat diagram explain the Vapor Absorption Refrigeration System.  
 c) Write the equation of non-ideal vapour liquid equilibrium. Show that it is equal to Raoult's law as a special case. What is the special case?  
 d) Derive the equation  $\ln \frac{K}{K_1} = -\frac{\Delta H_{\text{Reaction}}}{R} \left( \frac{1}{T} - \frac{1}{T_1} \right)$ .

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