Atomes et molécules

Antoine JOLLY
Enseignant - Chercheur au LISA
P3 – 315
jolly@lisa.u-pec.fr

Université Paris Est Créteil, Créteil, France

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Motivation: Why a chemistry course?

Chemistry is present in everyday life

health care, nutrition, clothing, fuel, etc

It is also involved in life itself

in the roots of cell operations of living organisms

Definition of chemistry

Study of matter

- structure
- organic matter
- inorganic matter

and

Transformations affecting its composition

- reactivity of chemical systems, thermodynamics
- organic chemistry reactions

Objectives of the course Chemistry1-1: Atomes &Molecules

Study the structure of matter

Study organic matter (basic concepts)

30 h course

21 h TD

6 h TP

Course Organization

Supervised Work (‘TD’)

14 sessions (+2 for CC) – 1h30 each – **presence mandatory**

A handout will be distributed: **Exercises must be prepared in advance**

Be on time (or risk to be refused by lecturer)

+ 3 Controls of 20 minutes (CC)

Practical work (‘TP’)

2 sessions – 3h each – **presence mandatory**

A handout will be distributed: **Practical tasks must be prepared in advance**

Be on time (penalization if you are late)

Bring an overall

Report handing over at end of session (one for two students)

Examination

Theory (85% = Exam (45 %) + CC (40%))
3 small controls (CC) during supervised work session
1 final exam

Practical work (15%)

- 1 séance en salle de TP
  compte rendu, à rendre en en fin de séance, celui-ci sera noté
- 1 séance en salle de TD modèle moléculaire

Lecturer in charge (enseignant référent)

1 lecturer per practical work group

His/Her tasks:
_ Supervision students in the group, advice
_ Detection of students with difficulties, help

Mandatory to follow the practical work with the group you are assigned, otherwise you will be considered absent by the lecturer

Chapter 1 : Review of elementary chemistry

Chapter 1 – Index

The atom is the basis of chemistry

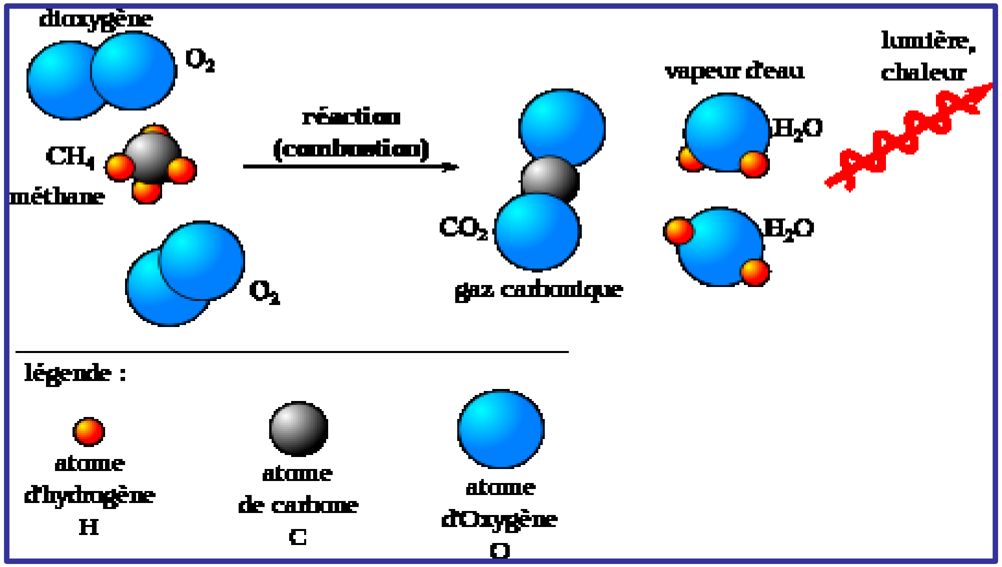
Concept of the atom: long maturation

IV B.C : Leucippus, Democritus → philosophers, matter (definition: everything with mass and occupying space): discontinuous structure and composed of indivisible particles (atoms).
“Atom” means : cannot be separated

