# CHAPTER 5 Chemicals in Action

What is Chemistry?

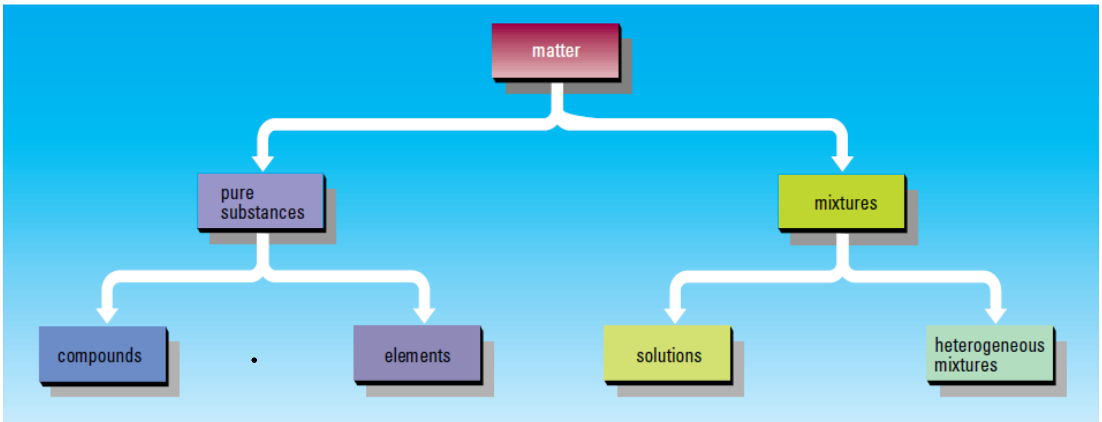
The study of matter, its properties, and its changes or transformations.

Matter

- Anything that has mass and takes up space. gas, liquid, solid
- Physical Properties: State, colour, odour, luster, solubility, melting and boiling point, conductivity.
- Chemical Property: Chemical changes or transformations that substances may undergo (reactivity).

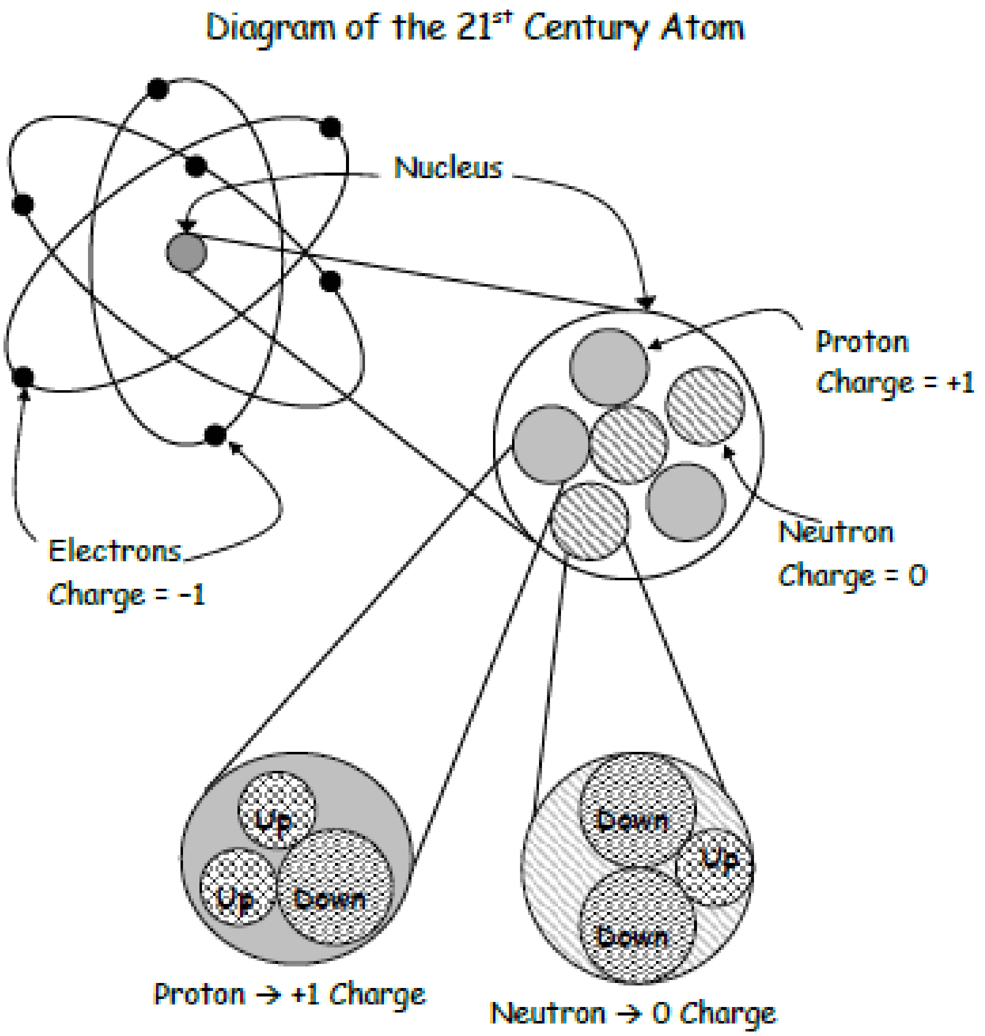
Pure Substance

- All particles that make up the substance are the same.
- Constant properties.
- Elements or compounds.
- Elements can not be broken down in to smaller substances.
- All elements that make up matter in the universe come from stars during nuclear fusion and supernova explosions.




- Elements have a symbol and are arranged in the periodic table.
- Consist of Protons, Neutrons, and electrons. } Subatomic particles
- Elements are defined by the number of protons in their nucleus.

Build an Atom



# Review Questions

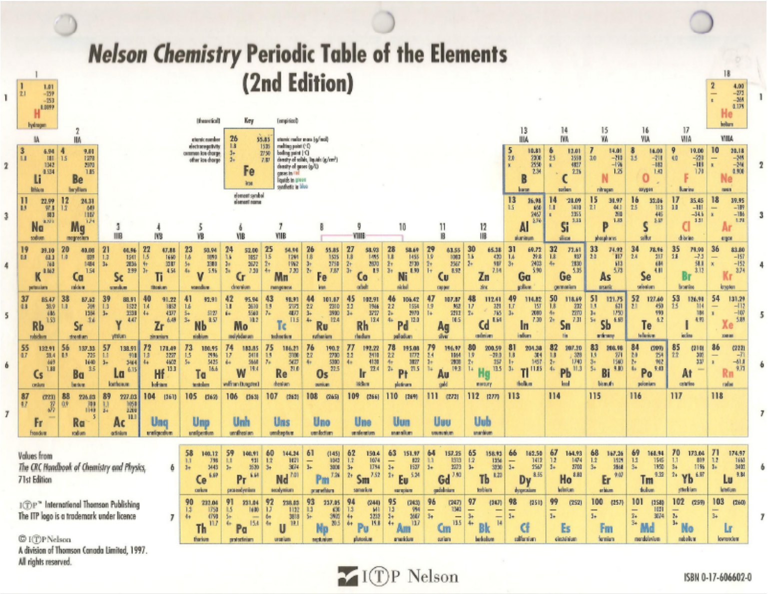
Page 175 #s 1, 2, 5, 6.

