The Smallest Pieces of Matter
Value of Theories

In order to unlock nature’s secrets man has an orderly approach for this - scientific method.

In the scientific method you use a hypothesis or a possible explanation of a happening or a phenomena.

A hypothesis can be tested by experimentation and if the findings are in agreement then a probable explanation or theory may be developed.
Continued and repeated experimentation which verifies the original explanation, or its modifications, may be eventually be recognized as a law or scientific statement of fact.
The Importance of the Imagination

- The imagination enables scientist to develop new hypothesis which enables them to find improvements in our lives and other advancements for mankind.
- Hypothesis, theories, and laws provide the ground work for further development in the field of chemistry and other science fields.
More on the Importance of Curiosity

It was the wondering about the nature of matter, seeking to explain research data obtained from experimentation, that led to the formulation of the atomic, kinetic, and electronic theories which have been of such value in our understanding of matter.
Democritus

Democritus, Greek philosopher, suggested that matter consisted of tiny particles. He called these particles atoms which is derived from two Greek words meaning indivisible.
John Dalton conducted a series of experiments which included the analysis of a number of pure compounds and the study of gases.

He realized that these compounds had a definite composition by weight (a fact not entirely accepted in his day).

As a result of this testing he developed a theory.
Dalton’s Atomic Theory

1. All matter is composed of very small indivisible particles called atoms.

2. Atoms of the same element are alike in weight and other properties. Atoms of different elements are different in weight and other properties.

3. Compounds are formed by the union or separation of definite numbers of atoms.

4. Atoms do not divide in chemical reactions; only whole atoms unite with other atoms.
Proust previously stated that the law of definite proportions.

Dalton backed up Proust’s idea with his experiment which lead to the Atomic Theory.

- Dalton agreed with Proust and said that indivisible particles of equal weight in any given element accounted in a very simple way for the law of definite proportions.
Enabling us to?

- Dalton and Proust idea enables us to predict the amount of substances needed to make a desired compound
Dalton’s Theory also proves the law of conservation of mass which had previously been stated by Lavoisier.

- Since the particles are indivisible and indestructible and that they unite in whole atoms, then matter is neither created nor destroyed but conserved.
- However there is one exception, Nuclear reactions- some matter is converted into energy with a resulting loss of mass.
Dalton also realized that two elements could unite in different proportions by weight so as to form in more than one compound, observations which are summarized in his law of multiple proportions.
Updating Dalton’s

- Dalton’s theory has been proven true for certain parts, but not all.
- The atom is not truly indivisible.
Definition of an atom

- An atom is the smallest particle of an element which can take part in chemical change (unite with other elements).
- Modern research has proven that atoms are complex structures made up of tiny electrical particles.
Indivisible…. Not!

- An atom is indivisible by a nuclear change.
- It is not divisible under ordinary chemical reactions.
- Atoms of different elements can be regarded as chemical building blocks which make up chemical compounds.
Redefining

- An element is a substance which is made up of the same kind of atoms
- Compounds are substances consisting of two or more different kinds of atoms
Atomic Weights

Atoms may be inconceivably small but they do have weight.

An atom's mass is $1.660 \times 10^{-24}$ grams.

That value is called the atomic mass unit (amu).

Chemists use numbers to express these values.
- Oxygen is 16.00 amu rather than $2.65 \times 10^{-23}$ grams.
More on AMU

- Atomic weights are relative weights and require no units.
- We could very well compare weights using grams, kilograms, grains, ounces, and pounds.
- You do not have to write amu after the weight. It is simply the weight.
Not Droids

- Not all atoms of an element have the same weight or mass.
- Kinda like people
- Atoms of the same element that have different masses are called isotopes.
- So chemist average the weight on the periodic table
Symbol Significance

- A chemical symbol represents more than the name of the element for which it stands
  - It stands for one atom of the element and weight of one atom
    - O represents oxygen weighing 16 amu
    - H represents hydrogen weighing 1 amu

- In most cases symbols do not stand for whole number atomic weights
  - Usually it is rounded off to the tenth position
Molecules

- Dalton referred to a union of two or more atoms as being compounds called complex atoms.
- As time marched on, it was discovered that many gaseous elements are made up of pairs of atoms instead of single atoms.
Count Amadeo Avogadro

- In 1811 Avogadro used the word molecule for all groups of atoms held in chemical combination.
- However, his research and his use of the word molecule did not come into effect until Stanislao Cannizzaro wrote about the idea of a molecule in his scientific writings.
Advancement of Molecules

- Molecules vary in size.
- No matter how large the molecule is, it cannot be seen with a human eye.
- A molecule contains at least two of the same or different kinds of atoms.
- Molecules formed from the same element are called molecules of elements.
- Molecules composed of different elements are called molecules of compounds.
- In both cases, they are diatomic (two atoms).
Rare Gases

- Rare gases helium, neon, argon, krypton, xenon, and radon are monatomic molecules.
- However, most ordinary gases of a single element such as oxygen, hydrogen, nitrogen, and chlorine are diatomic.
Redefining

Molecules are the smallest particle of a substance which has the properties of that substance.

