Unit 6. Structure of the matter II

1. The Atom

An atom is the smallest building block of matter. Knowledge about the size and make up of the atom grew very slowly as scientific theory progressed. One scientist who has greatly contributed to the knowledge on the atomic structure is, among others, **Ernest Rutherford**.

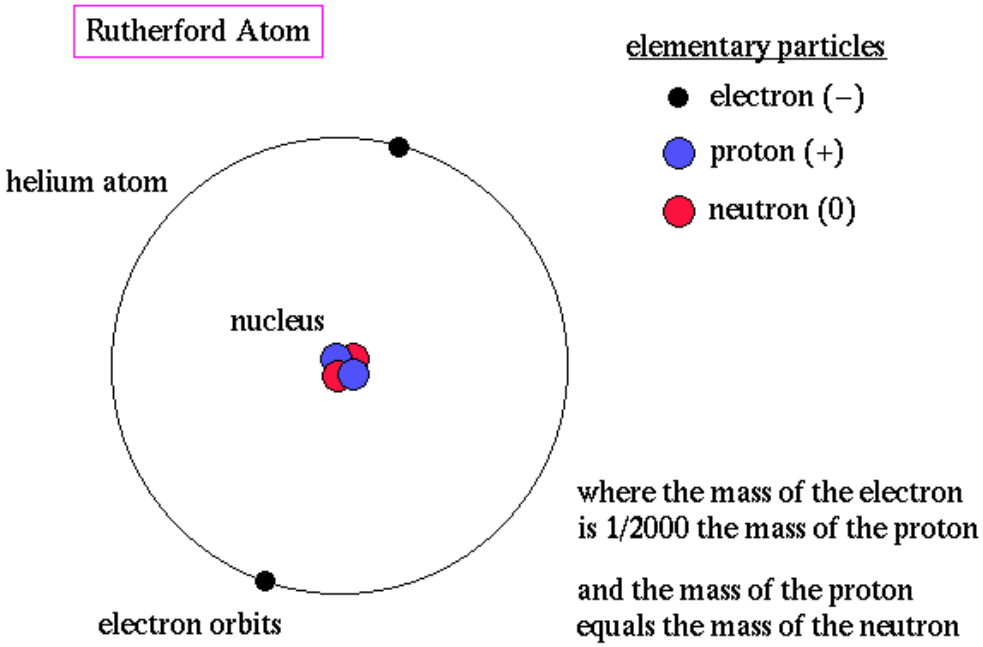
Today we know that atoms are made up of three fundamental sub-atomic particles: protons, neutrons, and electrons.

SUB-ATOMIC PARTICLES

The **electron** (e-) was discovered in 1897 by the physicist J.J. Thomson when studying cathodic rays. He also calculated the mass of the electron and found that it was very small compared to the total mass of the atom. Therefore, a revision of Dalton's indivisible atom was necessary. If the atom was not indivisible; how did it really look like?

More experiments were carried out and, in 1911, Rutherford discovered the positive particle that makes the atom. It was called a proton. Its mass was about 2 000 times greater than that of the electron, and its charge was exactly the same as the electron's but with a positive sign. The neutron still had to be discovered but this was not until 1932, by Chadwick, pupil of Rutherford. Its mass is similar to that of the proton, and it is not charged. Once the different sub-atomic particles had been discovered, the big question was how were they arranged inside the atom?

Rutherford's atomic model



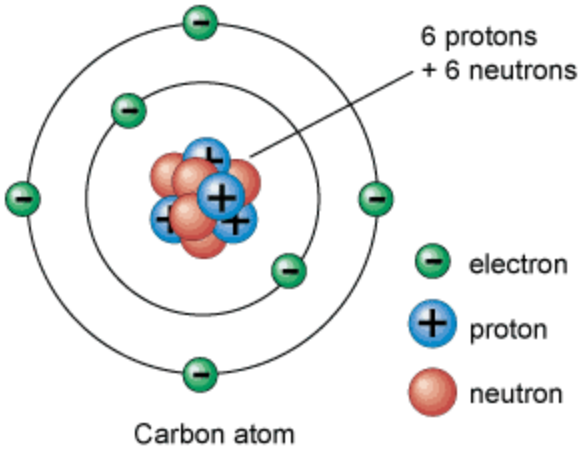
Ernest Rutherford (1871-1937), a major contributor to the atomic model, found the following conclusions:

Atoms are made of protons, neutrons and electrons

- The protons are particles which carry a positive electrical charge. The mass of a proton is very similar to the mass of a hydrogen atom.
- The neutrons have a mass which is similar to the mass of a proton. However, neutrons are not electrically charged.
- The electrons carry a negative electrical charge and their mass is around 1836 times smaller than the mass of a proton.

