AE 335 Separation Processes

(by PTS)

Problem Set 6

(Absorption & Stripping)

1. We are absorbing hydrogen sulphide (H_2S) in biogas at 15 °C into water. The entering water is pure. The feed gas contains 0.0012 mole fraction H_2S and the remaining CH_4, and we want to remove 97 mol% of H_2S in biogas into water. The gas flow rate is 10 kmol/h, while the liquid flow rate is 2,000 kmol/h. Total pressure is 2.5 atm. The equilibrium data is

   $$\text{Partial pressure of } H_2S \text{ (atm)} = \text{(Henry's constant)}x$$

   where Henry's constant of H_2S in water at 15 °C is 423 atm/(mole fraction) and x is mole fraction of H_2S.

   1.1) Calculate the outlet gas and liquid mole fraction of H_2S

   1.2) Calculate the number of equilibrium stages required, using a McCabe-Thiele diagram

   1.3) If actual $\dfrac{L}{V} = m\left(\dfrac{L}{V}\right)_{\min}$, find the value of m (a multiplier)

2. We wish to design a stripping column to remove carbon dioxide (CO_2) from water. This can be done by heating the water + CO_2 mixture and passing it counter-currently with a nitrogen stream in a stripper. The operation is isothermal and isobaric at 60 °C and 1 atm, respectively. The water contains 9.2×10^{-6} mole fraction CO_2 and flows at 100,000 lb_m/h. Nitrogen enters the column as pure N_2 and flows at 2,500 ft^3/h. Nitrogen is also at 1 atm and 60 °C. We desire an outlet water concentration of 2×10^{-7} mole fraction CO_2. Assume that N_2 is not dissolved in water and that water is not evaporated. The Henry's constant for CO_2 in water at 60 °C is 3,410 atm/(mole fraction). Find the number of equilibrium stages required.

3. A stripping tower with 4 equilibrium stages is being used to remove ammonia from waste water using air as the stripping gas. The operation is at 80 °F and 1 atm. The inlet air is pure air, and the inlet waste water contains 0.02 mole fraction ammonia. The column operates at L/V of 0.65. The equilibrium data in mole fraction is given as $y = 1.414x$. Find the outlet concentrations.

4. An absorption column for laboratory use has been carefully constructed so that it has exactly 4 equilibrium stages and is being used to measure equilibrium data. Water is used as the solvent to absorb ammonia from air. The system operates isothermally at 80 °F and isobarically at 1 atm. The inlet water is pure distilled water. The ratio of L/V is 1.2, the inlet gas concentration is 0.01 mole fraction ammonia, and the measured outlet gas concentration is 0.0027 mole fraction ammonia. Assuming the equilibrium is of the equation $y = mx$, determine the value of m.

5. We wish to strip CO_2 out of water at 20 °C and 2 atm using a staged, counter-current stripper. The liquid flow rate is 100 kmol/h of water, and the initial CO_2 mole fraction in water is 0.00005. The inlet air stream contains no CO_2. It is desired to obtain 98.4% removal of CO_2 from water. The Henry's constant for CO_2 in water at 20 °C is 1,420 atm.
    - 5.1) Find the outlet CO_2 mole fraction in water
    - 5.2) Find V_{min}
    - 5.3) If there are 7 equilibrium stages, find V and the outlet mole fraction CO_2 in water

6. We wish to absorb ammonia from air into water. The equilibrium data is given as $y = 1.414x$ in mole fraction. The counter-current column has 3 equilibrium stages. The entering air stream has a total flow rate of 10 kmol/h and is with 0.0083 mole fraction NH_3. The inlet water stream contains 0.0002 mole fraction NH_3. We desire an outlet gas concentration of 0.0005 mole fraction NH_3. Find the required liquid flow rate, L.