University of Baghdad	**Final Examination**	**Date: 7/6/2008**
College of Engineering	**First Attempt**	**Time: 3 hr**
Chem. Eng. Dept.	**Chem. Eng. Principles**	**First Year**

Answer Five Questions only

Q.1

(A) Five pounds of bismuth (MW=209) is heated along with one pound of sulfur (MW=32) to form Bi_2S_3 (MW=514). Determine

$$2\,Bi + 3\,S \longrightarrow Bi_2S_3$$

1. The limiting reactant. 2. The percent excess reactant.

(B) A vessel contains air: N_2 (g), O_2 (g), and Ar (g).

1. How many phases, components, and degrees of freedom are there according to the phase rule?
2. Repeat for a vessel one – third filled with liquid ethanol and two – thirds filled with N_2 plus ethanol vapor.

Q.2

All the concentrations shown in Figure Q.2 of both gases and liquids are specified in weight percent. Calculate A, F, W, B, and D in kg/hr.

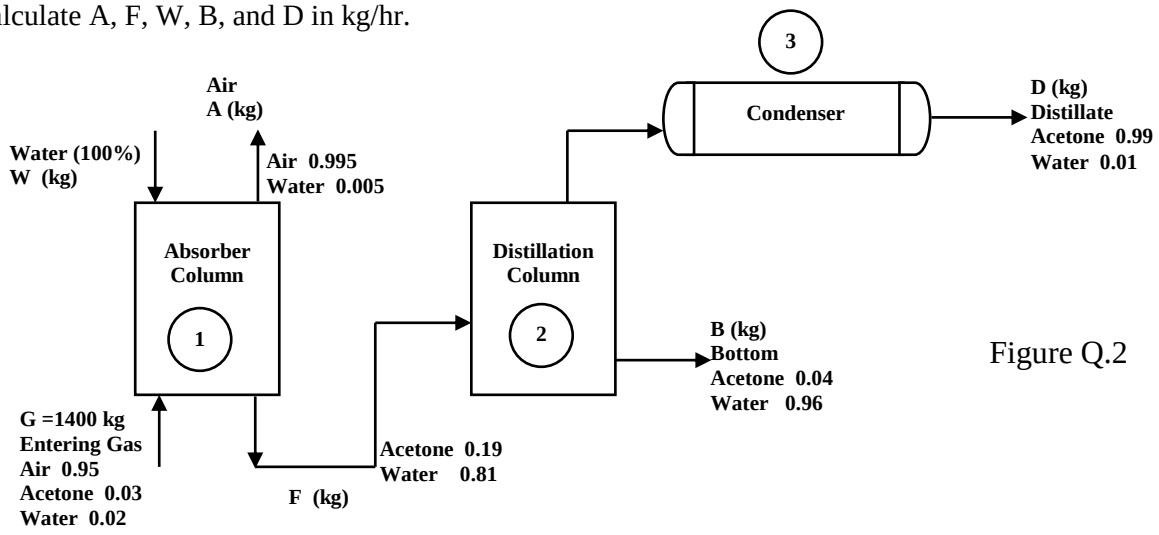


Figure Q.2

Q.3

A synthetic gas generated from coal has the following composition: CO_2 7.2% ; CO 24.3% ; H_2 14.1% ; CH_4 3.5% ; N_2 50.9%. (See Figure Q.3)

(a) Calculate the cubic feet of air necessary for complete combustion per cubic foot of synthetic gas at the same conditions (V_{Air}/V_{Feed}).

(b) If 38% excess air were used for combustion, what volume of flue gas at 750 ^oF and 738 mm Hg would be produced per cubic foot of synthetic gas at standard conditions ($V_{prod.}/V_{Feed}$).

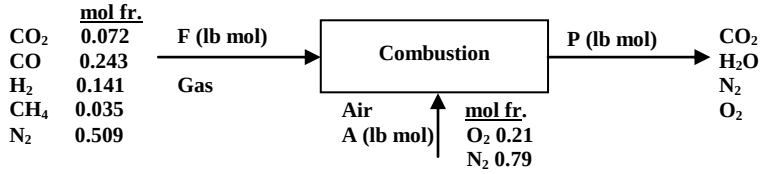


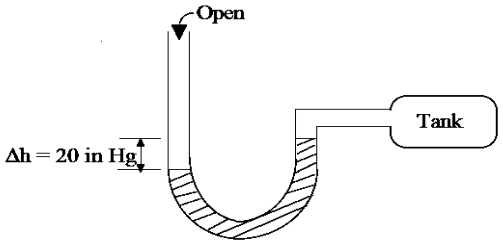
Figure Q.3

Q.4

(A) A gas containing nitrogen, benzene, and toluene is in equilibrium with 40 mole% benzene and 60 mole% toluene liquid mixtures at 100 ^oC and 10 atm. Estimate the gas phase composition (mole fractions) using Raoult's law. (1 atm = 760 mm Hg)

Antoine equation constants	A	B	C	Pressure (mm Hg) Temperature (K)
Benzene	15.9008	2788.51	- 52.36	
Toluene	16.0137	3096.52	- 53.67	

(B) The barometer reads 740 mm Hg. Calculate tank pressure in psia. (Conversion factors: 1atm = 760 mmHg, 1 atm = 29.92 in. Hg, 1 atm = 14.7 psia)



Q.5

As shown in Figure Q.5, the fresh feed of gas composed of 75.16% H_2, 24.57% N_2, and 0.27% Ar is mixed with the recycled gas and enters the reactor with a composition of 79.52% H_2. The gas stream leaving the ammonia separator contains 80.01% H_2 and no ammonia. The product ammonia contains no dissolved gases. Per 100 moles of fresh feed:

1. How many moles are recycled and purged?
2. What is the percent conversion of hydrogen per pass?

$$3\,H_2 + N_2 \longrightarrow 2NH_3$$

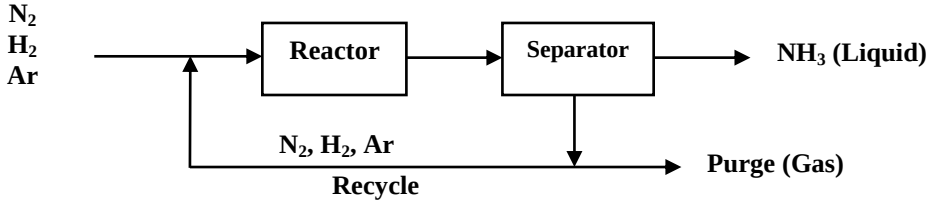


Figure Q.5

Q.6

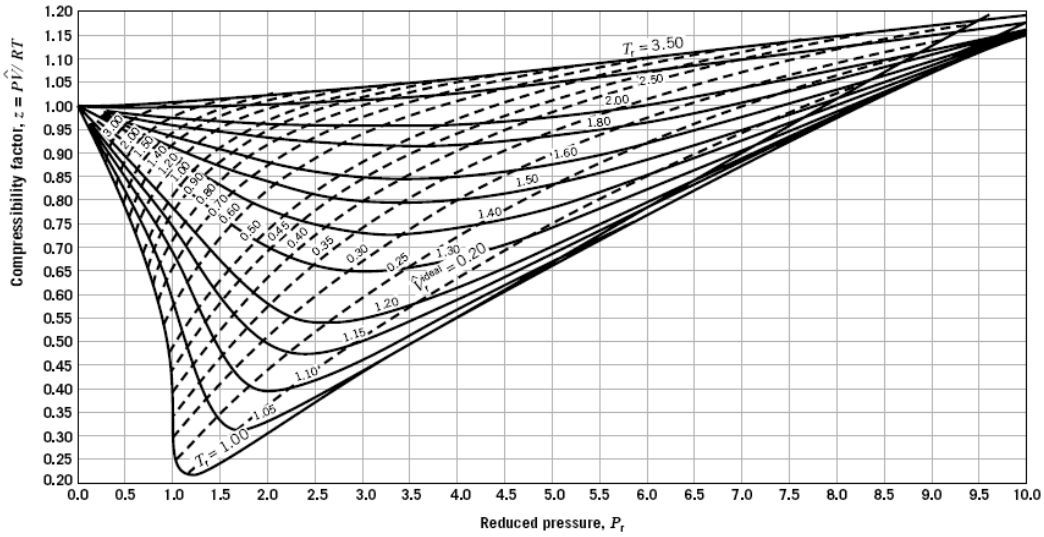
(A) A solution has a specific gravity of 1.075 and contains 12.7 wt% sugar. If all the sugar is assumed to be $C_{12}H_{22}O_{11}$, determine

1. kg sugar/kg H_2O 2. lb solution/ft^3 solution 3. g sugar/L solution

(Conversion factors: 1lb = 454 g, 1 L = 1000 cm^3, 1 ft^3 = 30.48 cm and density of H_2O = 1 g/cm^3)

(B) A gas consists of 20 mole% CH_4, 30% C_2H_6, and 50% C_2H_4. Ten kilograms of this gas is to be compressed to a pressure of 200 bar at 90 ^oC. Using Kay's rule, estimate the final volume of the gas. (Gas constant = 0.08314 (m^3.bar)/(kgmol.K), MW: CH_4 = 16.04, C_2H_6 = 30.07, C_2H_4 = 28.05 and 1atm = 1.01325 bar)

Additional Data	CH_4	C_2H_6	C_2H_4
T_c (K)	190.7	305.4	283.1
P_c (atm)	45.8	48.2	50.5



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June / 2008

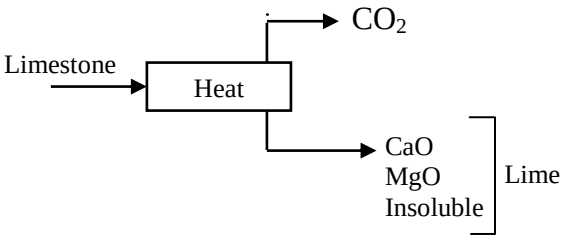
Answer Five Questions only

Q.1

A limestone analysis $CaCO_3$ 92.89%, $MgCO_3$ 5.41% and insoluble 1.7%

a. How many pounds of calcium oxide can be made from 5 tons of this limestone?
b. How many pounds of CO_2 can be recovered per pound of limestone?
c. How many pounds of limestone are needed to make 1 ton of lime?

(Mol. weight: $CaCO_3$ 100.1, $MgCO_3$ 84.32, CaO 56.08, MgO 40.32, CO_2 44 and 1 ton = 2000 lb)



$$CaCO_3 \longrightarrow CaO + CO_2$$
$$MgCO_3 \longrightarrow MgO + CO_2$$

Q.2

(A) Pure carbon is burned in oxygen. The flue gas analysis is: CO_2 75 mol%, CO 14 mol% and O_2 11 mol%. What was the percent excess oxygen used?

(B) A crystallizer contains 6420 lb of aqueous solution of anhydrous sodium sulfate Na_2SO_4 (concentration 29.6 wt %) at 104 °C. The solution is cooled to 20 °C to crystallize out the desired Na_2SO_4.10 H2O. The remaining solution (the mother liquor) is found to contain 16.1 % anhydrous sodium sulfate. What is the weight of this mother liquor? (Mol. Wt. Na_2SO_4 = 142 and H_2O = 18).

Q.3

Immobilized glucose isomers is used as a catalyst in producing fructose from glucose in a fixed bed reactor (water is the solvent). For the system shown in Figure Q.3, what percent conversion of glucose results on one pass through the reactor when the ratio of the exit stream to the recycle stream in mass unit is equal to 8.33?

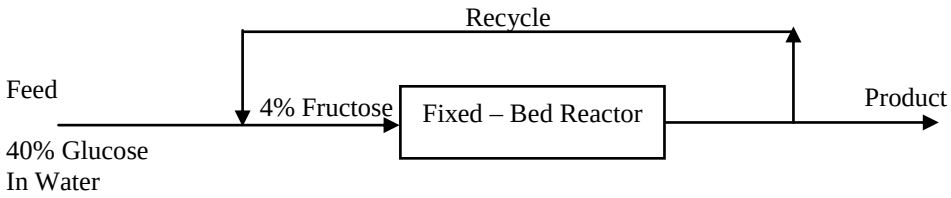
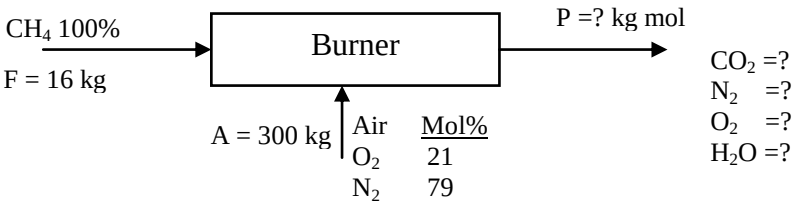


Figure Q.3

Q.4

(A) Figure Q.4 shows a simple combustion process, calculate the P and the four composition in P: x_{CO2}, x_{N2}, x_{O2} and x_{H2O}. (Mol. Wt. Air = 29 and CH_4 = 16)



(B) The specific heat capacity of toluene is given by following equation:

$C_p = 20.869 + 5.293 * 10^{-2} T$, where C_p is in Btu/ (lb mol) (^oF) and T is in ^oF. Express the equation in cal/ (g mol) (K) with T in K. (1 Btu = 252 cal and 1 lb = 454 g)

Q.5

(A) What is the minimum number of cubic meters of dry air at 20 ^oC and 100 kpa necessary to evaporate 6 kg of ethyl alcohol if the total pressure remains constant at 100 kpa and the temperature remains 20 ^oC? Assume that the air is blown through the alcohol to evaporate it in such a way that the exit pressure of the air alcohol mixture is at 100 kpa. {P^*alcohol at 20 ^oC = 5.93 kpa, Mol. Wt. ethyl alcohol = 46.07 and gas constant (R) = 8.314 (kpa) (m^3)/ (kg mol) (K)}

