Scientific Method

- Steps in the scientific method include:
  - Asking a question
  - Conducting background research
  - Developing a hypothesis
  - Designing and conducting an experiment
  - Collecting and analyzing data
  - Developing conclusions
  - Communicating findings
- A **control** is treated as the experimental condition and is not manipulated.
- The **independent variable** is manipulated.
- The **dependent variable** is what the experimenter is measuring.
- **Constants** are variables in an experiment that are not being tested or measured and should, therefore, remain constant throughout the experiment.

Observations can be made using your senses or instruments.

Inferences are logical conclusions based on observations.

MASS AND WEIGHT

What is the difference between mass and weight?

Mass is the **amount of matter** in a given substance and is measured using grams.
Weight is a **measure of the force due to gravity** acting on a mass and is measured in newtons.

- **Mass** is the measure of matter, or "stuff," in an object.
- **Mass** is measured by a **balance**. It is typically expressed in **kilograms or grams**.
- **Weight** is a measure of the force of gravity acting on a mass.
- **Weight** is measured with a **spring scale**. It is typically expressed in **pounds or newtons**.

MATTER

Matter is anything that has **mass** and **takes up space**.

Density is a measure of mass per volume. The average **density** of an object equals its total mass divided by its total volume (d=M/V). An object made from a comparatively dense material (such as iron) will have less volume than an object of equal mass made from some less dense substance (such as water)

Mass is the **amount of matter** (how much stuff) an object contains. The mass of an object will not change if the force of gravity on it changes. For mass, the SI unit is kilogram (kg). The mass of an object is equal to the volume multiplied by the density ($M = Vd$)

Volume is the **amount of space** that matter occupies. Common units of measurement for volume include cm^3, liter (L), and milliliter (mL). The volume of an object is equal to the mass divided by the density ($V = M/d$)

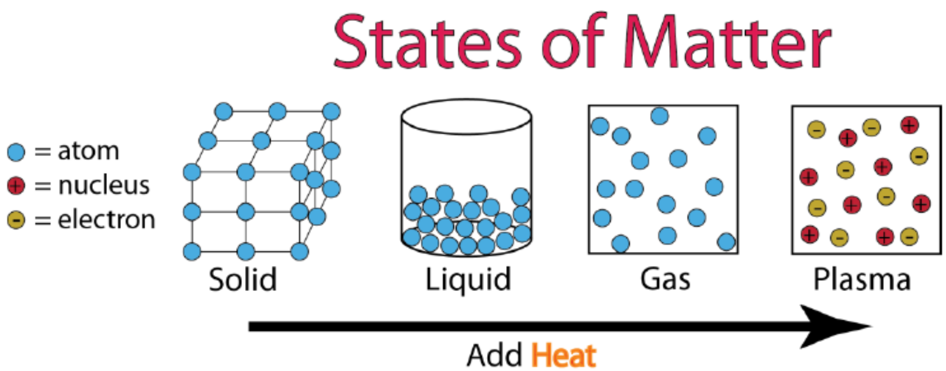
Thermal Expansion- Most matter expands when heated and contracts when cooled. The average kinetic energy of the particles increases when matter is heated and this increase in motion increases the average distance between its atoms.

Matter is made of smaller particles. **Elements** are smaller particles of matter, made of **one kind of atom** that cannot be broken down into other substances by chemical or physical means. **Atoms** are the **smallest units of an element** that has the properties of that element. Atoms are made of subatomic particles (protons, neutrons, and electrons):

PARTICLE THEORY OF MATTER

- All matter is made up of tiny particles called atoms.
- Particles of matter are constantly in motion.
- Particles of matter attract each other.
- Particles of matter have spaces between them.
- As temperature increases, particles of matter move faster.
- Atoms of the same element are essentially identical.
- Atoms of different elements are different.

STATES OF MATTER



	Solids	Liquids	Gases
Arrangement	Tightly Compacted	Close together	Occupy all the space available
Movement	Vibrate back and forth	Slide past one another	Move freely at high speeds
Shape/Volume	Definite shape & volume	No definite shape, definite volume	No definite shape or volume

Matter can be classified as:

- Elements
- Compounds
- Mixtures

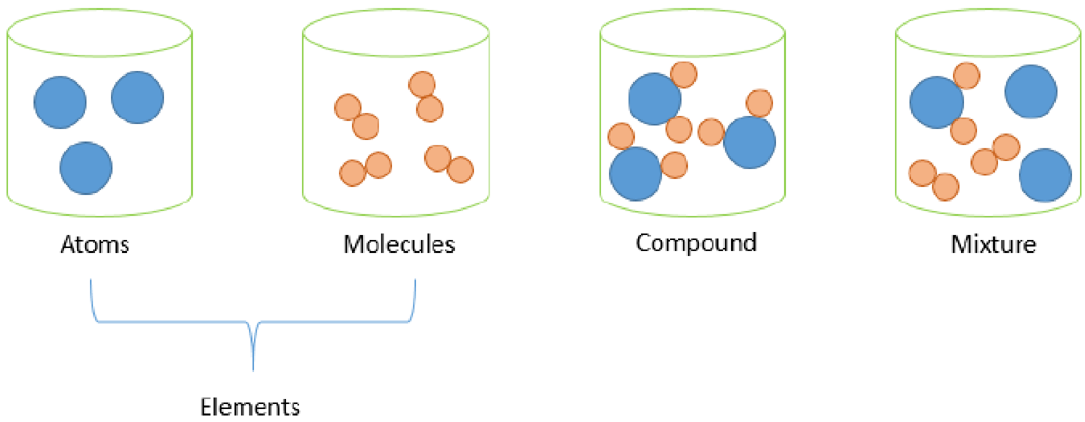
The atoms of any **element** are alike but are different from atoms of other elements.

