**Material Balance Calculations**

When come up with a problem that involves mass balances, it is important to transfer the given information into *flowcharts.* Flowchart drawing is a serious task:

* Use appropriate symbols for the defined and unknown variables.
* Use arrows to indicate inlet and outlet streams between the major units such as reactors and mixers.
* Minimize the number of unknown variables – by relating the variables to each other. By doing this, you will simplify your chart and make your job easier. You can proceed with the calculations right after flowchart drawing. For example, if you have a mixture consisting species A and B, the mass fractions of the species will be XA+ XB=1.0. Than you can write XB in terms of XA, as 1- XA.

Example





**Basis of Calculation**

Choosing a basis of calculation is important because in cases that total mass/moles/mass flow rates/mole flow rate are not given, you can proceed with calculations by taking 100 kg or 100 mole/h for the stream with known mass or mole fractions. Once you have done this, the unknowns desired will be obtained per 100 kg of that stream.

**Performing Mass Balances**

* If needed, take a basis of calculation.
* Label all the unknowns and given variables (pay attention to the minimization of the variables).
* Count the unknowns and set-up equations. Check if they are equal to each other. This is called the degree of freedom analysis.

**Degree of freedom analysis**

Below equation gives you an idea whether the problem can be solved or not:

#DOF = #unknowns-#independent equations

Do not immediately start doing calculations before you have an information on #DOF.

Before going through DOF analysis, it is vital to understand the meaning of independent equation. Below, some examples of some dependent and independent equations are shown.

#DOF < 0 ⟹ The number of independent equations is greater than the number of unknowns. This could be the case when unknowns were not properly labeled or some excess relations were specified between the variables. Check the independency of the equations and if there is an unknown ignored.

#DOF > 0 ⟹ The number of unknowns is greater than the number of independent equations. Don’t waste your time on solving the problem.

#DOF = 0 ⟹ you have equal number of independent equations and unknown variables.

**How to set-up independent equations and use them in DOF analysis and for solution?**

* Material balances- independent equations can be set-up for non-reacting species, atoms, and total mass.
* Energy balance that relates the energy carried by the inlet and outlet streams, energy generation and consumption.
* Additional information that gives you independent equations such as process specifications. A process specification can be mass fraction of a given stream.
* Physical laws such as ideal gas equation.
* Physical constraints such as the summation of mass or mole fraction of any stream is equal to 1.0.

One you have counted the number of independent equations that come from material balances, energy balances, process specifications, physical laws and physical constraints, then check DOF for the given problem.

Reference: Richard M. Felder, Ronald W. Rousseau, Elementary Principles of Chemical Processes, 3rdEdition.