Chemical Process Calculations

Three hundred gallons of a mixture containing 75.0 wt% ethanol (ethyl alcohol) and 25% water (mixture specific gravity = 0.877) and a quantity of a 40.0 wt% ethanol–60% water mixture (SG = 0.952) are blended to produce a mixture containing 60.0 wt% ethanol. The object of this problem is to determine V_{40}, the required volume of the 40% mixture.

(a) Draw and label a flowchart of the mixing process and do the degree-of-freedom analysis.

(b) Calculate V_{40}.

ANS: (a) DOF = 0 (b) 207 gallons

Two aqueous sulfuric acid solutions containing 20.0 wt% H_2SO_4 (SG = 1.139) and 60.0 wt% H_2SO_4 (SG = 1.498) are mixed to form a 4.00 molar solution (SG = 1.213).

(a) Calculate the mass fraction of sulfuric acid in the product solution.

(b) Taking 100 kg of the 20% feed solution as a basis, draw and label a flowchart of this process, labeling both masses and volumes, and do the degree-of-freedom analysis. Calculate the feed ratio (liters 20% solution/liter 60% solution).

(c) What feed rate of the 60% solution (L/h) would be required to produce 1250 kg/h of the product?

ANS: (a) 0.323 kg H_2SO_4 / kg solution (b) 2.96 (c) 257 L/h

A paint mixture containing 25.0% of a pigment and the balance water sells for \$18.00/kg, and a mixture containing 12.0% pigment sells for \$10.00/kg. If a paint retailer produces a blend containing 17.0% pigment, for how much (\$/kg) should it be sold to yield a 10% profit?

ANS: \$14.39/kg

A sedimentation process is to be used to separate pulverized coal from slate. A suspension of finely divided particles of galena (lead sulfide, SG = 7.44) in water is prepared. The overall specific gravity of the suspension is 1.48.

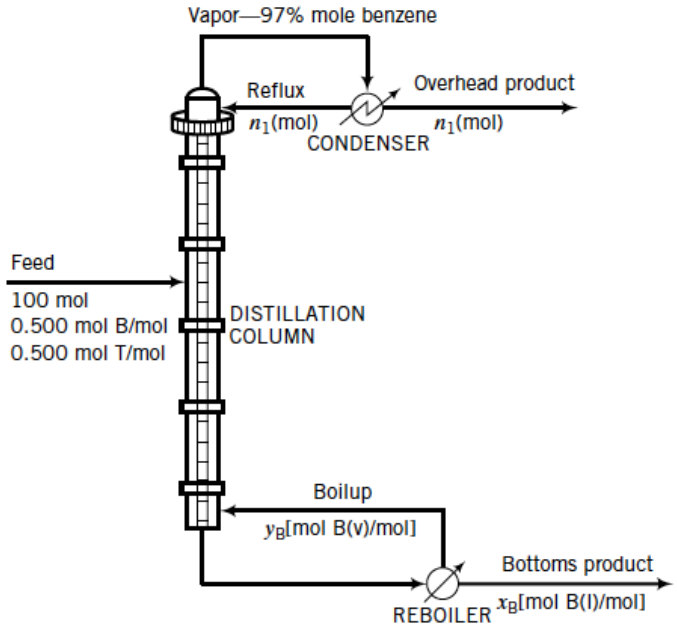
(a) Four hundred kilograms of galena and a quantity of water are loaded into a tank and stirred to obtain a uniform suspension with the required specific gravity. Draw and label the flowchart (label both the masses and volumes of the galena and water), do the degree-of-freedom analysis, and calculate how much water (m^3) must be fed to the tank.

(b) A mixture of coal and slate is placed in the suspension. The coal rises to the top and is skimmed off, and the slate sinks. What can you conclude about the specific gravities of coal and slate?

(c) The separation process works well for several hours, but then a region of clear liquid begins to form at the top of the cloudy suspension and the coal sinks to the bottom of this region, making skimming more difficult. What might be happening to cause this behavior and what corrective action might be taken? Now what can you say about the specific gravity of coal?

ANS: (a) 0.668 m^3 (b) Specific gravity of coal < 1.48 < Specific gravity of slate (c) The suspension begins to settle. Stir the suspension. 1.00 < Specific gravity of coal < 1.48

An equimolar liquid mixture of benzene and toluene is separated into two product streams by distillation. A process flowchart and a somewhat oversimplified description of what happens in the process follow:



Inside the column a liquid stream flows downward and a vapor stream rises. At each point in the column some of the liquid vaporizes and some of the vapor condenses. The vapor leaving the top of the column, which contains 97 mole% benzene, is completely condensed and split into two equal fractions: one is taken off as the overhead product stream, and the other (the **reflux**) is recycled to the top of the column. The overhead product stream contains 89.2% of the benzene fed to the column. The liquid leaving the bottom of the column is fed to a partial reboiler in which 45% of it is vaporized. The vapor generated in the reboiler (the **boilup**) is recycled to become the rising vapor stream in the column, and the residual reboiler liquid is taken off as the bottom product stream. The compositions of the streams leaving the reboiler are governed by the relation

$$\frac{y_B/(1-y_B)}{x_B/(1-x_B)} = 2.25$$

where y_B and x_B are the mole fractions of benzene in the vapor and liquid streams, respectively.

(a) Take a basis of 100 mol fed to the column. Draw and completely label a flowchart, and for each of four systems (overall process, column, condenser, and reboiler), do the degree-of-freedom analysis and identify a system with which the process analysis might appropriately begin (one with zero degrees of freedom).

(b) Write in order the equations you would solve to determine all unknown variables on the flowchart, circling the variable for which you would solve in each equation. Do not do the calculations in this part.

(c) Calculate the molar amounts of the overhead and bottoms products, the mole fraction of benzene in the bottoms product, and the percentage recovery of toluene in the bottoms product (100 × moles toluene in bottoms/mole toluene in feed).