1 – First models of the atom
1.2 Birth of modern atomic theory

1775: Lavoisier enounces: Nothing gets lost, nothing is created, everything is transforming. Masses are conserved in chemical reactions.
1803: John Dalton → idea of matter composed of **atoms with different masses: indivisible particles that can't be split**, not because of practical difficulties but due to their very nature

Every type of atom is represented by a symbol has particular properties, different mass and can be combined with different atoms to form **molecules…….**

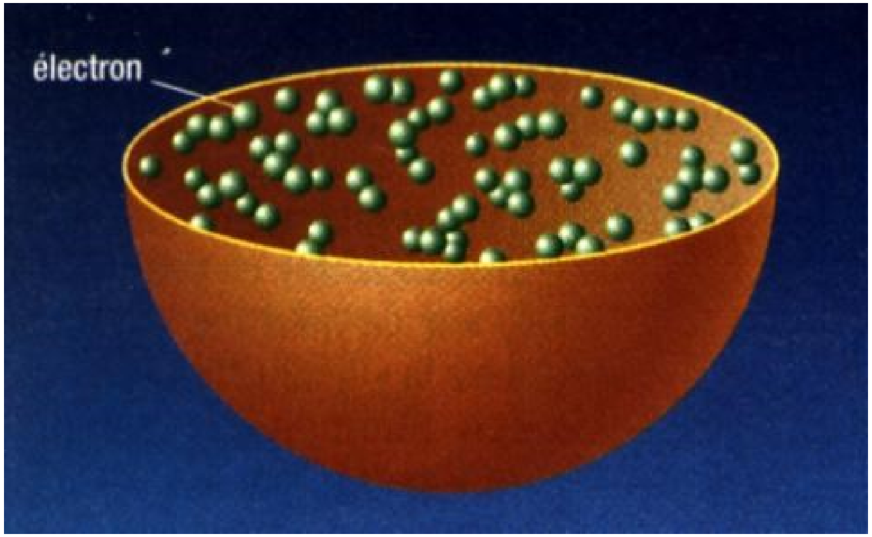


Chemical reactions are rearrangements into a different distributions of the atoms present in the initial body

Other experiments will show that atoms are not the ultimate constituents of matter !!!

1897: Joseph Thomson → show the presence of negatively charged particles inside the atom: the electrons. He showed that **atoms have different number of electrons**. The first subatomic particle.

