Name: Enrolment No:	UPES

UNIVERSITY OF PETROLEUM AND ENERGY STUDIES

End Semester Examination, December 2018

Programme Name: B. Tech. (APE-Gas/ CERP) **Semester : III**
Course Name : Chemical Process Calculations **Time : 3 hrs**
Course Code : CHCE 2005 **Max. Marks : 100**
Nos. of page(s) : 03
Instructions : Assume any missing data. Draw the diagrams, wherever necessary.

SECTION-A (10 × 6 = 60 marks)
(Answer all the questions)

		Marks	CO
1.	The following equation represent the heat capacity of air (with C_p in cal/(gmol-K) and T in K): $$C_p = 6.39 + 1.76 \times 10^{-3}\,T - 0.26 \times 10^{-6}\,T^2$$ Derive an equation giving C_p in terms of Btu/(lb-^{0}F) with temperature being expressed in ^{0}F.	**10**	**CO1**
2.	Phosgene gas can be made by the catalytic reaction between CO and chlorine gas in presence of a carbon catalyst. The chemical reaction is $$CO + Cl_2 \rightarrow COCl_2$$ The reaction products from a given reactor contain 3 kg of Chlorine, 10 kg of Phosgene and 7 kg of CO. Calculate the following: (a) the percent excess reactant used, (b) the percentage conversion of the limiting reactant, (c) the kmol of phosgene formed per kmol of total reactants fed to the reactor.	**10**	**CO2**
3.	(a) Define Raoult's Law. What are the characteristics of ideal solutions? (b) The vapor pressure of water at 363 K and 373 K are 70.11 kPa and 101.3 kPa, respectively. Estimate the mean heat of vaporization (kJ/kg) of water in this temperature range.	**2+2** **6**	**CO3**
4.	A mixture of benzene vapor and nitrogen gas at 105 kPa and 330 K contains benzene vapor to the extent that it exerts a partial pressure of 15 kPa. The vapor pressure of benzene is given by the Antoine equation $$\ln P^s = 13.8858 - \frac{2788.51}{T - 52.36}$$	**10**	**CO4**

	where P^s is in kPa and T is in K. Determine the following: (a) the molal humidity (b) the absolute saturation humidity (c) the percent humidity (d) the percent relative humidity (e) the mass of benzene in 100 m^3 of the mixture		
5.	A fresh pressed juice contains 5% of total solids and it is desired to raise this percentage to 10% of total solids by evaporation and then to add sugar to give 2% of added sugar in the concentrated juice. Calculate the quantity of water that must be removed and of sugar that must be added with respect to each 100 kg of pressed juice.	**10**	**CO5**
6.	One kg of water is heated from 250 K to 400 K at 1 atm pressure. How much heat is required for this? The mean heat capacity of ice between 250 K to 273 K is 2.037 kJ/kg-K, the mean heat capacity of liquid water between 273 K to 373 K is 75.726 kJ/kg-K and the heat capacity of water vapor (kJ/kmol-K) is $C_p = 30.475 + 9.652 \times 10^{-3}\ T + 1.189 \times 10^{-6}\ T^2$ where T is in K. the latent heat of fusion and vaporization of water are 6012 kJ/kmol and 40608 kJ/kmol, respectively.	**10**	**CO6**
SECTION-B (20 × 2 = 40 marks) **(Answer both questions)**			
7.(a)	Dry coke composed of 4% inert solids (ash), 90% carbon and 6% hydrogen is burned in a furnace with dry air. The solid residue after combustion contains 10% carbon and 90% inert ash (and no hydrogen). The inert ash content does not enter into the reaction. The Orsat analysis of the flue gas gives 13.9% CO_2, 0.8% CO, 4.3% O_2 and 81% N_2. Calculate the percent excess air used based on the complete combustion of coke.	**8**	**CO5**
(b)	Fresh feed stream flowing at 100 kg/h contains 20% by weight KNO_3 in H_2O. The fresh feed stream is combined with a recycle stream and is fed to an evaporator. The concentrated liquid solution exited the evaporator contains 50% KNO_3 is fed to a crystallizer. The crystals obtained from the crystallizer are 96% KNO_3 and 4% water. The liquid from the crystallizer constitutes the recycle stream and contains 0.6 kg KNO_3 per 1.0 kg of H_2O. Calculate all stream flow rate values and compositions.	**12**	
8.	Hydrogen gas is burned in an adiabatic reactor with two times the theoretical quantity of air, both air and hydrogen being initially at 298 K. What will be the temperature of the		**CO6**

