Uva Wellassa University of Sri Lanka
Faculty of Science and Technology
Department of Science and Technology
300 Level 2nd Semester Examination – Jan./Feb. 2016
SCT 314-2 Chemical Engineering Science

Instructions to candidates
Duration: Two (02) hours
Number of questions: Four (04)
Answer all questions
Mark allocation: 400 (All questions carry equal marks)

1. Fractional distillation is a special type of distillation process in which a mixture of volatile solution is seperated into its components.

   A mixture of benzene, toluene and xylene is seperated by continuous fractional distillation in two towers, the first of which produces benzene as overhead outlet and a mixture of toluene and xylene as the botom outlet, which is charged to the second tower. This tower produces toluene as overhead stream and xylene as bottom stream. The compositions of known streams are listed below.

	Distilate from Tower-I (mol%)	Distilate from Tower-II (mol%)	Residue from tower –II (mol%)
BENZENE	98.5	1.0	0.0
TOLUENE	1.5	98.5	0.7
XYLENE	0.0	0.5	99.3

The flow rates of distillates from tower I, tower II and residue tower II are 9240 kmol/hr, 6390 kmol/hr and 10800 kmol/hr respectively. Molar mass of benzene, toluene and xylene are approximately 78 g/mol, 92 g/mol and 106 g/mol respectively.

a. Draw a block diagram and lable all the inlets and outlets

(30 Marks)

b. Compute the mass flow rates of unknown streams and compositions in **weight %** of the initial mixture

(50 Marks)

c. What is the molar composition of residue discharged from the botom of tower-I

(20 Marks)

2. Materials of all types are often heat-treated to improve their properties. The phenomena that occur during a heat treatment almost always involves atomic diffusion. Often, an enhancement of diffusion rate is desired however some ocations, measures are taken to reduce it.

a. Briefly explain the difference between "self-diffusion" and "interdiffusion".

(20 Marks)

b. Briefly explain and compare "interstitial" and "vacancy diffusion" mechanisms. Use schematics if necessory.

(20 Marks)

c. Cite two reasons why interstitial diffusion is normally more rapid than vacancy diffusio

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(10 Marks)

d. The wear resistance of a steel gear is to be improved by hardening its surface. This is to be accomplished by increasing the carbon content within an outer surface layer as a result of carbon diffusion into steel; the carbon is to be supplied from an external carbon-rich gaseous atmosphere at an elevated and constant temperature. The initial carbon content of the steel is 0.20 wt.%, whereas the surface concentration is to be maintained at 1.00 wt.%. For this treatment to be effective, a carbon content of 0.60 wt.% must be established at a position 0.75 mm below the surface from carbon rich environement. Determine an appropriate heat treatment in terms of temperature vs. time from 900 °C to 1050 °C with 50 °C intervals. It is found that the temperature independent preexponential constant (D_0) is 2.3 x 10^{-5} m^2/s and the activation enegry for the diffusion of carbon into steel is 148 kJ/mol.

The Gaussian error function is defined by $\text{erf}(z) = \frac{2}{\sqrt{\pi}} \int_0^z e^{-y^2} dy$ where $\frac{x}{2\sqrt{Dt}}$ can be replaced by the variable z for the solution to the of Fick's second law for diffusion in semi-infinite solid. Use the following error funtion values given for particular z values for your calculations.

(50 Marks)

z	erf (z)	z	erf (z)	z	erf (z)
0	0	0.55	0.5633	1.3	0.9340
0.025	0.0282	0.60	0.6039	1.4	0.9523
0.05	0.0564	0.65	0.6420	1.5	0.9661
0.10	0.1125	0.70	0.6778	1.6	0.9763
0.15	0.1680	0.75	0.7112	1.7	0.9838
0.20	0.2227	0.80	0.7421	1.8	0.9891
0.25	0.2763	0.85	0.7707	1.9	0.9928
0.30	0.3286	0.90	0.7970	2.0	0.9953
0.35	0.3794	0.95	0.8209	2.2	0.9981
0.40	0.4284	1.0	0.8427	2.4	0.9993
0.45	0.4755	1.1	0.8802	2.6	0.9998
0.50	0.5205	1.2	0.9103	2.8	0.9999

3. In chemical engineering point of view, a production process can be explained as the processing of inputs to outputs in a defined series of actions. The inputs include reactants, auxiliary materials, energy etc. The outputs include products, by-products, energy, etc. Production processes can be carried out in several ways: continuous, batch or semi-continuous.

a. Define the terms "continuous process", "batch process" and "semi-batch process".

(15 Marks)

b. List the factors to be considered in desingning "continuous process", "batch process" and "semi-batch process".

(5 Marks)

c. Explain the terms "recycle" and "bypass" in terms on chemical engineering process. Draw two schematics and lable the recycle and bypass flows.

(20 Marks)

d. Assume that you are assigned to evaluate a production process of a novel drug called "Pharma A".

4500 kg/hr of aqueous solution that consists of 33.3 wt.% of "Pharma A" is joined with a recycle stream containing 36.4 wt.% "Pharma A". After thorough mixing of the combined streams, it is fed into an evaporator. The concentrated stream leaving the evaporator contains 49.4 wt.% "Pharma A" which is fed into a crystalizer. Then it is allowed to cool and filtered. The filter cake consists of "Pharma A" crystals and a solution that contains 36.4 wt.% "Pharma A" by mass. The crystals account for 95 wt.% of the total mass of the filter cake. The solution that passes through the filter that consists of 36.4 wt.% "Pharma A" is the recycle stream.

i. Draw a block diagram and label all the streams and compositions

(10 Marks)

ii. Calculate followings,

1. The rate of evaporation

(10 Marks)

2. The rate of procudtion of crystalline "Pharma A"

(10 Marks)

3. The feed rates that the evaporator and the crystallizer must be desing to handle

(10 Marks)

4. Mass of "recycle"/ "mass of fresh feed" ratio

(10 Marks)

iii. Suppose that the filterate were discarded instead of being recylced. Quantify the effect to the production rate of "Pharma A" .

(10 Marks)

4. Mass transfer coupled with fluid flow is a more complicated process than diffusive mass transfer. The value of the mass-transfer coefficient reflects the contribution to mass transfer from all the processes in the system that affect the boundary layer. Over the years, several models used to describe mass transfer between fluids.

a. Describe the term "film theory" and "penetration theory". Use schemactics if necessory.

(30 Marks)

b. Sulfur dioxide (SO_2) is absorbed into water in a packed column. This is a good example for mass transfer between gas-liquid interface. At a certain location in the gas phase, the bulk conditions are 50°C, 2 atm, and SO_2 mole fraction is 0.085. At the same contions mole fraction of SO_2 in bulk liquid phase is 0.001. At the equilibrium at 50°C, experimental values of the mass transfer coefficients are k_c = 0.18 m/hr and k_p = 0.040 kmol/hr.m^2.kPa. Compute the mass-transfer flux by assuming an average Henry's law constant of 161.61 kPa.m^3/kmol and a negligible bulk flow.

(70 Marks)

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