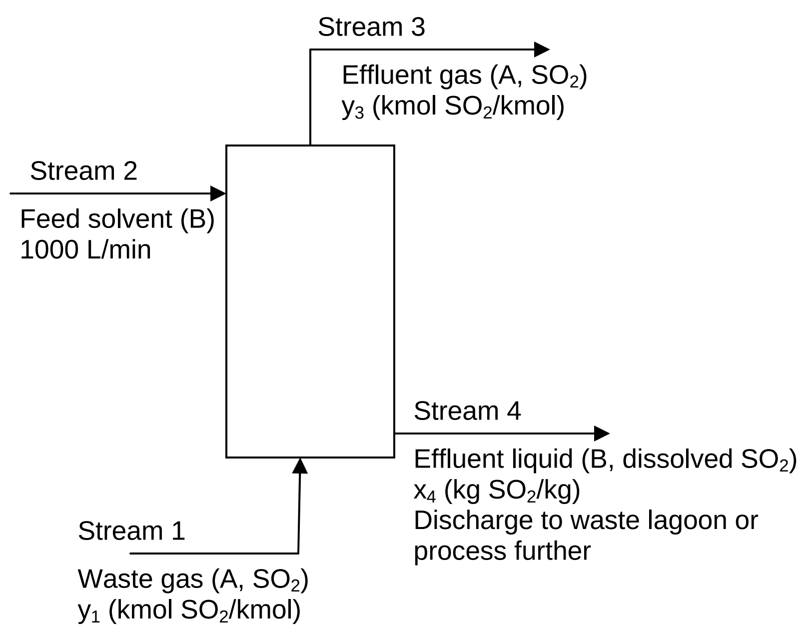
Homework 2 **Due date: 24-Jan-2007**

1. (Chapter 4, Prob. 4.30) Seawater containing 3.5 wt% salt passes through a series of ten evaporators. Roughly equal quantities of water are vaporized in each of the ten units and then condensed and combined to obtain a product stream of fresh water. The brine (solution of salt in water) leaving each evaporator but the tenth is fed to the next evaporator. The brine leaving the tenth evaporator contains 5.00 wt% salt.
   a) Draw a flowchart of the process showing the first, fourth and tenth evaporators. Label all the streams entering and leaving these three evaporators.
   b) Write in order the set of equations you would solve to determine the fractional yield of water from the process (kg H_2O recovered/kg H_2O in process feed) and weight percent of salt in the solution leaving the fourth evaporator. Solve the equations.

2. (Chapter 4, Prob. 4.26) Gas absorption or gas scrubbing is a commonly used method for removing environmentally undesirable species from waste gases in chemical manufacturing and combustion processes. The waste gas is contacted with a liquid solvent in which the potential pollutants are highly soluble and the other species in the waste gas are relatively insoluble. Most of the pollutants go into the solution and emerge with the liquid effluent from the scrubber, and the cleaned gas is discharged to the atmosphere. The liquid effluent may be discharged to a waste lagoon or subjected to further treatment to recover the solvent and/or to convert the pollutant to a species that can be released safely to the environment.

   A waste gas containing SO_2 (a precursor of acid rain) and several other species (collectively designated as A) is fed to a scrubbing tower where it contacts a solvent B that absorbs SO_2. The solvent fed to the tower does not contain SO_2 and its flow rate is 1000 L/min. The specific gravity is 1.30. Absorption of A and evaporation of B in the scrubber may be neglected.



   The gas in the scrubber rises through a series of trays (metal plates perforated with many small holes), and the solvent flows over the trays and through downcomers to the trays below. Gas bubbles emerge from the holes in each tray and rise through the covering liquid, and SO_2 diffuses out of the bubbles and into the solution. The molar density of the feed gas may be determined from the following formula