	reaction products? The standard heat of formation of gaseous water is –241.826 kJ/mol. The heat capacities (kJ/kmol-K) of the gases are given below: Water vapor $C_p = 30.475 + 9.652 \times 10^{-3}\ T$ Nitrogen $C_p = 27.034 + 5.815 \times 10^{-3}\ T$ Oxygen $C_p = 25.611 + 13.26 \times 10^{-3}\ T$	**20**	
	OR		
	A solution of 10% (weight) acetone in water is subjected to fractional distillation at a rate of 1000 kg/h to produce a distillate containing 90% acetone and a bottom product containing not more than 1% acetone. Feed enters at 340 K; distillate and residue leave the tower at 300 K and 370 K, respectively. A reflux ratio of 8 kg/h of liquid reflux to kg/h of distillate product is employed. The rise in temperature of 30 K is permitted for the cooling water circulated in the condenser employed for condensing the vapours into the distillate product and the reflux. Saturated steam at 276 kPa is available for supplying heat of vaporization in the reboiler. Latent heat of steam at 276 kPa is 2730 kJ/kg. Heat losses from the column may be neglected. The heat capacity of acetone is 2.2 kJ/kg-K and that of water is 4.2 kJ/kg-K. The boiling point of 90% acetone-water solution is 332 K. The latent heat of acetone at 332 K is 620 kJ/kg and that of water is 2500 kJ/kg. calculate the following: (a) the cooling water circulation rate (b) the rate of circulation of steam	**20**	

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Programme	:	**B. Tech. (APE-Gas) / CERP)**					
Semester	:	**III**					
Name of the Course	:	**Chemical Process Calculations**					
Course Code	:	**CHCE 2005**					
Name of Question Paper Setter	:	**Dr. Rajeshwar Mahajan**					
Employee Code	:	**40000036**					
Mobile & Extension	:	**9997843732/1313**					

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Course Name : Chemical Process Calculations **Time : 3 hrs**
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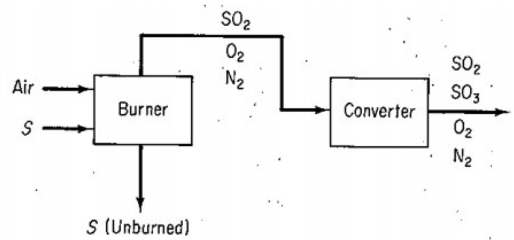
Nos. of page(s) : 04
Instructions : Assume any missing data. Draw the diagrams, wherever necessary.

SECTION-A (25 × 4 = 60 marks)
(Answer all the questions)

		Marks	CO
1.	(a) The conductance of a fluid flow system is defined as: $$C = 89.2\, A \sqrt{\frac{T}{M}}\, \frac{ft^3}{s}$$ where A is area of opening in ft^2, T is temperature in ^0R and M is molar mass. Convert this empirical equation into SI units with temperature expressed in K.	**5**	**CO1**
	(b) Calculate the empirical formula of an organic compound with following mass analysis: Carbon 26.9%; Hydrogen 2.2%; and oxygen as the only other element present.	**5**	
2.	The electrolytic manufacture of chlorine gas from a sodium chloride solution is carried out by the following reaction. $$2\ NaCl + 2\ H_2O \rightarrow 2\ NaOH + H_2 + Cl_2$$ How many kilograms of Cl_2 can be produced form 10 m^3 of a brine solution containing 5 weight % of sodium chloride? The specific gravity of the solution relative to water is 1.07 at 4^0C.	**10**	**CO2**
3	Calculate the total pressure and composition of vapors in equilibrium with a solution at 100^0C, containing 35% Benzene(C_6H_6), 40% Toluene ($C_6H_5CH_3$)and the rest ortho-Xylene ($C_6H_4(CH_2)_2$) by weight percent. Vapor pressures at 100^0C is Benzene = 1340 mmHg Toluene = 560 mmHg o-Xylene= 210 mm Hg	**10**	**CO3**
4.	An air water system has a dry bulb of 55^0C and an absolute humidity 0.03 kg water/kg dry air at 1 atmospheric pressure. Using Psychrometric charts, calculate percent humidity, molal absolute humidity, partial pressure of water vapor in the sample, relative humidity and the dew point temperature. (Vapor pressure of water at 55 ^0C is 118	**10**	**CO4**

mmHg.)

5 A simplified process for the production of SO_3 is to be used in the manufacture of sulfuric acid is as follows:



Sulfur is burned with 100% excess air in the burner where the conversion of sulfur to sulfur dioxide is only 90%. Assuming the excess oxygen present is utilized in the converter, and conversion of SO_2 to SO_3 is 95%, find kg of air required per 100 kg of sulfur burnt. Also find the exiting gas composition coming out of converter.

