Name : .....

Roll No. : .....

Invigilator's Signature : .....

CS/B.TECH(BT & FT)(NEW)/SEM-4/CH-401/2012

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) Slope of straight line in the log-log plot can be expressed as

a) $(y_2 - y_1)/(\log x_2 - \log x_1)$

b) $\log(y_2 - y_1)/(\log x_2 - \log x_1)$

c) $(y_2 - y_1)/(x_2 - x_1)$

d) none of these.

(ii) A mathematical expression is represented by $y = 0 \cdot 68(0 \cdot 084)^x$. The type of graph paper fitted for this equation will be

a) rectangular b) log-log

c) semi-log d) none of these.

(iii) Graphical integration is more accurate when using

a) Rectangular rule b) Trapezoidal rule

c) Simpson's rule d) None of these.

(iv) Standard enthalpy of reaction is measured at

a) 303 K and 10 K Pa b) 303 K and 100 kPa

c) 298 K and 1 atm d) all of these.

v) The Molal Humidity to Absolute Humidity conversion factor is

a) 0·72 b) 0·52

c) 0·62 d) 0·064.

vi) Unit of enthalpy is

a) kJ / (kg. K) b) kJ/(kg mole. K)

c) kJ/K d) kJ.

vii) $C_{p_{mix}} = \sum x_i C_{p_i}$ $(1 < i < n)$

a) The component gases are inert to each other

b) At least one gaseous component is inert

c) Most of the components are inert

d) None of these.

viii) For 100% yield, selectivity is

a) 1 b) $\frac{1}{2}$

c) 0 d) ∞ .

ix) Ideal solution obeys

a) Boyles law b) Amagat's law

c) Raoult's law d) all of these.

x) Average molecular weight of a mixture of O_2 and other gases is calculated to be 23·2 using an incorrect value of 16 for the molecular weight of O_2 whereas the correct value of that is 29·6. What is the volume % of O_2 in the mixture ?

a) 40 % b) 60 %

c) 50 % d) 28 % .

xi) Purging operation is performed on recycled stream for

a) increasing yield

b) reducing the accumulation of inerts

c) conserving heat

d) improving efficiency.

xii) The actual flame temperature is less than adiabatic flame temperature. This is due to

a) loss of heat

b) incomplete combustion

c) energy expended for performing mechanical work and increasing external kinetic and potential energies

d) all of these.

xiii) An exothermic reaction takes place in an adiabatic reactor. The product temperature.....the reactor temperature.

a) is always equal to

b) is always greater than

c) is always less than

d) may be greater or less than.

xiv) The heat of reaction is

a) independent of temperature and pressure

b) independent of temperature but changes with pressure

c) independent of number of intermediate steps involved

d) independent of state of aggregation of the reactants and products.

xv) Proximate analysis of coal gives

a) carbon, hydrogen and ash

b) carbon, hydrogen, sulphur and nitrogen

c) volatile matter, moisture, ash and fixed carbon

d) volatile matter, moisture, nitrogen and carbon.

GROUP – B

(Short Answer Type Questions)

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

2. The average molecular weight of a flue gas sample (containing CO_2, N_2, O_2) is calculated by two different ways. In one way using the correct molecular weight of N_2 (28) the average molecular weight comes 30·08 and in another way using the incorrect value of molecular weight for N_2 (14) results the average molecular weight of the flue gas of 18·74. Calculate the volume percentage of CO_2, N_2 and O_2 in the flue gas.

3. Distinguish between graphical integration and graphical differentiation.

4. Write short note on any *one* of the following topics :

   i) Bypass operation

   ii) Recycle operation.

