Queen Mary
University of London

December Examination Period 2019

DEN5406 Mass Transfer and Separation Processes 1

Duration: 2 hours 30 minutes

YOU ARE NOT PERMITTED TO READ THE CONTENTS OF THIS QUESTION PAPER UNTIL INSTRUCTED TO DO SO BY AN INVIGILATOR.

Answer TWO out of THREE questions for 50 marks each.
Only the first TWO answered questions will be marked. Clearly cross out any questions you do not want marked.

Only non-programmable calculators are permitted in this examination. Please state on your answer book the name and type of machine used.

Complete all rough workings in the answer book and cross through any work that is not to be assessed.

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EXAM PAPERS MUST NOT BE REMOVED FROM THE EXAM ROOM

Examiners:
Dr Petra SzilÃ¡gyi
Dr Stoyan Smoukov

Section A: Answer 2 out of 3 questions for 50 marks

Question A1: Physical transformations, phases

a) Consider a cooling alloy at the composition and temperature marked on the diagram in Figure 1. How many phases are present under the conditions marked by the red arrow?

[5 marks]

b) What is the composition of the phase(s)?

[10 marks]

c) If there are more than one phases present what is their proportion in terms of molarity?

[10 marks]

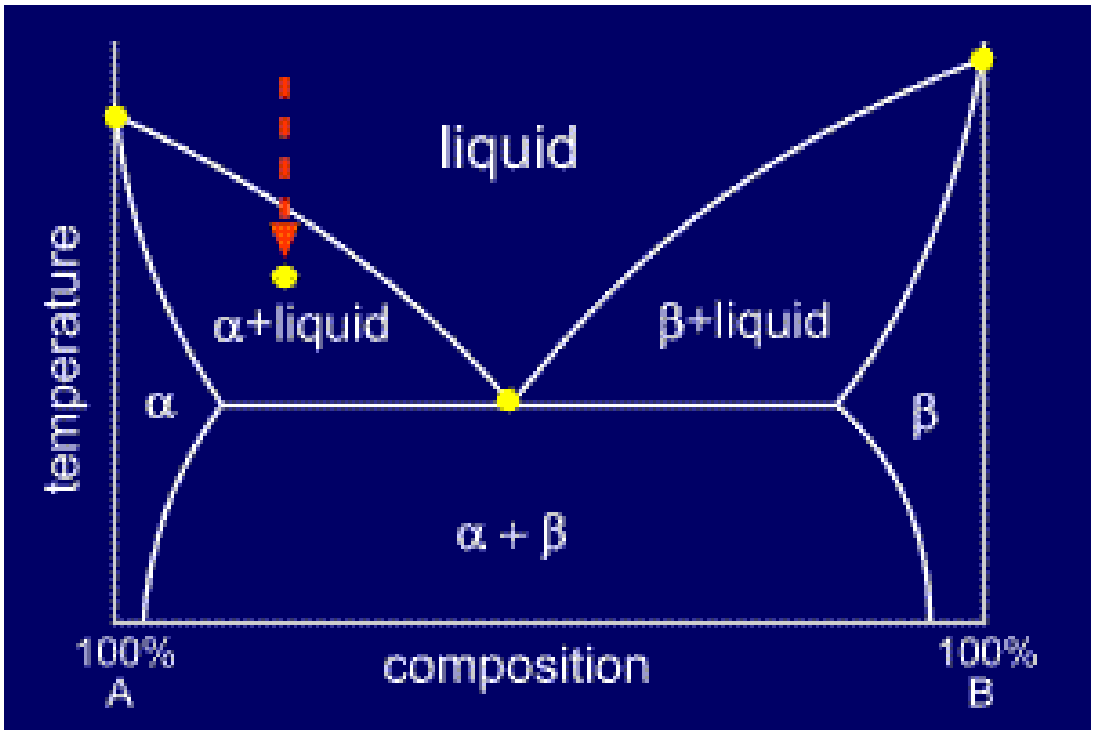


Figure 1 Temperature-composition phase diagram of alloy

Total: [25 marks]

Question A2: Mixtures, colligative properties

a) Explain the phenomenon of boiling point elevation using the expressions of the chemical potential.

