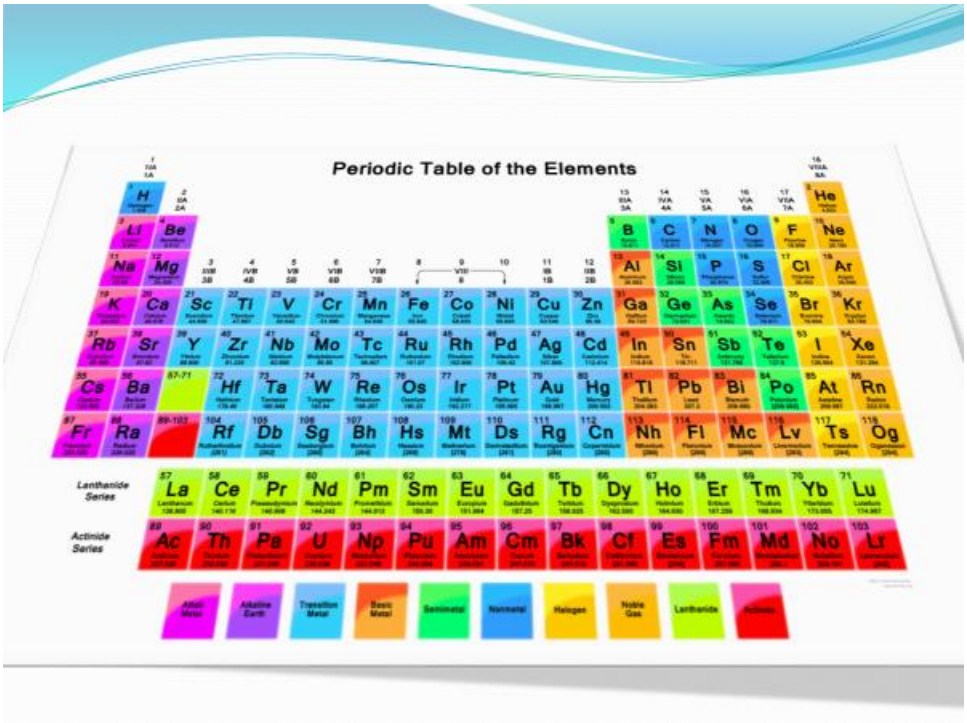
7th Course of Chemistry 1

Chapter 4: Periodic classification

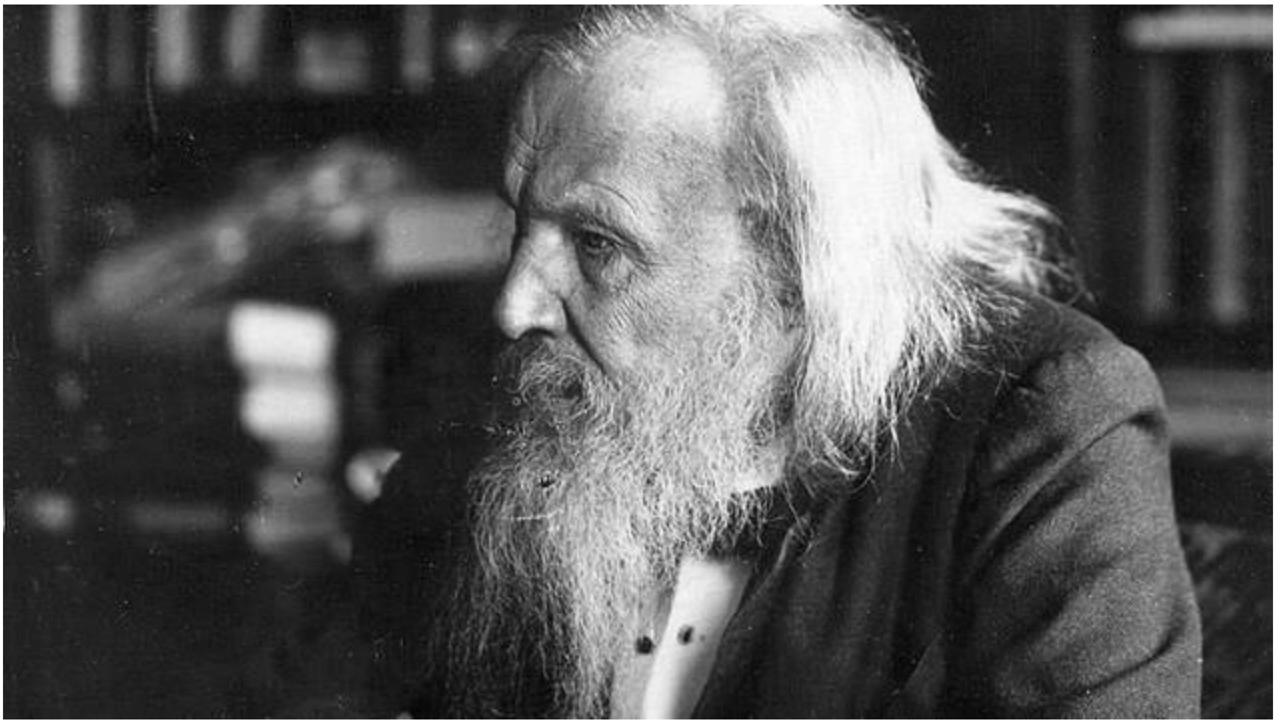


1. Introduction
2. Group (column), period (row)
3. Evolution of physical properties within the periodic table:
4. Atomic radius , Ionisation energy, electron affinity.

