BITS, PILANI – DUBAI CAMPUS

SECOND SEMESTER 2011 – 2012

SECOND YEAR (Chemical)

Course Code: CHE C221 **COMPREHENSIVE** Date: 12.06.12

Course Title: Chemical Process Calculations Max Marks: 80

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

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.

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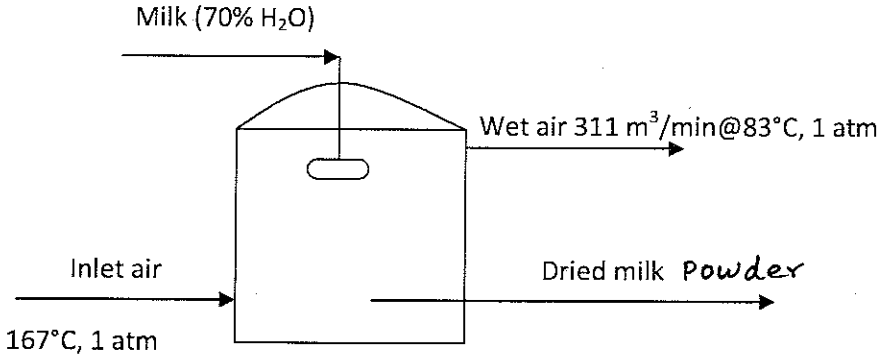
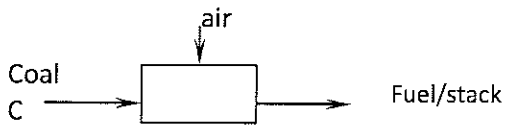
1. Powdered milk is produced in a spray dryer 6 m in diameter by 6 m high. Air enters at 167°C and 1 atm. The milk fed to the atmomizer contains 70% water by mass, all of which evaporates. The outlet gas contains 12 mole % water and leaves the chamber at 83°C and 1 atm (abolute) at a rate of 311 m^3/min.(R = 0.08206 m^3 atm/Kmol K) (12 m)



Calculate the production rate of dried milk and the volumetric flow rate of the inlet air. Estimate upward velocity of air (m/min) at the bottom of the dryer.

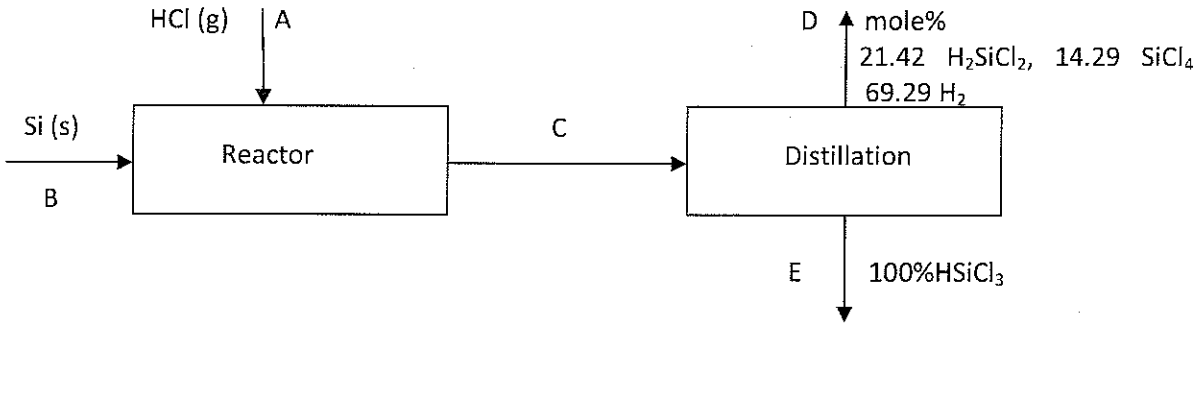
2. A coal has ultimate composition C 67.34%, H_2 4.67%, O_2 8.47%, N_2 1.25%, and S 4.77% and the rest is ash. All are in wt %. Find the theoretical air-fuel ratio (kg air/kg fuel) (10 m)



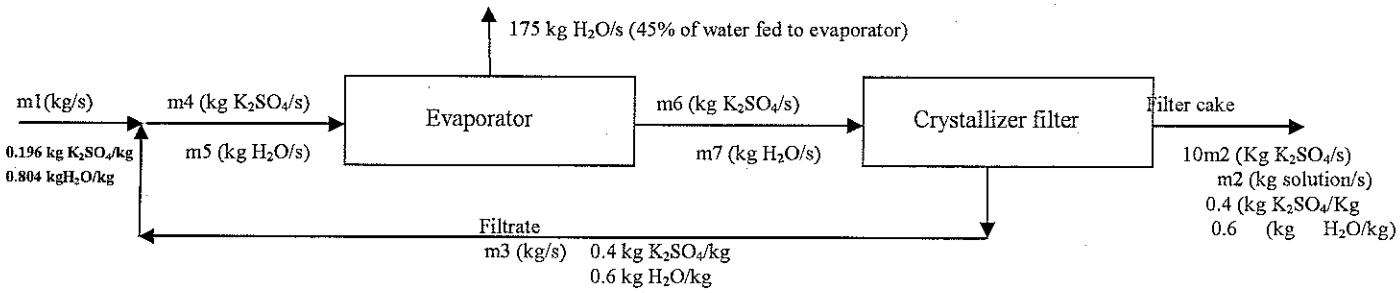
3. Metallurgical-grade silicon is purified to electronic grade for use in semiconductor industry by chemically separating it from its impurities. The Si metal reacts in varying degrees with hydrogen chloride gas at 300°C to form several polychlorinated silanes.

