Chemical Compounds

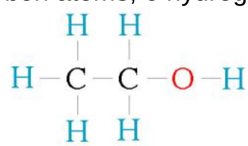
When any of the 112 elements combine into groups of 2 or more they form compounds. If an atom of an element transfers electrons to another atom of a different element, an ionic compound is formed. If atoms of elements are shared, a molecular compound is formed.

Understanding Formulas for Compounds

The combination of elements to form compounds has a chemical formula and a chemical name. The chemical formula uses symbols and numerals to identify which elements and how many atoms of each element are present in the compound.

For example:

ethanol (C_2H_6O) has **2** carbon atoms, **6** hydrogen atoms and **1** oxygen atom



To determine the chemical name, a standardized chemical naming system, or nomenclature, is used. Guyton de Morveau in France developed it in 1787. The metal name is always first. Since 1920, the **IUPAC** (*International Union of Pure and Applied Chemistry*) is responsible for determining the appropriate name for each compound.

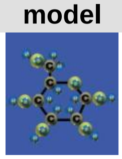
If you know the formula for a compound you can determine its chemical name
If you know its name, you can determine its formula.

Write the **chemical formula** as determined by the **name** of the compound.
(If a poly atomic ion is part of the formula, keep the poly-atomic ion intact)

Aluminum oxide	2 - Al	3 - O	Al_2O_3
Calcium nitrite	1 - Ca	2 - NO_2	$Ca(NO_2)_2$
Sodium Chloride	1 - Na	2 – Cl_2	NaCl

If the compound contains a metal the compound is ionic.
If the compound does not contain a metal, it is molecular.
Write the **name** of the compound as determined by the **chemical formula.**

Al_2O_3	2 - Al	3 - O	Aluminum oxide
$Ca(NO_2)_2$	1 - Ca	2 - NO_2	Calcium nitrite
NaCl	1 - Na	2 – Cl_2	Sodium Chloride

Chemical Name & Physical State	Atomic model	Chemical Formula
Glucose (s) - solid		**$C_6H_{12}O_6$** The chemical formula for glucose tells us that each molecule is made of 6 carbon atoms, 12 hydrogen atoms, and 6 oxygen atoms.
Nitrogen dioxide (g) - gas **Carbon dioxide** (g) - gas **Water** (l) – liquid		**NO_2** **CO_2** **H_2O**

(aq) – **aqueous solution** This is used when substances are dissolved in water.
A saltwater solution would be **NaCl** (aq)

Molecular Compounds

A molecule is the smallest independent unit of a pure substance. Diatomic molecules are molecules made up of 2 atoms of the same element (oxygen O_2, nitrogen N_2, hydrogen H_2). Most molecular compounds do not form large structures.

When *non-metals* combine, they produce a pure substance called a molecule, or molecular compound. They can be solids, liquids, or gases at room temperature. The bonding between atoms is strong, but the attraction between the molecules is weak.

Examples: sugar ($C_{12}H_{22}O_{11(s)}$)acetylene, water

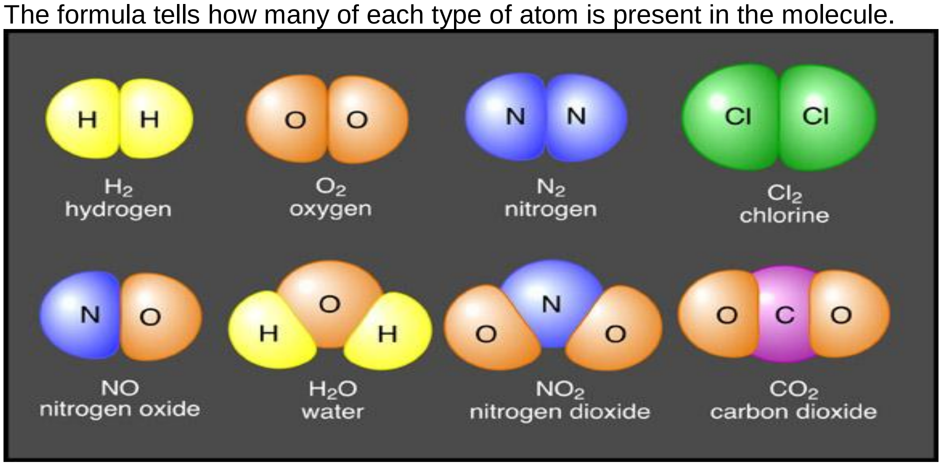
Properties of **molecular compounds**

- Low melting point
- Low boiling point
- Good insulators
- Poor conductors
- Distinct crystal shape

Of the 10 million compounds discovered so far, about 9 million are molecular compounds

Writing Formulas For Molecular Compounds

The formula tells how many of each type of atom is present in the molecule.



