

BITS, PILANI – DUBAI CAMPUS
FIRST SEMESTER 2012 – 2013
SECOND YEAR (Chemical)

Course Code: CHE F211

COMPREHENSIVE EXAMINATION

Course Title: Chemical Process Calculations

Duration: 3 hr

(Closed Book)

Date: 03.01.13

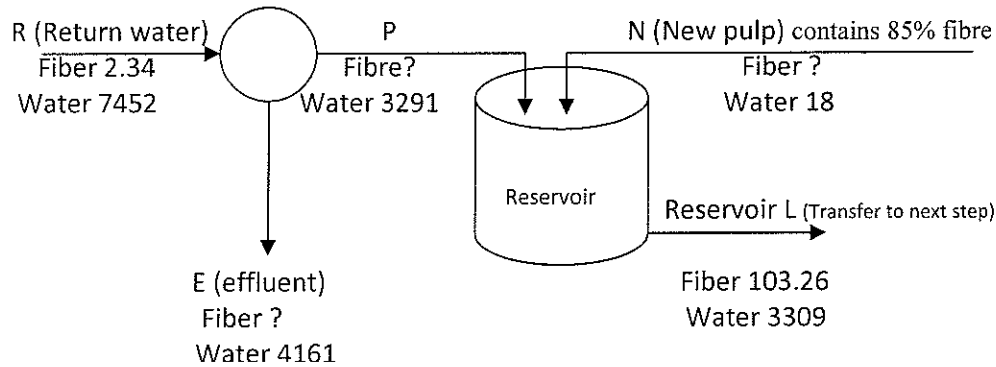
Max Marks: 80

Weightage: 40%

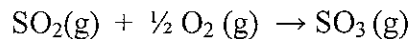
Note: Attempt ALL questions. Draw a labeled flow diagram wherever necessary, mentioning therein all the known and unknown variables. Write all assumptions and steps clearly.

- 1.a) Sludge is wet solids that result from the processing in municipal sewage systems. The sludge has to be dried before it can be composted or otherwise handled. If a sludge containing 70 % water and 30 % solids is passed through a drier, and the resulting product contains 25 % water, how much kg of water is evaporated per ton of sludge sent to the drier (all are in wt %) (4 m)
- 1.b) Gas A containing 90 % nitrogen and gas B containing 30 % nitrogen are mixed to get the product of gas C containing 65 % nitrogen. Determine the ratio of the gas used from gas A to that used from gas B. (5 m)
- 1.c) A drier takes in wet timber (20.1 wt % water) and reduces the water content to 8.6 wt %. Determine the kg of water removed per kg of timber that enters the operation. (4 m)
- 2.a) Define orsat analysis and extent of reaction (1.5 × 2 = 3 m)
- 2.b) FeS can be roasted in O₂ to form FeO.
- $$2\text{FeS} + 3\text{O}_2 \rightarrow 2\text{FeO} + 2\text{SO}_2$$
- If the slag (solid product) contains 80 % FeO (MW:71.85) and 20 % FeS (MW 87.85) and exit gas is 100 % SO₂, determine the extent of reaction and the initial number of g moles of FeS. (all are in wt%) (4 m)
- 2.c) A gas containing only CH₄ and N₂ is burned with air yielding a flue gas that has an orsat analysis of CO₂ 8.7 %, CO 1 %, O₂ 3.8 % and N₂ 86.5 %. Calculate the percentage excess air used in combustion and the composition of the CH₄-N₂ mixture. (all are in mol %) (7 m)
- $$\text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O}$$

- 3.(a) Define bypass stream and purge stream (1.5 × 2 = 3 m)
- 3.(b) In a tissue paper machine, stream N contains 85 % fibre. Find the unknown fibre values (all values in the figure are in kg) in kg for each stream. (8 m)

