Department of Chemical Engineering

CHL 351 Mass Transfer Operations: Major Exam (open book / notes)

Duration: 2 hr (1pm - 3pm) Max Marks: 40 5th May 2009

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(1) 1000 kg of an aqueous solution containing 30 wt% acetone is fed to a multistage counter-current extractor using kerosene as the solvent. It is recommended to use 5 kg of pure kerosene per kg of feed solution. Assume that the kerosene and water are nearly immiscible with each other. Determine the number of theoretical stages required to reduce the acetone concentration to 3 wt % in the final raffinate stream. All compositions are on weight basis. The distribution of acetone in water and kerosene follows the relationship: $y'=0.155\ x'$, where y' is kg acetone per kg kerosene and x' is kg acetone per kg water. Perform stage-wise calculations and determine all solute-free compositions with at least four digits of accuracy after the decimal point. Also compare the number of stages by solving the appropriate analytical expression. [14 M]

(2) Consider a three-stage crosscurrent cascade for recovering sodium hydroxide from a mixture containing sodium hydroxide (C) and calcium carbonate (B), using pure water (A) as the leaching solvent. 375 kg of dry solids to be leached containing 150 kg of NaOH is fed to stage 1 along with 4.0 kg of pure water per kg of total dry solids. The mixture is settled, and a clear NaOH solution is withdrawn as overflow. The underflow is treated again with 4.0 kg of pure water per kg of feed to the second stage. The objective is to reduce the final concentration of NaOH to 1 wt % in the final sludge. Perform stage-wise calculations and determine the fresh water requirement in the third stage along with the mass of overflow, underflow and compositions from each stage. The 'practical' equilibrium data for the system is as given below.

x	y	N
0.10	0.10	0.48
0.090	0.092	0.50
0.070	0.076	0.53
0.047	0.061	0.57
0.033	0.045	0.60
0.021	0.030	0.62
0.012	0.020	0.65
0.007	0.014	0.66
0.005	0.01	0.67

where x is the weight fraction of NaOH in clear solution, y is weight fraction of NaOH in solution of the settled sludge, and N is kg $CaCO_3$ per kg solution in settled sludge. [13M]

(3) 1000 kg of an aqueous sugar cane solution containing 40 wt % of sugar is colored by the presence of small quantities of impurities. It is to be decolorized by treatment with an adsorptive carbon. The data for an equilibrium adsorption isotherm were obtained by adding various amounts of carbon to decolorize the solution. The data, with the quantity of carbon expressed on the basis of the sugar content of the solution, are as follows:

kg carbon/ kg dry sugar	0	0.005	0.01	0.015	0.02	0.03
Color removed, %	0	47	70	83	90	95

The original solution corresponds to a color concentration of 30 units per kg sugar ($Y_0 = 30$), and it is desired to reduce the color to 3 % of its original value. (a) Convert the equilibrium data to Y^* = units of color / kg sugar and X = units of color adsorbed / kg carbon. Do they follow the Freundlich equation ? If so, determine the equation constants. Calculate n by taking the average of the slopes for all data points. And use the average n to calculate m for each data point and then find average m.

Using the values of constants $m = 1.4758 \times 10^{-7}$ and $n = 2.34$ in Freundlich isotherm, determine the necessary dosage of fresh carbon (b) for a two-stage crosscurrent treatment using the minimum total amount of fresh carbon, and (c) for a two-stage counter-current treatment. [13 M]