BITS, PILANI-DUBAI, ACADEMIC CITY, DUBAI

FIRST SEMESTER 2008-2009

CHE UC361 Mass-Transfer Operations

TEST - 1

(Closed Book)

DATE: 05.10.2008

DURATION: 50 MINUTES **MAXIMUM MARKS: 50**

Note: Attempt ALL questions. Mention appropriate units in your answers. Without units, the answer will not be deemed as correct, even if the numerical value is correct.

Question 1: [Total marks = 10]

Oxygen (A) is diffusing through carbon monoxide (B) under steady state conditions, with the carbon monoxide nondiffusing. The total pressure is 1 X 10^5 N/m^2, and the temperature 0 ^oC. The partial pressure of oxygen at two planes 2.0 mm apart is, respectively, 13000 and 6500 N/m^2. The diffusivity for the mixture is 1.87 X 10^{-5} m^2/s. Calculate the rate of diffusion of oxygen in kmol/s through each square meter of the two planes (N_A). Given gas constant R = 8314 N.m/kg-mol.K.

Question 2: [Total marks = 15]

Chloroform is to be used to extract benzoic acid from waste water effluent. The benzoic acid is present at a concentration of 0.05 mol/liter in the effluent, which is discharged at a rate of 1, 000 liters/h. The distribution coefficient for benzoic acid at process conditions is given by: $y = Kx$

Where K = 4.2, y = molar concentration of solute in solvent, and x = molar concentration of solute in water. Chloroform and water are immiscible. If 500 liters/h of chloroform is to be used, compare the fraction benzoic acid removed in:

(a) a single equilibrium contact,

(b) three cross-current contacts with equal portions of chloroform,

(c) Three counter-current contacts.

Question 3: [Total marks = 15]

The equilibrium adsorption of benzene vapor from a mixture of benzene vapor and nitrogen on a certain activated charcoal at 33.3 ^oC is reported as follows:

Benzene vapor absorbed, cm^3 (STP)/ g charcoal	65	80	90	100
Partial pressure benzene, mm Hg	0.251	1.00	2.81	7.82

Plot equilibrium data as X = g mol benzene/ kg charcoal and Y = g mol benzene/ kg mol nitrogen.

Question 4: [Total marks = 10]

a) What do you understand by "stage" as used in mass-transfer? [04]

b) Define dialysis and reverse osmosis as mass transfer operations. [06]

***** END *****

BITS, PILANI-DUBAI, ACADEMIC CITY, DUBAI
FIRST SEMESTER 2008-2009

CHE UC361 Mass Transfer Operations
TEST - 2
(Open Book)

DATE: 16.11.2008

DURATION: 50 MINUTES **MAXIMUM MARKS: 40**

Note: Attempt ALL questions. Mention appropriate units in your answers. Without units, the answer will not be deemed as correct, even if the numerical value is correct.

1. 100 kg mol binary mixture containing 60 mol% A (more volatile component) and 40 mol% B is vaporized at 101.3 kPa pressure until 40 kg mol are distilled. Estimate the composition of the distillate obtained, if the distillation is carried out by
   a) Equilibrium flash vaporization, [10]
   b) Differential distillation collecting all the distillate together. [15]

Mole fraction A in liquid, x	0.867	0.594	0.398	0.254	0.145	0.059	0.0
Mole fraction A in vapor, y	0.984	0.925	0.836	0.701	0.521	0.271	0.0

2. A liquid mixture containing 40 mol% methanol and 60 mol% water, in which components are miscible in all proportions, is heated at a constant pressure of 1 atm from a temperature of 60 °C to 90 °C. Using following T-x-y experimental data, find out: [15]
   a) At what temperature does the vaporization begin?
   b) What is the composition of the first bubble of equilibrium vapor formed?
   c) What is the composition of residual liquid when 25 mol% has vaporized? Assume that vapor formed is in equilibrium with residual liquid.

Temperature, °C	64.5	65.0	66.0	67.5	69.3	71.2	73.1
Mole % Methanol in vapor	1.000	0.979	0.958	0.915	0.870	0.825	0.779
Mole % Methanol in liquid	1.00	0.95	0.90	0.80	0.70	0.60	0.50
Temperature, °C	75.3	78.0	81.7	87.7	89.3	93.5	96.4
Mole % Methanol in vapor	0.729	0.665	0.579	0.418	0.365	0.230	0.134
Mole % Methanol in liquid	0.40	0.30	0.20	0.10	0.08	0.040	0.02

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BITS, PILANI-DUBAI, ACADEMIC CITY, DUBAI
FIRST SEMESTER 2008-2009
CHE UC361 Mass Transfer Operations
Surprise QUIZ - 1
(Closed Book)

DATE: .../ .../ ...

