Chemical Stoichiometry

- Stoichiometry – The study of quantities of materials consumed and produced in chemical reactions.

- Objects behave as though they were all identical.
- Atoms are too small to count.
- Need average mass of the object.

- ^{12}C is the standard for atomic mass, with a mass of exactly 12 atomic mass units (u).
- The masses of all other atoms are given relative to this standard.
- Elements occur in nature as mixtures of isotopes.
- Carbon = 98.89% ^{12}C
  1.11% ^{13}C
  < 0.01% ^{14}C

Average Atomic Mass for Carbon

98.89% of 12 u + 1.11% of 13.0034 u =

exact number

(0.9889)(12 u) + (0.0111)(13.0034 u) =

12.01 u

Average Atomic Mass for Carbon

- Even though natural carbon does not contain a single atom with mass 12.01, for stoichiometric purposes, we can consider carbon to be composed of only one type of atom with a mass of 12.01.
- This enables us to count atoms of natural carbon by weighing a sample of carbon.

- The number equal to the number of carbon atoms in exactly 12 grams of pure ^{12}C.
- 1 mole of something consists of 6.022×10^{23} units of that substance (Avogadro's number).
- 1 mole C = 6.022×10^{23} C atoms = 12.01 g C

Conceptual Problem Solving

- Where are we going?
  - Read the problem and decide on the final goal.
- How do we get there?
  - Work backwards from the final goal to decide where to start.
- Reality check.
  - Does my answer make sense? Is it reasonable?

Formulas

- Empirical formula = CH
  - Simplest whole-number ratio
- Molecular formula = (empirical formula)$_n$
  [n = integer]
- Molecular formula = C_6H_6 = $(CH)_6$
  - Actual formula of the compound

- A representation of a chemical reaction:

$$\underset{\text{reactants}}{C_2H_5OH + 3O_2} \longrightarrow \underset{\text{products}}{2CO_2 + 3H_2O}$$

- Reactants are only placed on the left side of the arrow, products are only placed on the right side of the arrow.

$$C_2H_5OH + 3O_2 \longrightarrow 2CO_2 + 3H_2O$$

- The equation is balanced.
- All atoms present in the reactants are accounted for in the products.
- 1 mole of ethanol reacts with 3 moles of oxygen to produce 2 moles of carbon dioxide and 3 moles of water.

- The balanced equation represents an overall ratio of reactants and products, not what actually “happens” during a reaction.
- Use the coefficients in the balanced equation to decide the amount of each reactant that is used, and the amount of each product that is formed.

Writing and Balancing the Equation for a Chemical Reaction

1. Determine what reaction is occurring. What are the reactants, the products, and the physical states involved?
2. Write the *unbalanced* equation that summarizes the reaction described in step 1.
3. Balance the equation by inspection, starting with the most complicated molecule(s). The same number of each type of atom needs to appear on both reactant and product sides. Do NOT change the formulas of any of the reactants or products.

Notice

- The number of atoms of each type of element must be the same on both sides of a balanced equation.
- Subscripts must not be changed to balance an equation.
- A balanced equation tells us the ratio of the number of molecules which react and are produced in a chemical reaction.
- Coefficients can be fractions, although they are usually given as lowest integer multiples.

Stoichiometric Calculations

- Chemical equations can be used to relate the masses of reacting chemicals.

Calculating Masses of Reactants and Products in Reactions

1. Balance the equation for the reaction.
2. Convert the known mass of the reactant or product to moles of that substance.
3. Use the balanced equation to set up the appropriate mole ratios.
4. Use the appropriate mole ratios to calculate the number of moles of the desired reactant or product.
5. Convert from moles back to grams if required by the problem.

Limiting Reactants

- Limiting reactant – the reactant that runs out first and thus limits the amounts of products that can be formed.
- Determine which reactant is limiting to calculate correctly the amounts of products that will be formed.

A. The Concept of Limiting Reactants

- Limiting reactant mixture
  - $N_2(g) + 3H_2(g) \longrightarrow 2NH_3(g)$
  - Limiting reactant is the reactant that runs out first.
    - H_2

Limiting Reactants

- The amount of products that can form is limited by the methane.
- Methane is the limiting reactant.
- Water is in excess.

Notice

- We cannot simply add the total moles of all the reactants to decide which reactant mixture makes the most product. We must always think about how much product can be formed by using what we are given, and the ratio in the balanced equation.

Percent Yield

- An important indicator of the efficiency of a particular laboratory or industrial reaction.

$$\frac{\text{Actual yield}}{\text{Theoretical yield}} \times 100\% = \text{percent yield}$$