MAULANA ABUL KALAM AZAD UNIVERSITY OF TECHNOLOGY, WEST BENGAL

Paper Code : CHE-302

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) An equation for calculating vapour pressure is given by $\log_{10} P = A - B/(t + C)$. This is called

a) Kistyakowsky equation
b) Antonie equation
c) Kopp's rule
d) Trouton's rule.

ii) Specific gravity on API scale is given by the relation

a) ${}^0API = 200\,(G - 1)$
b) ${}^0API = (141{\cdot}5/G) - 131{\cdot}5$
c) ${}^0API = (140/G) - 130$
d) ${}^0API = 145 - (145/G)$.

[Turn over

CS/B.TECH/CHE/ODD/SEM-3/CHE-302/2017-18

iii) A gas mixture contains 14 kg N_2, 16 kg O_2, 17 kg NH_3. The mole fraction of oxygen is

a) 0·16 b) 0·33
c) 0·66 d) 0·47.

iv) Which of the following ratios defines the recycle ratio in a chemical process ?

a) Gross feed stream / Recycle feed stream
b) Recycle stream / Fresh feed stream
c) Recycle stream / Gross feed stream
d) None of these.

v) 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.

vi) 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.

vii) The heat capacity of a solid compound may be determined theoretically using

a) Trouton's rule b) Kopp's rule
c) Amagat's law d) Henry's law.

viii) $C_p - C_v$ for a ideal gas is equal to

a) R b) $R/2$

c) $2R$ d) $3R$.

ix) Ideal gas law is applicable at

a) low T, low P b) high T, high P

c) low T, high P d) high T, low P.

x) Standard heat of a chemical reaction is

a) $[\ \Sigma \Delta H_f$ (products) $- \Sigma \Delta H_f$ (reactants) $]_{25^\circ C}$;

b) $[\ \Sigma \Delta H_f$ (products) $- \Sigma \Delta H_f$ (reactants) $]_{0^\circ C}$;

c) $[\ \Sigma \Delta H_f$ (reactants) $- \Sigma \Delta H_f$ (products) $]_{25^\circ C}$;

d) $[\ \Sigma \Delta H_f$ (reactants) $- \Sigma \Delta H_f$ (products) $]_{0^\circ C}$.

xi) Percentage saturation of a vapour bearing gas as compared to the relative saturation is

a) higher b) lower

c) equal d) uncertain.

xii) Which law states the statement 'the net heat change will be the same whether the chemical process occurs in one or in several stages' ?

a) Law of Lavoisier and Laplace

b) Hess's law

c) Both (a) and (b)

d) Neither (a) nor (b).

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 :
$CO_2 = 25\%$, $CO = 0{\cdot}2\%$, $SO_2 = 1{\cdot}2\%$, $N_2 = 68\%$ and $O_2 = 5{\cdot}6\%$. Calculate (i) the average molecular weight, (ii) the composition by weight.

3. Calculate the volume in litres of NH_3 gas under a pressure of 1 atm and at a temperature of 20°C that can be dissolved 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 :

$CO = 28\%$, $CO_2 = 3{\cdot}5\%$, $O_2 = 0{\cdot}5\%$ 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 vapour 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 :

$H_2(g) + \frac{1}{2} O_2(g) = H_2O(l)$ $\quad \Delta H_1 = -68317{\cdot}4$ cal

$C(\beta) + O_2(g) = CO_2(g)$ $\quad \Delta H_2 = -94051{\cdot}8$ cal

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

$CHCl_3(g) + \frac{1}{2} O_2(g) + H_2O(aq) = CO_2(g) + 3HCl(aq)$

$\Delta H_4 = -121800$ cal

GROUP – C

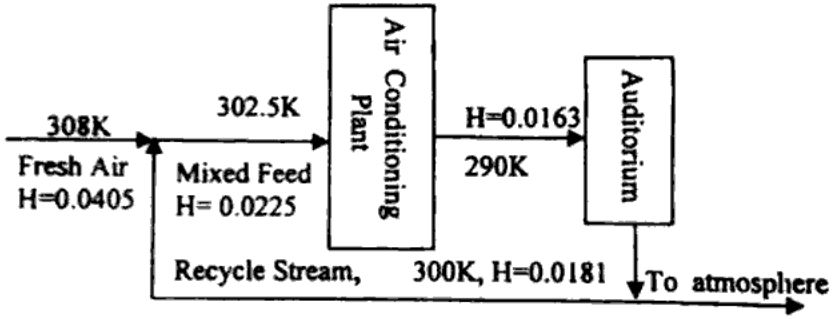
(Long Answer Type Questions)

Answer any *three* of the following. $3 \times 15 = 45$

7. a) State the Buckingham's π-theorem.