Trichlorosilane is liquid at room temperature and is easily separated by fractional distillation from other gases. If 100 kg of silicon is reacted as shown in the figure below, how much trichlorosilane is produced? (10 m)

(MW: Si = 28.09, Cl_3 = 10.35)



4. An evaporation-crystallization operation is used to obtain solid potassium sulfate from an aqueous solution of this salt. The fresh feed to the process contains 19.6 wt% K_2SO_4. The wet filter cake consists of solid K_2SO_4 crystals and a 40 wt% K_2SO_4 solution, in a ratio 10 kg crystals/kg solution. The filtrate, also a 40% solution, is recycled to join the fresh feed. Of the water fed to the evaporator, 45% is evaporated. The evaporator has a maximum capacity of 175 kg water evaporated. Assume the process is operating at maximum capacity. Calculate the maximum production rate of solid K_2SO_4, the rate at which fresh feed must be supplied to 75% of its maximum capacity. (10 m)



5.(a) Fourteen mol/h of a 20 mole% C_3H_8, 80% n-C_4H_{10} gas mixture at 0°C and 1.1 atm and nine mol/h of a 40 mole% C_3H_8, 60% C_4H_{10} mixture at 25°C and 1.1 atm are mixed and heated to 227°C at constant pressure. Calculate the heat requirement in KJ/h. Enthalpies of propane and n-butane are listed. (8 m)

T (°C)	Propane H (J/mol)	Butane H (J/mol)
0	0	0
25	1772	2394
227	20685	27442

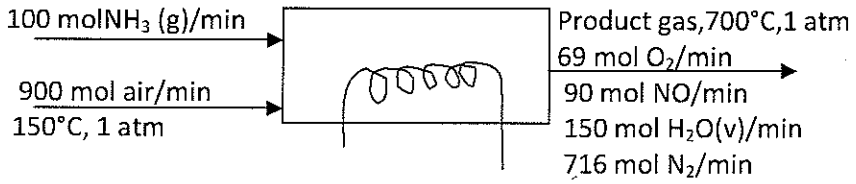
5.(b) Calculate the rate of cooling (kW) required to bring 300 kg/min of carbon monoxide (mw= 28) from 450°C to 50°C by direct method as well integration method. (4+4 = 8 m)

6. Ammonia is oxidized with air to form nitric oxide in the first step of the production of nitric acid. Two principal reactions occur: (12 m)

$$4NH_3 + 5\ O_2 \longrightarrow 4NO + 6\ H_2O$$

$$2\ NH_3 + 3/2\ O_2 \longrightarrow 3\ N_2 + 3\ H_2O$$

A flow chart of the reactor follows:



Calculate the required rate of heat transfer to or from the reactor in KW.

7.(a) The heat of solution of ammonia in water at 1 atm is

ΔH_s (25°C, r = 2 mol H_2O/mol NH_3) = -78.2 KJ/mol

Calculate the enthalpy change that accompanies the dissolution of 400 mol of NH_3 in 800 mol of water at 25°C and 1 atm. (2 m)

(b) Wet solids pass through a continuous dryer. Hot dry air enters the dryer at a rate of 400 kg/min and picks up the water that evaporates from the solids. Humid air leaves the dryer at 50°C containing 0.025 kg water /kg dry air and passes through a condenser in which it is closed to 10°C. The pressure is constant at 1 atm throughout the system. (8 m)

i) At what rate (kg/min) is water evaporating in the dryer

ii) Use the psychrometric chart to estimate the wet-bulb temperature, relative humidity, dew point, and specific enthalpy of the air leaving the dryer.

