General Procedure for Single-Unit Process Material Balance Calculations

This guide will help you confidently approach material balance problems for single-unit processes. Follow these steps carefully, and remember—attention to detail, especially with **units**, is crucial. Let's break it down step by step:

1. Choose a Basis of Calculation

Start by selecting an amount or flow rate for one of the process streams.

- If a stream's amount or flow rate is given, use it as the basis. This makes the rest of the calculations easier to scale.
- If multiple streams' amounts or flow rates are provided, use them collectively as the basis.
- If no specific amounts or flow rates are mentioned, select an arbitrary value for a stream with a known composition (e.g., 100 kg or 100 kg/h if mass fractions are known, or 100 mol or 100 mol/h if mole fractions are known). This is a practical starting point.

2. Draw a Flowchart

Visuazizing the problem is key. Draw a flowchart to map the system, fill in all the known values, and label the unknowns.

- Your flowchart is ready when you can express the mass or mass flow rate (or moles or molar flow rate) of each component in each stream using labeled variables. Variables for each process stream should include either:
    - (a) The total mass (e.g., m_1 in kg) or mass flow rate (e.g., $\dot{m}_1$ in kg/s), and the mass fractions of all components (e.g., y_{CH4} kg CH_4/kg), or
    - (b) The total moles (e.g., n_1 in kmol) or molar flow rate (e.g., $\dot{n}_1$ in kmol/s), and the mole fractions of all components (e.g., y_{CH4} kmol CH_4/kmol), or
    - (c) The mass (e.g., m_{H2} in kg H_2) or molar flow rate (e.g., n_{CO} in kmol CO/s) for each component in the stream.
- If you're given either the flow rate or component fractions for a stream, label both the total stream quantity and the component fractions. If no specific data is available for a stream, just label the individual component quantities or flow rates.
- If the problem includes relationships between variables, incorporate them into your labels. For example, if you know that the flow rate of Stream 2 is double that of Stream 1, label them n_1 and $2n_1$.

- **Be mindful of your units**—focus on mass or mole balances. Don't label volumetric quantities unless the problem explicitly asks for them.

3. Understand What Needs to Be Solved

Clearly define what the problem asks you to find, using the variables you have labeled. This helps you know which unknowns you need to solve for.

4. Pay Attention to Units!

This is a critical point: Mixing mass and mole units can lead to common mistakes, especially in exams. If a stream has mixed units (e.g., total mass flow rate but mole fractions), convert everything to either mass or moles. Moles and mass are not interchangeable, so take extra care during conversions. Getting the units right is key to solving the problem correctly!

5. Degree-of-Freedom Analysis

Now count how many unknown variables you have and identify the equations that relate them. These equations can come from mass balances, process specifications, or known relationships.

- If the number of unknowns equals the number of equations, you're ready to proceed.
- If there are more unknowns than equations, double-check that you've included all relationships and that the flowchart is fully labeled. If there are fewer equations, ensure that no important information is missing.

6. Organize Your Solution Strategy

With the correct number of unknowns and equations, write out the equations in the most efficient order. Start with simple equations that involve only one unknown, and then move on to more complex ones with multiple unknowns. This keeps the math manageable and helps you avoid errors.

7. Solve the Equations

You'll be solving all equations manually—or with your calculator! But don't worry, following the structured steps up to this point will make solving the equations straightforward. Take your time to go step by step and avoid rushing.

8. Scale the Solution

If the problem gives a stream quantity or flow rate and you've used a different basis during calculations, make sure to adjust your final results by scaling. Use the ratio of the actual stream value to your chosen basis to ensure accuracy.

9. Double-Check Your Units!

As you work through these problems, always keep an eye on the units—moles and mass are not the same. Converting between them correctly is essential to avoid mistakes, especially during exams. With practice, these steps will become second nature, and you'll feel more confident as you progress!