b) The diameter D of bubbles formed by a gas issuing from a small orifice beneath the surface of a liquid depends on the diameter (d) of the orifice, the properties of the liquid such as density (ρ), viscosity (μ), the surface tension (σ) as well as gravitational acceleration (g) : $D = f(d, \rho, \mu, \sigma, g)$. Find the dimensionless form of the governing equation using Buckingham's π-theorem. 3 + 12

8. a) An air-conditioning plant is employed to maintain 300 K dry bulb temperature and humidity 0·0181 kmol/kmol dry air in an auditorium. The air flow rate to the auditorium is measured to be 5·806 m^3/s. The effluent air from the auditorium is partially recycled and mixed with the incoming fresh air. The fresh ambient air flow rate is 1·25 m^3/s. Flow conditions of all streams are shown in the figure, where H is absolute humidity in kmol/kmol dry air. Calculate (i) the moisture removed in the air-conditioning plant, (ii) the moisture added in the auditorium, (iii) recycle ratio as moles of air recycled per mole of fresh air input. 10



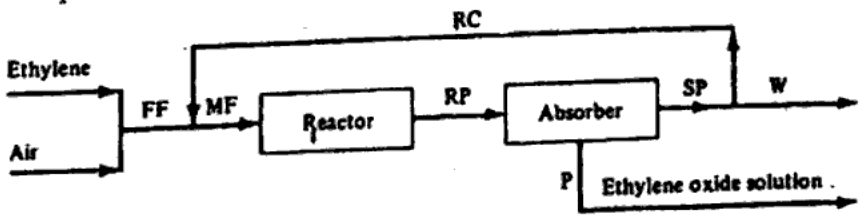
b) A solution of potassium dichromate in water contains 13% $K_2Cr_2O_7$ by weight. From 1000 kg of this solution, 640 kg of water is evaporated. The remaining solution is cooled to 20°C. Calculate the amount and the percentage yield of $K_2Cr_2O_7$ crystals produced. Solubility of K_2Cr_2O at 20°C = 0·39 kg-moles per 1000 kg of water.

[Atomic weight of K = 39 & Cr = 52] 5

9. a) Isothermal and isobaric absorption of SO_2 is carried out in a packed tower. The gases enter the bottom of the tower with 14·8% SO_2. Water is distributed at the top of the column at the rate of 1000 lt per minute. The total volume of the gas handled at 1 atm and 30°C is 1425 m^3/hr. The gases leaving the tower are tower are found to contain 1% of SO_2. Calculate the concentration of SO_2 in the outlet water in weight %.

b) 50 moles of liquid air is stored in a vessel at atmospheric 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 moles of liquid left in the vessel, when the residual liquid composition is 50 mole % nitrogen and 50 mole % oxygen. 8 + 7

10. The oxidation process for ethylene oxide production is depicted in the figure.



[Here *FF* = fresh feed, *MF* = mixed feed, *RP* = reactor product, *SP* = separator product & *W* = waste]

The reaction is $CH_2 = CH_2 + \frac{1}{2}O_2 \rightarrow CH_2 - CH_2$ (O)

Under steady-state condition, the analysis report shows that the composition of *W* is given as N_2 = 81·5%, O_2 = 16·5% and C_2H_4 = 2·0%.

If the recycle ratio (RC/W) is 3·0, compute the ethylene/air ratio in the fresh feed and the conversion on a once through basis.

11. a) For the following reaction of 1 kg mol of CH_4 at 101·32 kPa and 298 K,

$CH_4(g) + H_2O(l) \rightarrow CO(g) + 3\,H_2(g)$.

Calculate the standard heat of reaction ΔH_r° at 298 K in kJ.

Data : ΔH_f° of $CH_4(g) = -74{\cdot}848 \times 10^3$ kJ/kg-mol

ΔH_f° of $H_2O(l) = -285{\cdot}84 \times 10^3$ kJ/kg-mol

ΔH_f° of $CO(g) = -110{\cdot}523 \times 10^3$ kJ/kg-mol.

b) The waste gas from a process of 1000 g-mol/hr of CO at 473 K is burned at 1 atm pressure in a furnace using air at 373 K. The combustion is complete and 90% excess air is used. The flue gas leaves the furnace at 1273 K. Calculate the heat removed in the furnace.

$CO(g)) + \frac{1}{2}O_2(g) \rightarrow CO_2(g)$:

$\Delta H_r^{\circ} = -282{\cdot}989 \times 10^3$ kJ/kg mol

C_{pm} of CO = 29·38 kJ/kg-mol.K

C_{pm} of CO_2 = 49·91 kJ/kg-mol.K

C_{pm} of O_2 = 33·25 kJ/kg-mol.K

C_{pm} of N_2 = 31·43 kJ/kg-mol.K. 7 + 8