TOPIC 6.1

Chemical Equations: Writing and Balancing

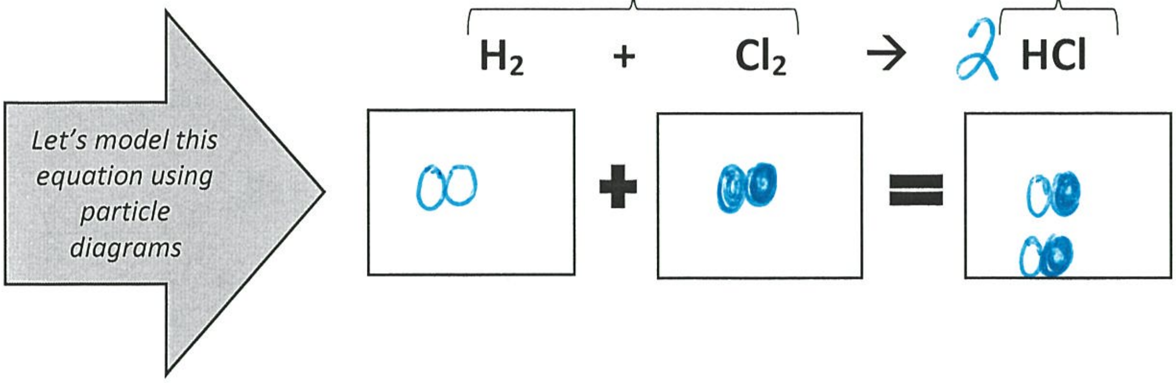
How can we represent the chemical changes that take place?

Chemical reactions are happening constantly; all around you and even inside you! How do we represent these changes taking place? The answer: writing chemical equations. Let's take a look at an example below:

Substances on LEFT side of arrow: reactants

Substances on RIGHT side of arrow: products

H_2 + Cl_2 → 2 HCl



o = H

● = Cl

Do you notice a problem here? *Find a way to fix it in the drawing, then in the equation.*
If you have a balanced budget, the amount of money that comes into your bank account is equal to the amount of money that goes out of your bank account. A **balanced equation** is similar: all that goes in must also come out. In other words:

Matter is neither created nor destroyed

Practically speaking, this means one of two things:

1. **The mass (g) that goes into a reaction is equal to the mass (g) that comes out of a reaction.**

   Example: 4Fe + $3O_2$ → $2Fe_2O_3$
   How many grams of oxygen are needed to react with 350. g of iron to produce 500 grams of iron (III) oxide?

   350 + x = 500
   x = 150 g

2. **The number of each type of element on the left side (reactants) is equal to its counterpart on the right side (products).** ★ adjust coefficients (#'s in front)

   Example: Math puzzle

   2 $KClO_3$ → 2 KCl + 3 O_2

K 1 2	K 1 2
Cl 1 2	Cl 1 2
O 3 6	O 2 6

   ✓

   Example: Treat polyatomic ions that appear on left and right as one "item" to count

   ____ Cu + 2 $Ag(NO_3)$ → ____ $Cu(NO_3)_2$ + 2 Ag

Cu 1	Cu 1
Ag 1 2	Ag 1
NO_3 1 2	NO_3 2

   ✓

TOPIC 6.2

Types of Chemical Reactions

How do we classify the different types of chemical reactions?

Chemical reactions are changes that take place. Miss Virga's one woman show, "OMG did you see...", will help us to understand different types of chemical reactions.

Act 1	Act 2
Summary: Justin & Selena get together I'll call this: dating General "algebra-style" reaction: $A + B \rightarrow C$ Chemistry calls this: synthesis *Example:* $2H_2 + O_2 \rightarrow 2H_2O$	*Summary:* Justin & Selena have a fight & leave separately I'll call this: break up General "algebra-style" reaction: $A \rightarrow B + C$ Chemistry calls this: decomposition *Example:* $2H_2O \rightarrow 2H_2 + O_2$
Act 3	**Act 4**
Summary: Katniss dumps Gale to be with Peeta I'll call this: General reaction: $A + BC \rightarrow B + AC$ Chemistry calls this: Single replacement *Example:* $Cu + Ag(NO_3) \rightarrow Ag + Cu(NO_3)$	*Summary:* Ann & Leslie BFFs Chris & Ben BFFs then couples are formed (Ann & Chris, Leslie & Ben) I'll call this: General reaction: $AB + CD \rightarrow AD + CB$ Chemistry calls this: double replacement *Example:* $NaOH + HCl \rightarrow NaCl + HOH$

TOPIC 6.3

The Mole Concept

How can we quantify such teeny tiny things as atoms?

