Stoichiometry

Calculations for chemical formulas and chemical equations based on balanced chemical equations

The Mole

Mole

of particles in 12.00g of C-12

Avogadro's number

N_a = 6.022 x 10^{23} particles/mol

Determined experimentally

Similar to the word "dozen"

Converts molecules to manageable numbers

1 Mole of each substance

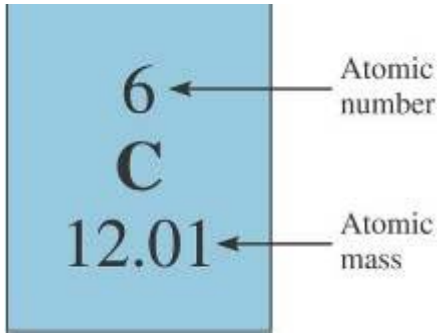
Conversions between molecular and real world values

C-12: $\frac{12.00g}{1mole} x \frac{1mole}{6.022x10^{23}atoms} = 1.993x10^{-23} g/1atom$

Molar Mass

The mass of one mole of a substance

Gives units of g/mol

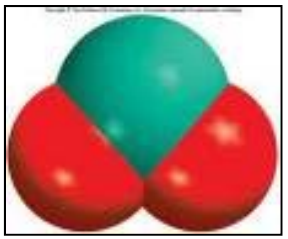


Calculations

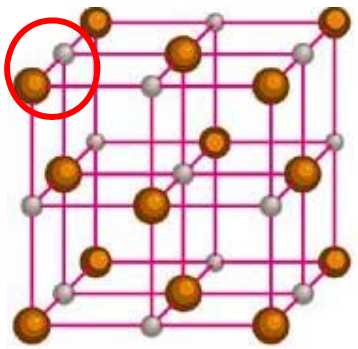
Atomic mass: Periodic table below symbol
Molecular mass: Addition of atomic masses
Formula mass: Addition of masses of ions in a salt

Examples:

1 mol C = 12.01 g/mol
1 mol SO_2 = 64.07g/mol
1 mole NaCl = 58.44g/mol



SO_2



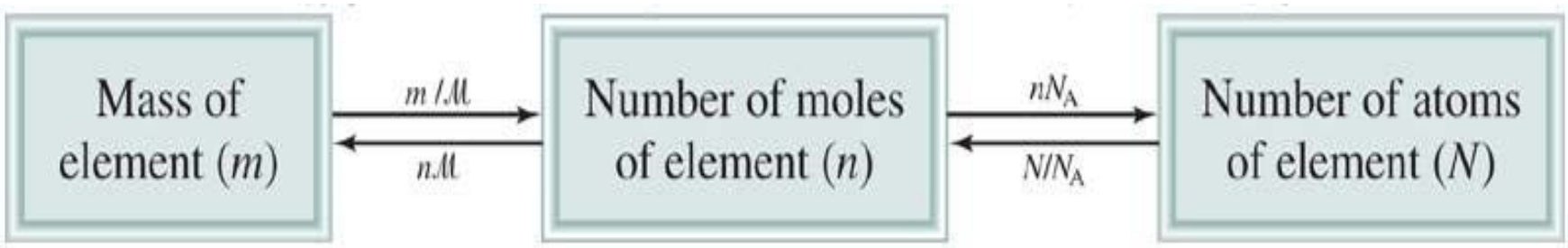
NaCl

Mole-based Calculations

Molar Mass ($\mathcal{M}$): grams/mol

Avogadro's Number N_a: 6.02×10^{23} particles/mol

$$10.0\text{g}_{\text{C}} \times \frac{1\text{mol}_{\text{C}}}{12.0\text{g}_{\text{C}}} = 0.833\text{mol}_{\text{C}} \times \frac{6.02\text{x}10^{23}\ \text{atoms}}{1\text{mol}_{\text{C}}} = 5.01\text{x}10^{23}\ \text{atoms}$$



$$10.0\text{g}_{\text{C}} = \frac{12.0\text{g}_{\text{C}}}{1\text{mol}_{\text{C}}} \times 0.833\text{mol}_{\text{C}} = \frac{1\text{mol}_{\text{C}}}{6.02\text{x}10^{23}_{\text{atoms}}} \times 5.01\text{x}10^{23}\ \text{atoms}$$

