Practice problems in ABSORPTION

1. A tray tower is absorbing ethanol from an inert gas stream using pure water at 303 K and 101.3 kPa. The inlet gas stream flow rate is 100.0 kmol/h and it contains 2.2 mol % ethanol. It is desired to recover 90 % of the alcohol. The equilibrium relationship is $y = mx = 0.68x$ for this dilute stream.

   Calculate the number of theoretical stages graphically and analytically using $1.3L'_{\text{min}}$.

   [N = 5.38 stages (analytical); N = 5.4 stages (graphical)]

2. The gas stream from a chemical reactor contains 25 mol % ammonia and the rest inert gases. The total flow is 181.4 kmol/h to an absorption tower at 303 K and 1.013×10^5 Pa pressure, where water containing 0.005 mol frac ammonia is the scrubbing liquid. The outlet gas concentration is to be 2.0 mol % ammonia. (Equilibrium data for ammonia-water is in Example 5 in your coursepack, slide 46.)

   What is the minimum flow L'_{min}? Using 1.5 times the minimum, plot the equilibrium and operating lines.

   [L'_{min} = 262.6 kmol/h; both equilibrium and operating lines are curved]

3. A relatively nonvolatile hydrocarbon oil contains 4.0 mol % propane and is being stripped by direct superheated steam in a stripping tray tower to reduce the propane content to 0.2 %. The temperature is held constant at 422 K by internal heating in the tower at 2.026×10^5 Pa pressure. A total of 11.42 kmol of direct steam is used for 300 kmol of total entering liquid. The vapour-liquid equilibria can be represented by $y = 25x$, where y is the mole fraction propane in the steam and x is mole fraction propane in the oil. Steam can be considered as an inert gas and will not condense.

   Plot the operating and equilibrium lines and determine graphically the number of theoretical stages needed.

   [N = 5.6 stages, starting from the top of the tower; operating line is curved]

4. Experimental data were obtained for absorption of dilute acetone in air by water at 80°F and 1 atm abs pressure in a packed tower with 25.4 mm Raschig rings. The inert gas flow was 95 lb_m air/h·ft^2 and the pure water flow was 987 lb_m/h·ft^2. The experimental coefficients are $k_y a$ = 4.03 lbmol/h·ft^3·mol frac and $k_x a$ = 57.0 lbmol/h·ft^3·mol frac. The equilibrium data can be expressed by $c_A = 1.37p_A$, where c_A = lbmol/ft^3 and p_A = atm partial pressure of acetone. (MW_{water} = 18 lb_m/lbmol; MW_{air} = 29 lb_m/lbmol; ρ_{water} = 61.8 $\text{lb}_\text{m}/\text{ft}^3$)

   a) Calculate the height of the film transfer units, H_G and H_L.
   b) Calculate H_{OG}.

   [H_G = 0.813 ft; H_L = 0.962 ft; H_{OG} = 0.957 ft]

Practice problems in EVAPORATION

1. In order to concentrate 4536 kg/h of an NaOH solution containing 10 wt % NaOH to a 20 wt % solution, a single-effect evaporator is being used, with an area of 37.6 m^2. The feed enters at 21.1°C. Saturated steam at 110°C is used for heating and the pressure in the vapour space of the evaporator is 51.7 kPa.

   Calculate the kg/h of steam used and the overall heat-transfer coefficient.

   [S = 2880 kg/h; U = 2249 W/m^2·K]

2. An evaporator is concentrating F kg/h at 311 K of a 20 wt % solution of NaOH to 50 %. The saturated steam used for heating is at 399.3 K. The pressure in the vapour space of the evaporator is 13.3 kPa abs. The overall heat-transfer coefficient is 1420 W/m^2·K and the area is 86.4 m^2.

   Calculate the feed rate F of the evaporator.

   [F = 9072 kg/h]

3. A single-effect evaporator is concentrating a feed solution of organic colloids from 5 to 50 wt %. The solution has a negligible boiling-point elevation. The heat capacity of the feed is c_p = 4.06 kJ/kg·K and the feed enters at 15.6°C. Saturated steam at 101.32 kPa is available for heating, and the pressure in the vapour space of the evaporator is 15.3 kPa. A total of 4536 kg/h of water is to be evaporated. The overall heat-transfer coefficient is 1988 W/m^2·K.

   What is the required surface area in m^2 and the steam consumption?

   [A = 35.35 m^2; S = 5119 kg/h]

4. A double-effect evaporator (forward-feed) is used to concentrate 4536 kg/h of a 10 wt % sugar solution to 50 %. The feed enters the first effect at 37.8°C. Saturated steam at 115.6°C enters the first effect and the vapour from this effect is used to heat the second effect. The absolute pressure in the second effect is 20 kPa abs. The overall coefficients are U_1 = 2270 and U_2 = 1705 W/m2·K. The heating areas for both effects are equal. (Boiling point rise and heat capacity correlations are given in Example 3 in your coursepack, slide 49)

   Calculate the area and steam consumption.