MATTER AND CHEMICAL CHANGE

When you are finished this unit, you should be able to …
- become familiar with WHMIS and hazardous product symbols
- describe and categorize matter
- distinguish between physical and chemical change
- observe and describe patterns of chemical change
- identify subatomic particles and draw a model of the atom
- demonstrate an understanding of the Periodic Table
- interpret simple formulas and name compounds
- distinguish between ionic and molecular compounds

PREREQUISITE SKILLS AND KNOWLEDGE

Prior to beginning this unit, you should be able to …
- understand matter and how it is organized
- relate structure of the atom to the Periodic Table
- understand how to identify chemicals and use them safely
- write chemical formulas and equations and predict products
- identify matter by considering physical and chemical properties
- predict and hypothesize experimental results
- demonstrate knowledge of safe handling of materials
- analyze experimental data relating to chemical reactions

Lesson 1 CHEMISTRY AND SAFETY

Bronze is an alloy made from copper and tin.

The study of matter and chemical change is a branch of science called chemistry. The first chemists learned how to control fire to make bricks, tools, and cooking utensils. Later on, chemists became interested in metals such as copper, iron, tin, and gold. Chemists soon realized that copper and tin could be heated to make a strong alloy called bronze. Bronze is easily shaped into tools and ornaments. In the late 1700s, scientists like Lavoisier and Dalton studied chemical composition and worked on chemical combinations. Today, the basis of chemistry is explained in terms of atomic particles. Chemistry is an important part of everyday living.

Some chemicals are corrosive and caustic, others are flammable and explosive. Working with chemicals demands caution and safety. WHMIS (Workplace Hazardous Materials Information System) symbols are used throughout Canada to identify dangerous materials on job sites and in schools.

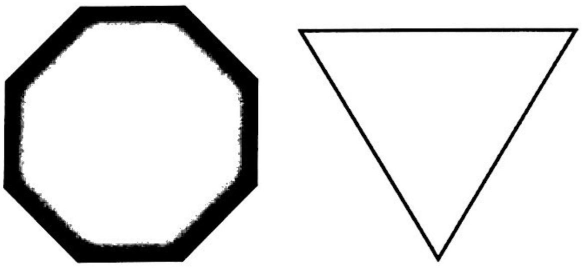
WHMIS: Workplace Hazardous Material Information System

WORKPLACE HAZARDOUS MATERIAL INFORMATION SYSTEM (WHMIS)

There are eight standard symbols that have been designed to advise people they must be careful in handling chemicals.

HAZARDOUS PRODUCT SYMBOLS

Many household products have hazard symbols on their containers. Each hazardous product symbol is enclosed either in a triangle, meaning caution, or an octagon, meaning danger.



Danger Caution

For example, these hazard symbols appear on a container of multi-purpose rust paint.

Anyone using this paint should take appropriate precautions because the product is:

- flammable
- poisonous
- explosive

MATERIAL SAFETY DATA SHEET (MSDS)

In Canada, all chemical substances must have a data sheet attached to them that identifies the physical properties, dangers, toxicity, first aid treatment, clean-up procedures, and the corresponding WHMIS symbols. It is important to become familiar with the properties and safety issues before handling any chemical. Below is an example of a Material Safety Data Sheet (MSDS).

MSDS: Material Safety Data Sheet

MSDS contains information on:

- physical properties
- reactivity
- toxicological properties
- preventative measures
- first aid

Material Safety Data Sheet

Section 1 – Product Information			
Product Name		Product ID #	
Product Use			
Manufacturer's Name		Supplier's Name	
Street Address		Street Address	
City	Prov.	City	Prov.
Postal code	Emergency telephone	Postal code	Emergency telephone

Section 2 – Hazardous Ingredients				
Hazardous Ingredients	%	CAS #	LC50	LD50

Section 3 – Physical Data				
Physical state	Odour and Appearance			Odour Threshold
Vapour pressure	Vapour density		Evaporation rate	Boiling point
Freezing point	pH	Specific gravity	Coefficient of water/oil distribution	

Section 4 – Fire and Explosion Data		
Flammability yes☐ no ☐ if yes, what conditions?		
Means of extinction	Flash point and method of determination	
Upper flammable limit	Lower flammable limit	Auto-ignition temperature
Hazardous combustion products		
Explosion data – mechanical impact	Explosion data – static discharge	

Lesson 2 MATTER

Matter: anything that has mass and occupies space

Matter is defined as anything that has **mass** and occupies **space**. Because rocks, water, and air have mass and occupy space, they are all considered matter. Matter is broken down into molecules, and molecules are further broken down into atoms. The basis of matter, therefore, is the atom.

PARTICLE THEORY

John Dalton proposed the Atomic Theory of Matter.

John Dalton, in 1808, proposed the Particle or Atomic Theory of Matter. He stated that:

- All matter is composed of tiny particles called atoms.
- Atoms of the same element are identical in mass and properties, and atoms of different elements have different masses and properties.
- Atoms unite chemically in specific proportions to produce new substances.