The nucleus of an atom is extremely small in comparison to the atom. If an atom was the size of a football stadium, then its nucleus would be the size of a pea.

atomic number, Z



The number of protons varies from one element to another, but **all atoms of the same element always have the same number of protons**.

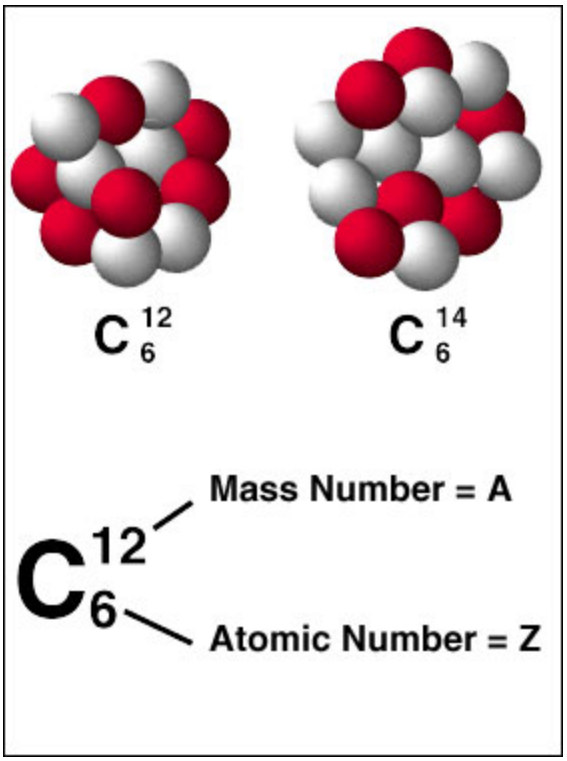
Example: Each atom of helium has two protons, the lithium atoms have three protons each, and every carbon atom presents six protons. In their natural state, atoms do not carry any electrical charge; they are **neutral**. This means that they have the same number of positively charged protons and negatively charged electrons. The helium atom, in its natural state, therefore has two electrons, the lithium atom three and the carbon atom six. Therefore, in a neutral atom the atomic number also indicates the number of electrons.

Z = atomic number = number of protons = number of electrons

Isotopes

The number of protons and electrons is always the same in all neutral atoms of a chemical element, but the number of neutrons can vary. Atoms which present this circumstance are called **isotopes**.

Example: The most abundant isotope of hydrogen (Z = 1) is protium (a single proton, no neutrons) followed by deuterium (a proton and a neutron) and the least abundant tritium (a proton



and two neutrons). Another example is oxygen, with atomic number of 8 can have 8, 9, or 10 neutrons.

mass number, A.

The protons and neutrons are situated in the nucleus of the atom. The **mass number** of an atom is the number of particles the atom contains. It is therefore, the sum of the number of protons and the number of neutrons. It is represented with the letter **A**.

If we call the number of neutrons n, we conclude that

A = Z + n

Consequently, we can know the number of all the fundamental particles which form an atom if we know Z (the atomic number) and A (the mass number).

Example: symbol = C name = carbon atomic nº (Z) = 6

atomic mass number (A) = 12 (→ atomic mass = 12 u)

2. The Periodic Table

An element is a substance formed by a single type of atoms. Actually, 109 different chemical elements are known. Very early on, scientists saw the need of arranging them in some type of order. They realized that there were groups of elements which had similar characteristics. Elements that resemble each other are on the same group.

There were a few scientists involved in the evolution of the periodice table. However, it was the periodic table of the Russian scientist Mendeleev that served as a prototype (precursor) of today's periodic table. He ordered the chemical elements by their **atomic mass** and into groups with similar behaviour, arranging them in rows and columns.