5. State Buckingham *Pi*-theorem with example.

6. Define heat of combustion, % of conversion, absolute humidity and relative humidity.

GROUP – C

(Long Answer Type Questions)

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

7. a) What do you understand by the term 'selectivity' ? Define limiting reactant and excess reactant in a chemical process with example. 2 + 2 + 2

   b) Estimate the consumption of 96% NaCl and 93% H_2SO_4 for the production of 600 kg HCl if the conversion is 95%. Also calculate the amount of Na_2SO_4 produced during process. HCl is produced according to the reaction—

   $$2NaCl + H_2SO_4 = Na_2SO_4 + 2HCl.$$

   Molecular weights of NaCl, H_2SO_4, Na_2SO_4 and HCl are 58·5, 98, 142 and 36·5, respectively. 9

8. a) The spent acid from a Nitrating process contains 37% H_2SO_4, 36% HNO_3 and 27% H_2O by weight. This acid is to be strengthened by the addition of conc. H_2SO_4 containing 95% H_2SO_4 and conc. HNO_3 containing 78% HNO_3. The strengthened mixed acid is to contain 40% H_2SO_4 and 43% HNO_3. Calculate the quantity of spent acid and the concentrated acids that should be mixed together to yield 1500 kg of the desired mixed acid. 5

b) Write the steps for material balance calculation. 5

c) Define enthalpy of water vapour-air mixture, dry bulb temperature, dew point, heat of the reaction, percentage of yield. 5

9. a) 1000 kg of Na_2CO_3 solution containing 25% Na_2CO_3 is subjected to evaporative cooling during which process 15% of the water present in the solution is evaporated. From the concentric solution Na_2CO_3, $10H_2O$ crystallizes out. Calculate how much crystals would be produced if the solubility of Na_2CO_3, $10H_2O$ is 21·5 gm per 100 gm of H_2O. 5

b) 1000 kg impure limestone containing 96% $CaCO_3$ and 4 % inert material is reacted with a H_2SO_4 acid solution containing 70% H_2SO_4 and 30% H_2O. The reacting mass is heated and all the CO_2 generated is driven off together with some of water vapour. The analysis of final solid mixture is as follows :

$CaSO_4 = 86 \cdot 54\%$, $CaCO_3 = 3 \cdot 11\%$, $H_2SO_4 = 1 \cdot 35\%$, $H_2O = 6 \cdot 23\%$, inerts = 2·77%.

Calculate :

i) the degree of completion of reaction

ii) mass of acid solution fed

iii) mass of gas driven off

iv) composition of gases driven off. 10

10. a) Calculate the heat of reaction for the esterification of ethyl alcohol with acetic acid if the standard heat of combustion are : ethyl alcohol = – 1366·91 kJ/mol, acetic acid = – 871·69 kJ /mol, ethyl acetate = – 2274·48 kJ/mol.

$$C_2H_5OH + CH_3COOH \longrightarrow C_2H_5COOCH_3 + H_2O$$ 7

b) For the following gas phase reaction, determine the heat of reaction at 800 K : 8

$$CO_2 + 4H_2 \longrightarrow 2H_2O + CH_4$$

The standard heats of formation are – 393·51 kJ/mol for CO_2, – 241·826 kJ/mol for H_2O and – 74·84 kJ/mol for CH_4. The constants in the heat capacity equation : $Cp = a + bT + cT^2$ are given below where Cp is in kJ /mol/K and T in K.

Components	a	$b \times 10^3$	$c \times 10^6$
CO_2	26·54	42·454	–14·2979
H_2	29·082	– 0·821	1·9917
CH_4	13·415	77·079	–18·7569
H_2O vapour	30·38	9·62	–1·19

11. a) Carbon monoxide and hydrogen reacts to give methanol : $CO + 2H_2 \longrightarrow CH_3OH$

The conversion of CO entering the reactor is only 20%. A feed stream consisting of 33% CO, 66·5% H_2 and 0·5% CH_4 is mixed with a recycle stream and send to a reactor. The methanol leaving the reactor is separated and the unconverted gases are recycled. To prevent the accumulation of methane and keep its concentration in the recycle stream at 3%, a portion of recycle stream is blown off. For 100 moles of fresh feed, determine the following :

(i) the moles of recycle stream

(ii) the moles of purge stream

(iii) the composition of purge stream

(iv) the moles of methanol produced. 8

b) Propane is burnt with excess air to ensure complete combustion. If 55 kg of CO_2 and 15 kg of CO are obtained when propane is completely burned with 500 kg air, determine the following :

(i) the mass of propane burnt

(ii) the per cent of excess air

(iii) the composition of flue gas. 7