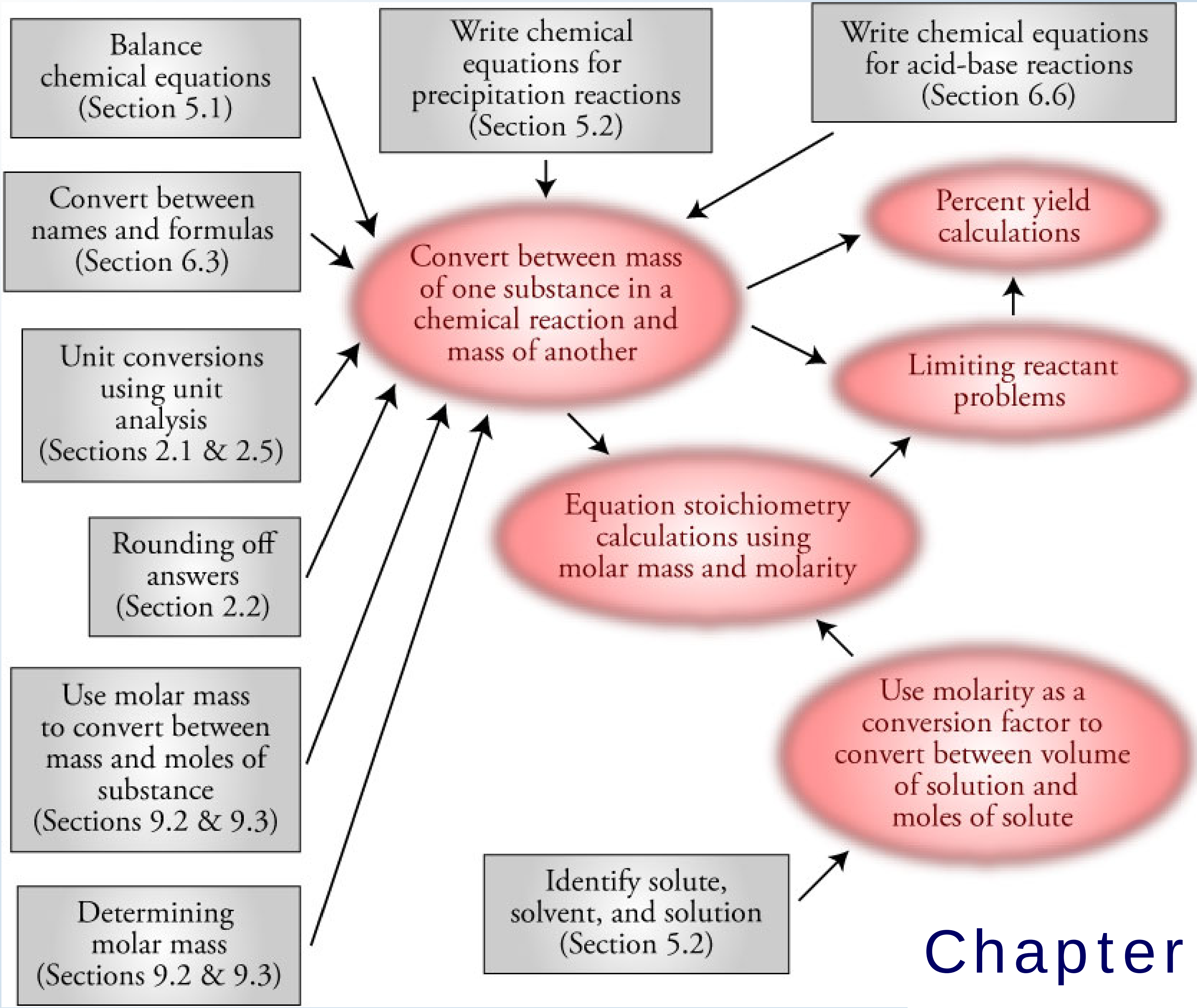

# Chapter 10

## Chemical Calculations and Chemical Equations


Balance chemical equations (Section 5.1)
Write chemical equations for precipitation reactions (Section 5.2)
Write chemical equations for acid-base reactions (Section 6.6)
Convert between names and formulas (Section 6.3)
Unit conversions using unit analysis (Sections 2.1 & 2.5)
Rounding off answers (Section 2.2)
Use molar mass to convert between mass and moles of substance (Sections 9.2 & 9.3)
Determining molar mass (Sections 9.2 & 9.3)
Convert between mass of one substance in a chemical reaction and mass of another
Percent yield calculations
Limiting reactant problems
Equation stoichiometry calculations using molar mass and molarity
Use molarity as a conversion factor to convert between volume of solution and moles of solute
Identify solute, solvent, and solution (Section 5.2)

# Chapter 10

# Equation Stoichiometry

- **Tip-off -** The calculation calls for you to convert from amount of one substance to amount of another, both of which are involved in a chemical reaction.
- **General Steps**

1. If you are not given it, write and balance the chemical equation for the reaction.

# Equation Stoichiometry

2. Start your dimensional analysis in the usual way.
