CHEMICAL BOND

- **A chemical bond is a force of attraction that holds atoms together in a chemical compound.** Atoms form bonds in order to achieve a more stable and lower energy state.

- The bonding between atoms allows them to combine in specific ratios to form molecules and compounds.

- Chemical bonds involve the interaction of electrons, which are negatively charged particles that orbit the atomic nucleus.

Types of Chemical Bond:

There are several types of chemical bonds, and the nature of the bond depends on how electrons are shared, gained, or lost between atoms. The three main types of chemical bonds are:

1. Ionic Bond

2. Covalent Bond

3. Metallic Bond

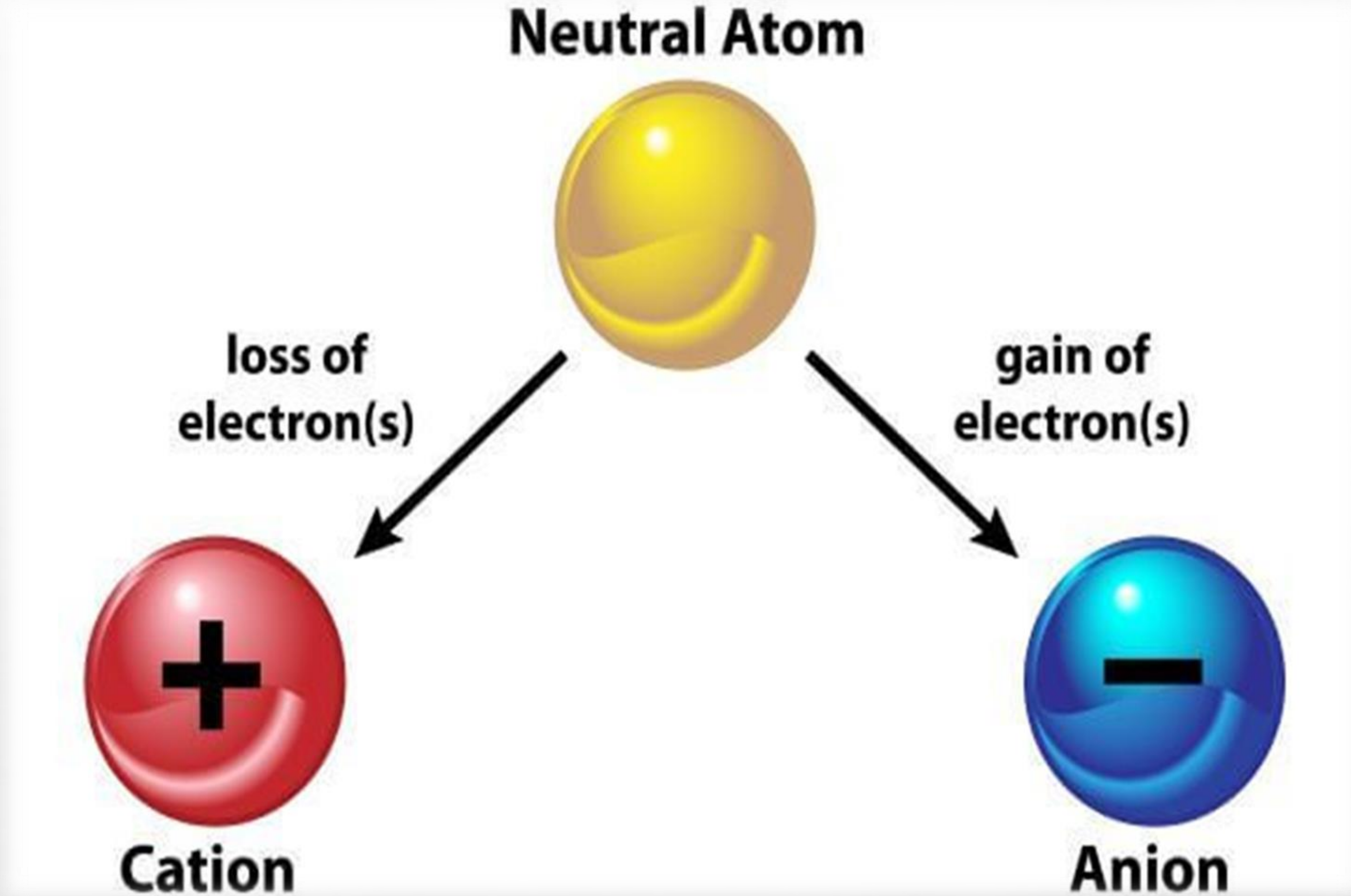
Ionic Bonds:

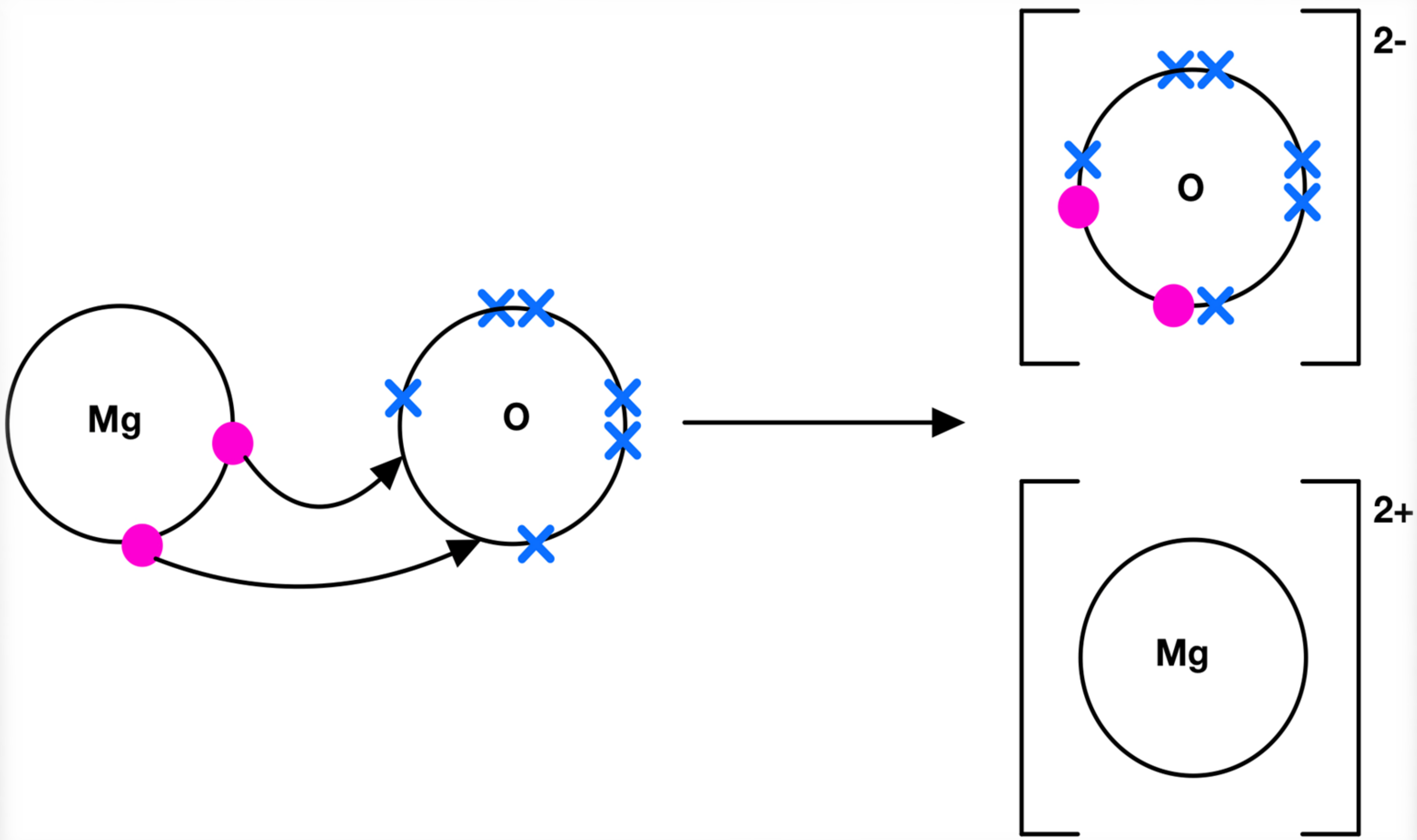
An ionic bond is a type of chemical bond formed by electrostatic attraction between two oppositely-charged ions. These ions are created by the transfer of valence electrons between two atoms, usually a metal and a non-metal.

*Formed by the transfer of electrons from one atom to another.

*Typically occurs between a metal and a non-metal.

*Results in the formation of positively charged ions (cations) and negatively charged ions (anions), which are attracted to each other due to electrostatic forces.

