We need for moles of chemical because atoms, molecules, and ions are extremely tiny particles with very small masses.

Mole:

Mole is the **SI** unit for the amount of a chemical substance.

1 mole represents 6.02×10^{23} of anything.

Exactly 12 g of ^{12}C contains 6.02×10^{23} carbon atoms.

Notes:

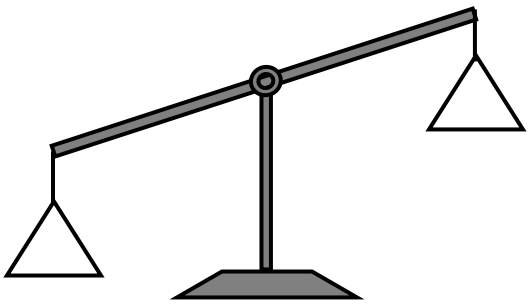
- A dozen stands for the number 12
- A mole stands for the number 6.02×10^{23}
- The mass of 1 mole of any chemical is called the **molar mass**.
- Molar masses are always in gram units.

Reactions and Equations

Reactants → Products

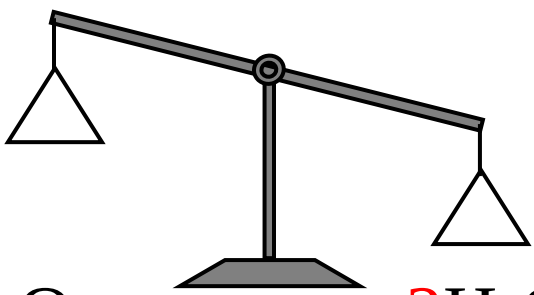
Low of conservation of mass:

In chemical change, mass is neither created nor destroyed.

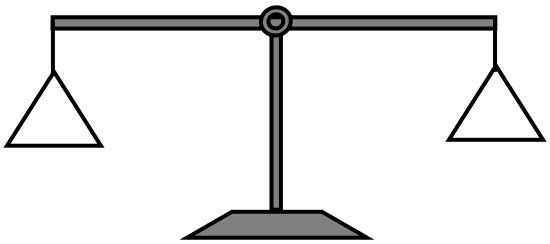


$$H_{2\,(g)} + O_{2\,(g)} \rightarrow H_2O_{(g)}$$

State symbols:
(s) solid, (l) liquid, (g) gas, (aq) aqueous



$$H_{2\,(g)} + O_{2\,(g)} \rightarrow 2H_2O_{(g)}$$



$2H_{2\,(g)} + O_{2\,(g)} \rightarrow 2H_2O_{(g)}$

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Interpreting Chemical Equations:

- Meaning on the particulate level:

$2H_{2\,(g)} + O_{2\,(g)} \rightarrow 2H_2O_{(g)}$

2 molecules	1 molecule	2 molecules
2 moles	1 mole	2 moles

- meaning on the macroscopic level:

mass = mole x molar mass

$2H_{2\,(g)} + O_{2\,(g)} \rightarrow 2H_2O_{(g)}$

2 x 2.00	1 x 32.00	2 x 18.00
4 **g**	32 **g**	36**g**

EXAMPLES OF CHEMICAL CHANGES:

Chemical reactions, also called chemical changes, are not limited to happening in a chemistry lab. Here are some examples of chemical reactions with the corresponding chemical equations:

A silver spoon tarnishes. The silver reacts with sulfur in the air to make silver sulfide, the black material we call tarnish.

$$Ag + S \rightarrow Ag_2S$$

$$2\ Ag + S \rightarrow Ag_2S$$

An iron bar rusts. The iron reacts with oxygen in the air to make rust.

$$Fe + O_2 \rightarrow Fe_2O_3$$

$$4\ Fe + 3\ O_2 \rightarrow 2\ Fe_2O_3$$

Methane combines with oxygen in the air to make carbon dioxide and water vapor.

$$CH_4 + O_2 \rightarrow CO2 + H_2O$$

$$CH_4 + 2\ O_2 \rightarrow CO2 + 2\ H_2O$$

An antacid (calcium hydroxide) neutralizes stomach acid (hydrochloric acid).