(B) A cylinder 0.15 m^3 in volume containing 22.7 kg of propane C_3H_8 (MW = 44) stands in the hot sun. A pressure gauge shows that the pressure is 4790 kpa gauge. What is the temperature of the propane in the cylinder? Use van der Waals equation. (a=9.24 * 10^6 atm(cm^3/g mol)^2, b=90.7 (cm^3/g mol), 1 atm=101.3 kpa, R = 82.06 cm^3 atm/ g mol K)

Q.6

20 ft^3 of nitrogen at 300 psig and 100 °F and 30 ft^3 of oxygen at 200 psig and 340 °F are injected into a 15 ft^3 vessel. The vessel is then cooled to 70 °F. Find the partial pressure of each component in the 15 ft^3 vessel. Assume that the ideal gas law applies. (R = 10.73 psia ft^3 / lb mol ^oR)

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September / 2008

Answer Five Questions only

Q.1

The two reactions of interest for this example are

$$Cl_2\,(g) + C_3H_6\,(g) \longrightarrow C_3H_5Cl\,(g) + HCl\,(g) \quad (1)$$
$$Cl_2\,(g) + C_3H_6\,(g) \longrightarrow C_3H_6Cl_2\,(g) \quad (2)$$

C_3H_6 is propylene (propene) (MW = 42.08), C_3H_5C1 is allyl chloride (3-chloropropene) (MW = 76.53), $C_3H_6Cl_2$ is propylene chloride (1,2—dichloropropane) (MW = 112.99)

The species recovered after the reaction takes place for some time are listed in Table.

species	Cl_2	C_3H_6	C_3H_5C1	$C_3H_6Cl_2$	HCl
g mol	141	651	4.6	24.5	4.6

Based on the product distribution assuming that no allyl chlorides were present in the feed, calculate the following:

a. How much Cl_2 and C_3H_6 were fed to the reactor in g mol?
b. What was the limiting reactant?
c. What was the excess reactant?
d. What was the fraction conversion of C_3H_6 to C_3H_5C1?
e. What was the selectivity of C_3H_5C1 relative to $C_3H_6Cl_2$?
f. What was the yield of C_3H_5C1 expressed in g of C_3H_5C1 to the g of C_3H_6 fed to the reactor?
g. What was the extent of reaction of the first and second reactions?

Q.2

(A) Cyclohexane (C_6H_{12}) can be made by the reaction of benzene (Bz) (C_6H_6) with hydrogen according to the following reaction:

$$C_6H_6 + 3H_2 \longrightarrow C_6H_{12}$$

For the process shown in Figure Q.2, determine the product stream and the ratio of the recycle stream to the fresh feed stream if the overall conversion of benzene is 95%, and the single-pass conversion is 20%. Assume that 20% excess hydrogen is used in the fresh feed, and that the composition of the recycle stream is 22.74 mol % benzene and 77.26 mol % hydrogen.

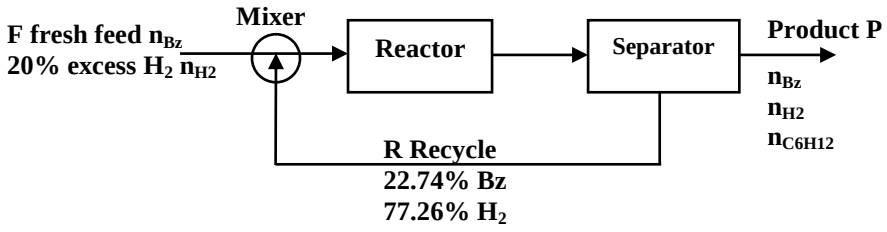


Figure Q.2

(B) Answer the following questions:

1. Distinguish between a steady-state and an unsteady-state process.
2. What is the difference between a semi-batch process and an open process?
3. Explain what dimensional consistency means in an equation.
4. What are g_c and specific volume?

Q.3

(A) An equimolar liquid mixture of benzene (B) and toluene (T) is in equilibrium with its vapor at 30°C. What are the system pressure and the composition of the vapor? (Using Raoult's law)

Antoine equation constants	**A**	**B**	**C**	Pressure (mm Hg) Temperature (K)
Benzene	15.9008	2788.51	- 52.36	
Toluene	16.0137	3096.52	- 53.67	

(B) A U-tube manometer filled with mercury is connected between two points in a pipeline. If the manometer reading is 26 mm of Hg, calculate the pressure difference in kPa between the points when (a) water is flowing through the pipeline, and (b) also when air at atmospheric pressure and 20°C with a density of 1.20 kg/m^3 is flowing in the pipeline. (density of H_2O = 1000 kg/m^3, density of Hg = 13550 kg/m^3, g = 9.81 m/s^2, 1 m = 1000 mm)

Q.4

(A) 40 gal/min of a hydrocarbon fuel having a specific gravity of 0.91 flows into a tank truck with a load limit of 40,000 lb of fuel. How long will it take to fill the tank in the truck? (density of H_2O = 1000 kg/m^3, 1 kg = 2.2 lb, 1 m^3 = 264.2 gal)

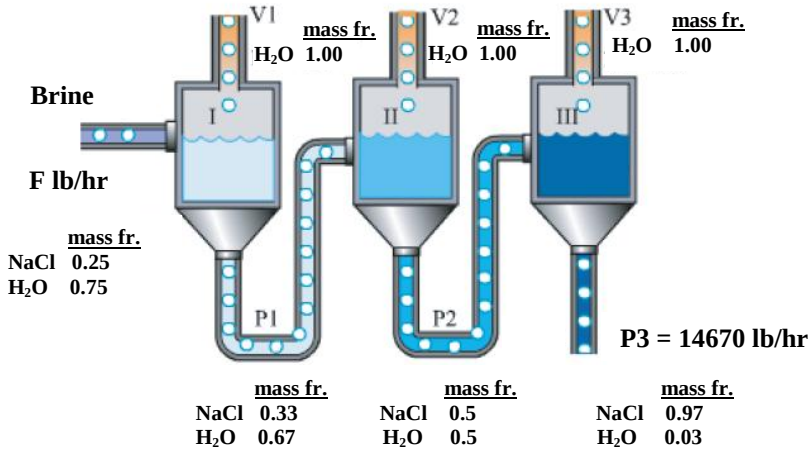
(B) 20 kg of C_3H_8 (MW: 44.09) is burned with 400 kg of air (MW: 29) to produce 44 kg of CO_2 and 12 kg of CO. What was the percent excess air?

Q.5

A triple effect evaporator is designed to reduce water from an incoming brine (NaCl + H_2O) stream. If the evaporator unit is to produce 14,670 lb/hr of NaCl, determine:

a. The feed rate of brine in lb/hr.
b. The water removed from the brine in each evaporator.

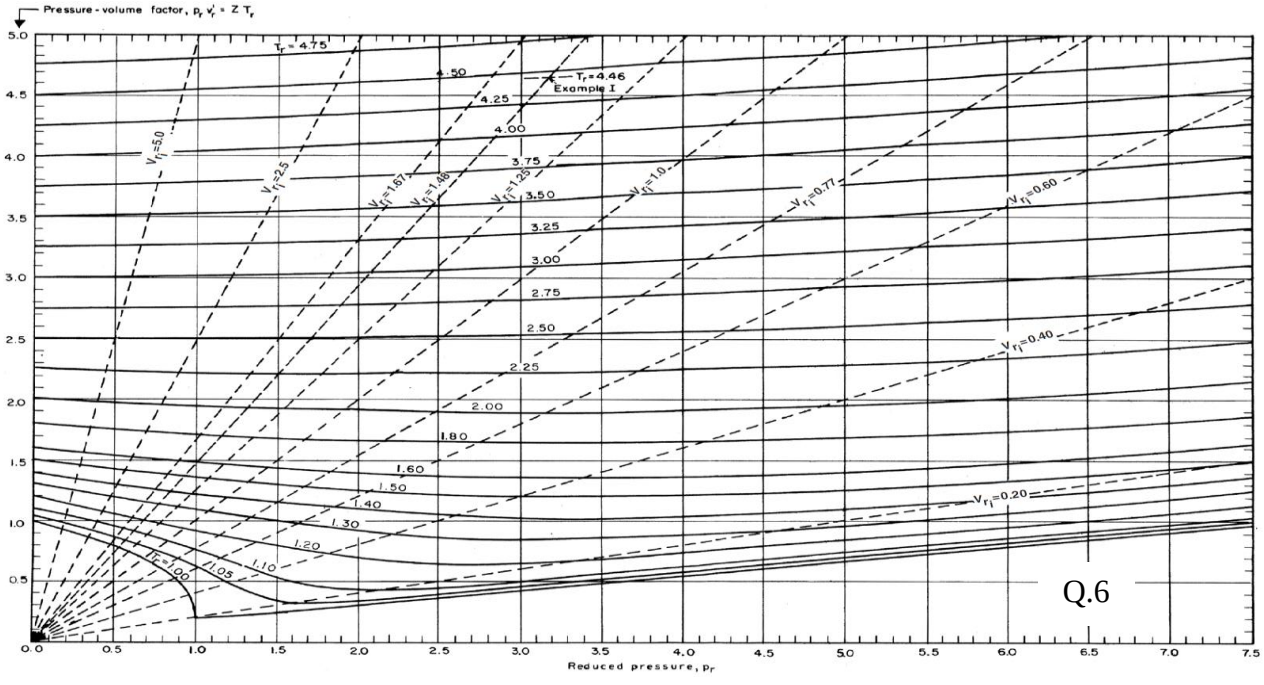
The data are shown in the accompanying figure.



Q.6

A gas analyzes 60% methane (MW: 16) and 40% ethylene (MW: 28) by volume. It is desired to store 12.3 kg of this gas mixture in a cylinder having a capacity of 5.14×10^{-2} m^3 at a maximum temperature of 45°C. Calculate the pressure inside the cylinder by (a) assuming that the mixture obeys the ideal gas laws; (b) using the compressibility factor determined by the pseudo critical point method. [R = 8.314 (kPa) (m^3)/(kg mol)(K), 1 atm = 101.3 kPa]

Additional Data	methane	ethylene
T_c (K)	190.7	283.1
P_c (atm)	45.8	50.5



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May / 2009

ملاحظة/ الاجابة على سبعة اسئلة فقط على ان يكون السؤال الخامس والسادس من ضمنها.

Q.1

A solution of HNO_3 in water has a S.G. of 1.10 at 25°C. The concentration of the HNO_3 (MW: 63.02) is 15 g/L of solution. What is the **1.** Mole fraction of HNO_3 in the solution? **2.** ppm of HNO_3 in the solution? (MW H_2O: 18.016, 1 L = 1000 cm^3, ρ_{H2O} = 1 g/cm^3)

Q.2

A medium – grade bituminous coal analyzes as follows:

Component	S	N	O	Ash	Water
wt%	2	1	6	11	3

The residuum is C and H in the mole ratio H/C=9. Calculate the mass fraction composition of the coal with the ash and the moisture omitted (MW: C=12 and H=1.008).

Q.3

Answer the following questions:

1. Explain why the so-called dimensionless group has no net dimensions. (give example)
2. How many ppb are there in 1 ppm?
3. What is the equation to convert gauge pressure to absolute pressure?
4. What is the difference between a semi-batch process and a closed process?
5. Methane burns with O_2 to produce a gaseous product that contains CH_4, O_2, CO_2, CO, H_2O, and H_2. How many independent element balances can you write for this system?

Q.4

Two well-known gas phase reactions take place in the dehydration of ethane:

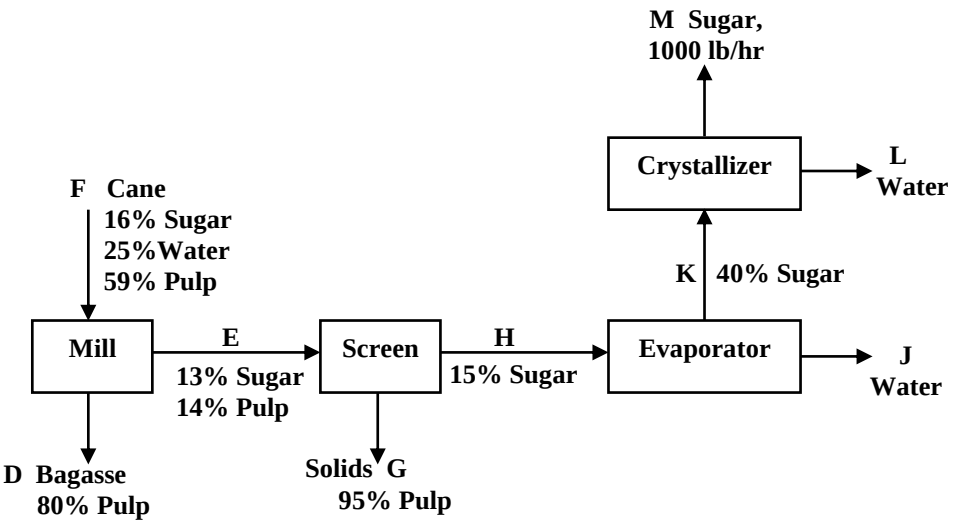
$$C_2H_6 \longrightarrow C_2H_4 + H_2$$
$$C_2H_6 + H_2 \longrightarrow 2CH_4$$

Given the product distribution measured in the gas phase reaction of C_2H_6 as follows: C_2H_6 27%, C_2H_4 33%, H_2 13%, and CH_4 27%

a. What species was the limiting reactant?
b. What species was the excess reactant?
c. What was the conversion of C_2H_6 to CH_4?
d. What was the selectivity of C_2H_4 relative to CH_4?
e. What was the extent of reaction of C_2H_6?

Q.5

Figure below shows the process and the known data. Calculate the compositions of every flow stream, and the fraction of the sugar in the cane that is recovered.