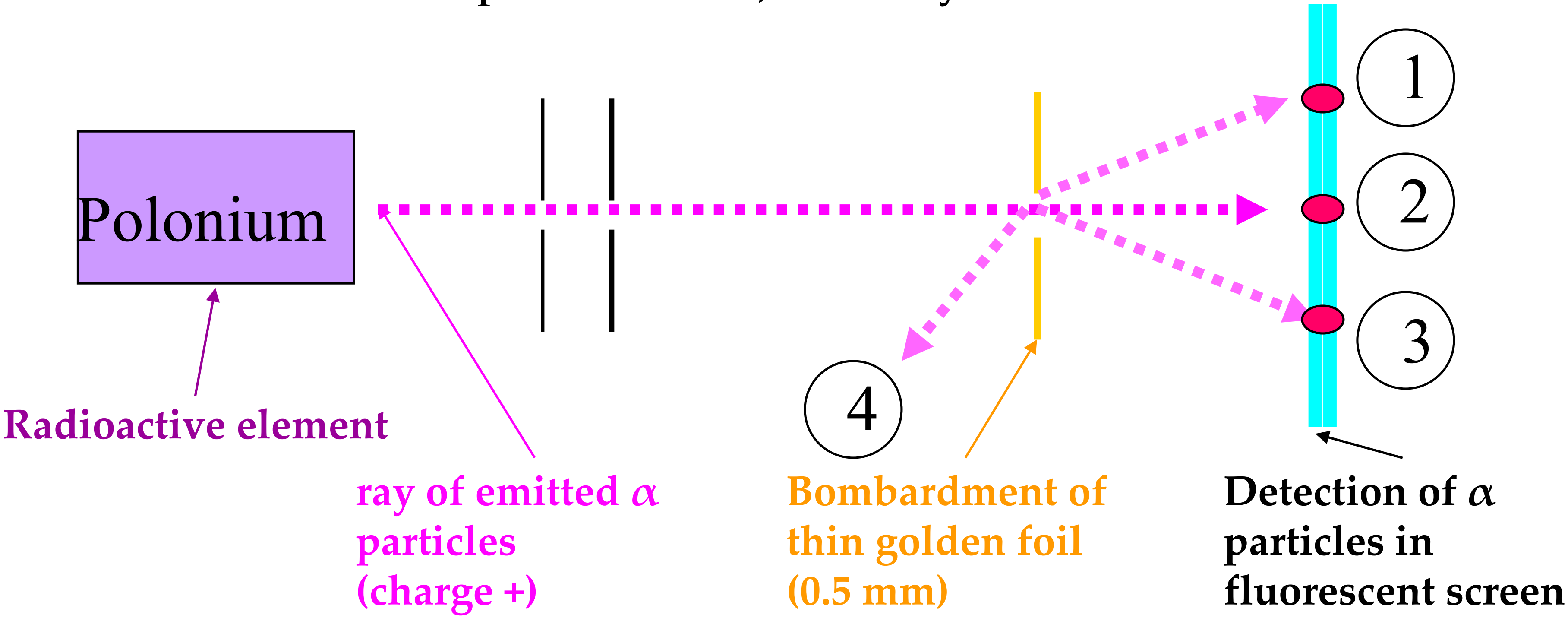
The atom is electrically neutral: Thomson proposes that the atom is a sphere with a surface positively charged and negatively charged electrons inside.



Thomson's model of the atom

University of Cambridge - Prix Nobel de Physique en 1906

1.3.a Rutherford experience (1911), discovery of atomic nucleus



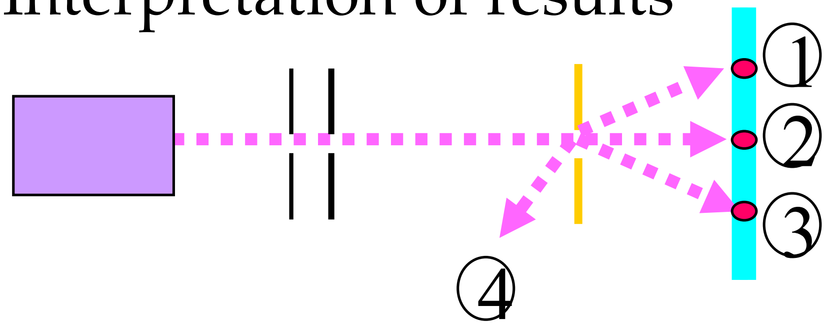
Results:

_ Most alpha particles (99 %) reach the screen center (2)

