LAPPEENRANTA UNIVERSITY OF TECHNOLOGY
Department of Chemical Technology
Laboratory of Separation Technology
BJ20A1801 Chemical Engineering Unit Operations II
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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. Describe precipitation processes and precipitation methods for obtaining small or large product crystals. (10 p)

2. You should design an MSMPR cooling crystallizer to produce a crystal product under the following specifications:

   Dominant (mode) crystal size: 4×10^{-4} m
   Production rate 400 kg/h
   Suspension density 200 kg/m^3 magma
   Volume shape factor 1
   Crystal density 1.8×10^3 kg/m^3
   Relative kinetics $B=1.8\times10^{15}\, M\, G^{1.5}$ (m^3 slurry)$^{-1}$ s^{-1}
   a) Plot the crystallizer and the inlet and outlet flows.
   b) Calculate the crystal growth rate.
   c) Calculate the residence time.
   d) Calculate the crystallizer volume. (16 p)

Multi-component mass transfer

3. Describe chemical activities of solutions containing water and ethanol. (7 p)

4. Give three examples how solid materials (inert media) can impact on mass transfer. (6 p)

Membrane separation

5. Mass transfer resistances in membrane separation. (10 p)

Problem 6 on next page!

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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 $VCR = 3$, i.e. the volumetric flow rate of the concentrate is 1/3 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)