Code No: RR210803 **Set No. 1**

II B.Tech I Semester Supplementary Examinations, November 2006
MATERIAL & ENERGY BALANCE
(Chemical Engineering)

Time: 3 hours **Max Marks: 80**

Answer any FIVE Questions
All Questions carry equal marks

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1. Two students are calculating the average molecular weight of a gas mixture containing N_2 and other gases. One student using the correct molecular weight of nitrogen calculates the average molecular weight as 36. Another student using an incorrect molecular weight of nitrogen as 14, calculates the average molecular as 29. This is the only mistake in computations. Calculate the composition in nitrogen in mole percent and weight percent. [16]

2. (a) Calculate the volume occupied by 13.6 kg of chlorine at a pressure 743 mm Hg and 21.1^0C.
   (b) Calculate the weight of 3 cu.m of water vapor, measured at a pressure of 15.5 mm Hg and 23^0C. [8+8]

3. A binary of A and B components have the following temperature and vapour pressure characteristics (vapour pressure in mm Hg)

T^0C	38.5	42	46	50	54	58	62
Vapour pressure A mm Hg	400	458	532	615	708	812	948
Vapour pressure B mm Hg	160	185	217	254	295	342	400

   Calculate the P-x-y & T-x-y diagrams for the above system at 50^0C and 400 mm Hg pressure respectively. [8+8]

4. A mixture of benzene and dry air at a temperature of 30^0C and a pressure of 750 mm Hg is found to have a dew point of 15^0C. Vapour pressure of benzene at 30^0C is 118.5 mm Hg. Calculate
   (a) Percentage by volume of benzene.
   (b) Moles of benzene per mole of air.
   (c) Weight of benzene per unit weight of air. [5+5+6]

5. Acetylene is produced by reacting Calcium Carbide and water as per the following reaction. $CaC_2 + H_2O \rightarrow CaO + C_2H_2$. Calcium carbide containing 5% impurities (by weight) is reacted with water and the reaction goes to completion. To produce one tonne of acetylene calculate
   (a) The weight of impure calcium carbide required.
   (b) The weight of the solid residue left behind after the reaction. [8+8]

6. A solution of ferric chloride in water contains 64.1% $FeCl_3$ by weight. Calculate the composition and yield of the material crystallized from 1000 kg of this solution,

if it is so cooled as to produce the maximum amount of crystallization from a residual liquid. If a solution of this composition is cooled, the hydrate $FeCl_3.6H_2O$ will crystallize. The maximum crystallization from a liquid residue will result from cooling to the eutectic temperature 27^0 C. Further cooling would cause complete solidification of the system. The solubility of $FeCl_3$ at the eutectic temperature is 68.3% by weight. [16]

7. (a) Define heat capacity and specific heat.
   (b) Show that $C_p = C_v + R$
   (c) Discuss about the effect of temperature and pressure on the heat capacity of gases. [6+5+5]

8. Write notes on
   (a) enthalpy-concentration charts
   (b) Partial molar enthalpy [8+8]

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Code No: RR210803 **Set No. 2**

II B.Tech I Semester Supplementary Examinations, November 2006
MATERIAL & ENERGY BALANCE
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Time: 3 hours **Max Marks: 80**

Answer any FIVE Questions
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1. A natural gas has the following composition, all figures being in volumetric per cent: Methane CH_4 83.5, Ethane C_2H_6 12.5, Nitrogen N_2 4.0. Calculate composition in mole percent and weight percent, average molecular weight, density at standard conditions as kg per m_3. [16]

2. (a) Butane (C_4H_{10}) at 360^0C and 3 atm absolute flows into a reactor at a rate of 1100 kg/h. Calculate the volumetric flow rate of this stream using conversion from standard conditions.
   (b) Write the applications of Henry's law and Raoult's law giving suitable examples. [8+8]

3. (a) What is steam distillation? Write about the applications of steam distillation in process industry.
   (b) Explain how the steam distillation temperature is computed for any system. [8+8]

4. (a) Write a short notes on
      i. Humid heat capacity of air.
      ii. Dew point.
   (b) The partial pressure of ethyl acetate in a hydrogen-ethylacetate mixture at 40^0C and 1 atm total pressure is 75 mm Hg. Calculate
      i. The humidity of the mixture.
      ii. The percentage humidity.
      iii. The relative humidity. [8+8]

5. CCl4 is made as follows
   $CS_2 + 3Cl_2 \rightarrow CCl_4 + S_2Cl_2$ The product gases are found to contain CCl_4 23.3 %, S_2Cl_2 23.3%, CS_2 21.4% and Cl_2 32 % (All percentages are by volume). Calculate
   (a) The percentage of excess reactant used.
   (b) The percentage of conversion.
   (c) The weight of CCl_4 produced per 100 kg of Cl_2 converted. [5+5+6]

