Balancing Chemical Equations

Chemical equations of a reaction illustrate what is made (product) when certain ingredients (reactants) are combined. Like a cooking recipe, where a certain amount of ingredients are required to produce a set amount of food, chemical reactions require a certain of reactants to get desired quantity of product. The relationship of reactants to product is shown through a chemical equation.

To be useful, the chemical equations must account for each atom used to make a product. Therefore a balanced chemical equation has an equal number of specific atoms on both sides of the equation.

E.g. $H_2 + O_2 \longrightarrow H_2O$

In order for this reaction for the formation of water from its elements to be balanced, the number of hydrogen and oxygen atoms on the reactants side must equal the number of hydrogen and oxygen atoms on the product side. In the equation, there is one more 1 more O atom on the reactants side than the products side. To make the number of atoms equal, a ½ is put in front of the O_2 to get the balanced equation.

$$H_2 + \frac{1}{2} O_2 \longrightarrow H_2O$$

The ½ in front of O_2 is a coefficient which shows how many units of O_2 are required in the reaction.

Note: It is also to put 2 in front of H_2 and H_2O instead of a ½ in front of O_2 to achieve the balanced equation.

$$2H_2 + O_2 \longrightarrow 2\,H_2O$$

Rules

Balancing equations is a bit of an art but there are a few guidelines that can help.

1. Write the equation with the reactant units or pieces on the left and the product units on the right.

E.g. $Zn_{(s)} + HCl_{(aq)} \longrightarrow ZnCl_{2(aq)} + H_{2(g)}$

2. Balance the atoms that only occur in on molecule on each side by choosing your appropriate coefficient.

3. Balance atoms, one kind at a time, don't jump all over the place.

4. Balance atoms which are in their elemental form last (O_2, H_2, Cu, P_4, etc.)

E.g. $Zn_{(s)} + 2HCl_{(aq)} \longrightarrow ZnCl_{2(aq)} + H_{2(g)}$

5. Never change what the reactants and the products are just to balance an equation.

NO! $Zn_{(s)} + HCl_{(aq)} \longrightarrow ZnCl_{(aq)} + H_{2(g)}$ **NO!**

6. Always check to make sure that the number of every kind of atom is the same on both sides of the equation.

Example
Balance the following equation

$$Fe_{(s)} + H_2O_{(l)} \longrightarrow Fe_2O_{3(s)} + H_{2(g)}$$

Check atom	Left side	Right side
Fe		
H		
O		

Thus, a balanced chemical equation must represent the facts. Three factors must be considered in writing a balanced equation ...
1) the equation must represent the facts.
2) the equation must include the symbols and formulas of all the elements and compounds that are used as reactants and formed as products.
3) Law of Conservation of Mass and Energy must be satisfied.

Useful symbols used in writing equations:

+	Used to separate reactants from products
$\longrightarrow$	yields or "to produce"
$\rightleftharpoons$	A reversible reaction
(s), (l), (g)	Indicates state of matter or phases
(aq)	Indicates solution in water, the solvent is water
(g)	Indicates a gas is released in a reaction
Δ	Indicates heat supplied or released, exothermic, or an endothermic reaction
$\xrightarrow{Pt,\ MnO_2}$	Material over an arrow means a catalyst
↓	Indicates a precipitate is formed

Practice Exercises: Balance the following equations ...

1. ___$H_{2(g)}$ + ____$Br_{2(g)}$ $\longrightarrow$ ____ $HBr_{(g)}$
2. ____$Na_{(s)}$ + ____$Cl_{2(g)}$ $\longrightarrow$ ____ $NaCl_{(s)}$
3. ____$Na_{(s)}$ + ____$O_{2(g)}$ $\longrightarrow$ ____$Na_{2(s)}$
4. ____$Fe_{(s)}$ + ____$O_{2(g)}$ $\longrightarrow$ ____Fe_2O
5. ____Al + ____Cl_2 $\longrightarrow$ ____$AlCl_3$
6. ____ $KClO_3$ $\longrightarrow$ ____KCl + ____O_2
7. ____CH_3 + ____ O_2 $\longrightarrow$ ____CO_2 + ____H_2O
8. ____NH_3 + ____Cl_2 ———— ____NH_4Cl + ____N_2
9. ____C_6H_6 + ____ O_2 $\longrightarrow$ ____CO_2 + ____

Remember:
1) balance the metals first
2) balance the polyatomic ions second
3) next balance the nonmetals except oxygen and hydrogen
4) balance the oxygen and hydrogen last!

Solubility of Common Inorganic Compounds in Water

(Low solubility = "insoluble")

Negative Ions (anions)	+	Positive Ions (cations)	_	Compounds with the solubility
Essentially all		Alkali ions (Li^+, Na^+, K^+, Rb^+, Cs^+, Fr^+)		Soluble
Essentially all		Hydrogen ions [$H^+_{(aq)}$]		Soluble (ACIDS)
Essentially all		Ammonium ions (NH_4^+)		Soluble
Nitrate, NO_3^-		Essentially all		Soluble
Acetate, CH_3COO^-		Essentially all		Soluble
Chloride, Cl^- Bromide, Br^- Iodide, I^-		Ag^+, Pb^+, Hg^{2+}, Cu^+, Ti^+		Low solubility
		All others		Soluble
Sulfate, SO_4^{2-}		Ca^{2+}, Sr^{2+}, Ba^{2+}, Pb^{2+}, Ra^{2+}		Low solubility
		All others		Soluble
Sulfide, S^{2-}		Alkali ions, $H^+_{(aq)}$, NH_4^+, Be^{2+}, Mg^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+}, Ra^{2+}		Soluble
		All others		Low solubility
Hydroxide, OH^-		Alkali ions, $H^+_{(aq)}$, NH_4^+, Sr^{2+}, Ba^{2+}, Ra^{2+}, Ti^+		Soluble
		All others		Low solubility
Phosphate, PO_4^{3-} Carbonate, CO_3^{2-} Sulfite, SO_3^{2-}		Alkali ions, $H^+_{(aq)}$, NH_4^+		Soluble
		All others		Low solubility

<u>Writing Net - Ionic Equations</u>

1. Write a balanced molecular equation, including the states.
2. Write the complete dissociated ionic equation representing the precipitate and all ions in aqueous solution. (Recall: solids, liquids, and gases do not dissociate)
3. Eliminate the spectator ions (i.e. those ions that do not take part in the reaction) from both sides of the equation.
4. Write the overall net ionic equation (containing no spectator ions).

To work out which is the precipitate in a double displacement reacion, use the solubility chart, (recall: Generally all nitrates, all Group I compounds, all ammonium compounds, all chlorate, all perchlorate, and all acetates are soluble)

Example: Write the net ionic equation for the following reaction:

$$FeCl_{3(aq)} + 3\ NaOH_{(aq)} \longrightarrow Fe(OH)_{3\ (s)} + 3\ NaCl_{(aq)}$$