$$Ca\ (OH)_2 + \ HCl \rightarrow CaCl_2 + \ H_2O$$

$$Ca\ (OH)_2 + 2\ HCl \rightarrow CaCl_2 + 2\ H_2O$$

Glucose (simple sugar) ferments to ethyl alcohol and carbon dioxide. The sugar in grapes or from grain ferments with **yeast** to make the alcohol and carbon dioxide. The carbon dioxide is the gas that bubbles out of beer or Champaign.

$$C_6H_{12}O_6 \rightarrow 2\ C_2H_5OH + 2\ CO_2$$

Glucose $\rightarrow$ ethyl alcohol + carbon dioxide

Alcohol plus oxygen becomes vinegar and a molecule of water. As in the fermentation of glucose, this is a more complex reaction than it appears here because it is a biochemical reaction.

$$C_2H_5OH + O_2 \rightarrow HC_2H_3O_2 + H_2O$$

Identifying six different kinds of chemical reactions:

Combination Reactions:

Also called Synthesis, Combination, Construction, or Composition Reactions.

A synthesis reaction might be symbolized: $A + B \rightarrow AB$

Example:

$$H_2 + O_2 \rightarrow 2H_2O$$

Sulfur trioxide reacts with water to make sulfuric acid.

$$H_2O_{(l)} + SO_{3\,(g)} \rightarrow H_2SO_{4\,(aq)}$$

Charcoal: $C_{(s)} + O_{2\,(g)} \rightarrow CO_{2\,(g)}$

Decomposition Reactions

Also call Desynthesis Reactions

A single reactant comes apart into two or more products, symbolized by: $XZ \rightarrow X + Z$

$$2H_2O_{\,(l)} \rightarrow 2H_{2\,(g)} + O_{2\,(g)}$$

$$CaCO_{3\,(s)} \rightarrow CaO\,(s) + CO_{2\,(g)}$$

Lime stone lime

Heating sodium bicarbonate releases water and carbon dioxide and sodium carbonate.

6 $NaHCO_3$ → 3 Na_2CO_3 + 3 H_2O + 3 CO_2

III. Complete oxidation or burning of organic compounds:

Petroleum products, alcohols, sugars, .. react with oxygen (burn in air).

$$CH_{4\,(g)} + O_{2\,(g)} \rightarrow CO_{2\,(g)} + H_2O_{\,(g)} + \text{energy}$$

$$CH_{4\,(g)} + 2O_{2\,(g)} \rightarrow CO_{2\,(g)} + 2H_2O_{\,(g)} + \text{energy}$$

$$C_2H_5OH_{(l)} + O_{2\,(g)} \rightarrow CO_{2\,(g)} + H_2O_{\,(l)}$$

$$C_2H_5OH_{(l)} + 3O_{2\,(g)} \rightarrow 2CO_{2\,(g)} + 3H_2O_{\,(l)} + \text{energy}$$

Do this example:

Let's try burning isopropyl alcohol, C_3H_7OH:

Identifying six different kinds of chemical reactions:

I. Combination Reactions

Symbolized by: $A + B \rightarrow AB$

II. Decomposition Reactions

Symbolized by: $AB \rightarrow A + B$

III. Complete oxidation or burning of organic compounds

Burning isopropyl alcohol, C_3H_7OH?!

$$C_3H_7OH + O_2 \rightarrow CO_2 + H_2O$$

First take care of the carbon and hydrogen.

$$C_3H_7OH + O_2 \rightarrow \mathbf{3}\ CO_2 + \mathbf{4}\ H_2O$$

An oxygen problem!

Multiply the whole equation (except oxygen) by two.

$$\mathbf{2}C_3H_7OH + O_2 \rightarrow \mathbf{6}\ CO_2 + \mathbf{8}\ H_2O$$

Now the number nine fits in the oxygen coefficient

$$\mathbf{2}C_3H_7OH + \mathbf{9}\ O_2 \rightarrow \mathbf{6}\ CO_2 + \mathbf{8}\ H_2O$$

IV. Single-Replacement (Redox) Reactions

Symbolized by: $A + BX \rightarrow AX + B$

V. Double-Replacement Precipitation Reactions

Symbolized by: $AX + BY \rightarrow AY + BX$

VI. Double-Replacement Neutralization Reactions

$$\text{Acid} + \text{Base} \rightarrow \text{Salt} + \text{Water}$$

Write the formula for each material, balance it and tell what type of reaction it is.