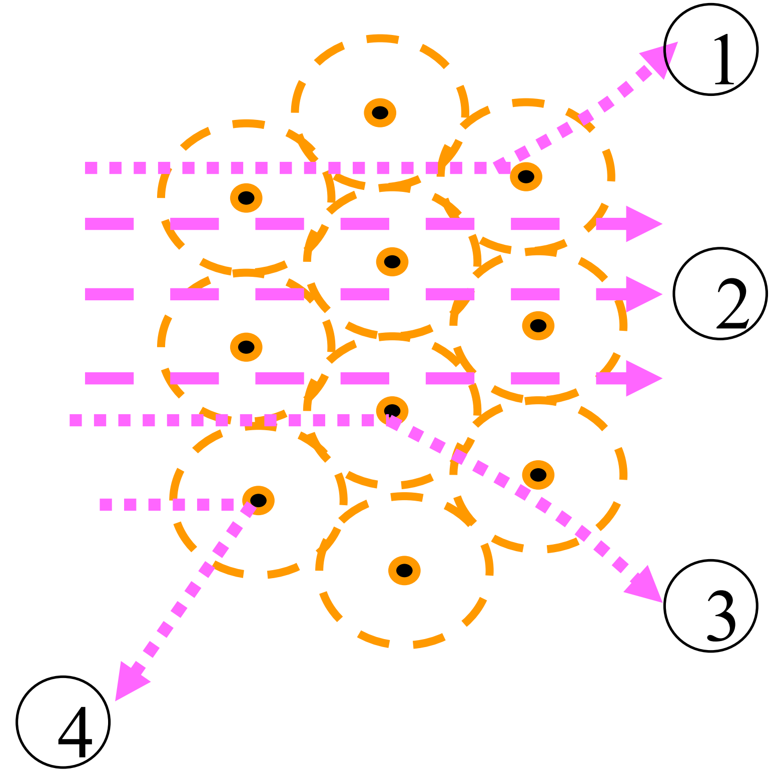
_ A small fraction (10^-4) is deviated: (1) and (3)

_ Some particles are backscattered: (4)

Interpretation of results



Golden foil made out of electrons and positive charges



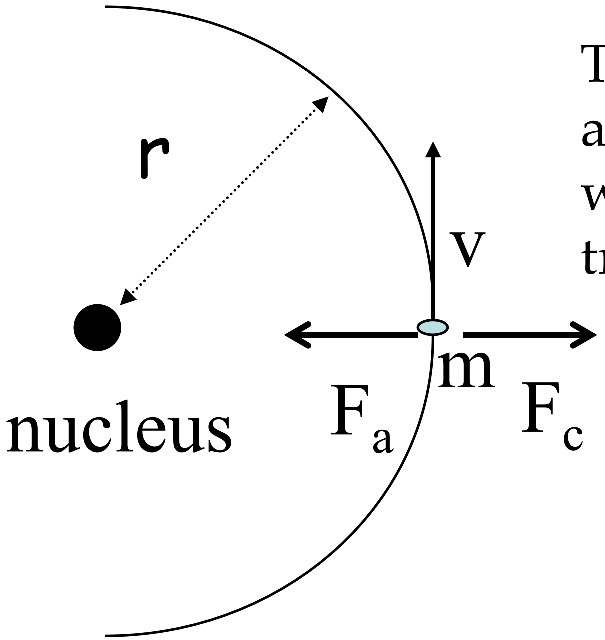
Deviated α particles : they suffered the repulsion of a heavy particle positively charged → the nucleus

Only a small fraction is deviated : The positive charge is concentrated in a very small space: the nuclei, surrounded by a big amount of space, basically vacuum.

1.3.b Rutherford's planetary model of the atom

Rutherford describes the atom as composed of a **positive nucleus**, surrounded by **orbiting electrons** at a distance much larger than the size of the nucleus. This distance corresponds to the atomic radius.

atom radius ~ 10000 * nucleus radius



The electron of charge $q=-e$ and mass m turns around the heavier fixed nucleus of charge $q=+e$ with uniform speed, describing a circular trajectory of **radius** r.

The electron is subject to:
_ electrostatic force by the nucleus, F_a
_ centripetal force, F_c

Calculating the forces involved, Rutherford gives the **total energy of the electron** on the trajectory:

$$E_{kinetic} + E_{potential} = E_{total} = -\frac{1}{8\pi\varepsilon_0}\frac{e^2}{r}$$