Compounds consist of **two or more elements** that are **chemically combined** in a fixed ratio.

Mixtures also consist of **two or more substances**, but the substances are **not chemically combined**.

How can you determine whether a substance is an element, compound or mixture?

- An element contains just one type of atom
- A compound contains two or more types of atom joined together
- A mixture contains two or more different substances that are not joined together
- The different substances in a mixture can be elements or compounds



Matter can be described by its <u>physical properties</u> (properties of matter which can be perceived or observed **without changing the chemical identity** of the sample)**:**

Physical Property	Description
Shape	External form or appearance characteristic; the outline of an area or figure:
Density	Mass per unit volume of an object (D = M/V)
Solubility	Ability to dissolve
Odor	Fragrance
Melting point	Temperature at which it changes state from solid to liquid
Boiling point	Temperature at which a liquid boils and turns to vapor.
Color	Byproduct of the spectrum of light, as it is reflected or absorbed, as received by the human eye

Matter can also be described by its **<u>chemical properties</u> (properties** of matter that may only be observed and measured by performing a **chemical change** or **chemical** reaction):

Chemical Property	Description
Acidity	The level of acid in substances
Basicity	**Condition of being a base**
Combustibility	Capable of catching fire and burning
Reactivity	The rate at which a chemical substance tends to undergo a chemical **reaction**

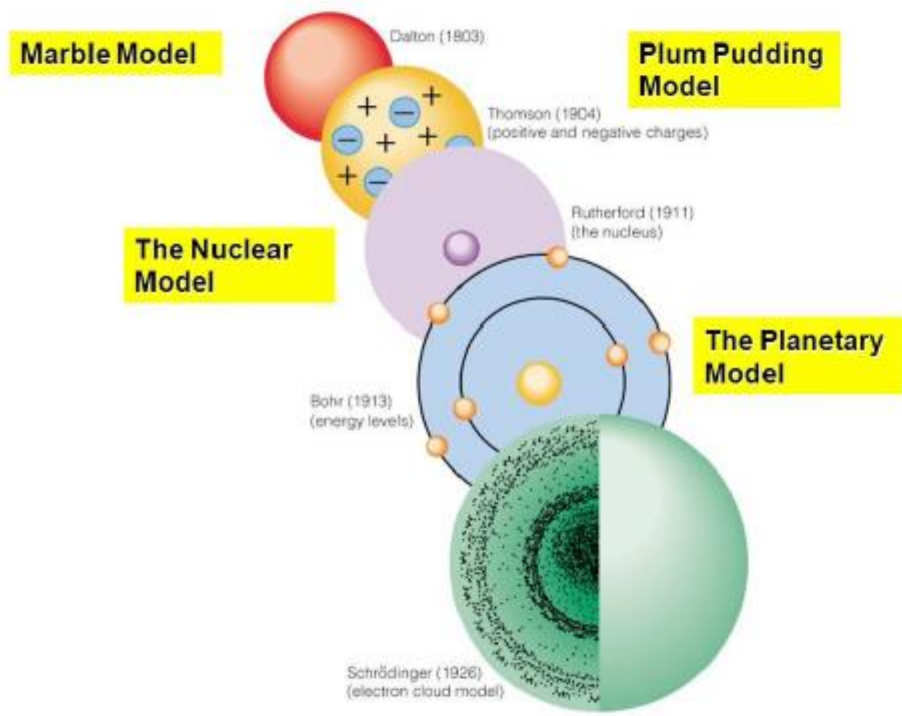
CHANGES IN MATTER

Types of Changes	Description	Examples
Physical	Physical changes, the chemical composition of the substances does not change.	• Energy stored in the Any phase change • Grinding something into powder
Chemical	Different substances are formed	• Iron rusting • Gasoline burning
Nuclear	Energy stored in the nucleus of an atom.	• Joining nuclei together (fusion) • Splitting nuclei (fission),

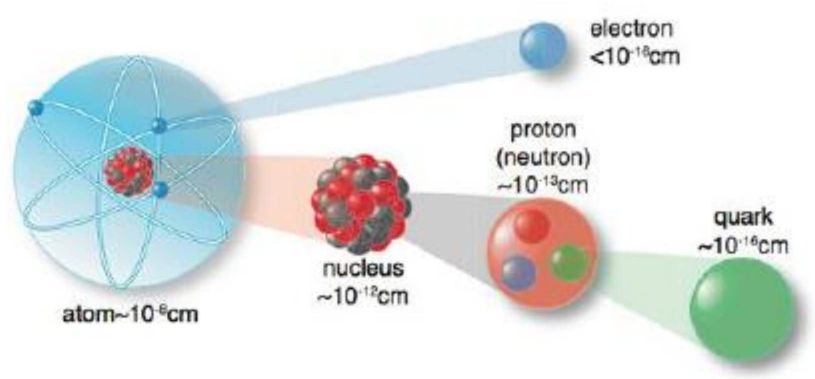
Gas Laws:

- **Boyle's law**: If temperature is constant, pressure and volume are inversely proportional.
- **Charles's law**: If pressure is constant, temperature and volume are directly proportional.
- **The combined gas law**: states that the ratio between the pressure-volume product and the temperature of a system remains constant.

