

CHEMISTRY

An understanding of chemistry has led to the development of almost everything that we have today. AIRPLANES can safely carry PASSENGERS because of chemistry. The MATERIALS for all our ELECTRONIC devices have been made using chemistry. The WINDOWS in our houses have been made using chemistry.

THE DEVELOPMENT OF CHEMISTRY

Ancient GREEK PHILOSOPHERS did not do EXPERIMENTATION, but manipulated ideas in their MINDS.

Two different viewpoints of matter were developed during the 5TH CENTURY B.C.

- EMPEDOCLES said matter was composed of FOUR ELEMENTS:
 - EARTH
 - WATER
 - AIR
 - FIRE
- DEMOCRITUS said matter was made up of tiny PARTICLES that could not be broken down any further. He called these particles ATOMS.
 - Atom means INDIVISIBLE
- In 350 B.C., ARISTOTLE rejected the ATOMIC model and adopted the FOUR ELEMENT model.

Since everything ARISTOTLE said was believed, this theory was accepted for almost 2000 years.

THE MIDDLE AGES:

- ALCHEMISTS were the first people to perform EXPERIMENTS. Their main goals were to turn other ELEMENTS into GOLD and find a substance to give them ETERNAL LIFE.
- Their experiments led to the discoveries of NEW ELEMENTS, the development of laboratory EQUIPMENT and TECHNIQUES, and new INFORMATION about existing MATERIALS.

THE INDUSTRIAL REVOLUTION:

- By 1600, 13 elements were known: Antimony, arsenic, bismuth, carbon, copper, gold, iron, mercury, lead, silver, sulfur, tin and zinc.
- In 1620 FRANCIS BACON argued that science should be built on EXPERIMENTATION, but just on PHILOSOPHICAL SPECULATION (thinking).
- In 1661 ROBERT BOYLE said elements were simple and pure and could be COMBINED to form COMPOUNDS.
- In the late 1700's ANTOINE DE LAVOISIER defined an element as:
 - A PURE SUBSTANCE that cannot be chemically broken down into simpler substances
- Lavoisier discovered 23 more elements

- He realized that AIR was a MIXTURE of gases, OXYGEN and “some other gas,” or “one that does not BURN and one that does.”
- Lavoisier proved that both WATER and AIR were NOT elements.

THE DEVELOPMENT OF ATOMIC STRUCTURE

THE BILLIARD BALL MODEL:

LAVOISIER showed the difference between NON-ELEMENTS and ELEMENTS

ISAAC NEWTON stated his understanding of the structure of MATTER.

JOHN DALTON developed the first model for the structure of the ATOM.

In 1808, Dalton developed a theory about the structure of matter called the ATOMIC THEORY.

- All matter is made of tiny PARTICLES called ATOMS
- Atoms cannot be CREATED, DESTROYED, or divided into smaller particles
- All atoms of the same ELEMENT are IDENTICAL in MASS and SIZE, but they are different in mass and size from the atoms of OTHER ELEMENTS.

- **COMPOUNDS** are created when atoms of **DIFFERENT** elements link together in **DEFINITE PROPORTIONS**.

From this, we got the definition of an element as:

- A **PURE SUBSTANCE** made up of **ONE** type of particle, or **ATOM**.

Dalton's Model became known as the **BILLIARD BALL** model because he pictured the atom as a solid, **INDIVISIBLE** sphere.

THOMPSON'S PLUM-PUDDING MODEL

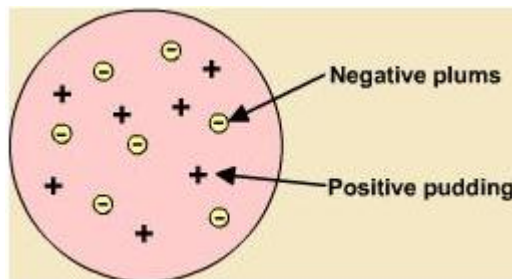
THOMPSON came up with the following ideas for the atom:

- Atoms contained particles called **ELECTRONS**
- **ELECTRONS** have a **SMALL MASS** and a **NEGATIVE** charge
- The rest of the atom is a sphere of **POSITIVE** charge
- **ELECTRONS** are **IMBEDDED** in the sphere, making the atoms **NEUTRAL**.

Thompson figured out there were **NEGATIVE** charges in atoms by passing an **ELECTRIC CURRENT** through a **GAS**. The gas gave off a **NEGATIVE** electrical charge so he concluded that the negative charge came from the **GAS**.

