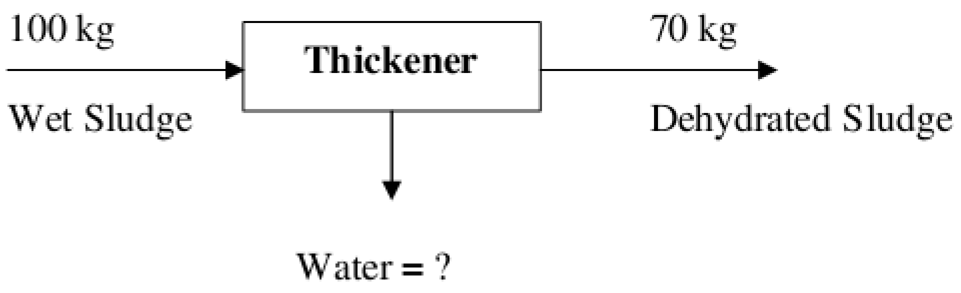
Lecture 10

Example 3

A thickener in a waste disposal unit of a plant removes water from wet sewage sludge as shown in Figure. How many kilograms of water leave the thickener per 100 kg of wet sludge that enter the thickener? The process is in the steady state.



Solution

Basis: 100 kg wet sludge

The total mass balance is

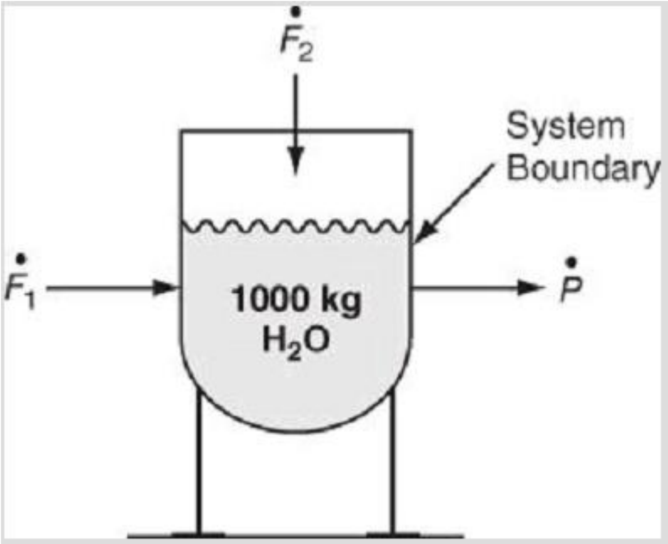
In= Out

100 kg = 70 kg + kg of water

Consequently, the water amounts to 30 kg.

Example 4

Consider the storage tank shown in Figure E3.2. Over a 3 h period, the accumulation of water in the tank was determined to be 6000 kg. Assuming that the feed and removal rates remain constant during the 3 h period of interest, determine the flow rate of the second feed stream, $\dot{F}_2$. $\dot{F}_1$, is 10,000 kg/h and the water removal rate, $\dot{p}$, is 12,000 kg/h.



Solution

What should be the basis? Pick a basis of Δt equal to 3 h.

$$S_T(t_2) - S_T(t_1) = \dot{F}_1\Delta t + \dot{F}_2\Delta t - \dot{P}\,\Delta t$$

$$6000 \text{ kg} = (10{,}000 \text{ kg/h})(3 \text{ h}) + \dot{F}_2(3 \text{ h}) - (12{,}000 \text{ kg/h})(3 \text{ h})$$

Divide both sides of the equation by 3 to get $\dot{F}_2 = 4000$ kg/h. Note that the amount of water entering the system during the 3 h, F_2, is equal to the flow rate multiplied by the time interval.

Degree of Freedom Analysis

Before you do any lengthy calculations, you can use degree of freedom analysis to determine whether you have enough information to solve a given problem.

Degrees of freedom = number of unknowns — number of independent equations

$N_D = N_U - N_E$

There are three possibilities:

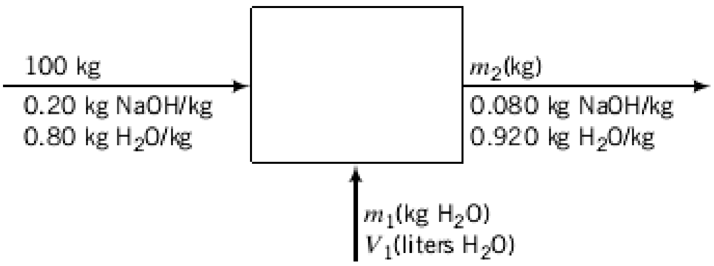
1. If N_D = 0, there are independent equations in unknowns and the problem can in principle be solved.
2. If N_D > 0, there are more unknowns than independent equations relating them, and more independent equations required.
3. If N_D < 0, there are more independent equations than unknowns.

Example 5

An aqueous solution of sodium hydroxide contains 20.0% NaOH by mass. It is desired to produce an 8.0% NaOH solution by diluting a stream of the 20% solution with a stream of pure water. Calculate the ratios (liters H_2O/kg feed solution) and (kg product solution/kg feed solution).

Solution

Basis: 100 kg of the 20% feed solution



$N_D = N_U - N_E$

N_U = 3 (m_1, m_2 and V_1)

N_E = 3 (NaOH M.B, H_2O M.B and density of water which relate m_1 and V_1).

N_D= 3– 3

N_D= 0 , therefore a solvable problem.

<u>NaOH mass balance</u>

Input = output

$$0.2\ \frac{\text{kg NaOH}}{\text{kg}} * 100\ \text{kg} = 0.080\ \frac{\text{kg NaOH}}{\text{kg}} * \text{m}_2$$

m_2 = 250 kg NaOH

Total mass balance

input = output

100 kg + m_1 = m_2

(m_2 = 250 kg NaOH)

m_1 = 150 kg H_2O

Diluents water volume

ρ_{H2O} = 1 kg/L

$$V_1 = 150\ \text{kg}\ \Big|\ \frac{1\ \text{litter}}{\text{kg}} = 150\ \text{litter}$$

Ratio requested

$$\frac{V_1}{100\ \text{kg}} = \frac{1.5\ \text{litter}\ H_2O}{\text{kg feed solution}}$$

$$\frac{m_2}{100\ \text{kg}} = \frac{2.5\ \text{kg product solution}}{\text{kg feed solution}}$$