6. A solution of ferric chloride in water contains 64.1% $FeCl_3$ by weight. Calculate the composition and yield of the material crystallized from 1000 kg of this solution, if it is so cooled as to produce the maximum amount of crystallization from a residual liquid. If a solution of this composition is cooled, the hydrate $FeCl_3.6H_2O$

will crystallize. The maximum crystallization from a liquid residue will result from cooling to the eutectic temperature 27^0 C. Further cooling would cause complete solidification of the system. The solubility of $FeCl_3$ at the eutectic temperature is 68.3% by weight. [16]

7. (a) State Clausius - Clapeyron equation. What are the assumptions made to obtain this form.

   (b) The vapor pressure of zinc in the range of 600 to 985 C is given by log P = -6160/T + 8.10 (P in mm Hg and T in K). Estimate the heat of vaporization of zinc at 907 ^{0}C, its normal boiling point. [8+8]

8. (a) State the law of constant heat summation.

   (b) Estimate the heat of formation of $ZnSO_4$ from the following:

$ZnS = Zn + S$	H_R = -48.5 kcal/gmol
$2\ ZnS + 3\ O_2 = 2\ ZnO + 2\ SO_2$	H_R = -211.26 kcal/g mol
$2\ SO_2 + O_2 = 2\ SO_3$	H_R = -46.98 kcal/g mol
$ZnO + SO_3 = ZnSO_4$	H_R = -56.26 K cal/g mol

[8+8]

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Code No: RR210803 **Set No. 3**

II B.Tech I Semester Supplementary Examinations, November 2006
MATERIAL & ENERGY BALANCE
(Chemical Engineering)

Time: 3 hours **Max Marks: 80**

Answer any FIVE Questions
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1. (a) The feed to an ammonia synthesis reactor contains 25 mole % N_2 and the balance hydrogen. The flow rate of the stream is 3000 kg/h. Calculate the rate of flow of nitrogen into the reactor in kg/h?
   (b) Liquid toluene is flowing through a pipe at a rate of 175 m^3/h. What is the mass flow rate of this stream in kg/min? What is the molar flow rate in mol/s? [8+8]

2. (a) 0.29 cubic meter of air at 22^0C and 1.00 atm is heated to 321^0C and compressed to 2.5 atm. What volume does the gas occupy in its final state?
   (b) What are standard temperature and pressure? What are the values of V_s in the SI, CGS, and American Engineering systems?
   (c) Calculate the volume occupied by 88 lb of CO_2 at a pressure of 32.2 ft of water and at 15^0C. [5+5+6]

3. (a) Write short notes on
      i. Critical properties.
      ii. Effect of temperature on vapor pressure.
   (b) What are reference substance plots? Discuss about equal-pressure. reference-substance plots and equal-temperature reference-substance plots giving examples. [8+8]

4. (a) Define saturation, partial saturation, relative saturation and percentage saturation.
   (b) A mixture of acetone vapor and nitrogen contains 14.8% acetone by volume. Calculate the relative saturation and percentage saturation of the mixture at a temperature of 20^0C, and the pressure of 745 mm Hg. Vapour pressure of acetone at 20 ^{0}C is 184.8 mm Hg. [8+8]

5. In a double effect evaporator a solution is concentrated in two stages. In the first effect fresh steam is used to evaporate part of water from the solution and this vapour is used as steam in the second effect to evaporate water further. The economy is defined as the ratio of water evaporated to the steam used. In such an operation, a solution containing 10% solids is concentrated to a final solution containing 45% solids. If the economy of the two effects is 0.7 and 0.9 respectively, calculate the steam used in the first effect and the water evaporated in the two effects per kg of feed solution. [16]

6. What will be the yield of Glauber salt ($Na_2SO_4.10H_2O$) if a pure 32% solution is cooled to 293K without any loss due to evaporation. Solubility of Na_2SO_4 in water at 293K is 19.4 kg per 100kg water. [16]

7. Sulfurdioxide is oxidized in 100% excess air with 80% conversion to sulfur trioxide. The gases enter the converter at 400 ^{0}C and leave at 450 ^{0}C. What is the magnitude of heat absorbed, in kcal, in the heat exchanger of the converter if 500 kmol of dioxide are introduced into the converter
SO_2 (g) + 1/2 O_2 (g) = SO_3 (g) -23490 cal/g mol
Mean molal heat capacity values in cal/gmol C
SO_2 = 11.0; O_2 = 7.4; N_2 =7.1; SO_3 = 15.5 [16]

