Name : ....

Roll No. : ....

Invigilator's Signature : ....

CS/B.TECH (CHE-N)/SEM-3/CHE-302/2012-13

2012

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 any *ten* of the following : $10 \times 1 = 10$

i) 1° Brix is equivalent to a sugar solution

a) 10% sugar
b) 1% sugar
c) 0·1% sugar
d) 0·01% sugar.

ii) 1 kg/cm^2 is equal to

a) 5 m water
b) 1 m water
c) 760 mm water
d) 10 m water.

iii) Dimension of viscosity is

a) $ML^{-1}T^{-1}$
b) MLT^{-1}
c) $ML^{-1}T$
d) $M^{-1}LT^{-1}$.

iv) The chart which is related to Antoine equation is .... concentration.

a) Ostwald
b) Cox
c) Moller's
d) enthalpy.

v) Which one is not a dimensionless group ?

a) $\frac{k}{\rho . Cp}$ b) $\frac{h.D}{k}$

c) $\frac{Cp.\mu}{k}$ d) none of these.

vi) The temperature coordinate on the 100% saturation line corresponding to the humidity of air at a certain temperature is

a) wet bulb temperature

b) adiabatic saturation temperature

c) dew point temperature

d) dry bulb temperature.

vii) A purge steam is a steam

a) one which is returned to the process unit

b) one that is bled off to remove the accumulation of inerts or unwanted materials that might otherwise build up in the recycle steam

c) one that skips one or more stages of the process and goes directly to another stage

d) one that is withdrawn as product.

viii) For a continuous steady state process the material balance on a reactive species is written as

a) Input = Output

b) Input + Generation + Accumulation = Output + Consumption

c) Input + Generation = Output + Consumption

d) Input + Generation = Accumulation.

ix) The negative of the standard heat of combustion of a fuel with H_2O (1) 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 enthalpy change for the reaction $C(g) + \frac{1}{2}O_2(g) = CO(g)$ and $CO(g) + \frac{1}{2}O_2(g) = CO_2(g)$ are 26·42 and – 67·63 kcal respectively. Then the enthalpy change for the reaction $C(g) + O_2(g) = CO_2(g)$ is

a) + 94·05 kcal b) – 94·05 kcal

c) – 41·21 kcal d) + 41·21 kcal.

xi) Heat of reaction is a function of the

a) pressure b) temperature

c) neither (a) nor (b) d) both (a) and (b).

xii) Heat of .... of a fuel is called its calorific value.

a) formation b) reaction

c) combustion d) vaporization.

GROUP – B

(Short Answer Type Questions)

Answer any *three* of the following $3 \times 5 = 15$

2. A flue gas has the following composition by volume measured at 760 mm Hg and 30°C. CO_2 = 25%, CO = 0·2%, SO_2 = 1·2%, N_2 = 68% and O_2 = 5·6%. Calculate (i) the average molecular weight, (ii) the composition by weight.

3. Calculate the volume in liters of NH3 gas under a pressure of 1 atm and at a temperature of 20°C that can be dissolve in 100 litres of water at the same temperature.

   Data : for ammonia and water at 20°C, Henry's constant is 2·7 atm/mole fraction.

4. A producer gas made from coke has the following composition by volume CO - 28%, CO_2 - 3·5%, O_2 - 0·5% and N_2 - 68%. The gas is burned with such a quantity of air that the oxygen from the air is 20% in excess of the net oxygen required for complete combustion. If the combustion is 98% complete calculate the weight and composition in volumetric percentage of the gaseous products formed per 100 kg of gas burned.

5. Using Antoine equation, calculate the vapor pressure of

   (i) Acetic acid at 316 K and (ii) SO_3 at 293·5 K

   P* is in mm of Hg; and T is in K

	A	*B*	*C*
Acetic acid	15·8667	4097·86	– 27·4937
SO_3	13·8467	1777·66	– 125·1972

6. Find the heat of formation of chloroform ($CHCl_3$) from the following data :

$$H_2(g) + \tfrac{1}{2}O_2(g) = H_2O(1) \qquad \Delta H_1 = -68317\cdot4 \text{ cal}$$

$$C(\beta) + O_2(g) = CO_2(g) \qquad \Delta H_2 = -94051\cdot8 \text{ cal}$$

$$\tfrac{1}{2}H_2(g) + \tfrac{1}{2}Cl_2(g) = HCl(aq) \qquad \Delta H_3 = -40023 \text{ cal}$$

$$CHCl_3(g) + \tfrac{1}{2}O_2(g) + H_2O(aq)$$

$$= CO_2(g) + 3HCl(aq) \qquad \Delta H_4 = -121800 \text{ cal}$$

GROUP – C

(Long Answer Type Questions)

Answer any *three* of the following. 3 × 15 = 45

7. a) Describe the Buckingham method for forming dimensionless groups.

b) The efficiency η of a fan depends on density ρ, dynamic viscosity μ of the fluid, angular velocity ω, diameter D of the rotor and the discharge Q. Express η in terms of dimensionless parameter. 5 + 10

