Writing and Balancing Chemical Equations

Coefficients versus Subscripts:

Coefficients:

- Placed in front of the formulas to indicate how many moles of that substance is used/produced.
- These can be changed in order to balance the chemical equation.

Subscripts:

- Part of the chemical formula of the reactants/product.
- These cannot be changed when balancing the chemical equation, or it would change the identity of the substance.

Common Types of Reactants and Products:

- Pure substance
  - A solid Metal
- Ionic Compounds:
  - Metal cation with Non-Metal anion (ends in *-ide*)
  - Metal cation with Negative Polyatomic Ion
  - Transition Metal with Non-Metal anion (may have a Roman Numeral; ends in *-ide*)
  - Transition Metal with Negative Polyatomic Ion (may have a Roman Numeral)
- Covalent Compounds:
  - Non-Metal with Non-Metal (includes prefixes)
  - Hydrocarbon (ends in *-ane*, *-ene*, or *-yne*)
- Diatomic Molecule:
  - H_2, N_2, F_2, O_2, I_2, Cl_2, Br_2 (all gases)
- Acid:
  - Starts with H (ends with *acid*)
- Base:
  - Ends with OH (ends with *hydroxide*)

Steps in Writing and Balancing a Chemical Equation:

1. Write the unbalanced reaction:
    a. Write the formulas of all the reactants and products
    b. Leave space before each compound (for the coefficients).
    c. Write plus signs between each reactant and product.
    d. Write an arrow between the last reactant and the first product.
2. List each element in the Reactants under the equation on the left. Write these in the same order under the Products on the right.
    a. If a Polyatomic Ion remains the intact from the Reactants to the Products, you can write the entire Polyatomic Ion, rather than breaking it into its elements.
3. Using the subscripts, count how many atoms of each element you have on the Reactant side and record these in the list under Reactants. Repeat on the Product side.
    a. Make sure to count the total of each element, even if it is spread over multiple compounds (especially true with C, H, and O).
    b. The equation is already balanced if the number of atoms on each side is the same.
4. Identify the most complex substance that does not have H or O in it. Adjust the coefficients (not the subscripts!) to obtain the same number of atoms of this element on both sides. Cross off the corresponding numbers in the list and write the new amounts next to them.
    a. Coefficients must be whole numbers
    b. A coefficient influences the number of every element in the compound
5. Balance Polyatomic Ions (if present).
6. Balance remaining compounds with H.
7. Balance remaining compounds with O.
8. Count the number of atoms of each kind on both sides of the equation to ensure the chemical equation is balance.

Easier Examples:

Aqueous solutions of lead (II) nitrate and sodium chloride are mixed to form an aqueous solution of sodium nitrate and a solid precipitate of lead (II) chloride.

_____$Pb(NO_3)_{2\ (aq)}$ + _____$NaCl_{\ (aq)}$ → _____$NaNO_{3\ (aq)}$ + _____$PbCl_{2\ (s)}$

Pb	1	Pb	1
NO_3	2	NO_3	1
Na	1	Na	1
Cl	1	Cl	2

Solid magnesium and aqueous hydrochloric acid react to produce aqueous magnesium chloride and hydrogen gas.

___$Mg_{(s)}$ + ___$HCl_{\ (aq)}$ → ___$MgCl_{2\ (aq)}$ + ___$H_{2\ (g)}$

Mg	1	Mg	1
H	1	H	2
Cl	1	Cl	2

The combustion of heptane with oxygen to form carbon dioxide and water.

___$C_7H_{16\ (aq)}$ + ___$O_{2\ (g)}$ → ___$CO_{2\ (g)}$ + ___$H_2O_{\ (aq)}$

C	7	C	1
H	16	H	2
O	2	O	2 + 1 = 3

Troubleshooting: Reactions with O in multiple compounds, often prove difficult to balance.

Method 1: Double the Coefficients

If you balance all other elements and find that a coefficient of fraction with ½ would balance the O's, double all current coefficients. Then finish balancing.

Method 2: Increase by One

If you balance all other elements and find that you have an odd number of O's on one side and an even number of O's on the other side, increase the coefficient of one compound that does not have an O by one. Then finish balancing.

Challenging Examples:

Solid iron (II) disulfide reacts with oxygen gas to form solid iron (III) oxide and sulfur dioxide gas.

___$FeS_{2\ (s)}$ + ___$O_{2\ (g)}$ → ___$Fe_2O_{3\ (s)}$ + ___$SO_{2\ (g)}$

Fe	1	Fe	2
S	2	S	1
O	2	O	3 + 2 = 5

The combustion of butane with oxygen gas to form carbon dioxide and water.

___$C_4H_{10\ (aq)}$ + ___$O_{2\ (g)}$ → ___$CO_{2\ (g)}$ + ___$H_2O_{\ (aq)}$

C	4	C	1
H	10	H	2
O	2	O	2 + 1 = 3