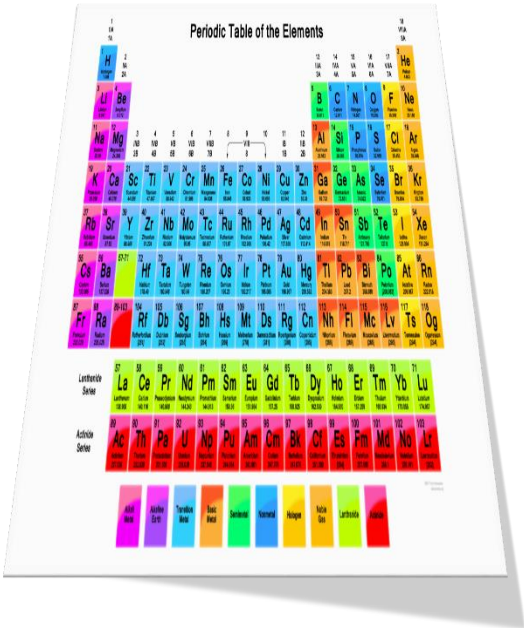
III-1. Introduction

- The periodic classification of elements, or simply the periodic table of elements (also known as Mendeleev's Table), represents all chemical elements ordered by increasing atomic number (Z) and organized according to their electronic configuration.
- Its invention is generally attributed to the Russian chemist Dimitri Mendeleev, who constructed a table in 1869 that was different from the one used today but similar in its principle. Its great interest was to propose a systematic classification of the chemical elements known at that time in order to highlight the periodicity of their chemical properties, identify the elements that remained to be discovered, and even predict the properties of these then-unknown elements.
- The periodic table has undergone numerous adjustments since 1869 until it took the form we know today, and has become a universal reference to which all types of physical and chemical behavior of elements can be related.
- Since the update by IUPAC (International Union of Pure and Applied Chemistry) in 2016, its standard form consisted of 118 elements, ranging from $_{1}$**H** to $_{118}$**Og.**

Dimitri Mendeleïev



Discovery of Mendeleev's Periodic Table



- It was in 1869 that Dimitri Mendeleev proposed the periodic classification of elements, which allowed him to group and classify all the known atoms at that time. This classification differs little from the one we know today. The development of this classification played a major role in the evolution of knowledge and the advancement of chemistry.

- Dimitri Mendeleev came up with the idea of classifying the known elements at the time by increasing atomic mass (the only parameter accessible during his time, as electrons were only later discovered by J.J. Thomson in 1897).

- His genius lies in the fact that he predicted a place for the missing elements and estimated their mass. Furthermore, he noticed that certain elements had the same chemical properties, thus anticipating the concept of families.
- However, some elements posed problems for him, as he did not know where to place them, such as the lanthanides and noble gases.
- During his lifetime, Mendeleev had the pleasure of knowing that three of the elements whose existence he had predicted were discovered (gallium, scandium, and germanium), and that the physical and chemical properties he had announced for these simple substances and their compounds were accurate. In some cases, he even predicted the method by which these elements would be discovered, and it was verified.

Modern Periodic Classification

- The current classification groups nearly 118 elements, including 90 natural elements (which can be found in the form of oxides in ores...).
- The others are artificially created in the laboratory and sometimes have a very short lifespan (on the order of microseconds: 10-6 s). The elements are classified by increasing atomic number Z and are grouped into metals on one side and non-metals on the other.
- The periodic table is divided into 7 rows, called periods, and 18 columns that form the families.
- The row number indicates the number of electron shells around the nucleus of the corresponding atom.
- The column number indicates the number of electrons in the outer shell of the corresponding atom.

Description of the Periodic Table

- This table should have 32 columns and 7 rows, but to reduce the clutter of the table, two series of elements from Z = 58 to 71 and from Z = 90 to 118 are represented below the main table, which has 18 columns (groups) and 7 rows (periods).
- Block structure of the elements in the periodic table:
- he periodic table is divided into 4 blocks (s, p, d, and f) corresponding to the type of the last occupied valence subshell. The number of columns in each block corresponds to the maximum number of electrons that can be placed in each subshell: 2 / 6 / 10 / 14, for the s / p / d / f sublevels, respectively.

