BITS, PILANI-DUBAI CAMPUS, KNOWLEDGE VILLAGE, DUBAI
Second Semester 2006-2007

CHE UC221 Chemical Process Calculations

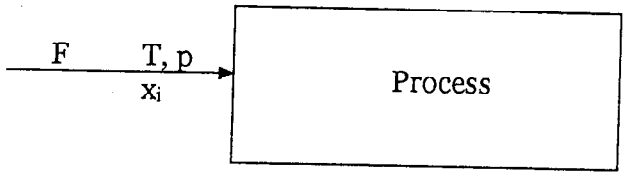
Comprehensive Examination
(Closed Book)

DURATION: 3 Hours **DATE: 31-05-07**
MAXIMUM MARKS: 120

Note: Attempt ALL questions. Draw a labeled flow diagram wherever necessary, mentioning therein all the known and unknown variables. Write all assumptions and steps clearly.

Question 1 Write brief and to-the-point answers to the following questions. Answer all the parts together and in sequence.
[5 + 3 + (2 + 2) + (2 + 2) + 2 + 2 + (2 + 2) + 2 + 2 + 2 + (2 +2) + 2 = 36]

(a) Trace the evolution of chemical engineering as an independent profession (in about 200 words).
(b) Site any six industry sectors where chemical engineers have major role to play.
(c) What are unit operations? Name any four unit operations encountered in chemical industry.
(d) How is specific gravity defined for liquids and for gases?
(e) What are the assumptions made in calculating the average molecular weight of air?
(f) In terms of number of unknown variables and number of equations, describe when a material balance problem will be labeled as underspecified?
(g) Briefly state why do we need recycling and purge in a chemical process?
(h) How are absolute saturation and relative saturation related? Write the formula relating the two.
(i) What is the difference between higher heating value (HHV) and lower heating value (LHV) of a fuel?
(j) How mixing of real solutions differs from that of ideal solutions in terms of energy considerations?
(k) Define wet bulb temperature. Relate it qualitatively to the humidity of the air.
(l) For the process stream shown below, count and show the number of stream variables associated.



Question 2 [3 + 4 + 12 = 19]
(a) A drain cleaner contains 5.00 kg of water and 5.00 kg of NaOH. What are the mass fraction and mole fraction of each component in the drain cleaner container. Given molecular weight of NaOH = 40. [1+2]

(b) Two engineers are calculating the average molecular weight of a gas mixture containing oxygen and other gases. One of them uses the correct molecular weight of 32 for oxygen and determines the average molecular weight as 39.2. The other uses an incorrect value of 16 and determines the average molecular weight as 32.8. This is the only error in calculations. What is the percentage of oxygen in the mixture expressed as mol %? [4]

(c) The burning of limestone, $CaCO_3 \rightarrow CaO + CO_2$, goes only 70% to completion in a certain kiln. (i) What is the composition (mass percent) of the solid withdrawn from the kiln? (ii) How many kilograms of CO_2 are produced per kilogram of lime stone fed? Assume that the limestone is pure calcium carbonate. Given: molecular weight of CaO = 57. [12]

Question 3 [4 + 12 = 16]

(a) Define selectivity and yield. [2+2]

(b) 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.

$$Sb_2S_3 + 3\ Fe \rightarrow 2\ Sb + 3\ FeS$$

If 0.600 kg of stibnite and 0.250 kg of iron turnings are heated together to give 0.200 kg of Sb metal, determine: (i) the limiting reactant, (ii) the percent of excess reactant, (iii) the degree of completion, and (iv) the yield. Given: molecular weights: Fe = 55.85, Sb = 121.8, S = 32.0. [3X4 =12]

Question 4 [2 + 12 + 5 = 19]

(a) Three gaseous mixtures, A, B, and C, with the compositions listed in the table below are blended into a single mixture.