Scientists have now added to Dalton's Particle Theory (Atomic Theory) a number of additional points in an attempt to further explain the nature of matter.

The particles of matter are constantly moving and bouncing off each other. This is similar to billiard balls colliding with one another. The amount of movement and the number of collisions is dependent on the heat energy available.

Particles with opposite charges attract each other. Particles become positively charged by losing electrons and negatively charged by gaining electrons. These charged particles are referred to as *ions*. *Positive ions* combine with *negative ions* to form new substances.

Ions: charged particles

Temperature affects the movement of particles. When the temperature increases, the particles collide more frequently and with more force. They become spaced out. When the spaces become larger, the substance changes *state*. Ice becomes liquid water at 0°C and gaseous water vapour at 100°C.

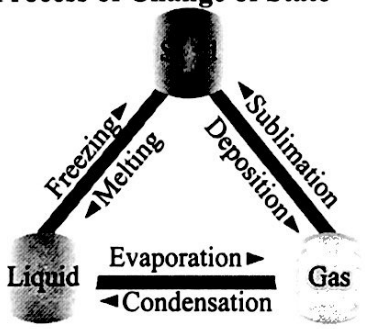
3 states of matter:

Solid

Liquid

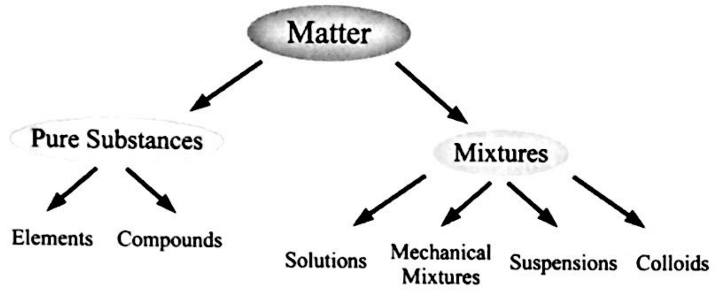
Gas

Process of Change of State



CLASSIFICATION OF MATTER

Scientists use common properties and characteristics to divide matter into subcategories. The relationship of these categories is shown in the chart below.



Pure substances are made up of identical particles with similar properties and include the subcategories elements and compounds.

An element is matter that consists of only *one kind of atom.* All elements are grouped into a special chart called the Periodic Table. Presently, there are 115 different elements.

A compound is matter that is made when two or more elements chemically unite in a specific ratio. Water is a compound made from two hydrogen atoms chemically bonded with one oxygen atom. There are thousands of different compounds.

Mixtures are combinations of pure substances, but in proportions that can vary. They are grouped into heterogeneous mixtures and homogeneous mixtures.

Heterogeneous mixtures have distinct visible particles, and include mechanical mixtures, suspensions, and colloids. Homogeneous mixtures appear as one phase and include all solutions.

A mechanical mixture has different particles that are visible to the eye. Soil, for example, has particles of humus, sand, leaves, and rock.

A suspension is a cloudy mixture with large floating particles. Mud is made up of dirt suspended in water.

A colloid is a cloudy mixture with very fine floating particles. Milk has cream particles suspended in the liquid.

A solution is a mixture made up of particles that dissolve in each other and appear to be the same throughout. A salt solution is a mixture of salt dissolved in water. It looks like ordinary water.

Matter is classified as pure substances or mixtures

Pure substances:
Elements
Compounds

Mixtures:
Heterogeneous:
– Colloids
– Suspensions
– Mechanical mixtures
Homogeneous:
– Solutions

Lesson 3 PHYSICAL AND CHEMICAL CHANGES

Matter can be identified by its physical and chemical properties. Oxygen, for example, is a colourless gas (physical property) that combines readily with iron (chemical property) to form rust.

PHYSICAL PROPERTIES

Physical properties are grouped into two categories:
Qualitative physical properties are those properties that can be identified through the senses. They include:

- Colour
- Taste
- Texture
- Smell
- Change in State
- Malleability (ability to be shaped)
- Ductility (ability to be stretched)

Qualitative Property: observed through the senses

Quantitative physical properties are those that require measurement. They include:

- Melting Point
- Boiling Point
- Density (mass / volume)
- Viscosity (flow rate)
- Solubility (dissolving rate)
- Conductivity (the ability for electricity to flow)

Quantitative Property: derived from measurement

The following physical properties identify aluminum.

- Silver in colour, solid at room temperature, soft metal, melting point: 660°C, boiling point: 2519°C, density: 2.7 g/cm^3

CHEMICAL PROPERTIES

Chemical property: describes how one substance interacts with another

A chemical property describes how one substance interacts with another substance. Chemical properties become evident when a change occurs. Alka-Seltzer dropped into a container of water bubbles or fizzes. There are 4 main indicators of a chemical change:

Precipitate: solid product formed in a chemical reaction

1. distinct colour change
2. release of energy usually in the form of light and heat
3. formation of a gas or solid (precipitate)
4. noticeable change in smell

When metallic magnesium is added to an acid solution, bubbling occurs (formation of a gas) and energy (heat) is released. A chemical change is occurring.