How Are Molecular Compounds Named?

Rules:

1. The first element in the compound uses the element name

2. The second element has a suffix – **ide** –

3. When there is more than 1 atom in the formula, a prefix is used which tells how many atoms there are:

4. Exception to #3 above – when the first element has only 1 atom the prefix mono is not used

# of Atoms	Prefix
1	mono
2	di
3	tri
4	tetra
5	penta

Examples: CO_2 carbon **di**oxide CCl_4 carbon **tetra**chloride

Ionic Compounds

Sodium Chloride (table salt) – **NaCl** – is an **ionic compound**. Ionic compounds are pure substances formed as a result of the attraction between particles of opposite charges, called **ions**.

Properties of **ionic compounds**
- **High melting point**
- **Good electrical conductivity**
- **Distinct crystal shape**
- **Solid at room temperature**

When the ionic compound is dissolved in water, the metal (**Na**) and nonmetal (**Cl_2**) form an aqueous solution of ions. An ion is an atom or group of atoms that has become electrically charged through ***a loss or gain of electrons***. (see Table **sia** p. 146)

Ion Charges
A superscript (**+**) or a (**–**) are used to indicate the charge. **Na^+** and **Cl^-**
Some ions can also form when certain atoms of elements combine. These ions are called **polyatomic** ions (*poly* meaning "*many*"). Polyatomic atoms are a group of atoms acting as one.

Example:

1 carbon atom reacting with 3 oxygen atoms produces
1 carbonate group of atoms, which act as one. **CO_3^{2-}**

Then, when carbonate ions react with calcium atoms they produce calcium carbonate, or limestone. **Ca CO_3^{2-}**

How Are Ionic Compounds Named?
Two rules:
1. The chemical name of the metal or positive ion goes first, followed by the name of the non-metal or negative ion.
2. The name of the non-metal negative ion changes its ending to **ide**.

NB: ***one exception*** – Where negative ions are polyatomic ions, the name remains unchanged. Some elements with *more than one ion charge* use a roman numeral in its chemical name to clearly show which ion is being used. **Cu(II)SO_4** (Copper II Sulfate)

Using Ion Charges and Chemical Names To Write Formulas

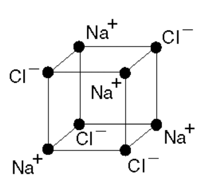
Step 1 – Print the metal element's name, symbol and ion charge, then the non-metals name, symbol and ion charge
Step 2 – Balance the ion charges (the positive ion must balance with the negative ion
Step 3 – Write the formula by indicating how many atoms of each element are in it.

Ca^{2+} Cl^{1-}
Ca^{2+} Cl^{1-} Cl^{1-}
$CaCl_2$

Ion Charges and the Periodic Table

Patterns:	**ion charge**
Alkali metals	1+
Halogens	1 -
Generally elements in a group all have the same ion charge (most consistency at either end of the table)	

All ionic compounds model ***distinct*** (different) ***crystal shapes***.



Chemical Reactions

- Chemical Reaction Movies (So Cool!)
- Examples of Chemical Reactions
- Cellular Respiration is a chemical reaction that takes place in the cells in your body.
- Animations of cellular respiration

A **chemical reaction** takes place when two or more substances combine to form new substances. Different types of chemical reactions can occur, including ***combination***, ***decomposition***, ***displacement*** and ***exchange*** reactions. The substances at the beginning of the reaction are called **reactants**. The new materials produced by the reaction are called **products**. Chemical reactions can be written as **word equations** which gives the names of all the reactants (separated by a "plus' sign +) followed by an arrow which points to the names of all the products (separated by a 'plus' sign +)

eg. (***iron + oxygen + water ---» rust***)

(***Iron plus oxygen plus water produces rust***)

Reactants -> Products

Although a chemical equation may look complicated, by knowing what you know now, it should be much easier to understand.

$$HC_2H_3O_{2(l)} + NaHCO_{3(g)} \rightarrow NaC_2H_3O_{2(aq)} + H_2O_{(l)} + CO_{2(g)}$$

(vinegar) (baking soda) (sodium acetate) (water) (carbon dioxide)

A **chemical change** results from a chemical reaction. Evidence that a chemical change has occurred include:

- A change on colour
- The formation of an odour
- The formation of a solid or a gas (bubbles)
- The release or absorption of energy
  - A chemical change, which **releases** energy, is called **EXOTHERMIC**.
  - A chemical change, which **absorbs** energy, is called **ENDOTHERMIC**

Chemical Reactions Involving Oxygen

Combustion is a chemical reaction that occurs when oxygen reacts with a substance to form a new substance and gives off energy.

