BITS, PILANI – DUBAI

SECOND SEMESTER 2009 – 2010

SECOND YEAR CHEMICAL ENGINEERING

Course Code: CHE C221 **COMPREHENSIVE EXAM** Date: 26.05.10

Course Title: Chemical Process Calculations Max Marks: 80

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

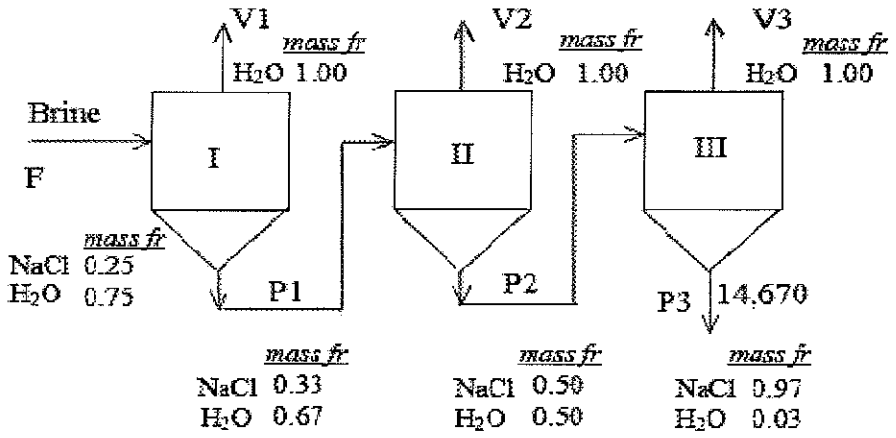
Note: Attempt ALL questions. Draw a labeled flow diagram wherever necessary, mentioning therein all the known and unknown variables. Write all assumptions and steps clearly.

1.(a) A liquid mixture of benzene and toluene contains 55% benzene by mass. The mixture is to be partially evaporated to yield a vapor containing 85% benzene and residual liquid containing 10.6 % benzene by mass. Suppose the process is to be carried out continuously and at steady state, with a feed rate of 100 kg/h of the 55% mixture. Let m_V(kg/h) and m_L (kg/h) be the mass flow rates of the vapor and liquid product streams, respectively. Determine the values of m_V and m_L.(5 m)

(b) Two methanol-water mixtures are contained in separate flasks. The first mixture contains 40 wt% methanol, and the second contains 70 wt% methanol. If 200g of the first mixture is combine with 150g of the second, what are the mass and composition of the product? (4 m)

(c) A paint mixture containing 25% of a pigment and the balance water sells for $ 18/kg, and a mixture containing 12% pigment sells for $10/kg. If a paint retailer produces a blend containing 17% pigment, for how much ($/kg) should it be sold to yield a 10% profit? (8 m)

2.(a) A triple effect evaporator is designed to reduce water from an incoming brine (NaCl + H_2O) stream from 25 wt % to 3 wt %. If the evaporator unit is to produce 14,670 kg/hr of NaCl (along with 3 wt % H_2O), determine the feed rate of brine in kg/hr and the water removed from the brine in each evaporator.
The data are shown in the accompanying figure. (15 m)



2.(b) Moist hydrogen containing 4 mole % water is burnt completely in a furnace with 32% excess air. Calculate the orsat analysis of the flue gas. (7 m)

3.(a) Hot air is being used to dry a wet material. The hot air enters at a total pressure of 770 mmHg and temperature of 433K. The partial pressure of water vapor in the incoming air is 25 mmHg. At the exit of the drier, the temperature is 383 K and the pressure is 760 mmHg. In the outgoing air, the partial pressure of water vapor is 100 mmHg. Calculate the absolute humidity of incoming air and outgoing air. Also calculate the weight of moisture picked up per $1000m^3$ of entering air. (8 m)

(b) Given $T_{DB} = 40°C$ and $T_{WB} = 25°C$, from the psychrometric chart find the (10 m)
(1) percentage relative humidity
(2) dewpoint
(3) specific enthalpy
(4) specific volume
(5) humidity

(c) Define the dew point and its significance. (3 m)

4.(a) A silica gel drier removes 1000 kg of water per hour. Air is supplied at a temperature of 55°C with mole fraction of 0.965. The air leaves the drier at a temperature of 32°C with mole fraction of 0.9898. The pressure in the system is constant at 100.0 kPa. Calculate the volume of the wet air (at the initial conditions) which is supplied per hour. (5 m)