DURATION: 20 MINUTES **MAXIMUM MARKS: 20**

Name of the student: ---------- I.D.: ----------

Q	1	2	3	4	5	6	7	8	9
Marks	1	1	1	1	2	1	1	1	1
Q	10	11	12	13	14	15	16	17	18
Marks	1	1	1	2	1	1	1	1	1

1. The units of diffusion coefficient, D_{AB}, are .....

2. If the equilibrium pressure of a gas at a given liquid concentration is high, the gas is said to be **highly soluble/ relatively insoluble** in the liquid

.....

3. The flux of a component relative to average molar velocity is denoted as **N / J**.

.....

4. For equimolal counterdiffusion in gases, the flux is given by,

a) $N_A = \frac{D_{AB}}{RTz}(\bar{p}_{A1} - \bar{p}_{A2})$ c) $N_A = \frac{D_{AB}p_t}{RTz\bar{p}_{B,M}}(\bar{p}_{A1} - \bar{p}_{A2})$

b) $N_A = \frac{D_{AB}}{RTz}(p_t - \bar{p}_{A1})$ d) $N_A = \frac{D_{AB}p_t}{RTz}(\bar{p}_{A1} - \bar{p}_{A2})$

5. For a cracking reaction on a catalyst, $C_2H_6 \rightarrow 2\ C + 3\ H_2$, the value of $N_A/(N_A + N_B)$ will be equal to

a) 1 b) 0 c) -1 d) -0.5

6. In molecular diffusion equation, ... is replaced by mass-transfer coefficient, F,

a) c_A/c b) D_{AB}/z c) $D_{AB}.c/z$ d) c/z

7. Which of the following are correct equation(s):

a) $N_A = k_y(y_{AG} - y_{Ai})$

b) $N_A = k_y(y_{AG} - y_A^*)$

c) $N_A = K_y(y_{AG} - y_{Ai})$

8. The overall- and individual-phase mass-transfer coefficients are related as:

a) $\frac{1}{K_y} = \frac{1}{k_y} + \frac{1}{m'' k_x}$ c) $\frac{1}{K_y} = \frac{1}{k_y} + \frac{m'}{k_x}$

b) $\frac{1}{K_y} = \frac{1}{k_x} + \frac{m'}{k_y}$ d) $\frac{1}{K_y} = \frac{m'}{k_x} + \frac{m''}{k_y}$

9. The effect of temperature is larger for (**liquid / gas**) phase mass-transfer coefficients.

.....

10. The equilibrium solubility of gases in liquids **increases/ decreases** with increasing temperature:

.....

11. For ideal solutions,

a) The volume of the solution varies linearly with composition
b) The volume of the solution remains unchanged with composition

c) The density of the solution remains unchanged with composition
d) The volume of the solution decreases exponentially with composition

12. For ideal solutions, the heat of mixing is:

a) Infinite, b) unity c) zero d) negative

13. For absorption a good solvent should have:

a) **High/ low** vapor pressure

b) **High/ low** viscosity

14. In gas-phase controlled mass transfer:

a) $\frac{1}{K_x} \cong \frac{1}{k_x}$ b) $\frac{1}{K_y} \cong \frac{1}{k_y}$ c) $K_x = 0$ d) $K_y = 0$

15. The mole fraction **f** and mole ratio **r** are related as:

a) $f = \frac{r}{1-r}$ b) $r = \frac{f}{1-f}$ c) $f = \frac{r}{1+r}$ d) $r = \frac{f}{1+f}$

16. The absorption factor is defined as:

a) $A = R_S / mE_S$ b) $A = E_S / mR_S$ c) $A = mR_S / E_S$ d) $A = R_S / E_S$

17. In a mass-transfer operation, if the equilibrium curve and the operating line touch each other at some point, the number of stages required for desired separation is equal to:

a) Zero, b) one, c) less than one d) infinity

18. In stripping mass-transfer operation, the molar flow rate of gases will **increase/ decrease**:

.....

