

National Exams May 2012

04-Chem-A3 Mass Transfer Operations

Three Hour Duration

NOTES:

- 1) If doubt exists as to the interpretation of any question, you are urged to submit a clear statement of any assumptions made along with the answer paper.
- 2) Property data required to solve a given problem are provided in the problem statement or are available in the recommended texts. If you are unable to locate the required data, do not let this prevent you from solving the rest of the problem. Even in the absence of property data, you still have the opportunity to provide a solution methodology.
- 3) This is an open-book exam.
- 4) Any non-communicating calculator is permitted.
- 5) The examination is in two parts – Part A (Questions 1 and 2), Part B (Questions 3, 4, 5 and 6). Answer **ONE** question from Part A, and **THREE** questions from Part B. **FOUR** questions constitute a complete paper.
- 6) Either question in Part A will count for 16%. Each question in Part B is of equal value, i.e. the remaining 84% of the marks are split equally into 28% for each question.

PART A: ANSWER ONE OF QUESTIONS 1-2

**Note: Four questions constitute a complete paper
(with one from Part A, and three from Part B)**

- 1) Estimate the binary diffusion coefficient of oxygen diffusing through water vapour at atmospheric pressure and 352.3 K using the Chapman-Enskog theory with the appropriate Lennard-Jones parameter.

- 2) A polymer solid is saturated with a salt solution such that the initial concentration of salt is constant at and equal to 0.2 kmol/m^3 . The solid is in the shape of a sphere with a diameter of 1.0 cm. At $t = t_0 = 0.0 \text{ s}$, the surface of the sphere is washed with high-velocity water. The diffusion coefficient for the salt in the polymer is $2.0 \times 10^{-10} \text{ m}^2/\text{s}$. Calculate the concentration of the salt at the centre of the sphere after 10 h.

PART B: ANSWER THREE OF QUESTIONS 3-6

**Note: Four questions constitute a complete paper
(with one from Part A, three from Part B)**

3) A cylindrical tank having a diameter of 3.0 m contains liquid toluene ($C_6H_5CH_3$) at $31.8^\circ C$. At this temperature the vapour pressure of toluene is 0.0526 atm. When this open tank is exposed to an air stream at atmospheric pressure, diffusion may be assumed to occur from the liquid phase into the vapour phase through a film 1.0 mm thick above the liquid. The diffusion coefficient of toluene in air at $0^\circ C$ is $7.530 \times 10^{-6} \text{ m}^2/\text{s}$. Estimate the rate of loss of toluene in kg/day.

4) Countercurrent stage stripping is to be used to remove a contaminant from milk. The contaminant is initially present in the milk at a concentration of 20 ppm. For every 100 kg of milk entering the tower, 50 kg of steam is used for stripping. The goal is to reduce the concentration of the contaminant to 1.0 ppm. The equilibrium relation between the contaminant in the steam vapour and the liquid milk is $y_A = 10x_A$, where y_A is the concentration of contaminant in the steam [ppm] and x_A is the concentration of contaminant in the milk [ppm]. Determine the number of theoretical stages required.

5) Air enters the base of a natural-draft cooling tower at a rate of $1100 \text{ m}^3/\text{min}$ at a pressure of 1.0 bar, a temperature of $15^\circ C$, and a relative humidity of 65%. Water enters the tower at $38^\circ C$ and leaves at $17^\circ C$. If the air leaves the tower at $32^\circ C$ in a saturated condition, find the mass flow of water entering the tower and the percentage loss of water by evaporation.

6) Air with a dry-bulb temperature of $47^\circ C$ and a wet-bulb temperature of $37^\circ C$ is to be dried by first cooling to $22^\circ C$ to condense water vapour followed by heating to $37^\circ C$. Use the attached psychrometric chart to determine the following:

- the initial absolute humidity and relative humidity;
- the final absolute humidity and relative humidity;
- the change in specific humid capacity (humid heat).

Show all your work on the chart. **Do not forget to hand in your chart with the exam booklet, and write your name on the chart.**