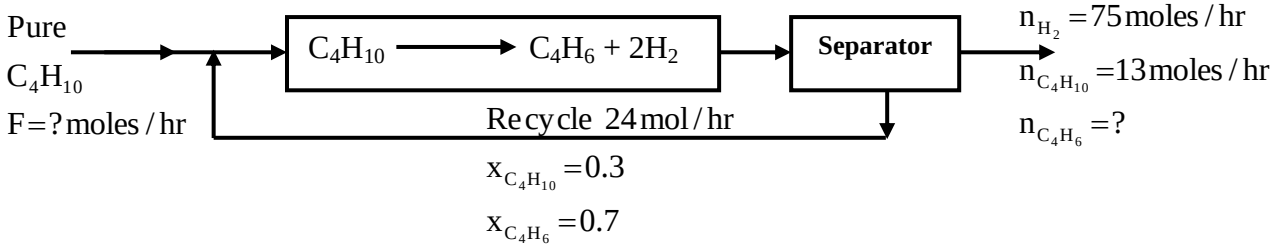


Q.6

A catalytic dehydrogenation process shown in Figure, produces 1, 3 butadiene (C_4H_6) from pure normal butane (C_4H_{10}). The product stream contains 75 mol/hr of H_2 and 13 mol/hr of C_4H_{10} as well as C_4H_6. The recycle stream is 30% (mol) C_4H_{10} and 70% (mol) C_4H_6, and the flow is 24 mol/hr.

(a) What are the feed rate, F, and the product flow rate of C_4H_6 leaving the process?

(b) What is the single-pass conversion of butane in the process?



Q.7

Calculate the temperature of 2 g mol of a gas using van der Waals' equation with a = 1.35 * 10^{-6} (m^6)(atm)(g mol^{-2}), b = 0.0322 * 10^{-3} (m^3)(g mol^{-1}) if the pressure is 100 kpa and the volume is 0.0515 m^3. (1 atm = 101.3 kpa)

Q.8

Liquid mixture of 4% (liquid A) in (liquid B), what is the composition of the first vapor formed if the total pressure is 1 atm and bubble point temperature is 393.3 K?

Antoine equation constants	A	B	C	Pressure is in mm Hg
Liquid A	15.8737	2697.55	- 48.784	T is in K
Liquid B	15.9798	3127.6	- 63.633	

Q.9

Calculate (a) the pressure at the dew point for the following mixture at 100 ^oF and (b) the liquid composition.

Component	**Mole fraction**	**K values at psia of**		
		190	**200**	**210**
C_2H_6	0.218	3.22	3.07	2.92
C_3H_8	0.665	1.005	0.973	0.92
i-C_4H_{10}	0.1073	0.45	0.43	0.41
n- C_4H_{10}	0.0097	0.315	0.305	0.295
Total	1			

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September / 2009

ملاحظة/ الاجابة على سبعة اسئلة فقط على ان يكون السؤال الثاني والثالث من ضمنها.

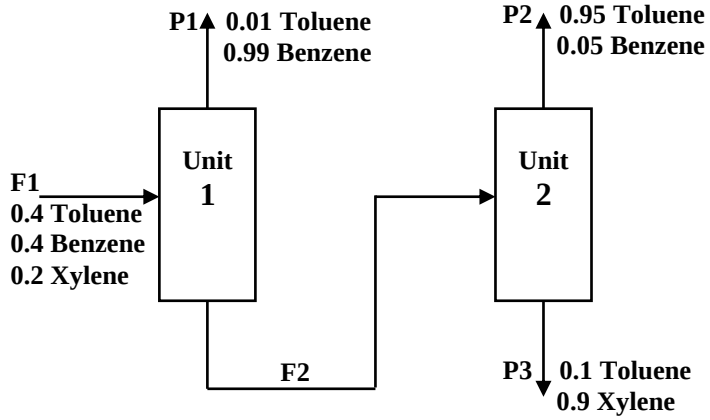
Q.1

Antimony is obtained by heating pulverized stibnite (Sb_2S_3) with scrap iron and drawing off the molten antimony from the bottom of the reaction vessel $Sb_2S_3 + 3\ Fe \longrightarrow 2\ Sb + 3\ FeS$
Suppose that 600 g of Sb_2S_3 (MW: 339.7) and 250 g of Fe (MW: 55.85) turnings are heated together to give 200 g of Sb (MW: 121.8) metal. Determine:

a. The limiting reactant
b. The percentage of excess reactant
c. The degree of completion (fraction)
d. The percent conversion of Sb_2S_3
e. The yield (kg Sb/kg Sb_2S_3)

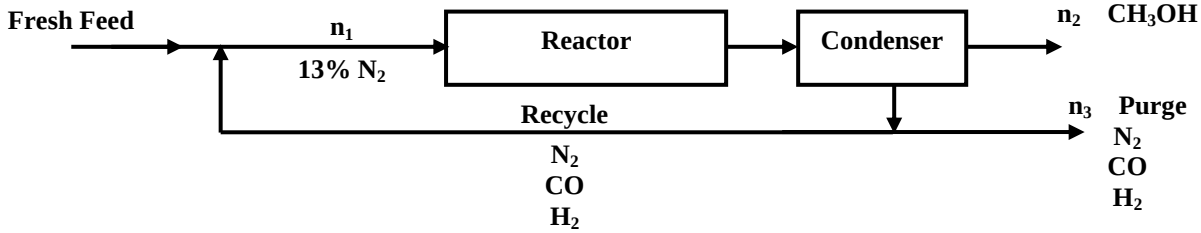
Q.2

A two-stage separations unit is shown in Figure. Given that the input stream Fl is 1000 lb/hr, calculate the value of F2 and the composition of F2. Assume that the compositions in the figure are mass fractions.



Q.3

Methanol is synthesized from carbon monoxide and hydrogen in a catalytic reactor. The fresh feed to the process contains 32 mole% CO, 64 % H_2, and 4 % N_2. This stream is mixed with a recycle stream in a ratio 5 mol recycle/1 mol fresh feed to produce the feed to the reactor, which contains 13 mole% N_2. For a basis of 100 mol fresh feed/h, calculate the production rate of methanol (mol/h), the molar flow rate and composition of the purge gas, and the overall and single-pass conversions.



Q.4

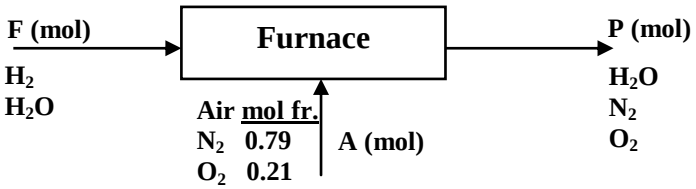
In the production of a drug having a molecular weight of 192, the exit stream from the reactor flows at a rate of 10.5 L/min. The drug concentration is 41.2% (in water), and the specific gravity of the solution is 1.024. Calculate the concentration of the drug (in kg/L) in the exit stream, and the flow rate of the drug in kg mol/min. (1 L = 10^3 cm^3, density of H_2O = 1 g/ cm^3)

Q.5

A U-tube manometer is used to determine the pressure drop across an orifice meter. The liquid flowing in the pipe line is a sulfuric acid solution having a specific gravity (60°/60°) of 1.250. The manometer liquid is mercury, with a specific gravity (60°/60°) of 13.56. The manometer reading is 5.35 inches, and all parts of the system are at a temperature of 60°F. What is the pressure drop across the orifice meter in psi. (1 ft = 12 in, density of H_2O = 62.4 lb/ft^3, g = 32.2 ft/s^2)

Q.6

Moist hydrogen containing 4 mole percent water is burnt completely in a furnace with 32% excess air. Calculate the Orsat analysis of the resulting flue gas.



Q.7

(a) What is the density of CH_4 (MW: 16) at 70 ^oF and 2 atm? (R = 0.7302 ft^3 atm/lb mol ^oR)

(b) What is the specific gravity of CH_4 at 70°F and 2 atm compared to air (MW: 29) at standard conditions?

Q.8

Use either Raoult's law or Henry's law to solve the following problems.

1. A gas containing 1mole% ethane is in contact with water at 20° C and 20 atm. Estimate the mole fraction of dissolved ethane.
2. An equimolar liquid mixture of benzene (B) and toluene (T) is in equilibrium with its vapor at 30° C. What are the system pressure and the composition of the vapor?

(Henry's law constant for ethane in water at 20°C as 2.63 x 10^4 atm/mole fraction)

Antoine equation constants	A	B	C	Pressure (mm Hg) Temperature (K)
Benzene	15.9008	2788.51	- 52.36	
Toluene	16.0137	3096.52	- 53.67	

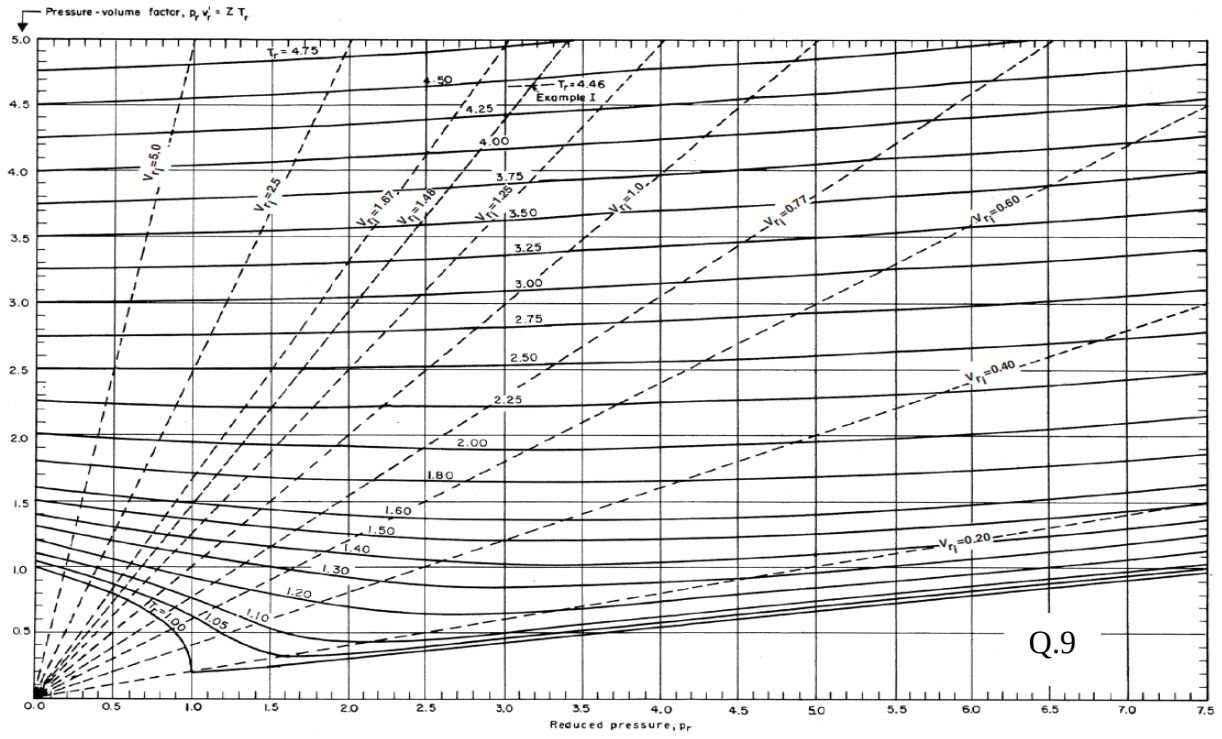
Q.9

Seven pounds of N_2 at 120°F are stored in a cylinder having a volume of 0.75 ft^3. Calculate the pressure in atmospheres in the cylinder

(a) assuming N_2 to be an ideal gas

(b) using the compressibility factor method

(R = 0.7302 atm ft^3 / lb mol ^oR, MW of N_2 = 28, P_c = 33.5 atm and T_c = 126.2 K)



Q.9

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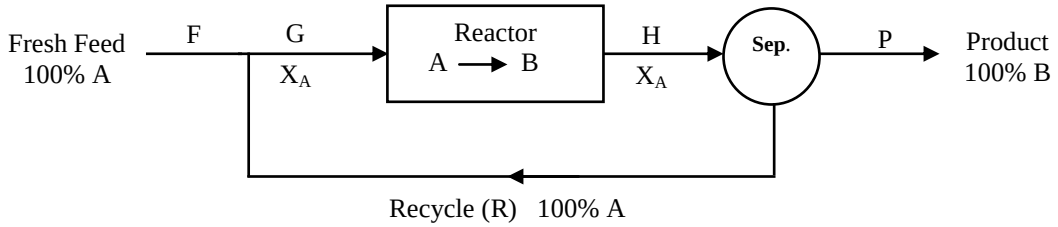
June / 2010

ملاحظة/ الاجابة على سبعة اسئلة فقط على ان يكون السؤال الاول والثاني من ضمنها.

