BITS PILANI - DUBAI CAMPUS

Dubai International Academic City, Dubai, U.A.E.

II Year Chemical Engineering, II Semester 2010-11

Course Code: CHE C221 **COMPREHENSIVE EXAM** Date: 05.06.11

Course Title: Chemical Process Calculations Max Marks: 80

Duration: 3 hr (Closed Book) Weightage: 40%

Note: Attempt ALL questions. Write all assumptions and steps clearly.

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1. (a) The synthesis of NH_3 is according to reaction $N_2 + 3H_2 \rightarrow 2\ NH_3$. 4202 kg of N_2 and 1046 kg of H_2 are fed to synthesis reactor per hour. Production of NH_3 from this reactor is 3060 kg / hr. Calculate (8 m)
   i) Limiting reactant (2.5)
   ii) Percentage excess reactant (2.5)
   iii) Percentage conversion obtained (based on the limiting reactant) (3)

   (b) An ideal gas mixture contains 40% N_2, 30% CO and 30% H_2 by volume at P = 202.65 kPa (absolute) and 338 K. Calculate (8 m)
   i) the partial pr. of each component, (2.5)
   ii) the mass fraction N_2, (2.5)
   iii) MW_{avg} of the gas (3)

2.(a) A liquid hydrocarbon is fed in to a flash vaporizer where it is heated in to vapor and liquid streams. All the data are in wt%. The analysis of various streams is given below (8 m)

	Feed	vapour	liquid
C_4H_{10}	20	71.4	?
C_5H_{12}	30	23.8	31.6
C_6H_{14}	50	4.8	?
	100	100	100

Calculate i) Vapor to feed ratio (2.5 m)
ii) Composition of liquid product (2.5 m)
iii) Average molecular weight of vapor (3 m)

(b) A coal has ultimate composition C 67.34%, H_2 4.67%, O_2 8.47%, N_2 1.25%, and S 4.77% and the rest is ash. All are in wt %. Find the theoretical air-fuel ratio (kg air/kg fuel) (8 m)

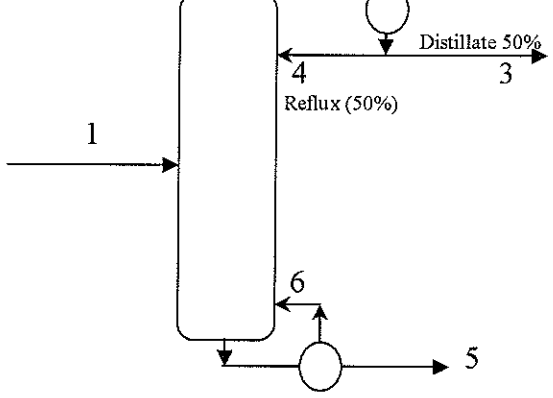
2. (c) Define the following, in terms of extent of the reaction

1) Overall conversion 2) Single pass conversion (2 marks each)

3. (a) A mixture containing 65 mole % acetone (Ac) and the balance acetic acid (AA) is separated in a continuous distillation column at 1 atm. The overhead stream from the column is a vapor that passes through a condenser. The condensed liquid is divided into two equal streams: one is taken off as the overhead product (distillate) and the other (the reflux) is returned to the column. The bottom stream from the column is a liquid that is partially vaporized in a reboiler. The liquid stream emerging from the reboiler is taken off as the bottoms product, and the vapor is returned to the column as boilup. Negligible heat is lost from the column, so that the only places in the system where external heat transfer takes place are the condenser and the reboiler. (12 m)

Stream Data:

Feed (1)	: Liquid, 67.5°C, 65 mol% Ac, 35% AA.
Overhead (2)	: Vapor, 63°C, 98 mole% Ac, 2% AA
Distillate (3) and Reflux (4)	: Liquid, 56.8°C, 98 mole% Ac, 2%AA
Bottoms (5)	: Liquid, 98.7°C, 15.5 mole% Ac, 84.5% AA
Boilup (6)	: 98.7°C, 54.4 mole % Ac, 45.6% AA



Distillation Column

Thermodynamic data

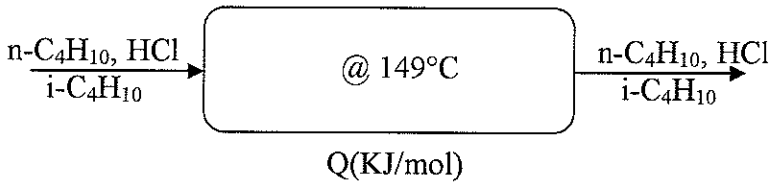
H (Cal/mol)				
	Acetone		Acetic Acid	
T (C)	$H_{(L)}$	$H_{(V)}$	$H_{(L)}$	$H_{(V)}$
56.8	0	7205	0	5723
63	205	7322	194	6807
67.5	354	7403	335	6884
98.7	1385	7946	1312	7420

