# BalancingChemicalEquations

## AChemicalEquation:

- is a representation of a chemical reaction in terms of chemical formulas

Example:

1. WordDescriptionofaChemicalReaction
   When methane gas ($CH_4$) burns in the presence of oxygen gas, it produces carbon dioxide gas and water vapor.
2. WordEquation
   - distinguishes between the starting substances (**REACTANTS**) and the substances that result from the chemical reaction (**PRODUCTS**)
   - indicates the chemical change with an arrow, referred to a the "**YIELD**" sign ( ⟶ )

**REACTANTS** —**YIELD**→ **PRODUCTS**

Methane gas + Oxygen Gas —Yield→ Carbon Dioxide gas + Water Vapor

3. UnbalancedChemicalEquation

- represents Reactants and Products with correct chemical formulas
- indicates the physical state (phase designation) of all substances involved:
  - "s" for solid
  - 'l" for liquid
  - "g" for gas
  - "aq" for "dissolved in water (aqueous solution)
- does not attempt to account for the number of atoms involved in the reaction. yields

$CH_4(g) + O_2(g) \longrightarrow CO_2(g) + H_2O(l)$

(recall that oxygen gas is made of diatomic molecules)

NOTE:

$CH_4(g) + O_2(g) \longrightarrow CO_2(g) + H_2O(l)$

**4 H atoms ≠ 2 H atoms**

**2 O atoms ≠ 3 O atoms**

This equation is not in agreement with one of the postulates of Dalton's Atomic Theory:

A Chemical Reaction consists of the **REARRANGEM ENT OF ATOM S** present in the reacting substances.

**ATOMS ARE NEITHER CREATED, NOR DESTROYED IN A CHEMICAL REACTION.**

4. BalancedChemicalEquation

- the number of atoms of each element are equal on both sides of the arrow
- uses "**coefficients**" to ensure that the "equation is balanced"
  - coefficients – are the **smallest set of whole numbers** placed in front of the formulas in order to balance the equation.

$$CH_4(g) + O_2(g) \longrightarrow CO_2(g) + H_2O(l)$$

Tobalance:

First:

- check number of atoms of each element on both sides of the arrow

| | | | |
|---|---|---|---|
| 1 C | → | 1 C | balanced |
| **4 H** | → | **2 H** | **not balanced** |
| **2 O** | → | **3 O** | **not balanced** |

Second:

- balance first the atoms for elements that occur in only one substance on each side of equation.

**?** $CH_4(g) + O_2(g) \longrightarrow CO_2(g) + $ **?** $H_2O(l)$

**1** $CH_4(g) + O_2(g) \longrightarrow CO_2(g) + $ **2** $H_2O(l)$

usually ommited

H is now balanced (4 H atoms on both side of the equation)

Third:

Balance all other atoms:

$CH_4(g)$ + ? $O_2(g)$ ⟶ ? $CO_2(g)$ + 2 $H_2O(l)$

2 O atoms 2 O atoms

2 O atoms 4 O atoms

$CH_4(g)$ + 2 $O_2(g)$ ⟶ $CO_2(g)$ + 2 $H_2O(l)$

4 O atoms 4 O atoms

The equation is now balanced:

**$CH_4(g)$ + 2 $O_2(g)$ ⟶ $CO_2(g)$ + 2 $H_2O(l)$**

Examples:

1. Propane gas ($C_3H_8$) burns in the presence of oxygen and produces carbon dioxide gas and water vapor.

(A) WordEquation

propane gas + oxygen gas ⟶ carbon dioxide gas + water vapor

(B) UnbalancedChemicalEquation(include State Designations)

$C_3H_8(g) + O_2(g) \longrightarrow CO_2(g) + H_2O(g)$

(C) BalancedChemicalEquation

$C_3H_8(g) + O_2(g) \longrightarrow CO_2(g) + H_2O(g)$

3 C — 1 C

8 H — 2 H

2 O — 2 O — 1 O

First: Balance C (occurs in only one substance):

$\mathbf{C_3}H_8(g) + O_2(g) \longrightarrow \mathbf{?}\ CO_2(g) + H_2O(g)$

$\mathbf{C_3}H_8(g) + O_2(g) \longrightarrow \mathbf{3}\ CO_2(g) + H_2O(g)$

Second: Balance H (occurs in only one substance):

$C_3\mathbf{H_8}(g) + O_2(g) \longrightarrow 3\ CO_2(g) + \mathbf{?}\ \mathbf{H_2}O(g)$

$C_3\mathbf{H_8}(g) + O_2(g) \longrightarrow 3\ CO_2(g) + \mathbf{4}\ \mathbf{H_2}O(g)$

Third: Balance O (occurs in more than one substance on right hand side):

$C_3H_8(g) + ?\ O_2(g) \longrightarrow 3\ CO_2(g) + 4\ H_2O(g)$

6 O 4 O

2O 10 O

$C_3H_8(g) + 5\ O_2(g) \longrightarrow 3\ CO_2(g) + 4\ H_2O(g)$

The Equation is now balanced:

$$C_3H_8(g) + 5\ O_2(g) \longrightarrow 3\ CO_2(g) + 4\ H_2O(g)$$

2. Ethane gas ($C_2H_6$) burns in the presence of oxygen and produces carbon dioxide gas and water vapor.

(A) WordEquation

ethane gas + oxygen gas ⟶ carbon dioxide gas + water vapor

(B) UnbalancedChemicalEquation(include State Designations)