(b) Two gram moles of carbon dioxide are heated from 400°C to 1100°C. Calculate ΔH by integrating the heat capacity equation for carbon dioxide. Compare your result with the value calculated from the enthalpy tables for the combustion gases. (5 + 2 m)

(c) The standard heat of reaction for the oxidation of ammonia is given below:

$$4\ NH_{3(g)} + 5O_{2(g)} \text{ gives } 4\ NO_{(g)} + 6\ H_2O_{(v)}: \quad \Delta H°r = -904.7\ KJ/mol$$

100 mole $NH_{3/s}$ and 200 mol $O_{2/s}$ at 25°C are fed into a reactor in which the ammonia is completely consumed. The product gas emerges at 300°C. Calculate the rate at which heat must be transferred to or from the reactor, assuming operation at approximately 1 atm. (8 m)

BITS, PILANI – DUBAI

SECOND SEMESTER 2009 – 2010

SECOND YEAR CHEMICAL ENGINEERING

Course Code: CHE C221 — TEST 2 — Date: 09.05.10

Course Title: Chemical Process Calculations — Max Marks: 20

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

Note: only prescribed txt book and own handwritten notes are allowed, Physical and chemical property tables are allowed

1. The standard heat of reaction for the combustion of liquid n-nonane liquid (C_9H_{20}) to form CO_2 and liquid water at 25°C and 1 atm is $\Delta\tilde{H}°_r$ = -6124 KJ/mol. (3 +2 m)

   a) If 25 mol/s of liquid nonane is consumed and the reactants and products are all at 25C, estimate the required rate of heat input or output in KW, assuming that $\hat{Q} = \Delta\tilde{H}$.

   b) The std heat of combustion of n-nonane vapor is $\Delta\hat{H}°_r$ = -6171 KJ/mol. What is the physical significance of the 47 KJ/mol difference between this heat of combustion and one given previously?

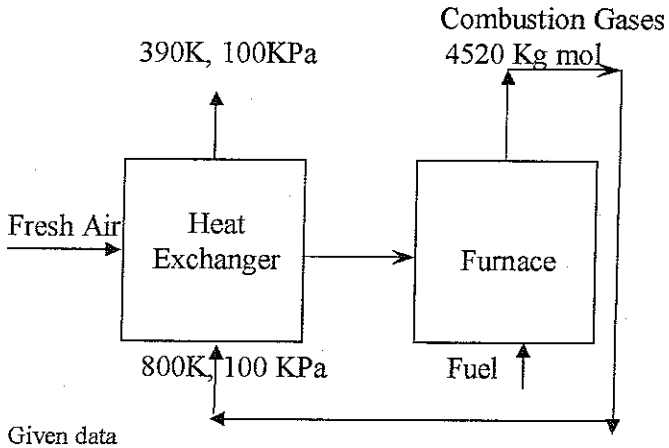
2. Calculate the following: (3 + 3 + 3m)

   a) The heat capacity (C_p) of liquid benzene at 40°C

   b) The heat capacity at constant pressure of benzene vapor at 40°C

   c) The heat capacity at constant pressure of solid carbon at 40°C

3. Energy can be saved by passing the combustion gases from a furnace or boiler through a heat exchanger in which the air entering the furnace is preheated. The air does not contact the combustion gases directly in the heat exchanger; the streams are separated by tube walls. Calculate the enthalpy change in kJ that occurs for the combustion gases (4520 Kg mol) on passing through the heat exchanger. (5 m)



Given data

Gases	Mol fractions
CO_2	0.07
H_2O	0.14
N_2	0.73
O_2	0.06

4. Define adiabatic flame temperature. (1 m)

BITS, PILANI – DUBAI

SECOND SEMESTER 2009 – 2010

SECOND YEAR CHEMICAL ENGINEERING

Course Code: CHE C221 **TEST 1** Date: 28.03.10

Course Title: Chemical Process Calculations Max Marks: 25

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

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1. A plant distills 1000 kg of a 20% solution of acetone in water. 50 kg of pure acetone is lost to the water residue. The distillate contains 90% acetone and 10% water. Calculate the weight of distillate and residue. (3 m)

