II B.Tech I Semester Regular Examinations, November 2005
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. (a) The analysis of magnesite ore obtained from chalk hill area, Salem district yields 81% $MgCO_3$, 14% SiO_2 and 5% H_2O (by weight). Convert the analysis into mole%.
   Atomic Weights: Mg-24.3 Si-28.08 H-1.007 O-16 C-12.0
   (b) The analysis of a sample of glass yields 7.8% Na_2O; 7.0% MgO; 9.7% ZnO; 2.0% Al_2O3; 8.5% B_2O_3 and 65% SiO_2 (by weight). Convert the composition into mole%.

   Atomic Weights: Na-22.98 Mg-24.3 Zn-65.37 Al-26.98 B-10.81 Si-28.086
   [8+8]

2. (a) Define the following:
   i. Partial pressure
   ii. Pure-component volume.
   (b) Prove that for an ideal gas mixture, the partial pressure of a component of the mixture is equal to the product of total pressure and the mole fraction of that component. [4+4+8]

3. (a) State Raoult's law. What are its limitations?
   (b) Estimate the vapor phase composition at 60^0C in equilibrium with a liquid mixture containing 40 mole% benzene and 60 mole% toluene. Also calculate the composition of the liquid mixture, which boils at 90^0C and 101.32 kPa. Vapor pressure data is given as: [8+8]

Temp. ^{0}C	Vapor pressure of Benzene, kPa	Vaporpressure of toluene,kPa
60	51.3	18.7
90	135.05	54.4

4. It is proposed to recover acetone, which is used as a solvent in an extraction process, by evaporation in to a stream of nitrogen. The nitrogen enters the evaporator at a temperature of 30^0C containing acetone such that its dew point is 10^0C. It leaves at a temperature of 25^0C with a dew point of 20^0C. The barometric pressure is constant at 750 mm Hg. Calculate
   (a) The vapor concentrations of the gases entering and leaving the evaporator, expressed in moles of vapor per mole of vapor free gas.
   (b) The moles of acetone evaporated per mole of vapor free gas passing through the evaporator.

(c) The weight of acetone evaporated per 1000 m^3 of gases entering the evaporator.

(d) The volume of gases leaving the evaporator per 1000 m^3 entering.
Vapor pressure of acetone:
116 mm Hg at 10^0C.
185 mm Hg at 20 ^{0}C. [4×4]

5. (a) It is desired to make 1000 kg of a mixed acid containing 60% H_2SO_4 , 32% HNO_3, and 8% water by blending
   i. a spent acid containing 11.3% HNO_3, 44.4% H_2SO_4 and 44.3% Water.
   ii. aqueous 90% HNO_3 and
   iii. aqueous 98%H_2SO_4 . All percentages are by weight. Calculate the quantities of each of the three acids required for blending.

   (b) Explain the terms Bypass and Recycle. [8+8]

6. A solution of sodium sulfate in water is saturate at a temperature of 40^0C. Calculate the weight of crystals and the percentage yield obtained by cooling 100 kg of this solution at a temperature of 5^0C.
   At a temperature of 5^0C the decahydrate will be the stable crystalline form. The solubility at 40^0C = 32.6% Na_2SO_4 and at 5^0C = 5.75% Na_2SO_4. [16]

7. Write short notes on:
   (a) Internal energy.
   (b) External energy.
   (c) Heat Work. [5+5+6]

8. The waste gas from a process of 1000 g mol/h of CO at 473 K is burned at 1 atm pressure in a furnace using air at 373 K. The combustion is complete and 90% excess air is used. The flue gas leaves the furnace at 1273 K. Calculate the heat removed in the furnace.
   The standard heat of combustion at 25^0C and 1 atm absolute = -282.989 x 10^3 kJ/kg mol.
   The mean molar heat capacities between 298 and T K in kJ/kg mol K are as follows:
   CO = 29.38, air = 29.29, CO_2 = 49.91, O_2 = 33.25, N_2= 31.43. [16]

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

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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 Raoult's law? What are the applications and limitations of Raoult's law?
   (b) Draw the schematic diagrams of vapour-liquid equilibria for a binary mixture for the following cases:
      i. When the total pressure is constant.
      ii. When the temperature is constant over the composition range. [8+4+4]

4. Air at a temperature of 20^0C and pressure of 750 mm Hg has a relative humidity 0f 80%. Calculate the following:
   (a) The molal humidity of the air.
   (b) The molal humidity of the air if its temperature is reduced to 10^0C and its pressure is increased to 2.4 atm, condensing out some of water.
   (c) The weight of the water condensed from 1000 m^3 of the original wet air in cooling and compressing to the conditions of part (ii).
   (d) The final volume of the wet air of part (iii).
   Vapour pressure of water:
   17.5 mm Hg at 20^0C.
   9.2 mm Hg at 10^0C. [4×4]

5. (a) Define the following:
   Yield per pass.
   Ultimate Yield
   Recycle Ratio.
   Space time yield.