Thompson then proposed that there had to be an equal number of **POSITIVE** charges, located in the **SPHERE** of the **ATOM**.

His model has negatively charged “**PLUMS**” in a positively charged “**PUDDING**.”

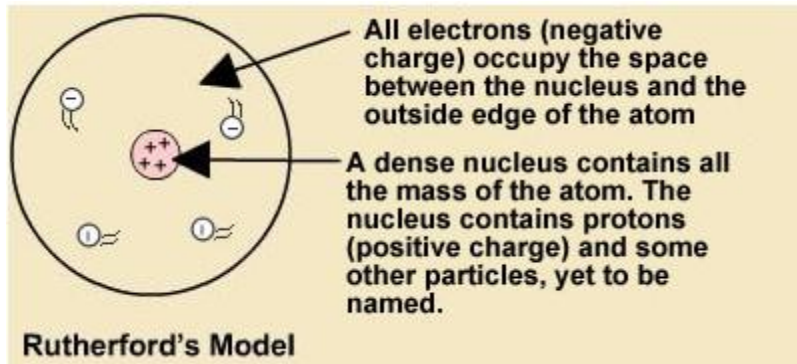


SUBATOMIC PARTICLE: A **PART** of an **ATOM**, it is **SMALLER** than an atom.

RUTHERFORD MODEL:

ERNEST RUTHERFORD contributed to the atomic model by hypothesizing that:

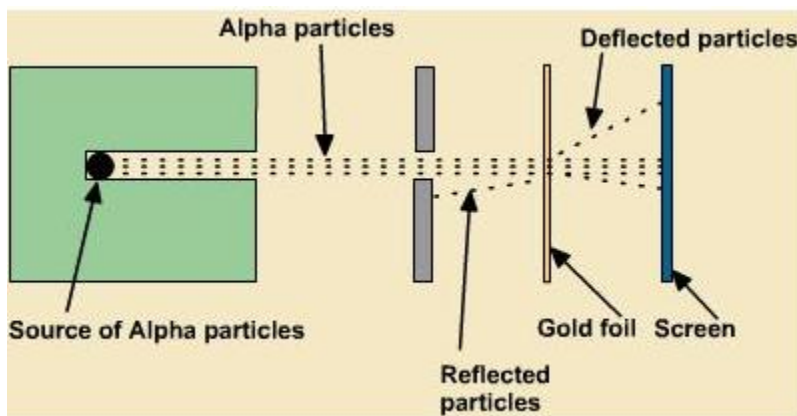
- The **NUCLEUS** is a very small, dense, **POSITIVELY** charged **CORE** of the atom.
- All of the atoms positively charged particles, called **PROTONS**, are located in the **NUCLEUS**



Rutherford set up an experiment where he fired small positively charged particles called **ALPHA PARTICLES** at a thin sheet of **GOLD FOIL**.

Most of the particles went **STRAIGHT THROUGH** the foil without changing **DIRECTION**. He concluded that an atom was mostly **EMPTY SPACE** with a **DENSE CORE** called a **NUCLEUS**; it was not a **SOLID SPHERE**.

The size of the nucleus in the atom can be compared to a **MARBLE** in a **FOOTBALL STADIUM**.



Rutherford also predicted that the **PROTONS** do not contain all the **MASS** of the **ATOMS**, he believed there was **ANOTHER PARTICLE** present in the **NUCLEUS**

THE BOHR MODEL

The Bohr Model:

RUTHERFORD proved that **ELECTRONS** occupied the space **OUTSIDE** the **NUCLEUS** of the atom.

NIELS BOHR made a model that helped explain the **POSITION** and **BEHAVIOUR** of the **ELECTRONS**.

BOHR proposed that **ELECTRONS** occupy special **POSITIONS** around the **NUCLEUS** called **ORBITS** or **SHELLS**.

- He said the **ORBITS** were **CIRCULAR**
- **ELECTRONS** went around the orbits like **PLANETS** around the **SUN**
- **ORBITS** were a certain **DISTANCE** from the nucleus
- A specific **NUMBER** of **ELECTRONS** occupy each **ORBIT**

OCCUPYING OF ORBITALS:

- The **CLOSEST** orbital to the **NUCLEUS** is always filled **FIRST**
- The first orbital contains a **MAXIMUM** of **TWO** electrons
- The **SECOND** and **THIRD** orbits can hold **EIGHT** electrons

When **DRAWING** Bohr models, think of the **NUCLEUS** as the **SUN** and the **ELECTRONS** as **PLANETS**.

