Chemical Reactions, Counting Atoms, and Balancing Chemical Equations.
A Chemical Reaction is...

- A process where one or more elements or compounds are changed into one or more different substances
- A process where the original substance changes into a new substance with new properties

But, are new atoms created? Are other atoms destroyed?
Law of Conservation of Mass states that...

Matter is never created or destroyed...

Therefore, the mass and types of atoms that make up the reactants must be equal to the mass and types of atoms in the products. The atoms are simply rearranged.
Reactants and Products

- Reactant: the original substance (s)
- Product: the new substance (s)

In the chemical equation, $A + B \rightarrow AB$, the **reactants** are ‘A’ and ‘B’, which are on the **left** side of the equation. The **product** is ‘AB’ and is found on the **right** side of the equation.

The arrow in the equation means ‘yields’, or ‘produces’.
How Do We Know If It Is A Chemical Reaction?

• The following observations provide evidence that a chemical reaction is taking place:
  – The temperature changes
  – A gas is produced (bubbling)
  – A precipitate forms (a solid forms from the combination of two solutions and separates out)
  – A permanent change in color

Be aware: Some physical changes produce some of the above observations. For example, food coloring in water and boiling water may look like chemical changes, but are physical changes.
A Chemical Reaction

- Adding HCl (hydrochloric acid) to zinc metal will produce bubbling and a temperature increase, two indications that a chemical change has taken place.
- The atoms are simply rearranged during the reaction.
A chemical equation, or formula equation, represents what happens in a chemical reaction.

For instance: The formula equation for the addition of zinc metal and hydrochloric acid looks like this:

$$2\text{HCl} + \text{Zn} \rightarrow \text{H}_2 + \text{ZnCl}_2$$

The arrow means ‘yields’ or ‘produces’.
Counting Atoms in Formulas

• Before you can correctly write and balance an equation, you must be able to correctly count atoms in chemical formulas.

• Let’s learn some basics...
Know Your ‘Equation’ Terms

• Coefficient – a whole number in front of the formula that represents the relative number of *moles* of the substance

• Subscript – the small number to the lower right of an atom that represents the *number of atoms* of that element in the molecule

2H₂O

Coefficient of 2 means there are 2 moles of water

Subscript of 2 means there are 2 hydrogen atoms in a molecule of water
Counting Atoms in Formulas

How many atoms are in this formula?

The subscript ‘2’ belongs to the oxygen only and does not affect the carbon atom.

3 *atoms* in this formula

1 *mole* of CO$_2$

1 *atom* of carbon

2 *atoms* of oxygen
Counting Atoms in Formulas

How many atoms are in this formula?

3 moles of CH₄

1 atom of carbon and 4 atoms of hydrogen per molecule

3CH₄

15 atoms in this formula
Counting Atoms in Formulas

How many atoms are in this formula?

1 mole of Al(OH)$_3$

(OH)$_3$ means there are three molecules of OH bonded to the atom of aluminum.

‘OH’ is in parentheses because the oxygen and hydrogen atoms are a ‘pair’.

There are 7 atoms in this formula.
Counting Atoms in Formulas

How many atoms are in this formula?

2\text{Cr}_2(\text{CO}_3)_3

(CO_3)_3 means there are three molecules of CO_3 bonded to two atoms of chromium. Count carefully!

There are 28 atoms in this formula.
How To Balance Chemical Equations

• Now that we know how to count atoms in formulas, we can begin to balance equations.
• Let’s look at a balanced equation.
Chemical Equations

2HCl + Zn $\rightarrow$ H$_2$ + ZnCl$_2$

• The chemical equation above is a balanced equation.
• The reactants are: HCl and Zn
• The products are: H$_2$ and ZnCl$_2$
• There are equal numbers and kinds of atoms in the reactants as there are in the products.
Chemical Equations

A well-written chemical equation must:

– Represent a real situation – the actual reactants must be able to react and form the products given

– Contain correct formulas for the reactants and products

– Abide by the Law of Conservation of Mass, which means that atoms are never created nor destroyed during chemical reactions

\[ 2 \text{H}_2\text{O} \rightarrow 2\text{H}_2 + \text{O}_2 \]
Chemical Equations

Balancing chemical equations is easy if you follow some rules.

– You can only add a coefficient in front of a chemical formula \(2H_2O\)

– You cannot change any subscripts, nor add any subscripts \(O_2\)

– You may not place a coefficient in the ‘middle’ of a chemical formula \(Ca2Cl\)

– You must end up with the same number and kinds of atoms on both sides of the equation when you are finished. Count atoms on both sides upon completion to check yourself. \(2AB_2 \rightarrow A_2 + 4B\)
Let’s Try To Balance An Equation...