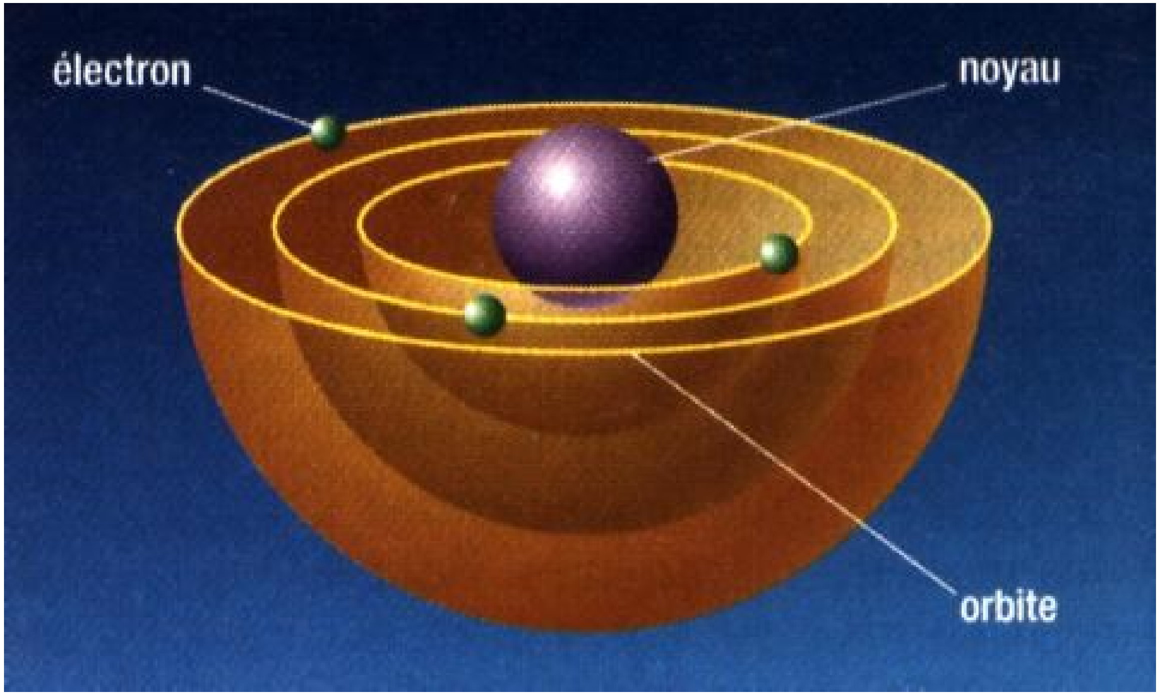
note: SI units!

ε_0 : vacuum permitivity
e : electron charge
r: trajectory radius

The total energy of the electron is ONLY a function of its distance to the nucleus.

It is a continuous function of r, as r can vary continuously

Note: E_{total} ↓(stability of the sytem ↑) when r ↓.



Rutherford's model of the atom:
Electrons orbit the nucleus in circular trajectories

2 – Atomic composition

1875 – 1932 : Several 'historical' experiments have shown that the atom is not the ultimate constituent of matter

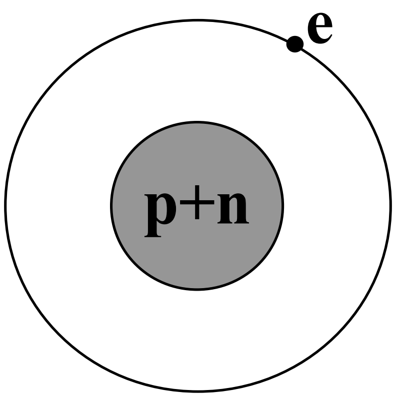
Atoms are formed of several particles of different types:

_ electrons (**e**)

_ protons (**p**)

_ neutrons (**n**)

2 – Atomic composition - 2.1 Nucleus and electrons characteristics



		Charge	**Mass**
Nucleus	Proton (**p**)	+e	$1.6726\ 10^{-27}$ kg
	Neutron (**n**)	0	$1.6750\ 10^{-27}$ kg
	Electron (**e**)	-e	$9.1095\ 10^{-31}$ kg

