Reading

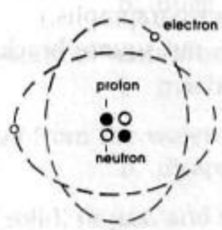
The Infinitesimal Atom

There are over four million substances known to man. [Yet it is one of the amazing facts of science that all these substances are made up of only about 100 different varieties of matter, which are called elements.] Oxygen, hydrogen, gold, aluminum, sulfur, carbon, and chlorine are all examples of elements that combine in different ways to make the more than four million substances. Elements are made of particles called molecules, too tiny to be seen even with a powerful microscope. Molecules are made of even smaller particles called atoms. All the world is made of atoms.

The concept of atoms first emerged in ancient Greece. In 400 B.C. the philosopher Democritus theorized that matter could be divided into smaller and smaller particles until a point was reached beyond which no further subdivision was possible. These indestructible particles were called *atomos*, a Greek word meaning indivisible. We know today that atoms are so small that it would take more than a million of them to equal the thickness of this sheet of paper. Democritus' theory, however, was not universally accepted in the ancient world, for many believed in Aristotle's theory that matter is composed of four elements: earth, fire, air, and water.

During the Middle Ages in Europe, the concept of atoms was considered too abstract and was accordingly rejected. Finally, in 1804 the Englishman John Dalton formulated an atomic theory based on his experimentation. He claimed that all matter is made of atoms; that all atoms of a single element have the same shape, size, weight, and behavior; and that atoms of each element are different from those of any other element. He said that atoms are not created or destroyed but rather form new combinations in chemical reactions.

Dalton thought that atoms were solid, but today atoms are believed to consist mainly of space, with a dense nucleus at the center. The size of the nucleus inside an atom is comparable to the size of an ant on a football field. Each nucleus contains protons, which have a positive electric charge, and neutrons, which have no charge. The nucleus is surrounded by electrons, which have a negative electric charge. The number of protons equals the number of electrons in each atom, and therefore the entire atom has no charge. In 1913, the Danish physicist Niels Bohr proposed a model of the atom in which the electrons revolved around the nucleus like the planets revolve around the sun. Today the movement of electrons is thought to be more like bees hovering around a hive. The force of attraction between the positive protons in the nucleus and the negative electrons whirling around keeps the electrons in their paths.



helium atom

What is it that makes iron hard, oxygen a gas, and mercury a liquid? The properties of an element are determined by the number of electrons in an atom, which is called the atomic number. All atoms of the same element are alike. If you've seen one atom of oxygen, you've seen them all. Hydrogen, the lightest element, has one electron and one proton. In fact, the hydrogen atom, the most common atom in the universe, is the basis on which our entire universe was formed. Oxygen has eight protons and eight electrons. Uranium, one of the heaviest elements, has 92 protons and 92 electrons.

CHEMICAL ELEMENTS AND THE PERIODIC TABLE

The Periodic Table of Elements categorizes like elements together. Dmitri Mendeleev, a Russian scientist, was the first to create a widely accepted arrangement of the elements in 1869. Mendeleev believed that when the elements are arranged in order of increasing atomic mass, certain sets of properties recur periodically. Although most modern periodic tables are arranged in eighteen groups (columns) of elements, Mendeleev's original periodic table had the elements organized into eight groups and twelve periods (rows).

On the periodic table, elements that have similar properties are in the same groups (vertical). From left to right, the atomic number (z) of the elements increases from one period to the next (horizontal). The groups are numbered at the top of each column and the periods on

the left next to each row. The main group elements are groups 1,2 and 13 through 18. These groups contain the most naturally abundant elements, and are the most important for life. The elements shaded in light pink in the table above are known as transition metals. The two rows of elements starting at z=58, are sometimes called inner transition metals and have that have been extracted and placed at the bottom of the table, because they would make the table too wide if kept continuous. The 14 elements following lanthanum (z=57) are called lanthanides, and the 14 following actinium (z=89) are called actinides.

Elements in the periodic table can be placed into two broad categories, metals and nonmetals. Most metals are good conductors of heat and electricity, are malleable and ductile, and are moderate to high melting points. In general, nonmetals are nonconductors of heat and electricity, are nonmalleable solids, and many are gases at room temperature. Just as shown in the table above, metals and nonmetals on the periodic table are often separated by a stairstep diagonal line, and several elements near this line are often called metalloids (Si, Ge, As, Sb, Te, and At). Metalloids are elements that look like metals and in some ways behave like metals but also have some nonmetallic properties. The group to the farthest right of the table, shaded orange, is known as the noble gases. Noble gases are treated as a special group of nonmetals.

1.1.2. The Importance of the Periodic Table

The modern periodic table has changed since Mendeleev's original table, yet both the first tables and the modern table are important for the same reason: The periodic table organizes elements according to similar properties so you can tell the **characteristics** of an element just by looking at its position on the table.

Before all the naturally occurring elements were discovered, the periodic table was used to **predict** the chemical and physical properties of elements in the gaps on the table. Today, the table can be used to predict properties of elements yet to be discovered, **although** these new elements are all highly radioactive and break down into more familiar elements almost instantly.