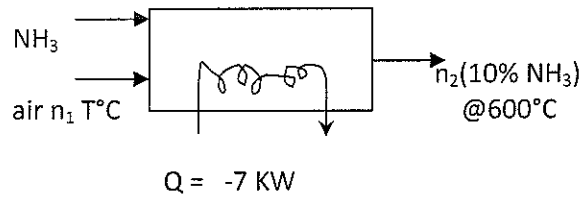


- 4.(a) Define the following:
Relative humidity, Humidity, Dew point, Bubble point (1.5 × 4 = 6 m)
- 4.(b) One liter of a gas is under a pressure of 780 mm Hg. What will be its volume at standard pressure, the temperature remaining constant? (3 m)
- 4.(c) A 25 L glass vessel is to contain 1.1 g moles of nitrogen. The vessel can withstand a pressure of only 20 kPa above atmospheric pressure (taking into account a suitable safety factor). What is the maximum temperature to which the N₂ can be raised in the vessel? (R = 8.314 kPa m³/Kg mol K) (3 m)
- 5.(a) Sulfuric acid is a major bulk chemical used in a wide variety of industries. After sulfur is oxidized to SO₂, the SO₂ is further oxidized in the converters (reactors) to SO₃ and the SO₃ is absorbed in dilute H₂SO₄ to form concentrated H₂SO₄



In the first converter the entering gases at 400K and 1 atm are composed of 9% SO₂, 9.5% O₂, and 81.5% N₂. Only 75% of the entering SO₂ reacts on going through the first converter. If the maximum temperature of the gas before going to the next converter (where the reaction is completed) can be 700 K. How much heat must be removed from the gas before it goes to the second converter per kg mol of S entering the process? (8 m)

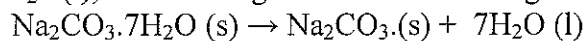
- 5.(b) In the manufacture of nitric acid, ammonia and preheated air are mixed to form a gas containing 10.0 mole% NH_3 (MW:17.03) at 600°C . The ammonia is then catalytically oxidized to form NO_2 , which is absorbed in water to form HNO_3 . If ammonia enters the gas blending unit at 25°C at a rate of 520 kg/h and heat is lost from the mixer to its surroundings at a rate of 7 KW, determine the temperature to which the air must be preheated. (8 m)



- 6.(a) For 900 kg of water are mixed with 63 kg nitric acid (MW: 63) occurs in an open steady state system. Calculate the heat transfer to or from the system if it is isothermal. (4 m)

Compound	H°_f (KJ/kg)
HNO_3 (liquid)	-173.234
In 1 g mol H_2O	-186.347
2 H_2O	-193.318
5 H_2O	-201.962
10 H_2O	-205.014
50 H_2O	-205.978
100 H_2O	-205.983

- 6.(b) Calculate overall enthalpy change for one g mole of $\text{Na}_2\text{CO}_3 \cdot 7\text{H}_2\text{O}$ (s) is dissolved in 8 g mol of H_2O (l), the resulting solution contains 1 g mol of and 15 g mol of H_2O . (4 m)



Given data:

$$\Delta H^\circ_f \text{ Na}_2\text{CO}_3 \cdot 7\text{H}_2\text{O} (\text{s}) = -3201.18 \text{ KJ/mol}$$

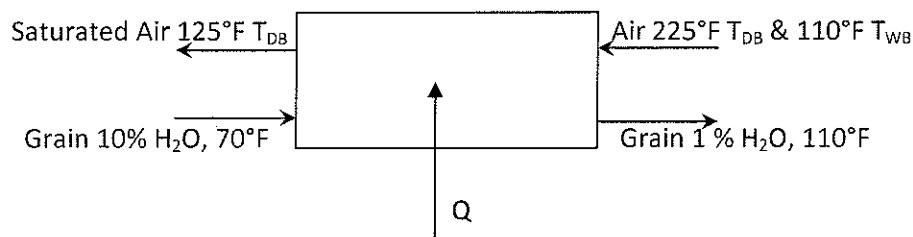
$$\Delta H^\circ_f \text{ Na}_2\text{CO}_3 \cdot 15\text{H}_2\text{O} = -1163.7 \text{ KJ/mol}$$

- 6.(c) A rotary dryer operating at atmospheric pressure dries 10 tons/day of wet grain at 70°F , from a moisture content of 10 % to 1 % moisture. The air flow is countercurrent to the flow of grain, enters at 225°F dry bulb and 110°F wet bulb temperature, and leaves at 125°F dry bulb.