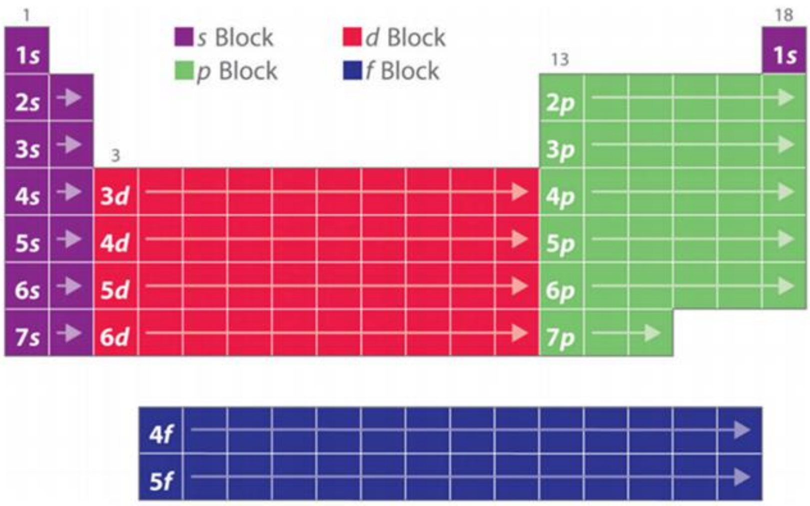
Block structure of the elements in the periodic table

Block s: It is located on the left side of the periodic table and consists of columns 1 and 2, which contain elements with electron configurations involving ns^1 and ns^2 electrons. The number of valence electrons indicates the column number.

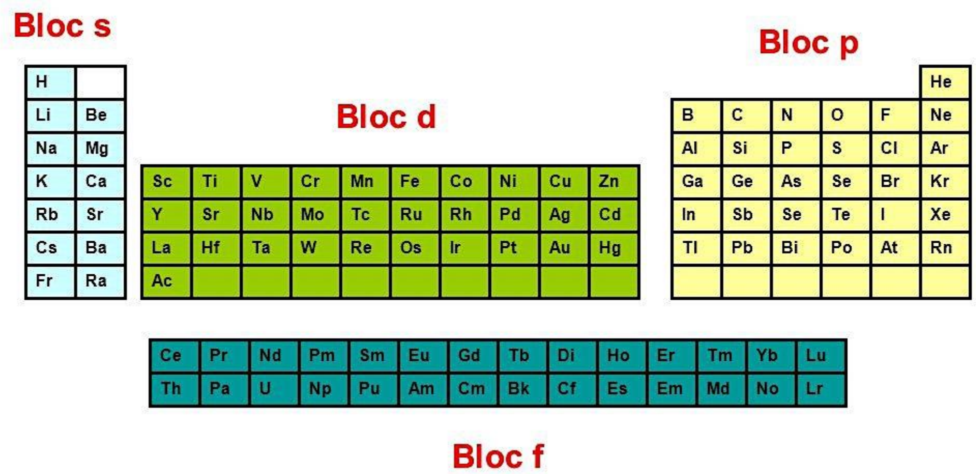
Block p: It is located on the right side of the periodic table and consists of six columns from 13 to 18, corresponding to the progressive filling of the np subshell, with the (n-1)d and ns subshells being saturated with **$(n-1)d^{10}$** and ns^2 electrons. The number of valence electrons plus 10 indicates the column number.

Block d: It is located between block s and block p, consisting of 10 columns from 3 to 12, involving the progressive filling of the (n-1)d subshell, with the ns subshell being saturated with ns^2 electrons. It is noted that the column number indicates the number of **s** and **d** electrons.

Block f: This block, presented in two rows, is located at the bottom of the main table. The elements in this block, 14 in each row, correspond to the filling of the f subshells.

