

Module 5: Counting Molecules and Atoms in Chemical Equations

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1 Overview

1. **Decomposition Reactions**
2. **Formation Reactions**
3. **Complete Combustion Reactions**
4. **Incomplete Combustion Reactions**
5. **Molecular Mass**
6. A **Mole** is a fixed number of objects (usually molecules or atoms).

2 Classifying Chemical Reactions

2.1 Decomposition Reactions

Definition 1 (Decomposition Reaction) *A reaction that changes a compound into its constituent elements*

- these are reasonably easy to predict
- they often (not always) involve some sort of energy input¹
- we can think of our old friend: $2\text{H}_2\text{O}(\text{l}) \longrightarrow 2\text{H}_2(\text{g}) + \text{O}_2(\text{g})$

¹A stable compound represents a *localized* low-energy state, so getting it to decompose can require some energy input.

2.2 Formation Reactions

Definition 2 (Formation Reaction) *A reaction that starts with two or more elements and produces one compound*

- these are really the opposite of decomposition reactions
- we can even write them by writing decomposition reactions backwards: $2\text{H}_2(\text{g}) + \text{O}_2(\text{g}) \longrightarrow 2\text{H}_2\text{O}(\text{l})$

2.3 Complete Combustion Reactions

Definition 3 (Complete Combustion Reaction) *A reaction in which O_2 is added to a compound containing carbon (C) and hydrogen (H), producing CO_2 and H_2O*

- this is a narrow definition of *burning*²
- this definition excludes some really exciting combustion reactions, like $2\text{Mg}(\text{s}) + \text{O}_2(\text{g}) \longrightarrow 2\text{MgO}(\text{s})$
- technically, our *formation* example is a combustion, but we’re classifying that differently for now

2.4 Incomplete Combustion Reactions

- these are combustion reactions where insufficient O_2 means the combustion produces CO or even just C instead of CO_2
- these can be pretty harmful — even dangerous (breathing CO can actually kill you) — but they can also be beneficial³
- the main take-away here is just that a combustion reaction can go one of three ways, depending on the O_2 levels in the environment

3 Atomic Mass

We’ve already talked about The Law of Definite Proportions, and how that led Dalton to formulate theories about atoms. Now we’re going to dig more into that...

- every element on the Periodic Table contains two important numbers: the *atomic number* (above the element symbol), and the *atomic mass* (below the symbol)
- remember that an element is made up of only one type of atom, so we’ll use the terms “atom” and “element” interchangeably here

²This is really a glimpse into the exciting world of *organic chemistry*.

³This is, after all, how we make charcoal.

- the atomic number tells us the number of protons (and hence the number of electrons) in the atom⁴
- the atomic mass tells us how much mass the atom has, in atomic mass units (**amu**)
- the relationship between amu and grams is: $1g = 6.02214076 \times 10^{23}amu$
- so one H atom has the mass of $1.00794amu$, the mass of $6.02214076 \times 10^{23}$ H atoms is $1.00794g$
- that means our Periodic Table can help us calculate how many atoms of any given element we have, if we know the mass of the sample:

Example 1 How many atoms are in $1.00kg$ of gold (Au)?

$$\begin{aligned}
 m_{unit} &= \frac{196.966569amu}{1atom} \\
 m_{sample} &= 1.00kg \\
 &= (1.00kg) \left(\frac{1000g}{1kg} \right) \left(\frac{6.02214076 \times 10^{23}amu}{1g} \right) \\
 &= (1.00\cancel{kg}) \left(\frac{1000\cancel{g}}{1\cancel{kg}} \right) \left(\frac{6.02214076 \times 10^{23}amu}{1\cancel{g}} \right) \\
 &= 6.02214076 \times 10^{26}amu \\
 count &= \frac{m}{m_{unit}} \\
 &= (6.02214076 \times 10^{26}amu) \left(\frac{1atom}{196.966569amu} \right) \\
 &= (6.02214076 \times 10^{26}\cancel{amu}) \left(\frac{1atom}{196.966569\cancel{amu}} \right) \\
 &= 3.0574430933 \times 10^{24}atoms \\
 &= 3.05744309 \times 10^{24}atoms
 \end{aligned} \tag{1}$$

4 Molecular Mass

5 Mole

Definition 4 (Mole) *A mole is $6.02214076 \times 10^{23}$ objects.*

- a *mole* is a number of objects
- a mole is like a pair, or a dozen, or a gross (see Table 1)

⁴More on this later

6 Homework

Review Problems: p. 131 # 1–10 (not to be turned in)

Practice Problems: p. 132 # 1–10 (due 2025-10-24)

Experiment 4.3, p. 110 (due 2025-10-10)

Take-home Exam: Quarter 1 Cumulative Exam (due 2025-10-10)

References

[Wile, 2003] Wile, J. L. (2003). *Exploring Creation with Chemistry*. Apologia Educational Ministries, Inc., 2 edition.

Name	Number
pair	2
trio	3
half-dozen	6
dozen	12
baker's dozen	13
score	20
gross	144
mole	6.022×10^{23}

Table 1: Names of collections of objects