The table is useful for modern students and scientists because it helps predict the types of chemical reactions that are likely for an element. Rather than memorize facts and **figures** for each element, a quick **glance** at the table reveals a lot about the reactivity of an element, whether it is likely to conduct electricity, whether it is hard or soft, and many other characteristics.

Elements in the same column as each other (groups) share **similar** properties. For example, the elements in the first column (the alkali metals) are all metals that usually carry a 1+ charge in reactions, react **vigorously** with water, and combine readily with nonmetals.

Another useful feature of the periodic table is that most table **provide** all the information you need to balance chemical reactions at a glance. The table tells an element’s atomic number and usually its atomic weight. The usual charge on an element is **indicated** by an element's group.

IN THE LABORATORY

The work in an organic chemistry laboratory involves handling of chemicals many of which are highly flammable, poisonous, and corrosive. In order to prevent hazards it is imperative to observe fundamental safety rules.

Eyes must be protected at all times properly. Contact lenses and prescription glasses are not sufficient. Special safety glasses made of shatterproof glass or plastic and having side protectors must be worn. Better still are safety goggles. If a chemical gets into the eye it is necessary to wash the eye first with a copious amount of lukewarm water. In case of an acid, a 2% solution of boric acid is used.

In case of a spillage of a corrosive chemical over a part of the body, the chemical must be washed away with a large amount of water. Acid and base residues must be neutralized: acids with 2% solution of sodium bicarbonate or ammonia and bromine with a dilute solution of sodium bisulphate.

Many solvents and chemicals used are highly flammable. Utmost care is necessary to prevent fire hazards. No flammable compounds should be heated in open vessels such as dishes, beakers, or open flasks. Before lighting a Bunsen burner or switching on a heater, it is necessary to make sure that no flammable chemical in open vessel is nearby. The location and handling of fire extinguisher must be known to every student.
Highly volatile liquids should never be kept in the vicinity of free flame. In working with extremely poisonous substances other hazards might happen. In such cases special precautionary measures should be undertaken.

A universal rule for safety in the laboratory is to maintain cleanliness. Puddles on the desk or on the floor must be mopped immediately.

In view of environmental regulations it is necessary to dispose of waste chemicals in an appropriate way. Most of the aqueous solutions of acids, bases and salts can be drained into the sink. Organic waste chemicals which cannot be properly identified such as mixtures of solvents or residues after crystallizations and distillations must be placed in glass containers properly labelled as "waste", and disposed of professionally.

HYDROGEN, OXYGEN, AND WATER

One of the reasons so much attention is devoted to hydrogen and oxygen is that these two elements form binary compounds with almost every other element. Hydrogen and oxygen react with each other to form water, a simple molecule whose unusual properties are necessary for the development and maintenance of life.

Hydrogen is the most abundant element in our vast universe. Fifteen per cent of the atoms on the Earth's crust are hydrogen. However, because the atomic mass of hydrogen is small, its contribution to the total mass of the Earth's crust is slight – less than 1%. Since the mass of hydrogen is so small, all the hydrogen gas in the Earth's atmosphere either escaped the Earth's gravitational pull or was chemically combined during the early development of our planet. Almost all the hydrogen present on Earth today is present as compounds – water, petroleum and natural gas, and the organic substances.

All living organisms require hydrogen-containing molecules. Life would not be possible if it were not for the special properties of these molecules.

Hydrogen gas is a colourless, odourless and highly combustible substance.

Hydrogen is a moderate reducing agent and can reduce the oxides of moderately active metals at high temperature. It oxidizes very active metals to form ionic compounds containing hydrogen ions, H^-.

The three isotopes of hydrogen are protium (^1H), deuterium (^2H or D), and tritium (^3H or T). *Protium* is by far the most abundant isotope.

Oxygen. Of the 107 known elements, oxygen has a special significance for life on Earth. Its elemental form (O_2) is an oxidant for metabolism in most animal organisms, and water, its most important compound, is an essential ingredient of the living cell and provided the environment in which life evolved. Oxygen accounts for approximately 20% by weight of the Earth's atmosphere, mostly as O_2, 89% of its water, and 50% of its crust, primarily as oxides, carbonates, and sulphates. .

Water is so common and so much a part of our lives we tend to take it for granted and regard it as uninteresting. On the contrary, its many unusual properties continue to fascinate chemists. Because water molecules form strong hydrogen bonds, it has an unusually high boiling point, freezing point, and heat of evaporation. Unlike most substances, it expands when it freezes.

Water's unusual properties are due to the ability of its molecules to engage in hydrogen bonds. The low density of ice compared to water is due to the free space maintained in the crystal structure by hydrogen bonding. Water is an effective solvent for ionic substances because its molecules surround ions in a manner that insulates against their charges. This process is known as *solvation.*

Water participates in two classes of compounds, clathrates and hydrates. *Clathrates* ("cage compounds") are solid substances in which small molecules, such as that of water, are trapped in the holes of an open crystal structure. *Hydrates* are compounds in which water molecules occupy definite positions in an ionic crystal lattice.