10 **CO5**

6 An inventor thinks that he has developed a new catalyst that can make the gas phase reaction

$$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$$

Proceeding with 100% conversion, estimate the heat must be provided or removed, if the gases enter and leave at a temperature of 500^0C.

$$C_p = a + b\,T + c\,T^2 \text{ where T in K}$$

Component	Standard Heat of formation (J/gmol) at 298K	a	b	C
CO_2	-393513	26.75	42.26×10^{-3}	-14.25×10^{-6}
H_2	0	26.88	4.35×10^{-3}	-0.33×10^{-6}
H_2O	-241826	29.16	14.49×10^{-3}	-2.02×10^{-6}
CH_4	-74828	13.41	77.03×10^{-3}	-18.74×10^{-6}

10 **CO6**

SECTION-B (20 × 2 = 40 marks)

(Answer both questions)

7. (a) In a fixed bed reactor glucose is converted to fructose using immobilized glucose isomerase as a catalyst. The conditions of the reactor are such that the initial feed enters with a concentration of 45% glucose in water. Since the reactor could not convert all the glucose into fructose, some stream is recycled back to further convert the unreacted glucose. It is noticed that after mixing the recycle stream with main feed stream, the concentration of fructose in the mixed stream is 6%. It is also found that the ratio of exit stream to the recycle stream is 7.33. Evaluate the fractional conversion for one pass through the reactor. **15** **CO5**

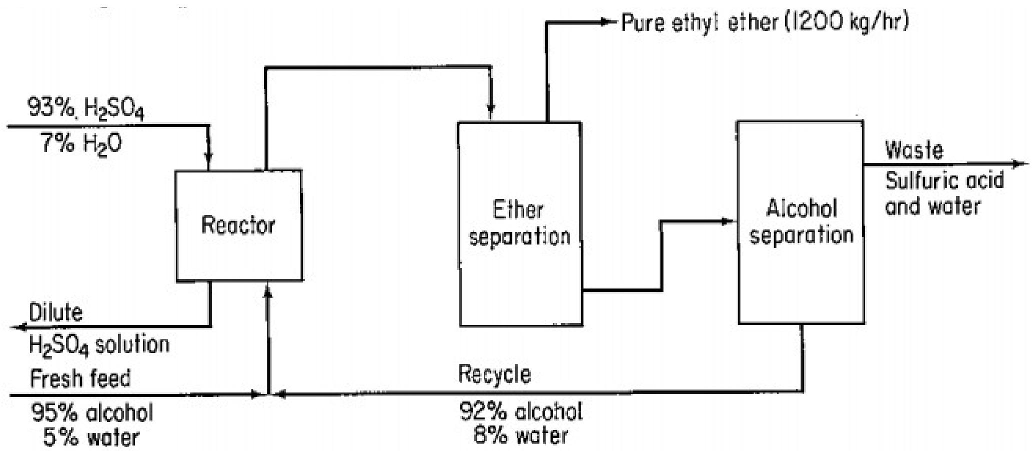
(b) A hydrocarbon fuel is burnt with excess air. The orsat analysis of the flue gas shows 10.2% CO_2, 1.0%CO, 8.4% O_2 and rest N_2. What is the atomic ratio of hydrogen to carbon in the fuel. **5**

OR

Ethyl ether is made by the dehydration of ethyl alcohol in the presence of sulfuric acid at 140^0C.

$$2C_2H_5OH \rightarrow C_2H_5OC_2H_5 + H_2O$$

A simplified process diagram is as follows.



If 87% conversion of the alcohol fed to the reactor occurs per pass in the reactor, calculate kg per hour of fresh feed and kg per hour of recycle. **20**

8 (a) One kg of water is heated from 250 K to 400 K at 1 atm pressure. How much heat is required for this? The mean heat capacity of ice between 250 K to 273 K is 2.037 kJ/kg-K, the mean heat capacity of liquid water between 273 K to 373 K is 75.726 kJ/kg-K and the heat capacity of water vapor (kJ/kmol-K) is **8** **CO6**