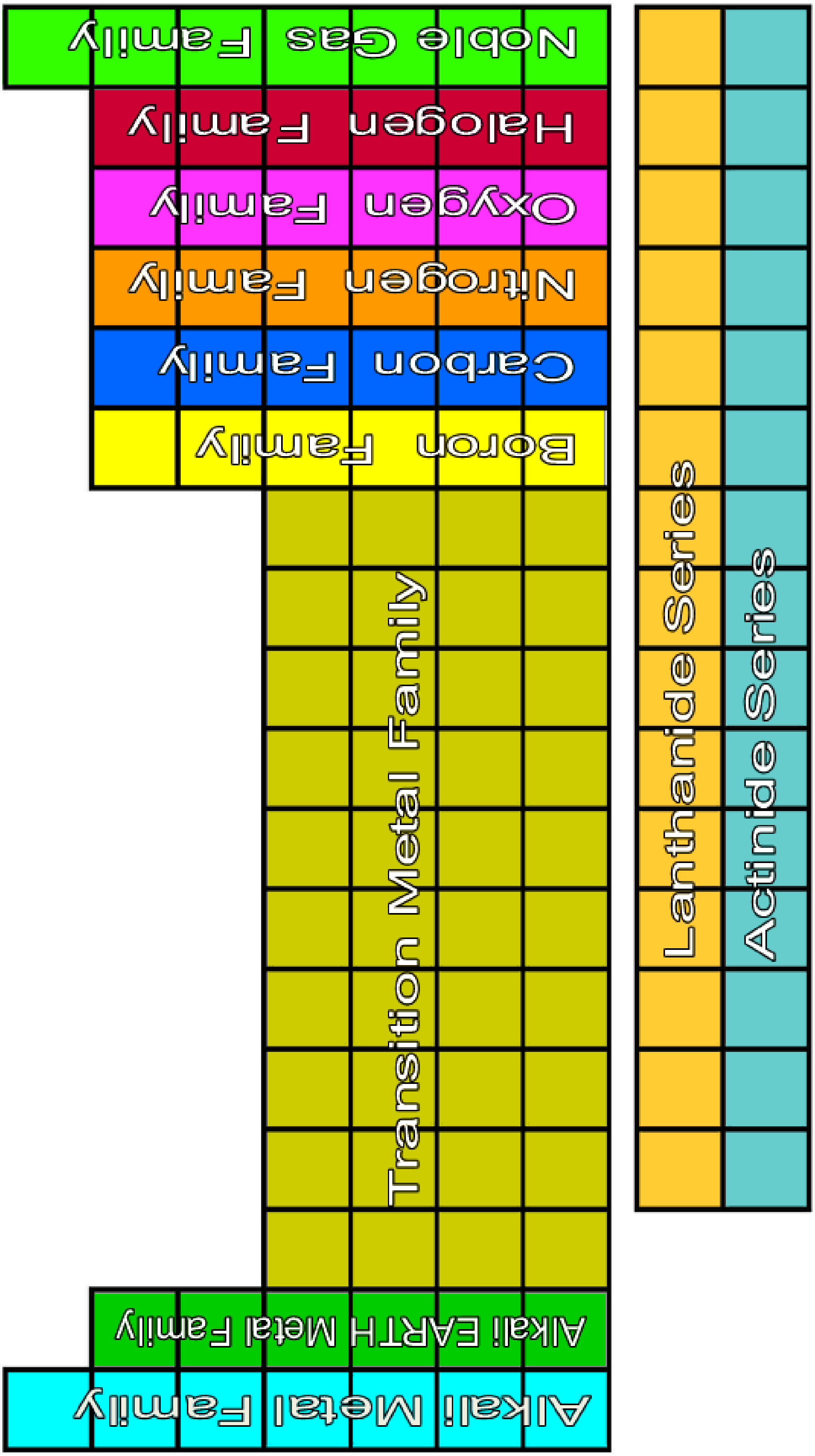


Les différents blocs de la Classification Périodique



Cas de l'Hélium : Bien qu'appartenant au bloc S ($1s^2$), celui-ci est placé dans le bloc p (groupe des gaz rares).

Main families in the periodic table (Familles principales du tableau périodique)



Major Groups

The periodic table can be divided into **eleven major** groups:

1) Alkali Metals: Column one

2**) Alkali-earth Metals:** Column two

3) Transition Metals: Columns three to twelve

4) Lanthanides: Upper row below table

5) Actinides: Lower row below table

6) Boron Group: Column thirteen

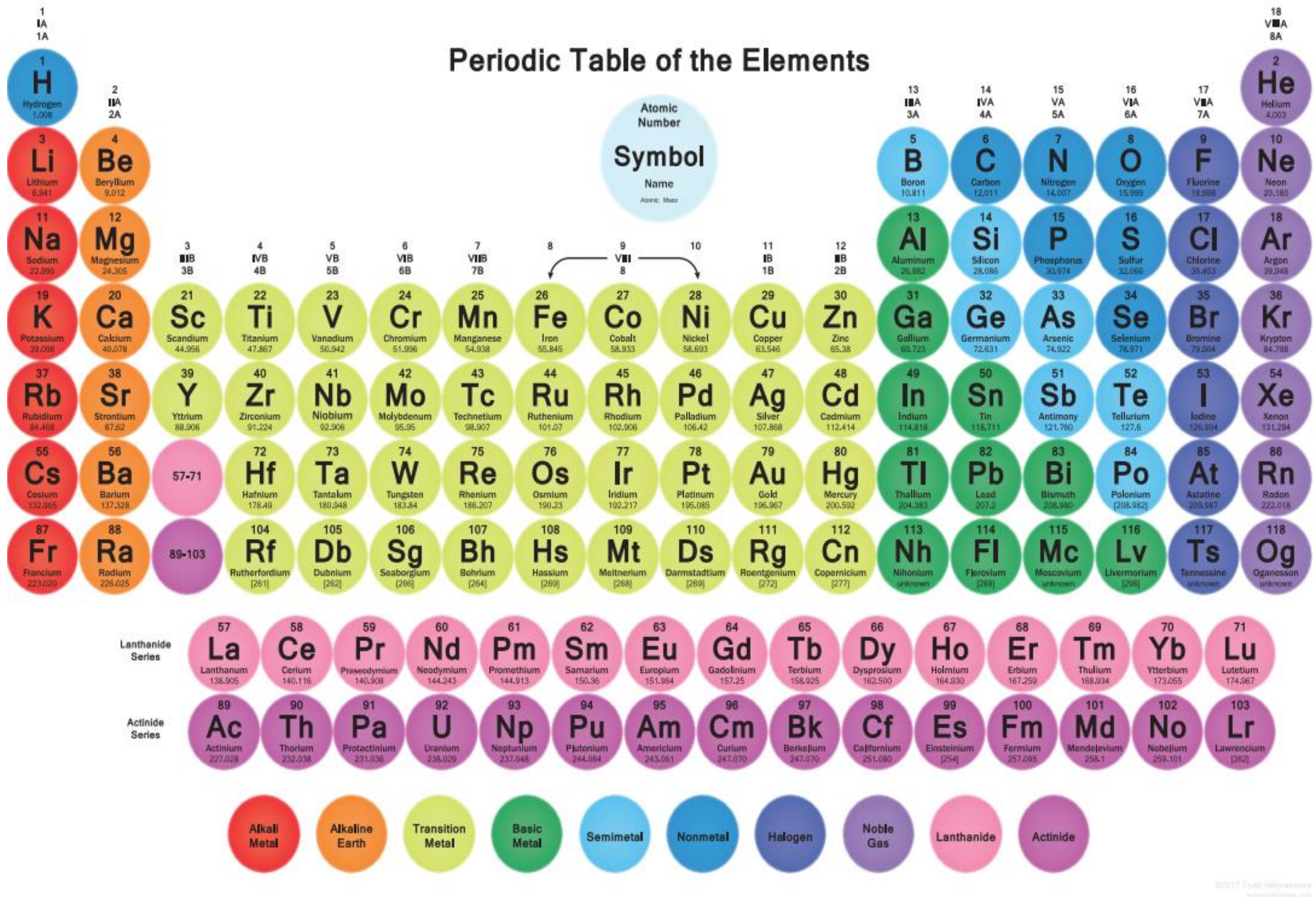
7) Carbon Group: Column fourteen

8) Nitrogen Group: Column fifteen

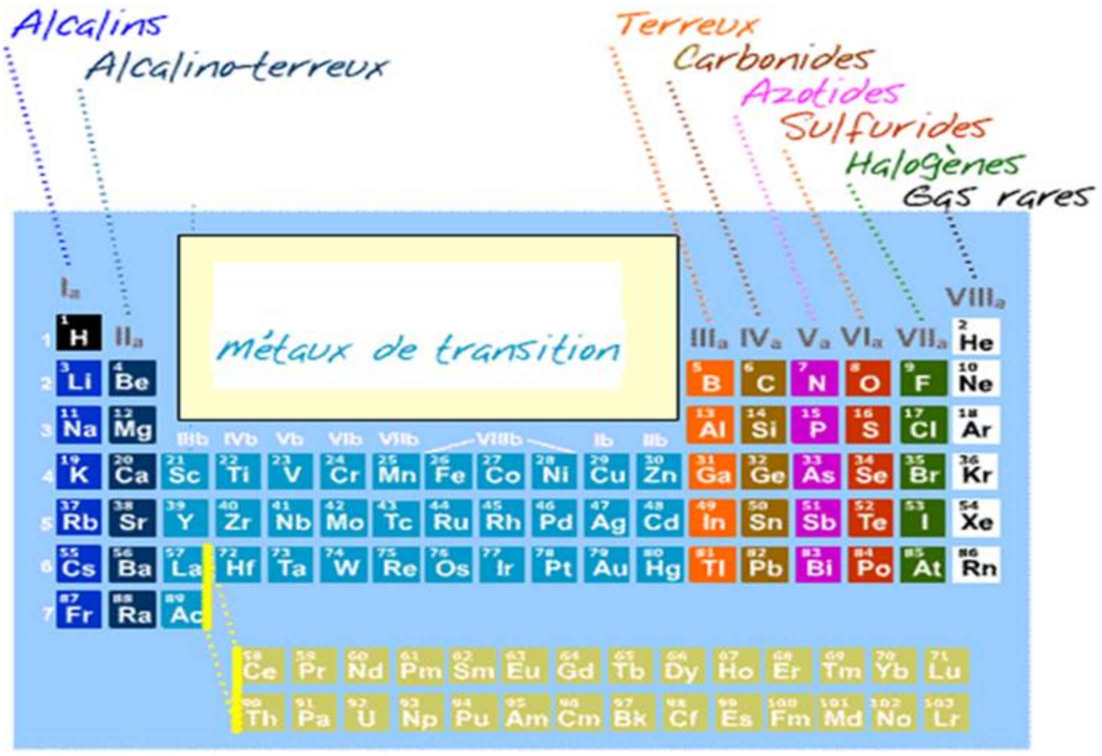
9) Oxygen Group: Column sixteen

10) Halogens: Column seventeen

11) Noble Gases: Column eighteen



Periodic Table of the Elements
Atomic Number
Symbol
Name
Atomic Mass
1 IA 1A
2 IIA 2A
3 IIIB 3B
4 IVB 4B
5 VB 5B
6 VIB 6B
7 VIIB 7B
8
9 VIII 8
10
11 IB 1B
12 IIB 2B
13 IIIA 3A
14 IVA 4A
15 VA 5A
16 VIA 6A
17 VIIA 7A
18 VIIIA 8A
1 H Hydrogen 1.008
2 He Helium 4.003
3 Li Lithium 6.941
4 Be Beryllium 9.012
5 B Boron 10.811
6 C Carbon 12.011
7 N Nitrogen 14.007
8 O Oxygen 15.999
9 F Fluorine 18.998
10 Ne Neon 20.180
11 Na Sodium 22.990
12 Mg Magnesium 24.305
13 Al Aluminum 26.982
14 Si Silicon 28.086
15 P Phosphorus 30.974
16 S Sulfur 32.066
17 Cl Chlorine 35.453
18 Ar Argon 39.948
19 K Potassium 39.098
20 Ca Calcium 40.078
21 Sc Scandium 44.956
22 Ti Titanium 47.867
23 V Vanadium 50.942
24 Cr Chromium 51.996
25 Mn Manganese 54.938
26 Fe Iron 55.845
27 Co Cobalt 58.933
28 Ni Nickel 58.693
29 Cu Copper 63.546
30 Zn Zinc 65.38
31 Ga Gallium 69.723
32 Ge Germanium 72.631
33 As Arsenic 74.922
34 Se Selenium 78.971
35 Br Bromine 79.904
36 Kr Krypton 84.798
37 Rb Rubidium 84.468
38 Sr Strontium 87.62
39 Y Yttrium 88.906
40 Zr Zirconium 91.224
41 Nb Niobium 92.906
42 Mo Molybdenum 95.95
43 Tc Technetium 98.907
44 Ru Ruthenium 101.07
45 Rh Rhodium 102.906
46 Pd Palladium 106.42
47 Ag Silver 107.868
48 Cd Cadmium 112.414
49 In Indium 114.818