3. If you are not given grams of substance 1, convert from the unit that you are given to grams. This may take one or more conversion factors.
4. Convert from grams of substance 1 to moles of substance 1.

# Equation Stoichiometry


5. Convert from moles of substance 1 to moles of substance 2 using the coefficients from the balanced equation to create the molar ratio used as a conversion factor.
6. Convert from moles of substance 2 to grams of substance 2, using its molar mass.
7. If necessary, convert from grams of 2 to the desired unit for 2. This may take one or more conversion factors.

# Equation Stoichiometry Steps

Given unit of substance 1

↓

Grams of substance 1

↓ Using molar mass of substance 1

$$\left(\frac{1 \text{ mol } 1}{(\text{formula mass}) \text{ g } 1}\right)$$

Moles of substance 1

↓ Using the mole ratio derived from the coefficients in the balanced equation

$$\left(\frac{(\text{coefficient in balanced equation for 2}) \text{ mol } 2}{(\text{coefficient in balanced equation for 1}) \text{ mol } 1}\right)$$

Moles of substance 2

↓ Using molar mass of substance 2

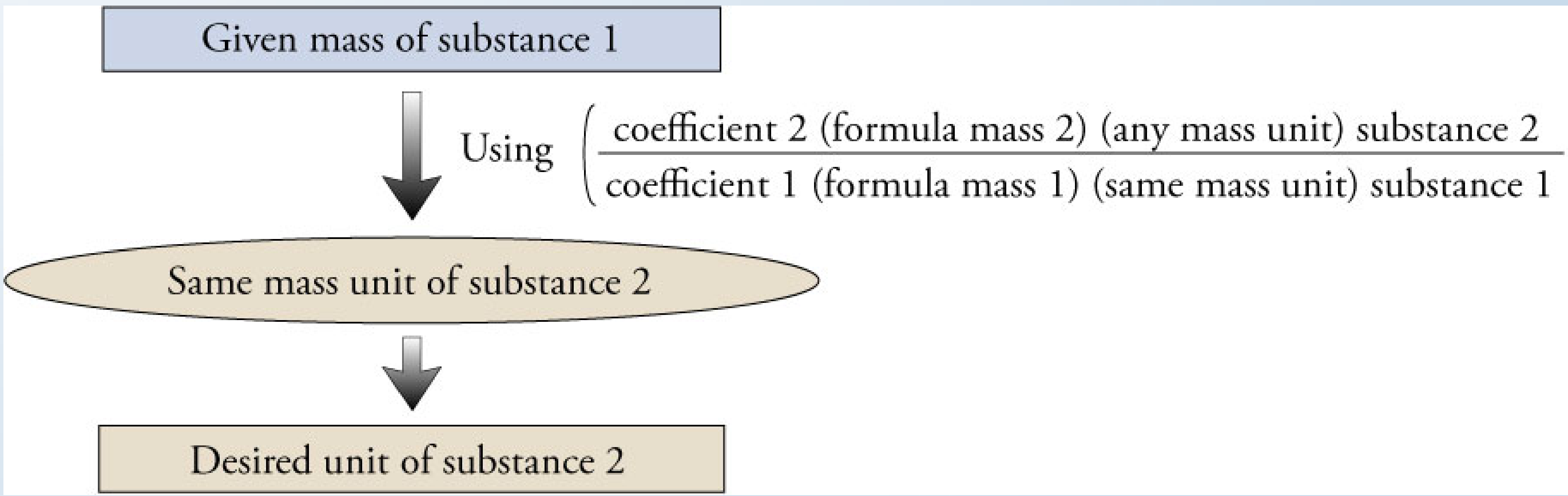
$$\left(\frac{(\text{formula mass}) \text{ g } 2}{1 \text{ mol } 2}\right)$$