The first two **ELEMENTS** are **HYDROGEN** with **ONE** electron and **HELIUM** with **TWO** electrons. All electrons can be on the **FIRST** orbital.

The **THIRD** element, **LITHIUM**, has **THREE** electrons. The third electron occupies a **SECOND** orbital.

QUANTUM THEORY:

Bohr's model was able to explain the behaviour of **SIMPLE ATOMS**, but it did not work for more **COMPLEX** atoms.

The **QUANTUM** model was able to propose the following:

- According to the theory of **WAVE MECHANICS**, electrons **DO NOT** move around the atom's **NUCLEUS** like planets around the sun.
- It is **IMPOSSIBLE** to determine the **EXACT** location of an **ELECTRON**

- The probable LOCATION of an electron is based on its ENERGY
- Energy levels are divided into FOUR sublevels, each sublevel is made up of several PAIRS of electrons called ORBITALS.
- Electrons move randomly in ELECTRON CLOUDS called orbitals.

THE ATOMIC NUCLEUS:

- HENRY MOSELEY discovered that POSITIVE charge in an atom INCREASED as ATOMIC WEIGHT increased.
- MOSELEY called the number of protons in the nucleus the ATOMIC NUMBER.
- JAMES CHADWICK and ERNEST RUTHERFORD discovered that PROTONS did not contain the TOTAL MASS of the nucleus.
- CHADWICK discovered the NEUTRON, which has a MASS similar to the proton but has NO CHARGE

Summary:

- The number of ELECTRONS equal the number of PROTONS in an ATOM, which is the ATOMIC NUMBER.

THE DEVELOPMENT OF THE PERIODIC TABLE:

During the 18th CENTURY, many elements were DISCOVERED, so these new elements needed NAMES and SYMBOLS.

ELEMENTAL SYMBOLS:

- The **FIRST** letter of an **ELEMENT CAPITALIZED** is often its **SYMBOL**. Eg. **C** is the symbol for **CARBON**
- If **TWO** elements have the same **FIRST** letter, the symbol has **TWO** letters, the first being **CAPITALIZED** and the second **LOWERCASE**. Eg. **Ca** is **CALCIUM** and **Co** is **COBALT**.
- Some symbols come from the **GREEK** or **LATIN**, so they do not relate to the **ENGLISH** name. Eg. **LEAD** is **Pb** (**PLUMBUM**) and **COPPER** is **Cu** (**CUPRUM**)

The following is a selection of elements and their symbols

Table of Elements and Symbols

Element	Symbol	Element	Symbol	Element	Symbol	Element	Symbol
Hydrogen	H	Fluorine	F	Chlorine	Cl	Silver	Ag*
Helium	He	Neon	Ne	Argon	Ar	Tin	Sn*
Lithium	Li	Sodium	Na*	Potassium	K*	Iodine	I
Beryllium	Be	Magnesium	Mg	Calcium	Ca	Tungsten	W*
Boron	B	Aluminum	Al	Iron	Fe*	Gold	Au*
Carbon	C	Silicon	Si	Nickel	Ni	Mercury	Hg*
Nitrogen	N	Phosphorus	P	Copper	Cu*	Lead	Pb*
Oxygen	O	Sulphur	S	Zinc	Zn	Uranium	U

MODERN ATOMIC THEORY

The MASS of an atom (ATOMIC MASS) is measured in ATOMIC MASS UNITS (amu).

An atom is made up of THREE smaller parts called SUBATOMIC particles.

- PROTONS
- ELECTRONS
- NEUTRONS

ELECTRON:

- Located OUTSIDE the NUCLEUS of the atom
- Has a charge of -1
- Has a MASS so small that it is considered ZERO.

PROTON:

- Located in the NUCLEUS
- Has a charge of +1
- Has a mass of one AMU

NEUTRON:

- Located in the NUCLEUS
- Has NO CHARGE
- Has a mass of one AMU

ATOMIC NUMBER:

- Concept developed by HENRY MOSELEY
- Defined by the number of PROTONS in the NUCLEUS

- The **ATOMIC NUMBER** can always be used to identify an **ELEMENT**
- Ex. **COPPER** has an atomic number of **29** and there are **29 PROTONS** in the nucleus.