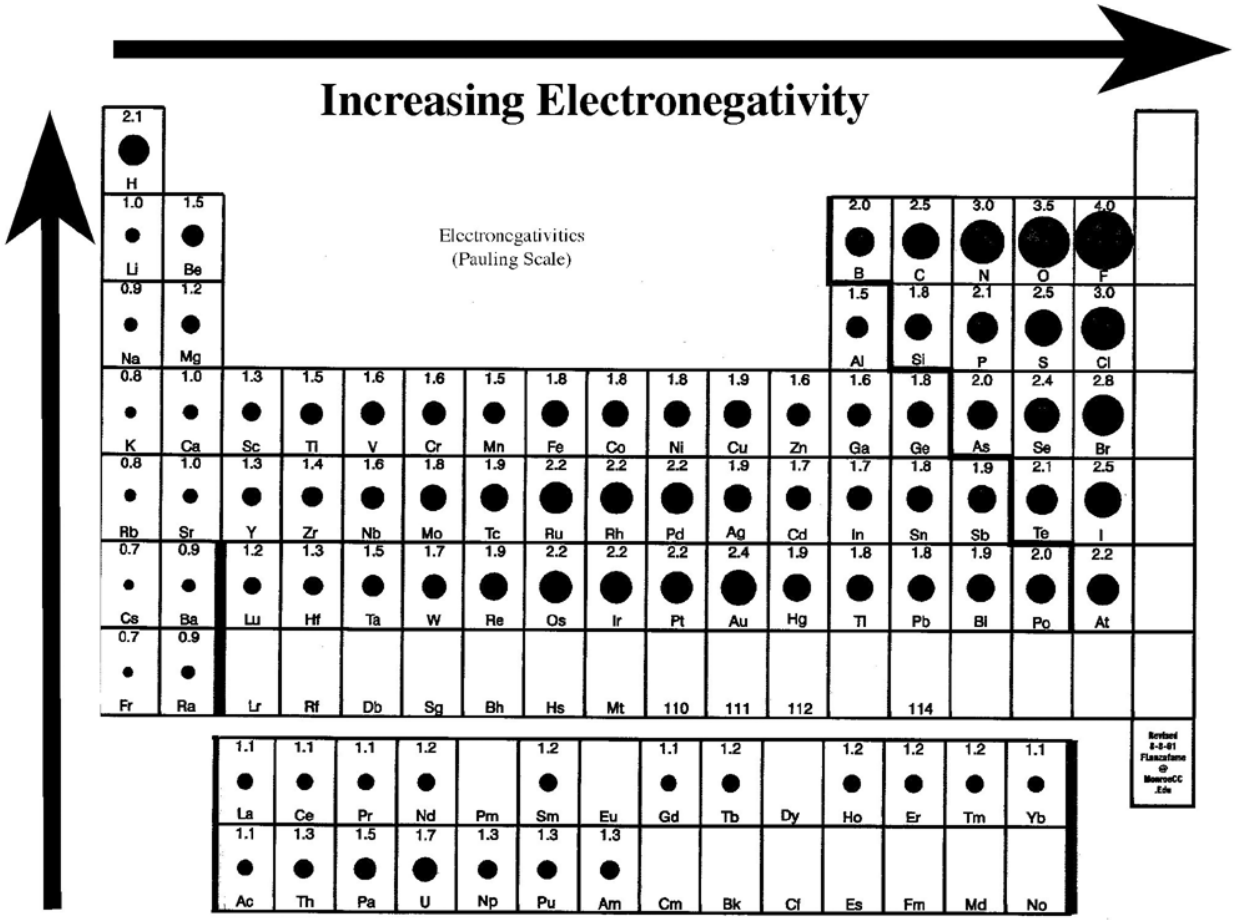
All the elements in a given **period** have the same number of electronic shells. In the periodic table there are 7 "periods" (the horizontal rows). The 4th, 5th, and 6th periods are called the transition metals. The transition metals include two periods known as the lanthanides and the actinides which are located at the very bottom of the periodic table.

All the elements in a given **group** share the same number of electrons in their last shell. In the periodic table there are 18 groups (the vertical columns). Some of the groups or families have special names:

- Group 1 is also called **the alkali metals.**
- Group 2 is also called **the alkaline earth metals.**
- Group 13 is **the earth metals.**
- Group 17 is **the halogens.**
- Group 18 is **the noble gases.**

All the elements in the same group have similar properties and it is said that they belong to

the same family. There are many different chemical properties that show a certain periodicity when we study them in the elements of the periodic table, such as atomic volume, atomic mass or electronegativity.



Electronegativity is a chemical property that describes the tendency of an atom or functional group to attract electrons towards itself. The higher the electronegativity, the more an element attracts electrons towards it.

In general, electronegativity increases on passing from left to right along a period, and decreases on descending a group. Hence, fluorine is undoubtedly the most electronegative of the elements (not counting noble gases) while caesium is the least electronegative, at least of those elements for which substantial data is available.

In an atom with a neutral charge, the number of electrons equals the number of protons; the periodic table represents neutral atoms. The atomic number is typically located above the element symbol. The **atomic mass number** is typically found beneath the element symbol.

An **ion** is an atom or molecule in which the total number of electrons is not equal to the total number of protons, giving the atom a net positive or negative electrical charge. Since the electric charge on a proton is equal in magnitude to the charge on an electron, the net electric charge on

an ion is equal to the number of protons in the ion minus the number of electrons.

An **anion** (−) is an ion with more electrons than protons, giving it a net **negative charge** (since electrons are negatively charged and protons are positively charged). A **cation** (+) is an ion with fewer electrons than protons, giving it a **positive charge**.

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