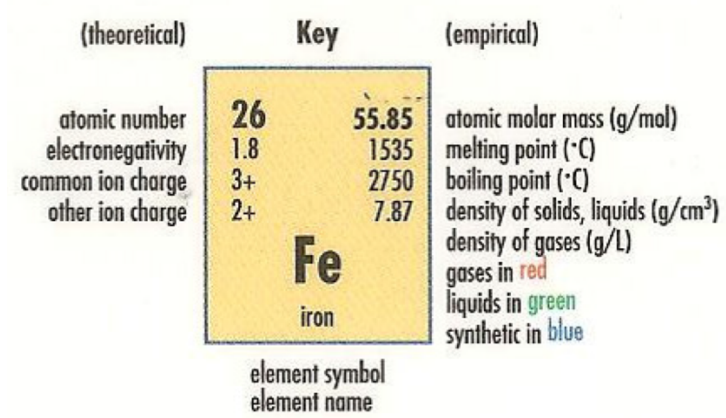
5.5

https://ptable.com/

# Elements and the Periodic Table

Carefully read pages 184 - 187.



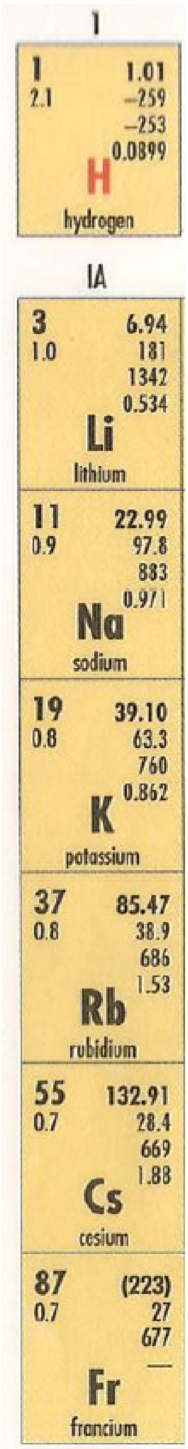

Periodic Table

- Structured arrangement of elements that helps explain and predict physical and chemical properties by using the groups and rows of elements.
- Separated into metals and non-metals.

**Table 1** **Properties of Metals and Nonmetals**

| Property | Metals | Nonmetals |
|---|---|---|
| lustre | shiny | dull |
| malleability | malleable | brittle |
| conductivity | conductors | mostly insulators |
| reactivity with acid | mostly yes | no |
| state at room temperature | mostly solids | solids, liquids, and gases |

lkali Metals

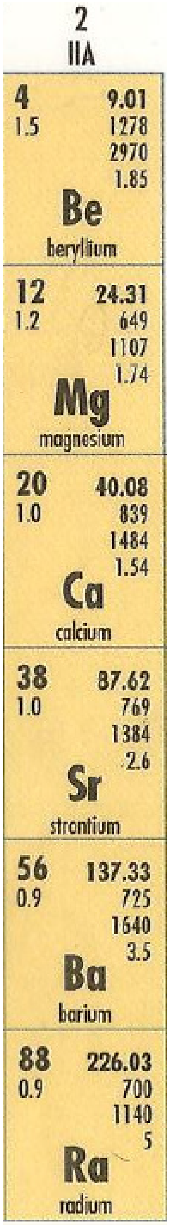



Chemical Families: elements in the same vertical column have similar physical and chemical properties.

- Shiny, silvery metals.
- Very reactive with other elements and compounds - including water.
- Form compounds that are mostly white solids.
- Compounds formed are very soluble in water.

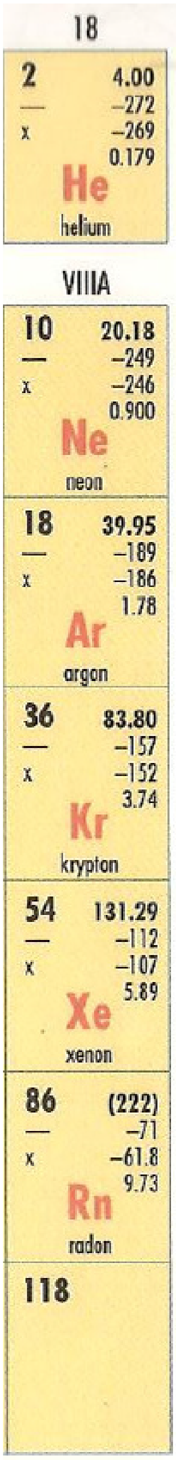
https://www.youtube.com/watch?v=jI__JY7pqOM

# Alkaline Earth Metals



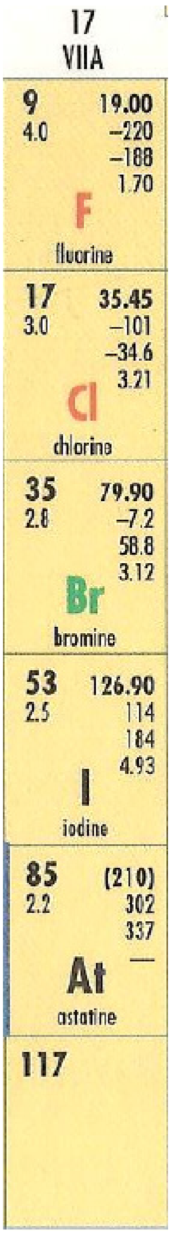

- Shiny, silvery metals but form compounds that are often insoluble in water.

Noble Gases




- Generally do not form compounds.  The atoms are made up of just the right amount of electrons.

# Halogens




- Nonmetals that are all poisonous elements that react readily (very reactive) with sodium and other alkali metals.