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BITS, PILANI-DUBAI, ACADEMIC CITY, DUBAI
FIRST SEMESTER 2008-2009
CHE UC361 Mass Transfer Operations
Surprise QUIZ - 2
(Closed Book)

DATE: 27/10/08

DURATION: 25 MINUTES **MAXIMUM MARKS: 25**

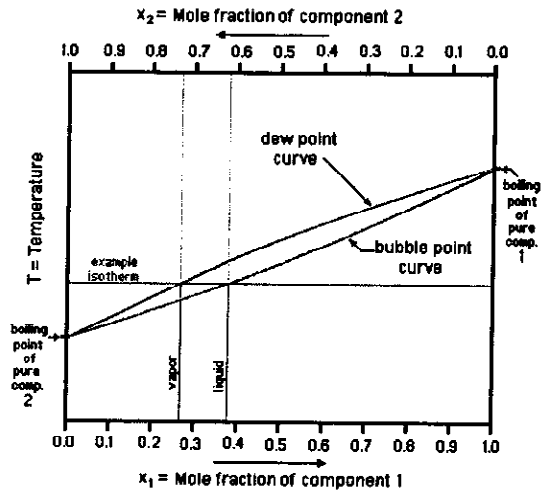
Name of the student: ---------- I.D.: ----------

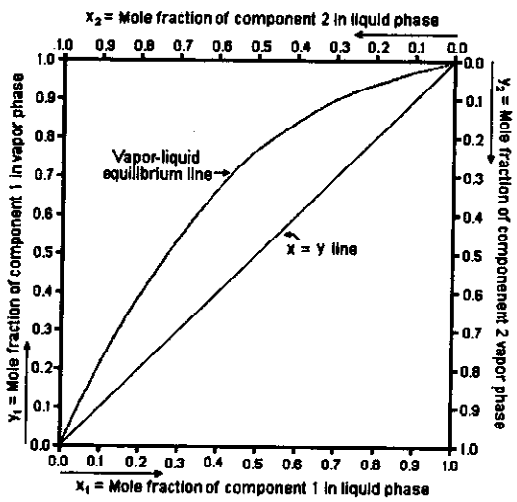
Q	1	2	3	4	5	6	7	8	9
Marks	1	1	1	2	1	1	1	1	1
Q	10	11	12	13	14	15	16	17	18
Marks	2	1	4	2	1	1	1	1	2

ATTEMPT ALL QUESTIONS.

1. In stripping operation, the transfer of solute is from ..... phase to ..... phase.
2. The rate at which a gaseous component of a mixture will dissolve in an absorbent liquid depends upon .....
3. *van't Hoff's law of mobile equilibrium*: If the temperature of a system at equilibrium is raised, that change will occur which will ..... heat.
4. When the gas mixture in equilibrium with an ideal liquid solution also follows the ideal gas law, the ..... of a solute gas A equals the product of it's ..... at the same temperature and its mole fraction in the solution, x.
5. For an absorber (mass transfer from gas to liquid) the operating line always lies **above/ below** the equilibrium-solubility curve.
6. In the design of absorbers, the quantity of gas to be treated, G, is fixed by process requirements, the quantity of the liquid to be used is subject to choice. The minimum liquid that can be used corresponds to **minimum number of stages/ infinite number of stages/ optimum number of stages.**
7. The minimum liquid-gas ratio for Absorbers can only be found for **co-current/ counter-current absorbers.**

8. In absorption operation, the **nearer/ farther** the operating line to the equilibrium curve, the more steps will be required.
9. When the operating line and the equilibrium curve touch at any point, the number of stages required will be **minimum/ infinite/ optimum**.
10. As a thumb rule for purposes of rapid estimates, it has been found that most economical value of absorption factor A will be in the range from ..... TO ....
11. An adiabatic absorber will require **more/ less** number of stages than an isothermal absorber for same degree of absorption.
12. For a good solvent in absorption operation, following properties are important considerations:
    a) Gas Solubility: **high/ low**
    b) Volatility: **high/ low**
    c) Viscosity: **high/ low**
    d) Freezing point: **high/ low**.
13. In distillation, instead of introducing a new substance into the mixture in order to provide the second phase, as is done in gas absorption, the new phase is created from the original solution by .... or ....





14. A mixture on the lower curve (bubble point curve) is a **saturated liquid/ saturated vapor**.

15. For a binary mixture, the greater the distance between the equilibrium curve and the diagonal, the greater the difference in vapor and liquid compositions and the **harder/ easier** the separation by distillation.

16. Relative volatility, α is defined as:

a) $\alpha = \frac{y^*(1-x)}{x(1-y^*)}$ b) $\alpha = \frac{x(1-x)}{y^*(1-y^*)}$

c) $\alpha = \frac{y^*-x}{x-y^*}$ d) $\alpha = \frac{y^*-x}{1-x}$

17. If relative volatility α = 1.0 the separation will be **maximum/ minimum/ optimum/ impossible**.

18. A mixture whose total pressure is greater than that computed for ideality is said to show **positive/ negative** deviations from Raoult's law. Such mixtures are likely to form **maximum boiling/ minimum boiling** azeotropes.