Grams of substance 2

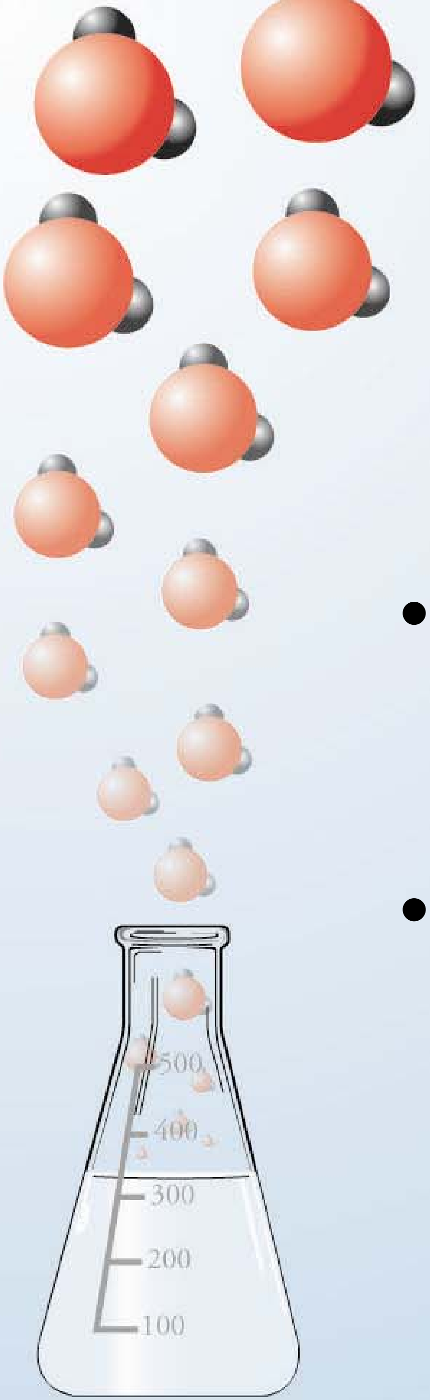
↓

Desired unit of substance 2

# Equation Stoichiometry Shortcut

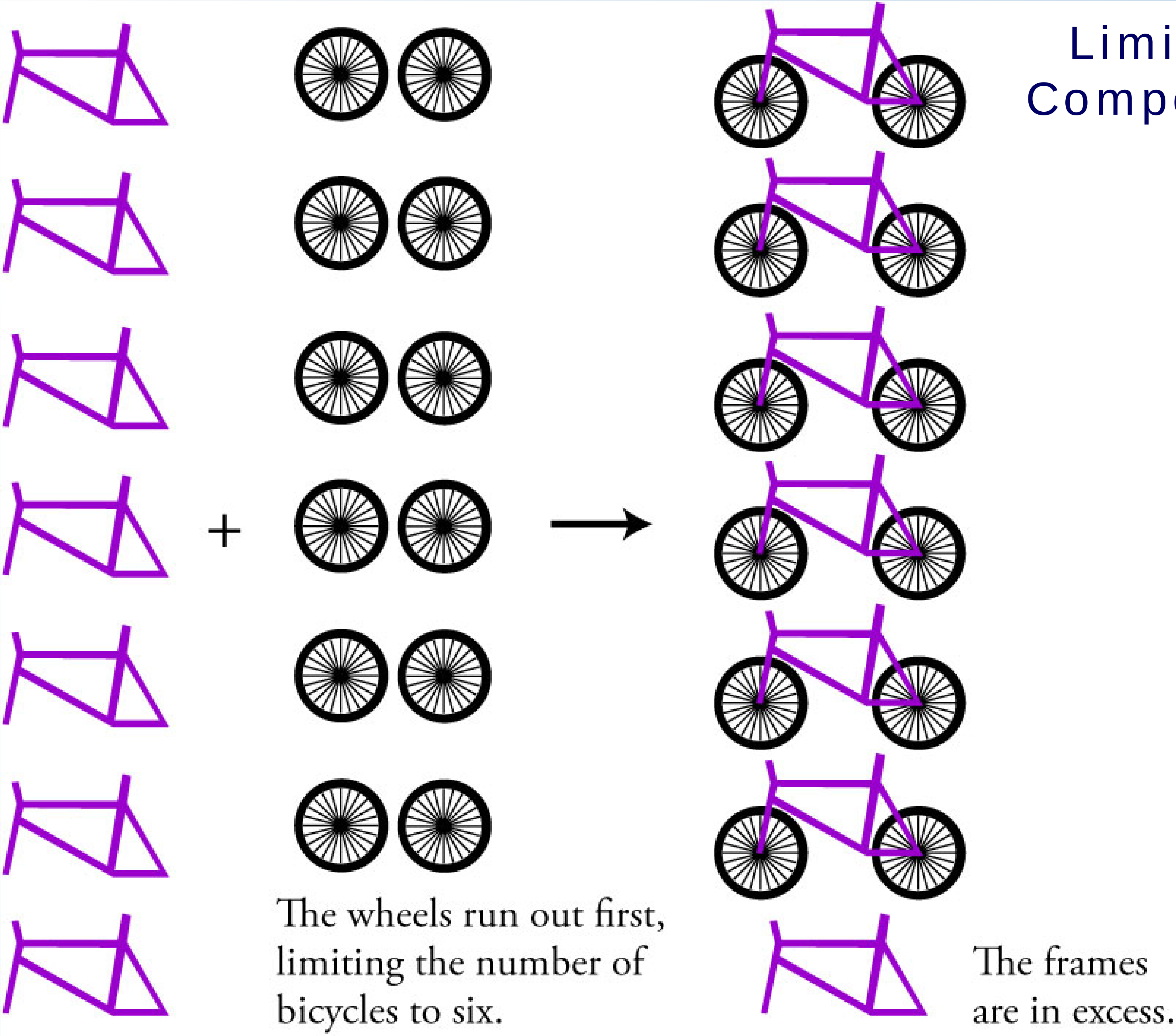


# Questions to Ask When Designing a Process for Making a Substance




- How much of each reactant should be added to the reaction vessel?
- What level of purity is desired for the final product? If the product is mixed with other substances (such as excess reactants), how will this purity be achieved?