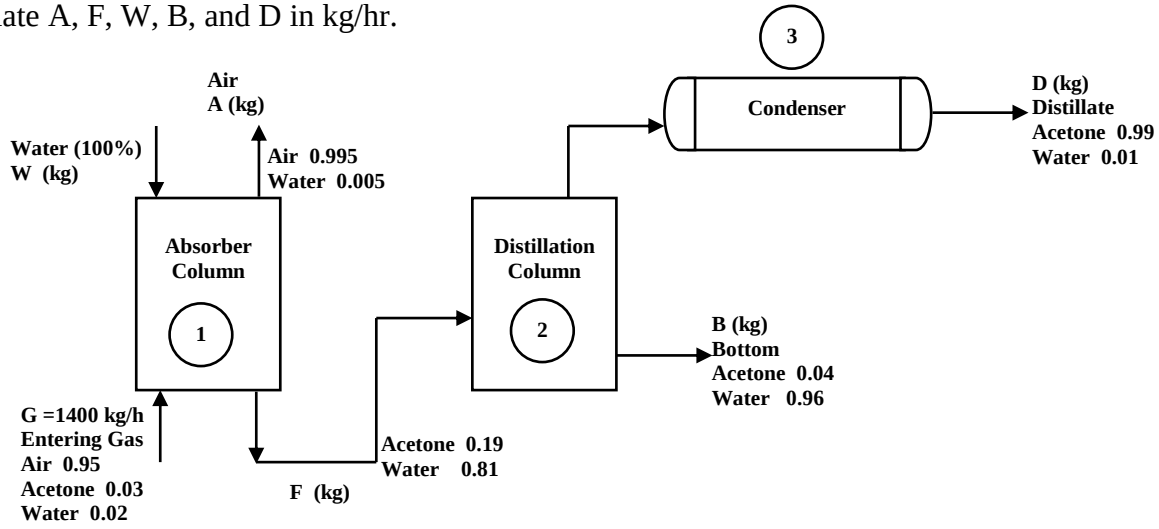
Q.1

30% of a compound A is converted to B on a single pass through the reactor, as illustrated in Figure, calculate the value of R, the recycle, on the basis of 100 moles of fresh feed, F.



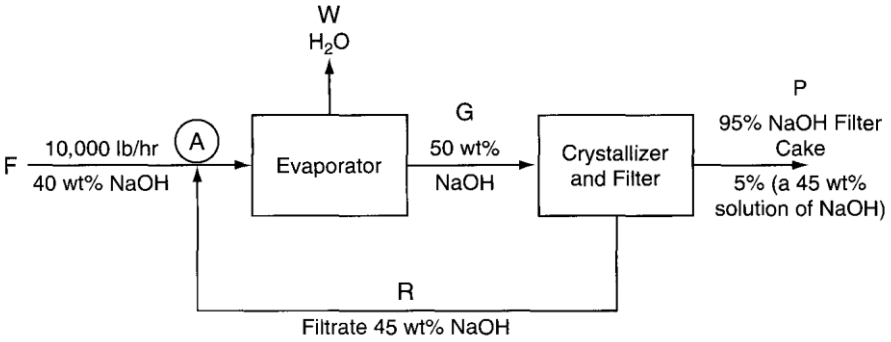
Q.2

All the concentrations shown in Figure of both gases and liquids are specified in weight percent. Calculate A, F, W, B, and D in kg/hr.



Q.3

Figure below is a schematic of a process for the production of flake NaOH, which is used in households to clear plugged drains in the plumbing.



The fresh feed to the process is 10,000 lb/hr of a 40% aqueous NaOH solution. The fresh feed is combined with the recycled filtrate from the crystallizer, and fed to the evaporator where water is removed to produce a 50% NaOH solution, which in turn is fed to the crystallizer. The crystallizer produces a filter cake that is 95% NaOH crystals and 5% solution that itself consists of 45% NaOH. The filtrate contains 45% NaOH.

a. Determine the flow rate of water removed by the evaporator, and the recycle rate for this process.
b. Assume that the same production rate of NaOH flakes occurs, but the filtrate is not recycled. What would be the total feed rate of 40% NaOH have to be then? Assume that the product solution from the evaporator still contains 50% NaOH.

Q.4

A liquefied mixture has the following composition: n-C_4H_{10} 50% (MW=58), n-C_5H_{12} 30% (MW=72), and n-C_6H_{14} 20% (MW=86). For this mixture, calculate: (a) mole fraction of each component. (b) Average molecular weight of the mixture.

Q.5

Determine the extent of reaction for the following chemical reaction [A + 3B $\longrightarrow$ 2C] given the following analysis of feed [A 100 g, B 50 g and C 5 g] and product [C 90 g]. Also, determine the g of A and B in the product. (MW: A 28; B 2; C 17)

Q.6

Pure carbon is burned in oxygen. The flue gas analysis is: CO_2 75 mo1%, CO l4 mol% & O_2 11 mol%. What was the percent excess oxygen used?

Q.7

A mixture of air and benzene contains 10 mole% benzene at 43°C and 105 kPa pressure. At what temperature does the first liquid form? What is the liquid? (1 kPa = 7.502 mm Hg)

Antoine equation constants	A	B	C	Pressure is in mm Hg
Benzene	15.9008	2788.51	- 52.36	T is in K

Q.8

You measure that 0.00220 lb mol of a certain gas occupies a volume of 0.95 ft^3 at 1 atm and 32°F. If the equation of state for this gas is $pV = nRT(1 + bp)$, where b is a constant, find the volume at 2 atm and 71°F. (hint: calculate R from Standard Conditions for the Ideal Gas)

Q.9

Calculate the number of degrees of freedom from the phase rule for the following materials at equilibrium:

(a) Pure liquid benzene.
(b) A mixture of ice and water only.
(c) A mixture of liquid benzene, benzene vapor, and helium gas.
(d) A mixture of salt and water designed to achieve a specific vapor pressure.
(e) A vessel contains air: N_2 (g), O_2 (g), and Ar (g). Repeat for a vessel one – third filled with liquid ethanol and two – thirds filled with N_2 plus ethanol vapor.

Dr. Ahmed Faiq Al-Alawy
September / 2010

ملاحظة/ الاجابة على خمسة اسئلة فقط على ان يكون السؤال الاول والثاني من ضمنها.

Q.1

Figure Q.1 shows a three – stage separation process. The ratio of P_3/D_3 is 3, the ratio of P_2/D_2 is 1, and the ratio of A to B in stream P_2 is 4 to 1. Calculate the composition and percent (wt %) of each component in stream E.

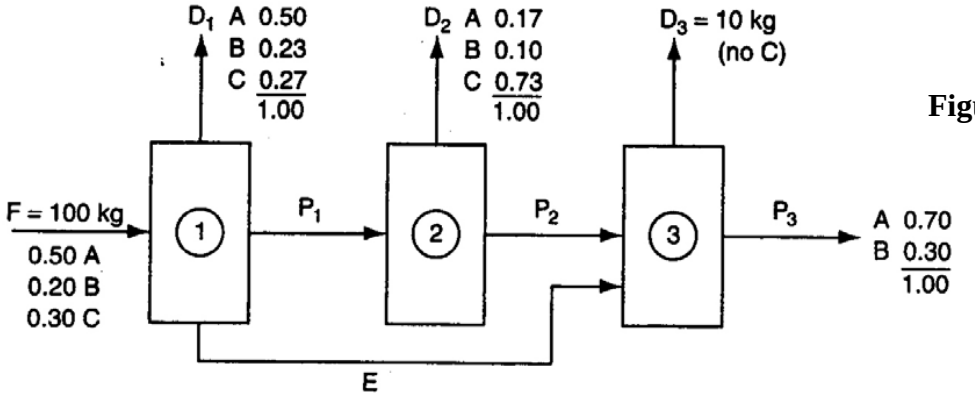


Figure Q.1

Q.2

Ethyl ether ($C_2H_5OC_2H_5$, MW= 74) is made by the dehydration of ethyl alcohol in the presence of sulfuric acid at 140°C:

$$2C_2H_5OH \rightarrow C_2H_5OC_2H_5 + H_2O$$

Figure Q.2 is a simplified process diagram. If 87% conversion of the alcohol fed to the reactor occurs per pass in the reactor, calculate: (a) kg mole per hour of fresh feed, and (b) kg mole per hour of recycle.

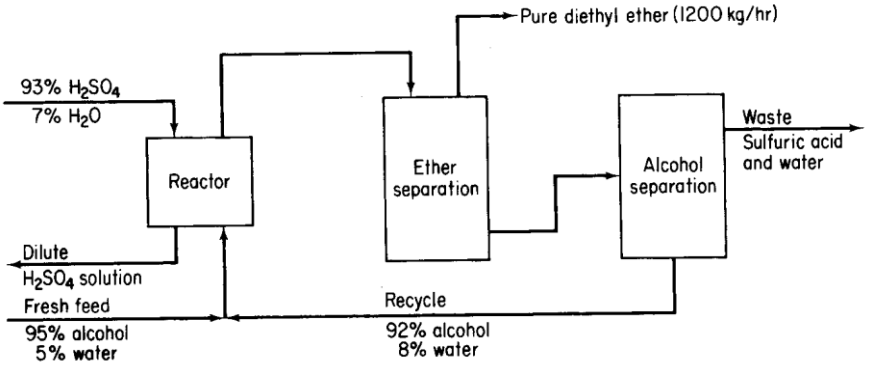


Figure Q.2

Q.3

Figure Q.3 is a schematic of a process for the production of flake NaOH, which is used in households to clear plugged drains in the plumbing (e.g., Drano).

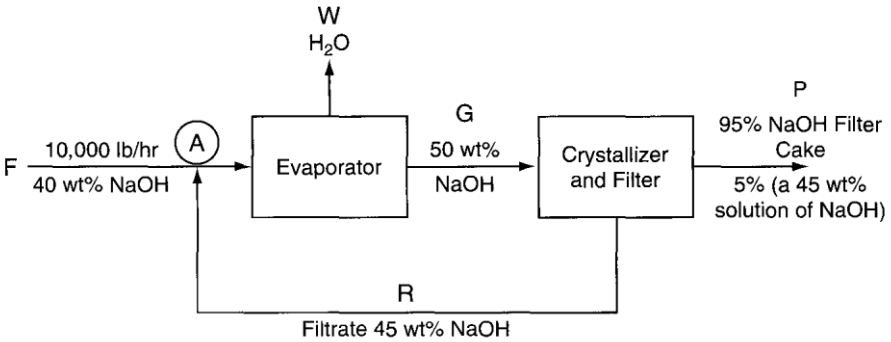


Figure Q.3

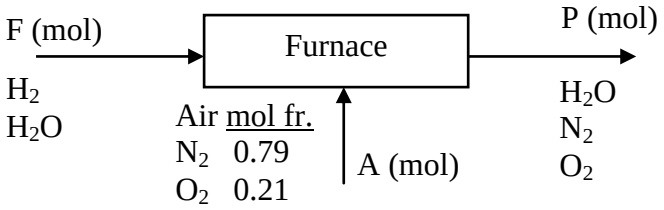
a. Determine the flow rate of water removed by the evaporator, and the recycle rate for this process.
b. Assume that the same production rate of NaOH flakes occurs, but the filtrate is not recycled. What would be the total feed rate of 40% NaOH have to be then? Assume that the product solution from the evaporator still contains 50% NaOH.

Q.4

A well known reaction to generate hydrogen from steam is the so called water gas shift reaction: $CO + H_2O \rightleftharpoons CO_2 + H_2$. If the gaseous feed to a reactor consists of 30 moles of CO per hour, 12 moles of CO_2 per hour, and 35 moles of steam per hour at 800 ^oC, and 18 moles of H_2 are produced per hour, calculate (a) The limiting reactant. (b) The excess reactant. (c) The fraction conversion of steam to H_2. (d) The degree of completion of the reaction. (e) The kg of H_2 yielded per kg of steam fed. (f)The moles of CO_2 produced by the reaction per mole of CO fed. (g) The extent of reaction. [MW of H_2 = 2.016, MW of H_2O = 18]

Q.5

(A) Moist hydrogen containing 4 mole percent water is burnt completely in a furnace with 32 % excess air. Calculate the Orsat analysis of the resulting flue gas.



(B) The contents of a gas cylinder are found to contain 20 percent CO_2, 60 percent O_2, and 20 percent N_2 at a pressure of 740 mm Hg and at 20 ^oC. What are the partial pressures of each component? If the temperature is raised to 40 ^oC, will the partial pressures change? If so, what will they be?

Q.6

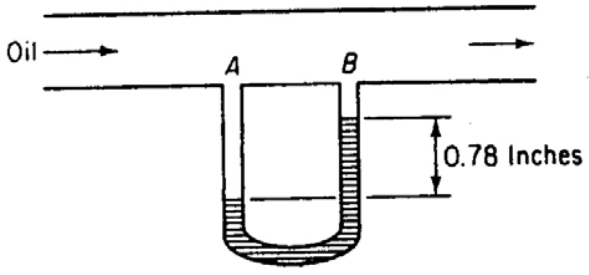
(A) A starting stock solution has a specific gravity of 1.075 and contains 12.7 wt% sugar. If all the sugar is assumed to be $C_{12}H_{22}O11$, determine (a) kg sugar/kg H_2O. (b) lb solution/ft^3 solution. (c) g sugar/L solution. (Density of H_2O = 1 g/cm^3, 1 lb = 454 g, 1 L = 1000 cm^3, 1 ft = 30.48 cm)

(B) A natural gas has the following composition: CH_4 87%, C_2H_6 12% and C_3H_8 1%. (1) What is the composition in weight percent? (2) What is the composition in volume percent? (3) What is the average molecular weight? (4) How many m^3 will be occupied by 80 kg of the gas at 9 ^oC and 600 kPa? (5) What is the density of the gas in kg/m^3 at SC? (6) What is the specific gravity of this gas at 9 ^oC and 600 kPa referred to air at SC? [(CH_4, MW=16), (C_2H_6, MW=30), (C_3H_8, MW=44), MW of air = 29, 1 atm = 101.3 kPa, and R = 8.314 kPa m^3/kg mol K]

Q.7

(A) If 100 g of Na_2SO_4 (MW=142) is dissolved in 200 g of H_2O (MW=18) and the solution is cooled until 100 g of $Na_2SO_4.10H_2O$ crystallizes out; find (a) the composition of the remaining solution (the mother liquor) and (b) the grams of crystals recovered per 100 g of initial solution. (Note: Unsteady-State process).