HISTORICAL DEVELOPMENT OF THE ATOM



MODERN MODEL OF ATOM



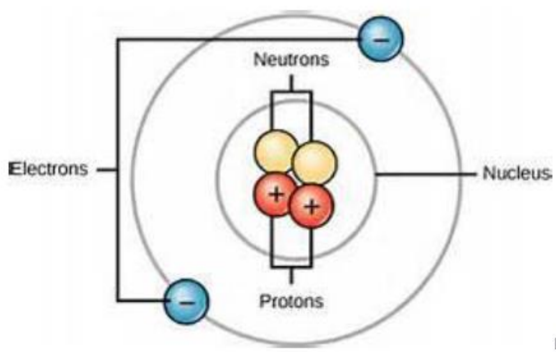


Image Source: voer.edu.vn

John Dalton, a scientist, is known for his "Atomic Theory". Here are Dalton's main conclusions which still hold true until today:

- Atoms can't be broken into smaller pieces. Atoms are indivisible.
- In any element, all the atoms are exactly alike.
- Atoms of different elements are different.
- Atoms of two or more elements can combine to form compounds.
- Atoms of each element have a unique mass.
- The masses of the elements in a compound are always in a constant ratio

Elements

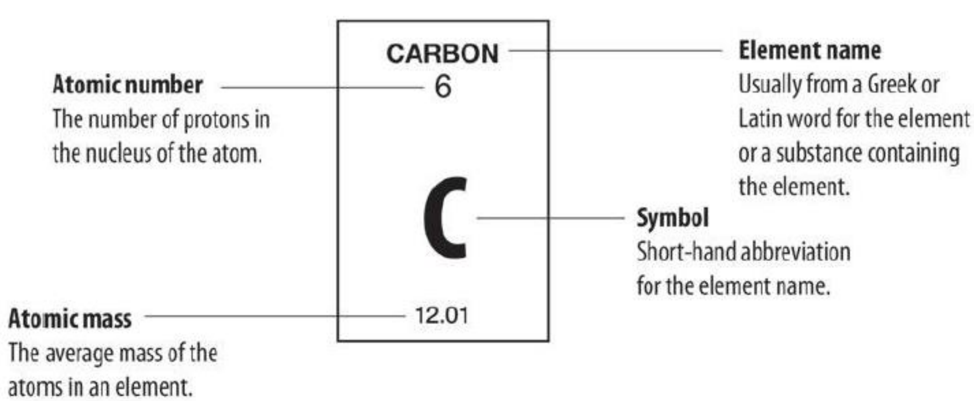


Image Source: Middle School Chemistry.com

Chemical symbols are abbreviations used to represent over 100 known elements. Chemical symbols use one or two letters. The first letter is always capitalized and the second, if there is one, is always lowercase. Usually these are the first two letters of the element's name but this is not always possible, because it would sometimes cause the same letter(s) to be used more than once.

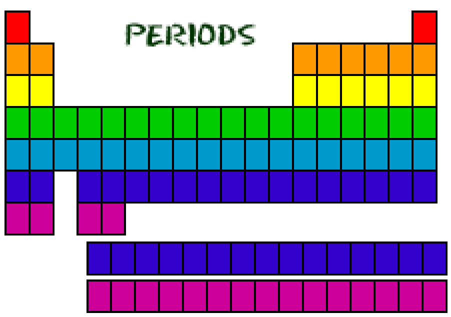
ORGANIZATION OF PERIODIC TABLE

The Russian scientist Dmitri Mendeleev discovered a set of patterns in the properties of the elements. He noticed that a pattern of properties appeared when he arranged the elements in order of increasing atomic mass. The **atomic mass** of an element is the average mass of all the isotopes of that element. After protons were discovered, elements were **rearranged according to atomic number**.

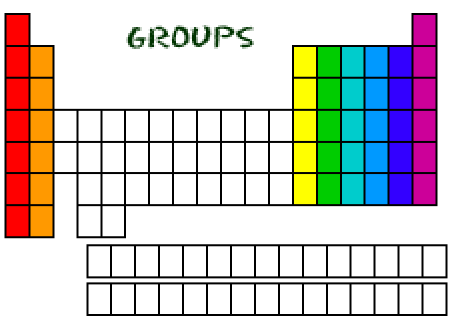
The Periodic Table: *The* **periodic table** *is a chart of the elements arranged into rows and columns according to their physical and chemical properties.*

Each **element** is placed in a specific location because of its atomic structure. The periodic table has rows (left to right) and columns (up and down). Each row and column has specific characteristics.

All of the rows read left to right. Each row is called a **period**. All of the elements in a period have the same number of **atomic orbitals**. For example, every element in the top row (the first period) has one orbital for its **electrons**.



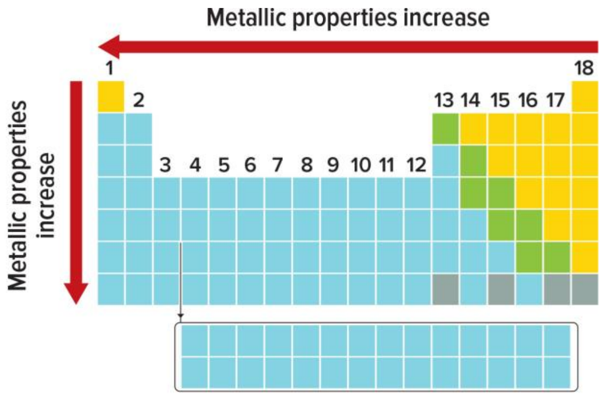
Each column is called a **group or family**. The elements in each group have the same number of electrons in the outer **orbital**. Those outer electrons are also called **valence electrons**. They are the electrons involved in chemical bonds with other elements.