Lesson 4 ATOMIC STRUCTURE

NOTES

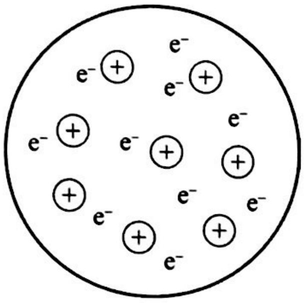
HISTORY

In 1808, Dalton proposed that all matter was made from tiny building blocks called atoms. Thomson followed up on the idea and, in 1898, proposed a model of the atom based on a sphere of positive charges in which electrons were embedded like "plums in a pudding."

Dalton: proposed that matter is made from atoms

Thomson: proposed that an atom had electrons

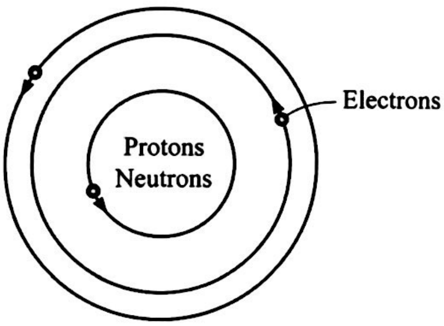
Thomson's Model



Rutherford took some of Thomson's ideas and, in 1911, did a number of experiments to show that atoms had a dense central nucleus. Chadwick, a short period later, discovered that the nucleus of an atom contained positively charged protons and "no charge" neutrons. Bohr took the three subatomic particles: electrons, protons, and neutrons and placed them into a model representing what he thought was the structure of a typical atom.

Rutherford: determined that an atom had a central nucleus

Bohr Atom



THE ATOM

The Bohr model of the atom is frequently used today to explain subatomic parts and their location. A typical atom consists of protons, electrons, and neutrons (remember the acronym PEN).

	Charge	Location	Size
Proton	Positive charge	Nucleus	Large
Electron	Negative charge	Orbits or electron cloud	Very small
Neutron	No charge	Nucleus	Large

Subatomic particles:
Proton
Electron
Neutron

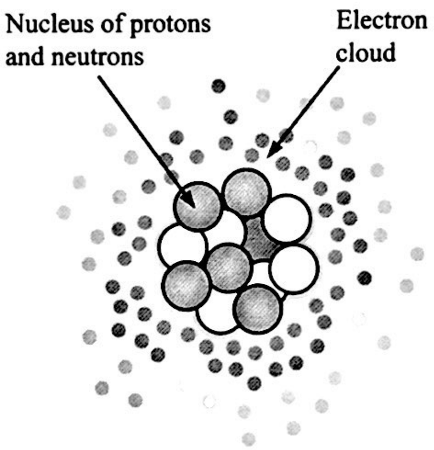
Protons and neutrons are about the same size and both are located in the nucleus. Protons and neutrons are stationary and generally do not leave the nucleus. Electrons are extremely small, about 1 837 times smaller than a proton or neutron. Electrons are in constant motion around the nucleus, just like planets move around the sun.

An electron is $\frac{1}{1\,837}$ the size of a proton.

Most of an atom is empty space (about 99 %) and most of its mass comes from protons and neutrons. Electrons are too small to make any difference in the mass of an atom. Electrons tend to zip around in orbits called energy levels. The first energy level near the nucleus holds a maximum of 2 electrons, the second energy level holds a maximum of 8 electrons, the third holds a maximum of 8 electrons, the fourth holds a maximum of 18 electrons, and the fifth, a maximum of 32 electrons.

Today, further research in the area of quantum mechanics proposes that electrons around the nucleus are not in orbits but exist as an electron cloud.

An atom is mostly empty space.



Bohr's representation of the atom had electrons in rings.

Most recent representation of the atom has electrons in a cloud.

Lesson 5 PERIODIC TABLE OF THE ELEMENTS

NOTES

Mendeleev, a Russian chemist, noticed that certain elements had similar properties. He grouped these elements together. As more elements were discovered and grouped together, a pattern developed. Eventually, Mendeleev was able to place 63 elements into a pattern of increasing atomic mass. Today, there are 115 different elements appearing on the Periodic Table. The first 92 elements are naturally occurring and are found somewhere in or on Earth. The remaining 23 elements are man-made.

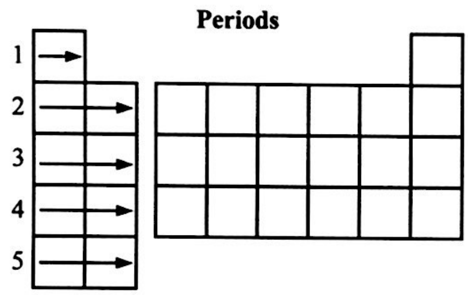
Mendeleev: father of the Periodic Table

WHAT PATTERN IS THE PERIODIC TABLE BASED ON?

