LAPPEENRANTA UNIVERSITY OF TECHNOLOGY
Department of Chemical Technology
Laboratory of Separation Technology
BJ20A1802 Chemical Engineering Unit Operations II
Marjatta Louhi-Kultanen, Harri Niemi

EXAM 17.2.2014, page 1/2

The duration of the examination is 3 hours. In the exam writing tools (pens, erasers, rulers), scientific pocket calculator and equation note (distributed in the exam) are allowed. A student has to achieve min 25 % from maximum points of each parts.

Crystallization

1. Importance of polymorphism on crystalline product (10 p)

2. A 10-liter continuous MSMPR crystallizer has been used for crystallization of $K_2SO_4 \cdot Al_2(SO_4)_3 \cdot 2H_2O$. The residence time was 15 min. The suspension sample for sieving analysis had a volume of 100 ml. The following sieving results were obtained:

Size, µm	**Mass, g**
850	-
710	0.23
500	1.63
355	2.09
250	2.89
180	1.80
125	1.07
90	0.37
63	0.15
45	0.06
under 45	0.02
Totally	10.31

The solid density is 1770 kg/m^3 and volume shape factor 0.47. Calculate
a) population densities of each size fractions
b) population density of nuclei
c) crystal growth rate
d) nucleation rate

(16 p)

Multi-component mass transfer

3. Distillation of ethanol and water: comparison of ideal and non-ideal solutions (7 p)

4. Influence of various solid materials (inert medium) on mass transfer: give examples (6 p)

Problems 5 and 6 on page 2!

LAPPEENRANTA UNIVERSITY OF TECHNOLOGY
Department of Chemical Technology
Laboratory of Separation Technology
BJ20A1802 Chemical Engineering Unit Operations II
Marjatta Louhi-Kultanen, Harri Niemi

EXAM 17.2.2014, page 2/2
Membrane separation

5. Spiral wound modules. Structure, operation, properties and applicability. (10 p)

6. Salt (NaCl) is removed from water by reverse osmosis using hollow fiber modules. The system of the membrane and solution has the following mass transfer parameters: membrane permeability coefficient $A = 3.04 \times 10^{-7}$ kmol/(m^2 s kPa), parameter of the solution-diffusion model $D_{AM}K_A/\delta_M = 8.03 \times 10^{-7}$ m/s, and mass transfer coefficient at the membrane surface $k = 22 \times 10^{-6}$ m/s. The feed concentration of salt is 0.6 mol/kg solution, feed pressure is 4.0 MPa, and temperature 298 K. The present process treats the feed solution 25 m^3/h with total volumetric concentration ratio $VCR = 2$, i.e. the volumetric flow rate of the concentrate is half of the feed flow rate. The diameter of the fiber bundle in a single module is 30 cm. The length of the fibers is 88 cm, of which 8 cm is the sealing section, where no permeation takes place. The inner diameter of the fiber is 20 micrometers, and the outer diameter is 40 micrometers. The porosity of the fiber bundle is 0.4.

   How many modules are needed? The pressure inside the fibers (at the permeate side) is allowed to increase max. 50 % of the feed pressure (4.0 MPa). (16 p.)