Gas	***A***	***B***	***C***
CH_4	25	25	60
C_2H_6	35	30	25
C_3H_8	40	45	15
Total	100	100	100

A new analyst reports that the composition of the mixture is 25% CH_4, 25% C_2H_6, and 50% C_3H_8. Without making any detailed calculations, explain how you know the analysis is incorrect. [2]

(b) A gas containing only CH_4 and N_2 is burned with air yielding a flue gas that has an Orsat analysis of CO_2 = 8.7%, CO = 1.0%, O_2 = 3.8%, and N_2 = 86.5%. Calculate the percent excess air used in combustion and the composition of the CH_4-N_2 mixture. [12]

(c) d-Glucose and d-Fructose have the same chemical formula ($C_6H_{12}O_6$) but different properties. Glucose is converted to fructose as shown in figure, but only 60% is converted on one pass through the converter vessel so that unconverted material is recycled. Calculate the flow of the recycle stream per kg 100% glucose fed to the converter. Ignore the solvent water used to carry the glucose and fructose. [5]

A

BITS, PILANI-DUBAI CAMPUS, KNOWLEDGE VILLAGE, DUBAI

Second Semester 2006-2007

CHE UC221 Chemical Process Calculations

Quiz - 1

(Closed Book)

DATE: 11-04-07

DURATION: 30 MINUTES **MAXIMUM MARKS: 30**

Note: Attempt ALL questions. Do rough calculations on the back.

1. A liquefied mixture of n-butane and n-pentane has the following composition in mole percent:

   n - C_4H_{10} 50

   n – C_5H_{12} 50

   For this mixture calculate the average molecular weight.

Answer: Average molecular weight = ...

2. A stack gas contains 70.0% N_2, 12.0% CO_2, 8.0% O_2, and the balance H_2O. Calculate the molar composition on a dry basis.

Answer:

3. In methyl alcohol, find out the mass fractions of carbon and oxygen.

Answer: Mass fraction Carbon = Mass fraction Oxygen =

4. The oxidation of ethyl alcohol proceeds according to following equation:

   $$C_2H_5OH + 3\,O_2 \rightarrow 2\,CO_2 + 3\,H_2O$$

   The feed to a reactor contains 50 kg of C_2H_5OH and 100 kg of O_2. What is the percent excess air?

Answer: Percent excess air =

5. If feed of 100 tones per hour at 5% concentration is fed to a crystallizer, the product obtained at 25% concentration is equal to _____ tones per hour.

Answer:

6. In a drying process moisture is reduced from 60% to 30%. Initial weight of the material is 200 kg. Calculate the final weight of the product.

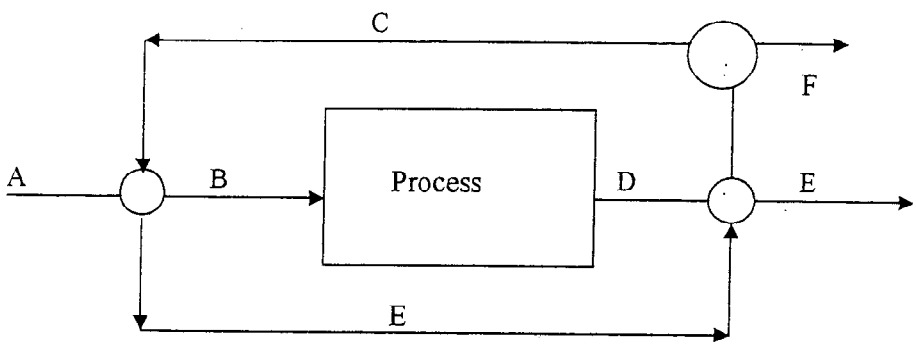
Answer:

7. Two hundred kg per hour of a mixture of benzene (B) and toluene (T) containing 50% benzene by mass is separated by distillation into two fractions. The mass flow rate of benzene in top stream is 80 kg B/h and that of toluene in the bottom stream is 85 kg T/h. calculate the mass fraction of benzene in top stream.

Answer:

8. The percent absolute humidity of air at 30 ^{o}C and a total pressure of 750 mm Hg is 20%. Calculate the partial pressure of water vapor in air. Given the vapor pressure of water at 30 ^{o}C = 31.8 mm Hg.

Answer:



9. In the above diagram, identify: (Write the stream name in front of each)
   1. the process feed
   2. the gross product
   3. the net product
   4. the recycle stream
   5. the bypass stream
   6. the purge stream

***

B

BITS, PILANI-DUBAI CAMPUS, KNOWLEDGE VILLAGE, DUBAI

Second Semester 2006-2007

CHE UC221 Chemical Process Calculations

Quiz - 1

(Closed Book)

DATE: 11-04-07

DURATION: 30 MINUTES **MAXIMUM MARKS: 30**

Note: Attempt ALL questions. Do rough calculations on the back.

1. A liquefied mixture of n-butane and n-pentane has the following composition in mole percent:

   n - C_4H_{10} 50

   n – C_3H_8 50

   For this mixture calculate the average molecular weight.

Answer: Average molecular weight = ...

2. A stack gas contains 65.0% N_2, 12.0% CO_2, 8.0% O_2, and the balance H_2O. Calculate the molar composition on a dry basis.

Answer:

3. In methyl alcohol, find out the mole fractions of carbon and oxygen.

Answer: Mole fraction Carbon = Mole fraction Oxygen =

4. The oxidation of ethyl alcohol proceeds according to following equation:

   $$C_2H_5OH + 3\,O_2 \rightarrow 2\,CO_2 + 3\,H_2O$$

   The feed to a reactor contains 50 kg of C_2H_5OH and 150 kg of O_2. What is the percent excess air?

Answer: Percent excess air =

5. If feed of 100 tones per hour at 5% concentration is fed to a crystallizer, the product obtained at 25% concentration is equal to _____ tones per hour.

Answer:

6. In a drying process moisture is reduced from 60% to 30%. Initial weight of the material is 200 kg. Calculate the weight of the water evaporated.

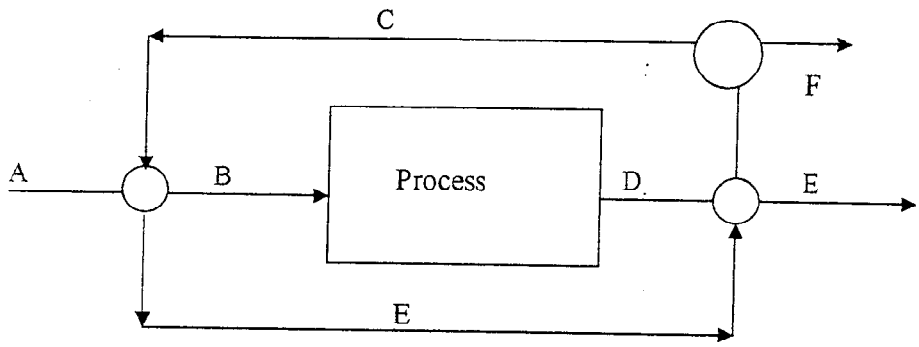
Answer:

7. Two hundred kg per hour of a mixture of benzene (B) and toluene (T) containing 50% benzene by mass is separated by distillation into two fractions. The mass flow rate of benzene in top stream is 80 kg B/h and that of toluene in the bottom stream is 85 kg T/h. Calculate the mass fraction of benzene in bottom stream.

Answer:

8. The percent absolute humidity of air at 30 ^{o}C and a total pressure of 100 kPa is 20%. Calculate the partial pressure of water vapor in air. Given the vapor pressure of water at 30 ^{o}C = 4.272 kPa.

Answer:



9. In the above diagram, identify: (Write the stream name in front of each)
   1. the fresh feed
   2. the process feed
   3. the net product
   4. the recycle stream
   5. the bypass stream
   6. the purge stream

***

BITS, PILANI-DUBAI CAMPUS, KNOWLEDGE VILLAGE, DUBAI
Second Semster 2006-2007

CHE UC221 Chemical Process Calculations

TEST - 1
(Closed Book)

DATE: 18-03-07

DURATION: 50 MINUTES **MAXIMUM MARKS: 60**

Note: Attempt ALL questions. Draw a labeled flow diagram wherever necessary, mentioning therein all the known and unknown variables.

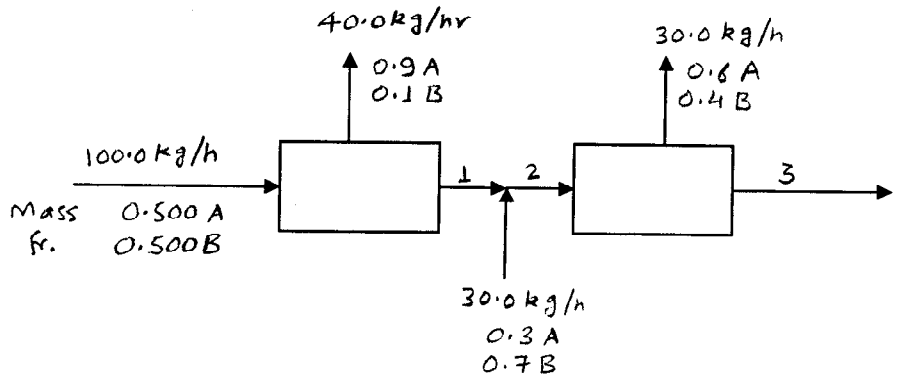
1. Express the pressure of 25 psi in (a) atm, (b) kPa, (c) kgf/cm^2, (d) mm Hg. Show conversion calculations. [08]