The family name of a group is typically the name of the first element in the column. Elements in each group have similar characteristics.

Patterns in Properties of Metals

Recall that the properties of elements follow repeating patterns across the periods of the periodic table. In general, elements increase in metallic properties such as luster, malleability, and electrical conductivity from right to left across a period.



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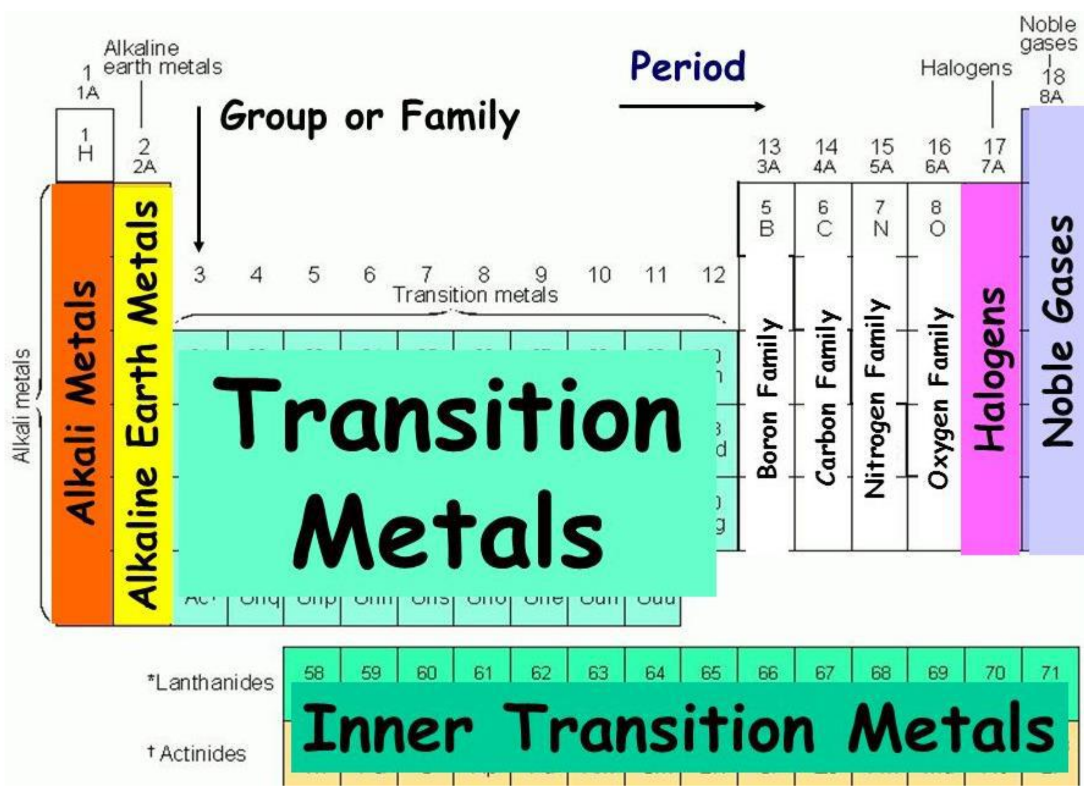
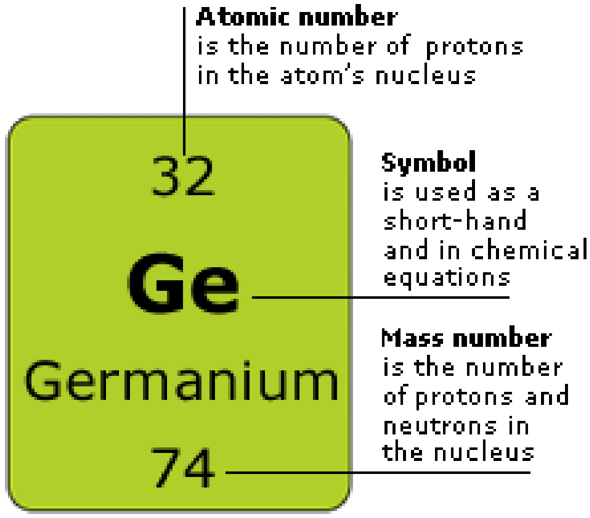


Hydrogen (H) and helium (He) are special elements. **Hydrogen** can have the electron traits of two groups: one and seven. **Helium** (He) is different from all of the other elements. It is very stable with only two electrons in its outer orbital (valence shell). Even though it only has two, it is still grouped with the **noble gases** that have eight electrons in their outermost orbitals. The noble gases and helium are all "happy," because their valence shell is full.