# Atomic Structure

https://phet.colorado.edu/en/simulation/build-an-atom

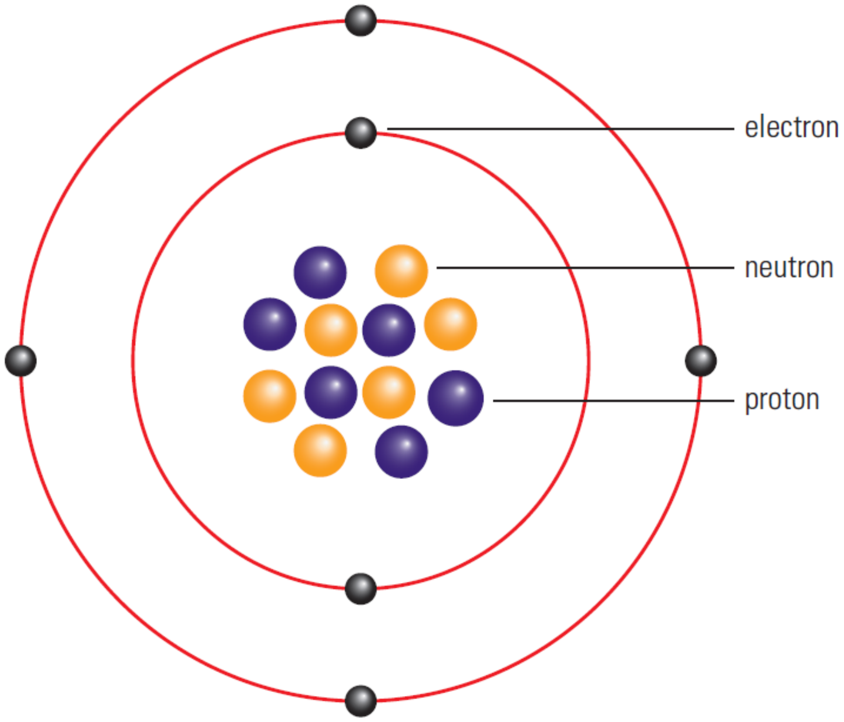



**Figure 4**

In the Bohr-Rutherford model of the atom, electrons travel in orbits about a positively charged nucleus. This is a model of carbon atom (not to scale).

Protons: Massive ($10^{-27}$), positive particles found in the dense nucleus. Number of protons define an element on the periodic table.

Think about it: How can a nucleus of an atom even exist if positive charges repel each other?

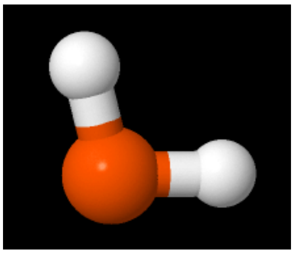
Neutrons: Massive, neutral particles found in the nucleus. Neutrons affect the "stability" of an atom.

Electrons: Negatively charged particles with almost no mass ($10^{-31}$ kg) that "circle" the nucleus at different energy levels - called orbits or shells. These are the key to understanding all non-nuclear chemistry.

## Bohr Diagrams

The electrons in the outermost orbit are involved in chemical reactions as they bond with other elements or compounds to create something completely different.

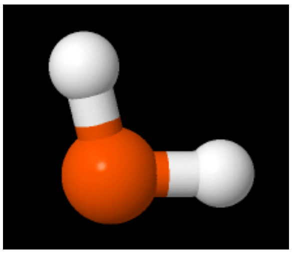
Consider water: $H_2O$



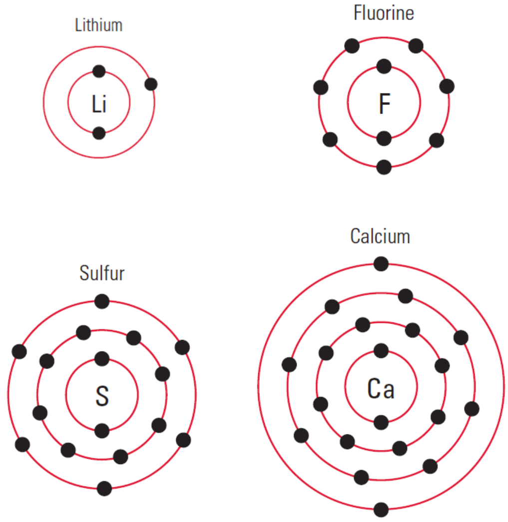
Hydrogen is a very explosive gas.

Oxygen is required to burn - it fuels fire and explosions.

But when oxygen shares two electons - one each for a hydrogen - it forms a compound that puts out fires.



The outer electron shell of an atom is also called the **valence shell**, and the electrons in this shell are called valence electrons.




To form compounds the electrons get rearranged. Some reactions will see elements transferring electrons to another while other reactions will have elements that share electrons.

All of this happens ~~to~~ so that atoms can have an electron arrangement like a noble gas.

When electrons are transferred the new arrangement of electrons forms an **ion**.

If the number of protons and electrons in an element are different then it is called an ion.

Positive ions have more protons than electrons. Many metals form positive ions. The symbol for a positive ion is the element symbol with the charge in the top right corner.

$Ca^{2+}$ ← sign is after the number

Negative ions have more electrons than protons. Many nonmetals form negative ions.

$O^{2-}$

Positive ions are also called cations, and negative ions are also called anions. An easy way to remember these terms is that **a**n**i**ons are **n**egative and ca$^{+}$ions are $^{+}$ve.

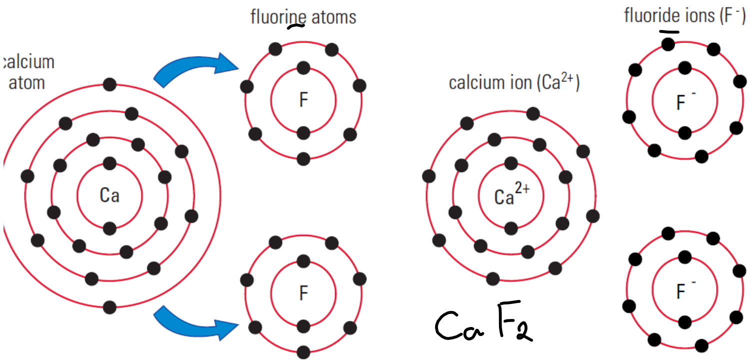
Pg.187 #s 1, 2, 4-7.

5.6

# How Elements Form Compounds

**Figure 1**
Sodium burns rapidly in chlorine gas to form the compound sodium chloride, a compound so harmless that you sprinkle it as salt onto your French fries. This reaction is too dangerous to carry out in a classroom. Each atom of sodium loses an electron to an atom of chlorine.