Chemical Equations

Shorthand description of a chemical reaction

Symbols & formulas represent elements & compounds

$$1H_2(g) + 2C(s) + 1Cl_2(g) \rightarrow 1C_2H_2Cl_2(g)$$

Reactants: Starting substances on left: H_2, C, Cl_2
Products: Substances formed on right: $C_2H_2Cl_2$

Values in front of symbols: Stoichiometric coefficients
Represent number of moles of that substance

+ sign: Think of it as saying "and", not mathematical adding!

Arrow: Direction of reaction ($\rightarrow$, $\leftarrow$, $\leftrightarrow$)
(g), (s), (l), (aq): chemical phase, gas, solid, liquid, aqueous

Rules For Balancing Chemical Equations

1. If an element is present in just 1 compound on each side of the equation, balancing that element *first*.

2. Balance *free* elements *last*. (O_2, C, H_2, etc.)

3. Fractions can be cleared at any time by multiplying all coefficients by a common multiplier.

4. Groupings of atoms (such as in polyatomic ions) may remain unchanged. Balance these groupings as a unit.

The number and type of all atoms must be the same on both sides of the equation!!!

Balancing Chemical Equations

Starting: $C_2H_5O_2 + O_2 \rightarrow CO_2 + H_2O$

(No coefficients!)

1 reactant/product: C $1C_2H_5O_2 + O_2 \rightarrow 2CO_2 + H_2O$

1 reactant/product: H $2C_2H_5O_2 + O_2 \rightarrow 4CO_2 + 5H_2O$

Free element: O $2C_2H_5O_2 + 9/2O_2 \rightarrow 4CO_2 + 5H_2O$

Clear Fractions $4C_2H_5O_2 + 9O_2 \rightarrow 8CO_2 + 10H_2O$

Stoichiometry:
Mole Ratios in Chemical Reactions

$$2C(s) + 1Cl_2(g) + 2H_2(g) \Rightarrow 1C_2H_4Cl_2(g)$$

2moles of carbon graphite and 1 mole of chlorine gas and 2 moles of hydrogen gas react to form 1 mole of dichloroethane

What is the mass of CO_2 produced when 10.7g of CO reacts with O_2 to form CO_2?

Write and balance the equation:

$$2CO\ (g) + 1O_2(g) \rightarrow 2CO_2(g)$$

Calculate moles of CO in 10.7g of CO

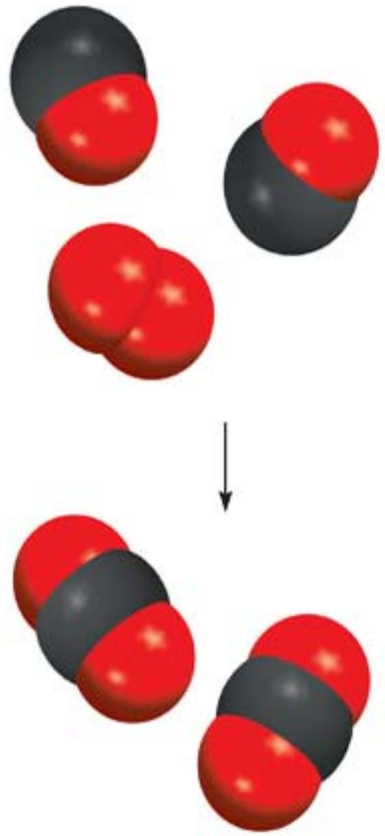
$$10.7 g_{CO} x \frac{1 mol_{CO}}{28.01 g_{CO}} = 0.382 mol_{CO}$$