(b) Write short notes on recycling operations practiced in chemical processing industries. [8+8]

6. What will be the yield of Glauber salt ($Na_2SO_4.10H_2O$) if a pure 32% solution is cooled to 20^0C without any loss due to evaporation.
Solubility of Na_2SO_4 in water at 20^0C is 19.4 kg per 100 kg water. [16]

7. Water and a liquid mixture of propane and butane are admitted into a vaporizer at 50 ^{0}C and leave as vapors at 175 ^{0}C. The hourly feed rate is 25 kg water, 350 Kg propane and 550 Kg of butane. Estimate the heat requirement in the vaporizer. [16]

	latent heat of vaporization $\frac{cal}{gm\,mole}$ at 100^0C	$T_C{}^0$C	a	b.10^3	c.10^6
Propane	5038	96.6	8.41	35.95	-6.97
Butane	6138	151.8	2.25	45.40	-8.83
Water	10388	96.6	7.14	2.64	0.046

C_P=a+bT+cT^2 C_P in cal/mol.k and T in K.

8. (a) Differentiate between heat of solution and heat of solvation.

(b) Define standard integral heat of solution. How is it determined?

(c) Calculate the heat of formation of H_2SO_4 to form an aqueous solution containing 5 moles of water per mole of H_2SO_4.
ΔH_f of H_2SO_4(l) at 25^oC and 1 atm = -8,11,319.44 J
$\Delta H_s$of H_2SO_4 (l) (n_1 = 5.0) at 25^0C = -56,902.4 J [5+5+6]

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

II B.Tech I Semester Regular Examinations, November 2005
MATERIAL & ENERGY BALANCE
(Chemical Engineering)

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

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1. In the Leblanc Soda process the first step is carried out according to the following reaction.
$$2NaCl + H_2SO_4 \longrightarrow NaCl + NaHSO_4 + HCl.$$
The acid contains 80% H_2SO_4. It is supposed to be supplied 5% excess of this acid, compared to the theoretically required.
Calculate:
   (a) The weight of acid supplied per 1000kg salt charged.
   (b) The weights of HCl and water removed per 1000kg of salt charged, assuming that the reaction goes to completion and 90% of the acid (HCl) formed and 25% of water present are removed. [8+8]

2. (a) A gas mixture contains 0.1243 kg-mole of HCl, 0.153 kg-mole of nitrogen, and 0.04037 kg-mole of oxygen. Calculate
      i. the volume occupied by this mixture and
      ii. its density in kg/m^3 at a pressure of 2.72 atm and a temperature of 30^{0}C.
   (b) Chlorine is produced by the reaction
$$4Hcl + O_2 \rightarrow 2Cl_2 + 2H_2O$$ Calculate
      i. the molar composition of product gases on dry basis if 50% excess air is used and the reaction is 75% complete.
      ii. The volume of chlorine produced per 100m^3 of Hcl fed if both are metered at the same conditions. [8+8]

3. (a) State Raoult's law. What are its limitations?
   (b) Estimate the vapor phase composition at 60^{0}C in equilibrium with a liquid mixture containing 40 mole% benzene and 60 mole% toluene. Also calculate the composition of the liquid mixture, which boils at 90^{0}C and 101.32 kPa. Vapor pressure data is given as: [8+8]

Temp. ^{0}C	Vapor pressure of Benzene, kPa	Vaporpressure of toluene,kPa
60	51.3	18.7
90	135.05	54.4

4. Air at atmospheric pressure has a wet bulb temperature of 20^{0}C and a dry bulb temperature of 30^{0}C. Using the humidity chart.
   (a) Estimate the percentage saturation, molal humidity and the dew point.

(b) Calculate the weight of water contained in 100m^3 of the air. [8+8]

5. Common salt and Sulfuric acid are heated together in a retort to manufacture Hydrochloric acid. The HCl gas coming out is cooled and absorbed in water to produce 31.5% HCl by weight. Some amount of HCl is lost during absorption. To produce 1 tonne of 31.5% HCl a retort is charged with 550 kg of NaCl and 480 kg of 98% H_2SO_4. The reaction $2NaCl + H_2SO_4 \rightarrow Na_2SO_4 + 2HCl$ goes to completion.

   (a) Which is the limiting reactant?

   (b) What % of HCl formed is lost during absorption?

   (c) Calculate the composition and quantity of the residue left in the retort assuming that 50% of the water in H_2SO_4 distills over. [5+5+6]

6. After crystallization process a solution of calcium chloride in water contains 62 parts of $CaCl_2$ per 100 parts water. Calculate the weight of this solution necessary to dissolve 250 kg of $CaCl_2.6H_2O$ crystals at a temperature 298K. Solubility of $CaCl_2$ at 298K is 7.38 kg.mole of $CaCl_2$ per 1000 kg of water. [16]

7. Flue gases leaving a stack at 300^{0}C have an overall molar composition of 8.2% CO_2, 2.7% CO, 2.7% H_20, 9.4% O_2 and the rest N_2. Calculate the heat lost in 100 kg moles of this gas basing the gas on a datum temperature of 35^{0}C. Assume water is in the vapor form. The constants for C_p are as follows:

Gas	a	b x 10^3	c x 10^6
CO_2	7.7	5.30	-0.83
CO	6.6	1.20	—
H_2O (vapor)	8.2	0.15	1.34
O_2	6.8	0.61	0.13
N_2	6.8	0.61	0.13

   Where C_p is in cal/g mol K and T is in K. [16]

8. Carbon monoxide gas is burned at constant pressure with 100% excess air. The reactants enter at 25^{0}C and the exhaust gases leave the reaction chamber at 1200^{0}C. Estimate the heat loss from the reaction chamber
   Standard heat of combustion of CO = -282,900 J/mol
   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
N_2	27.02	5.81	- 0.29
O_2	25.29	13.25	- 4.20

[16]

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

II B.Tech I Semester Regular Examinations, November 2005
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1. (a) The analysis of magnesite ore obtained from chalk hill area, Salem district yields 81% $MgCO_3$, 14% SiO_2 and 5% H_2O (by weight). Convert the analysis into mole%.
   Atomic Weights: Mg-24.3 Si-28.08 H-1.007 O-16 C-12.0
   (b) The analysis of a sample of glass yields 7.8% Na_2O; 7.0% MgO; 9.7% ZnO; 2.0% Al_2O3; 8.5% B_2O_3 and 65% SiO_2 (by weight). Convert the composition into mole%.
   Atomic Weights: Na-22.98 Mg-24.3 Zn-65.37 Al-26.98 B-10.81 Si-28.086
   [8+8]

2. Nitric acid is produced in the Ostwald process by the oxidation of ammonia with air. In the first step of the process ammonia and air are mixed together and passed over a catalyst at a temperature of 700^0C. The following reaction takes place:
   $4\ NH_3 + 5O_2 \rightarrow 6\ H_2O + 4\ NO$
   The gases from this process are passed into towers where they are cooled, and the oxidation is completed according to the following theoretical reactions:
   $2\ NO + O_2 \rightarrow 2\ NO_2$
   $3\ NO_2 + H_2O \rightarrow 2\ HNO_3 + NO$
   (a) Calculate the volume of air to be used per 100 cu m of ammonia entering the process.
   (b) Calculate the percentage composition by volume of the gases entering the catalyzer.
   (c) Calculate the percentage composition by volume of the gases leaving the catalyzer, assuming that the degree of completion of the reaction is 85% and that no other decompositions takes place. [5+5+6]

3. (a) What are critical properties? Write about estimation of critical properties of organic substances and inorganic substances.
   (b) A mixture of ethyl acetate vapor and air has a relative saturation of 50% at 30^0C and a total pressure of 740 mm Hg. Calculate the analysis of vapor and percentage molar saturation, the vapor pressure of ethyl acetate at 30^0C is 119 mm Hg. [8+8]

4. (a) Define humid heat, humid volume, adiabatic cooling line and humid chart.

(b) A wet air of 26.8 m^3 at 21.1^{0}C and 740 mm Hg is dehydrated. If the water removed is 0.42 kg, what was the humidity of wet air? The vapor pressure of H_2O at 21.1^{0}C is 19 mm Hg. [8+8]

5. Urea is produced by reacting NH_3 and CO_2 to form ammonium carbamate which then decomposes to urea and water as per the following reactions
$2NH_3 + CO_2 \rightarrow NH_2COONH_4$
$NH_2COONH_4 \rightarrow NH_2CONH_2 + H_2O$
If only 60% of the ammonia takes part in the desired reaction and 1000kg of urea are to be produced Calculate

   (a) The volume of NH_3 to be fed at NTP.

   (b) The quantity of water produced. [8+8]

6. A solution of sodium chloride in water is saturated at a temperature of 15^{0}C. Calculate the weight of NaCl that can be dissolved by 100 kg of this solution if it is heated to a temperature of 65^{0}C.
Solution of NaCl at 15^{0}C = 0.358 kg per kg of H_2O.
Solution of NaCl at 65^{0}C = 0.372 kg per kg of H_2O. [16]

7. Carbon monoxide at 200 ^{0}C is burnt under atmospheric pressure with dry air at 500 ^{0}C in 90 % excess of that theoretically required. Assuming 80 % conversion and no heat loss, find the temperature of the leaving gases Heat of combustion of CO = -57.10 kcal /mol
Cp = a + b T + cT^2 ; Cp in cal/gmol - k, T in K

	a	b x 10^3	C x 10^6
CO	6.350	1.811	-0.2675
O_2	6.117	3.167	-1.0050
N_2	6.946	0.196	0.4760
CO_2	6.339	10.140	-3.4150

[16]

8. (a) If a solute forms a hydrate, how is the standard heat of solution of hydrates determined?

   (b) What is the heat of hydration?

   (c) Calculate the standard heat of solution of $CaCl_2.6H_2O$ to form a solution containing 10 moles of water per mole of $CaCl_2$.
   ΔH_f at 25^{o}C and 1 atm are as follows: $CaCl_2$= -794960 J
   H_2O = -285840 J
   $CaCl_2.\ 6H_2O$ = -2607259.6 J
   ΔH_s at 25^{0}C, for $CaCl_2$ (n_1 = 10) = -64852 J [5+5+6]

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