- NaCl, or table salt, is an example of an ionic compound.
- Ionic compounds are formed by atoms transferring electrons, leaving two charged atoms that are held together by the attraction of positive and negative charges.
- Metals and non-metals form these types of compounds.



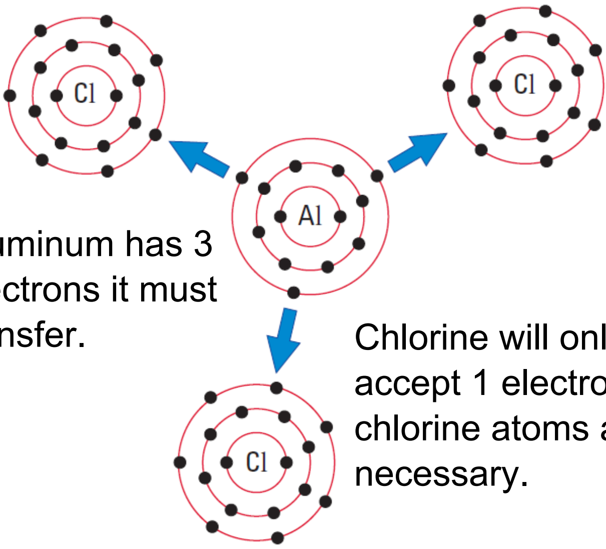

- Atoms will lose or gain electrons to have a stable electron configuration - an electron configuration of a noble gas.
  > Atoms with more or less electrons than protons are not unstable - they just have a charge.
- Look at your periodic table:
  > How many electrons does group 1 have to gain or lose to be stable?
  > Group 2, 16, & 17?

5.8

## Ionic Compounds

- You will learn:
  > How to create the chemical formula for ionic compounds.
  > How to name ionic compounds.

- The compounds we will study will form to be a total charge of zero, or neutral. ⚹
- For example, if aluminum and chlorine form a compound then all the charged must add to zero.



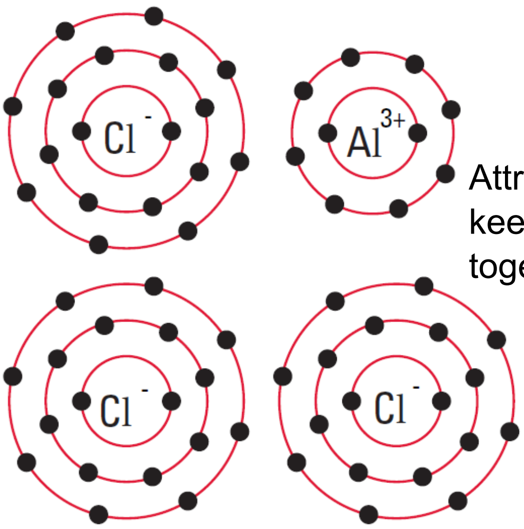

Aluminum has 3 electrons it must transfer.

Chlorine will only accept 1 electron, so 3 chlorine atoms are necessary.

The formula is then: $AlCl_3$

#of atoms

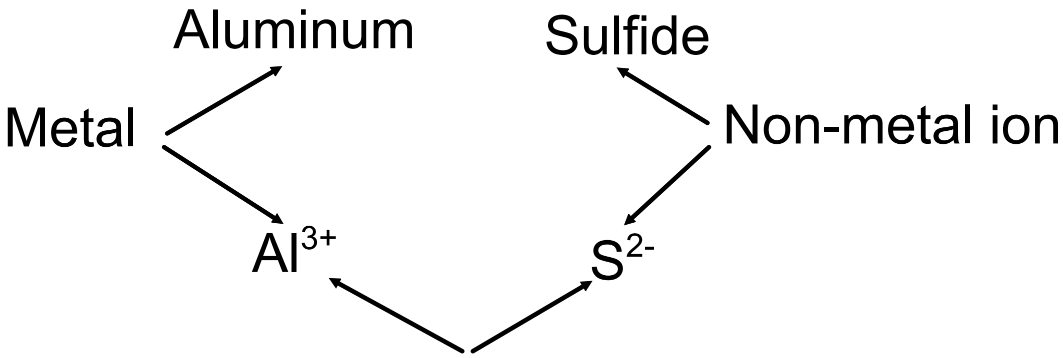
If the # of atoms is 1, we don't write it.




Attraction of ions keep the compound together.

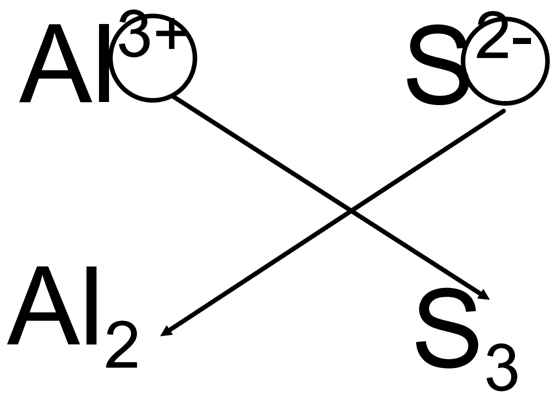
# Creating Formulas for Ionic Compounds

Example: Create the formula for the compound aluminum sulfide.




Use the table of ions handout to find these symbols based on the compound's name.

The charges crisscross and become the number of atoms necessary to have a neutral compound. Do not cross over the sign.




Write the compound with the atoms altogether:

$$Al_2S_3$$

Aluminum Sulfide

## Another Example

Write the formula for Radium Oxide

$Ra^{2+}$ $O^{2-}$

→ This is Balanced, charges add to zero.

Answer: $RaO$

Pg 195 # 3, 5

Calcium Phosphide

$Ca^{2+}$ $P^{3-}$

$Ca_3$ $P_2$

$Ca_3P_2$

## Naming Ionic Compounds

The name of an ionic compound is the name of the metal followed by the name of the nonmetal ion (usually just the name of the element with the ending changed to *-ide*).