Taking 100 mol of feed as a basis, calculate

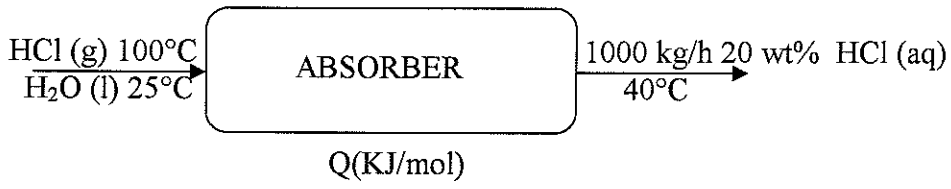
- Overhead products (2)
- Bottom Products (2)
- The net heat requirement (cal) for the process (3)
- The amount of heat removed from condenser (3)
- The amount of heat added to reboiler (2)

3. (b) n-Butane is converted to isobutene in a continuous isomerization reactor that operates isothermally at 149°C. The feed to the reactor contains 93 mol% n-butane, 5% isobutene, and 2% HCl at 149°C and a 40% conversion of n-butane is achieved. Taking a basis of 1 mol of feed gas, calculate (8 m)

- The extent of the reaction, ξ (2)
- The std heat of the reaction (KJ/mol) (3)
- The required heat transfer rate (kW) for a reactor feed of 300 mol/hr (3)



4. (a) Hydrochloric acid (mw: 36.5) is produced by absorbing gaseous hydrogen chloride in water. Calculate the heat that must be transferred to or from an absorption unit if HCl(g) at 100°C and H_2O at 25°C are fed to produce 1000 kg/h of 20 wt% HCL(aq) at 40°C.
Data: ΔHs (25°C, r =8.1) = -67.4 KJ/mol, Cp = 0.557 KJ/mol HCl °C (8 m)



4. (b) Determine specific enthalpy (KJ/mol NaOH) of NaOH containing 1 mol NaOH/5 mol H_2O at 25°C relative to : (4 m)

- NaOH (s) and H_2O (l) at 25°C
- H_2O (l) and an infinitely dilute HCl solution at 25°C

5. (a) Mention the applications of humidity chart for various operations. (4 m)

5. (b) Humid air is enclosed in a 2 liter flask at 40°C. The flask is slowly cooled to wet bulb temperature of 25.5°C. Although the pressure in the flask changes when the temperature drops, it remains close enough to 1 atm. Using psychrometric chart determine relative humidity, moisture content and the mass of dry air. (8 m)

BITS PILANI, DUBAI CAMPUS

Dubai International Academic City, Dubai, U.A.E.

II Year Chemical Engineering, II Semester 2010-11

Course Code: CHE C221 **Test 2** Date: 17.04.11

Course Title: Chemical Process Calculations Max Marks: 20

Duration: 50 minutes (Open Book) Weightage: 20%

Note : only prescribed text book and own handwritten notes are allowed, physical and chemical property tables are allowed

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1. Acrylonitrile is produced in the reaction of propylene, ammonia and oxygen:

$$C_3H_6 + NH_3 + 3/2\ O_2 \rightarrow C_3H_3N + 3H_2O$$

The feed contains 10 mole% propylene, 12% ammonia and remaining is air. A fractional conversion of 30% of the limiting reactant is achieved. Taking 100 mol of feed as a basis, determine which reactant is limiting, percentage by which each of other reactants is in excess, and the molar amounts of all product gas constituents for a 305 conversion of the limiting reactant. (6 m)

2. Mention the reasons for using recycle in a process (3 m)

3. The dry flue gas has CO_2 11.2%, O_2 5.8%, and rest is N_2. Calculate % excess air and weight of air per kg oil fired. Fuel has C 82%, H 12%, S 3%, and rest impurities in wt%. (5 m)

4. Calculate the heat of reaction at 25°C for the reaction (2 m)

$$Na_2CO_3 + Fe_2O_3 \rightarrow Na_2O\ Fe_2O_3 + CO_{2(g)}$$

Thermodynamic data: ΔH_f° $Na_2O\ Fe_2O_3$ - 337.3 Kcal/g mol

5. Benzene vapor at 580°C is cooled and converted to a liquid at 25c in a continuous condenser. The condensate is drained into 1.75 m^3 drums, each of which takes 2 minutes to fill. Calculate the rate (kW) at which heat is transferred from the benzene in the condenser. (4 m)

BITS PILANI, DUBAI CAMPUS

Dubai International Academic City, Dubai, U.A.E.

