CHEM-E7100, Engineering Thermodynamics, Separation Processes, part 1

Calculation Exam, 20th October 2020

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Answer in the both of the questions, 6 points per each question, 12 points in total.

Duration: 3 hours

Allowed material during the last 3 hours: The course material in MyCourses, books in paper or in electronic format for example in Knovel, any material found in web.

This exam is the personal exam, do it alone. As in the conventional exams regarding plagiarism, the same rules are valid in online exams.

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Question 1

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The topic of removal of dilute acetic acid (abbr. HAc) in water is studied for several decades. One of the studies proposes n-heptanol (abbr. n-HtOH) as solvent and data is given in Table 1. The reference is Darwish, N.A.; Abdulkarim, M.A.; Ashour, I.; Dwaidar, A.M.; Athamneh, F.S.; Liquid–liquid equilibrium for the system water + acetic acid + 1-heptanol at 278.1, 293.1, 303.1 and 313.1 K., *Fluid Phase Equilibria*, 2002, 200, 2, 277-285

Table 1. *One row is a tie-line, data given in mole fractions.(given in Excel in MyCourses also)*

x'(n-HtOH)	x'(HAc)	x'(water)	x''(n-HtOH)	x''(HAc)	x''(water)	T/K	p/kPa
0.0003	0.0000	0.9997	0.6965	0.0000	0.3035	303.15	101.325
0.0003	0.0174	0.9823	0.6276	0.0545	0.3180	303.15	101.325
0.0004	0.0360	0.9636	0.5557	0.1011	0.3432	303.15	101.325
0.0008	0.0719	0.9273	0.4595	0.1690	0.3715	303.15	101.325
0.0015	0.1043	0.8942	0.3819	0.2158	0.4023	303.15	101.325
0.0026	0.1788	0.8186	0.2363	0.2927	0.4710	303.15	101.325

The feed into the continuous multistage counter current liquid-liquid extraction column is given in mole fractions. The feed is a mixture of acetic acid and water where x(acetic acid) = 0.12 and x(water) = 0.88. Solvent is pure n-heptanol.

a) Draw the Kinney-diagram where solvent is the horizontal axis and acetic acid the vertical axis.

b) The column is isothermal at 30 °C. The target mole fraction of acetic acid in raffinate is maximum x(acetic acid,raff) = 0.017. What is the minimum solvent to feed ratio into the column?

c) Select the phase equilibrium model for this system and compare it to the given data using Aspen software and draw the Kinney-diagram. The McCabe diagram (acetic acid in raffinate in horizontal and acetic acid in extract in vertical axis) in Excel is easier to draw. Does the model give more or less ideal stages for a specified solvent to feed rate than the experimental data?

d) If the feed is 1.0 mol/s, solvent 0.4 mol/s and the same raffinate specification applies, how many ideal stages is needed? Make a table of your testing to find the raffinate specification.

Question 2

Upload files as "ETSPp1_exam20Oct2020_Q2_Familyname_Givenname.*" where * is the file type.

Design a vacuum evaporative crystallization process in Aspen Plus. At temperature of 20 °C and 1 bar, a saturated sucrose solution with total mass flow rate 100 kg/h is fed to a MSMPR crystallizer. The crystallizer is operated at 40 mbar with heat duty 20 kW. Crystal shape is cubic. Solubility of sucrose as a function of temperature you can find for instance from the appendix of Mullin's Crystallization book, via aalto.finna.fi. Kinetic parameters are $Kb=1.6\cdot10^{10}$, i=0.92, and j=1. Crystallizer volume is 1 m^3. Solids are separated with a filter at 20 °C and 1 bar.

a) Calculate the product rate, crystal growth rate, and plot the crystal size distribution.

b) If the pressure in the crystallizer is increased to 60 mbar with the same heat duty of 20 kW, how does this affect product rate, crystal growth rate and the crystal size distribution?