**Table 1** Names and Ionic Charges of Some Nonmetals

| Name of element | Symbol | Ionic charge | Name in compound |
|---|---|---|---|
| fluorine | F | 1– | fluoride |
| chlorine | Cl | 1– | chloride |
| bromine | Br | 1– | bromide |
| iodine | I | 1– | iodide |
| oxygen | O | 2– | oxide |
| sulfur | S | 2– | sulfide |
| nitrogen | N | 3– | nitride |
| phosphorus | P | 3– | phosphide |

Examples

$Li_2O$ Lithium Oxide

$AlBr_3$ Alluminum Bromide

$K_3P_2$ Potassium Phosphide

## Names and Formulas for Atoms with More Than One Ionic Charge

**Table 2** Names and Multiple Ionic Charges of Some Metals

| Name of element | Symbol | Ionic charges | Roman numeral |
|---|---|---|---|
| copper | Cu | 1+, 2+ | I, II |
| iron | Fe | 2+, 3+ | II, III |
| lead | Pb | 2+, 4+ | II, IV |
| tin | Sn | 2+, 4+ | II, IV |

FeO Iron (II) Oxide

$Fe_2O_3$ Iron (III) Oxide

$O^{2-}, O^{2-}, O^{2-}$ → 6 –

$Fe^{3+}$

$Fe^{3+}$

SnO

$Fe^{3+}$ $O^{2-}$ (2) (3)

5.9

# Polyatomic Compounds

Groups of atoms that tend to stay together and have an overall ionic charge.

**Table 1** **Common Polyatomic Compounds**

| Compound | Formula | Use or source |
|---|---|---|
| calcium carbonate | $CaCO_3$ | chalk and building materials |
| magnesium hydroxide | $Mg(OH)_2$ | stomach antacids |
| sulfuric acid | $H_2SO_4$ | car battery acid |
| sodium hypochlorite | $NaClO$ | clothing bleach |
| copper(II) sulfate | $CuSO_4$ | fungicide |
| sodium carbonate | $Na_2CO_3$ | laundry detergents |
| ammonium nitrate | $NH_4NO_3$ | fertilizer |

**Table 2** **Common Polyatomic Ions and Their Ionic Charges**

| Name of polyatomic ion | Ion formula | Ionic charge |
|---|---|---|
| nitrate | $NO_3^-$ | 1– |
| hydroxide | $OH^-$ | 1– |
| bicarbonate (hydrogen carbonate) | $HCO_3^-$ | 1– |
| chlorate | $ClO_3^-$ | 1– |
| carbonate | $CO_3^{2-}$ | 2– |
| sulfate | $SO_4^{2-}$ | 2– |
| phosphate | $PO_4^{3-}$ | 3– |

5.11

# Molecular Compounds

- Atoms share electrons to have a stable electron configuration.
- The bond that holds the atoms together is called a covalent bond.

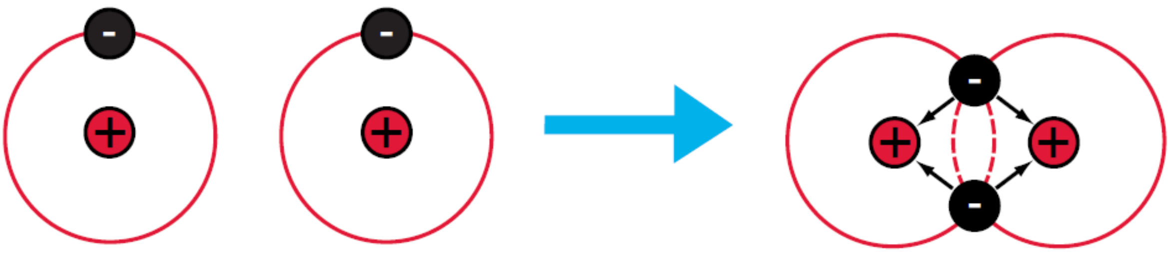



**Figure 2**

Two hydrogen atoms share a pair of electrons to form a covalent bond. Both negative electrons are attracted by the positive nuclei of both atoms.