[10 marks]

b) Illustrate the dependence on the chemical potential on solvent activity with the help of a graph.

[7 marks]

c) Seawater is about 3.5 wt% dissolved solids, almost all of which is NaCl. Calculate the normal boiling point of seawater.

[8 marks]

Consider that NaCl is a strong electrolyte, *i.e.* it dissociates as $NaCl \rightarrow Na^{+} + Cl^{-}$ in an aqueous environment. The ebullioscopic constant of NaCl = 0.52 °C m^{-1}.

Total: [25 marks]

Question A3: Mass transfer and diffusion

The diffusion coefficient of a particular kind of t-RNA molecule is $D=1.1x10^{-11}$ m^2 s^{-1} in the medium of a cell interior. How long does it take for the molecules produced in the cell nucleus to reach the walls of the cell at a distance of 1.0 μm, corresponding to the radius of the cell?

[25 marks]

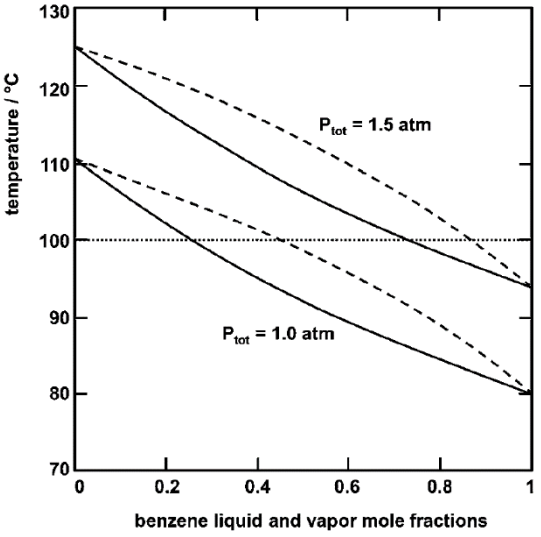
Section B: Answer 2 out of 3 questions for 50 marks

Question B1: Distillation

a) Define the terms: flash distillation, rectification, downcomer and reflux ratio

[10 marks]

b) In a flash distillation of benzene from a benzene-toluene mixture, the feed mixture has 0.5 mol fraction benzene, and pressure is 1 atmosphere (consider = 1 bar). The drum should produce a liquid with 0.40 mol fraction benzene. Using the Liquid-vapour equilibrium graph on the right, determine
- The temperature of feed in the drum
- The composition of the resulting vapour in equilibrium with the liquid
- The mol% of feed evaporated in the drum



[15 marks]

Total: [25 marks]

Question B2: Osmotic pressure

a) Describe the following processes: forward osmosis, reverse osmosis, and pressure-retarded osmosis. For each draw (if any) appropriate application of pressure and specify the phase where it is applied. Compare the osmotic and applied pressures.

[12 marks]

b) A patient with diarrhoea has been severely dehydrated. Direct intravenous fluid delivery is necessary. An incompetent volunteer starts a fast drip of pure water into the vein. What happens to patient? Describe any

   i. movement of water with respect to the red blood cells.

   ii. If an isotonic solution for injection is 0.9% NaCl (MW=58.5), calculate the pressure inside the red blood cells.

[13 marks]

Total: [25 marks]

Question B3

a) Define in general for a filter, what is filter porosity, filtrate velocity, resistance (and its units), and cake

[10 marks]

A clean new filter has active area of 4 cm^2. Passing pure water at room temperature ($\eta = 10^{-3}$ Pa.s), keeping a column of 15.3 cm above the filter (1500 Pa) through it results in collection of 1L in 1 min. Then after passing 1L contaminated water with 1 g/L particles that don't pass through the filter, the permeability to pure water is such that with the same column of 15.3 cm only 0.5 L passes in 1 min.

b) Calculate the:

i) Resistance of the filter membrane

ii) The resistance of the cake after filtering the contaminated water.

iii) The amount of sugar syrup with viscosity 0.5 Pa.s that would filter in 5 min through the caked filter, again with same height column.

[15 marks]

Total: [25 marks]

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