# Limiting Component

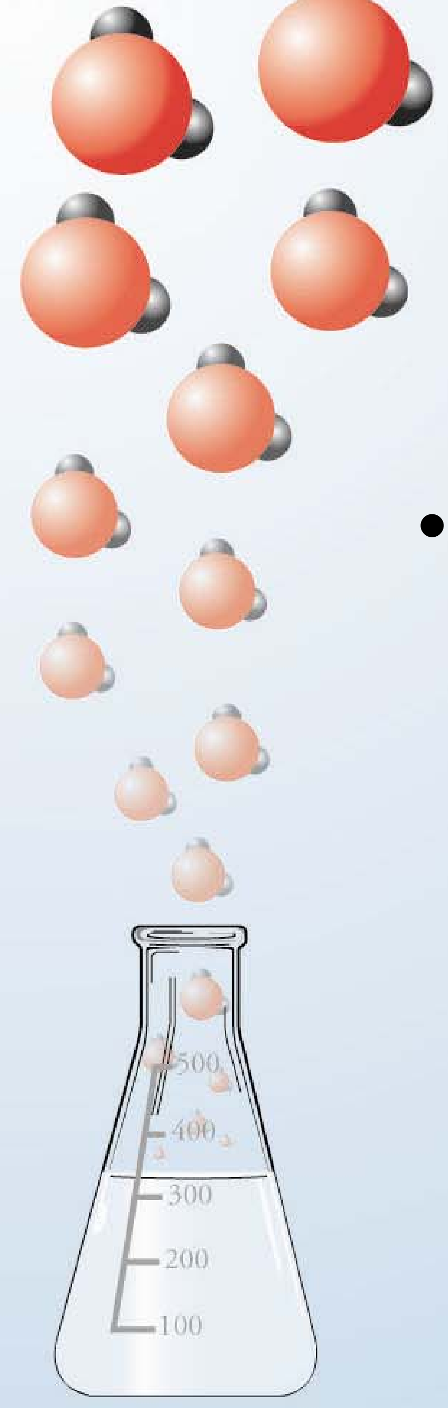


# Limiting Component (2)

$$\left(\frac{1\ \text{bicycle}}{1\ \text{frame}}\right) \quad \text{and} \quad \left(\frac{1\ \text{bicycle}}{2\ \text{wheels}}\right)$$

$$?\ \text{bicycles} = 7\ \cancel{\text{frames}}\left(\frac{1\ \text{bicycle}}{1\ \cancel{\text{frame}}}\right) = 7\ \text{bicycles}$$

$$?\ \text{bicycles} = 12\ \cancel{\text{wheels}}\left(\frac{1\ \text{bicycle}}{2\ \cancel{\text{wheels}}}\right) = 6\ \text{bicycles}$$




# Limiting Reactant

- The reactant that runs out first in a chemical reaction limits the amount of product that can form. This reactant is called the ***limiting reactant***.

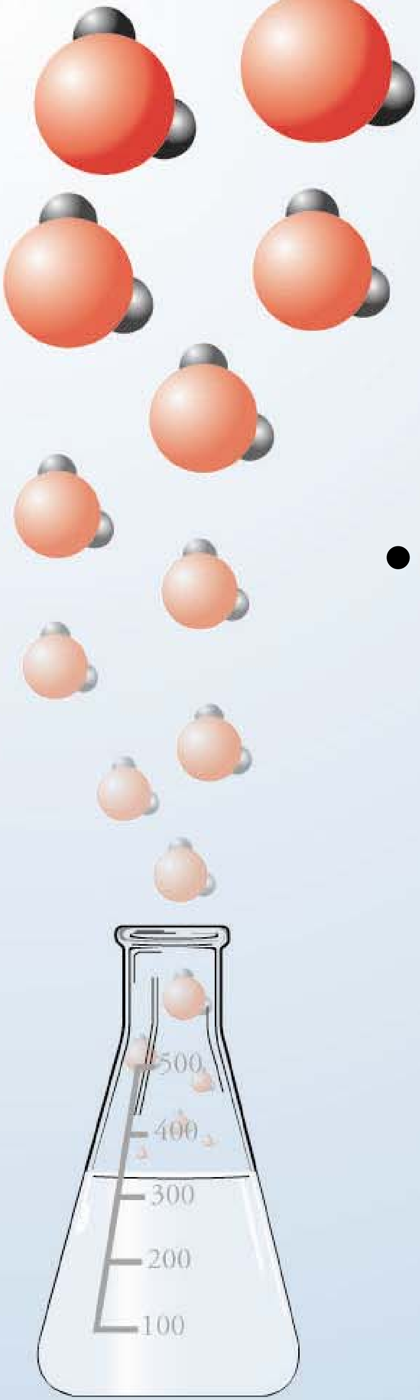
# Why substance limiting? (1)