When we balance chemical equations, the coefficients out front tell us how many **molecules** there are. Imagine I asked [you] to go get 1 molecule of water and weigh it. Is that even possible? NO.

Atomic Mass

- The mass of a single atom
- We CANNOT measure something this small, instead we use Molar Mass

Chemists use a value that can be easily seen, manipulated and measured:

One mole: unit of measurement used to count the # of particles → = 6.02×10^{23}

- It was determined based on Carbon-12
  - 12.01 grams of carbon has 6.02×10^{23} atoms of carbon
  - Known as "Avogadro's Number" (named after Amadeo Avogadro)
- Similar to dozen (12), pair (2), ream (500)

Conversions:

Atoms ↕ Moles	If atoms is given and you want to get moles: ___atoms x $\frac{1\text{ mole}}{6.02\text{x}10^{23}\text{ atoms}}$ = ___ mole	Ex #1: How many moles of Mg are in 1.25×10^{23} atoms? $1.25 \times 10^{23} \times \left(\frac{1\text{ mol}}{6.02 \times 10^{23}}\right) =$ 0.208 mol
Moles ↕ Atoms	If moles is given and you want to get atoms: ___mol x $\frac{6.02\text{x}10^{23}\text{ atoms}}{1\text{ mole}}$ = __atoms	Ex #2: How many atoms of C are in 2.0 moles? $2.0\text{ mol} \times \left(\frac{6.02 \times 10^{23}}{1\text{ mol}}\right) =$ 12×10^{23} atoms

Molar mass (Gram-Formula Mass): Mass (g) of 1 mole of a substance

use atomic masses from P.T.

Calculate the gram-formula mass of the following substances (show a numerical setup):

Na_3PO_4

Na: 3(22.99) = 68.97 +
P: 1(30.97) = 30.97 +
O: 4(16.00) = 64.00
= 163.9 g/mol

$Ca(OH)_2$

Ca: 1(40.08) = 40.08 +
O: 2(16) = 32 +
H: 2(1) = 2
74.08 g/mol

$Cr(CO_3)_3$

Cr: 1(52) = 52 +
C: 3(12.01) = 36.03 +
O: 9(16) = 144 +
232 g/mol

TOPIC 6.4

Percent Composition

How much of water is made up of oxygen? How could we find out?

Now that we know how to find the total mass of a compound we can learn how to calculate the <u>percent composition</u> of compounds also.

how many parts out of 100

Suppose you sleep 7 hours a night; what percentage of each day do you spend sleeping? How would you figure this out?

part → 7 / whole → 24 × 100

Table T

$$\% \text{ Comp.} = \frac{\text{part}}{\text{whole}} \times 100$$

Just like the length of a day can be broken up in to smaller units such as hours, we know that the mass of a compound can be broken up in to the masses of the individual elements in it.

How can we find out what percent, by mass, of the total composition of water (H_2O) is made up of hydrogen (H)?

1st → GFM : H - 2(1) = 2, O - 1(16) = 16, total 18

2nd → $\% \text{ comp} = \frac{2}{18} \times 100 = 11\%$

What percentage of water is oxygen then? 100 − 11 = 89%

Even though there are two atoms of hydrogen for every 1 atom of oxygen in water, each hydrogen atom is a lot smaller than an oxygen atom, so water is mostly oxygen.

1st calculate GFM
2nd use formula

Let's practice this. Determine the percentage composition of the following compounds:

NH_3

N: 1 (14) = 14
H: 3 (1) = 3
17 g/mol

$\% N = \frac{14}{17} \times 100 = 82\% \text{ N}$

$\% H = 18\% \text{ H}$

$KClO_3$

K: 1 (39) = 39
Cl: 1 (35.5) = 35.5
O: 3 (16) = 48
122.5 g/mol

$\% K = \frac{39}{122.5} \times 100 = 32\% \text{ K}$

$\% Cl = \frac{35.5}{122.5} \times 100 = 29\% \text{ Cl}$

$\% O = \frac{48}{122.5} \times 100 = 39\% \text{ O}$

Al_2S_3

Al: 2 (27) = 54
S: 3 (32) = 96
150 g/mol

$\% Al = \frac{54}{150} \times 100 = 36\% \text{ Al}$

$\% S = 64\% \text{ S}$

TOPIC 6.5

Mass to Mole Conversions

How do we convert grams to moles and vice versa?

Chemical "recipes" in the form of chemical equations are measured using moles of substances, since we can actually weigh out a mole of something to be used in a physical or chemical change. Therefore, converting between moles of a substance and grams of a substance is an essential skill for all lab-based science work.