8. (a) Derive Kirchoff's equation to calculate heat of reaction at any temperature T.
   (b) Calculate the heat of reaction of the following reaction at 900 K and 1.013 bar pressure:
   $C_7H_{16} \rightarrow C_7H_8 + 4H_2$
   ΔH_f data: C_7H_{16} = -224.5 kJ
   C_7H_8 = -50.3 kJ
   The constants for C_p are as follows:

Gas	a	b x10^3	c x10^6
Heptane	29.70	516.80	-162.11
Toluene	2.41	391.43	-130.70
Hydrogen	29.08	-0.84	2.01

[8+8]

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Code No: RR210803 **Set No. 4**

II B.Tech I Semester Supplementary Examinations, November 2006
MATERIAL & ENERGY BALANCE
(Chemical Engineering)

Time: 3 hours **Max Marks: 80**

Answer any FIVE Questions
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1. (a) Calculate the average molecular weight of air. The composition of air at mean sea level is Oxygen 21%, Nitrogen 78%, Argon 1% on volume basis.
   (b) By electrolyzing a mixed brine, a mixture of gases is obtained at the cathode having the following percentage composition by weight: Cl_2 67%, Br_2 28% and O_2 5%. Calculate the composition of the gas mixture by volume. Atomic weights of chlorine, bromine and oxygen are 35.5, 80 and 16 respectively. [8+8]

2. (a) Butane (C_4H_{10}) at 360^0C and 3 atm absolute flows into a reactor at a rate of 1100 kg/h. Calculate the volumetric flow rate of this stream using conversion from standard conditions.
   (b) Write the applications of Henry's law and Raoult's law giving suitable examples. [8+8]

3. (a) Estimate the heat of vaporization of isobutyric acid at 200^0C.
   Data: vapour pressure data for isobutyric and are:

Pressure (atm)	Temperature, ^{0}C
2	179.8
5	217.0

   (b) Write down the assumptions involved in solving the Part(a). [8+8]

4. (a) A sample of air at a dry bulb temperature 30^0C has a wet bulb temperature of 20^0C. Calculate absolute humidity, Molar humidity, percentage humidity, humid volume.
   (b) Find the enthalpy of dry air at 30^0C. If 100^3 of the moist air in part(a) is heated to 110^0C, how much heat is required. [8+8]

5. A batch of leather after drying weighs 500kg and contains 6% moisture. During the process of drying the leather lost 60% of its original weight. Calculate
   (a) The moisture content in the leather before drying expressed as kg of water per kg of bone dry moisture free leather.
   (b) kg of water removed per kg of bone dry leather.
   (c) water removed expressed as percentage of the water originally present. [8+8]

6. Copperas (crude ferrous sulfate) is purified by dissolving it in water and recrystallizing it in a crystallizer. First copperas is dissolved in pure water to give a solution containing 28% $FeSO_4$ (by weight). The solution is cooled to 283K to give out the crystals of $FeSO_4.7H_2O$.The loss of water due to evaporation during the cooling operation is 5% on the basis of total solution, charged to the crystalliser. It is desired to yield 0.5 T of $FeSO_4.7H_2O$ crystals. The original copperas contains 96% $FeSO_4.7H_2O$ (by weight). Find the quantity of the copperas charged to the crystalliser. The solubility of $FeSO_4$ at 283K is 20.51 gm per 100 gm water. Assume the solubility of $FeSO_4$ at 283K is unaffected by impurities present in copperas. [16]

7. Calculate the heat that is available by coooling the flue gases
having the following volumetric composition from 300 oC to 25 oC.
CO2 .. 10.32 ; CO ..0.37 ; O2 ..5.72
N2 .. 75.76 ; H2 O..7.83
Cp=a+b T + c T2 Cp in cal/gmol - k, T in K

	a	b x 10^3	C x 10^6
CO_2	6.339	10.140	-3.415
CO	6.350	1.811	-0.267
O_2	6.117	3.167	-1.005
N_2	6.457	1.389	-0.069
H_2O	7.136	2.640	0.046

[16]

8. Estimate the heat that must be provided or removed for the following reaction,
$CO_2 + 4H_2 = 2H_2O + CH_4$
The reaction is complete. All reactants and products enter and leave the reaction chamber at 400^0C
Heat of reaction at 25^0C = -164,987 J/gmol
Cp = a + b T + c T^2 Cp in J /gmol - k, T in K

	a	b x 10^3	C x 10^6
CO_2	26.75	42.26	-14.25
H_2	26.88	4.35	- 0.33
H_2O	29.16	14.49	- 2.02
CH_4	13.41	77.03	-18.74

[16]

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