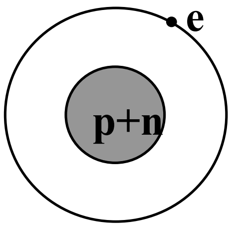
(e = $1.602\ 10^{-19}$ coulomb)

Me/Mp = 1/1836

Me 2000 times < than Mp

=> $M_{atom} \approx M_{nucleus}$

2 – Atomic composition - 2.2 Nuclides, elements and isotopes



An atom is characterized by 2 numbers:
Z : number of protons or electrons (neutral case)
N : number of neutrons

A pair of these values {Z, N} defines a **nuclide**.

Nuclide:

Group of atoms with the same number of **protons (Z)** and the same number of **neutrons (N)** in the nucleus.

In practice: to identify a nuclide with symbol X, we write:

$$^{A}_{Z}\mathbf{X}$$

[A : mass number]

[Z = atomic number]

$A = Z + N$
$= n$ (protons) + n (neutrons)
$= n$ (nucleons)

Examples: $^{12}_{6}\mathrm{C}$ $^{13}_{6}\mathrm{C}$

<u>Element :</u>

The group of atoms and ions that have nuclei composed by the same number of protons Z, i.e, the same atomic number Z.

2 different elements cannot have the same Z

Note:

Z and the atomic symbol **X** are redundant information:

e.g:

$${}^{35}_{17}Cl$$

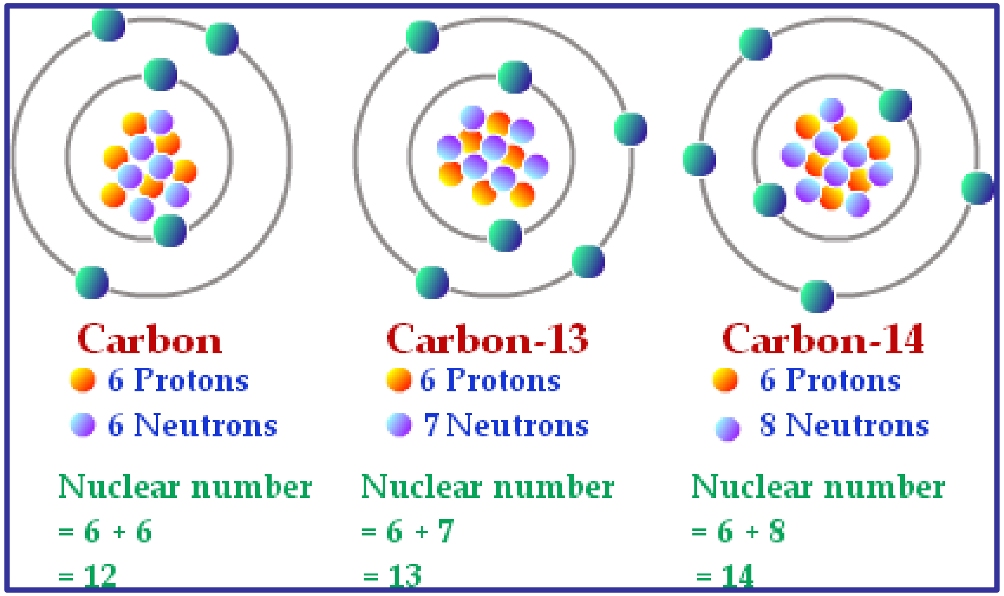
as the chlorine has always 17 protons and electrons, we can write:

$${}^{35}Cl$$

Isotopes of an element:

Nuclides having:

_ the **same number of protons (same Z)**, which defines the element
_ but a **different number of neutrons (N)**, therefore their mass number **A is also different.**



Isotopes have the same chemical properties.

