Name : ....

Roll No. : ....

Invigilator's Signature : ....

CS/B.TECH(CHE-N)/SEM-3/CHE-302/2011-12

2011

INDUSTRIAL STOICHIOMETRY

Time Allotted : 3 Hours Full Marks : 70

The figures in the margin indicate full marks.

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

GROUP – A

(Multiple Choice Type Questions)

1. Choose the correct alternatives for the following : $10 \times 1 = 10$

   i) A bypass stream in a chemical process is useful, because it
      - a) facilitates better control of the process
      - b) improves the conversion
      - c) increases the yield of products
      - d) none of these.

   ii) Enthalpy of formation of NH_3 is – 46 kJ/kg. mole. The enthalpy change for the gaseous reaction, $2NH_3 \rightarrow N_2 + 3H_2$, is equal to .... kJ/kg. mole.
      - a) 46
      - b) 92
      - c) – 23
      - d) – 92.

iii) A 'limiting reactant' is the one, which decides the .... in the chemical reaction.

a) equilibrium constant

b) conversion

c) rate constant

d) none of these.

iv) Hess's law of constant heat summation is based on conservation of mass. It deals with

a) equilibrium constant

b) reaction rate

c) changes in heat of reaction

d) none of these.

v) In a chemical process, the recycle stream is purged for

a) increasing the product yield

b) lienriching the product

c) limiting the inerts

d) heat conservation.

vi) The percentage ratio of the partial pressure of the vapour to the vapour pressure of the liquid at the existing temperature is

a) termed as relative saturation

b) not a function of the composition of gas mixture

c) called percentage saturation

d) not a function of the nature of vapour.

vii) To know the nature of relationship between x and y, which kind of graph paper is ideal for plotting of points (x, y) satisfying equation of the form $y = 2*10^x$?

a) Log-Log
b) Semilog
c) Triangular
d) Power.

viii) The temperature attained when a fuel is burnt in air or oxygen without gain or loss of heat is termed

a) the theoretical flame temperature
b) the maximum adiabatic flame temperature
c) the maximum theoretical flame temperature
d) none of these.

ix) The negative of the standard heat of combustion of a fuel with H_2O (l) as a combustion product is known as

a) lower heating value
b) higher heating value
c) the standard heat of formation
d) none of these.

x) The reference temperature during enthalpy calculation

a) must be same for all the streams of the plant
b) may not be same for all the streams of the plant
c) is always taken as 298 K
d) none of these.

GROUP – B

Answer any *five* questions. 5 × 12 = 60

2. a) Using Buckingham's π-theorem show that the volumetric discharge of a centrifugal pump (Q) is given by :

$$Q = ND^3 \, f\left[\frac{gH}{N^2 D^2} \cdot \frac{\mu}{ND^2 \rho} \right]$$

where, N is the speed of the pump in revolution per minute, D, the diameter of impeller, g, the acceleration due to gravity, μ, the viscosity of the fluid and ρ, the density of the fluid.

b) Using Raoult's or Henry's law for each substance (whichever one you think appropriate), calculate the pressure and gas phase composition (mole fraction) in a system containing a liquid that is 0·3 mole % N_2 and 99·7 mole % water in equilibrium with N_2 gas and water vapour at 80°C.

Data : At 80°C :

Henry's constant for N_2 = $12 \cdot 6 \times 10^4$ atm/mole fraction

Vapour pressure of water = 355·1 mm Hg. 6 + 6

3. a) A saturated solution of $MgSO_4$ at 353 K (80°C) is cooled to 303 K (30°C) in a crystallizer. During cooling, mass equivalent to 4% solution is lost by evaporation of water. Calculate the quantity of the original saturated solution to be fed to the crystallizer per 1000 kg crystals of $MgSO_4 \cdot 7H_2O$. Solubilities of $MgSO_4$ at 303 K (30°C) and 353 K (80°C) are 40·8 kg and 64·2 kg per 100 kg water respectively.

b) 50 moles of liquid air is stored in a vessel at 1·013 bar pressure. Heat leaks through the vessel walls so that vaporization occurs. Under these conditions the relative volatility of N_2 to O_2 may be taken as constant at 2 :

1. Calculate the mole of liquid left in the vessel, when the residual liquid composition is N_2 , 50 mole % and O_2 50 mole %. 6 + 6

4. a) State Raoult's Law with all the conditions.

b) Extimate the vapour phase composition at 60°C in equilibrium with a liquid mixture constaining 40 mole % Benzene (C_6H_6) and 60 mole % Toluene ($C_6H_5CH_3$) . Also calculate the composition of the liquid mixture, which boils at 90°C and 760 torr. Vapour pressure data is given below in the table :

