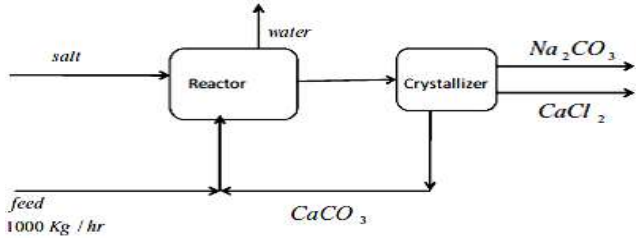
(b) In the given figure below, NaCl is fed to a reactor together with a solution of feed containing 90% $CaCO_3$ and 10% Na_2CO_3. 76% of $CaCO_3$ is converted. Unreacted $CaCO_3$ is recycled as shown in the figure. Calculate
(i) the kg of Na_2CO_3 exsiting the separator per 1000 kg of feed.
(ii) the kg of $CaCO_3$ recycled per 1000 kg of feed.



6 + 6 = 12

Group – E

8. (a) The standard heat of reaction at 298 K for the following reaction is -42.433 kJ.

C_2H_4 (g) + H_2O (g) = C_2H_5OH (g).

Calculate the heat of reaction at 400 K. The constants in the heat capacity equation are given below (C_P is in J/mol-K).

	α	$\beta\times10^3$	$\gamma\times10^6$
C_2H_4	11.85	119.75	-36.53
H_2O	30.38	9.62	1.19
C_2H_5OH	29.27	166.39	-49.93

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

$C_2H_6 + 7/2\ O_2 \rightarrow 2CO_2 + 3H_2O$ $\quad \Delta H_1 = -1559.8$ kJ / mol
$C + O_2 \rightarrow CO_2$ $\quad \Delta H_2 = -393.5$ kJ / mol
$H_2 + 1/2\ O_2 \rightarrow H_2O$ $\quad \Delta H_3 = -285.8$ kJ / mol

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

8 + 4 = 12

9. (a) Water is to be pumped from a reservoir to an overhead tank at 30 l/min. The overhead tank is situated 15 m above the ground. A heater puts 250 kW into the water during its transfer from reservoir to overhead tank. If the tank water temperature is to be kept at 10°C above the reservoir temperature what is the power required to drive the pump assuming the pump efficiency to be 60%. Given, heat capacity of water 4.184 kJ/kg K.

(b) Pure carbon monoxide is mixed with 50% excess air and completely burned at constant pressure. The reactants are fed to the furnace at 400K. Determine the rate of heat added to or removed from the furnace if carbon monoxide combustion rate is 42 kg/h. The standard heat of combustion of carbon monoxide at 298K is -283 kJ/mol. The mean specific heats in kJ/mol K applicable in the range of the problem are given for the following constituents carbon monoxide 29.1, oxygen 29.7, nitrogen 29.1 and carbon dioxide 41.45.

6 + 6 = 12

B.TECH/CHE/3RD SEM/CHEN 2104(BACKLOG)/2019

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)

1. Choose the correct alternative for the following: **10 × 1 = 10**

(i) The critical point for gas liquid transition is the point at which
(a) pressure of liquid and vapour become identical
(b) density of liquid and vapour become identical
(c) temperature of liquid vapour become identical
(d) none of (a), (b) and (c).

(ii) The mass flow rate of heptane with density ρ = 0.6g/cc is 7 g/s. What is the volumetric flow rate?
(a) 12 cc/sec (b) 720 cc/min (c) 11 cc/sec (d) both a and b.

(iii) Integrated Circuit Si etching can be usually represented by $d = 15(1-e^{-0.01t})$ where d is the depth of silicon etch in microns and t is the time of etch in seconds. The same expression with time expressed in minutes would be
(a) $d = 15(1-e^{-0.01t})$ (b) $d = 15(1-e^{-2t})$
(c) $d = 15(1-e^{-0.6t})$ (d) $d = 15(1-e^{-0.000167t})$.

(iv) A mixture of gases contain A and B in volume ratio 20:80. If ρ_A and ρ_B are 1.4 kg/m³ and 0.7 kg/m³, what is the w/w ratio of A:B?
(a) 1:2 (b) 22:78 (c) 2:1 (d) 80:20.

(v) Antoine's equation relates two variables for pure components. They are
(a) partial pressure and temperature (b) viscosity and temperature
(c) vapor pressure and temperature (d) density and temperature.

(vi) The vapour pressure of pure water at 100°C is
(a) 101 N/m² (b) 101 kN/m²
(c) 76 mm of Hg column (d) 760 mm of water column.

(vii) Heat of solution in a system in which both solute and solvent are liquid is termed as
(a) heat of solvation (b) heat of mixing
(c) standard integral heat of solution (d) heat of hydration.

(viii) The mass ratio of nitrogen to oxygen in air is closely equal to
(a) 2.52 (b) 2.83 (c) 3.35 (d) 3.76.

(ix) With rise in temperature, the solubility of gases in solvent at a fixed temperature
(a) increases (b) decreases
(c) remain unchanged (d) depends on the type of gas.