(B) Examine figure Q.7. Oil (density = 0.91 g/cm^3) flows in pipe, and the flow rate is measured via a mercury (density = 13.546 g/cm^3) manometer. If the difference in height of the two legs of the manometer is 0.78 in., what is the corresponding pressure difference between points A and B in mm Hg? At which point, A or B, is the pressure higher? g = 9.8 m/s^2, 1 m = 100 cm, 1 in. = 2.54 cm, 1 kg = 1000 g, 1 atm = 760 mm Hg, 1 atm = 101.3 kPa, 1 kPa = 1000 pa)



Dr. Ahmed Faiq Al-Alawy
June / 2011

GOOD LUCK

University of Baghdad	**Final Examination**	**Date: 13/9/2011**
College of Engineering	**Second Attempt**	**Time: 3 hr**
Chem. Eng. Dept.	**Chem. Eng. Principles**	**First Year**

Answer Five Questions only

Q.1

(1) a. How many ppm are there in 1 ppb? b. Is the density and specific gravity of mercury are the same? Why? c. What is g_c? What are the value and units of g_c in the SI system?

(2) The following equation: $k = 1.2*10^5 \exp(-20000/1.987\ T)$, the units of the quantity 20000 are cal/mol, k is in (mol/cm^3.s) and T is in Kelvin. What are the units of $1.2*10^5$ and 1.987?

(3) A solution in water contains 1.704 kg of HNO_3/kg H_2O, and the solution has a specific gravity of 1.382 at 20°C. What is the mass of HNO_3 in kg per cubic meter of solution at 20°C? ρ_{H2O} = 1000 kg/m^3

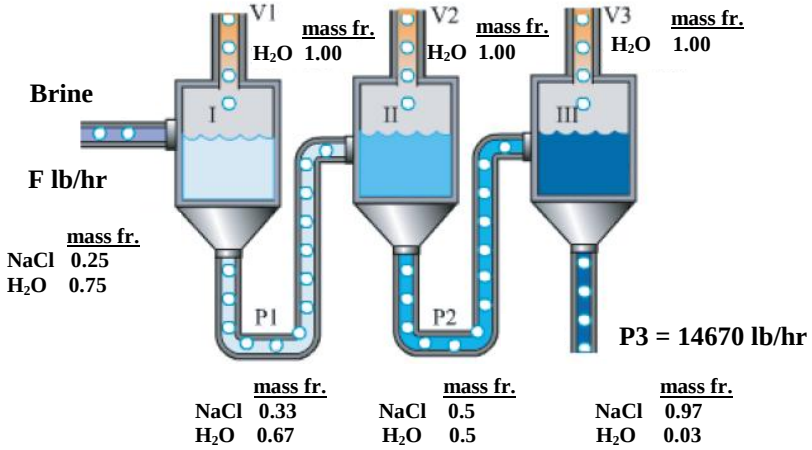
Q.2

A triple effect evaporator is designed to reduce water from an incoming brine (NaCl + H_2O) stream. If the evaporator unit is to produce 14,670 lb/hr of NaCl, determine:

a. The feed rate of brine in lb/hr.

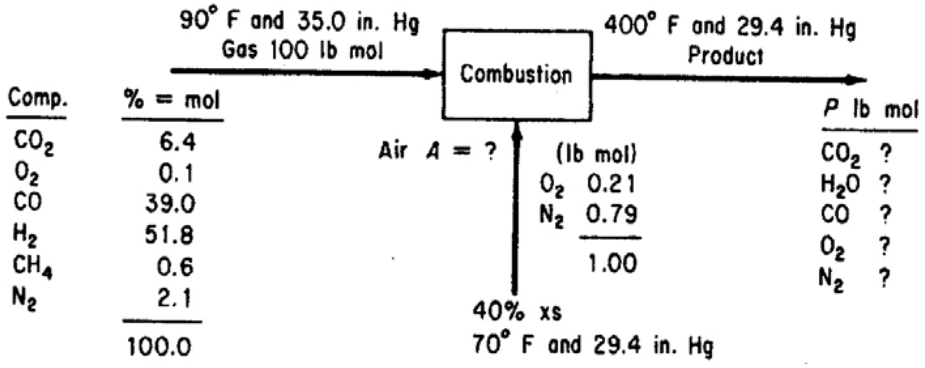
b. The water removed from the brine in each evaporator.

The data are shown in the accompanying figure.



Q.3

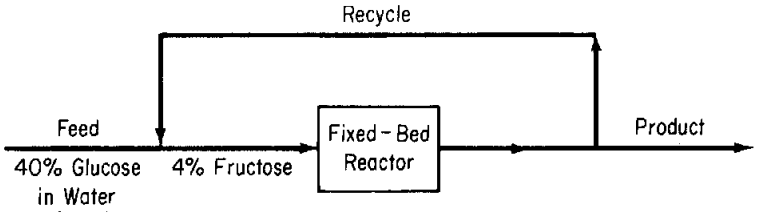
The product gas analyzed 6.4% CO_2, 0.1% O_2, 39% CO, 51.8% H_2, 0.6% CH_4, and 2.1% N_2. It enters the combustion chamber at 90 °F and a pressure of 35 in. Hg, and is burned with 40% excess air (dry) which is at 70 °F and the atmospheric pressure of 29.4 in. Hg; 10% of the CO remains unburned. How many cubic feet of air are supplied per cubic foot of entering gas? How many cubic feet of product are produced per cubic foot of entering gas if the exit gas is at 29.4 in. Hg and 400 °F? [R = 21.83 in. Hg ft^3/lb mol °R]



Q.4

Immobilized glucose isomers is used as a catalyst in producing fructose from glucose in a fixed-bed reactor (water is the solvent). For the system shown in Figure, what percent conversion of glucose results on one pass through the reactor when the ratio of the exit stream to the recycle stream in mass units is equal to 8.33? The reaction is

$$\underset{\text{Glucose}}{C_{12}H_{22}O_{11}} \rightarrow \underset{\text{Fructose}}{C_{12}H_{22}O_{11}}$$



Q.5

In a process for the manufacture of chlorine by direct oxidation of HCl with air over a catalyst to form Cl_2 and H_2O (only), the exit product is composed of HCl 4.4%, Cl_2 19.8%, H_2O 19.8%, O_2 4%, and N_2 52%. What was

a) The limiting reactant?
b) The percent excess reactent?
c) The degree of completion of the reaction?
d) The extent of reaction?

$$4HCl + O_2 \rightarrow 2Cl_2 + 2H_2O$$

MW	35.45	32	71.0	18

Q.6

Two tanks containing N_2 at the following conditions sit next to each other

	Tank A	Tank B
Volume (m^3)	1	5
Temperature (°C)	25	40
Pressure (kPa)	300	?
Amount of gas (g mol)	?	?

After the two tanks are connected and reach equilibrium, the conditions in the combined tanks are 700 kPa and 35 ^oC. What was the pressure in Tank B? [R = 8.314 kPa m^3/kg mol K, 1 kg = 1000 g]

Dr. Ahmed Faiq Al-Alawy
September / 2011

GOOD LUCK

ATTEMPT FIVE QUESTIONS ONLY

Q.1 Benzene (C_6H_6) is converted to cyclohexane (C_6H_{12}) by direct reaction with H_2. The fresh feed to the process is 260 L/min of C_6H_6 plus 950 L/min of H_2 at 100 ^oC and 150 kPa. The single pass conversion of H_2 in the reactor is 48% while the overall conversion of H_2 in the process is 75%. The recycle stream contains 90% H_2 and the remainder benzene (no cyclohexane). See **Figure Q.1**

a) Determine the molar flow rates of H_2, C_6H_6, and C_6H_{12} in the exiting product.
b) Determine the volumetric flow rates of the components in the product stream if it exits at 100 kpa and 200 ^oC.
c) Determine the molar flow rate of the recycle stream and the volumetric flow rate if the recycle stream is at 100 ^oC and 100 kPa. (Gas constant R = 8.314 (m^3.kPa)/(kgmol.K), 1 m^3=1000 L)

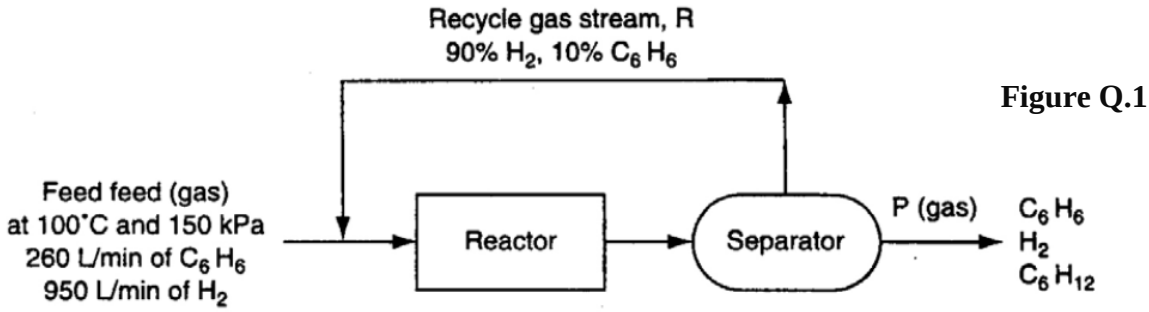


Figure Q.1

Q.2 Several streams are mixed as shown in **Figure Q.2**. Calculate the flows of each stream in kg/min (A, B, C, D and E and the composition of C).

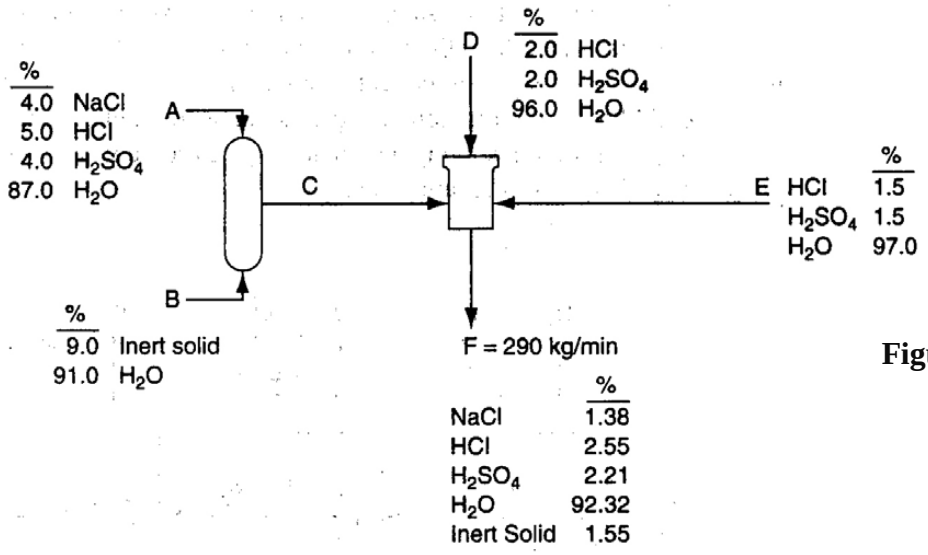


Figure Q.2

Q.3 (A) What is the mass of 1 m^3 of H_2 (MW = 2) at 5 ^oC and 110 kPa? What is the specific gravity of this H_2 compared to air (MW = 29) at 5 ^oC and 110 kPa?

(B) A U-tube manometer is used to determine the pressure drop across an orifice meter. The liquid flowing in the pipe line is a sulfuric acid solution having a specific gravity (60°/60°) of 1.250. The manometer liquid is mercury, with a specific gravity (60°/60°) of 13.56. The manometer reading is 5.35 inches, and all parts of the system are at a temperature of 60°F. What is the pressure drop across the orifice meter in psi? (1 ft = 12 in, density of H_2O = 62.4 lb/ft^3, g = 32.2 ft/s^2)

Q.4 Formaldehyde (CH_2O) is produced industrially by the catalytic oxidation of methanol (CH_3OH) according to the following reaction:

$$CH_3OH + 1/2O_2 \rightarrow CH_2O + H_2O \qquad (1)$$

Unfortunately, under the conditions used to produce formaldehyde at a profitable rate, a significant portion of the formaldehyde reacts with oxygen to produce CO and H_2O, that is,

$$CH_2O + 1/2O_2 \rightarrow CO + H_2O \qquad (2)$$

Assume that methanol and twice the stoichiometric amount of air needed for complete conversion of the CH_3OH to the desired products (CH_2O and H_2O) are fed to the reactor. Also assume that 90% conversion of the methanol results, and that a 75% yield of formaldehyde occurs based on the theoretical production of CH_2O by Reaction 1. Determine the composition of the product gas leaving the reactor.

Q.5 Sulfur dioxide may be converted to SO_3, which has many uses including the production of H_2SO_4 and sulphonation of detergent. A gas stream having the composition shown in **Figure Q.5** is to passed through a two-stage converter. The fraction conversion of the SO_2 to SO_3 (on one pass through) in the first stage is 0.75 and in the second stage 0.65. To boost the overall conversion to 0.95, some of the exit gas from stage 2 is recycled back to the inlet of stage 2. How much must be recycled per 100 Kg moles of inlet gas (stream F)? Ignore the effect of temperature on the conversion.

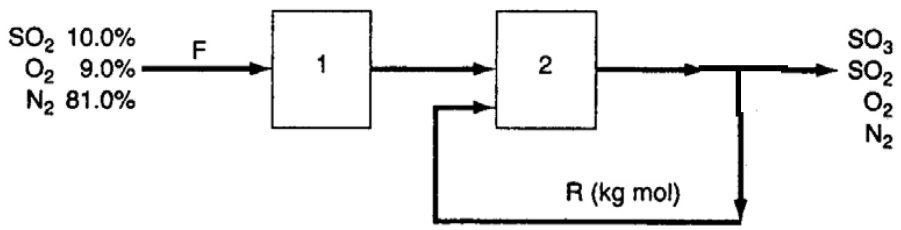


Figure Q.5

Q.6 Acrylonitrile is produced in the reaction of propylene, ammonia, and oxygen:

$$C_3H_6 + NH_3 + 1.5O_2 \longrightarrow C_3H_3N + 3H_2O$$

The feed contains 10 mole% propylene, 12% ammonia, and 78% air. A fractional conversion of 30% of the limiting reactant is achieved. Taking 100 gmol of feed as a basis, determine which reactant is limiting, the percentage by which each of the other reactants is in excess, and the molar amounts of all product gas constituents for a 30% conversion of the limiting reactant.