Temperature, °C	**V_p of Benzene (C_6H_6), Torr**	**V_p of Toluene ($C_6H_5CH_3$), Torr**
60	385	140
90	1013	408

3 + 9

5. Continuous fractionating column operating at a pressure of 101·3 kPa is to be used to separate 2500 kg/hr of a solution of benzene and toluene, containing 0·50 mass fraction benzene at 45°C, into an overhead product containing 0·98 mass fraction benzene at 15°C and a bottom product containing 0·02 mass fraction benzene at 50°C. A reflux ratio of 4·0 kg of reflux per kg of product is to be used. The feed will be liquid at its boiling point and the reflux will be returned to the column at 40°C.

a) Calculate the quantity of top and bottom product in kg/hr.

b) Calculate the condenser duty, if all the vapour entering the condenser is condensed.

c) Calculate the rate of heat input to the boiler, if the liquid leaving the reboiler is saturated liquid.

Data :

Enthalpy of feed mixture = 188·4 kJ/kg

Enthalpy of overhead product = 62·94 kJ/kg

Enthalpy of bottom product = 209·3 kJ/kg

Enthalpy of vapour = 540 kJ/kg. 4+ 4 + 4

6. a) Calculate the heat required to bring 150 mol/hr of a stream containing 60% C_2H_6 and 40% C_3H_8 by volume from 0°C to 400°C.

Data :

For C_2H_6, $C_P = 0{\cdot}04937 + 13{\cdot}92 \times 10^{-5}\ T - 5{\cdot}816 \times 10^{-8}\ T + 7{\cdot}280 \times 10^{-12}\ T^3$

For C_3H_8, $C_P = 0{\cdot}06803 + 22{\cdot}59 \times 10^{-5}\ T - 13{\cdot}11 \times 10^{-8}\ T + 31{\cdot}71 \times 10^{-12}\ T^3$

where, C_P is in kJ/mol. °C and T = temperature in °C.

b) The standard heats of the following combustion reactions have been determined experimentally.

$C_2H_6 + \frac{7}{2} O_2 \rightarrow 2CO_2 + 3H_2O \quad \Delta H_1 = -1559{\cdot}8$ kJ/mol

$C + O_2 \rightarrow CO_2 \quad \Delta H_2 = -393{\cdot}5$ kJ/mol

$H_2 + \frac{1}{2} O_2 \rightarrow H_2O \quad \Delta H_3 = -285{\cdot}8$ kJ/mol

Use Hess's law to determine the heat of formation of ethane. 8 + 4

7. a) Define theoretical flame temperature and maximum adiabatic flame temperature. Calculate the theoretical flame temperature of a gas containing 20% CO and 80% N_2 when burnt with 100% excess air, both air and gas initially being at 25°C.

Data : Heat capacity (C_p) = $a + b\text{T} + c\ \text{T}^2$, k cal/kmol. K

The values of the coefficients for different materials are as follows :

Material	*a*	$b \times 10^3$	$c \times 10^6$
CO_2	6·339	10·14	– 3·415
O_2	6·117	3·167	– 1·005
N_2	6·457	1·389	– 0·069

The standard heat of formation of CO_2 (ΔH°_{298K}) = – 67636 kcal/mol.

b) A well stirred batch reactor wrapped in an electrical heating mantle is charged with a liquid reaction mixture. The reactant must be heated from an initial temperature of 25°C to 250°C befor the reaction can take place at a measureable rate. Using the data given below determine the time required for this heating to take place.

Reactant : mass = 1·5 kg, C_V = 0·90 kcal / kg°C

Reactor : mass = 3·0 Kg, C_V = 0·12 kcal / kg°C

Heating rate (Q) = 500 W

Negligible reaction and no-phase change during heating. Negligible energy added to the system by the stirrer.

(1 + 1 + 6) + 4

8. An evaporator is to be fed with 1500 kg/hr of a solution containing 2% solute by weight at a temperature 45°C. It is to be concentrated to solution of 3% solute by weight in the evaporator operating at a pressure of 101·3 kPa in the vapour space. The heating surface is supplied with saturated steam at 198·54 kPa ($t_s = 120°C$). Calculate the weight of the vapour produced and the weight of the steam required. If the overall heat transfer coefficient of the evaporator is 1400 W/m^2 K, calculate the necessary heating surface.

   The solution is so dilute that its specific heat, latent heat and boiling point may be assumed to be the same as those of water.

   h_f = 188·4 kJ/kg, h_p = 419·1 kJ/kg, H_v = 2676 kJ/kg, H_s = 2706 kJ/kg, h_c = 503·7 kJ/kg.