Determine:

(3 × 2 = 6 m)

- The humidity of the entering and leaving air if the latter is saturated at 125°F
- The water removal in kg per hr



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TEST 2

Date: 25.11.12

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

1. The vapor pressure of zinc in the range 600 to 985°C is given by the equation

$$\log p = - \frac{6160}{T} + 8.10$$

Where p = vapor pressure, mmHg

T = temperature, K

Estimate the heat of vaporization of zinc at its normal boiling point. Compare the same with experimental value. (4 m)

2. 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 (4 m)

3. If carbon dioxide is cooled at 1 atm, it condenses directly to a solid (dry ice) at -78.4°C. The heat of sublimation at this temperature is $\Delta H_{\text{sub}} (-78.4^\circ\text{C}) = 25.22$ KJ/mol. Calculate the heat removal rate (KW) required to produce 300 kg/hr of dry ice at 1 atm and -78.4°C if $\text{CO}_{2(\text{v})}$ at 20°C is the feed. (6 m)

4. Benzene vapor at 580°C is cooled and converted to a liquid at 25°C in a continuous condenser. The condensate is drained into 1.75 m³ drums, each of which takes 2 minutes to fill. Calculate the rate (kW) at which heat is transferred from the benzene in the condenser. (6 m)

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Course Title: Chemical Process Calculations
Duration : 50 minutes

TEST 1
(Closed Book)

Date: 11.10.12
Max Marks: 25
Weightage: 25%

1. A lacquer plant requires 1000 kg of 80 wt % nitrocellulose solution. 5.5% (wt %) nitrocellulose solution is available. How much of dry nitrocellulose must be added with 5.5 wt % nitrocellulose solution in order to meet the requirement? (5 m)

2. A distillation column separates a mixture of ethanol and water into high purity alcohol and wastewater. The feed is 20 mol% ethanol and 80 mol% water mixture. The distillate is to contain 85 mol% ethanol and the residue is to have 3 mol% ethanol.
Compute
 - (i) The quantity of distillate and residue produced per 1000 kg of feed, and (5 m)
 - (ii) The percentage of alcohol in the feed that has been recovered as distillate (4 m)

3. In the processing of the fish, after the fish oil is extracted, the fish cake is dried in rotary drum dryer, finely ground and packed. The resulting product contains 65 wt% proteins. In a given batch of fish cake that contains 80 % water. 100 kg of water is removed, and it is found that the fish cake is then 40% water. Calculate the total weight of the fish cake originally put into the dryer. (5 m)

4. A manufacturer of briquets has a contract to make briquets for barbecuing that are guaranteed to not contain over 10 wt % moisture and 10 wt % ash. The basic material they use has the analysis; moisture 12.4 wt %, volatile material 16.6 wt %, carbon 57.5 wt % and ash 13.5 wt %. To meet the specifications (at their limits) they plan to mix with the base material a certain amount of petroleum coke has the analysis; volatile material 8.2 wt %, carbon 88.7 wt% and moisture 3.1 wt %. How much petroleum coke must be added per 100 lb of the base material? (6 m)

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Course Title: Chemical Process Calculations

Duration : 20 minutes

QUIZ 2

(Closed Book)

Date: 07.11.12

Max Marks: 07

Weightage: 07%

Name: ID No: Prog:

1. Define the following terms. (1× 3 = 3 m)
 - a) Critical state
 - b) Pseudocritical values
 - c) Reduced variables

2. Mention the significance of Pitzer factors. 1 m

3. Supercritical is a state above its _____ point. 1 m

4. _____ factor is introduced into the ideal gas law to compensate for the nonideality of a gas. 1 m

5. _____ is two parameter equation of state. 1 m

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QUIZ 1

Date: 26.09.12

Course Title: Chemical Process Calculations

Max Marks: 08

Duration : 20 minutes

(Closed Book)

Weightage: 8%

Name: ID No: Prog:

1. A tank purchased with volume of 2.1 ft^3 . Pump out all the gases in the tank and add first 20 lb of CO_2 and then 10 lb of N_2 . What is the mole percentage of the final gas in the tank? (1.5 m)
2. Harbor sediments in the New Bedford, Massachusetts, area contain polychlorinated biphenyls (PCBs) at levels up to 190,000 ppm according to a report. What is the concentration in percent? (1.5 m)
3. A housing development is served by a water tower with the water level maintained between 20 and 30 meters above the ground, depending on demand and water availability. Responding to a resident's complaint about the low flow rate of water at his kitchen sink a representative of developer came and measured the water pressure at the tap above the kitchen sink and at the junction between the water main (a pipe connected to the bottom of the water tower) and the feed pipe to the house. Junction is 5 m below the level of the kitchen tap. All water valves in the house were turned off.
 - a) if the water level in the tower was 25 m above tap level, what should be the gauge pressures (kPa) at the tap and junction? (2.5 m)
 - b) If pressure measurements corresponded to the predictions in part (a), what else could be responsible for the low water flow to the sink? (2.5 m)