University of Baghdad
Chemical Engineering Department
Final Examination
2011/2012

Subject: Chem. Eng. Principles
Examiner: Dr.Ahmed Faiq Al-Alawy

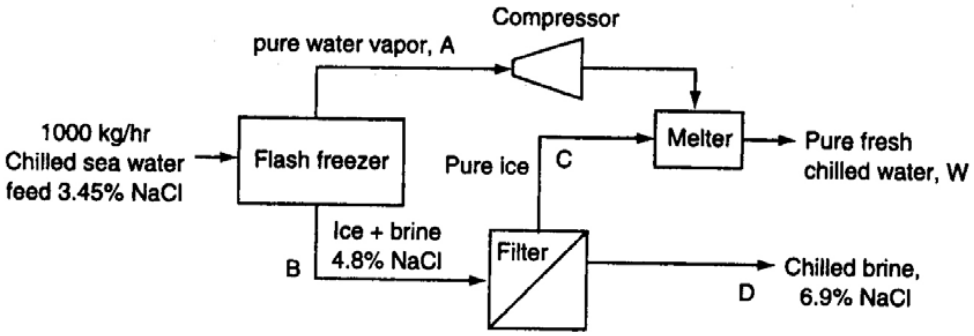
Class: First
Time: 3 hours
Date: 3/9/2012

ATTEMPT FIVE QUESTIONS ONLY

Q.1

Figure Q.1 shows a schematic for making fresh water from sea water by freezing.

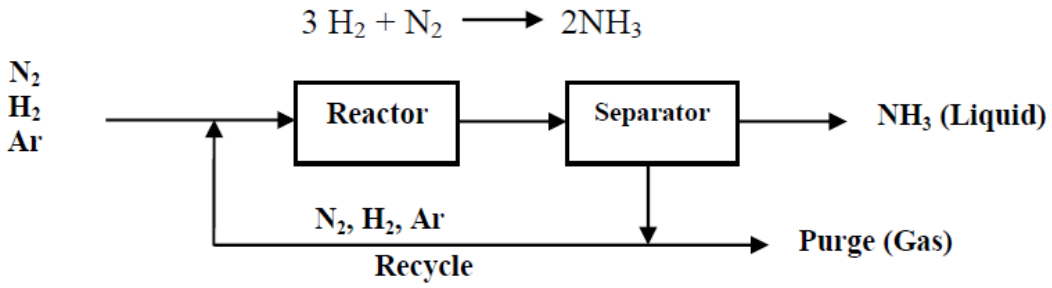
a. Determine the flow rates of streams W and D if the feed is 1000 kg per hour?
b. Determine the flow rates of streams C, B and A per hour?



Q.2

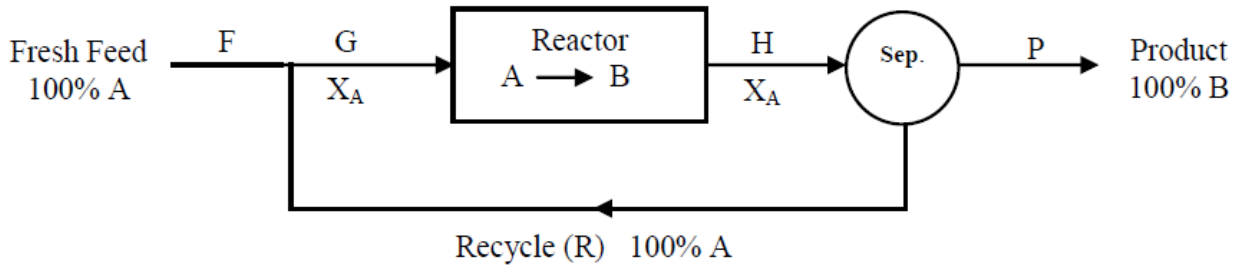
As shown in Figure Q.2, the fresh feed of gas composed of 75.16% H_2, 24.57% N_2, and 0.27% Ar is mixed with the recycled gas and enters the reactor with a composition of 79.52% H_2. The gas stream leaving the ammonia separator contains 80.01% H_2 and no ammonia. The product ammonia contains no dissolved gases. Per 100 moles of fresh feed:

1. How many moles are recycled and purged?
2. What is the percent conversion of hydrogen per pass?



Q.3

(A) 30% of a compound A is converted to B on a single pass through the reactor, as illustrated in Figure Q.3, calculate the value of R, the recycle, on the basis of 100 moles of fresh feed, F.



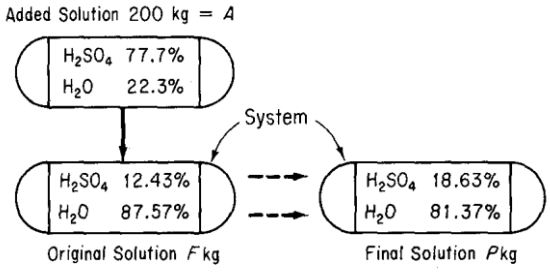
(B) A mixture of the gases has the following composition by mass: O_2 16%, CO 4%, CO_2 17%, and N_2 63%. What is the molar composition? {MW(O_2)=32, MW(CO)=28, MW(CO_2)=44, and MW(N_2)=28}, Basis: 100 g of the mixture.

Q.4

20 ft^3 of nitrogen at 300 psig and 100 °F and 30 ft^3 of oxygen at 200 psig and 340 °F are injected into a 15 ft^3 vessel. The vessel is then cooled to 70 °F. Find the partial pressure of each component in the 15 ft^3 vessel. Assume that the ideal gas law applies. (R = 10.73 psia ft^3 / lb mol ^oR)

Q.5

A batch of 18.63% battery acid prepare as follows. A tank of old weak battery acid (H_2SO_4) solution contains 12.43% H_2SO_4 (the remainder is pure water). If 200 kg of 77.7% H_2SO_4 is added to the tank, and the final solution is to be 18.63% H_2SO_4, how many kilograms of battery acid have been made? Assume (1) An unsteady-state process (2) Steady-state process.



Q.6

A well known reaction to generate hydrogen from steam is the so called water gas shift reaction:

$$CO + H_2O \rightleftarrows CO_2 + H_2.$$

If the gaseous feed to a reactor consists of 30 moles of CO per hour, 12 moles of CO_2 per hour, and 35 moles of steam per hour at 800 °C, and 18 moles of H_2 are produced per hour, calculate

(a) The limiting reactant.
(b) The excess reactant.
(c) The fraction conversion of steam to H_2.
(d) The degree of completion of the reaction.
(e) The kg of H_2 yielded per kg of steam fed.
(f) The moles of CO_2 produced by the reaction per mole of CO fed.
(g) The extent of reaction.

ATTEMPT FIVE QUESTIONS ONLY

Q.1 In the process for the production of pure acetylene, C_2H_2 (see Figure Q.1), pure methane (CH_4), and pure oxygen are combined in the burner, where the following reactions occur:

$$CH_4 + 2O_2 \rightarrow 2H_2O + CO_2 \qquad CH_4 + 1\tfrac{1}{2}O_2 \rightarrow 2H_2O + CO \qquad 2CH_4 \rightarrow C_2H_2 + 3H_2$$

a. Calculate the ratio of the moles of O_2 to moles of CH_4 fed to the burner.
b. On the basis of 100 lb mol of gases leaving the condenser, calculate how many pounds of water are removed by the condenser (MW H_2O: 18).
c. What is the overall percentage yield of product (pure) C_2H_2, based on the carbon in the natural gas entering the burner? In the absorber: 97% of the C_2H_2 and essentially all the CO_2 are removed with the solvent.

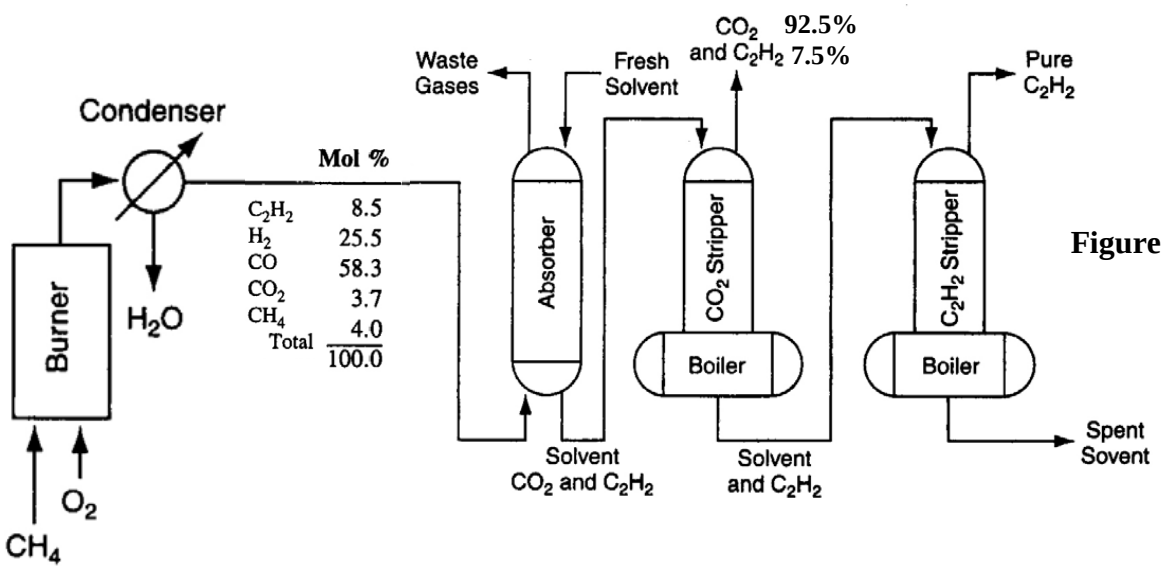


Figure Q.1

Q.2 In a sulfuric acid plant, sulfur is burned in the presence of excess oxygen to produce sulfur dioxide which in turn is further reacted in the next step with oxygen in a converter to produce sulfur trioxide. In the plant SO_2 along with 10% excess air is fed into the converter which operates at 1500°C and 1 atm. The per pass conversion of SO_2 is 75% and overall conversion is 100%. If 10^6 m^3/hr of SO_2 at 1100°C and 1 atm is fed to the converter, calculate the:

(a) Flow rate of the product stream P in m^3/hr at 1500°C and 1 atm and its composition in mole percent;

(b) Flow rate of the recycle stream R in m^3/hr at 1500°C and 1 atm. {1 atm=101.3 kPa, gas constant (R) = 8.314 kJ/kgmol.K}.

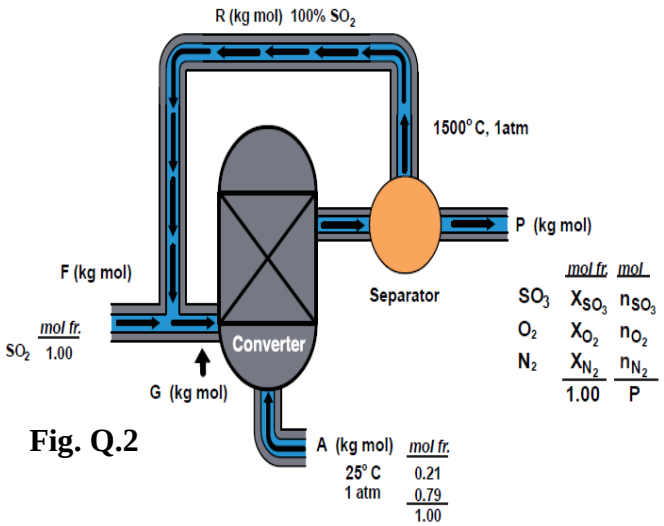
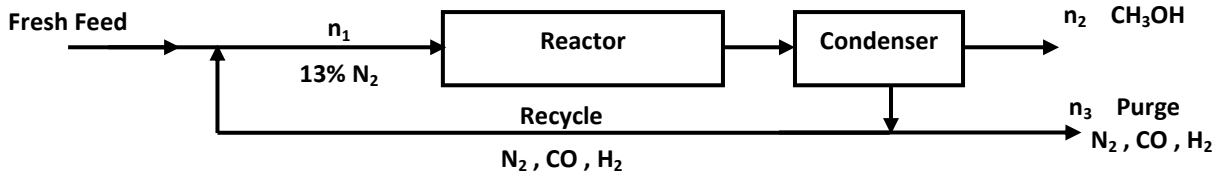


Fig. Q.2

Q.3 Methanol is synthesized from carbon monoxide and hydrogen in a catalytic reactor. The fresh feed to the process contains 32 mole% CO, 64 % H_2, and 4 % N_2. This stream is mixed with a recycle stream in a ratio 5 mol recycle/1 mol fresh feed to produce the feed to the reactor, which contains 13 mole% N_2. For a basis of 100 mol fresh feed/h, calculate the production rate of methanol (mol/h), the molar flow rate and composition of the purge gas, and the overall and single-pass conversions.



Q.4 A natural gas has the following composition: CH_4 (methane) 87% , C_2H_6 (ethane) 12%, C_3H_8 (propane) 1%. (a) What is the composition in weight percent? (b) What is the composition in volume percent? (c) How many m^3 will be occupied by 80 kg of the gas at 9°C and 600 kPa? (d) What is the density of the gas in kg/m^3 at SC? (e) What is the specific gravity of this gas at 9°C and 600 kPa referred to air at SC?{MW:CH_4 = 16, C_2H_6 = 30, C_3H_8 = 44, R= 8.314 kJ/kgmol.K }.