2. One mole of butane is burnt with 80% of theoretical air. Calculate the analysis of gases leaving (in moles), assuming that all the hydrogen in butane is converted into water. (6 m)

3. You are asked to measure the rate at which waste gases are being discharged from a stack. The gases entering contain 2.1 % carbon dioxide. Pure carbon dioxide is introduced into the bottom of the stack at a measured rate of 4.0 Kg per minute. You measure the discharge of gases leaving the stack, and the concentration of carbon dioxide is 3.2 %. Calculate the rate of flow, in kg mol/minute, of the entering waste gases. The given concentrations are in mole %. (6 m)

4. A continuous fractionating column is to be designed to separate 118 k gmol/hr of a mixture of 50 mol % benzene and 50 mo l% toluene to give an overhead product containing 98 mol % benzene and a bottom product of 97 mol % toluene. Compute the overhead product and bottom products obtained per hour. (6 m)

5. A certain soap conatning 60% moisture on wet basis when raw. Before it can be pressed into cakes for sale, enough water must be evaporated to reduce the moisture content to 205, also on wet basis. How many 125g cakes of soap can be pressed from one ton of original raw soap? Neglect cutting waste. (4 m)

BITS, PILANI – DUBAI

SECOND SEMESTER 2009 – 2010

SECOND YEAR CHEMICAL ENGINEERING

Course Code: CHE C221 **QUIZ 2** Date: 06.04.10
Course Title: Chemical Process Calculations Max Marks: 07
Duration : 20 minutes (Closed Book) Weightage: 7%

Name: ..... **ID No:** ..... **Sec / Prog:** .....

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1. A manufacturer blends lubricating oil by mixing 300 kg/min of No.10 with 100 kg/min of No.40 oil in a tank. The oil is well mixed, and is withdrawn at the rate of 380 kg/min. Assume the tank contains no oil at the start of the blending process. How much oil remains in the tank after one hour? (1 m)

2. % Excess air for combustion process is defined as (1 m)

(A) $$\%\ Excess\ air = \frac{(O_2\ required - O_2\ entering\ the\ process)}{O_2\ entering\ the\ process} \times 100$$

(B) $$\%\ Excess\ air = \frac{(O_2\ entering\ the\ process - O_2\ required)}{O_2\ required} \times 100$$

(C) $$\%\ Excess\ air = \frac{O_2\ required}{(O_2\ entering\ the\ process - O_2\ required)} \times 100$$

(D) $$\%\ Excess\ air = \frac{O_2\ entering\ the\ process}{(O_2\ required - O_2\ entering\ the\ process)} \times 100$$

3. Mention the difference between bypass and recycle streams. (2 m)

4. Acetylene is hydrogenated to form ethane. The feed to the reactor contains 1.5 mol H_2/molC_2H_2. Calculate the stoichiometric reactant ratio (mol H_2 react/mol C_2H_2 react).(1 m)

5. 100 kg mol/hr of 40 mol% of solution of ethylene dichloride in toluene is fed to middle of the distillation column. The distillation column contains 95 mol% ethylene dichloride and the bottom part consists of 90 mol% toluene. What is the rate of flow of each stream?

(2 m)

BITS, PILANI – DUBAI

SECOND SEMESTER 2009 – 2010

SECOND YEAR CHEMICAL ENGINEERING

Course Code: CHE C221 **QUIZ 1** Date: 23.02.10

Course Title: Chemical Process Calculations Max Marks: 08

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

Name: ..... **ID No:** ..... **Sec / Prog:** .....

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1. It is desired to make 100 kg of a solution containing 40% salt by mixing solution A containing 25% salt and solution B containing 50% salt. Determine the mass in kg of solution A required. (2 marks)

2. 5 kg Bismuth (mw = 209) is heated along with 1 kg of S to form Bi_2S_3 (mw = 514). Determine the percentage excess reactant. (2 marks)

3. Define the degree of conversion. (1 mark)

4. In Bhopal Union Carbide storage tank containing methyl isocyanate (MIC), CH_3CNO, a chemical for insecticide, leaked, resulting in injury and death to thousands of people.

Safety rules limit the concentration less than 0.02 ppm (0.02 g mol MIC/10^6 g mol air) Assume ideal behavior and calculate the concentration in mg/m^3 at 20°C and atm pressure. (3 marks)