- To ensure that one or more reactants are converted to products most completely.
  - Expense

$$P_4(s) + 5O_2(g) \rightarrow P_4O_{10}(s) + \text{excess } O_2(g)$$

  - Importance

$$SiO_2(s) + 2C(s) \rightarrow Si(l) + 2CO(g) + \text{excess } O_2(g)$$




# Why substance limiting? (2)

- Concern for excess reactant that remains
  - danger

$$P_4(s) + 5O_2(g) \rightarrow P_4O_{10}(s) + \text{excess } O_2(g)$$

  - ease of separation

$$SiO_2(s) + 2C(s) \rightarrow Si(l) + 2CO(g) + \text{excess } O_2(g)$$

# Limiting Reactant Problems

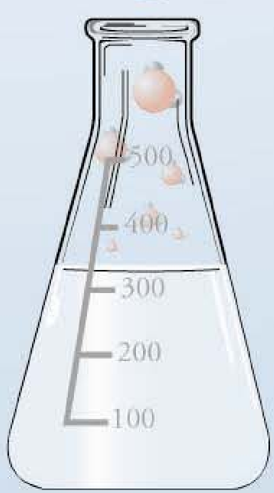

- **Tip-off -** You are given two amounts of reactants in a chemical reaction, and you are asked to calculate the maximum amount of a product that can form from the combination of the reactants.
- **General Steps**

1. Do two separate calculations of the maximum amount of product that can form from each reactant.
2. The smaller of the two values calculated in the step above is your answer. It is the maximum amount of product that can be formed from the given amounts of reactants.

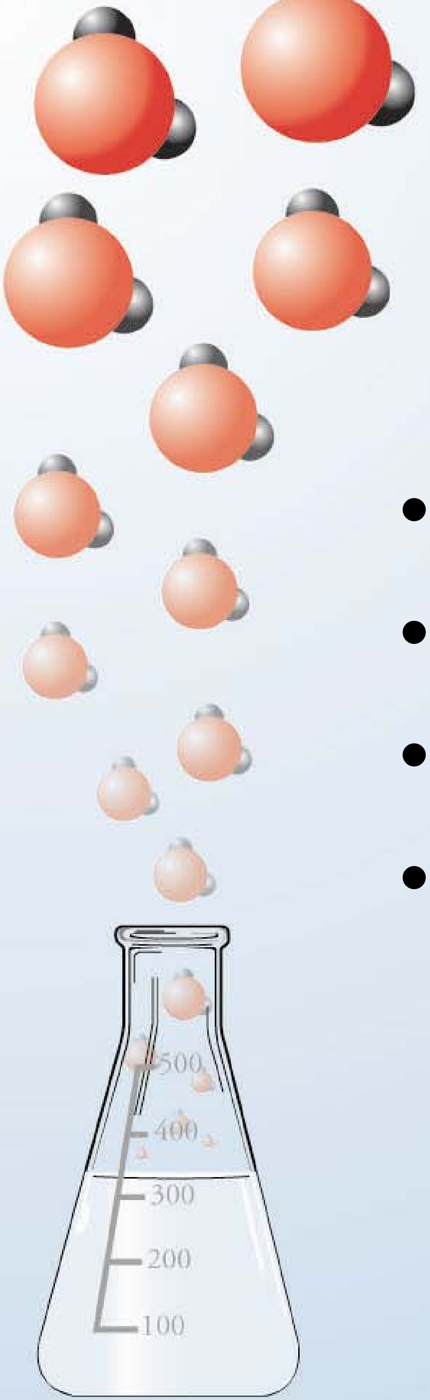
# Percent Yield

$$\text{Percent Yield} = \frac{\text{Actual Yield}}{\text{Theoretical Yield}} \times 100\%$$

- **Actual yield** is measured. It is given in the problem.
- **Theoretical yield** is the maximum yield that you calculate.

