Seat No.: _____ Enrolment No._____

GUJARAT TECHNOLOGICAL UNIVERSITY

B. E. Sem-IV Examination June- 2011

Subject Code: 140504

Subject Name: Fundamental Chem. Engg. Calculations & Stoichiometry

Date:13/06/2011 **Time: 10.30 am – 01.00 pm**

Total Marks: 70

Instructions:

1. **Attempt all questions.**
2. **Make suitable assumptions wherever necessary and mention them clearly.**
3. **Figures to the right indicate full marks.**
4. **All the Notations bear their conventional meanings.**
5. **Answers without calculation steps carry no marks.**

Q.1 **(a)** Briefly explain fundamental units and derived units. Also explain dimensional consistency. **03**

(b) The diameter and height of a vertical cylindrical tank are 5 ft and 6 ft 6 inch respectively. It is full up to 75% height with carbon tetrachloride (CCl_4), the density of which is 1.6 kg/lit. Find the mass in kg. **04**

(c) A gas mixture has the following composition by volume: **07**

Ethylene: 30.6%
Benzene: 24.5%
Oxygen: 1.3%
Methane: 15.5%
Ethane: 25.0%
Nitrogen: 3.1%

Find: i) the average molecular weight of the gas mixture,
ii) the composition by weight, and
iii) the density of the gas mixture in kg/m^3 at 101.325 kPa and 273 K.

Q.2 **(a)** In case of liquids, the local heat-transfer coefficient for long tubes and using bulk-temperature properties is expressed by the empirical equation **07**

$$h = 0.023\, G^{0.8} \times k^{0.67} \times c_p^{0.33}/(D^{0.2} \times \mu^{0.47})$$

where h = heat-transfer coefficient, $Btu/(h.ft^2.^0F)$
G = mass velocity of liquid, $lb/(ft^2.s)$
c_p = heat capacity, $Btu/(lb.^0F)$
k = thermal conductivity, $Btu/(h.ft.^0F)$
D = diameter of tube, ft and
μ = viscosity of liquid, lb/(ft.s)

Convert the empirical equation into SI units.

(b) It is required to make 1000 kg mixed acid containing 60% H_2SO_4, 32% HNO_3, and 8% water by blending **07**

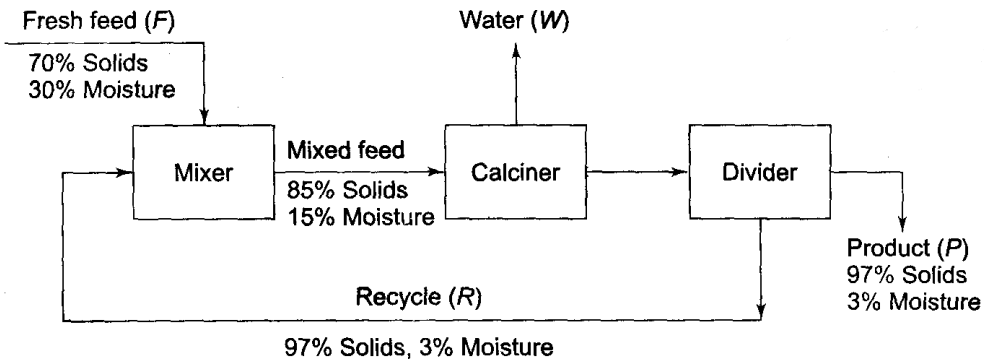
i) the spent acid containing 11.3% HNO_3, 44.4% H_2SO_4, 44.3% H_2O,
ii) aqueous 90% HNO_3 and
iii) aqueous 98% H_2SO_4.

All % are by weight. Calculate the quantities of each of the three acids required for mixing.

OR

(b) Carbon dioxide is dissolved to the extent of 38 liters per liter of aqueous solution of 27.5% (by weight) DAPOL -diamino-iso-propanol [$C_3H_4OH(NH_2)_2$]. The volume of carbon dioxide gas is measured at 101.325 kPa and 288.7 K. Find the weight % and mole% of carbon dioxide in the solution, if the density of DAPOL solution as 1.04 kg/l. **07**

Q.3 (a) In a particular drying operation, it is necessary to hold the moisture content of feed to a calciner to 15% (by weight) to prevent lumping and sticking. This is accomplished by mixing the feed having 30% moisture (by weight) with a recycle stream of dried material having 3% moisture (by weight). The drying operation is shown in the figure. What fraction of the dried product must be recycled? **08**



Drying of Solids

(b) Ethyl alcohol is industrially produced by fermentation of molasses. A sample of molasses contains 45% (wt./wt.) fermentable sugars (in the form of sucrose). The reactions taking place in the fermenter are as follows: **06**

$$\underset{\text{(sucrose)}}{C_{12}H_{22}O_{11}} + H_2O \xrightarrow{\text{invertase}} \underset{\text{(d-Glucose)}}{C_6H_{12}O_6} + \underset{\text{(d-Fructose)}}{C_6H_{12}O_6}$$

$$\underset{\text{(monosaccharide)}}{C_6H_{12}O_6} \xrightarrow{\text{zymase}} \underset{\text{(alcohol)}}{2C_2H_5OH} + 2CO_2$$

Calculate the theoretical production of alcohol (having density of 0.785 kg/l) in liters per tonne of molasses.