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BITS, PILANI-DUBAI, ACADEMIC CITY, DUBAI
FIRST SEMESTER 2008-2009
CHE C361 Mass Transfer Operations
Comprehensive Examination (Closed Book)

DATE: 07.01.2009

DURATION: 3 hours **MAXIMUM MARKS: 80**

Note: Attempt ALL questions. Mention appropriate units in your answers. Without units, the answer will not be deemed as correct, even if the numerical value is correct.
Attempt questions from each section in different answer sheets.

Section – 1

Give brief and to-the-point answers to following questions. Answer all the parts sequentially. [25 marks]

1. What is an absorption factor? [2]
2. On a *Y-X* plot for a stripper, is the operating line above or below the equilibrium curve? Explain. [2]
3. How is *q* related to the feed condition? What are the five possible feed conditions? For each of these feed conditions, give q values and slope of q-line. [6]
4. Draw pressure versus composition curve for a positive azeotrope. [1]
5. Draw x versus y* curve for a negative azeotrope. [1]
6. Draw a suitable phase diagram for a partially miscible binary solution. [2]
7. Define relative volatility of a vapor-liquid system. [1]
8. What is meant by constant molal overflow in distillation? [2]
9. Determine the composition of the liquid phase in equilibrium with a vapor of 50 mol% A and 50 mol% B, where the relative volatility of A to B is 1.9. [3]
10. Discuss various properties which have important consideration in choice of solvent for absorption. [5]

Section – 2

Solve following questions, clearly showing each step in calculation, and mention all the assumptions you make. [55 marks]

1 A coal gas is to be freed of its light oil by scrubbing with wash oil as an absorbent and the light oil recovered by stripping the resulting solution with steam. The conditions are:

Absorber: Gas in, 0.250 m^3/s at 26 ^oC, $p_t = 1.07 \times 10^5$ N/m^2 (803 mmHg), containing 2.0% by volume of light oil (benzene) vapors. A 90% removal is required. The wash oil is to enter at 26 ^oC, containing 0.005 mole fraction benzene, and has an average molecular weight of 260. An oil circulation rate of 1.5 times the

minimum is to be used. Wash oil-benzene solutions are ideal. The temperature will be constant at 26 °C.

Stripper: The solution from the absorber is to be heated to 120 °C and will enter the stripper at 1 std atm pressure. Stripping stream will be at std atm pressure, superheated to 122 °C. The debenzolized oil, 0.005 mole fraction benzene, is to be cooled to 26 °C and returned to the absorber. A steam rate of 1.5 times the minimum is to be used. The temperature will be constant at 122 °C.

Compute the oil-circulation rate and the steam rate required.
Determine the number of theoretical trays required for the absorber and the stripper.
Given: Vapor pressure of benzene at 26 °C = 100 mm Hg,
at 122 °C = 2400 mm Hg [15]

2 (a) A mixture of He and N_2 is contained in a pipe at 298 K and 1 atm total pressure which is constant throughout. At one end of the pipe at point 1 the partial pressure p_{A1} of He is 0.60 atm and at the other end 0.2 m apart, p_{A2} = 0.20 atm. Calculate the flux of He at steady state if for this mixture, $D_{AB} = 0.687 \times 10^{-4}$ cm²/s. [5]

2 (b) Calculate algebraically the composition of final mixture resulting from mixing of following two mixtures: mixture A: 1000 kg: 40% sand, 10% water, 50% salt; mixture B: 200 kg: 10% sand, 70% water, 20% salt. [3]

3 A 20 wt% solution of uranyl nitrate (UN) in water is to be treated with tributyl phosphate (TBP) to remove 90% of the UN. All operations are to be batch-wise equilibrium contacts. Assuming that water and TBP are mutually insoluble, how much TBP is required for 100 g of solution if at equilibrium (g UN/g TBP) = 5.5 (g UN/g water) and:
(a) All the TBP is used at once in one stage?
(b) Half is used in each of two consecutive stages?
(c) Two counter-current stages are used? [10]

4 A binary mixture of two miscible liquids A and B containing 50 mol% A (more volatile) is to be flash vaporized at 1 atm pressure to vaporize 65% of the feed. Estimate the composition of the distillate obtained, if relative volatility is 2.5. [7]

5 A rectification column is fed 100 kg mol/h of a mixture of 50 mol% benzene and 50 mol% toluene. The feed is saturated vapor at dew point. The distillate is to contain 90 mol% benzene and the bottoms 10 mol% benzene. Calculate the flow rates of distillate and bottoms, and minimum reflux ratio. If operating reflux is 1.5 times the minimum, calculate the number of stages required. Assume constant relative volatility of 2.2. [15]

*** END OF PAPER ***