B.Tech. (Chemical Engineering) Fourth Semester (C.B.S.)

Process Calculations Paper - I

P. Pages : 3 **TKN/KS/16/7821**

Time : Three Hours * 0 3 9 6 * Max. Marks : 80

Notes : 1. All questions carry equal marks.
2. Answer **any four** questions.
3. Assume suitable data wherever necessary.

1. a) The saturation solubility of KCl in water solution is 0.29 gm/gm of solution at 40ºC & 0.32 gm/gm of solution at 60ºC. If 1000gm of a saturated solution of KCl in water is prepared at 40ºC & its temperature is then increased to 60ºC. How much additional quantity of KCl be added to this solution, so as to make it saturated at 60ºC? **12**

b) A typical product gas composition in Lurgi process of coal gasification on dry & mole basis is as given below: **8**

$H_2 : 38\%, CO : 20.2\%, CO_2 : 28.6\%, CH_4 : 11.4\%, C_2H_6 : 1\%, H_2S : 0.5\%$ & $N_2 : 0.3\%$

Calculate :-

i) Average molecular weight of gas mixture

ii) Composition of the gas mixture on weight basis

Atomic weights: H=1, S=32, N=14, C=12 O=16

2. a) A sample of a stack gas analyses as: $CO_2 : 9.5\%, CO : 0.2\%, O_2 : 9.6\%$ & $N_2 : 80.7\%$ on volume basis. **10**

Calculate the composition by weight & also volume occupied by 1kg of gas at 27ºC & 740mm Hg. Also calculate the volume occupied by the gas for 1kg of carbon content in it at same temperature & pressure conditions.

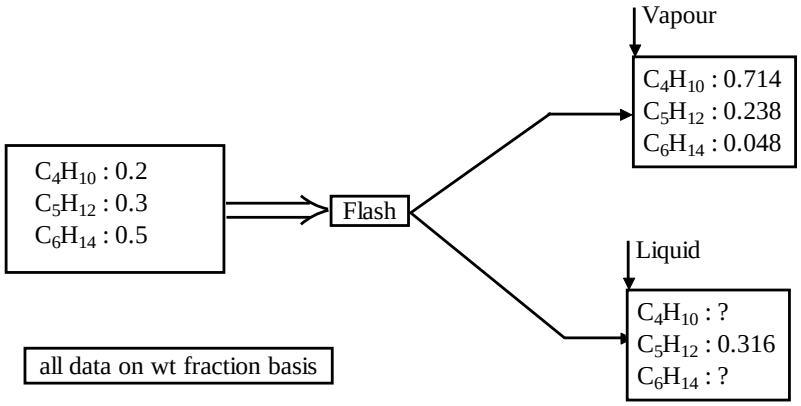
b) A mixture of vapour of 'A' and 'B' at 20ºC & 745mm Hg contains 0.35 kg of 'A'/kg of 'B'. Calculate the partial pressure of 'A' in the mixture. **10**
Assume molecular weight of 'A' as 58 & that of 'B' as 28.

3. a) A gas mixture having composition of 22% NH_3 & 78% air by volume is scrubbed by using water in a packed column operated counter-currently. The entering flow rate of gas mixture is $270\,m^3/hr$ & 75% of NH_3 is to be removed from it. **10**

The tower can be assumed to be operating at 38ºC & 900mm Hg. Also the exit gas leaving the column is saturated with water vapour calculate composition & volumetric flow rate of exit gas stream.