^{12}C	**98,93 %**	stable with 6 neutrons			
^{13}C	1,07 %	stable with 7 neutrons			
^{14}C	trace	5 730 years	β-	0,156	^{14}N

Examples of isotopes

Natural hydrogen is composed of (in mass):

99.985 %	${}^{1}_{1}H$	Z=1, A=1, N=0
0.015 %	${}^{2}_{1}H$ (D: deuterium)	Z=1, A=2, N=1
1 x 10^{-7} %	${}^{3}_{1}H$ (T: tritium)	Z=1, A=3, N=2

Natural chlorine is composed of (in mass):

75.4 %	${}^{35}Cl$	Z=17, A=35, N=18
24.6 %	${}^{37}Cl$	Z= 17, A=37, N=20

The atomic mass of a natural element (mixture of isotopes) is the weighted averaged of the atomic mass of its isotopes

e.g.: for **Chlorine: M = 0,754 * 35 + 0,246 * 37 = 35,5**

3 - Concept of pure body

3.1 Simple bodies

substances composed of one type of atom, i.e., of only one element
_ as independent atoms (neon Ne, argon Ar, etc.)
_ as molecules (dioxygen O_2, Ozone O_3, etc.)

3.2 Composed bodies

substances composed of at least two different elements in definite proportions (water H_2O, sulfuric acid H_2SO_4, etc.)

3.2.a Organic compounds

Molecular compounds having the element carbon, and usually hydrogen (methane CH4, sugars: glucose, etc.)

3.2.b Inorganic compounds

All the others (water H_2O, amonia NH_3, calcium sulfate $CaSO_4$, some simple carbon compounds: carbon dioxide CO_2, chalk: calcium carbonate $CaCO_3$)

The atoms of a compound are connected or bounded to each other in a specific way. They form a **molecule** or they exist in the form of **ions**.

Molecule:

defined and independent group of atoms with a particular layout. A fomula is associated to each molecule, showing the nature and number of atoms involved in its formation.

Molecular compound: composed of molecules. **For example: Water**

Ion:

Atom or group of bounded atoms, positively or negatively charged.

Ionic compound:

composed of ions maintained by Coulombic attraction between opposite charges. For example: **Sodium Chloride Na^+,Cl^-**.

4 - Mixtures

Many materials are neither simple bodies nor complex ones, but a mixture of them.

Composition of air ?

Chemical Composition of Air		
Name	**Symbol**	**% by volume**
Nitrogen	N2	78.084 %
Oxygen	O2	20.9476 %
Argon	Ar	0.934 %
Carbon Dioxide	CO2	0.0314 %
Neon	Ne	0.001818 %
Methane	CH4	0.0002 %
Helium	He	0.000524 %
Krypton	Kr	0.000114 %
Hydrogen	H2	0.00005 %
Xenon	Xe	0.0000087 %

CO Daily$_2$

Mauna Loa Observatoire | CO atmosphérique$_2$ Concentrations

Septembre 1, 2019	**408.24 ppm**	NOAA-ESRL
Septembre 1, 2018	**405.42 ppm**	NOAA-ESRL

concentrations moyennes quotidiennes | ppm = parties par million

sea water: H2O + dissolved bodies (sodium chloride NaCl)

fuel: hydrocarbon + additives

medicines, perfumes, etc.

The constituents of a mixture are ‘mixed’ together and not attached to each other by chemical bonds like in a compound.

Parmi les propositions concernant ${}^{12}_{6}C$ et ${}^{14}_{6}C$, laquelle(lesquelles) est(sont) exacte(s) ?

- ☐ Leur nombre d'électrons est identique.
- ☐ Leur nombre de neutrons est identique.
- ☐ Leur nombre de protons est identique.
- ☐ Leur nombre de nucléons est identique.
- ☐ Il s'agit de deux éléments chimiques différents

QCM 2

La masse d'un atome est essentiellement due à la masse de ses électrons

A. Vrai **B.** Faux

QCM 3

L'hydrogène naturel contient 3 isotopes (dont le deutérium et le tritium) qui ne diffèrent que par leur nombre de neutrons et leur nombre de masse A :

A. Vrai **B.** Faux