The Periodic Table is a series of rows and columns. The horizontal rows are called periods and the vertical columns are called groups or families.

Elements placed in a *period* have the *same number of orbits* or *energy levels.*

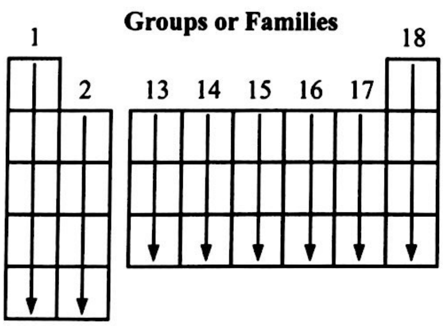
Periods: horizontal rows based on rings of electrons



Elements placed in the same *group* or *family* have similar *chemical properties.* Based on specific chemical properties, the groups or families have been given names:

- Alkali metals
- Alkali Earth metals
- Metalloids
- Non-metals
- Halogens
- Inert or noble gases

Groups (Families): vertical rows based on common chemical properties



NOTES

Metals: solids that appear on the left side of the table

Group 1: Alkali metals

Group 2: Alkali Earth metals

METALS

Metals appear on the left side of the Periodic Table. Most are shiny solids at room temperature and most conduct heat and electricity. Many are malleable (can be shaped) and some are ductile (can be stretched). Metals generally give up electrons to bond with non-metals. Sodium, magnesium, aluminum, and gold are examples of metals.

Metalloids: 8 elements that are intermediate between metals and non-metals

METALLOIDS

Metalloids are 8 elements located in a step-like pattern between the metals and non metals. Metalloids are brittle solids at room temperature. Some are shiny, some are dull. Some metalloids conduct electricity, others do not. Metalloids have properties between those of metals and non-metals. Silicon and arsenic are examples.

Non-metals: appear on the right side of the table

NON-METALS

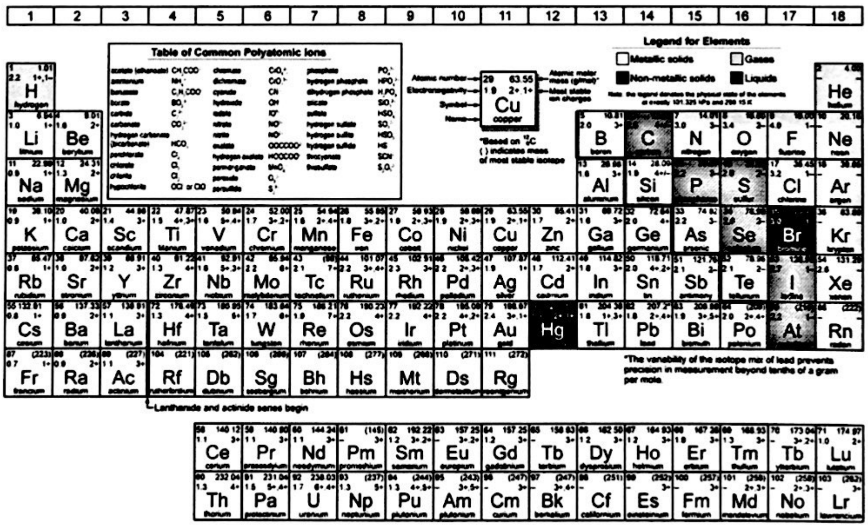
Non-metals appear on the right side of the Periodic Table. Some are solids (iodine, sulphur), many are gases (oxygen, chlorine) and bromine is a liquid (state is indicated by colour on the Periodic Table). Non-metals are usually dull in colour and are poor conductors of heat and electricity. Non-metals readily accept electrons and bond with metals to form compounds. Other examples of non-metals are phosphorous, nitrogen, and fluorine.

Halogens: Group 17 elements, including many gases

Halogens are non-metals that appear in Group 17 of the Periodic Table. At room temperature, fluorine and chlorine are gases, bromine is a liquid, and iodine is a solid.

Inert gases: Group 18 elements that are stable and non-reactive with other elements

Inert or **noble gases** are non-metals that appear in Group 18 of the Periodic Table. These elements are stable gases at room temperature and do not react with other elements.



NOTES

ARRANGEMENTS OF ELEMENTS

The Periodic Table represents a table of 115 elements. Because elements are made up of atoms, it is sometimes easier to represent each element listed in the table as an atom. Element 1 is represented as the hydrogen atom.