1. Sulfur trioxide and water combine to make sulfuric acid.

2. Lead (II) nitrate and sodium iodide react to make lead iodide and sodium nitrate.

3. Calcium fluoride and sulfuric acid make calcium sulfate and hydrogen fluoride (Hydrofluoric acid).

4. Calcium carbonate will come apart when you heat it to leave calcium oxide and carbon dioxide.

5. Ammonia gas when it is pressed into water will make ammonium hydroxide.

6. Sodium hydroxide neutralizes carbonic acid.

7. Lithium oxide and water make lithium hydroxide.

8. Aluminum hydroxide and sulfuric acid neutralize to make water and aluminum sulfate.

9. Sulfur burns in oxygen to make sulfur dioxide.

10. Barium hydroxide and sulfuric acid make water and barium sulfate.

11. Aluminum sulfate and calcium hydroxide become aluminum hydroxide and calcium sulfate.

12. Copper metal and silver nitrate react to form silver metal and copper (II) nitrate.

13. Sodium metal and chlorine react to make sodium chloride.

14. Phosphoric acid plus sodium hydroxide.

15. Propane burns (with oxygen).

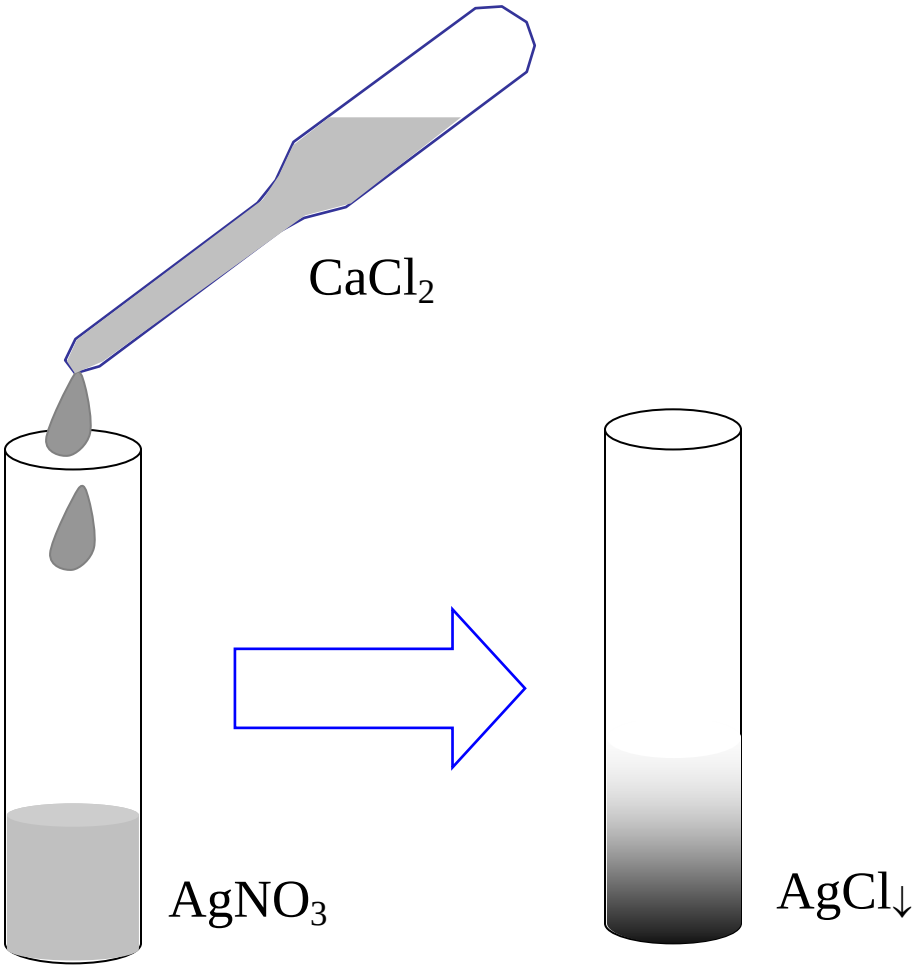
16. Zinc and copper (II) sulfate yield zinc sulfate and copper metal.