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SECOND SEMESTER 2011 – 2012

SECOND YEAR (Chemical)

Course Code: CHE C221 **TEST 2** Date: 13.05.12

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. Chlorine gas is to be heated from 100°C and 1 atm to 200°C. Calculate the heat input (KJ) required to raise the temperature of 5 kmol of chlorine in a closed rigid vessel from 100°C and 1 atm to 200°C. (6 m)

2. The heat capacity of liquid n - hexane is measured in a bomb calorimeter. A small reaction flask (the bomb) is placed in well-insulated vessel containing 2 L of liquid n - hexane at T = 300K. A combustion reaction known to release 16.73 KJ of heat takes place in the bomb, and the subsequent temperature rise of the system contents is measured and found to be 3.1 K. In a separate experiment, it is found that 6.14 KJ of heat is required to raise the temperature of everything in the system except the hexane by 3.1K. Estimate C_p (KJ/mol K) for liquid n-hexane at T = 300 K from the given data and compare the same with tabulated value. (5 m)

3. Calculate the heat required to raise 50 kg of sodium carbonate from 10°C to 50°C at 1 atm using the true heat capacity of Na_2CO_3, which is 1.14 KJ/Kg °C. (2 m)

4. Determine the sp. enthalpy (KJ/mol) of n-hexane vapour at 200°C and 1 atm relative to n-hexane liquid at 20°C and 1 atm, assuming ideal gas behavior for the vapour. (7 m)

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SECOND SEMESTER 2011 – 2012

SECOND YEAR (Chemical)

Course Code: CHE C221 **TEST 1** Date: 22.03.12

Course Title: Chemical Process Calculations Max Marks: 25

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

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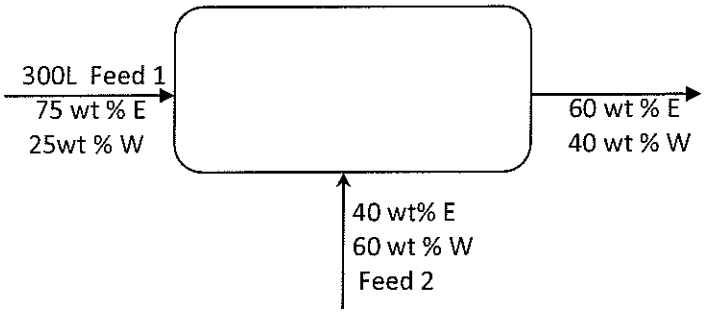
1. Three hundred liters of a mixture containing 75 wt% ethyl alcohol and 25 wt% water (mixture sp gravity 0.877) and a quantity of a 40% ethyl alcohol – 60% water mixture (mixture sp gravity 0.952) are blended to produce mixture containing 60 wt% ethyl alcohol. Calculate the required volume of 40% ethyl alcohol – 60% water mixture to produce the above said mixture. (7 m)



2. One thousand kilogram per hour of a mixture containing equal parts by mass of methanol and water is distilled. Product streams leave the top and the bottom of the distillation column. The flow rate of the bottom stream is measured and found to be 673 kg/h and the overhead stream is analyzed and found to contain 96 wt% methanol. Calculate the mass and mole fractions and the molar flow rates of methanol and water in the feed, top and bottom product streams. (10 m)

3. Wet air containing 4 mole % water vapor is passed through a column of calcium chloride pellets. The pellets adsorb 97% of the water and none of the other constitute of the air. The column packing was initially dry and had a mass of 3.4 kg. Following 5 hr of operation, the pellets are reweighed and found to have a mass of 3.5 kg. Calculate the molar flow rate (mol/hr) and mole fraction of the feed gas and product gas. (8 m)

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SECOND SEMESTER 2011 – 2012

SECOND YEAR (Chemical)

Course Code: CHE C221 **QUIZ 2** Date: 23.04.12

Course Title: Chemical Process Calculations Max Marks: 07

Duration : 20 minutes (Closed Book) Weightage: 7%

Name: ..... **ID No:** ..... **Prog:** .....

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1. Corrosion rate of pipes in boiler can be brought down by removing oxygen from feed water using sodium sulfite (Na_2SO_3, mw = 126), calculate the kg of sodium sulfite required to remove the oxygen from 4000 KL of water containing 9 PPM. To ensure complete removal of oxygen 25% excess sodium sulfite is used. (4 m)

2. Methane is burned with air. Calculate the possible volume percent of carbon dioxide (on dry basis) in the flue gas. (3 m)

BITS, PILANI – DUBAI CAMPUS

SECOND SEMESTER 2011 – 2012

SECOND YEAR (CHEMICAL)

Course Code: CHE C221 **QUIZ 1** Date: 05.03.12

Course Title: Chemical Process Calculations Max Marks: 08

Duration : 20 minutes (Closed Book) Weightage: 8%

Name: ..... **ID No:** ..... **Prog:** .....

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1. 5.0 g of neon is at 256 mm Hg and at a temperature of 35° C. What is the volume in L ? (MW of Ne = 20.1797) (1.5m)

2. The specific gravity of gasoline is approximately 0.7 (1.5 m)
   a) Determine the mass (kg) of 50 liters of gasoline
   b) The mass flow rates of gasoline exiting a refinery tank is 1150 kg/min. Estimate the volumetric flow rate in liters

3. A mixture of methane and air is capable of being ignited only if the mole percent of methane is between 5% and 15%. A mixture containing 9 mole % methane in air flowing at a rate of 700Kg/h is to be diluted with pure air to reduce the methane concentration to the lower flammability limit. Calculate the dilution air required (mol/hr) to reduce the mole percent of methane 5% and the percent by mass of oxygen in the product gas. (5 m)