2. The oxidation of ethylene to produce ethylene oxide proceeds according to following equation: $2\ C_2H_4 + O_2 \rightarrow 2\ C_2H_4O$

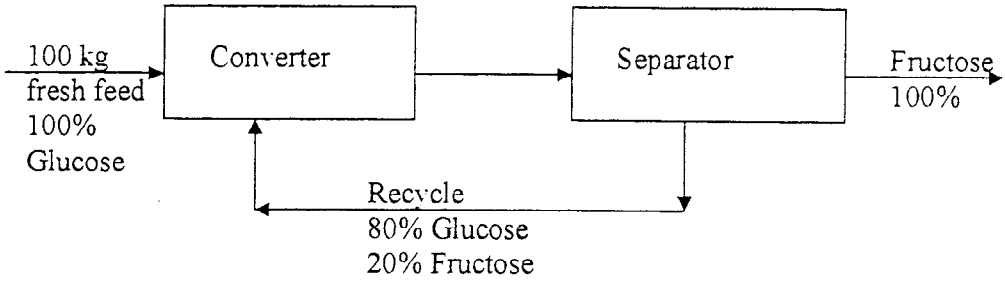
   The feed to a reactor contains 100 kg mole of C_2H_4 and 100 kg mole of O_2. Find out:
   (a) Which reactant is limiting? [03]
   (b) What is the percent excess of the other reactant? [03]
   (c) If the reaction proceeds to completion, how much of the excess reactant will be left; how much of the C_2H_4O will be formed? [06]

3. A gas with following composition is burned with 50% excess air in a furnace. What is the composition of the flue gas by percent?
   CH_4: 60%; C_2H_6: 20%; CO: 5%; O_2: 5%; N_2: 10% [20]

4. A labeled flowchart of a continuous steady state two-unit process is shown below. Three streams whose flow rates and/ or compositions are unknown are labeled as 1, 2, and 3. Calculate the unknown flow rates and compositions of streams 1, 2, and 3. [20]



***



Question 5 [10 + 5 + 5 = 20]

(a) The vapor pressure of hexane (C_6H_{14}) at -20 °C is 14.1 mm Hg absolute. Dry air at this temperature is saturated with the vapor under a total pressure of 760 mm Hg. What is the percent excess air for combustion? [10]

(b) Two gram moles of nitrogen are heated from 50 °C to 250 °C in a cylinder. What is ΔH for the process? The heat capacity equation is $C_p = 27.32 + 0.6226 \times 10^{-2} T - 0.0950 \times 10^{-5} T^2$ where T is in Kelvin and C_p is in J/(g mol)(°C). [5]

(c) The following enthalpy changes are known for reactions at 25 °C in the standard thermo-chemical state:

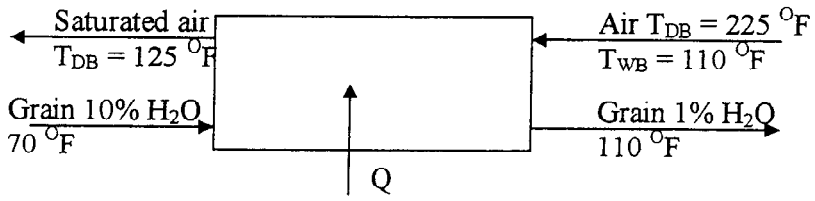
C_3H_6 (g) + H_2 (g) → C_3H_8 (g)	ΔH° (kJ) = -124.0
C_3H_8 (g) + $5O_2$ (g) → $3CO_2$ (g) + $4H_2O$ (l)	ΔH° (kJ) = -2220.0
H_2 (g) + ½ O_2 (g) → H_2O (l)	ΔH° (kJ) = -286.0
H_2O (l) → H_2O (g)	ΔH° (kJ) = -44.0
C + O_2 (g) → CO_2 (g)	ΔH° (kJ) = -393.5

Calculate heat of formation of propylene. [5]

Question 6 [2 + 4 + 4 = 10]