$C_2H_6(g) + O_2(g) \longrightarrow CO_2(g) + H_2O(g)$

(C) BalancedChemicalEquation

$C_2H_6(g) + O_2(g) \longrightarrow CO_2(g) + H_2O(g)$

2 C 1 C

6 H 2 H

2 O 2 O 1 O

First: Balance C (occurs in only one substance):

$\mathbf{C_2}H_6(g) + O_2(g) \longrightarrow \mathbf{?}\ CO_2(g) + H_2O(g)$

$\mathbf{C_2}H_6(g) + O_2(g) \longrightarrow \mathbf{2}\ CO_2(g) + H_2O(g)$

Second: Balance H (occurs in only one substance):

$C_2\mathbf{H_6}(g) + O_2(g) \longrightarrow 2\ CO_2(g) + \mathbf{?}\ \mathbf{H_2}O(g)$

$C_2\mathbf{H_6}(g) + O_2(g) \longrightarrow 2\ CO_2(g) + \mathbf{3}\ \mathbf{H_2}O(g)$

Third: Balance O (occurs in more than one substance on right hand side):

$C_2H_6(g) + ?\ O_2(g) \longrightarrow 2\ CO_2(g) + 3\ H_2O(g)$

4 O + 3 O = 7 O

2O

$C_2H_6(g) + 7/2\ O_2(g) \longrightarrow 2\ CO_2(g) + 3\ H_2O(g)$

7 O = 7 O

NOTE: The equation is balanced, but it uses a fractional coefficient (3/2)
- while this is mathematically correct, the fractional coefficient is not consistent with the chemical reality (half molecules do not exist)

Fourth: To remove the fractional coefficient, the whole equation (all the coefficients) are multiplied by 2:

$1\ C_2H_6(g) + 7/2\ O_2(g) \longrightarrow 2\ CO_2(g) + 3\ H_2O(g)$ | X 2

$2\ C_2H_6(g) + 7\ O_2(g) \longrightarrow 4\ CO_2(g) + 6\ H_2O(g)$

| | | | | |
|---|---|---|---|---|
| 4 C | = | 4C | | |
| 12 H | = | | | 12 H |
| 14 O | = | 8 O | + | 6 O |

Balanced Chemical Equation:

$2\ C_2H_6(g) + 7\ O_2(g) \longrightarrow 4\ CO_2(g) + 6\ H_2O(g)$

3. An aqueous solution of iron (III) chloride reacts with an aqueous solution of sodium hydroxide and forms solid iron (III) hydroxide and an aqueous solution of sodium chloride.

Write a balanced chemical equation that illustrates this chemical reaction.

(A) <u>WordEquation</u>

iron(III)chloride (aq) + sodium hydroxide (aq) ⟶ iron(III)hydroxide + sodium chloride(aq)

(B) <u>UnbalancedChemicalEquation</u>

| 3+ 1- | 1+ 1- | 3+ 1- | 1+ 1- |
|---|---|---|---|
| $FeCl_3(aq)$ | + $NaOH(aq)$ ⟶ | $Fe(OH)_3(s)$ | + $NaCl(aq)$ |

NOTE: Make absolutely sure that all formulas are correctly written before you go to the next step (consider the names given and the charges of ions)

(C) <u>BalancedChemicalEquation</u>

| | | | |
|---|---|---|---|
| $FeCl_3(aq)$ | + $NaOH(aq)$ ⟶ | $Fe(OH)_3(s)$ | + $NaCl(aq)$ |
| 3 Cl | | | 1 Cl |
| 1 Fe | | 1 Fe | |
| | 1 Na | | 1 Na |
| | 1 OH | 3 OH | |

(since the $OH^-$ ion does not change, it may be balanced as a group)

First: Balance Cl:

$FeCl_3(aq) + NaOH(aq) \longrightarrow Fe(OH)_3(s) + ?\,NaCl(aq)$

$FeCl_3(aq) + NaOH(aq) \longrightarrow Fe(OH)_3(s) + 3\,NaCl(aq)$

Second: Balance Na:

$FeCl_3(aq) + ?\,NaOH(aq) \longrightarrow Fe(OH)_3(s) + 3\,NaCl(aq)$

$FeCl_3(aq) + 3\,NaOH(aq) \longrightarrow Fe(OH)_3(s) + 3\,NaCl(aq)$

Third: Check all other atoms and groups:

$FeCl_3(aq) + 3\,NaOH(aq) \longrightarrow Fe(OH)_3(s) + 3\,NaCl(aq)$

| | | | | |
|---|---|---|---|---|
| 1 Fe | | = | 1 Fe | |
| 3 Cl | | = | | 3 Cl |
| | 3 Na | = | | 3 Na |
| | 3 OH | = | 3 OH | |

The equation is correctly balanced:

**$FeCl_3(aq) + 3\,NaOH(aq) \longrightarrow Fe(OH)_3(s) + 3\,NaCl(aq)$**