# Lecture 12

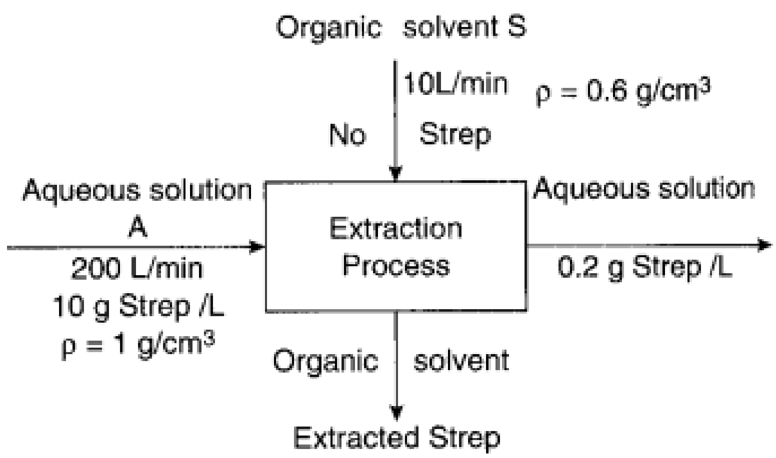
## 2.3 Solving Material Balance Problems for Single Units without Reaction

The use of material balances in a process allows you (a)to calculate the values of the total flows and flows of species in the streams that enter and leave the plant equipment, and (b)to calculate the change of conditions inside the equipment.

**Example 9**

Determine the mass fraction of Streptomycin in the exit organic solvent assuming that no water exits with the solvent and no solvent exits with the aqueous solution. Assume that the density of the aqueous solution is 1g/cm$^3$and the density of the organic solvent is 0.6 g/cm$^3$.

**Solution**




This is an open(flow), steady-state process without reaction. Assume (because of the low concentration of Strep. in the aqueous and organic fluids) that the flow rates of the entering fluids equal the flow rates of the exit fluids.

Basis: Feed = 200 L (flow of aqueous entering aqueous solution)

- Flow of exiting aqueous solution (same as existing flow)
- Flow of exiting organic solution (same as existing flow)

The material balances are in = out in grams. Let x be the g of Strep per L of solvent S

**Strep. balance:**

$$\frac{200 \text{ L of A}}{}\Bigg|\frac{10 \text{ g Strep}}{1 \text{ L of A}} + \frac{10 \text{ L of S}}{}\Bigg|\frac{0 \text{ g Strep}}{1 \text{ L of S}} = \frac{200 \text{ L of A}}{}\Bigg|\frac{0.2 \text{ g Strep}}{1 \text{ L of A}} + \frac{10 \text{ L of S}}{}\Bigg|\frac{x \text{ g Strep}}{1 \text{ L of S}}$$

x = 196 g Strep/L of solvent

To get the g Strep/g solvent, use the density of the solvent:

$$\frac{196 \text{ g Strep}}{1 \text{ L of S}}\Bigg|\frac{1 \text{ L of S}}{1000 \text{ cm}^3 \text{ of S}}\Bigg|\frac{1 \text{ cm}^3 \text{ of S}}{0.6 \text{ g of S}} = 0.3267 \text{ g Strep/g of S}$$

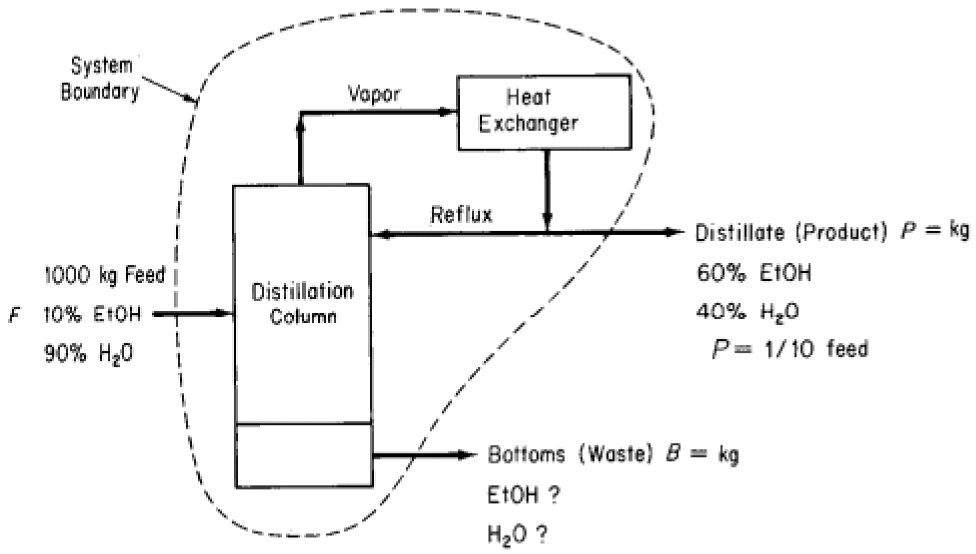
$$\text{The mass fraction Strep} = \frac{0.3267}{1 + 0.3267} = 0.246$$

**Example 10**

A novice manufacturer of ethyl alcohol (denoted as EtOH) for gasohol is having a bit of difficulty with a distillation column. The process is shown in Figure . It appears that too much alcohol is lost in the bottoms (waste). Calculate the composition of the bottoms and the mass of the alcohol lost in the bottoms based on the data shown in Figure that was collected during 1 hour of operation.

**Solution**

The process is an open system, and we assume it is in the steady state. No reaction occurs.




Basis: 1 hour so that F = 1000 kg of feed

We are given that P is (1/10) of F, so that P = 0.1(1000) = 100 kg

Specifications:

$$m^F_{EtOH} = 1000(0.10) = 100$$

$$m^F_{H_2O} = 1000(0.90) = 900$$

$$m^P_{EtOH} = 0.60P$$

$$m^P_{H_2O} = 0.40P$$

P = (0.1) (F) = 100 kg

Material balances: EtOH and $H_2O$

Implicit equations: $\Sigma m^B_i = B$ or $\Sigma \omega^B_i = 1$

The total mass balance: F = P + B

B = 1000 – 100 = 900 kg

The solution for the composition of the bottoms can then be computed directly from the material balances:

| | *kg feed in* | | *kg distillate out* | | *kg bottoms out* | *Mass fraction* |
|---|---|---|---|---|---|---|
| EtOH balance: | 0.10(1000) | – | 0.60(100) | = | 40 | 0.044 |
| $H_2O$ balance: | 0.90(1000) | – | 0.40(100) | = | <u>860</u> | <u>0.956</u> |
| | | | | | 900 | 1.000 |

As a check let's use the redundant equation

$$m^B_{\text{EtOH}} + m^B_{\text{H}_2\text{O}} = B \quad \text{or} \quad \omega^B_{\text{EtOH}} + \omega^B_{\text{H}_2\text{O}} = 1$$

40 + 860 = 900 = B

**Problems**

1. A cellulose solution contains 5.2% cellulose by weight in water. How many kilograms of 1.2% solution are required to dilute 100 kg of the 5.2% solution to 4.2%?

2. If 100 g of $Na_2SO_4$ is dissolved in 200 g of $H_2O$ and the solution is cooled until 100 g of $Na_2SO_4.10H_2O$ crystallizes out; find (a) the composition of the remaining solution (the mother liquor) and (b) the grams of crystals recovered per 100 g of initial solution.