Q.5

(A) In a process for the manufacture of chlorine by direct oxidation of HCl with air over a catalyst to form Cl_2 and H_2O (only), the exit product is composed of HCl (4.4%), Cl_2 (19.8%), H_2O (19.8%), O_2 (4%), and N_2 (52%). What was (a) the limiting reactant? (b) the percent excess reactant? (c) the degree of completion of the reaction? (d) the extent of reaction?.

(B) A U-tube differential mercury manometer is connected between two pipes. One pipe contains carbon tetra chloride (sp.gr. 1.59) under a pressure of 103 kPa, and the other pipe contains oil (sp.gr. 0.8) under a pressure of 172 kPa. Find the manometer reading h in meters. {ρ_{H2O} = 1000 kg/m^3}

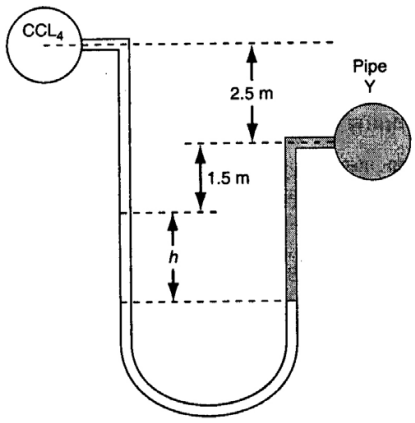


Figure Q.5 (B)

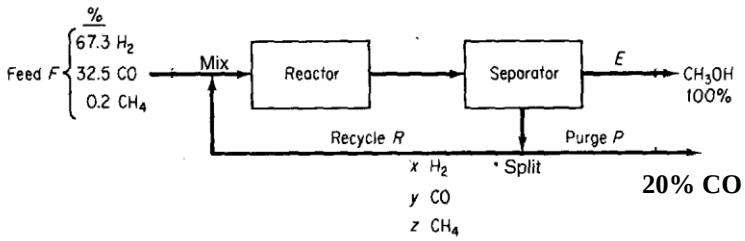
Q.6

(A) The density of a fluid is given by the empirical equation $\rho = 70.5 \exp(8.27 \times 10^{-7} P)$ where ρ is the density (lb_m/ft^3) and P is pressure ($lb_f/in.^2$). (1) what are the units of 70.5 and 8.27×10^{-7}? (2) Derive a formula for ρ (g/cm^3) as a functionof P (N/m^2). {1 lb=454 g, 1 ft=30.48 cm, 1 N=0.2248 lb_f, 1 m=39.37 in.}

(B) Sulfur trioxide (SO_3) can be absorbed in sulfuric acid solution to form more concentrated sulfuric acid. If the gas to be absorbed contains 55% SO_3, 41% N_2, 3% SO_2, and 1% O_2, how many parts per million of O_2 are there in the gas? What is the composition of the gas on a N_2 free basis?

ATTEMPT FIVE QUESTIONS ONLY

Q.1 Figure Q.1 illustrates a steady-state process for the production of methanol. All of the compositions are in mole fractions. The stream flows are in moles.



$$CO + 2H_2 \rightarrow CH_3OH$$

Figure Q.1

Note in Figure Q.1 that some CH_4 enters the process, but does not participate in the reaction. A purge stream is used to maintain the CH_4 concentration in the exit from the separator at no more than 3.2 mol%, and prevent hydrogen buildup as well. The once-through conversion of the CO in the reactor is 18%.
Compute the moles of recycle, CH_3OH, and purge per mole of feed, and also compute the purge gas composition.

Q.2 Figure Q.2 shows the process and the known data. Calculate the compositions of every flow stream, and the fraction of the sugar in the cane that is recovered

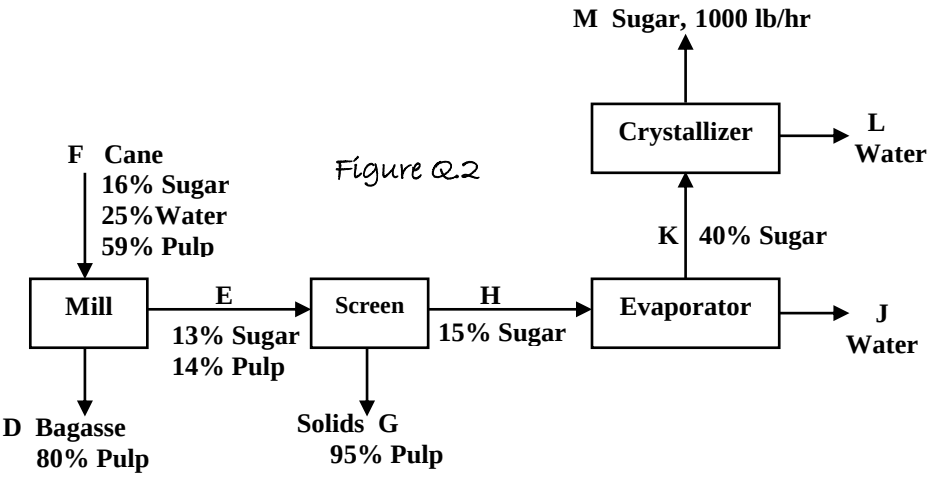


Figure Q.2

Q.3 **(A)** Sea water is to be desalinized by reverse osmosis using the scheme indicated in Figure Q.3 (A). Use the data given in the figure to determine: (a) the rate of waste brine removal (B); (b) the rate of desalinized water (called potable water) production (P); (c) the fraction of the brine leaving the reverse osmosis cell (which acts in essence as a separator) that is recycled.

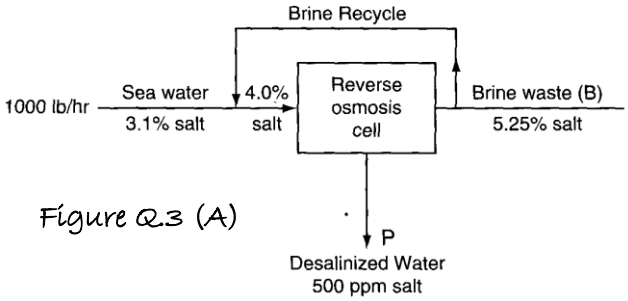


Figure Q.3 (A)

(B) A 400 ft^3 tank of compressed H_2 is at a pressure of 55 psig. It is connected to a smaller tank with a valve and short line. The small tank has a volume of 50 ft^3 and contains H_2 at 1 atmosphere absolute and the same temperature. If the interconnecting valve is opened and no temperature change occurs, what is the final pressure in the system? [The barometer reads 1 atm , 1 atm = 14.7 psia]

Q.4 A synthetic gas generated from coal has the following composition: CO_2 7.2% ; CO 24.3% ; H_2 14.1% ; CH_4 3.5% ; N_2 50.9%. (See Figure Q.4)

(a) Calculate the cubic feet of air necessary for complete combustion per cubic foot of synthetic gas at the same conditions (V_{Air}/V_{Feed}).

(b) If 38% excess air were used for combustion, what volume of flue gas at 750 ^oF and 738 mm Hg would be produced per cubic foot of synthetic gas at standard conditions ($V_{prod.}/V_{Feed}$). [R=554.55 mmHg. ft^3/lb mol. °R]

(c) Calculate the flue gas analysis for (a) and (b).

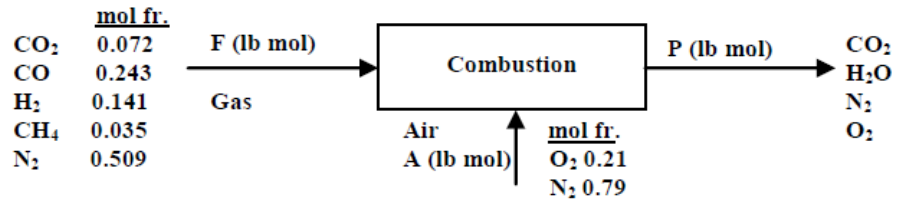


Figure Q.4

Q.5 (A) Which of these three sets of containers represents respectively one mole of lead (Pb), one mole of zinc (Zn) and one mole of carbon (C)? {Pb: MW = 207.21 & Sp Gr = 11.33, Zn: MW = 65.38 & Sp Gr = 7.14, C: MW = 12.01 & Sp Gr = 2.26, density of water = 1 g/cm^3}

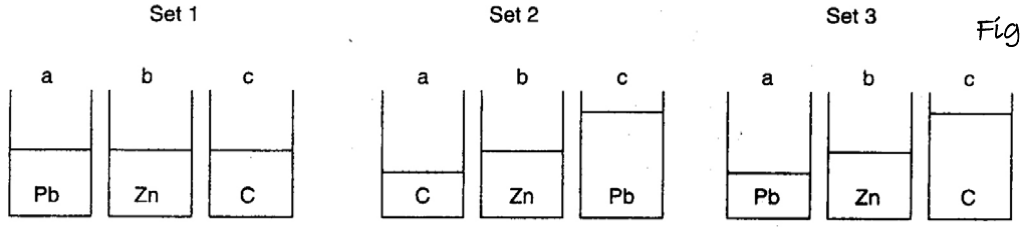


Figure Q.5 (A)

(B) Thirty pounds (30 lb) of coal (analysis 80% C and 20% H ignoring the ash) are burned with 600 lb of air, yielding a gas having an Orsat analysis in which the ratio of CO_2 to CO is 3 to 2. What is the percent excess air? {MW (C) = 12, MW (H) = 2, MW (air) = 29}

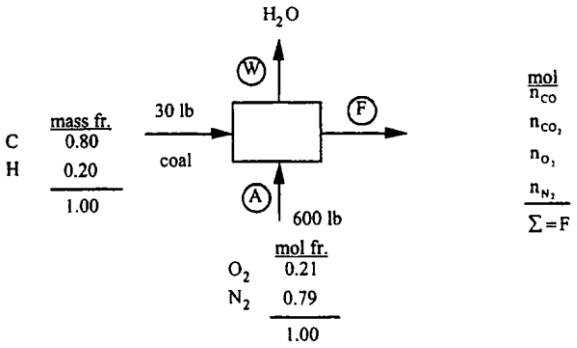
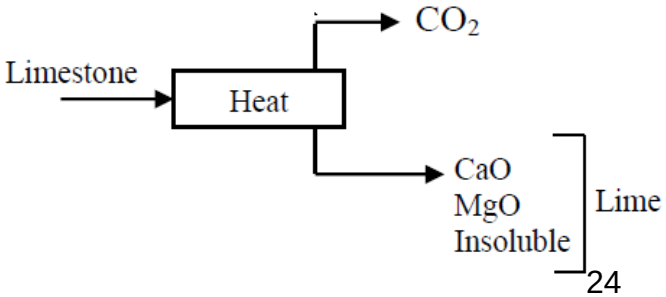


Figure Q.5 (B)

Q.6 A limestone analysis $CaCO_3$ 92.89%, $MgCO_3$ 5.41% and insoluble 1.7%

a. How many pounds of calcium oxide can be made from 5 tons of this limestone?
b. How many pounds of CO_2 can be recovered per pound of limestone?
c. How many pounds of limestone are needed to make 1 ton of lime?

(Mol. weight: $CaCO_3$ 100.1, $MgCO_3$ 84.32, CaO 56.08, MgO 40.32, CO_2 44 and 1 ton = 2000 lb)



$$CaCO_3 \longrightarrow CaO + CO_2$$
$$MgCO_3 \longrightarrow MgO + CO_2$$

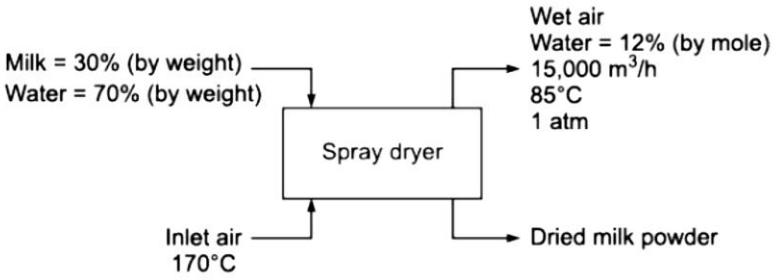
University of Baghdad
Chemical Engineering Department
Final Examination
2013/2014

Subject: Chem. Eng. Principles
Examiner: Dr.Ahmed Faiq Al-Alawy

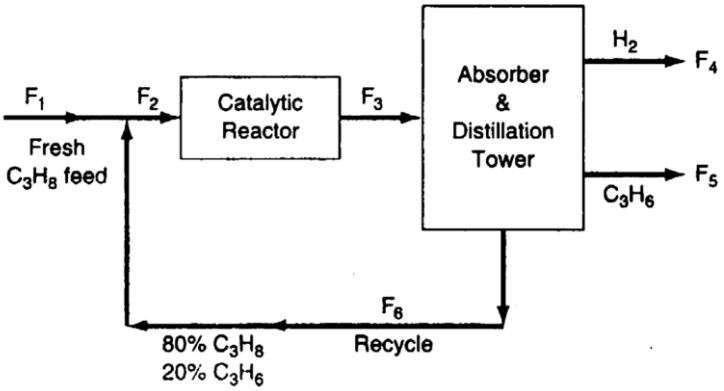
Class: First
Time: 3 hours
Date: 15/06/2014

ATTEMPT FIVE QUESTIONS ONLY

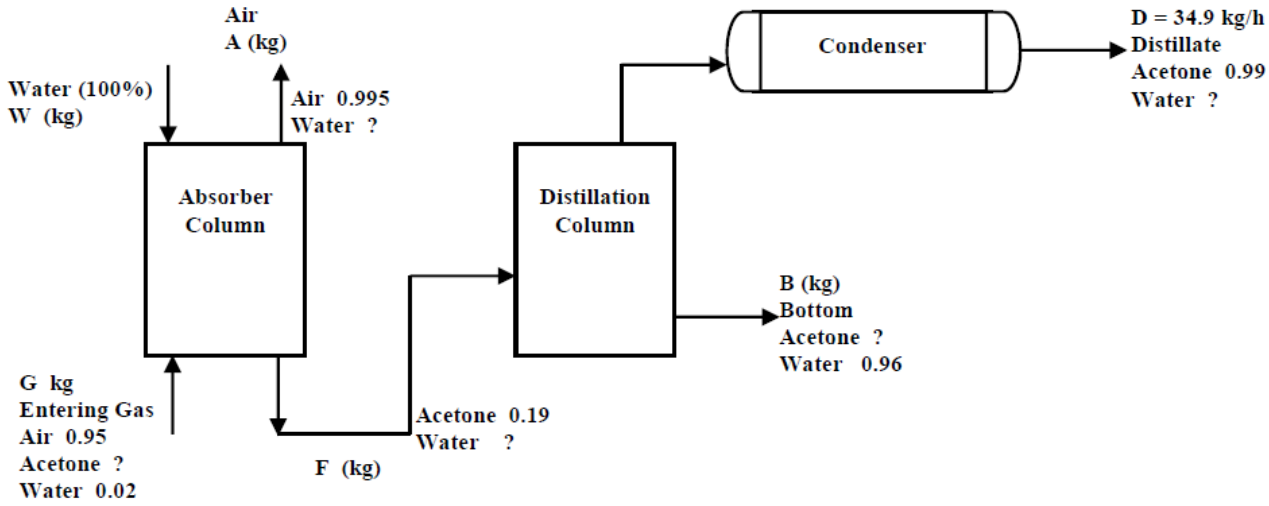
Q.1 Milk powder is produced in a spray dryer which evaporates all of liquid (H_2O, MW = 18). The operation is shown in figure. Assuming inlet air contains no water and R = 0.082 m^3.atm/kgmol. K. Calculate:
(i) Production rate of powdered milk.
(ii) Molal flow rate of the inlet air.