A rotary drier operating at atmospheric pressure dries 2000 lb/ day of wet grain at 70 °F, from a moisture content of 10% to 1% moisture. The air flow is counter current to the flow of grain, enters at 225 °F dry-bulb and 110 °F wet-bulb temperature, and leaves at 125 °F dry-bulb as saturated. Determine:

(a) The humidity of the entering and leaving air
(b) The water removal in pounds per hour
(c) The daily product output in pounds per day [2+4+4]



*** Best of Luck ***

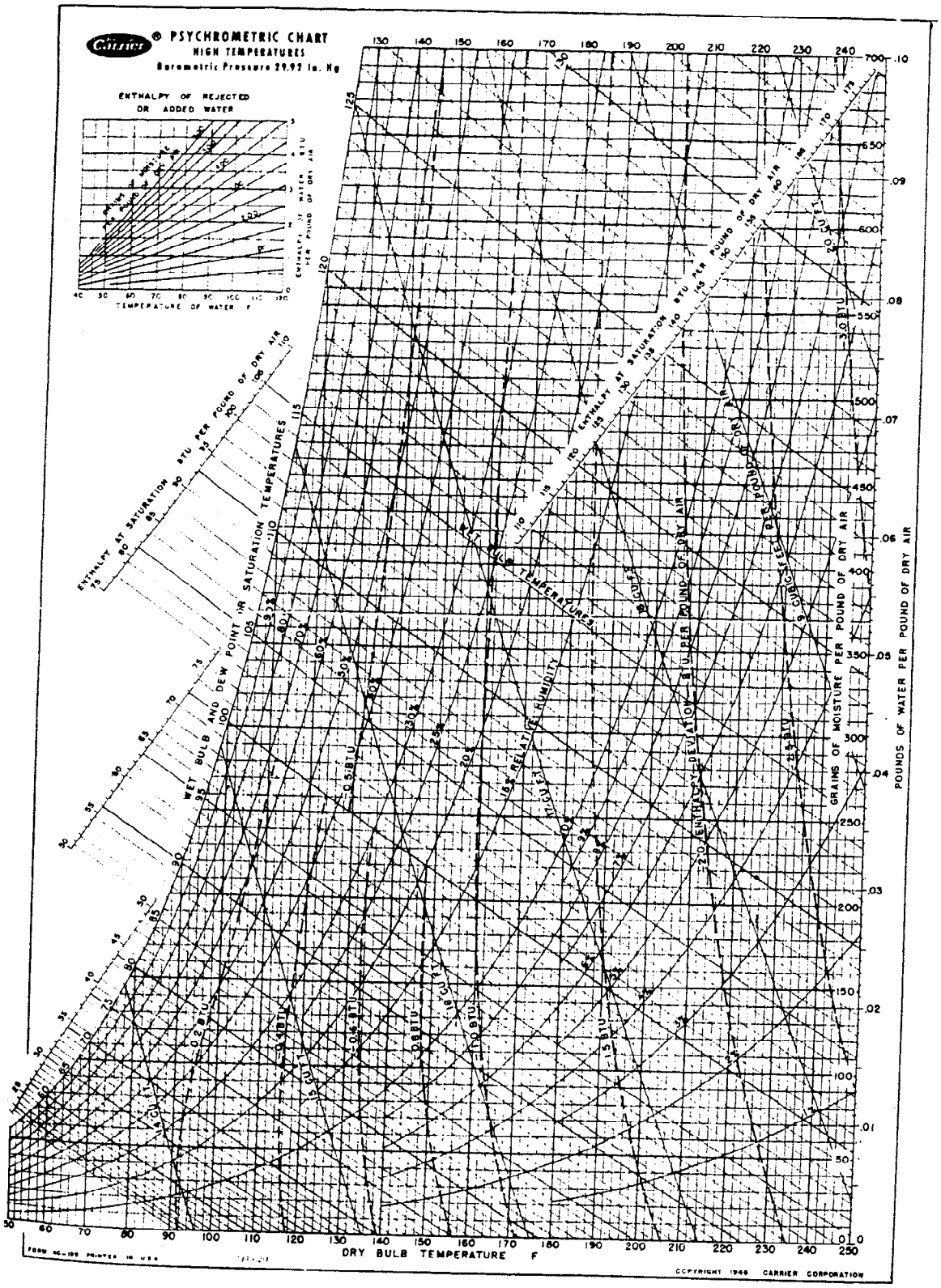


Figure 5.19a (Reprinted by permission of Carrier Corporation.)