50 Sn Tin 118.711
51 Sb Antimony 121.760
52 Te Tellurium 127.6
53 I Iodine 126.904
54 Xe Xenon 131.294
55 Cs Cesium 132.905
56 Ba Barium 137.328
57-71
72 Hf Hafnium 178.49
73 Ta Tantalum 180.948
74 W Tungsten 183.84
75 Re Rhenium 186.207
76 Os Osmium 190.23
77 Ir Iridium 192.217
78 Pt Platinum 195.085
79 Au Gold 196.967
80 Hg Mercury 200.592
81 Tl Thallium 204.383
82 Pb Lead 207.2
83 Bi Bismuth 208.980
84 Po Polonium [208.982]
85 At Astatine 209.987
86 Rn Radon 222.018
87 Fr Francium 223.020
88 Ra Radium 226.025
89-103
104 Rf Rutherfordium [261]
105 Db Dubnium [262]
106 Sg Seaborgium [266]
107 Bh Bohrium [264]
108 Hs Hassium [269]
109 Mt Meitnerium [268]
110 Ds Darmstadtium [269]
111 Rg Roentgenium [272]
112 Cn Copernicium [277]
113 Nh Nihonium unknown
114 Fl Flerovium [289]
115 Mc Moscovium unknown
116 Lv Livermorium [298]
117 Ts Tennessine unknown
118 Og Oganesson unknown
Lanthanide Series
57 La Lanthanum 138.905
58 Ce Cerium 140.116
59 Pr Praseodymium 140.908
60 Nd Neodymium 144.243
61 Pm Promethium 144.913
62 Sm Samarium 150.36
63 Eu Europium 151.964
64 Gd Gadolinium 157.25
65 Tb Terbium 158.925
66 Dy Dysprosium 162.500
67 Ho Holmium 164.930
68 Er Erbium 167.259
69 Tm Thulium 168.934
70 Yb Ytterbium 173.055
71 Lu Lutetium 174.967
Actinide Series
89 Ac Actinium 227.028
90 Th Thorium 232.038
91 Pa Protactinium 231.036
92 U Uranium 238.029
93 Np Neptunium 237.048
94 Pu Plutonium 244.064
95 Am Americium 243.061
96 Cm Curium 247.070
97 Bk Berkelium 247.070
98 Cf Californium 251.080
99 Es Einsteinium [254]
100 Fm Fermium 257.095
101 Md Mendelevium 258.1
102 No Nobelium 259.101
103 Lr Lawrencium [262]
Alkali Metal
Alkaline Earth
Transition Metal
Basic Metal
Semimetal
Nonmetal
Halogen
Noble Gas
Lanthanide
Actinide