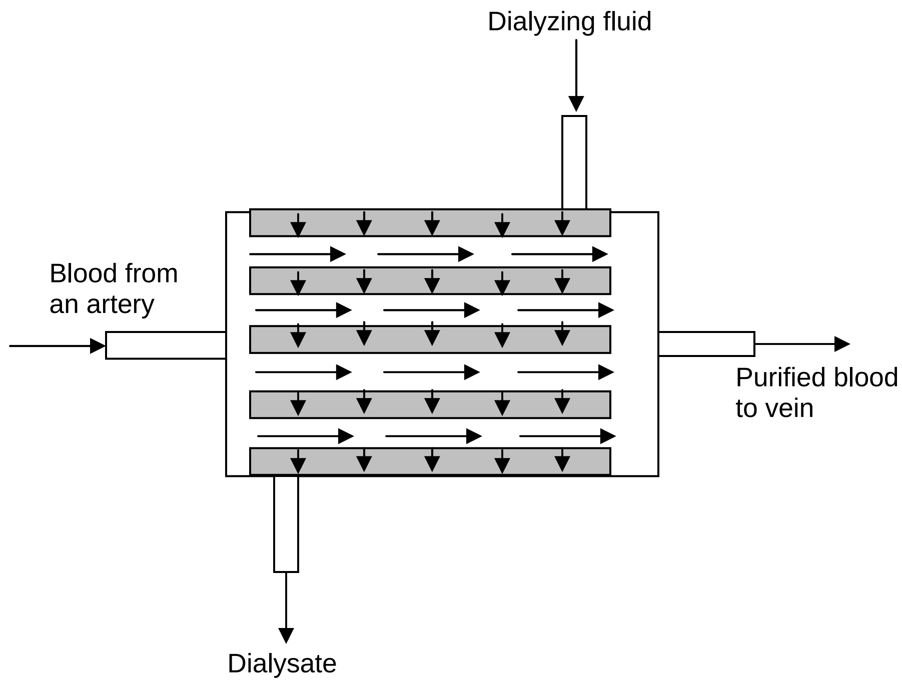
$$\rho\left(\frac{mol}{liter}\right) = \frac{12.2P(atm)}{T(K)}$$

Where P and T are absolute pressure and temperature of the gas. The following data are given: P = 150 psig; T = 75^{o}F, flow rate of the gas entering the scrubber is 205 m^3/min b. The mole fraction of SO_2 in the entering stream is 0.1107 and in the exiting stream it is 0.00166.

a) Draw and completely label the flowchart. Include in the labeling the molar flow rates and SO_2 mole fractions of the gas streams and the mass flow rates and SO_2 mass fractions of the liquid streams. Show that the scrubber has zero degrees of freedom.
b) Calculate (i) the mass fraction of SO_2 in the liquid effluent stream and (ii) the rate at which SO_2 is removed from the feed gas (kg SO_2/min)

3. (Chapter 4, Prob. 4.29) A liquid mixture containing 30.0 mole% benzene (B), 25.0% toluene (T) and the balance xylene (X) is fed to a distillation column. Two product streams continuously flow out of the column; one from the top and one from the bottom. The bottoms product contains 98.0 mole% X and no B and 96.0% of the X in the feed is recovered in this stream. The top product is fed to a second column. The top product from the second column contains 97.0% of the B in the feed to this column. The composition of this stream is 94.0 mole% B and the balance T.
   a) Draw and label a flowchart on this process and do the degree of freedom analysis to prove that for an assumed basis of calculation (molar flow rate of feed to the first column), molar flow rates and compositions of all process streams can be calculated. Write in order the equations you would solve to calculate the unknown process variables. In each equation (or pair of simultaneous equations), circle the variable(s) for which you would solve. Do not do the calculations.
   b) For a 2000 L/min feed to the first column with a specific gravity of 0.89, calculate (i) the % of benzene in the process feed (that is feed to the first column) that emerges in the top product from the second column and (ii) the % of T in the process feed that emerges in the bottom product from the second column.

4. (Chapter 4, Prob. 4.23) An artificial kidney is a device that removes water and waste metabolites from the blood. In one such device, the **hollow fiber hemodialyzer,** blood from an artery through the inside of a bundle of hollow fiber cellulose acetate fibers, and dialyzing fluid, which consists of water and various dissolved salts, flows on the outside of the fibers. Water and waste metabolites—principally urea, creatinine, uric acid and phosphate ions—pass through the fiber walls into the dialyzing fluid, and the purified blood is returned to a vein.



At sometime during dialysis, the flow rate of blood into the device is 200.0 mL/min and out of the device is 195.0 mL/min. Urea concentration in the blood flowing into the device is 1.90 mg/mL and in the blood flowing out of the device is 1.75 mg/mL. If the dialyzing fluid enters at 1500 mL/min and leaves at almost the same flow rate, calculate the concentration of urea in the dialysate. What is the rate (mg/min) at which urea is being removed?

Suppose we have a patient whose blood urea needs to be brought down to 1.1 mg/mL from 2.7 mg/mL. If the total blood volume is 5.0 liters and the average rate of removal of urea equals that calculated from the information in the paragraph above, how long must the patient be dialyzed?