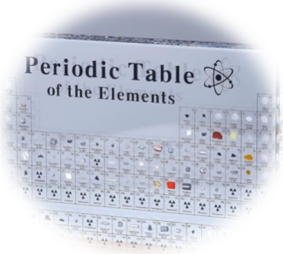
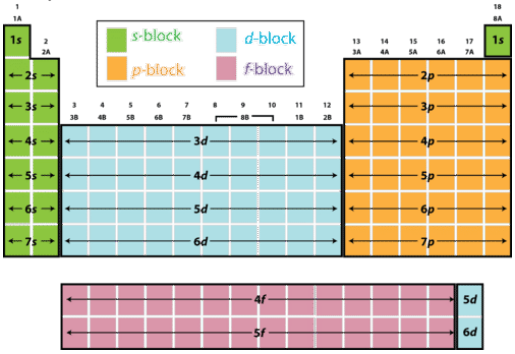
Stability of a chemical element

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



Note: The periodic table can be seen as structured in relation to the electron configuration of an atom.



For an element of d-block, for example, the last sublayer on which electrons are found is sublayer d.

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:

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

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.

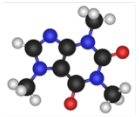
Ex : Na^+ *(Z = 11)* $1s^2 2s^2 2p^6$

Cl^- *(Z = 17)* $1s^2 2s^2 2p^6 3s^2 3p^6$

Note: When writing the electron structure of an atom, Klechkowski's rule has to be followed. However, when electrons are released to form an anion, the first ones to be taken off are the ones on the highest layer.

Ex: *Fe:* $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^6$ Fe^{2+}: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^6$

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 $-\frac{1}{2}$.

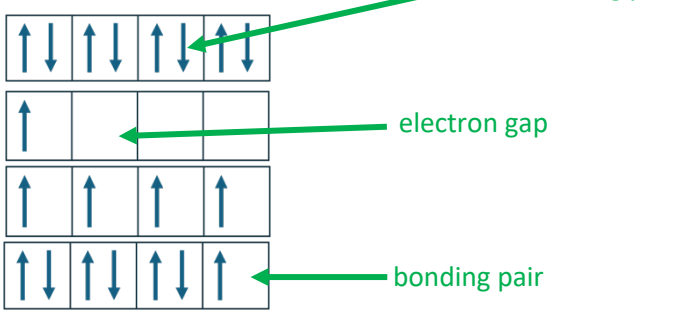
2 electrons of the same shell with opposite spins are able to form a pair.

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 one 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.**