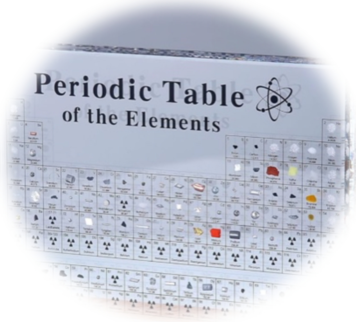
STABILITY OF A CHEMICAL ELEMENT

Chemical element

A chemical element is characterized by its atomic number Z. It groups together all entities (atoms, monoatomic ions and their isotopes) with the same atomic number.
Chemical elements are classified in order of increasing atomic mass in the periodic table of elements. All chemical elements in the same column form a chemical family. They have similar chemical properties, and the same number of electrons in their valence shell



The noble gases

Noble gases are the most stable chemical elements. They are rarely involved in chemical reactions and are mostly found as single atoms (under normal temperature and pressure conditions).

Electron structure of noble gases**:**

<u>Helium</u>:	He (Z = 2)	$\mathbf{1s^2}$
<u>Néon</u>:	Ne (Z = 10)	$1s^2\mathbf{2s^2 2p^6}$
<u>Argon</u>:	Ar (Z = 18)	$1s^2 2s^2 2p^6\mathbf{3s^2 3p^6}$
<u>Krypton</u>:	Kr (Z = 36)	$1s^2 2s^2 2p^6 3s^2 3p^6\mathbf{4s^2}3d^{10}\mathbf{4p^6}$
<u>Xenon</u>:	Xe (Z = 54)	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6\mathbf{5s^2}4d^{10}\mathbf{5p^6}$
<u>Radon</u>:	Rn (Z = 86)	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10} 5p^6\mathbf{6s^2}4f^{14} 5d^{10}\mathbf{6p^6}$

The stability of noble gases is related to their outer layer with 2 electrons (for He) or 8 electrons for the others.

Criteria for the stability of an element – s and p blocks

To increase its stability, a chemical element will therefore try to acquire the same outer layer as that of the noble gas closest to it:

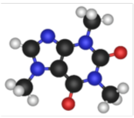
- Either helium He **DUET RULE: 2 ELECTRONS ON THE VALENCE SHELL**
- Either any other noble gas **OCTET RULE: 8 ELECTRONS ON THE VALENCE SHELL**

Note: These rules are valid only for the elements of blocs s and p.

Forming monoatomic ions

To increase its stability, an element can form a monoatomic ion. It gains or loses one or more electrons to respect the duet or octet rule. The electrons are then distributed in the same way as for atoms.

Ex : *Na^+ (Z = 11)* *$1s^2 2s^2 2p^6$*
Cl^- (Z = 17) *$1s^2 2s^2 2p^6 3s^2 3p^6$*



Forming molecules

To increase its stability, an element can also bond with other atoms to form molecules.

How do I know?

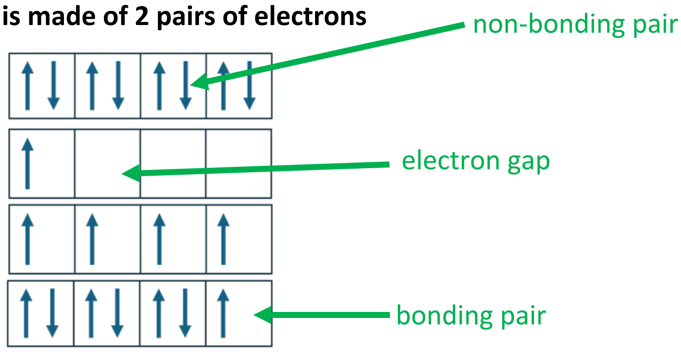
An electron is characterized by its charge, its mass, and also its spin. This is a number that can take 2 values: $+\frac{1}{2}$ or $-\frac{1}{2}$.
2 electrons of the same shell with opposite spins are able to form a pair.
The stability criteria can therefore have a different expression:
OCTET RULE: An atom is stable if the valence shell is made of 4 pairs of electrons
DUET RULE: An atom is stable if the valence shell is made of 2 pairs of electrons

Argon: Ar (Z = 18) $1s^2 2s^2 2p^6 \mathbf{3s^2 3p^6}$

Sodium: Na (Z = 11) $1s^2 2s^2 2p^6 \mathbf{3s^1}$

Carbon: C (Z = 6) $1s^2 \mathbf{2s^2 2p^2}$

Chlorine: Cl (Z = 17) $1s^2 2s^2 2p^6 \mathbf{3s^2 3p^5}$



- **An atom which has only non-bonding pairs of electrons is already stable.**
- **An atom which has at least 1 electron gap will always loose electron(s) to form a cation.**
- **An atom which has only bonding pairs of electrons will always form molecules.**
- **An atom which has both bonding and non-bonding pairs of electrons will either gain electron(s) to form an anion or form molecules, depending on their environment.**

What about elements from d and f blocks?

The stability of these elements is more complicated to establish. However, some key rules related to electronic configuration or oxidation states can be defined:

- **A half-filled or fully-filled d or f subshell provides extra stability.**
- **+2 oxidation states for transition metals are common, because of the easy removal of the ns electrons.** +3 oxidation state also occurs when 1 3d electron can also be removed to reach a half-filled d subshell.
  Lanthanides mostly show the +3 oxidation state, because of stable f-orbital configurations.
  Actinides show a wider range of oxidataion states, due to their more delocalized f-electrons.