Modified Source: http://www.chem4kids.com/files/elem_pertable.html



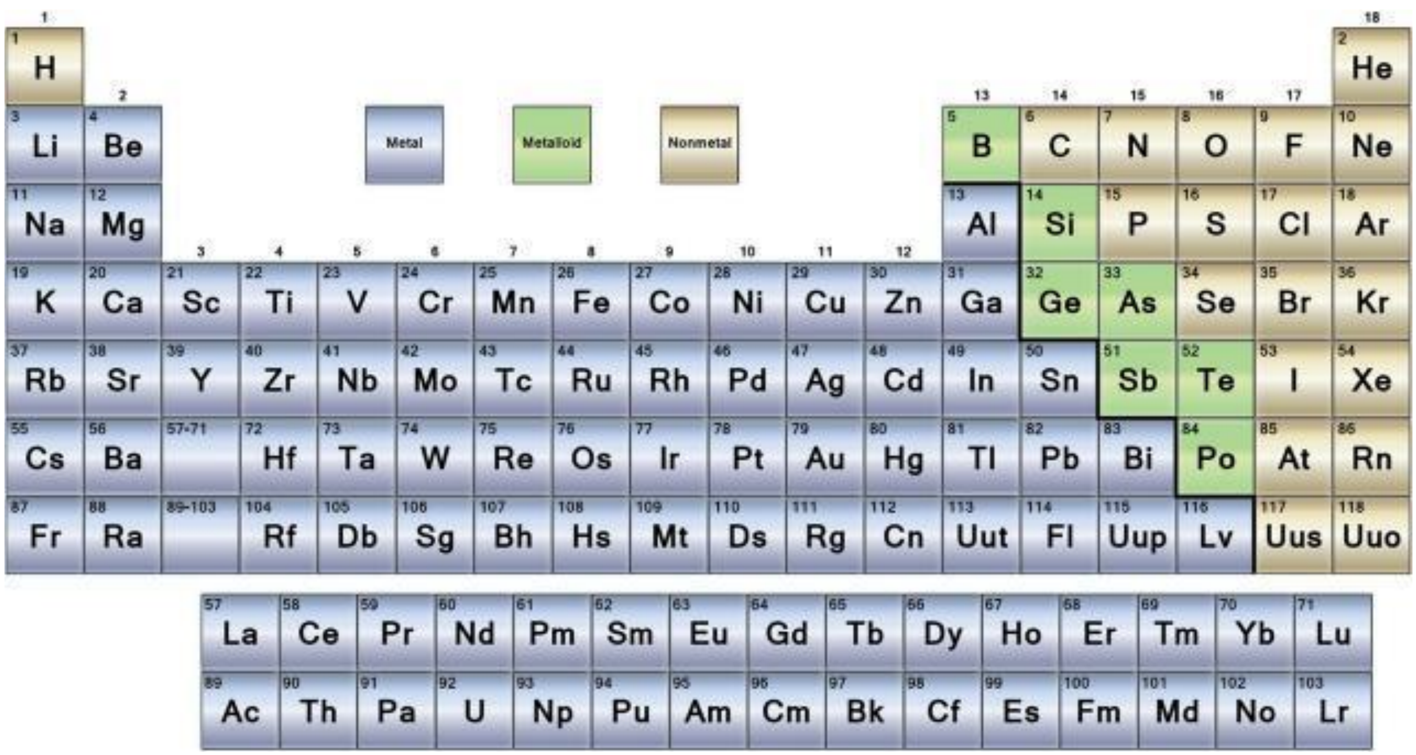
Atomic Number = number of protons or number of electrons

Atomic Mass = Atomic Number/Number of Protons/Number of Electrons – Number of Neutrons

Elements of the periodic table are grouped as metals, metalloids or semimetals, and nonmetals. The metalloids separate the metals and nonmetals on a periodic table. Also, many periodic table have a stair-step line on the table identifying the element groups. The line begins at boron (B) and extends down to polonium (Po). Elements to the left of the line are considered *metals*. Elements just to the right of the line exhibit properties of both metals and nonmetals and are termed *metalloids* or *semimetals*.

Elements to the far right of the periodic table are *nonmetals*. The exception is hydrogen (H), the first element on the periodic table. At ordinary temperatures and pressures, hydrogen behaves as a nonmetal.

Properties of Metals	Properties of Metalloids or Semimetals	Properties of Nonmetals
• usually solid at room temperature (mercury is an exception) • high luster (shiny) • metallic appearance • good conductors of heat and electricity • malleable (can be bent and pounded into thin sheets) • ductile (can be drawn into wire)	• dull or shiny • usually conduct heat and electricity, though not as well as metals • often make good semiconductors • often ductile • often malleable	• dull appearance • usually brittle • poor conductors of heat and electricity



Periodic Table of the Elements
For Assessments Based on the 2010 Chemistry Standards of Learning

Periodic Table of the Elements

Atomic mass — 28.0855
Symbol — Si
Atomic number — 14
Name — Silicon

Transition Elements (Groups 3–12)