Calculate moles of CO_2 from moles of CO

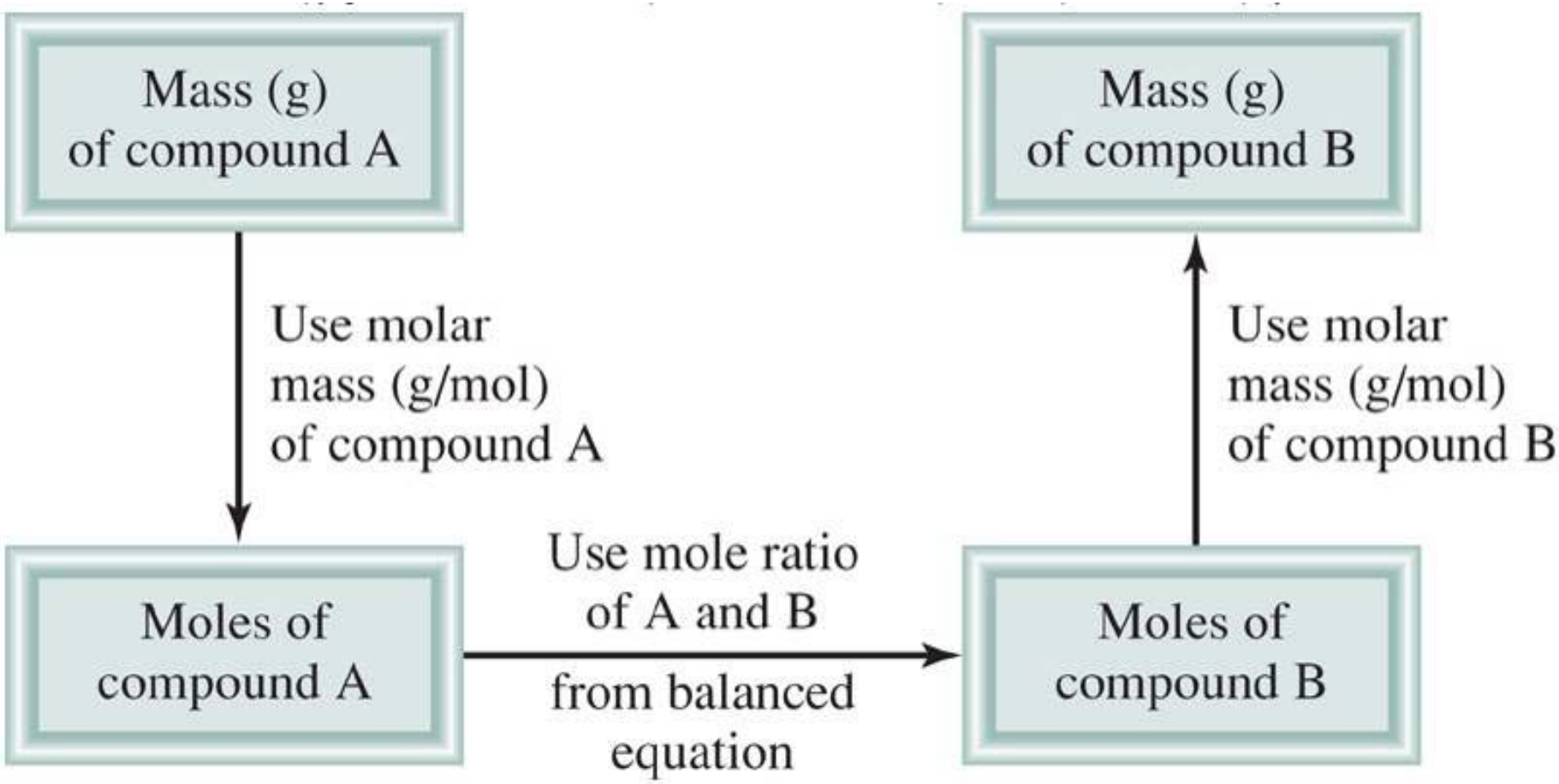
$$0.382 mol_{CO} x \frac{2 mol_{CO_2}}{2 mol_{CO}} = 0.382 mol_{CO_2}$$