Identification Tests:

- *f*or OXYGEN

Light a wooden splint. Blow out the flame, allowing the splint to continue glowing. Hold the glowing splint in a small amount of the unknown gas. If the splint bursts into flame, then the gas being tested is oxygen.

- for HYDROGEN

Light a wooden splint. Hold the glowing splint in a small amount of the unknown gas. If you hear a "**pop**", then the gas being tested is Hydrogen.

- for CARBON DIOXIDE

If you put a burning splint into Carbon Dioxide, the flame will go out and you will know the gas is not oxygen or hydrogen, but you will not know for sure that it is Carbon Dioxide. The test for Carbon Dioxide is not a combustion test, but rather uses a liquid called **limewater** (a clear colorless solution of calcium hydroxide, or slaked lime)Bubble the unknown gas through the limewater solution, or add a few drops of the limewater solution to the gas and swirl it around. If the limewater turns ***milky***, the gas is Carbon Dioxide

Breaking Chemical Bonds

Chemical bonds are forces that cause a group of atoms to behave as a unit. Energy is stored in these bonds. To break the bonds energy must be added. When bonds form, energy is released. All chemical reactions involve energy being absorbed ENDOTHERMIC**,** or released EXOTHERMIC. Photosynthesis is an endothermic reaction, because it needs light energy to occur, whereas combustion is an exothermic reaction, because it gives off light and heat.

Reaction Rate

The speed of a chemical reaction is called the **reaction rate**.

- **Temperature** of the reactants affects the rate of all reactions (The higher the temperature the faster the reaction rate)
- **Surface Area** of the reactants affects the reaction rate (The more surface in contact, the faster the reaction rate)
- **Concentration** of the reactants affects the reaction rate. (The higher the concentration, the faster the reaction rate)
- **The presence of a Catalyst** affects the reaction rate

Speeding Up a Reaction With Catalysts

A catalyst is a substance that help a reaction proceed faster and are not consumed in the reaction. Types of reactions involving catalysts can be found in living and non-living things. Enzymes are natural catalysts that help in the reactions in the body, which break down food. They also get rid of poison in the body. *Catalase* (an enzyme found in plant and animal cells) speeds up the breaking down of hydrogen peroxide into harmless oxygen and water.

Slowing Down a Reaction With Inhibitors

Inhibitors are substances that slow down chemical reactions. Plants have natural inhibitors in their seeds to prevent germination until the right conditions are present. Inhibitors are added to foods to slow down their decomposition.

Corrosion

Corrosion is a slow chemical change that occurs when oxygen in the air reacts with a metal. Corrosion is a chemical reaction in which the metal is decomposed (eaten away), when it reacts with other substances in the environment. The corrosion of iron is called '*rusting*'.

Many metals can corrode. The green roofs of the parliament buildings are an example of corrosion. The red-brown copper color is replaced with the green color because copper corrodes. Gold does not corrode. Solid solutions of metals (alloys) resist corrosion.

Preventing Corrosion

Corrosion protection (e.g. painting the metal) involves protecting metal from contact with the environment and the factors that affect the reaction rate of this chemical reaction. Coating a corrosive metal with a thin layer of zinc is called galvanization. The process of coating a corrosive metal with another metal through electrolysis (review p.110) is called electroplating.

Combustion

Combustion is the highly exothermic combination of a substance with oxygen. Combustion requires heat, oxygen, and fuel.

Products of Combustion

The burning of propane (C_3H_8) in a barbeque is an exothermic reaction that produces heat to cook the food. If the heat is too intense, the products being cooked will be changed into pure carbon (the meat will be burnt). The products of combustion are not always beneficial. Burning fossil fuels (such as propane) produces carbon monoxide, carbon dioxide, sulfur oxides, nitrogen oxides, smoke, soot, ash and heat. Some of these products are pollutants which will be covered in more detail in Environmental Chemistry – Unit C.

```
    H   H   H
    |   |   |
H – C – C – C – H
    |   |   |
    H   H   H
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(Propane C_3H_8)