The word equation is:

Hydrogen gas + chlorine gas $\rightarrow$ hydrogen chloride

The formula, or chemical equation is:

\[ \text{H}_2 + \text{Cl}_2 \rightarrow \text{HCl} \]

The above equation does not satisfy the requirements of a balanced equation. Let’s balance it.
Balance the Equation

Begin by counting atoms on both sides of the arrow. Remember that the number and kinds of atoms in the reactants has to equal the numbers and kinds of atoms in the products.

It will help if you divide the two sides with a line below the arrow and list the atoms.

\[ \text{H}_2 + \text{Cl}_2 \rightarrow \text{HCl} \]

- \( \text{H} - 2 \) \quad || \quad \text{H} - 1
- \( \text{Cl} - 2 \) \quad || \quad \text{Cl} - 1
Balance the Equation

\[ \text{H}_2 + \text{Cl}_2 \rightarrow 2\text{HCl} \]

You can see that it appears as if a hydrogen and an oxygen atom were lost in this reaction. That violates the Law of Conservation of Mass, so we must balance the equation by adding coefficients where necessary.

Let’s add the coefficient ‘2’ in front of the ‘HCl’.

Now let’s adjust our atom totals below the equation and check.
Balanced!

Now we have a balanced equation that satisfies the Law of Conservation of Mass.
Balance This Equation

Here’s another example:

\[ \text{Al} + \text{O}_2 \rightarrow \text{Al}_2\text{O}_3 \]

<table>
<thead>
<tr>
<th></th>
<th>\text{Al}</th>
<th>\text{O}</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>R</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

Count the number of atoms and list them under the equation. Compare each side.

You might try adding a coefficient of 2 in front of the Al to balance the aluminum atoms.

\[ 2\text{Al} + \text{O}_2 \rightarrow \text{Al}_2\text{O}_3 \]

<table>
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It’s OK if the first coefficient you try does not balance the equation.
Balance This Equation

\[ \text{2Al} + 3\text{O}_2 \rightarrow 2\text{Al}_2\text{O}_3 \]

Adjust the numbers of atoms below the equation.

How should we fix the number of oxygen atoms?

Add a coefficient of 3 in front of the \(\text{O}_2\) on the left, and a coefficient of 2 in front of the \(\text{Al}_2\text{O}_3\) on the right.
Balance This Equation

2Al + 3O₂ → 2Al₂O₃

How should we fix the number of oxygen atoms?

Adjust the numbers of atoms below the equation.

2Al – 2
3O₂ – 6
2Al₂O₃ – 4
6O – 6

Add a coefficient of 3 in front of the O₂ on the left, and a coefficient of 2 in front of the Al₂O₃ on the right.
Balance This Equation

2Al + 3O₂ → 2Al₂O₃

Al – 2  |  Al – 4
O – 6  |  O – 6

Now we still have a problem. The number of aluminum atoms do not match.

Remove the 2 in front of the Al, and add a coefficient of 4. Adjust the numbers of atoms.
Balanced!

4Al + 3O₂ → 2Al₂O₃

Al – 4  |  Al – 4
O – 6   |  O – 6

Now we have a balanced equation!
1. Which of the following are balanced equations?

a. \( \text{NaCl} \rightarrow \text{Na} + \text{Cl}_2 \)

b. \( 2\text{H}_2\text{O} \rightarrow 2\text{H}_2 + \text{O}_2 \)

c. \( 2\text{Fe(OH)}_3 + 3\text{H}_2\text{SO}_4 \rightarrow \text{Fe}_2(\text{SO}_4)_3 + 6\text{H}_2\text{O} \)

d. \( 4\text{NH}_3 + 3\text{O}_2 \rightarrow 2\text{N}_2 + 4\text{H}_2\text{O} \)
Balance the following equation:

$$\text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + \text{O}_2$$
1. Which of the following are balanced equations?

a. \( \text{NaCl} \rightarrow \text{Na} + \text{Cl}_2 \)

b. \( 2\text{H}_2\text{O} \rightarrow 2\text{H}_2 + \text{O}_2 \)

c. \( 2\text{Fe(OH)}_3 + 3\text{H}_2\text{SO}_4 \rightarrow \text{Fe}_2(\text{SO}_4)_3 + 6\text{H}_2\text{O} \)

d. \( 4\text{NH}_3 + 3\text{O}_2 \rightarrow 2\text{N}_2 + 4\text{H}_2\text{O} \)
Balance the following equation:

\[ \text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + \text{O}_2 \]

Start by adding a coefficient of 6 in front of the ‘\text{CO}_2’ and recount the atoms; add a coefficient of 6 in front of the ‘\text{H}_2\text{O}’ and recount; finish by adding a ‘6’ in front of the ‘\text{O}_2’ and check.

\[ 6\text{CO}_2 + 6\text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \]