Generality

I. Structure of the atom

Matter has a discontinuous structure, it is made up of infinitely small particles called atoms (from the Greek atomos: indivisible)

The atom has a spherical shape composed of an extremely small central nucleus, surrounded by a region of negative charge called an electronic cloud made up of infinitely small particles called electrons.

1/ The nucleus

The nucleus occupies $1/10^{15}$ of the volume of the atom, its radius is of the order of 10^{-12} cm. The mass of the atom is entirely concentrated in its nucleus.

It is made up of two types of particles of different nature called nucleons: protons and neutrons.

Proton: charge $q_p = +e = +1.6.10^{-19}$C , mass $m_p = 1.675.10^{-27}$ kg

Neutron: charge $q_n = 0$C , mass $m_n = 1{,}673.10^{-27}$ kg

Remarks :

- The proton and the neutron have approximately the same mass.
- The nucleus is positively charged, if Z represents the number of protons contained in the nucleus of an atom, its charge will be $Q_{nucleus} = +Z .1{,}6.10^{-19}$ C.

2/ Électrons

Electrons are small particles that orbit the nucleus at a fairly high speed and constitute an electronic cloud around the nucleus.

Electron: charge qelec = -e = - $1,6.10^{-19}$C , mass melec= $9,11.10^{-31}$kg

Remarks :

• mp/melec = 1833. Electrons have an almost negligible mass compared to that of protons.

• The free atom in its ground state is electrically neutral. Therefore, as the mass of a nucleus with Z protons is +Ze we will have a charge equal to –Ze for the electrons which means that the number of the protons and the neutrons are the same.

3/ Representation of an atom in its fundamental state

The atom is generally represented by a capital letter which is the first letter of the name corresponding to it.

In the case where two or more atoms have the same first letter, the first letter is followed by the second or third letter of the name which corresponds to it but this time in a lowercase letter.

Example :

H denotes the symbol for hydrogen.

C denotes the symbol for carbon.

He denotes the symbol for helium , **Ca** denotes the symbol for calcium.

Ar denotes the symbol for argon , Ag denotes the symbol for silver(argent).

4/ Charge number and mass number.

a) number of charge.

We call the charge number or atomic number of an atom the number Z of protons in its nucleus.

b) mass number

We call the mass number of an atom with charge number Z, the number denoted A of nucleons contained in its nucleus. A=Z+N , such that N represents the number of neutrons.

5/ The mass of atoms and the concept of atomic mass unit.

The mass of an atom is the sum of the masses of its electrons and that of its nucleus: Matome=Z.mp+N.mn+Z.me.

As mp/ me =1800 and mp≈ mn , we will have :

m(atome)≈ Z.mp+N.mn ≈ (Z+N) mp ≈A mp

At the microscopic scale and in order to avoid negative powers of 10, we have chosen, to evaluate the masses of atoms and micro particles, a unit called atomic mass unit (denoted a.m.a).

1a.m.u = (1/12). m(1 atom of carbon) = (1/12).(12/NA) = 1/ NA(g)

1amu = $1.66.10^{-24}$ g).

We notice that: 1a.m.u ≈ mn≈ mp

Result :

The mass number A designates at the same time the number of nucleons and the mass of the nucleus expressed in a.m.u

If an atom of an element X contains Z protons and A nucleons, we denote it with the symbol : ${}^{A}_{Z}X$

Example :

In the symbol ${}^{12}_{6}C$ (C: symbol of the element carbon , 6: the number of protons , 12: the number of nucleons, which corresponds approximatelly to the mass of an atom of carbon expressed in a.m.u and also the approximatelly mass of one mole of carbon atoms expressed in grams).

6/ Concept of isotope.

a) Definition:

We call isotope of an element, atoms having the same number of protons Z and differing in their mass number A.

Note: In nature most elements exist in the form of a mixture of isotopes.

b) Abundance of isotopes:

The natural abundance of an isotope of an element in % is the number of atoms of this isotope in a mixture of 100 atoms of this element.

Example:

Carbon is found in nature in the form of three isotopes.

$^{12}_{6}C$ (ab= 98,9) , $^{13}_{6}C$(ab=1,1) , $^{14}_{6}C$(ab<0,0001)

c) Average atomic mass of an element:

The average atomic mass of an element is the average mass of all the isotopes that constitute it.

$M_X = \sum A_i . \chi_i/100 = (A_1 . \chi_1 + A_2 . \chi_2 + \ldots\ldots + A_n . \chi_n)/100$

Example:

Find the average atomic mass of chlorine, knowing that:

$^{35}_{17}Cl$ (χ_1 =77.5%) , $^{37}_{17}Cl$ (χ_2 =25.5%)

II. Nucleus stability and cohesion.

The nucleus of any atom is condensed, it is made up of positively charged protons and neutrally charged neutrons.

How can such a system cohexist?

1/ Binding energy of the nucleus.

Let us take as an example the case of the helium nucleus.

$$2p + 2n \longrightarrow He$$

Mass (amu) :	(2.1.007278) + (2.1.008665)		4.001503
Which gives :	4.031886		4.001503

Mass defect : Δm=4.031886 - 4.001503=0.030383 amu

Any nuclear chemical reaction is accompanied by a loss of mass Δm, called mass defect.

This loss of mass was converted into energy. Einstein's relation links mass to energy which are two equivalent quantities is :

$\Delta E = \Delta m .C^2$,where Δm represents the loss of mass, ΔE the equivalent energy rleased and C the speed of light equal to 3.10^8 m/s.

2/ Nuclear and chemical reactions.

The synthesis of a helium nucleus releases an energy equal to $4{,}540.10^{-12}$ J.

For the synthesis of one mole of nucleus, the energy released will be $6{,}54.10^8$ Kcal.

Remarks :

- This energy is considerable compared to the energy released during the combustion of one mole of coal (M=12g).

- The synthesis of 4 g of helium from its nucleons is equivalent from an energetic point of view to the combustion of 83 tonnes of coal.

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3/ Energy unit

At the microscopic scale, we use the electron volt(ev) as a unit of energy.

$1ev = 1{,}6.10^{-19}$ J and sometimes the mega electron volt (Mev)

$1Mev = 10^{6}$ ev

The formation of a helium nucleus is accompanied by an energy released equal to 28,35 Mev. Inversion, if we want to split the helium nucleus into protons and neutrons, we must provide an energy of 28,35 Mev .This energy measures the tenacity with which nucleons stick to each other. This energy is called nuclear binding energy.

4/ Binding energy per nucleon.

The helium nucleus has 4 nucleons with a binding energy of 28,35 Mev and the ratio 28,35/4 ≈ 7,1 Mev represents the binding energy per nucleon.

Remarks :

- The stability of a nucleus is greater as the binding energy per nucleon is high.
- A weak binding energy per nucleon leads to its decay and corresponds to a radioactive element.