Period	Group 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1.00794 **H** 1 Hydrogen																	4.00260 **He** 2 Helium
2	6.941 **Li** 3 Lithium	9.01218 **Be** 4 Beryllium											10.81 **B** 5 Boron	12.0111 **C** 6 Carbon	14.0067 **N** 7 Nitrogen	15.9994 **O** 8 Oxygen	18.998403 **F** 9 Fluorine	20.179 **Ne** 10 Neon
3	22.98977 **Na** 11 Sodium	24.305 **Mg** 12 Magnesium											26.98154 **Al** 13 Aluminum	28.0855 **Si** 14 Silicon	30.97376 **P** 15 Phosphorus	32.06 **S** 16 Sulfur	35.453 **Cl** 17 Chlorine	39.948 **Ar** 18 Argon
4	39.0983 **K** 19 Potassium	40.08 **Ca** 20 Calcium	44.9559 **Sc** 21 Scandium	47.88 **Ti** 22 Titanium	50.9415 **V** 23 Vanadium	51.996 **Cr** 24 Chromium	54.9380 **Mn** 25 Manganese	55.847 **Fe** 26 Iron	58.9332 **Co** 27 Cobalt	58.69 **Ni** 28 Nickel	63.546 **Cu** 29 Copper	65.39 **Zn** 30 Zinc	69.72 **Ga** 31 Gallium	72.58 **Ge** 32 Germanium	74.9216 **As** 33 Arsenic	78.96 **Se** 34 Selenium	79.904 **Br** 35 Bromine	83.80 **Kr** 36 Krypton
5	85.4678 **Rb** 37 Rubidium	87.62 **Sr** 38 Strontium	88.9059 **Y** 39 Yttrium	91.224 **Zr** 40 Zirconium	92.9064 **Nb** 41 Niobium	95.94 **Mo** 42 Molybdenum	(98) **Tc** 43 Technetium	101.07 **Ru** 44 Ruthenium	102.906 **Rh** 45 Rhodium	106.42 **Pd** 46 Palladium	107.868 **Ag** 47 Silver	112.41 **Cd** 48 Cadmium	114.82 **In** 49 Indium	118.71 **Sn** 50 Tin	121.75 **Sb** 51 Antimony	127.60 **Te** 52 Tellurium	126.905 **I** 53 Iodine	131.29 **Xe** 54 Xenon
6	132.905 **Cs** 55 Cesium	137.33 **Ba** 56 Barium	138.906 **La** 57 Lanthanum	178.49 **Hf** 72 Hafnium	180.948 **Ta** 73 Tantalum	183.85 **W** 74 Tungsten	186.207 **Re** 75 Rhenium	190.2 **Os** 76 Osmium	192.22 **Ir** 77 Iridium	195.08 **Pt** 78 Platinum	196.967 **Au** 79 Gold	200.59 **Hg** 80 Mercury	204.383 **Tl** 81 Thallium	207.2 **Pb** 82 Lead	208.980 **Bi** 83 Bismuth	(209) **Po** 84 Polonium	(210) **At** 85 Astatine	(222) **Rn** 86 Radon
7	(223) **Fr** 87 Francium	226.025 **Ra** 88 Radium	227.028 **Ac** 89 Actinium	(261) **Rf** 104 Rutherfordium	(262) **Db** 105 Dubnium	(263) **Sg** 106 Seaborgium	(262) **Bh** 107 Bohrium	(265) **Hs** 108 Hassium	(266?) **Mt** 109 Meitnerium	(269?) 110								

Mass numbers in parentheses are those of the most stable or most common isotope.

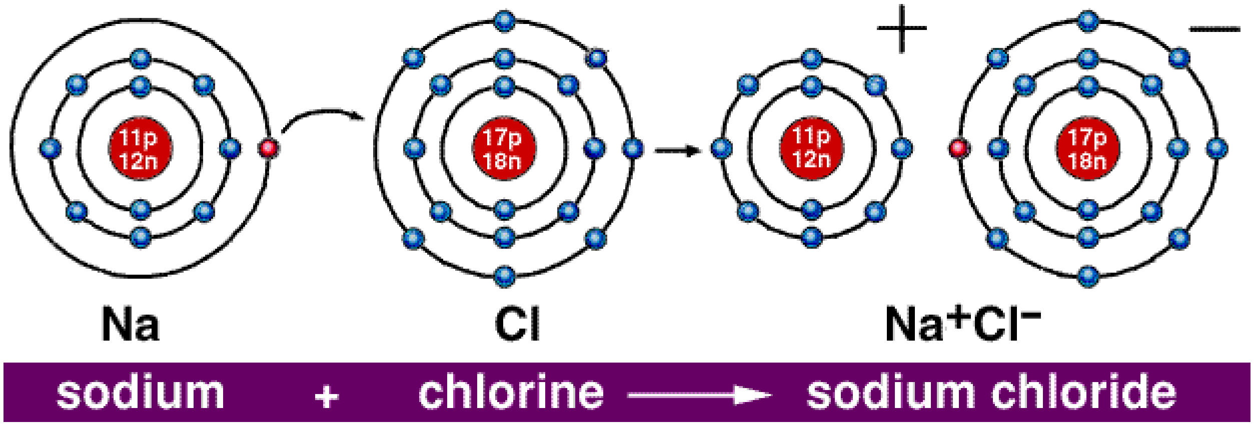
Metals ← → Nonmetals

Series														
Lanthanoid Series	140.12 **Ce** 58 Cerium	140.908 **Pr** 59 Praseodymium	144.24 **Nd** 60 Neodymium	(145) **Pm** 61 Promethium	150.36 **Sm** 62 Samarium	151.96 **Eu** 63 Europium	157.25 **Gd** 64 Gadolinium	158.925 **Tb** 65 Terbium	162.50 **Dy** 66 Dysprosium	164.930 **Ho** 67 Holmium	167.26 **Er** 68 Erbium	168.934 **Tm** 69 Thulium	173.04 **Yb** 70 Ytterbium	174.967 **Lu** 71 Lutetium
Actinoid Series	232.038 **Th** 90 Thorium	231.036 **Pa** 91 Protactinium	238.029 **U** 92 Uranium	237.048 **Np** 93 Neptunium	(244) **Pu** 94 Plutonium	(243) **Am** 95 Americium	(247) **Cm** 96 Curium	(247) **Bk** 97 Berkelium	(251) **Cf** 98 Californium	(252) **Es** 99 Einsteinium	(257) **Fm** 100 Fermium	(258) **Md** 101 Mendelevium	(259) **No** 102 Nobelium	(260) **Lr** 103 Lawrencium

Revised May 2011

IONIC and COVALENT BONDING

An atom by itself generally has a neutral charge, because the positive charge from the protons in its nucleus is balanced by the negative charge of its electrons. However, when many types of atoms come into contact with one another, **electrons can be transferred** from one atom to another. A **negative ion** is created when one atom **gains electrons**. Conversely, a **positive ion** is created when an atom **loses electrons**. The **oppositely charged ions attract** one another, creating **an ionic bond**, and a neutrally charged compound.