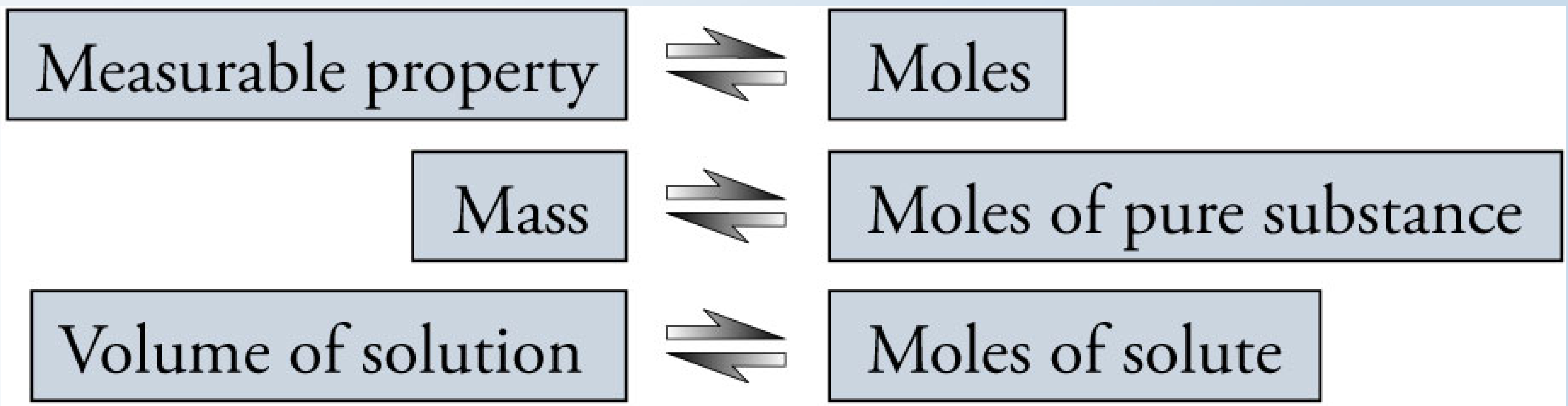


# Why not 100% Yield?




- Reversible reactions
- Side Reactions
- Slow Reactions
- Loss during separation/purification