Each element (atom) is placed in a box with the following identifying information:

8 O oxygen 16.00

Name:	oxygen
Chemical symbol:	O
Atomic number:	8
Atomic mass:	16.0
Ion charge:	2^-

The **atomic number** indicates the number of protons in the nucleus. This is also the number of electrons in the energy levels. Oxygen has 8 protons and 8 electrons. The 8 positively charged protons match the 8 negatively charged electrons to form a **neutral atom.**

Atomic Number (A.N.): number of protons in the nucleus

The **atomic mass** refers to the total number of protons and neutrons in an atom. An atomic mass of 16 means that oxygen has 8 neutrons and 8 protons. *To determine the number of neutrons, simply subtract the atomic number from the atomic mass.*

Atomic Mass (A.M.): Sum of the protons and neutrons in the nucleus

Atomic Number = number of protons	**P**
= number of electrons	**E**
Atomic Mass – Atomic Number = number of neutrons	**N**

Try this: Use the information in the Periodic Table to draw a simplified Bohr atom for sodium.

Number of neutrons: A.M. – A.N.

Steps: Determine the number of protons, electrons, and neutrons in the sodium atom.

Sodium
Atomic Number 11 represents 11 protons and 11 electrons
Atomic Mass 23 and Atomic Number 11 represents 12 neutrons
P = 11 E = 11 N = 12

Place the protons and neutrons in the nucleus.

Place the electrons in energy levels or orbits outside the nucleus according to these rules:

- A maximum of 2 electrons in the first level or orbit
- A maximum of 8 electrons in the second level
- A maximum of 8 electrons in the third level

Maximum number of electrons for each energy level:

1st—2 electrons
2nd—8 electrons
3rd—8 electrons
4th—18 electrons

As each level fills up, the electrons must be placed in the next level.
The sodium atom has 3 levels: 2 electrons in the first, 8 in the second, and 1 in the third.

Sodium Atom

Lesson 6 CHEMICAL COMPOUNDS

Compounds are made from *different atoms* that are bonded together in a *definite pattern*. Two hydrogen atoms bond to one oxygen atom at an angle of 105° to form one molecule of the compound water. Chemical compounds are classified as **ionic** or **molecular.** This classification is based on the bonds that are formed between atoms or how they are joined together.

IONIC COMPOUNDS

Ionic compounds are made when metallic and non-metallic atoms develop a charge and bond with one another. These charged atoms are called *ions.* Why does the sodium atom develop an ion charge of 1^+ and chlorine atom, an ion charge of 1^-?

Ionic compound: formed when a metal bonds with a non-metal

Molecular compound: formed when atoms share electrons

For example, consider the compound NaCl.
Sodium has one electron in its last energy level. Because this electron is the farthest away from the attractive forces of the nucleus, it may be released from the atom. Remember, an electron is negatively charged. The neutral sodium atom has just lost a negative charge. It now becomes a positive ion and is represented as Na^+.

Metallic elements become positive ions — Na^+

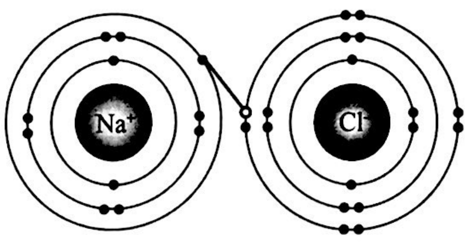
Chlorine has 7 electrons in its last energy level. For it to be stable and for it to form a compound with sodium, the chlorine atom must pick up the electron released by the sodium atom. In so doing, chlorine gains an extra negative charge. It becomes a negative ion and is represented as Cl^-.

Non-metallic elements become negative ions — Cl–

The positive sodium ion is attracted to the negative chlorine ion, just like the N pole of a magnet is attracted to the S pole of a magnet. Sodium ions unite with chlorine ions to form the compound sodium chloride,which is commonly known as table salt.

Positive ions attract negative ions to form compounds — $Na^+ + Cl^- = NaCl$

This formation can be illustrated with a Bohr model diagram.



CHARACTERISTICS OF IONIC COMPOUNDS

Ionic compounds conduct electricity when in solution with water.
Ionic compounds have a high boiling and melting point.
Ionic compounds have strong bonds holding the atoms together.
Ionic compounds are solids at room temperature.

POLYATOMIC IONS

Chlorine exists as a single atomic ion represented as Cl^-. Some ions are made up of several different atoms, usually non-metals, joined together.

NOTES

These are called polyatomic ions. Polyatomic ions are a group of elements with a charge. Some of the more common polyatomic ions are:

Polyatomic ions: charged groups of elements
$(CO_3)^{2-}$
$(PO_4)^{3-}$

Hydroxide	$(OH)^{-}$
Sulfate	$(SO_4)^{2-}$
Phosphate	$(PO_4)^{3-}$
Nitrate	$(NO_3)^{-}$
Carbonate	$(CO_3)^{2-}$

Most polyatomic ions are positively charged.

One polyatomic ions acts like a metal and has a positive charge.

