

**Department of Chemical Engineering
Thapar Institute of Engineering &
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**Course: Material and Energy Balances
UCH301**

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Solution Methods for M.B. Problems

- First, try to find a tie/inert material in the process and write material balance for it.
Why??
- *Tie material is a material that does not distribute in streams.*

For example-while concentrating a solution in an evaporator, the solids content is a tie material.



Solution Methods for M.B. Problems

- While drying a **solid**, the mass of solids does not change, hence is a tie material.
- While burning fuel with air, N_2 is **inert**.
- ✓ When all the components in a process are distributed in many streams then the material balance equations are solved simultaneously



We shall now attempt writing
material balances for different
types of processes



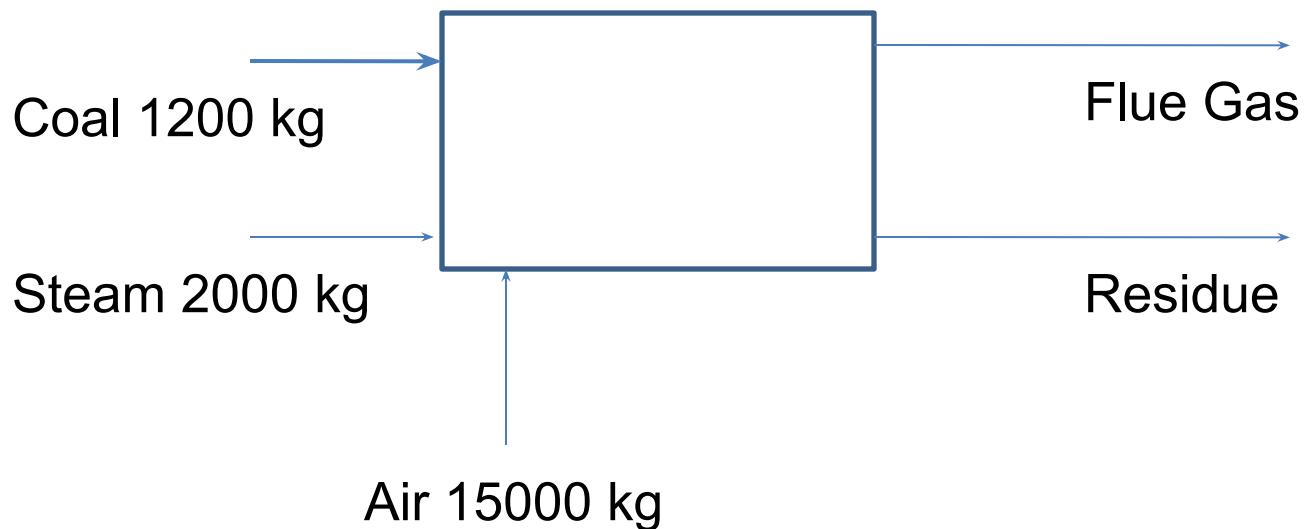
Exercise

- 1200 kg coal (having 80%C, 10%H, and 10%inert) is put into a fluidized bed reactor for **combustion**. 2000 kg/hr of steam and 15,000 kg/hr of air is blown through the reactor. How many kg of gas leaves the reactor per hour assuming complete combustion of the coal in one hour.



Solution

- ✓ First make a sketch using the statement given



- ✓ Try to think only about mass of the different materials entering and leaving the process

$$\begin{aligned}\text{Inert material in coal} &= (10/100)*1200 \\ &= 120 \text{ kg}\end{aligned}$$

$$\begin{aligned}\text{Mass entering} &= 1200 + 15000 + 2000 \\ &= 18200 \text{ kg}\end{aligned}$$

$$\begin{aligned}\text{Mass of the gases leaving} &= 18200 - 120 \\ &= 18,080 \text{ kg}\end{aligned}$$



Drying of a wet solid/pulp

- As you may visualize that the drying of a wet solid/pulp would involve removing the moisture (or liquid) from the solid.
- Drying can be complete or partial, this information is usually available in the problem statement



Drying of a wet solid/pulp

- A wet paper pulp is found to contain 71% water. After drying it is found 60% of the original water has been removed. Calculate:
 - (a) the composition of the dried pulp
 - (b) mass of water removed/kg of wet pulp.