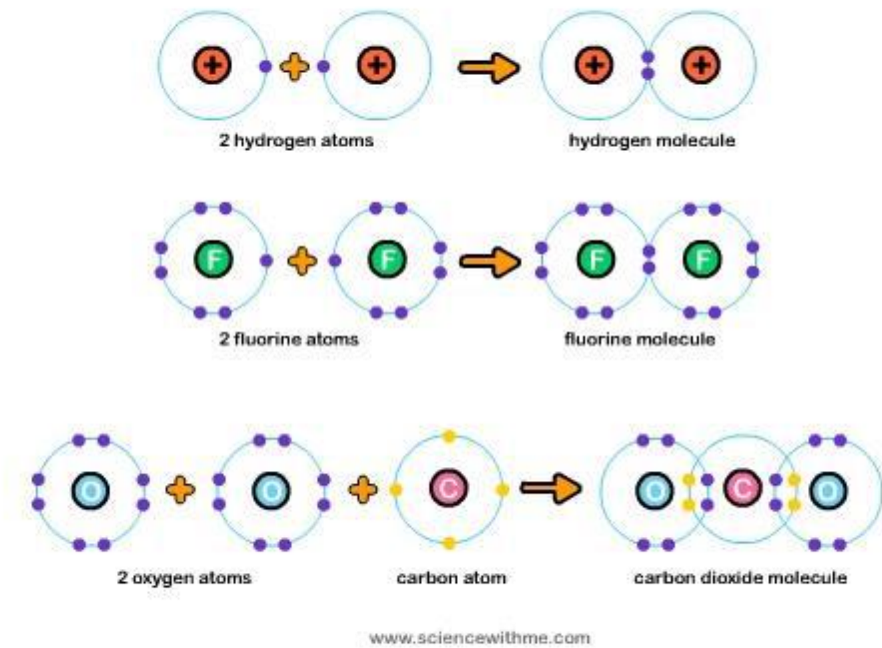
An everyday example of an ionic compound is table salt—sodium chloride (NaCl). Table salt is sodium and chloride ions joined together with ionic bonds.

According to the atomic model, electrons orbit the nucleus at specific levels, or shells. Electrons fill shells, starting from the innermost, going to the outermost. Atoms are **more stable** when their **outer shell is filled**, and therefore, atoms will lose, gain, or share electrons to complete their outer shells. **Electrons in the outermost shell**, which are involved in bonding, are known as **valence electrons**.

When two atoms vary significantly in electronegativity (the measure of the ability of atoms to attract electrons), they tend to form ionic bonds. Some atoms tend to lose electrons, while others are more likely to gain them. Elements with **low electronegativity**, such as metals, have outer **shells that are almost empty** and give up electrons fairly easily. Elements with **high electronegativity**, such as nonmetals, have outer **shells that are mostly full** and tend to hold on to their electrons. In general, elements on the **left of the periodic table** have **low electronegativities,** whereas elements on the **right side of the periodic** have **high electronegativities**.

Sodium has relatively low electronegativity, with only one electron in its outer shell. With most of its outer shell full, chlorine has relatively high electronegativity and needs only one extra electron to fill its shell. When sodium and chlorine atoms come together, the sodium atom lends its outer electron to the chlorine atom. The positively charged sodium ion is then attracted to the negatively charged chloride ion and creates an ionic bond.

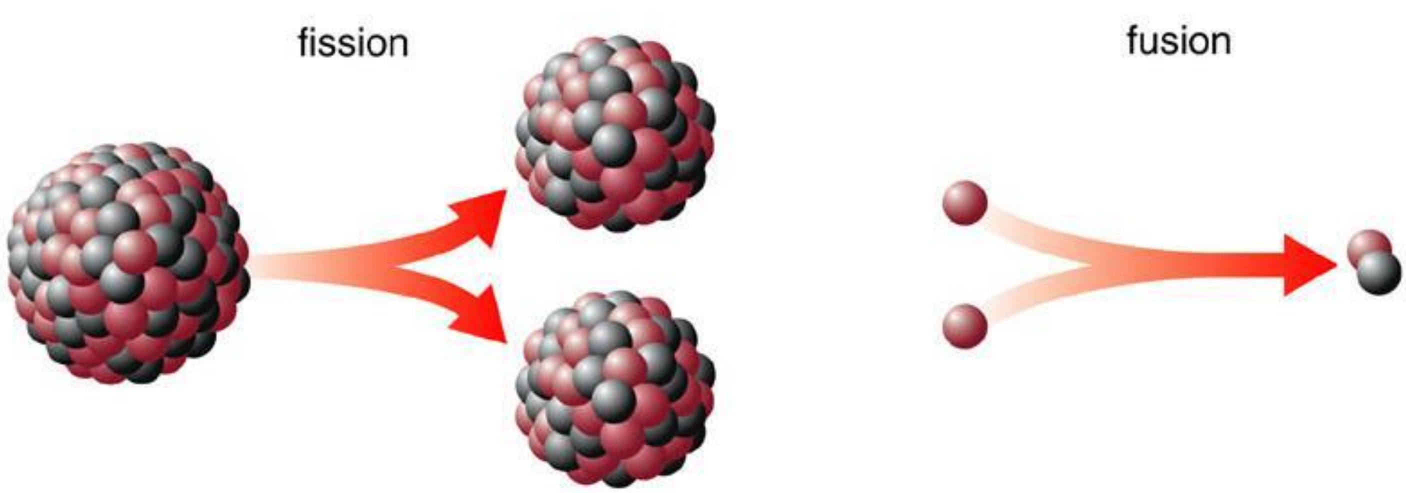
When atoms have **similar electronegativity**, a **covalent bond** forms. Covalent bonds differ from ionic bonds in that instead of transferring electrons, the atoms **share electrons**.