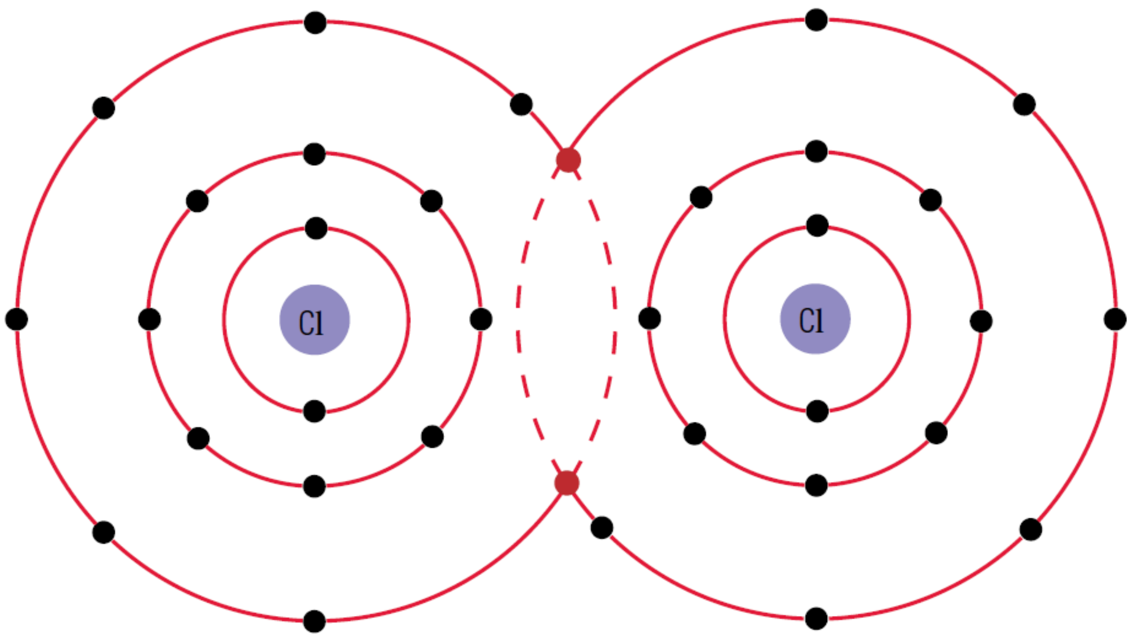


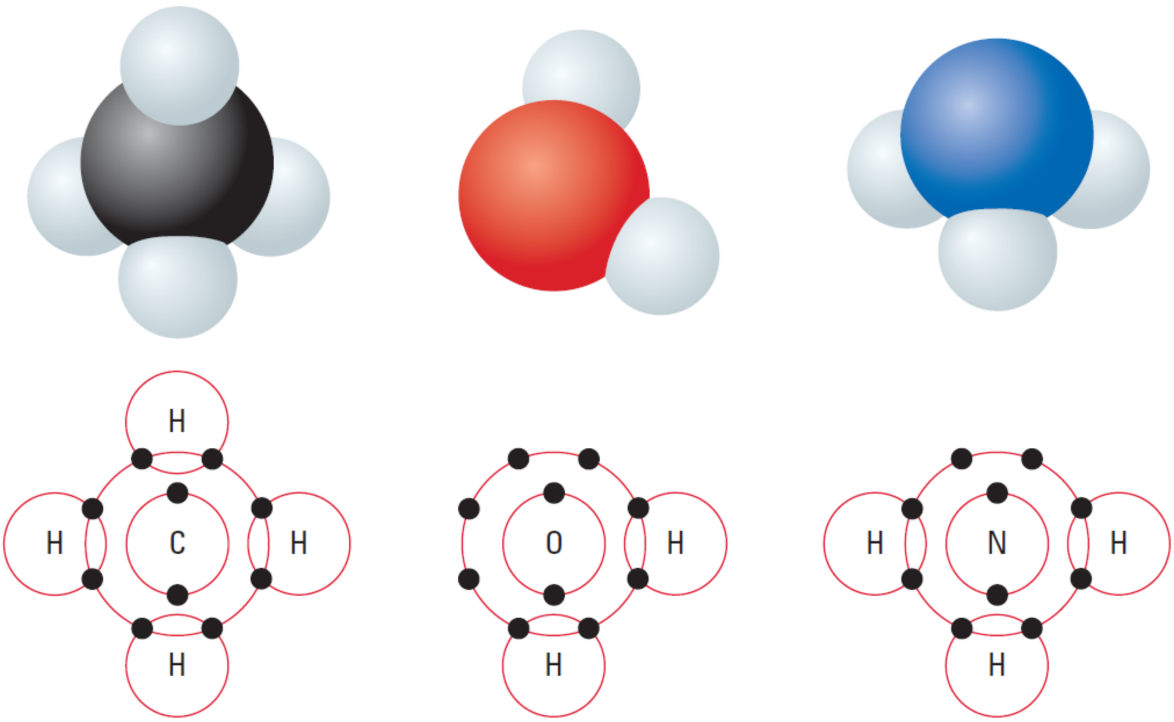

**Figure 3**

Two chlorine atoms share a pair of electrons to form a covalent bond. Each chlorine atom now has eight electrons in its outer orbit.

# Diatomic Elements

**Table 1** **Elements That Form Diatomic Molecules**

| Name of element | Chemical symbol | Formula (and state at room temperature) |
|---|---|---|
| hydrogen | H | $H_2$ (gas) |
| oxygen | O | $O_2$ (gas) |
| nitrogen | N | $N_2$ (gas) |
| fluorine | F | $F_2$ (gas) |
| chlorine | Cl | $Cl_2$ (gas) |
| bromine | Br | $Br_2$ (liquid) |
| iodine | I | $I_2$ (solid) |




methane ($CH_4$) water ($H_2O$) ammonia ($NH_3$)

**Figure 5**
Methane, water, and ammonia are all covalently bonded molecules.

# Writing Formulas for Molecular Compounds

**Combining Capacity**: a measure of the number of covalent bonds that it will need to form a stable molecule.

**Table 2** Combining Capacities of Nonmetal Atoms

| 4 | 3 | 2 | 1 |
|---|---|---|---|
| | | | H |
| C | N | O | F |
| Si | P | S | Cl |
| | As | Se | Br |
| | | | I |

**How would you write the formula for a compound formed between carbon and sulfur?**

*Rule 1: Write the symbols, with the left-hand element from **Table 2** first, with the combining capacities.*

4 2
C S

*Rule 2: Crisscross the combining capacities to produce subscripts.*

4 2
C S

The formula is $C_2S_4$.

*Rule 3: Reduce the subscripts if possible.*

The formula $C_2S_4$ can be reduced to $C_1S_2$.

*Rule 4: Any "1" subscript is not needed.*

The correct formula is $CS_2$.

# Naming Molecular Compounds

Many molecular compounds use prefixes which count the number of atoms of each element.

**Table 3 Prefixes in Molecular Compounds**

| Prefix | Number | Example (formula) |
|---|---|---|
| mon(o)- | 1 | carbon monoxide ($CO$) |
| di- | 2 | carbon disulfide ($CS_2$) |
| tri- | 3 | sulfur trioxide ($SO_3$) |
| tetra- | 4 | carbon tetrafluoride ($CF_4$) |
| pent(a)- | 5 | phosphorus pentabromide ($PBr_5$) |

When there is only one atom in the first element the prefix "mono" is not used.

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Test Wednesday, May 13.

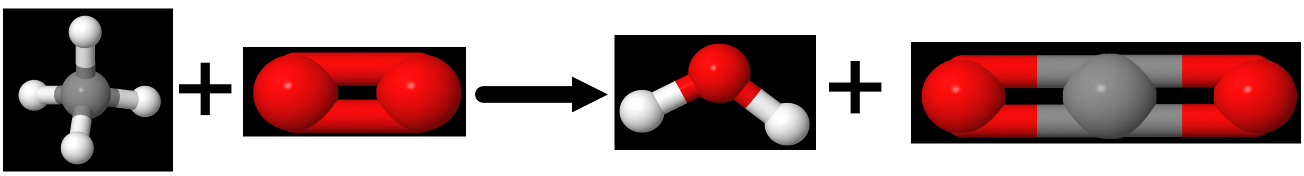
Provincial Assessment: Thursday, May 14.

# CHAPTER 6 Understanding Chemical Reactions

- Chemical reactions are what happens when new compounds are produced.
- They are represented by a chemical equation.

Methane reacts with oxygen producing water and carbon dioxide

Methane + Oxygen → Water + Carbon Dioxide



$$CH_4 + O_2 \longrightarrow H_2O + CO_2$$

Reactants Products

6.1

# Word Equations

all the reactants ⟶ all the products

The reactants, as well as the products, are separated by a plus sign (+):

reactant 1 + reactant 2 ⟶ product 1 + product 2

## Examples

Iron reacts with oxygen to form iron (III) oxide

iron + oxygen ⟶ iron(III) oxide

Copper is placed in a beaker of silver nitrate solution:

copper + silver nitrate ⟶ silver + copper(II) nitrate

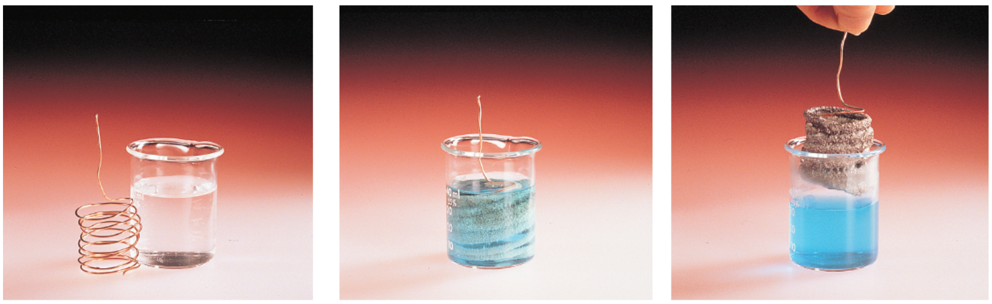


**Figure 2**

Vhen a coil of copper is dipped in silver nitrate solution, a furry deposit of silver metal forms on the :oil. The solution also turns blue as a copper(II) nitrate solution forms.