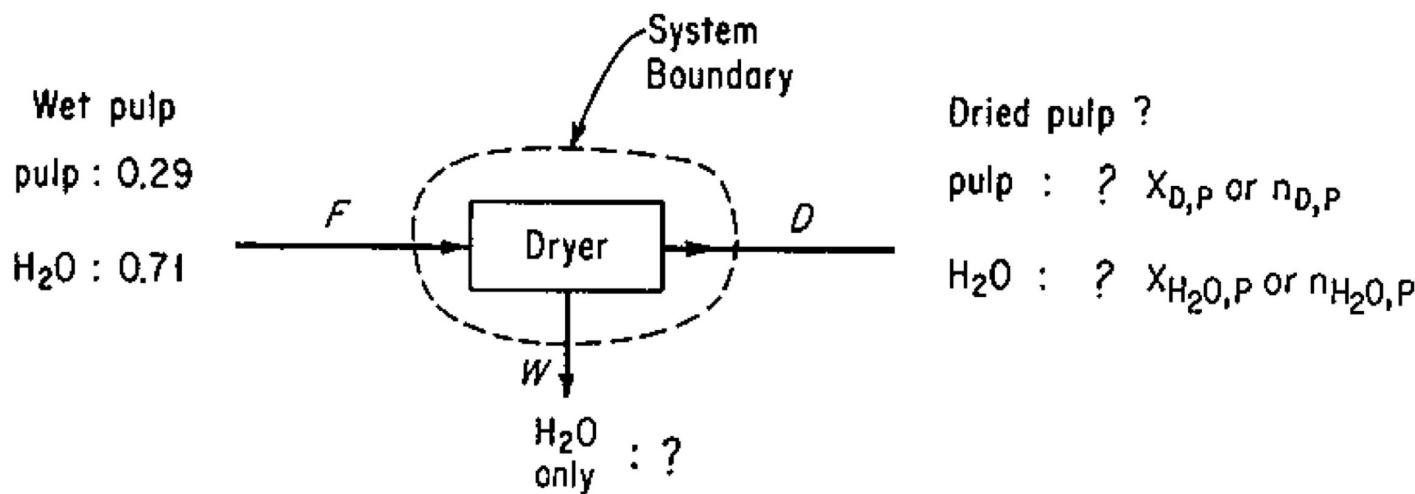
Solution:

- ✓ Before we start solving this problem, we need to understand the process involved
- ✓ it is always desirable (required also) that a sketch be made showing the material streams



✓ How to think and make a sketch

- A sketch consisting of dryer block with one input stream for wet pulp and one output stream for dried pulp can be made.
- Also, as the water is being removed from the wet pulp, one more outflow stream for the water will be needed.



- *THE COMPOSITIONS ARE ALSO MARKED WITH THE STREAMS IN THE above sketch.*



- ✓ Once a correct sketch is made, the material balances can be written.

Choose a basis, we can use **100 kg/h of wet pulp as basis**

Water in with wet pulp = $100 * 0.71 = 71 \text{ kg/h}$

60% of this water is being removed,

therefore water being removed is = $71 * 0.6 = 42.6 \text{ kg/h}$

From the m.b. for water:

water in with wet pulp = water removed + water in dried pulp

water in dried pulp = $71 - 42.6 = 28.4 \text{ kg/h}$



M.B. on pulp:

$$\text{Pulp in} = \text{Pulp out}$$

$$\text{Pulp in} = 100 * 0.29 = 29 \text{ kg/h}$$

$$\text{So, Pulp Out} = 29 \text{ kg/h}$$

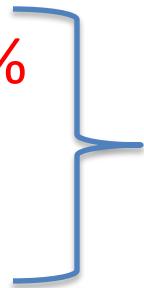
Composition of dried pulp:

$$\text{water in dried pulp} = 28.4$$

$$\text{Pulp in dried pulp} = 29$$

$$\% \text{ water} = (28.4 / 57.4) * 100 = 49.5\%$$

$$\% \text{pulp} = (29 / 57.4) * 100 = 50.5\%$$



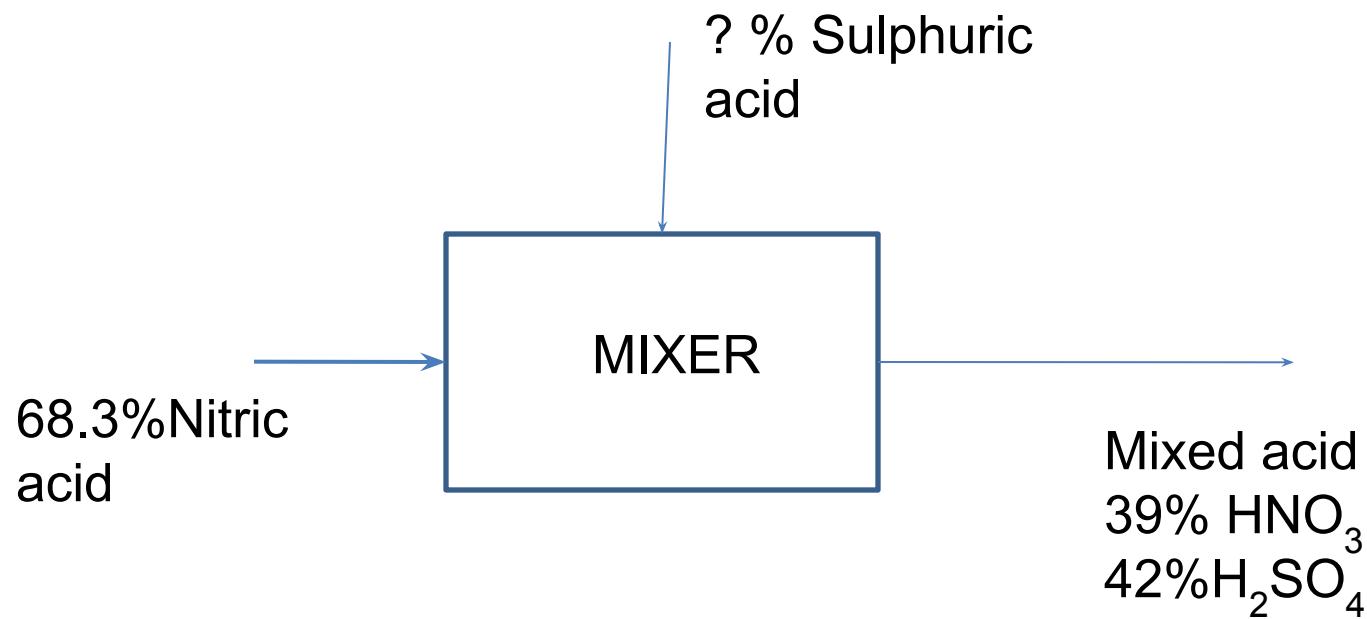
Mixing of different streams to get a desired stream (solution of simultaneous equations)

- For carrying out a reaction, it is desired to have a mixed acid containing 39% HNO_3 and 42% H_2SO_4 . For preparing this mixed acid Nitric acid of 68.3% is readily available. Calculate (a) required strength of sulphuric acid to obtain the required mixed acid (b) weight ratio of nitric acid to sulphuric acid to be mixed.

Solution Steps:

- Make a sketch, Choose a basis
- Write, m.b. for HNO_3 and H_2SO_4
- Solve these equations to get the answers





Solution

Basis: 100 kg mixed acid

It contains 39 kg HNO_3 and 42 kg H_2SO_4

Let A kg of HNO_3 and B kg of H_2SO_4 are mixed

M.B. equations:

HNO_3 balance :

$$\text{HNO}_3 \text{ in} = \text{HNO}_3 \text{ out}$$

$$A * 0.683 = 39 \quad \rightarrow \quad A = 57.1 \text{ kg}$$

H_2SO_4 balance:

$$\text{H}_2\text{SO}_4 \text{ In} = \text{H}_2\text{SO}_4 \text{ Out}$$

$$B * x_{\text{H}_2\text{SO}_4} = 42$$

H_2O balance: $A * (1 - 0.683) + B * (1 - x_{\text{H}_2\text{SO}_4}) = 19$

Solving above equations $\rightarrow B = 42.9 \text{ kg}$



- The required strength of sulphuric acid
$$=(42/42.9)*100 = 97.9\%$$
- Weight ratio of nitric acid to sulphuric acid to be mixed
$$= 57.1/42.9 = 1.331$$