MASS NUMBER:

- The mass number is equal to the number of **PROTONS PLUS** the number of **NEUTRONS**
- Ex. **CARBON** has **SIX** protons and **SIX** neutrons.
The mass number for carbon is:

$$\text{MASS NUMBER} = \text{NUMBER OF PROTONS} + \text{NUMBER OF NEUTRONS}$$

DETERMINING THE NUMBER OF SUBATOMIC PARTICLES:

- The number of **PROTONS** is equal to the **ATOMIC** number
- All atoms are **NEUTRAL**, so in any atom the number of electrons is **EQUAL** to the atomic number.
- The number of **NEUTRONS** is equal to the **MASS** number **MINUS** the **ATOMIC** number.

$$\begin{aligned} \# \text{ electrons} &= \# \text{ protons} = \text{atomic number} \\ \# \text{ protons} + \# \text{ neutrons} &= \text{mass number} \\ \text{Mass number} - \text{atomic number} &= \# \text{ neutrons} \end{aligned}$$

DRAWING BOHR MODELS:

Example: Nitrogen

These are the steps for drawing a Bohr model:

1. Determine the number of **PROTONS**, **NEUTRONS** and **ELECTRONS** in the atom.
2. Draw a small **CIRCLE** to represent the **NUCLEUS**.
3. Label the number of **PROTONS** and **NEUTRONS** in the nucleus.
4. Draw a **CIRCLE** around the nucleus to represent the **FIRST ORBITAL**. This orbital is filled with **TWO ELECTRONS**.
5. Draw a **SECOND CIRCLE** around the first and place electrons on it up until a maximum of **EIGHT**.
6. If needed draw a **THIRD** orbital.

PERIODIC TABLE

- By the middle of the **19th CENTURY**, scientists had discovered **63** elements which they arranged **ALPHABETICALLY**.

Rb	Sr	? Yt	Zr	Nb	Mo	?	Ru 104, Rh 104, Pd 105, Ag 108
(Ag)	Cd	In	Sn	Sb	Te	I	
Cs	Ba	? Di	? Ce	-	-	-	
-	-	-	-	-	-	-	
-	-	? EF	? La	Ta	W	-	Os 195, Ir 197, Pt 198, Au 199
(Au)	Hg	Ti	Pb	Bi	-	-	
-	-	-	Th	-	U	-	

Mendeleev noticed that some elements with the next highest **ATOMIC MASS** did not fit the **CHARACTERISTICS** of the elements above them, so he decided to leave **GAPS** and predicted that elements could be discovered to **FILL** those gaps.

- Mendeleev predicted the properties of many of the “**MISSING**” elements. This led to the discovery of **23** more elements in the next **30** years.
- His periodic table still had flaws since it was arranged by **ATOMIC MASS** (**IODINE** and **TELLURIUM** appeared in the **WRONG** order so he ignored the **ATOMIC MASS** and put them with the elements of similar **CHARACTERISTICS**).
- **HENRY MOSELEY** fixed this when he implemented his concept of the **ATOMIC NUMBER** and remade the period table according to the atomic number. This is how the periodic table is **TODAY**.
- Today we call the rows of elements **PERIODS** and the columns of elements **GROUPS**.

EXPLAINING THE MODERN PERIODIC TABLE

Today's periodic law states that:

- The properties of **ELEMENTS** are a periodic function of their **ATOMIC NUMBERS**.

PERIOD:

- **HORIZONTAL** row on the **PERIODIC TABLE**.
- Each period represents an **ENERGY** level in the **QUANTUM** model of the atom.

GROUP:

- **VERTICAL** column on the **PERIODIC TABLE**
- Numbered **1-18** from left to right
- Old system numbered **I-VIII** based on **BOHR** model
- Elements in the same group have similar **PROPERTIES**
- Elements in the same group have the same number of **ELECTRONS** in their **OUTERMOST** shell
- Also called **FAMILIES**

The diagram shows a single cell from the periodic table for the element Nitrogen. The cell contains the following information: the atomic number 7, the combining capacity -3, the symbol N, the atomic mass 14.01, and the name Nitrogen. Arrows point from text labels on the right to each of these elements within the cell.

