7.1 Problem Solving

- What is problem solving?

- Problem solving is to plan how to solve the problem effectively and efficiently

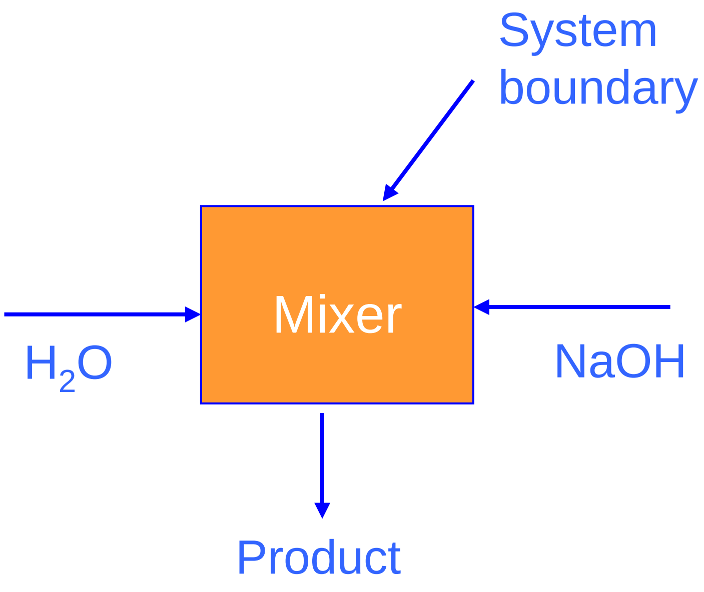
Example: a continuous mixer mixes NaOH with H_2O to produce an aqueous solution of NaOH. Determine the composition and flow rate of the product if the flow rate of NaOH is 1000 kg/hr, and the ratio of the flow rate of the H_20 to the product solution is 0.9.

7.2 The Strategy for Solving Problems

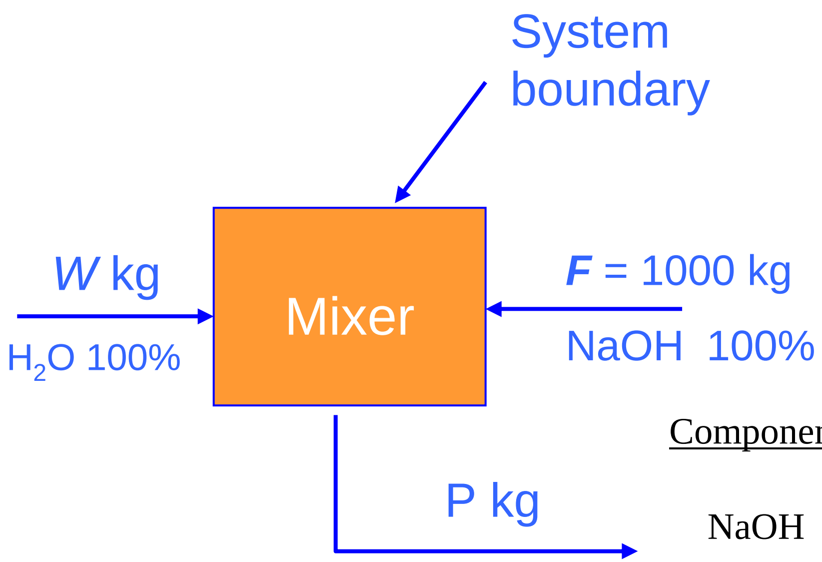
1. Read and understand the problem statement.

   - We pick the mixer as the system.
   - The process is an open one.
   - We assume it to be steady state.

2. Draw a sketch of the process and specify the system boundary.



3. Place labels for unknown variables and values for known variables on the sketch.



Component	Kg	w	
NaOH	P_{NaOH}	$w^P_{NaOH} =$	$\frac{P_{NaOH}}{P}$
H2O	P_{H2O}	$w^P_{H_2O} =$	$\frac{P_{H_2O}}{P}$
Total	P	1.00	P

A GENERAL STRATEGY FOR SOLVING MATERIAL BALANCE PROBLEMS

F kg	Flow of mass in kg
F_{Total} or F_{Tot}	Total flow of material
F^1 or $F1$	Flow in stream number 1.
F_A lb	Flow of component A in stream Fin lb
m_A	Mass flow of component **A.**
m_{Total} or m_{Tot}	Mass flow of the total material.
m_A^{F1}	Mass flow of component **A** in stream Fl.
n_A^W	Molar flow of component A in stream *W*
w^F_A	The mass (weight) fraction of **A** in stream F. (The superscript is not required if the meaning is otherwise clear.)
x^F_A	The mole fraction of A in stream *F*, a liquid. (The superscript is not required if the meaning is otherwise clear.)
y^F_A	The mole fraction of A in stream F, usually a gas.

4. Obtain any missing needed data.

- Physical properties (molecular weight, density, etc.)
  - You can look the values up in a physical properties database such as the one on the CD that accompanies your text book, in reference books, on the Web, and many other places.
- Some value may be missing, but you can calculate the value in your head.

A GENERAL STRATEGY FOR SOLVING MATERIAL BALANCE PROBLEMS

5. Choose a basis.

   (1) What do I have

   (2) What do I want to find,

   (3) What is convenient

- Pick one of the following

  1000 kg

  I hour

  1000 kg/hr

6. Determine the number of unknowns.

- We have four unknowns:

$$W, P, P_{NaOH}, \text{ and } P_{H_2O}$$

7. Determine the number of independent equations, and carry out a degree of freedom analysis.

- To get a unique answer, the number of variables whose values are unknown equals the number of independent equations you formulate to solve a problem.
- For the above example we can write three material balances :

  - One for the NaOH
  - One for the H_2O
  - One total balance (the sum of the two component balance)

Only two are independent where you can use any combination of two of the three to solve the problem

A GENERAL STRATEGY FOR SOLVING MATERIAL BALANCE PROBLEMS

- Two independent equations can be obtained from the specifications and values of variables that are given in the problem statement such as:
  - Given ratio: $W = 0.9P$
  - Sum of components in P.

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

or

$$N_D = N_U - N_E$$

$$N_D = 4 - 4 = 0$$ → Solution exists

8. Write down the equations to be solved.

NaOH balance: $1000 = P_{NaOH}$, or $1000 - P_{NaOH} = 0$ (1)

H_2O balance: $W = P_{H_2O}$ or $W - P_{H_2O} = 0$ (2)

Given ratio: $W = 0.9P$ or $W - 0.9P = 0$ (3)

Sum of components in P: $P_{NaOH} + P_{H2O} = P$ or $P_{NaOH} + P_{H_2O} - P = 0$ (4)

9. Solve the equations and calculate the quantities asked for.

Substitute eq.(3) in eq.(4):

$P_{NaOH} + P_{H2O} = W/0.9$ → $1000 + W = W/0.9$

$900 + 0.9W = W$ → $W = 9000$ → $P = 10000$

$P_{H_2O} = 9000$

$P_{NaOH} = 1000$

10. Check your answer(s).

$$P_{NaOH} + P_{H2O} = P$$

$$1000 + 9000 = 10000$$

A GENERAL STRATEGY FOR SOLVING MATERIAL BALANCE PROBLEMS

Example: Sludge is wet solids that result from the processing in municipal sewage systems. The sludge has to be dried before it can be composted or otherwise handled. If a sludge containing 70% water and 30% solids is passed through a drier, and the resulting product contains 25% water, how much water is evaporated per ton of sludge sent to the drier.