$$C_p = 30.475 + 9.652 \times 10^{-3}\ T + 1.189 \times 10^{-6}\ T^2$$

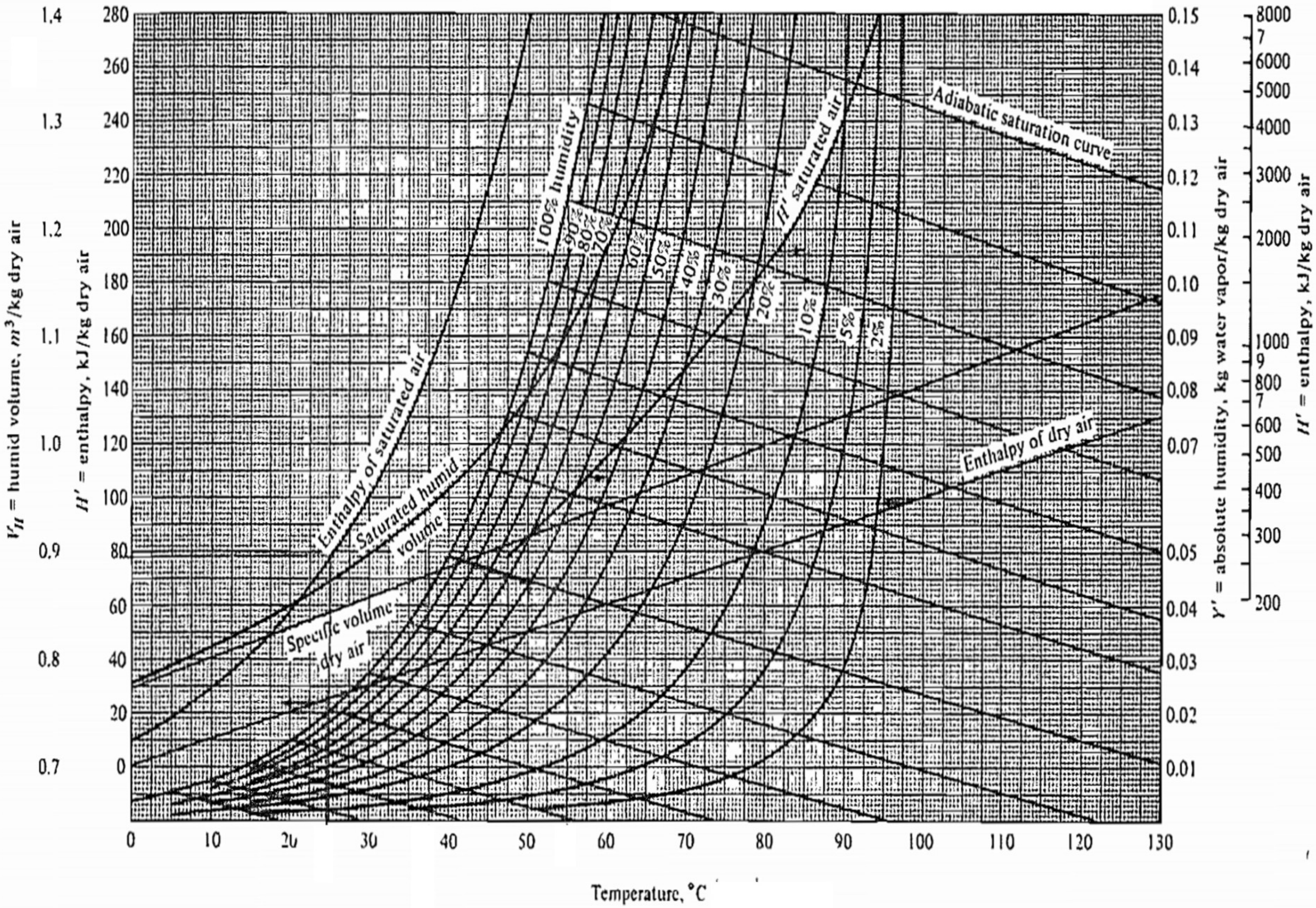
where T is in K. the latent heat of fusion and vaporization of water are 6012 kJ/kmol and 40608 kJ/kmol, respectively.

(b) Solid municipal gas can be burned into gas with the resulting composition of 9.2% CO_2, 1.5% CO, 7.3% O_2 and 82% N_2. By neglecting the presence of water vapor in the gas, evaluate the enthalpy difference for lbmol of the gas between 200^0F and 500^0F

The heat capacity equation is $C_p = A + B\ T - C\ T^2 + D\ T^3$ where C_p is in Btu/lbmol ^{0}F and T in ^{0}F. The values of constants are as given in the table. **12**

Component	A	B	C	D
CO_2	6.895	0.7624×10^{-3}	0.7009×10^{-7}	
CO	7.104	0.7851×10^{-3}	0.5528×10^{-7}	
O_2	8.448	5.757×10^{-3}	21.59×10^{-7}	3.059×10^{-10}

		N_2	6.865	0.8024×10^{-3}	0.7367×10^{-7}				


V_H = humid volume, m^3/kg dry air
H′ = enthalpy, kJ/kg dry air
Temperature, °C
Y′ = absolute humidity, kg water vapor/kg dry air
H′ = enthalpy, kJ/kg dry air
Enthalpy of saturated air
Saturated humid volume
Specific volume dry air
100% humidity
90%
80%
70%
60%
50%
40%
30%
20%
10%
5%
2%
H′ saturated air
Adiabatic saturation curve
Enthalpy of dry air