8. a) 50,000 m^3/h of a gas mixture containing 5·46% NO_2, 2·14% N_2O_4, rest N_2 on dry basis enters the bottom of an absorption tower (percentages represent mole%). 500 l/min caustic soda solution (density 1·25 kg/l) containing 24% by mass NaOH is introduced at the top of the column. The outgoing gas is found to contain 3·93% NO_2, 0·82% N_2O_4, 0·25% NO and rest N_2 on dry basis. The temperature and pressure of the gas are 295·5 K and 100 KPa. Calculate the composition of the aqueous liquor leaving the column. Assume that the gas mixture leaving the tower contains 0·045 Kmol H_2O/Kmol dry gas mixture.

b) A continuous countercurrent dryer is used to dry 425 kg dry solid/hr containing 0·04 kg total moisture/kg dry solid to a value of 0·018 kg total moisture/kg dry solid. The solid enters at 25°C and leaves at 60°C.

Air used as heating medium enters at 84°C with a humidity of 0·018 kg water/kg dry air and leaves at 33°C. Calculate the air flow rate and the outlet humidity assuming that heat losses from the dryer are 9300 KJ/hr. The heat capacity of the dry solid is 1·465 KJ/kg K. Humid heat in KJ/kg dry air is given as : Cs = 1·005 + 1·88 H and latent heat water at 0°C is 2501 KJ/kg. Draw the process flow diagram. For the air-water vapour mixture, if the dry and wet bulb temperatures are 65°C and 35°C, compute the humidity and corresponding humid volume of air using psychometric chart. (Psychometric chart required) 8 + 7

9. Fuel oil having the formula $C_{18}H_{36}$ is burnt in 50% excess dry air. The products of the combustion are dried to remove all the water. Analysis of the flue gas shows a molar ratio of CO_2 to CO of 2. Determine the flue gas compositions and volumetric flow rate with molar density at 1368 K and 124·1 KPa after drying if 2268 kg/hr of the fuel oil is burnt. The volume of 1 kg-mol flue gas is 12·83 m^3.

$$C_{18}H_{36} + 27O_2 \longrightarrow 18CO_2 + 18H_2O$$

$$C_{18}H_{36} + 18O_2 \longrightarrow 18CO + 18H_2O$$

10. a) A fertilizer plant produces ammonia by reforming naptha with steam. The synthesis gas, obtained from the methanator is passed through the converter after mixing with the recycle steam. The conversion per pass is limited to 25%. The composition of fresh feed is CH_4 - 0·7%, Ar - 0·3%, H_2 - 74·25% and N_2 - 24·75% on molar basis. The converter outlet gases pass through a heat exchanger where it cools down. Later the gases are passed through a chiller-cum-separator which separates 65% of the ammonia present in the converter outlet gas. Noncondensible gases and uncondensed gas are recycled back. In order to limit the concentration of inerts, to (CH_4 + Ar) 10 mol% in the mixed feed, a portion of the recycle steam is purged. Based on a fresh feed rate of 100 K mol/s, calculate the

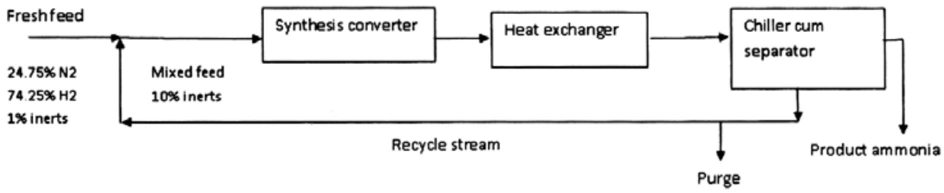
i) recycle feed rate and recycle ratio

ii) the purge gas rate

iii) the product ammonia rate

iv) composition of various streams

The process flow sheet is as follows :



b) A small still is separating propane and butane at 135°C and initially contains 10 Kmol of a mixture whose composition is x = 0·3 (x = mole fraction of butane). Additional mixture $(x_F = 0 \cdot 3)$ is fed at the rate of 5 Kmol/hr. If the total volume of liquid in the still is constant, and the concentration of vapour from the still (x_D) is related to that of liquid in still by the relation

$$x_D = \frac{x_s}{1 + x_s}$$

How long will it take for x_s to change from 0·3 to 0·4 ?

10 + 5

11. a) The heat capacity of carbon monoxide is given by the following equations :

$$C_p = 6 \cdot 935 + 6 \cdot 77 \times 10^{-4} T + 1 \cdot 3 \times 10^{-7} T^2 \ ;$$

where C_p = cal/(gmol °C)

What is the enthalpy change associated with heating carbon-monoxide from 500°C to 1000°C.

b) The sulphate process for the production of HCl acid is described by the following reaction :

$$2NaCl + H_2SO_4 \Leftrightarrow Na_2SO_4 + 2HCl$$

Calculate the heat of reaction and the consumption of coke, over gas for production of 600 kg of HCl.

The heat of formation (MJ/kmol) is

$NaCl\ (-410 \cdot 9)$; $H_2SO_4(-811 \cdot 3)$; $Na_2SO_4(-1384 \cdot 0)$;

$HCl(-92 \cdot 3)$

The calorific value of the coke-oven gas is 19·0 MJ/m3.

7 + 8

=============