# Conversions to Moles

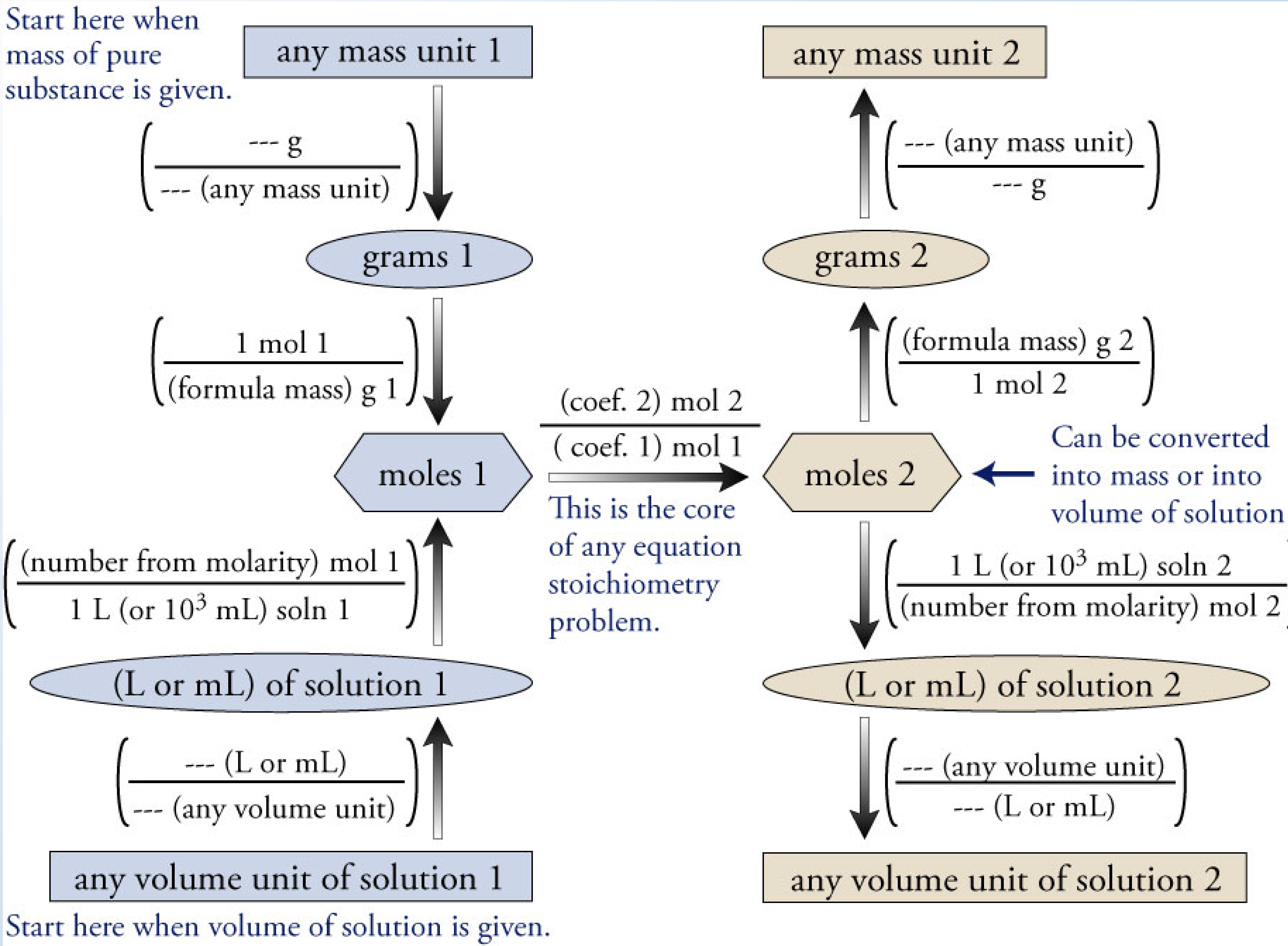


# Molarity

$$\text{Molarity} = \frac{\text{moles of solute}}{\text{liter of solution}}$$

- Converts between moles of solute and volume of solution

volume 1 solution → mol 1 → mol 2 → volume 2 solution


Start here when mass of pure substance is given.
any mass unit 1
--- g / --- (any mass unit)
grams 1
1 mol 1 / (formula mass) g 1
moles 1
(coef. 2) mol 2 / ( coef. 1) mol 1
This is the core of any equation stoichiometry problem.
(number from molarity) mol 1 / 1 L (or 10^3 mL) soln 1
(L or mL) of solution 1
--- (L or mL) / --- (any volume unit)
any volume unit of solution 1
Start here when volume of solution is given.
any mass unit 2
--- (any mass unit) / --- g
grams 2
(formula mass) g 2 / 1 mol 2
moles 2
Can be converted into mass or into volume of solution
1 L (or 10^3 mL) soln 2 / (number from molarity) mol 2
(L or mL) of solution 2
--- (any volume unit) / --- (L or mL)
any volume unit of solution 2


# Equation Stoichiometry (2)

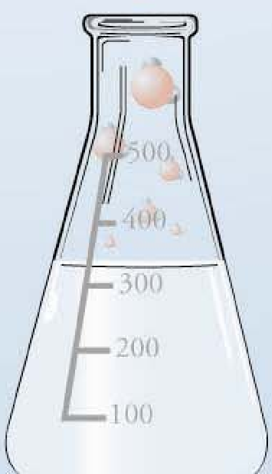
- **Tip-off -** The calculation calls for you to convert from amount of one substance to amount of another, both of which are involved in a chemical reaction.
- **General Steps**

1. If you are not given it, write and balance the chemical equation for the reaction.
2. Start your dimensional analysis in the usual way.

# Equation Stoichiometry (3)

3. Convert from the units that you are given for substance 1 to moles of substance 1.
   - For pure solids and liquids, this means converting mass to moles using the molar mass of the substance.
   - Molarity can be used to convert from volume of solution to moles of solute.

# Equation Stoichiometry (4)




4. Convert from grams of substance 1 to moles of substance 1.
5. Convert from moles of substance 2 to the desired units for substance 2.
   - For pure solids and liquids, this means converting moles to mass using the molar mass of substance 2.
   - Molarity can be used to convert from moles of solute to volume of solution.
6. Calculate your answer and report it with the correct significant figures (in scientific notation, if necessary) and unit.