OR

Q.3 (a) A solution containing 55% benzene, 28% toluene and 17% xylene by weight is in contact with its vapour at 373 K. Using Raoult's law, calculate the total pressure and molar composition of the liquid and vapour phases. **07**

Vapour pressure data at 373 K:

Benzene : 178.6 kPa
Toluene : 74.6 kPa
Xylene : 28.0 kPa

(b) In an electrochemical cell, the current is passed at the rate of 1130 amperes for 18000 seconds through a solution containing copper sulphate. At the end of the process, 1.12 m^3 oxygen (at NTP) is collected. Find: **07**

i) the amount of copper liberated, and
ii) the current efficiency of the cell.

Q.4 (a) The dry bulb temperature and dew point of ambient air were found to be 303 K and 289 K respectively. The barometer reads 100 kPa. Calculate: **07**

i) the absolute molal humidity,
ii) the absolute humidity,
iii) % RH,

iv) % saturation, and
v) the humid heat

Data: vapour pressure of water at 289 K = 1.818 kPa
vapour pressure of water at 303 K = 4.243 kPa

(b) Using the following Antoine equation, calculate the vapour pressure of n-hexane at 305 K. **03**

$$\log_{10} p = 5.9951 - \frac{1168.7}{T - 48.95}$$

where p = vapour pressure in kPa and
T = absolute saturation temperature in K

(c) Discuss about recycling and bypassing operations. **04**

OR

Q.4 (a) What will be the composition of gases obtained by burning pure FeS_2 with 60% excess air? Assume that the reaction proceeds in the following manner. **05**

$$4FeS_{2(s)} + 11O_{2(g)} \longrightarrow 2Fe_2O_{3(s)} + 8SO_{2(g)}$$

(b) A vapour at 411 K and atmospheric pressure, containing 0.72 mole fraction benzene and 0.28 mole fraction toluene serves as a feed to a fractionating column in which it is separated into a distillate containing 0.995 mole fraction benzene and bottoms with 0.97 mole fraction toluene. The reflux ratio is desired to be 1.95 kmol/kmol distillation product. For a feed of 100 kmol, compute the overall material and energy balances. Assume that there is no heat loss to the surrounding and the heat of solution is negligible. **09**

	Phase	Benzene (Mole%)	Enthalpy (kJ/kmol) [Ref. Temp. = 273 K]
Feed	Vapour	72	44567
Distillate	Liquid	99.5	11433
Distillate	Vapour	99.5	42200
Bottoms	Liquid	3	18467

Q.5 (a) Crystals of $MgCl_2.6H_2O$ have a solubility of 190 g per 100 g ethanol at 298.15 K. It is desired to make 1000 kg of saturated solution. Calculate the quantities of the crystals and ethanol required to make above solution. **04**

(b) Define the following terms: **03**

i) excess reactant
ii) percentage conversion
iii) yield

(c) Obtain an empirical equation for calculating the heat of reaction at any temperature T (in K) for the reaction: $CH_{4(g)} + C_2H_{4(g)} \rightarrow C_3H_{8(g)}$ **07**

Data: ΔH_R^o at 298 K = -82660 J/mol

$C_p^o = a + bT + cT^2 + dT^3$, J/(mol.K)

Component	a	$b \times 10^3$	$c \times 10^6$	$d \times 10^9$
$CH_{4\,(g)}$	19.2494	52.1135	11.973	-11.3173
$C_2H_{4(g)}$	4.1261	155.0213	-81.5455	16.9755
$C_3H_{8(g)}$	-4.2227	306.264	-158.6316	32.1455

OR

Q.5 (a) Chlorinated diphenyl (Diphyl A-30) is heated from 313 K to 553 K at the rate of 4000 kg/h in an indirectly fired hater. In this particular temperature range the heat capacity of the fluid is given by the equation: **07**

$$C_1 = 0.7511 + 1.465 \times 10^{-3}\,T \quad \text{kJ/(kg.K) where T is in K}$$

Also, the heat capacity values of Diphyl A-30 at 313 K to 553 K are 1.1807 and 1.5198 kJ/(kg.K) respectively. Calculate the heat must to be supplied to the fluid in the heater using the heat capacity equation. Also, calculate the % error involved in using the mean heat capacity data for the heat change calculations.

(b) A mixture containing 47.5% acetic acid and 52.5% water (by weight) is being separated by the extraction in a counter-current multistage unit. The operating temperature is 297 K and the solvent used is pure iso-propyl ether. Using the solvent in the ratio of 1.3 kg/kg feed, the final extraction composition on a solvent free basis is found to be 82% by weight of acetic acid. The raffinate is found to contain 14% by weight of acetic acid on a solvent-free basis. Calculate the percentage of acetic acid of the original feed which remains unextracted. **07**

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