1- Family of alkali metals (column 1)

This family is named as such because when one of its elements comes into contact with water, the resulting solution is basic. The term "alkali" is a synonym for basic. They are represented in blue in the above periodic table. These elements all have a single valence electron.

- Hydrogen is not part of the alkali metal family. However, it is placed above the alkali metal family because it also has a single valence electron.

- The electron configuration of the valence shell is ns1, which includes Li, Na, K, Rb, Cs, and Fr.

- Alkali metals are metals that possess only one valence electron. They all form cations by losing one electron (Li+, Na+, K+, etc.).

Properties of Alkali Metals

1. They are metals.
2. They are soft solids; they can be cut with a knife.
3. They are extremely reactive. For this reason, in their pure state, they must be stored in oil as they react strongly with water.
4. They are never found alone in nature; they are always bound to other elements.
5. They are very good conductors of electricity and heat.

Uses of Alkali Metals

- Alkali metals are rarely used in their pure state due to their extreme chemical reactivity. Once combined with other elements, they can be found in many everyday products.
- ***Examples: Lithium (Li)***
  - Medication for treating depressive states.
  - Manufacturing of batteries.
  - Metal alloys for aircraft.

Sodium (Na)

- ✓ Table salt (NaCl)
- ✓ Fertiliser
- ✓ Steam can be used to produce light
- ✓ Transmission of nerve impulses in the human body

2- Alkaline earth family (column 2)

1. The external electronic structure ns2 (Be, Mg, Ca, Sr, Ba and Ra).
2. They have two valence electrons.
3. They all form cations by losing two electrons (Be2+, Mg2+, Ca2+ etc ,,,,,).
4. This family is called alkaline earths for two reasons.
5. Firstly, they form bases when dissolved in water (alkalino).
6. Secondly, they are found in the composition of many rocks (terreux).

Properties of alkaline earths

1. They are all metals.
2. They are soft solids, but less soft than alkalis.
3. They are reactive, but less so than alkalis.
4. They are good conductors of electricity and heat.

Use of alkaline earths

Alkaline earths are widely used in pyrotechnics (fireworks). They also play important roles in living organisms.

Examples

Beryllium (Be)

- ✓ Spring construction (highly elastic alloys)
- ✓ Alloy construction for aircraft (heat resistance and low density).

- Magnesium (Mg)

- ✓ Fireworks and "lightning" in photography
- ✓ Milk of magnesia (neutralises stomach acid)
- ✓ Construction of numerous alloys to take advantage of its lightness (low density).

3- Halogen family (column 17, group VIIA)

1. with external electronic structure ns2 np5 they have 7 valence electrons. It includes fluorine, chlorine, bromine, iodine and astatine.
2. They are non-metals and form the ions F-, Cl-, Br-, I- and As-.
3. Halogens are the elements in the penultimate column of the periodic table and therefore belong to family VII (7) or the 17 columns.
4. The word halogen comes from the Greek and means "to produce a salt".
5. In fact, halogens usually form salts with alkalis or alkaline earths, and are extremely reactive with which they react.
6. The halogen family is the only one to have elements in all three phases at room temperature:
   Gaseous: Fluorine (F) and Chlorine (Cl)
   Liquid: Bromine (Br)
   Solid: Iodine (I) and Astatine (As).

Properties of halogens

1.They are very colourful elements.
2.They are all non-metals.
3.They are extremely reactive. They are therefore always found bound to other chemical elements in nature.
4.They are corrosive elements (عناصر مسببة للتآكل).

5.As they are toxic (سامة) and bactericidal (مبيد للجراثيم), they are frequently used in disinfectant products(مطهرات).

Example:

Iodine (I)

- ✓ Used in medicine to treat the thyroid gland
- ✓ Present in antiseptic solutions.

Bromine (Br)

1.Used as a sedative in certain nervous disorders.
2.Used as photographic film (silver bromide)
3.Present in a powerful antiseptic, mercurochrome ($C_{20}H_8Br_2HgNa_2O_6$)

4- Family of rare gases (noble or inert) (column 18, group VIIIA or 0),

- ✓ This family includes helium, neon, argon, krypton, xenon and radon,
- ✓ they all have a complete outer layer ns2np6 except for 2He $1s^2$. Rare gases exist in atomic form (not associated in molecules) and are chemically very stable.
- ✓ Inert gases or rare gases are elements in the last column of the periodic table and therefore belong to family VIII (8).