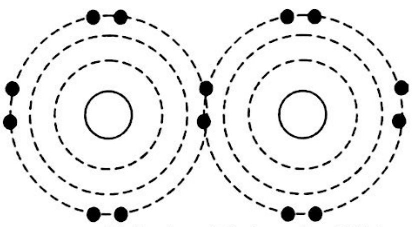
Ammonium	$(NH_4)^{+}$

Molecular compound: formed by non-metal elements sharing outer ring electrons

MOLECULAR COMPOUNDS (OFTEN CALLED COVALENT COMPOUNDS)

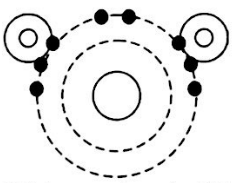
Instead of gaining or losing electrons as ionic compounds do, molecular compounds share electrons. They share electrons in such a way as to complete their outer orbits. That means a total of 2 electrons if shared in the first orbit, or 8 electrons if shared in the second orbit.

For example, consider chlorine gas as a molecular compound. Chlorine has 7 electrons in the outer energy level. Two chlorine atoms share one outer ring electron. By sharing this electron, each atom has a stable 8 electrons in the outer ring.



Chlorine Molecule (Cl_2)

Hydrogen and oxygen atoms share electrons. Each atom now has a stable 2 or 8 electrons in its last ring.



Water molecule (H_2O)

Characteristics of molecular compounds:

1. Molecular compounds tend to be good insulators. They do not conduct electricity.
2. Molecular compounds have low melting and boiling points.
3. Molecular compounds have weak bonding forces.
4. Molecular compounds can be solids, liquids, or gases at room temperature.

Lesson 7 WRITING CHEMICAL FORMULAS AND NAMING COMPOUNDS

When atoms are bonded together, they form substances that can be represented by a chemical formula.

NOTES

For example:
CO_2

Subscript: in a chemical formula, it refers to the number of atoms in an element

Two atoms of oxygen are indicated by the number 2 written to the right of oxygen and slightly below the line. This number is called a subscript. The carbon atom could have a subscript 1 to its right, but this is not necessary when a substance has only one such atom.

Al_2O_3
Aluminum oxide has 2 atoms of aluminum (subscript 2) and 3 atoms of oxygen (subscript 3).

(OH): hydroxyl grouping

$Ca(OH)_2$ is calcium hydroxide

$CaSO_4$: calcium sulphate, has 3 elements and has a total of 6 elements

In summary:
- carbon dioxide is made from 2 elements (carbon, oxygen) and has a total of 3 atoms (1 carbon, 2 oxygen)
- aluminum oxide is made from 2 elements (aluminum, oxygen) and has a total of 5 atoms (2 aluminum, 3 oxygen)

What about the case of a molecule made from a metallic ion and a *polyatomic* non-metallic ion?

For example:
- Calcium carbonate has the formula $CaCO_3$. One molecule of calcium carbonate is made up of 1 calcium atom, 1 carbon atom, and 3 oxygen atoms, for a total of 5 atoms.
- Magnesium hydroxide has the formula $Mg(OH)_2$. One molecule of magnesium hydroxide has 1 magnesium atom, 2 oxygen atoms, and 2 hydrogen atoms, for a total of 5 atoms.

Important Point: The subscript 2 that appears after the (OH) grouping doubles the atoms within the grouping; i.e., there are 2 atoms of oxygen and 2 atoms of hydrogen.

When two atoms of the same element bond, they form a diatomic molecule. Generally, these molecules are gases at room temperature. Examples of diatomic molecules are:
- oxygen gas—O_2
- hydrogen gas—H_2
- nitrogen gas—N_2
- chlorine gas—F_2

Diatomic molecule: exists as 2 identical atoms that are bonded together, such as

Cl_2 O_2 N_2

Oxygen gas is a diatomic molecule.

Most diatomic molecules are gases.

Some metallic elements may have 2 different charges, such as

Iron(II) Fe^{++} Iron(III) Fe^{+++}

When ionic atoms combine to form a compound, the charge must balance:

$Na^+ + F^- \rightarrow NaF$
$2Na^+ + S^{--} \rightarrow Na_2S$

Compounds made from two elements have an "ide" ending.

Occasionally, a metallic ion has 2 different charges. The iron ion can be a +2 charge or a +3 charge. To show which iron ion bonds with oxygen, a Roman numeral is added.

Iron(II) oxide	FeO (Fe^{2+})
Iron(III) oxide	Fe_2O_3 (Fe^{3+})

Important Fact: A formula ending in "ide" is made up of two different atoms.

IONIC COMPOUNDS

When writing the chemical formula for ionic substances, follow these steps:

- place the ion symbol and charge of the metal to the left
- place the ion symbol and charge of the non-metal to the right
- balance the ion charges
- write the formula using subscripts
- compounds made from 2 elements have an "ide" ending

Sodium chloride	
Sodium	Chlorine
Na^+	Cl^-
$NaCl$	
Sodium oxide	
Sodium	Oxygen
$Na^+ \rightarrow 2Na^+$	$O^{--}O^{--}$
Na_2O	
Copper(II) chloride	
Copper(II)	Chlorine
$Cu^{++} \rightarrow Cu^{++}$	$2Cl \leftarrow Cl^-$
$CuCl_2$	
Copper(II) nitrate	
Copper(II)	Nitrate
Cu^{++}	$(NO_3)^-$
$Cu(NO^3)_2$	

MOLECULAR COMPOUNDS

Molecular compounds are formed by *non-metallic* elements sharing electrons. Writing molecular formulas is not as predictable as writing ionic formulas. Prefixes representing the number of atoms are often used.