Page 219 #s 1 - 4.

6.3

# Conserving Mass

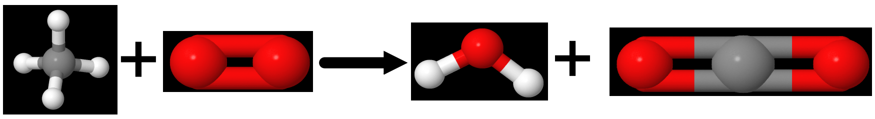
Law of Conservation of Mass:

- In a (non-nuclear) chemical reaction, the total mass of the reactants is always equal to the total mass of the products.
- Atoms are not destroyed, just rearranged.

Consider the burning of methane, is mass conserved in the chemical reaction shown below?

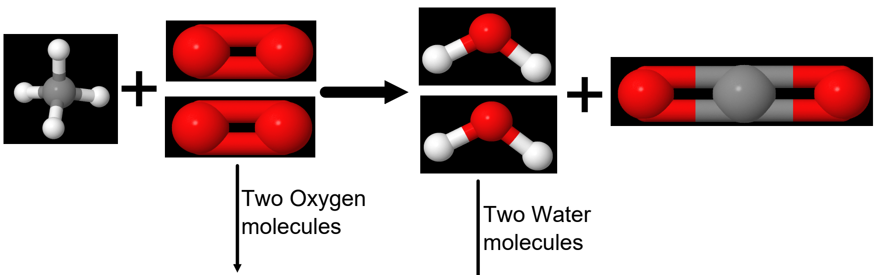
Methane + Oxygen → Water + Carbon Dioxide

$CH_4 + O_2 \longrightarrow H_2O + CO_2$



It is not possible to "lose" two hydrogen atoms and gain a third oxygen. So if we only have one molecule of methane and oxygen the reaction can't take place.

To conserve mass we need the following:




$CH_4 + 2O_2 \longrightarrow 2H_2O + CO_2$

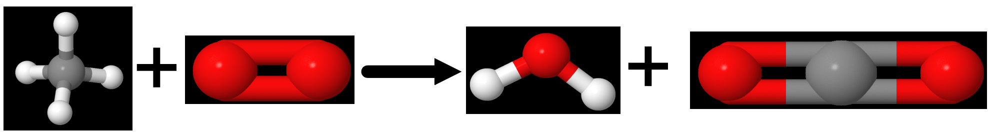
The above chemical reaction is now called **balanced** because mass (or the number of atoms) is conserved - there are the same number of a specific atom in the reactants and products.

6.5

# Balancing Chemical Equations

- Balancing a chemical equation refers to the act of conserving mass.
- Word equations describe the reactants and products, but do not communicate the number of atoms involved.
- We use a **skeleton equation** to represent the reaction.  This uses chemical formulas for the reactants and products.

Consider, for example our reaction of methane and oxygen:



Word Equation:

Methane + Oxygen → Water + Carbon Dioxide

Skeleton Equation:

$CH_4 + O_2 \longrightarrow H_2O + CO_2$

Balanced Equation:

$CH_4 + \textcolor{red}{2}O_2 \longrightarrow \textcolor{red}{2}H_2O + CO_2$

coefficients

Skeleton equations are balanced by changing the coefficients until there are the same number of atoms in the reactants and products.

PhET

Examples

$$Fe \quad + \quad S \rightarrow \quad Fe_2S_3$$

$$MgO \rightarrow \quad Mg \quad + \quad O_2$$

$$Fe_2O_3 \quad + \quad C \rightarrow \quad Fe \quad + \quad CO$$

Page 229 #s 1 & 2

6.6

# Combustion

There are different categories of chemical reactions. One possible category is combustion. **Combustion** is the very rapid reaction of a substance with oxygen to produce compounds called oxides. We often call this process burning. One way to represent combustion is using the following word equation:

fuel + oxygen → oxides + energy

hydrocarbon + oxygen → carbon dioxide + water vapour + energy

When butane is allowed to escape the lighter through a valve and a spark ignites it, the following reaction occurs:

butane + oxygen → carbon dioxide + water + energy

$2C_4H_{10} + 13O_2 \rightarrow 8CO_2 + 10H_2O$

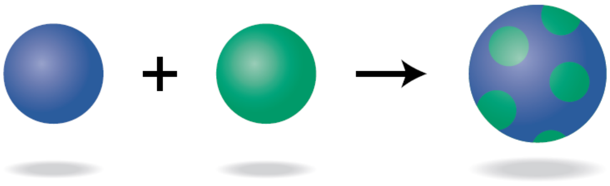
6.7

# Types of Chemical Reactions: Synthesis and Decomposition

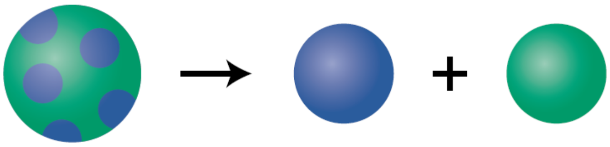
Chemists use these patterns to classify groups of chemical changes. Most chemical reactions can be grouped into four categories:

- synthesis
- decomposition
- single displacement
- double displacement

synthesis reaction



decomposition reaction



## Synthesis Reactions

**Synthesis reactions** involve the combination of smaller atoms and/or molecules into larger molecules. These reactions are also called **combination reactions.** Often the reactants are elements that combine chemically to form compounds. Synthesis reactions have the following general formula:

$A + B \rightarrow AB$

hydrogen chloride + ammonia → ammonium chloride

$HCl + NH_3 \rightarrow NH_4Cl$

## Decomposition Reactions

**Decomposition reactions** involve the splitting of a large molecule into elements or smaller molecules. Decomposition reactions have the following general formula:

$AB \rightarrow A + B$

nitrogen triiodide → nitrogen + iodine

$NI_3 \rightarrow N_2 + I_2$

$2NI_3 \rightarrow N_2 + 3I_2$

ammonium nitrate → nitrous oxide + water

$NH_4NO_3 \rightarrow N_2O + H_2O$

$NH_4NO_3 \rightarrow N_2O + 2H_2O$

**Table 1** Elements That Occur as Diatomic Molecules

| Element | Diatomic molecule |
|---|---|
| hydrogen | $H_2$ |
| oxygen | $O_2$ |
| nitrogen | $N_2$ |
| fluorine | $F_2$ |
| chlorine | $Cl_2$ |
| bromine | $Br_2$ |
| iodine | $I_2$ |

If any of these elements appear alone in a chemical reaction they must come as a pair (you will be given this table for the exam).