II Year Chemical Engineering, II Semester 2010-11

Course Code: CHE C221 **Test 1** Date: 27.02.11

Course Title: Chemical Process Calculations Max Marks: 25

Duration: 50 minutes (Closed Book) Weightage: 25%

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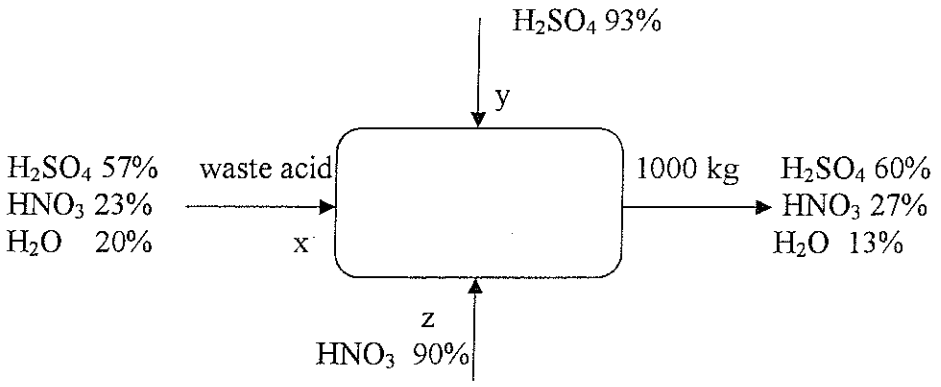
1. Two liquid streams are flowing at constant rates into a blender. One is benzene, which flows at a measured rate of 20 l/min, and the other is toluene. The blended mixture enters a storage tank and found 35640 lit after an hour; during this interval no liquid leaves the storage tank. Calculate the flow rate of toluene into the blender (L/min) and the composition of the tank contents (wt% benzene). Assure additive volumes. (ρ_T = 0.866 g/ml; ρ_B = 0.879 g/ml) (5 m)

2. The volume of a dry box (a closed chamber with dry nitrogen flowing through it) is 2 m^3. The dry box is maintained at a slight positive gauge pressure of 10 cm H_2O and room temperature of 25°C. If the contents of the box are to be replaced every 5 min, calculate the required mass flow rate of nitrogen in g/min by a direct solution of the ideal gas equation of state. (10.33 m H_2O = 1 atm, MW = 28.02, R = 0.08206 L atm/mol K) (5 m)

3. The waste acid from a nitrating process containing HNO_3 23%, H_2O 20%, by weight. This acid is to be concentrated to contain 27% HNO_3, 60% H_2SO_4 by the addition of H_2SO_4 93% and HNO_3 90%. Calculate the weight of waste acid and concentrated acids that must be combined to obtain 1000 Kg of desired mixture. (10 m)
(Note: Not to use programming calculator)



4. A stream of air (21 mol% O_2, 79 mol % N_2) flowing at a rate of 10 kg/h is mixed with a stream of CO_2. The CO_2 enters the mixer at a rate of 20 m^3/h at 150°C and 1.5 bar. What is the mole percent of CO_2 in the product stream? (Assume ideal gas behavior, R = 8.314 m^3 Kpa/kmol K; 1 bar = 100 Kpa) (5 m)

BITS PILANI, DUBAI CAMPUS

Dubai International Academic City, Dubai, U.A.E.

II Year Chemical Engineering, II Semester 2010-11

Course Code: CHE C221 **Quiz 2** Date: 03.05.11

Course Title: Chemical Process Calculations Max Marks: 07

Duration: 20 minutes (Closed Book) Weightage: 07%

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1. A 100-hp engine is used to pump sodium hydroxide into a reactor. Calculate the rate at which the pump is doing work in J/s. (1 m)

2. An ideal gas in a tank at 500°C and 100 kPa is compressed isothermally to 1000 kPa. What was the work (in J/g mol) of compression? (1.5 m)

3. Lead is used in a number of manufacturing industries. To prevent lead vapor from escaping from a molding unit, the vapors from the unit are passed through a chilling unit to condense the lead vapor. What is the enthalpy change per kg mol of lead if the lead vapor entering the chiller is at 1850°C and the product of the chiller is solid lead at 280°C. (4.5 m)

   Data:

   Melting point of lead: 327.4°C

   Boiling point of lead: 1744°C

   Heating capacity data: J/(g mol)(K) with T in K:

   Solid : 24.1 + 0.049 T

   Liquid : 6.8

   Vapor : 20.8

   Heat of fusion: 5.121 kJ/g mol

   Heat of vaporization: 175.98 kJ/g mol

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II Year Chemical Engineering, II Semester 2010-11

Course Code: CHE C221 **Quiz 1** Date: 22.03.11

Course Title: Chemical Process Calculations Max Marks: 08

Duration: 20 minutes (Closed Book) Weightage: 08%

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1. What is the unit for concentration (1 m)

   a) PPM b) PPB c) both (a) & (b) d) none

2. An equimolar liquid mixture of liquid A and liquid B is in equilibrium with its vapour at 500 K. At this temperature, the vapour pressures of the species are P_1^{sat} = 100 kPa and P_2^{sat} = 130 kPa. Assuming that Raoult's law is valid. Determine the mole fractions of vapor mixture. (3 m)

3. Reduced parameter is defined as the ratio of existing parameter of substance to its _____, both being expressed on the absolute scale. (parameter may be temperature, pressure, volume) (1 m)

4. The _____ is a vapor pressure equation and describes the relation between vapor pressure and temperature for pure components. (Antoine, Raoult's law, Henry's law, Dalton's law, Amagat's law,) (1 m)

5. The dew point and bubble point mean the same thing as _____ and _____ (none, saturated vapor, boiling point, saturated liquid, melting point, none) (1 m)

6. A steel tank having a capacity of 25 m^3 holds carbon dioxide at 30°C and 1.6 atm. Calculate the weight, in grams, of the carbon dioxide. (1 m)