17. Sulfuric acid reacts with zinc.

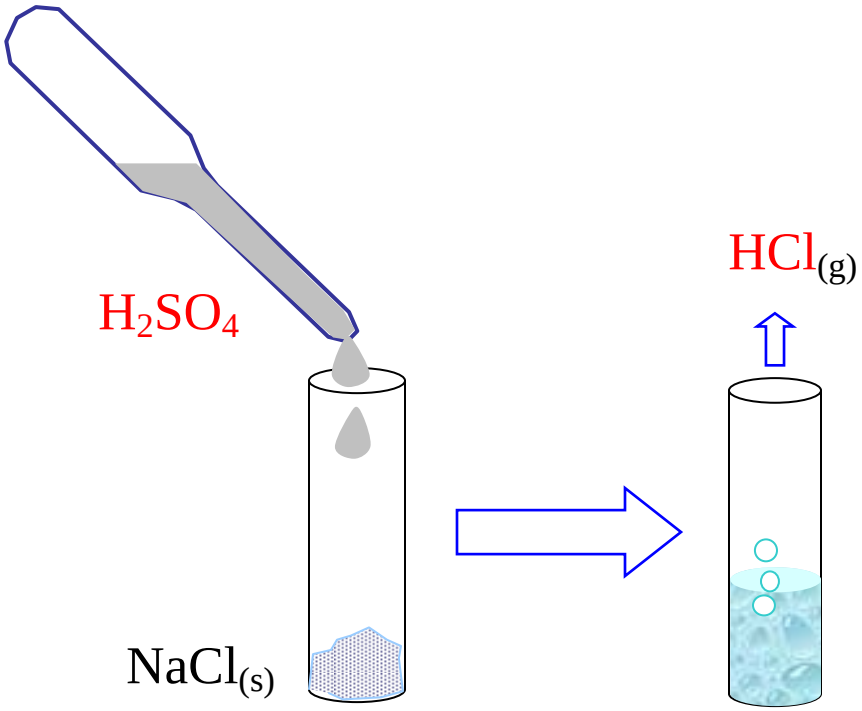
18. Chlorine gas and sodium bromide yield sodium chloride and bromine.

ANSWERS TO EQUATIONS

1. $SO3 + H2O \rightarrow H2SO4$ Combination.
2. $Pb(NO_3)_2 + 2NaI \rightarrow PbI_2 + 2NaNO_3$ Double-Reaction-Precipitation
3. $CaF_2 + H_2SO_4 \rightarrow CaSO_4 + 2\ HF$ D-R-Precip.
4. $CaCO_3 \rightarrow CaO + CO_2$ Decomposition
5. $NH_3 + H_2O \rightarrow NH_4OH$ Comb.
6. $2\ NaOH + H_2CO3 \rightarrow Na_2CO_3 + 2\ H_2O$ Neutralization
7. $Li_2O + H_2O \rightarrow 2\ LiOH$ Comb.
8. $2\ Al(OH)_3 + 3\ H_2SO_4 \rightarrow 6\ H_2O + Al_2(SO4)_3$ Neut.
9. $S + O2 \rightarrow SO_2$ Comb.
10. $Ba(OH)_2 + H_2SO_4 \rightarrow 2\ H_2O + BaSO_4$ Neut.
11. $Al_2(SO4)_3 + 3\ Ca(OH)_2 \rightarrow 2\ Al(OH)_3 + 3\ CaSO_4$ D-Reac-Precip.
12. $Cu + 2AgNO_3 \rightarrow 2Ag + Cu(NO_3)_2$ (CATIONIC) Single-Replacement
13. $2Na + Cl2 \rightarrow 2\ NaCl$ Comb.
14. $H_3(PO_4) + 3\ NaOH \rightarrow Na_3PO_4 + 3\ H_2O$ Neut.
15. $C_3H_8 + 5\ O_2 \rightarrow 4\ H_2O + 3\ CO_2$ Burning
16. $Zn + CuSO_4 \rightarrow ZnSO_4 + Cu$ (CATIONIC) S-Replac.
17. $H_2SO_4 + Zn \rightarrow ZnSO_4 + H_2$ (CATIONIC) S-Replac.
18. $Cl_2 + 2\ NaBr \rightarrow 2\ NaCl + Br_2$ (ANIONIC) S-Replac



Formation of an insoluble compound or a gas product is referred to as a **driving force** for a reaction.


H_2SO_4
$HCl_{(g)}$
$NaCl_{(s)}$