Number of Atoms	Prefix
1	mono
2	di
3	tri
4	tetra
5	penta
6	hexa

Molecular compounds have prefix names:

N_2O_4 = <u>di</u>nitrogen <u>tetra</u>oxide

If the **first** element in a formula has one atom, the prefix "mono" is not used.

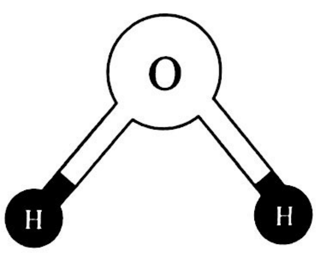
- Carbon dioxide has 1 atom of carbon and 2 atoms (di) of oxygen. Formula: CO_2
- Carbon monoxide has 1 atom of carbon and 1 atom (mono) of oxygen. Formula: CO
- Dinitrogen trioxide has 2 atoms of nitrogen (di) and 3 atoms of oxygen (tri). Formula: N_2O_3

NAMING MOLECULAR COMPOUNDS

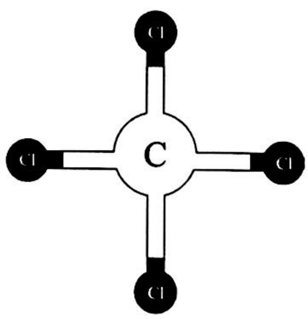
Follow these steps in naming molecular compounds:

- use the name of the first element in the compound
- use the name of the second element but end it with the suffix "ide".
- when there is more than one atom, use the specific prefix that denotes that number
  - Water H_2O dihydrogen oxide
  - Air Pollutant SO_2 sulfur dioxide
  - Cleaning Agent CCl_4 carbon tetrachloride

Molecular compounds are easier to illustrate than are ionic compounds. Below are the model illustrations for water and carbon tetrachloride.



Water



Carbon tetrachloride

Lesson 8 CHEMICAL REACTIONS

Reactants: starting materials in a reaction

Products: end materials in a reaction

Chemical equations are written in the form:

Reactants → Products

The **Law of Conservation of Mass** states that the total mass on the product side = the total mass on the reactant side

A chemical reaction occurs when materials react with one another to produce entirely different materials. The starting materials are called **reactants** and the end materials are the **products**.

When hydrochloric acid is added to sodium hydroxide (reactants), sodium chloride and water (products) are produced.

All chemical reactions must conform to the Law of Conservation of Mass, which states that:

The total mass of the products is equal to the total mass of the reactants.

If 100 g of hydrochloric acid is added to 100 g of sodium hydroxide, one would expect 200 g of product to be produced. It would be difficult to predict the exact proportions of sodium chloride and water that make up the 200 g.

When methane gas is burned in air, carbon dioxide gas and water vapor is produced, along with heat and light energy. This reaction can be written in the form of an equation.

Word Equation:

methane + oxygen gas → carbon dioxide + water + heat energy

Symbol Equation:

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O + \text{heat}$$

Quick Check

Total number of atoms in the REACTANTS		Total number of atoms in the PRODUCTS
5 + 4	=	3 + 6
9	=	9

$2O_2$ means O_2 is doubled. (2 × 2 atoms)
$2H_2O$ means H_2O is doubled. (2 × 3 atoms)

This reaction conforms to the Law of Conservation of Mass.

Chemical reactions are classified according to whether they release energy or absorb energy.

NOTES

Exothermic reaction: releases heat energy

Endothermic reaction: absorbs heat energy

Oxidation reaction: uses oxygen from the air

Oxidation reactions can be grouped as combustion, corrosion, and cellular respiration.

EXOTHERMIC REACTIONS

Exothermic reactions release heat. The burning of methane gas or wood releases energy in the form of heat and light.

ENDOTHERMIC REACTIONS

Endothermic reactions absorb energy. A cold pack is triggered by a chemical reaction that absorbs heat from its surroundings. If placed on an injured hand, the reaction triggered in the cold pack absorbs heat from the skin. This cools the area to reduce swelling.

OXIDATION REACTIONS

Oxidation reactions are those involving oxygen. They can be of three types: combustion, corrosion, and cellular respiration.

Combustion Reaction

All combustion reactions require oxygen as a fuel. Fire is the most common combustion reaction. Combustion reactions produce carbon dioxide gas, water, and energy. The burning of propane fuel is a combustion reaction.

$$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4\ H_2O + \text{heat}$$

Corrosion Reaction

Corrosion is a slow oxidation reaction that occurs when a metal reacts with oxygen. Rusting is an example. Iron combines with oxygen to form iron oxide (rust).