If you flip over to Reference Table T, you'll see this handy equation there to guide you:

Mole Calculations	$\text{number of moles} = \dfrac{\text{given mass}}{\text{gram-formula mass}}$

Why does this equation work? Let's take a minute and break it down piece by piece.

$$\underset{\text{mol}}{\text{number of moles}} = \frac{\overset{\text{g}}{\text{given mass}}}{\underset{\text{g/mol}}{\text{gram-formula mass}}} = \frac{\cancel{g}}{\cancel{g}/\text{mol}}$$

(mol)

A typical can of Coke contains 39 grams of table sugar ($C_{12}H_{22}O_{11}$). How many moles of sugar are in a can of Coke?

GFM

C: 12(12.01) = 144.12 +
H: 22(1.01) = 22.22
O: 11(16) = 176 +
342.34

$$\text{mol} = \frac{39\text{ g}}{342.34\text{ g/mol}} = \boxed{0.11\text{ mol}}$$

The maximum daily recommended salt intake is equivalent to 0.102 moles of NaCl. How many grams of salt does this value represent?

GFM

Na: 1(22.99) +
Cl: 1(35.45)
58.44

$$0.102\text{ mol} = \frac{X}{58.44\text{ g/mol}}$$

$$\boxed{X = 5.96\text{ g}}$$

REVIEW: Most Americans consume about 13 grams of salt daily. What is their "percent error" from the maximum recommended daily value?

$$\%\text{ error} = \frac{mv - av}{av} \times 100$$

$$\frac{13 - 5.96}{5.96} \times 100 = \boxed{118\%} \text{ !!}$$

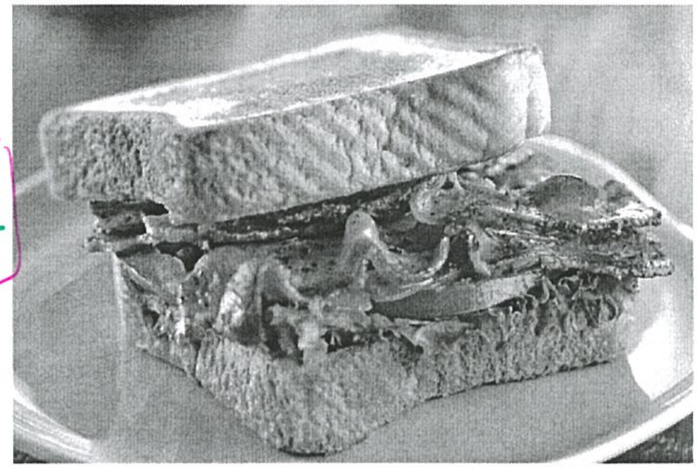
TOPIC 6.6

Mole Ratios

How can we use chemical equations to make predictions?

How do you make a BLT sandwich?

2 slices bread + 3 strips bacon + 2 slices tomato + 2 lettuce leaves → 1 BLT



A chemical equation is just a recipe for a chemical reaction. We can use the **coefficients** in a chemical equation (mole ratios) to make predictions about how much reactant is used in a chemical reaction, or how much product will be made. For instance, in our sandwich example, how many strips of bacon do you need to make 25 BLT sandwiches?

$25 \text{ BLT} \times \left(\frac{3 \text{ bacon}}{1 \text{ BLT}}\right) = 75$ bacon strips

OR

$\frac{3 \text{ bacon strips}}{x} = \frac{1 \text{ BLT}}{25 \text{ BLT}}$

$x = 75$ bacon

Alright, let's see this process with the chemical reaction that shows the formation of aluminum oxide.

$$4\ Al + 3\ O_2 \rightarrow 2\ Al_2O_3$$

Al	1 4		Al	2 4	
O	2 6		O	3 6	

How many moles of O_2 are needed to react completely with 8.0 moles of aluminum?

$8 \text{ mol Al} \times \left(\frac{3 \text{ mol } O_2}{4 \text{ mol Al}}\right) = \frac{24}{4} = 6 \text{ mol } O_2$

$\frac{4 \text{ mol Al}}{8 \text{ mol Al}} = \frac{3 \text{ mol } O_2}{x}$

$4x = 24$

$x = 6 \text{ mol } O_2$

How many moles of aluminum oxide will be produced when 2.0 moles of oxygen react completely with aluminum?

$2 \text{ mol } O_2 \times \left(\frac{2 \text{ mol } Al_2O_3}{3 \text{ mol } O_2}\right) = \frac{4}{3} = 1.3 \text{ mol } Al_2O_3$

$\frac{2 \text{ mol } Al_2O_3}{x} = \frac{3 \text{ mol } O_2}{2 \text{ mol } O_2}$

$4 = 3x$

$x = 1.3$