7	Atomic number
-3	Combining capacity
N	Symbol
14.01	Atomic Mass(μ)
Nitrogen	Name

GROUP NAMES:

HYDROGEN:

- Hydrogen is in a group by itself, it does not have SIMILAR PROPERTIES to any other ELEMENTS
- Only contains one PROTON and one ELECTRON

ALKALI METALS:

- LEFTMOST column on the periodic table (1 or I)
- Lithium, SODIUM, POTASSIUM, Rubidium, Cesium, Francium.
- Contains ONE ELECTRON in outermost orbit
- All ALKALI METALS are found COMBINED with other elements in nature, they are too REACTIVE to be by themselves
- Ex. NaCl – Sodium Chloride or table salt

ALKALINE EARTH METALS:

- SECOND column of the periodic table (2 or II)
- LESS REACTIVE than ALKALI metals because they have TWO electrons in their outermost orbital
- Includes Beryllium, MAGNESIUM, CALCIUM, Strontium, Barium, Radium

CHALCOGENS:

- 16th column of the periodic table (column VI)
- Contain SIX electrons in outer orbit
- Includes OXYGEN, SULFUR, Selenium, Tellurium, Polonium
- LESS REACTIVE than HALOGENS

HALOGENS:

- 17th family of periodic table (column VII)
- Contains SEVEN electrons in outer orbit
- Includes FLUORINE, CHLORINE, BROMINE, Iodine, Astatine
- HIGHLY reactive, Fluorine and Chlorine normally found only in compounds

NOBLE GASES:

- 18th family of periodic table (column VIII)
- Includes HELIUM, Neon, ARGON, Krypton, Xenon and Radon
- UNREACTIVE because they have a FULL outer shell (8 electrons)
- No natural COMPOUNDS exist with these compounds

As you go left to right across the periodic table melting temperature DECREASES, so the left is all SOLIDS and the right is GASES

The left side of the periodic table are METALS, then are METALLOIDS and NON-METALS on the right

PROPERTIES OF MATERIALS

There are **THREE** types of elements:

- **METALS**
- **METALLOIDS**
- **NON-METALS**

METALS:

- Most **COMMON** form of matter
- The **LEFT** and **CENTRE** of the **PERIODIC** table, all elements left of the **METALLOIDS**

PROPERTIES OF METALS:

- **LUSTRE**: All metals are **SHINY**
- All metals are **SILVER-GREY** in colour except **COPPER** and **GOLD**.
- **MALLEABILITY**: Metals are **FLEXIBLE** (bend easily) and can be **HAMMERED** into very thin **SHEETS**
- **DUCTILE**: They can be drawn into **WIRES**
- All metals are **SOLID** at room **TEMPERATURE** except **MERCURY**
- Metals can transfer **HEAT** along their length; **CONDUCT** heat
- Metals are able to conduct **ELECTRIC CURRENT**

Not all metals possess these characteristics to the same degree.

- **GOLD** is extremely malleable

- SILVER is the best conductor of electricity followed by COPPER.

NON-METALS:

- Located on the RIGHT of the periodic table
- Have properties OPPOSITE of METALS
- Have no LUSTRE
- BRITTLE; not malleable or ductile.
- Non-metals are INSULATORS and NON-CONDUCTORS of heat and electricity (except CARBON)
- SOLID or GAS at room temperature (except BROMINE)

CARBON and HYDROGEN combine with other elements like NITROGEN, SULFUR and OXYGEN to form HYDROCARBONS. Hydrocarbons form items like COAL, OIL, PLANTS and ANIMALS. Hydrocarbons are studied in ORGANIC chemistry and BIOCHEMISTRY.

METALLOIDS:

- Located on the STAIRCASE between metals and non-metals
- Demonstrate some properties of METALS and some of NON-METALS
- All metalloids are SOLID at room temperature
- Some have LUSTRE
- Tend to behave like NON-METALS in their PHYSICAL and CHEMICAL properties.

- **SEMICONDUCTORS**: used in **ELECTRONICS** for components and **MICROCHIPS**.

CHEMICAL REACTIVITY:

- Chemical **REACTIONS** must take place to form a new **MATERIAL**.
- The number of **OUTER-SHELL** electrons determines **WHEN** reactions will take place
- When an **ELEMENT** has a **FULL** outer electron shell, they do not want to **REACT** with other substances. **NOBLE GASES** have full outer shells and are **UNREACTIVE**
- Elements that **DO NOT** have full outer electron shells will react to form new **MATERIALS**
- **ALKALI METALS** and **HALOGENS** are the most reactive. **ALKALI** metals need to **LOSE ONE** electron to have a full outer shell while **HALOGENS** need to **GAIN ONE** electron to have a full outer shell.
- In general, the **LESS** electrons that need to be **GAINED** or **LOST**, the **MORE REACTIVE** the element is.