The properties of elements that usually exist in the solid state are not due to single atoms of that particular element but to clusters of atoms.

Copper as a group is a crystal.

It can only exist by themselves under high temperatures and then they do not have the same properties as the crystal.
Molecular Properties

- Most substances whether they are solids, liquids, or gases are composed of molecules.
- Molecules come in different sizes.
- Molecules of different substances have different shapes and weights.
- Some are simple and some are complex.
Whether a substance is brittle or elastic, hard or soft, transparent or opaque, or whatever properties it does have, because of its atoms and their arrangement.
Keeping it together

What keeps the molecules together?

Van der Waals forces- electrical forces that bind the atoms together.

- Solids and liquids experience it more than gases because gasses are so spread out.
- At low temperatures, the molecules of a substance are sluggish and tend to group together in an orderly, more or less symmetrical patterns, often producing crystals.
- The higher the temperature the faster the motion.
Molecules and Formulas

To write a molecule of a substance we simplify our life by writing a succession of symbols of each kind of atom it contains.

\[ \text{NH}_3 \]
Molecules and Formulas

- The succession of symbols is called a formula.
- If there is more than one atom present in the compound, then the number is written as a subscript slightly below and to the right of the symbol.
- If the molecule is monatomic (He, Na, C, etc) then the symbol represents a molecule of the substance.
More on that

- Diatomic molecules have the formula $C_2$, $Cl_2$, $H_2$, and so forth.
- Formulas of compounds are written to show the number and kind of the various elements, the subscript 1 never being used.
Molecular vs. Empirical formulas

To know the actual formula of a substance it is necessary to know the elements present and the molecular weight.

- If this is known, the formula represents the actual number, kind, and weight of the atoms present in each molecule and is called the molecular formula.
Empirical formula

- In some cases the formulas only represent the relative proportions of the individual elements and are called empirical formulas.
- Some substances like starch have yet to be determined for their molecular weights.
Significance of Formulas

The symbol stands for an atom and its weight includes:

1. One molecule of an element or compound
2. The constituents of the molecule
3. The molecular weight, which is the sum of the weights of the constituents
Understanding formulas

- $2 \text{H}_2\text{O}$ --> what does it all mean?
- The 2 in front of the compound is called a coefficient.
  - So there are 4 hydrogens and 2 oxygens total
  - 1 is never written rather it is understood as a coefficient
- When combining- the number of atoms which will combine depends upon the valence electrons (outside shell)
Kinetic Molecular Theory

This theory explains the motion of molecules

- Kinetic is Greek for motion

Molecules which make up matter are constantly moving

The kinetic molecular theory of matter deals with the motion of molecules, particularly in gases, but also in liquids and solids.

No matter the state the molecules are in constant motion
Molecular motion in gases

Gases consist of tiny separate molecules.

Molecules are relatively far apart and are in constant motion. The particles move in straight lines until they collide with other molecules and the walls of the container.

- This collision against the container is what causes pressure.

In the collisions the molecules rebound without loss of speed or energy and are therefore called elastic collisions.
KMT and Gases

- The speed of the molecules determines their average kinetic energy or energy of motion
  - Also called heat energy (molecular motion)
- Increasing the temperature increases the speed of molecules and vice versa
- At a given temperature the KE of molecules of different gases will be the same, since heat energy is the same
The heavier molecules move more slowly than the lighter molecules.

Due to the immense distances between the molecules, the weak forces of attraction between them, and their rapid motion, gases tend to have an indefinite volume and shape determined by their container only.
Molecular motion in Liquids

- Brownian motion is random motion caused by the bombardment of molecules in a liquid.
- Liquid molecules are closer to one another than gases and they also are held together more tightly than the gases by the van der Waals forces.
Liquid movements

- If a liquid gains enough energy to escape then it evaporates.
- The difference between evaporation and vaporization is that in vaporization heat is being added by an outside source.
More on Liquids

- When molecules jump from one state to another state the molecules build up pressure.
  - This pressure is called vapor pressure
- There is a constant loss gain from the surface of a liquid causes an equilibrium
  - Equilibrium- state of balance between two opposite reactions occurring at the same rates
  - The total amount of reactants and products remain the same- there is physical equilibrium between the liquid and gas state.
Molecular Motion in Solids

- Molecules are also in motion, but the motion is quite limited due to the van der Waals forces and other forces that causes the molecules to attract.
- In general molecules of solids may be thought as vibrating about fixed points rather than sliding past each other as they apparently do in liquids.