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6.10

# Types of Chemical Reactions: Single and Double Displacement

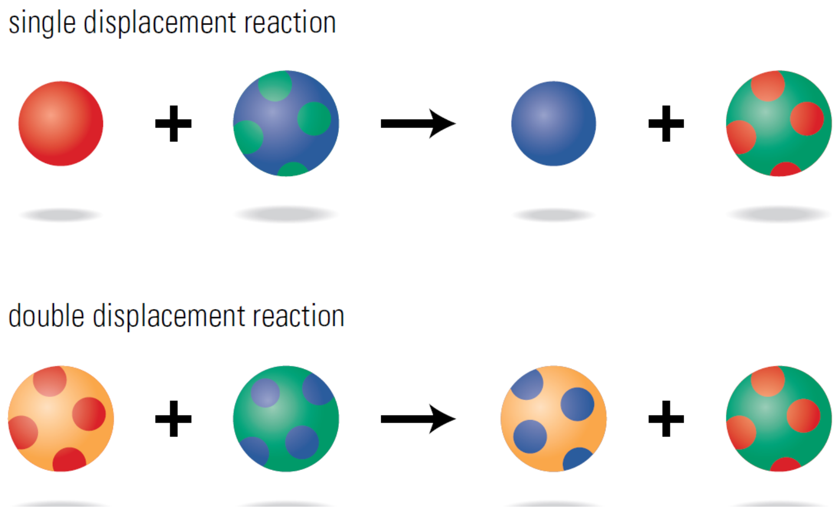


**Figure 1**

In single displacement reactions, an element takes the place of another element in a compound. In double displacement reactions, elements in two compounds "change partners."

## Single Displacement

- Involve an element and a compound as reactants.
- If the element is a metal it takes the place of the metal in the compound.
- If the element is a non-metal it takes the place of the non-metal in the compound.

## Metal (cation) Replacement

magnesium + silver nitrate → silver + magnesium nitrate

$$Mg + AgNO_3 \rightarrow Ag + Mg(NO_3)_2$$

$$Mg + 2AgNO_3 \rightarrow 2Ag + Mg(NO_3)_2$$

## Non-Metal (anion) Replacement

bromine + calcium iodide → iodine + calcium bromide

$$Br_2 + CaI_2 \rightarrow I_2 + CaBr_2$$

Ex. 1 Complete and balance the following single displacement reaction:

$$Zn + Ag_3P \rightarrow$$

Step 1 - Write the products as a word equation.

$Zn + Ag_3P \rightarrow$ silver + zinc phosphide

Step 2 - Write the formulas of the products to create the skeleton equation.

silver: Ag

zinc phosphide

$Zn^{2+}$ $P^{3-}$ ← *Use Ion Chart

$Zn_3$ $P_2$

$Zn_3P_2$ ← zinc phosphide

skeleton equation:

$$Zn + Ag_3P \rightarrow Ag + Zn_3P_2$$

Step 3: Balanced equation.

$$3Zn + 2Ag_3P \rightarrow 6Ag + Zn_3P_2$$

# Ex.2 Complete and balance the following single displacement reaction:

$$O_2 \quad + \quad SnI_2 \quad \rightarrow$$

*Is this Tin (II) or Tin (IV)?

Since Iodine is $I^{1-}$, this must be Tin (II).

**Table 1** Elements That Occur as Diatomic Molecules

| Element | Diatomic molecule |
|---|---|
| hydrogen | $H_2$ |
| oxygen | $O_2$ |
| nitrogen | $N_2$ |
| fluorine | $F_2$ |
| chlorine | $Cl_2$ |
| bromine | $Br_2$ |
| iodine | $I_2$ |

## Step 1: Products as word equation.

$O_2 \quad + \quad SnI_2 \quad \rightarrow$ Iodine + Tin (II) Oxide

## Step 2: Formulas and skeleton equation.

Iodine: $I_2$

diatomic molecule

Tin (II) Oxide

$Sn^{2+}$ $O^{2-}$ ←*Use Ion Chart

$Sn_2$ $O_2$

SnO ← Tin (II) Oxide

skeleton equation:

$$O_2 \quad + \quad SnI_2 \quad \rightarrow \quad I_2 \quad + \quad SnO$$

## Step 3: Balanced Equation

$$O_2 \quad + \quad 2SnI_2 \quad \rightarrow 2I_2 \quad + \quad 2SnO$$

**Work on the handout: Single Displacement Reactions**

## Double Displacement Reactions

These reactions occur when the negative ions in compounds switch places.

For Example:

lead(II) nitrate + potassium iodide → lead(II) iodide + potassium nitrate

$$Pb(NO_3)_2 + KI \rightarrow PbI_2 + KNO_3$$

Anions Switch

$$Pb(NO_3)_2 + 2KI \rightarrow PbI_2 + 2KNO_3$$

# Ex. 1: Complete the balance the reaction:

$$Na_2O \quad + \quad CaCO_3 \quad \longrightarrow$$

## Step 1: Word Equation

$Na_2O \quad + \quad CaCO_3 \quad \longrightarrow$ Sodium Carbonate + Calcium Oxide

## Step 2: Formulas and skeleton equation

Sodium Carbonate

$Na^+$ $CO_3^{2-}$

$Na_2CO_3$

Calcium Oxide

$Ca^{2+}$ $O^{2-}$

$CaO$

$$Na_2O \quad + \quad CaCO_3 \quad \longrightarrow \quad Na_2CO_3 \quad + \quad CaO$$

## Balanced:

$$Na_2O \quad + \quad CaCO_3 \quad \longrightarrow \quad Na_2CO_3 \quad + \quad CaO$$

## Double Displacement Worksheet

Attachments

Balancing Chemical Equations.jar

Build Atom.jar

Build Molecule.jar