Industrial Stoichiometry
(CHEN 2104)

Time Allotted : 3 hrs | Full Marks : 70

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 5 (five) from Group B to E, taking at least one from each group.

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

Group – A
(Multiple Choice Type Questions)

10 x 1=10

1. Choose the correct alternatives for the following:

(i) A gas mixture contains 28 kg N_2, 16 kg O_2 and 17 kg NH_3. The volume fraction of oxygen in the mixture is:
a) 0.262 b) 0.20 c) 0.355 d) 0.25.

(ii) For the equation D (m) = **a** t (s) + b, the units of **a** are
a) m b) m / s c) s /m d) none of the above.

(iii) Air contains 21 mol% O_2 (mol. wt. = 32) and 79 mol% N_2 (mol. wt = 28). The average molecular weight of air is:
a) 29 b) 28 c) 25.24 d) 27.50.

(iv) Clausius – Clapeyron equation is valid when heat of vaporization of a substance:
a) is independent of temperature b) is dependent on temperature
c) is independent of pressure d) is dependent on pressure.

(v) Addition of a non-volatile solute to a solvent results in _____ of the solvent
a) freezing point elevation b) boiling point depression
c) vapour pressure lowering d) none of these.

(vi) 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 the above.

(vii) °API is given by
(a) $\frac{141.5}{G} - 131.5$ (b) $\frac{131.5}{G} - 141.5$
(c) $\frac{G}{141.5} - 131.5$ (d) none of the above.

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

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

(ix) A 'limiting reactant' is the one which decides the _____ of a chemical reac

a) equilibrium conversion
b) yield
c) selectivity
d) rate constant.

(x) In chemical process, the recycle stream is purged for

a) increasing the yield
b) enriching the product
c) limiting the inerts
d) energy conservation.

Group – B

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

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

Where, N is the speed of the pump in revolution per minute, D, the diameter of i g, the acceleration due to gravity, μ the viscosity of the fluid, ρ the density of t and H the head of fluid..

(b) Over a short temperature ranges, the viscosity of a liquid appears to follo relationship given by:

$$\mu = A \exp\left(\frac{B}{T}\right)$$

Determine the values of A and B from the following data for CCl_4.

T, (in K)	303	313	323	333	345
μ, (in mPa.S)	0.843	0.739	0.651	0.585	0.524

6+

3.(a) Calculate the composition of the vapours in contact with a solution at containing 35% benzene, 40 % toluene and 25 % orthoxylene by weight. pressures of benzene, toluene and o-xylene are respectively 1340, 560 and 210 m

(b) A vapour stream containing 65 mol % styrene and 35 mol % toluene is in equi with a liquid mixture of the same two species. The pressure in the system is 150 absolute. Use Raoult's law to estimate the composition of the liquid. For styrene toluene (t) the vapour pressures (P^0) in mm Hg are given by the equations:

$$\log P_s^0 = 7.06623 - \frac{1507.434}{T+214.985} \text{ and } \log P_t^0 = 6.95805 - \frac{1346.773}{T+219.693},$$

where, Temperature (T) is in ^0C

6+

Group – C

A solution of potassium dichromate in water contains 15% $K_2Cr_2O_7$ by weight. 1000 g of this solution is fed to a evaporator where it is cooled to 20° C after evaporation. If the yield of $K_2Cr_2O_7$ crystals is 80%, calculate the amount of water evaporated. [Solubility of $K_2Cr_2O_7$ at 20° C is 11.47 gm / 100 gm water]

2.5 m^3 of air initially at 50° C and 1 atm pressure with a molal humidity of 0.03 is compressed isothermally to 506.5 kPa and finally cooled to 21° C. Calculate the weight of water condensed and the final volume of air. [the vapour pressure of water at 50° C and 21° C are 12.34 and 2.49 kPa respectively]

6 + 6= 12

(a) In a continuous kraft pulp bleaching unit, 10% caustic soda (by wt) is required at a rate of 1.65 kg/s. The solution is prepared by introducing 50% caustic lye (by wt) and water continuously in a 1900 lit tank equipped with an agitator and withdrawing 10% NaOH solution continuously at desired rate. Suddenly, the inflow of caustic lye fails. Assuming that the volume of liquid in the tank is constant, calculate the time required for the effluent concentration to fall to 8% NaOH. Specific gravity of NaOH solution in the above concentration range may be assumed to be constant at 1.1.

(b) Air at a temperature of 30°C and a pressure of 100 kPa has a relative humidity 90%. Calculate:

i) the molar humidity of air.

ii) the molar humidity of air if its temperature is reduced to 15°C and pressure is increased to 200 kPa to condense some amount of water vapour from air.

iii) the weight of water condensed per 100 m^3 of original wet air.

[Vapour pressure of water at 30°C and 15°C are 4.24 kPa and 1.7 kPa respectively].