Data: Vapour pressure of water at 38ºC = 49mm Hg

b) A liquid hydrocarbon feed is passed into a flash vaporiser where it is heated & separated in vapour & liquid streams. The schematic of the process with composition of various streams is as shown: **10**



Calculate:

i) Kg of vapour produced per kg of feed

ii) Kg of liquid produced per Kg of feed

iii) Give the complete composition of the liquid stream

4. a) Explain the following terms: **8**

i) Wet bulb temperature

ii) % Relative Humidity and percentage humidity

b) In Winkler gassifier, coal is fed by a screw feeder inside a fluidised bed steam enters at the bottom & fluidises coal supported on the grate. The temperature inside the column can be assumed to be near 980ºC & following reactions take place: **12**

$$C + H_2O \rightarrow CO + H_2 \quad (1)$$
$$C + 2H_2O \rightarrow CO_2 + 2H_2 \quad (2)$$
$$C + 2H_2 \rightarrow CH_4 \quad (3)$$

Overall conversion of coal is typically 80% & of the coal converted 90% goes for reaction

1) 8% for reaction

2) & 2% for reaction

3) If the effluent gas leaving the gassifier is freed of CO_2 by contracting with a suitable solvent in a scrubber, then calculate, the composition of synthesis gas for 1 ton/hr of coal fed. How much steam is required ?

5. a) The analysis of dry flue gas on mole basis is as given: **10**
$N_2 : 83.4\%, O_2 : 8.9\%, CO : 4.6\%$ & $CO_2 : 3.1\%$
Obtain the equation for heat capacity of this flue gas mixture as a function of temperature. What is the heat content of 1kmol of this gas mixture at 1000ºC. Assume 25ºC as reference temperature.
Data: heat capacity in kJ/(k mol k)

$C_{p_{co_2}} : 21.36 + 64.28 \times 10^{-3} T - 41.05 \times 10^{-6} T^2 + 9.79 \times 10^{-9} T^3$

$C_{p_{co}} : 29.02 - 2.81 \times 10^{-3} T + 11.64 \times 10^{-6} T^2 - 4.71 \times 10^{-9} T^3$

$C_{p_{N_2}} : 29.59 - 5.14 \times 10^{-3} T + 13.18 \times 10^{-6} T^2 - 4.96 \times 10^{-9} T^3$

$C_{p_{O_2}} : 26.02 + 11.71 \times 10^{-3} T - 2.34 \times 10^{-6} T^2 - 0.56 \times 10^{-9} T^3$

b) Calculate the enthalpy of 1kg of acetic acid at 400K with respect to acetic acid at 16.7ºC. Acetic acid melts at 16.7ºC & boils at 118ºC. **10**

Data:

$C_p\,(\text{vapour})\ (\text{kJ/kmol K})(118 - 127^\circ C) = 4.43 + 254.68 \times 10^{-3} T - 175.3 \times 10^{-6} T^2 + 49.5 \times 10^{-9} T^3$

$C_p\,(\text{liquid})\ (\text{kJ/kmol K})(16.7 - 118^\circ C) = -36.1 + 604.7 \times 10^{-3} T - 393.9 \times 10^{-6} T^2 - 561.6 \times 10^{-9} T^3$

$\lambda(\text{fusion})$ at $16.7^\circ C = 195.5$ kJ/kg

$\lambda(\text{vapourisation})$ at $118^\circ C = 23681$ kJ/kmol

Molecular Weight of acetic acid = 60

6. a) Calculate the theoretical requirement of air for complete combustion of coal tar fuel having following analysis: **10**
Carbon : 90%, Hydrogen : 6%, Sulphur = 0.3%, Nitrogen : 1.2% & Oxygen : 2.5% (weight basis) If the fuel sample is burnt with 25% excess air, what will be the Orsat analysis of flue gas ?

b) Write material and energy balance equations for **10**
i) Crystallizer (cooling type)
ii) Evaporator

7. a) Calculate the theoretical flame temperature for CO when burned with 120% excess air when both the reactants are at 373K. The C_p in J/(mol.k) may be assumed to be constant at 29.23 for CO, 34.83 for O_2, 33.03 for N_2 and 53.6 For CO_2 The Standard heat of combustion at 298K is – 282.99 kJ/mol Co. **10**

b) Methane CH_4 is burned with 60% excess air. The % conversion of methane is 80% No Co is formed. Calculate the composition of the flue gas. **10**

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