Calculate grams of CO_2 from moles of CO_2

$$0.382 mol_{CO_2} x \frac{44.01 g_{CO_2}}{1 mol_{CO_2}} = 16.8 g_{CO_2}$$



Using Mole Ratios to Predict Products

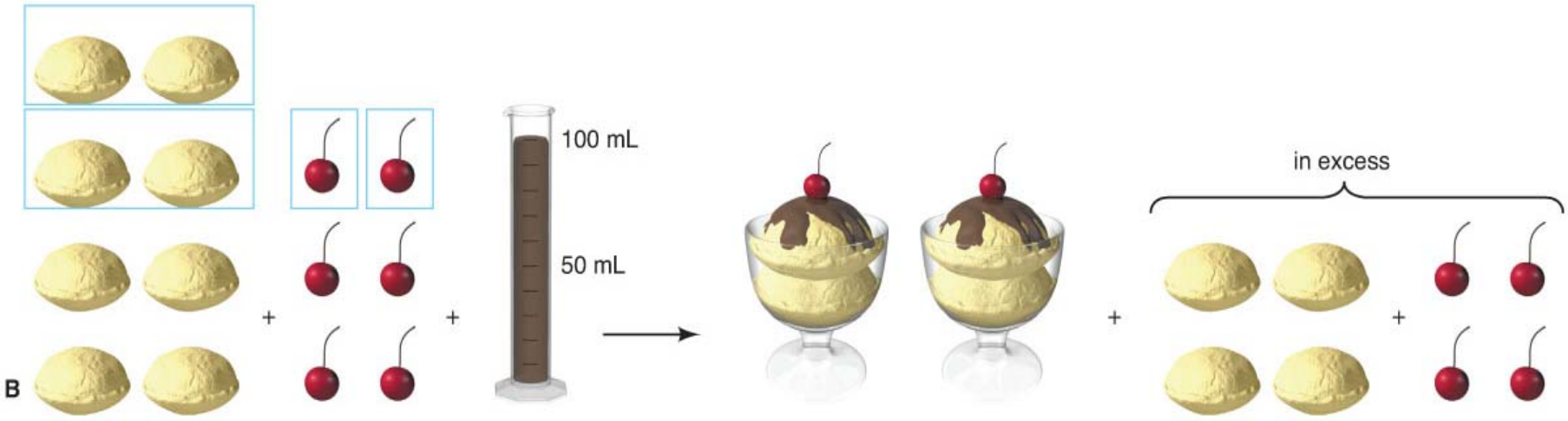


Limiting Reagents

Limiting Reagent: Reactant that runs out first!

Find by calculating the moles of 1 product from each given amount of reactant

Limiting reagent is the reactant producing the least amount of product



Yields of Chemical Reactions

Reactions rarely produce maximum product

a. Impure reactants
b. Incomplete reaction
c. All product not fully recovered
d. Side reactions may occur

Actual yield: Yield recovered during experiment

Theoretical yield: Yield calculated from limiting reagent

Percent yield = Actual yield/theoretical yield x 100

If a reaction of 17.6g NH_3 and 26.2g O_2 produce 15.2g NO, what is the percent yield?

1. Balance equation: $4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(l)$
2. Find limiting reagent

$$17.6g_{NH_3} \times \frac{1mole_{NH_3}}{17.0g_{NH_3}} \times \frac{4mol_{NO}}{4mol_{NH_3}} = 1.035mol_{NO}$$

$$26.2g_{O_2} \times \frac{1mole_{O_2}}{32.0g_{O_2}} \times \frac{4mol_{NO}}{5mol_{O_2}} = 0.655mol_{NO}$$ ⟸ Limiting Reagent

3. Calculate theoretical yield $0.6550mol_{NO} \times \frac{30.0g_{NO}}{1mole_{NO}} = 19.7g_{NO}$

4. Calculate theoretical yield $\frac{15.2g_{NO}}{19.65g_{NO}} = 77.4\%$

Experiment 2 Concept Review Topics

You should be able to do the following:

1. Understand and define the terms in bold in the experiment.
2. Reproduce any calculations required to generate your results table.
3. Calculate molar masses of any given chemical.
4. Calculate mass or moles using molar mass of any given chemical.
5. Use dimensional analysis to determine the mass of any other reactant or product that is related to a reactant in a given chemical equation.
6. Write and balance all chemical equations associated with the reactions in this experiment. Know the phase of each chemical in the equation.
7. Perform percent yield calculations.
8. Give observations associated with each reaction.