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

Cellular Respiration

Cellular respiration takes place in body cells. Food (glucose) reacts with oxygen to produce carbon dioxide, water, and energy.

$$C_6H_{12}O_6 + 6O_2 \rightarrow CO_2 + 6H_2O + \text{energy}$$

This chemical reaction gives us energy to do daily activities.

Lesson 9 CHEMICAL REACTION RATES

NOTES

The rate of a chemical reaction is affected by:

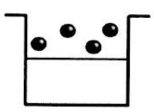
—temperature
—surface area
—concentration
—catalyst

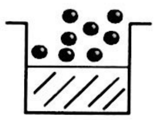
A catalyst speeds up a reaction but is not consumed in one.

Chemical reactions occur when particles collide with other particles. The collisions can be slowed down or speeded up. The rate at which these collisions occur is dependent on four factors.

TEMPERATURE

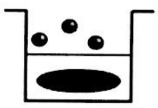
Increasing the temperature of the reactants speeds up a chemical reaction. Similarly, decreasing the temperature slows it down. Temperature affects the number of collisions between reactant particles. As the temperature increases, the number of collisions increases. More collisions results in a faster rate of reaction. Baking soda reacts more vigorously with warm vinegar than cold vinegar.

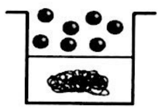

20°C


80°C

SURFACE AREA

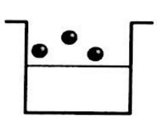
Increasing the surface area of reactants speeds up a chemical reaction. A greater surface area means more particle collisions. More collisions results in a higher rate of reaction. A **crushed** Alka-Seltzer tablet reacts faster with water than a **solid** piece of the same sized tablet does.

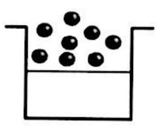




CONCENTRATION

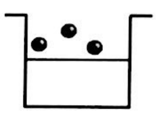
A concentrated substance reacts more quickly than a dilute substance does. A concentrated substance has more particles, which means more collisions. A concentrated hydrochloric solution reacts more quickly with magnesium than a weak solution does.

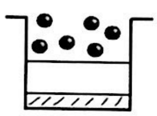

dilute


concentrated

CATALYST

A catalyst is a substance that speeds up or slows down a chemical reaction. A catalyst is not consumed by a reaction; it remains unchanged. The body produces enzymes to help digest food. Carbohydrate digestion is aided by the enzyme amylase which acts as a catalyst to speed up the digestive process.


No catalyst


Catalyst

REVIEW SUMMARY

- Matter has mass and occupies space. It is generally grouped into pure substances (elements, compounds) and mixtures (solutions, mechanical mixtures, colloids, suspensions.) All forms of matter have physical and chemical differences. Water, for example, is a pure compound that is distinguished by its clear colour, 100°C boiling point, and its violent reaction with sodium metal.
- Safety becomes an issue when working with chemicals. Proper handling and storage of chemical substances must follow WHMIS and product safety guidelines. For example, a spray paint container may have the WHMIS symbol for compressed gas () and the product symbol for poisonous ()
- An atom, the basis of all matter, is the smallest part of matter that can exist by itself. Three subatomic particles, *electrons*, *protons,* and *neutrons*, give an atom its properties. Protons and neutrons remain stationary within the nucleus of an atom while electrons revolve around the nucleus. The element aluminum has an atomic number of 13 and an atomic mass unit of 27. This means that the aluminum atom has 13 protons, 13 electrons, and 14 neutrons.
- All naturally occurring and man-made elements are grouped together in the Periodic Table. Mendeleev determined the groupings according to similarities in properties and placed the elements in family and period groupings. Metals are placed on the left side, non-metals toward the right side, metalloids between the metals and non-metals, and the inert gases appear on the extreme right.
- Electrons are the basis of all chemical reactions and are responsible for forming new compounds. Electrons are transferred or shared to make ionic and molecular compounds. Metal atoms combine with non-metal atoms to produce ionic compounds.
- Often, 2 non-metallic atoms share electrons. Sulfur and oxygen share electrons to form the molecular compound sulfur dioxide.
- Chemical compounds react with each other to form new substances. The mass of the starting materials (reactants) is always equal to the material formed (products). This is referred to as the Law of Conservation of Mass.
- Chemical reactions are written in word and symbol equations. For example, the reaction of hydrogen gas with oxygen gas to form water can be written as:

  – hydrogen gas + oxygen gas → Water **OR** $2H_2 + O_2 \rightarrow 2H_2O$
- Some reactions occur very slowly, while others occur rapidly. The rate at which a chemical reaction occurs is affected by *surface area*, *concentration*, and *temperature*.
- Some reactions release energy in the form of heat and light (exothermic) while other reactions require energy to get started (endothermic). All oxidation reactions require oxygen. Corrosion, respirations and combustion are examples of oxidation reactions.