(x) If partial pressure of water vapour in air is less than its vapour pressure at the temperature of air, the relative humidity is
(a) 0 (b) in between 0 to 100 %
(c) 100 % (d) greater than 100%.

Group – B

2. (a) The diameter, d of bubbles produced by bubble-making toy depends on the soap water viscosity, μ density, ρ and the pressure differential Δp generating the bubbles. Use dimensional analysis to find the Π parameters that characterize this process.

(b) A gas containing 1 mol% ethane is in contact with water at 20 °C and 20 atm pressure.
(i) Estimate the mole fraction of dissolved ethane.
(ii) Define bubble and dew point temperature.

7 + (3 + 2) = 12

3. (a) Humid air at 75°C and 1 atm pressure and 30% relative humidity is fed into a unit at 500 m^3/hr.
(i) Determine the molar flow rate of dry air and water vapor entering the chamber. Assume ideal gas equation of state for wet air.
(ii) In the above problem, what is the molal humidity, absolute humidity and percentage humidity?

(b) What do you understand by 'degrees of superheat'? if you are given the mole fraction of vapor and the total pressure, how do you determine the degree of superheat?

(3 + 4) + 5 = 12

Group – C

4. (a) In a continuous kraft pulp bleaching unit, caustic soda is required at a concentration of 10% NaOH (by wt) and a flow rate of 1.65 kg/s. The solution is prepared by introducing 50% caustic lye (by wt) and diluted with water continuously in a 1900 lt tank, equipped with an agitator and withdrawing water continuously at desired rate of 10% NaOH. 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. Given, NaOH sp.gr. in the range of 10 to 8% concentration to be approximately constant at 1.1.

(b) 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. Given: the vapour pressure of water at 50°C and 21°C are 12.34 and 2.49 kPa respectively.

6 + 6 = 12

5. (a) Carbon dioxide is absorbed from a gas stream by counter-current flow of liquid absorbent solution in an absorption column that operates at 1atm pressure and 60°C. Feed gas enters the column at a volumetric flow rate of 15m^3/min with

carbon dioxide concentration of 12.5% by volume. Treated gas has carbon dioxide concentration of 2% by volume. Liquid solution is fed to the column at a rate of 30 kg/min with absorbent mass fraction of 35%. Determine the molar flow rate of feed gas. Also determine the exit liquid and gas flow rate. (Molecular weight of absorbent is 61)

(b) Atmospheric air at 35°C and 90% relative humidity (H_i = 0.033) is to be brought to 25°C and 60% relative humidity (H_f = 0.012) by cooling part of the air to 10°C (Humidity of saturated air 10°C is 0.0075) and mixing it with inlet air. The resulting mixture is heated to 25°C. For 60 m^3/hr of air at 25°C with relative humidity is 60%. Calculate the volumetric flow rate of fresh air and the fraction of incoming air passing through the cooler.

6 + 6 = 12

Group – D

6. (a) Given the reactions

$$CH_4 + \frac{3}{2}O_2 \rightarrow CO + 2H_2O$$
$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

The feed to the reactor contains 7.8 mole % methane and 19.4% oxygen with the remaining nitrogen. The percent conversion of methane is 85% and the gas leaving the reactor contains 9 moles CO_2 per mole of CO.
(i) Perform and atomic balance of C atoms.
(ii) Calculate the extent of reaction based on CO and CO_2.
(iii) Calculate the yield based on the reactant consumed.

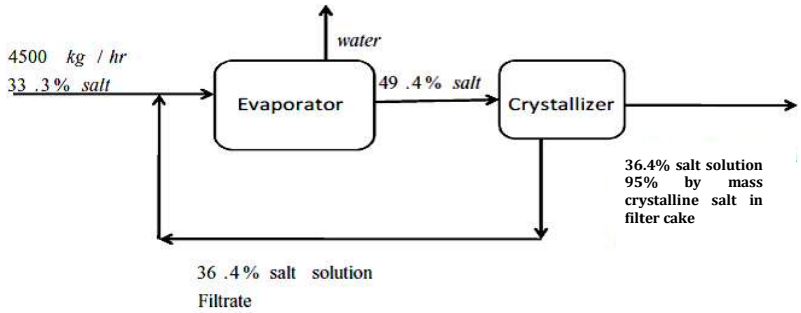
(b) Ammonia is reacted to form nitric acid in the reaction:

$$4NH_3 + 5O_2 \rightarrow xNO + yH_2O$$

(i) Ammonia is fed to the reactor at 100 kmol/hr. If 40% excess oxygen is provided, what is the flow rate of oxygen?
(ii) If 65 kg of ammonia is fed to a continuous reactor together with100 kg of oxygen, determine the limiting reactant.
(iii) Determine the percentage by which the other reactant is in excess.

(2 × 3) + (2 × 3) = 12

7.



The above figure shows the salt crystalline process through evaporation.
(i) Calculate the rate of evaporation in the evaporator.
(ii) Calculate the rate of production of crystalline salt.