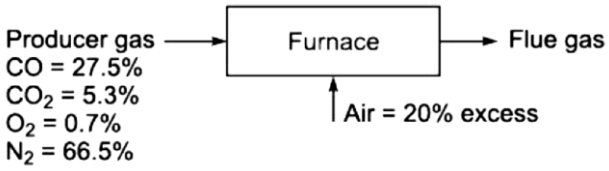
Q.2 The process shown in figure is the dehydrogenation of propane (C_3H_8) to propylene (C_3H_6) according to the reaction $C_3H_8 \longrightarrow C_3H_6 + H_2$. The conversion of propane to propylene based on the total propane feed into the reactor at F_2 is 40%. The product flow rate F_5 is 50 kg mol/h.
(a) Calculate the flow rates F_1, F_2, F_3, F_4 and F_6.
(b) What is the percent conversion of propane in the reactor based on the fresh propane fed to the process (F_1).



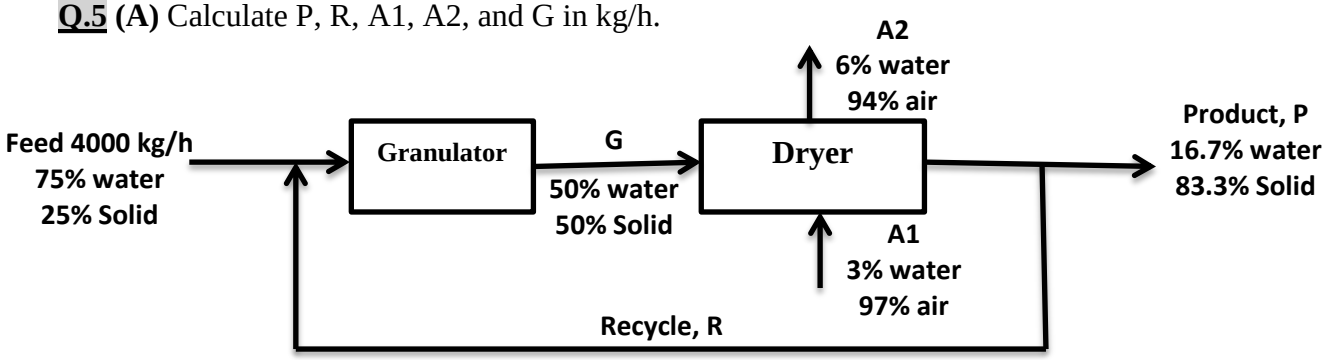
Q.3 All the concentrations shown in Figure of both gases and liquids are specified in weight percent. Calculate A, F, W, B, and G in kg/h



Q.4 A producer gas with composition by volume is as follows: CO = 27.5%, CO_2 = 5.3%, O_2 = 0.7% and N_2 = 66.5%. It is burnt with 20% excess air. If the combustion is 96% complete, calculate the composition by mole of the flue gas.

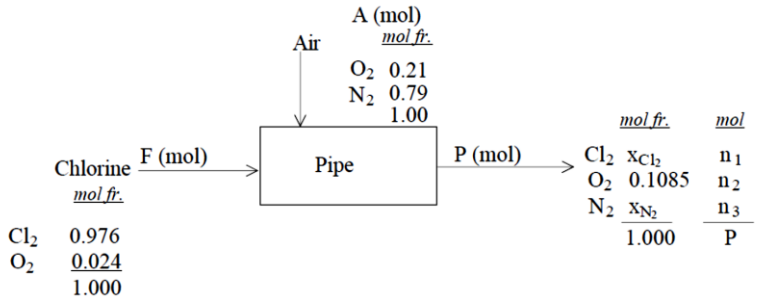


Q.5 (A) Calculate P, R, A1, A2, and G in kg/h.



(B) A steel container has a volume of 200 m^3. It is filled with nitrogen at 22°C and 1 atm pressure. If the container valve is opened and the container heated to 200°C, calculate the fraction of the nitrogen which leaves the container. {R = 0.082 m^3.atm/kgmol. K}

Q.6 (A) Chlorine gas containing 2.4 percent O_2 is flowing through an earthenware pipe. The gas flow rate is measured by introducing air into it at the rate of 115 m^3/min. Further down the line, after mixing is complete, the gas is found to contain 10.85 percent O_2. How many m^3 of the initial gas were flowing per minute through the pipe?



(B) Determine the extent of reaction for the following chemical reaction [A + 3B ⟶ 2C] given the following analysis of feed [A = 100g, B = 50 g and C = 5 g] and product [C = 90 g]. Also, determine the g of A and B in the product. (MW: A 28; B 2; C 17)

ATTEMPT FIVE QUESTIONS ONLY

Q.1 In the feedstock preparation section of a plant manufacturing natural gasoline, isopentane is removed from butane free gasoline. Assume for purposes of simplification that the process and components are as shown in Figure Q.1. What fraction of the butane free gasoline is passed through the isopentane tower? The process is in the steady state and no reaction occurs.

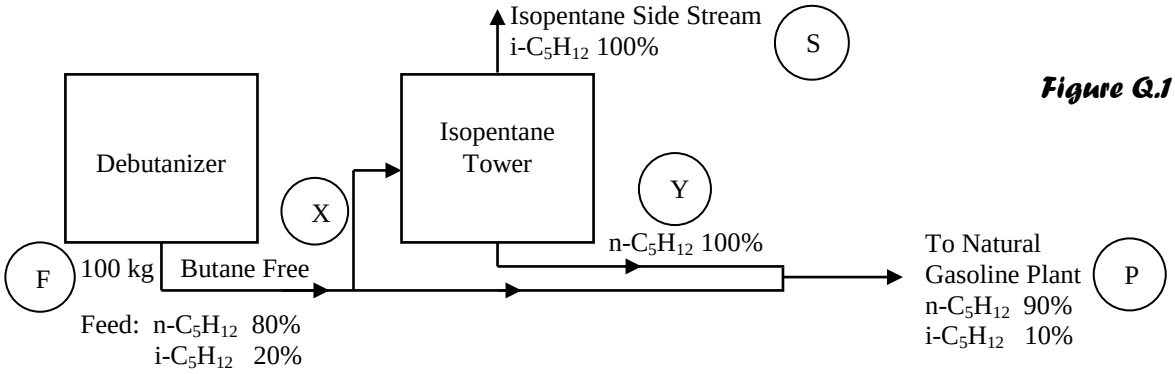


Figure Q.1

Q.2 (A) Small animals such as mice can live (although not comfortably) at reduced air pressures down to 20 kPa absolute. In a test, a mercury manometer attached to a tank, as shown in Figure Q.2A, reads 64.5 cm Hg and the barometer reads 100 kPa. Will the mice survive?{1 atm = 101.3 kPa and 1 atm = 76 cm Hg}

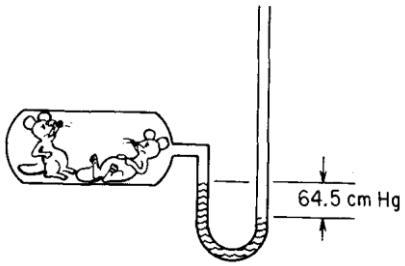


Figure Q.2 (A)

(B) A medium – grade bituminous coal analyzes as follows:

Component	S	N	O	Ash	Water
wt%	2	1	6	11	3

The residuum is C and H in the mole ratio H/C=9. Calculate the mass fraction composition of the coal with the ash and the moisture omitted (MW: C=12 and H=1.008).

Q.3 Immobilized glucose isomers is used as a catalyst in producing fructose from glucose in a fixed-bed reactor (water is the solvent). For the system shown in Figure Q.3, what percent conversion of glucose results on one pass through the reactor when the ratio of the exit stream to the recycle stream in mass units is equal to 8.33? The reaction is

$$C_{12}H_{22}O_{11} \rightarrow C_{12}H_{22}O$$
Glucose Fructose

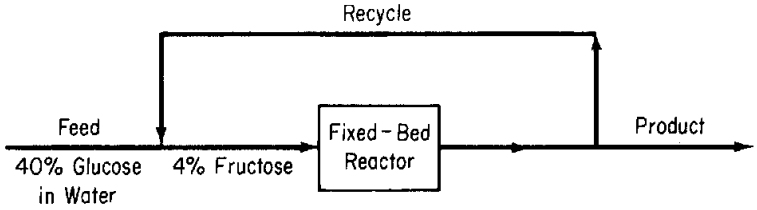


Figure Q.3

Q.4 The two reactions are:

$$Cl_2\,(g) + C_3H_6\,(g) \longrightarrow C_3H_5Cl\,(g) + HCl\,(g) \qquad (1)$$

$$Cl_2\,(g) + C_3H_6\,(g) \longrightarrow C_3H_6Cl_2\,(g) \qquad (2)$$

C_3H_6 is propylene (propene) (MW = 42.08), C_3H_5C1 is allyl chloride (3-chloropropene) (MW = 76.53), $C_3H_6Cl_2$ is propylene chloride (1,2—dichloropropane) (MW = 112.99)
The species recovered after the reaction takes place for some time are listed in Table.

species	Cl_2	C_3H_6	C_3H_5C1	$C_3H_6Cl_2$	HCl
g mol	141	651	4.6	24.5	4.6

Based on the product distribution assuming that no allyl chlorides were present in the feed, calculate the following:

a. How much Cl_2 and C_3H_6 were fed to the reactor in g mol?
b. What was the limiting reactant?
c. What was the excess reactant?
d. What was the fraction conversion of C_3H_6 to C_3H_5C1?
e. What was the selectivity of C_3H_5C1 relative to $C_3H_6Cl_2$?
f. What was the yield of C_3H_5C1 expressed in g of C_3H_5C1 to the g of C_3H_6 fed to the reactor?
g. What was the extent of reaction of the first and second reactions?

Q.5 Figure Q.5 shows a three – stage separation process. The ratio of P_3/D_3 is 3, the ratio of P_2/D_2 is 1, and the ratio of A to B in stream P_2 is 4 to 1. Calculate the composition and percent (wt %) of each component in stream E.

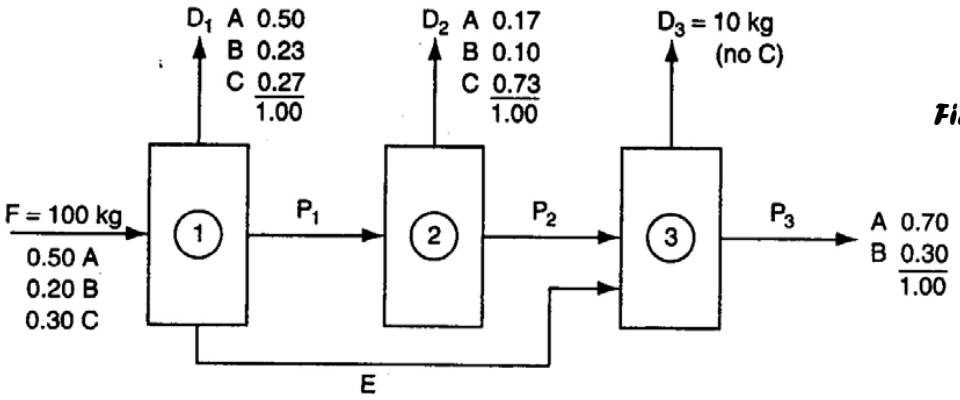


Figure Q.5

Q.6 Two tanks containing N_2 at the following conditions sit next to each other

	Tank A	**Tank B**
Volume (m^3)	1	5
Temperature (°C)	25	40
Pressure (kPa)	300	?
Amount of gas (g mol)	?	?

After the two tanks are connected and reach equilibrium, the conditions in the combined tanks are 700 kPa and 35 ^oC. What was the pressure in Tank B? [R = 8.314 kPa m^3/kg mol K]