They therefore have eight valence electrons, with the exception of helium, which has only two. Inert gases get their name from the fact that they all form gases in their pure state. They are also very unreactive (inert) and are relatively rare in the Earth's atmosphere.

Properties of inert gases

1. They are all non-metals.
2. They are colourless in their natural state.
3. They produce coloured light when subjected to an electrical voltage at low pressure.
4. They have very low chemical reactivity.

➢ **Use of inert gases**

Helium (He):

1. Used to inflate sounding (and party!) balloons.
2. Used for deep-sea diving.
3. Used in illuminated signs (pink).

Neon (Ne)

1. Used in illuminated signs (orange).
2. Used in plasma television tubes
3. Used in some lasers

5- Family of 1st category transition elements: (columns from 3 to 12).

- Their configurations end on a d sublayer.
- All the members of this family :

1. are metals
2. do not obey the octet rule.
3. They can accommodate more than 8 electrons on their valence layer. Some of them can even have up to 18! This sometimes makes interactions with elements from other families difficult.
4. Most of them also tend to combine with each other, or with compounds from other families, to form what are known as alloys.

6- (Boron family) or Earths column 13

1. This family is also known as the "boron family".
2. Elements in the boron family: have 3 valence electrons (family IIIA)
3. will therefore tend to donate three electrons to saturate the energy level and form a cation with a charge of +3: B^{3+}, Al^{3+}, Ga^{3+}, In^{3+}, etc.
4. The worthy representative of this family (at least, the one that gives it its name) is an element belonging to the metalloids; the other 4 are metals.

7- Carbonides Column 14

1. This family, also known as the "carbon family", is very unusual compared with the other families on the periodic table.
2. Its members all have: 4 valence electrons (family IVa),
3. They can therefore give up or attract electrons to saturate themselves and form a cation with a charge of +4 or an anion with a charge of -4 respectively.
4. Carbon (C), silicon (Si) and germanium (Ge) are metalloids.
5. Tin (Sn) and lead (Pb) are metals.
6. Azotides column 15
7. have 5 valence electrons (VA family)
8. will therefore tend to attract 3 electrons to obey the octet rule and form an anion with charge -3: N^{3-}, P^{3-}, etc.
9. The most important elements are certainly nitrogen and phosphorus, which are essential to animal and plant life and many of their compounds have important applications.

8- Sulphurides: Column 16

- Have 6 valence electrons (family VIa)
- will therefore tend to attract 2 electrons to obey the octet rule and form an anion with charge -2: O^{2-}, S^{2-}, ...

- ***Sulphurides*** are happy to take 2 electrons from anyone who dares to do so. They form ionic bonds with other families in the metal region, as well as covalent bonds with our fellow non-metals.

9- The family of poor metals:

In chemistry, a poor metal is a metallic chemical element located, in the periodic table, between transition metals on their left and metalloids on their right.

They are soft or brittle metals. They tend to form covalent bonds and possess amphoteric acidic and basic properties. In this family, we find **aluminum (Al), zinc (Zn), tin (Sn), mercury (Hg), or lead (Pb).**

The term "poor metal" is rarely used and competes with various other rarely used designations that cover related concepts, such as p-block metal; it reflects the fact that the metallic properties of these elements are the least pronounced among all metals. It is used here in the absence of terminology validated by IUPAC to collectively refer to elements of this nature.

10- The family of metalloids:

it is a family where the elements that compose it have particular characteristics. They resemble metals, are brittle, and do not conduct electricity. Among them, we find **boron, silicon, arsenic, or antimony.**

11- The family of non-metals:

these are elements that are very good thermal and electrical insulators.

- Non-metals represent almost the entire composition of living beings: among them, we find carbon, nitrogen, oxygen, sulfur, chlorine.

12- The family of rare earth elements (f-block):

These are transition elements of the 2nd category, corresponding to the filling of the f-subshell.

- In fact, the orbitals that correspond to the filling of the 4f orbital follow Lanthanum (La), hence their name, they are called lanthanides. Those that correspond to the filling of the 5f orbital follow Actinium (Ac), hence their name, they are called actinides.
  - ***The family of lanthanides:*** comprises 15 elements. The name lanthanide comes from the leader of the elements composing this family: lanthanum. They are shiny metals that quickly tarnish in the open air. In this family, we find elements like lanthanum, cerium, gadolinium, or terbium.
  - ***The family of actinides:*** is a chemical family comprising 15 elements as well. These are heavy metals that derive their name from their leader, actinium. All actinides are radioactive.