6 + (2+2+2) = 12

Group – D

(a) What is meant by yield and selectivity of a chemical reaction?

(b) The fresh feed to an ammonia production process contains 24.75 mole % nitrogen, 74.25 mole % hydrogen, and the balance inerts (I). The feed is combined with a recycle stream containing the same species, and the combined stream is fed to a reactor in which a 25% single-pass conversion of nitrogen is achieved. The products pass through a condenser in which essentially all of the ammonia is removed, and the remaining gases are recycled. However, to prevent build up of the inerts in the system, a purge stream must be taken off. The recycle stream contains 12.5 mole% inerts. Calculate the overall conversion of nitrogen, the ratio (moles purge gas/mole of gas leaving the condenser), and the ratio (moles fresh feed/mole fed to the reactor).

2 + 10 = 12

(a) Propane is dehydrogenated to form propylene in a catalytic reactor for a 95% overall conversion of propane. The overall reaction is $C_3H_8 \rightarrow C_3H_6 + H_2$. The output

10.(a) Calculate the standa
$C_2H_5OH(1) + C$
Heats of combustio
C_2H_5OH
CH_3COOH
$C_2H_5OOCCH_3$

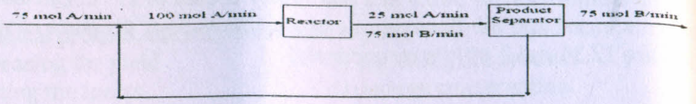
(b) Carbon monoxide a
air at 500° C in 90
combustion leave
evolved in the reac
burned assuming c
CO_2, O_2 and N_2 a
respectively.)

11.(a) 50 moles of liquid
leaks through the
conditions the relati
Calculate the mole
composition is 50 m

(b) When 1.0g of n
calorimeter, with al
being condensed, 4
value and the net h
C. The latent heat o

from the reactor is separated into two streams: one, the product which con
C_3H_6, and 0.555% of unreacted propane. The other contains the balanc
unreacted propane and 5% of the propylene formed and is recycled to the
Calculate the composition of the product, the ratio (moles recycled)/(moles fre
and the single-pass conversion.

(b) Find the overall and single pass conversion of A according to the scheme
below:



2+

Group – E

8.(a) Calculate the heat required to bring 150 mol / hr of a stream containing 60
and 40 % C_3H_8 by volume from 0°C to 400°C.
[For C_2H_6, $C_P = 0.04937 + 13.92 \times 10^{-5} T - 5.816 \times 10^{-8} T^2 + 7.280 \times 10^{-12} T^3$
For C_3H_8, $C_P = 0.06803 + 22.59 \times 10^{-5} T - 13.11 \times 10^{-8} T^2 + 31.71 \times 10^{-12} T^3$
Where, C_P is in kJ / mol. °C and T = temperature in °C]

(c) The standard heats of the following combustions reactions have been deter
experimentally. Use Hess's law to determine the heat of formation of ethane.
$C_2H_6 + 7/2\ O_2 \rightarrow 2CO_2 + 3H_2O$ $\Delta H_1 = -1559.8$ kJ / mol;
$C + O_2 \rightarrow CO_2$ $\Delta H_2 = -393.5$ kJ / mol;
$H_2 + 1/2\ O_2 \rightarrow H_2O$ $\Delta H_3 = -285.8$ kJ / mol.

6+

9.(a) Calculate the theoretical flame temperature of a gas containing 20% CO and
when burned with 100% excess air, both air and gas initially being at 25°C.
[Heat capacity (C_P) = a + b T + c T^2, Kcal / kmol. K]
The values of the coefficients for different materials are as follows:

Material	a	b x 10^3	c x 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^0_{298K}) = - 67636 kcal /mol

(b) A well stirred batch reactor wrapped in an electrical heating mantle is charged
liquid reaction mixture. The reactant must be heated from an initial temperat
25°C to 250°C before the reaction can take place at a measurable rate. Using th
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.
/Kg. °C; Heating rate(Q) = 500 W; [Negligible reaction and no phase change
heating. Negligible energy added to the system by the stirrer].

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CH (CHE)-30

BASIC ENVIRONMENTAL ENGINEERING A

Time Allotted: 3 Hours

The questions are of equ
The figures in the margin indic
Candidates are required to give their answers in th
All symbols are of usual s

GROUP A
(Multiple Choice Type

1. Answer any *ten* questions.

(i) The catalysts used in the Three Way type catalyt
(A) Pt + Pd (B) Pt + Pt
(C) Ru + Rh (D) Pt + R

(ii) Which one of the following is true for waste wat
(A) BOD > COD (B) COD >
(C) BOD = COD (D) BOD =

(iii) Water will be considered saline if the TDS value
(A) < 1500 mg/L; (B) > 5000
(C) < 500 mg/L; (D) none o