Source: http://www.pbslearningmedia.org/resource/lsps07.sci.phys.matter.ionicbonding/ionic-bonding/

Nuclear Changes

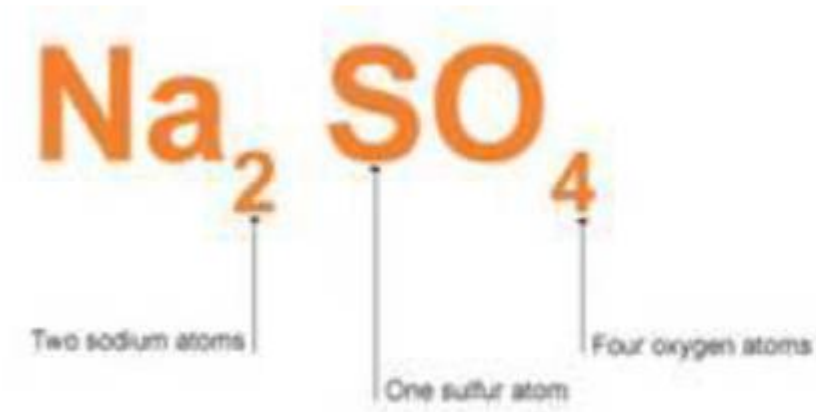
Types of Changes	Description	Examples
Physical	Physical changes, the chemical composition of the substances does not change.	• Energy stored in the Any phase change • Grinding something into powder
Chemical	Different substances are formed	• Iron rusting • Gasoline burning
Nuclear	Energy stored in the nucleus of an atom.	• Joining nuclei together (fusion) • Splitting nuclei (fission),



BALANCING SIMPLE EQUATIONS

A chemical equation is a written symbolic representation of a chemical reaction. The reactant chemical(s) are given on the left-hand side and the product chemical(s) on the right-hand side. The law of conservation of mass states that no atoms can be created or destroyed in a chemical reaction, so the number of atoms that are present in the reactants has to balance the number of atoms that are present in the products.

Chemical symbols are used in writing chemical formulas, in which the symbols represent the atoms of the elements present in a compound.



What information can be learned from the chemical formula?

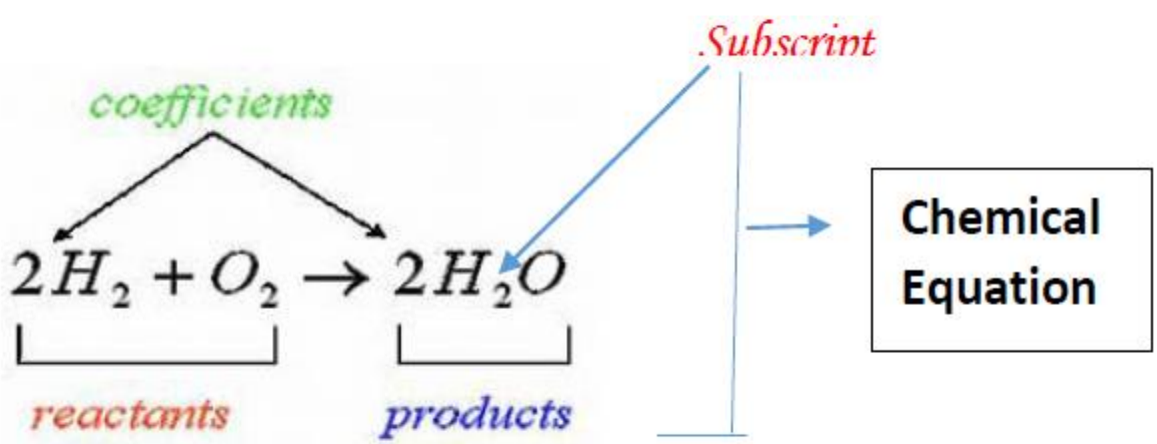
- The elements that are present in the compound
- The ratio of the elements in the compound

Compounds are pure substances that are made up of *two or more elements that are chemically combined* in fixed mass ratios. The elements in the compound are joined together by chemical bonds.

The properties of a compound are unique and differ from the elements that make up the compound.

The arrow usually points toward the right or toward the product side of the equation.

The elements in an equation are represented by their chemical symbols. Coefficients next to the symbols indicate the *number of molecules*. Subscripts are used to indicate the *number of atoms of an element* present in a chemical.



A chemical equation is a *written representation of* the process that occurs in a *chemical reaction*. A chemical equation is written with the *reactants on the left side* of an arrow (yield symbol) and the *products* of the chemical reaction *on the right side* of the equation.

Is it balanced?

$$C_3H_8 + 5\,O_2 \rightarrow 4\,H_2O + 3\,CO_2$$

	LEFT SIDE	RIGHT SIDE
C	3	3 ✓
H	8	8 ✓
O	10	10 ✓