All elements want a **FULL** outer shell.

Ex. **SODIUM**, an alkali metal, needs to lose **ONE** electron to have the electron configuration of **NEON**.

CALCIUM, an alkaline earth metal, needs to lose **TWO** electrons to have the electron configuration of **ARGON**.

CHLORINE, a **HALOGEN**, will **GAIN** an electron to get a full outer shell like **ARGON**.

OXYGEN, a chalcogen, will **GAIN TWO** electrons to get a full outer shell like **NEON**.

METALS will **LOSE** electrons and **NON-METALS** will **GAIN** electrons.

Ex. Na and Cl

Non-metals can share electrons.

Ex. Cl and Cl.

COMPOUNDS

- A **COMPOUND** is made up of **MORE THAN ONE** element.
- A **MOLECULE** is the **SMALLEST** particle of a **COMPOUND**.
- An **ELEMENT** is the simplest form of a **MATERIAL**, it can be made up of many **ATOMS**, but only **ONE TYPE** of atom.

- An ATOM is the SMALLEST particle, it can no longer be divided.

Some substances are made up of ONE element.

- COPPER, ALUMINUM and LEAD are METALS made of one element.
- NEON is a GASEOUS element in bright signs
- MERCURY is a LIQUID element in thermometers

Substances like WATER, STEEL, RUBBER, and SUGAR are COMPOUNDS.

Compounds have completely DIFFERENT characteristics than the ELEMENTS they are made up of.

Ex. SODIUM METAL is extremely reactive and reacts violently with WATER or even WATER VAPOR. It must be stored in OIL to keep it away from water and water vapor. CHLORINE is a gas that is extremely POISONOUS. It was used in WWI to attack troops and killed many soldiers. It also permanently damaged the lungs of others. One CHLORINE atom can combine with one SODIUM atom to create sodium chloride (NaCl), or TABLE SALT.

It is possible to have a MOLECULE of an ELEMENT. Examples are OXYGEN, O₂, and HYDROGEN, H₂. These are called DIATOMIC molecules, which means "TWO ATOMS."

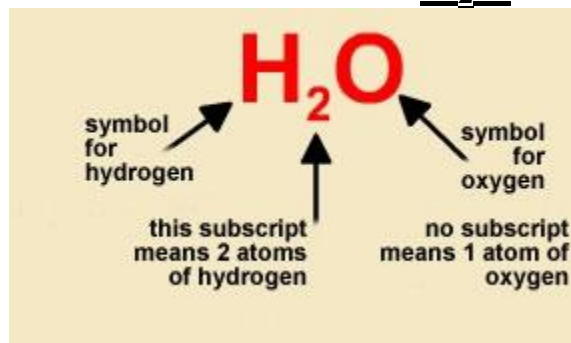
FORMING COMPOUNDS:

- Compounds are formed in a process called a **CHEMICAL REACTION**.
- There are **TWO** types of chemical reactions.
- In a reaction between a **METAL** and a **NON-METAL** the metal will **GIVE UP** electrons and the non-metal will **RECEIVE** electrons. This is called **IONIC BONDING**
- In a reaction between **TWO NON-METALS**, the atoms will **SHARE** electrons so both have a full outer shell. This is called **COVALENT** bonding.

Element	The simplest form of a substance
Atom	The smallest particle of an element
Compound	The simplest form of any material containing two or more elements
Molecule	Two or more atoms joined together chemically - also, the smallest particle of a compound

CHEMICAL FORMULAS

- Recall that compounds are formed when two or more elements **SHARE** or **TRANSFER** electrons in a process called a **CHEMICAL REACTION**.
- Compounds are represented by **CHEMICAL FORMULAS**.
- Ex. Water's chemical formula is **H₂O**.



- One **MOLECULE** of water is the **SMALLEST** particle to have the **CHARACTERISTICS** of water.
- How many atoms of **HYDROGEN** and **OXYGEN** are needed to make **10** molecules of water?

Ex. **GLUCOSE** is a form of sugar with the chemical formula **C₆H₁₂O₆**. From this formula:

- What **ELEMENTS** are present in glucose?
- How **MANY** of each element are present?

The number of **ATOMS** in a sample can be found by multiplying the number of **MOLECULES** by the **SUBSCRIPT**:

Ex. There are **4** molecules of carbon dioxide (**CO₂**). How many **ATOMS** are there?