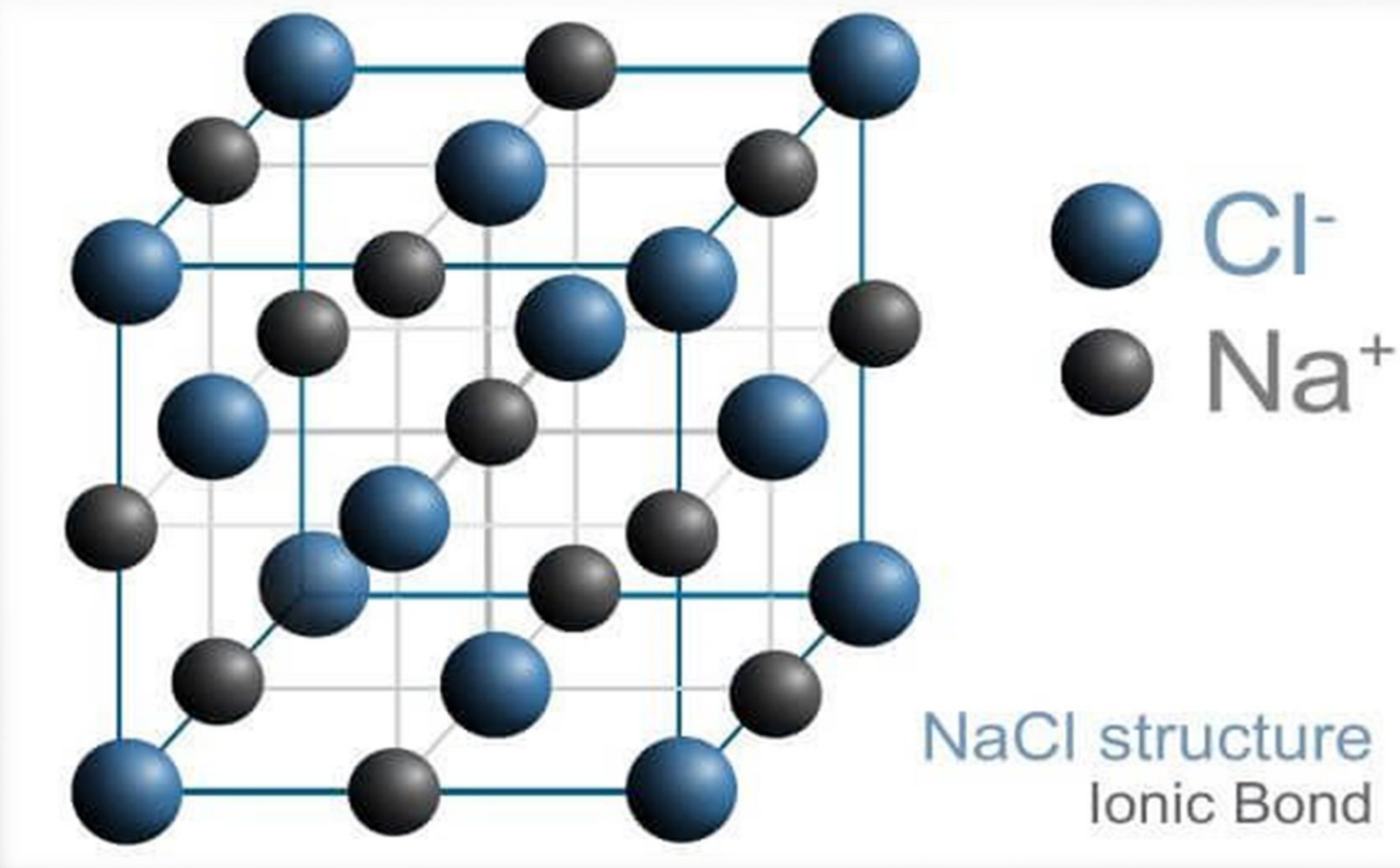

Neutral Atom
loss of electron(s)
gain of electron(s)
+
−
Cation
Anion


Mg
O
2-
O
2+
Mg

How Are Ionic Bonds Formed?

Oppositely-charged ions have a strong **electrostatic attraction** between them. This attraction is the ionic bond, and it allows a positive ion and a negative ion to form a stable ionic compound with a **neutral charge.**

For example, when a sodium atom meets a chlorine atom, the sodium donates one valence electron to the chlorine. This creates a positively-charged sodium ion and a negatively-charged chloride ion. The electrostatic attraction between them forms an ionic bond, resulting in a stable ionic compound called sodium chloride (table salt).


Cl-
Na+
NaCl structure
Ionic Bond

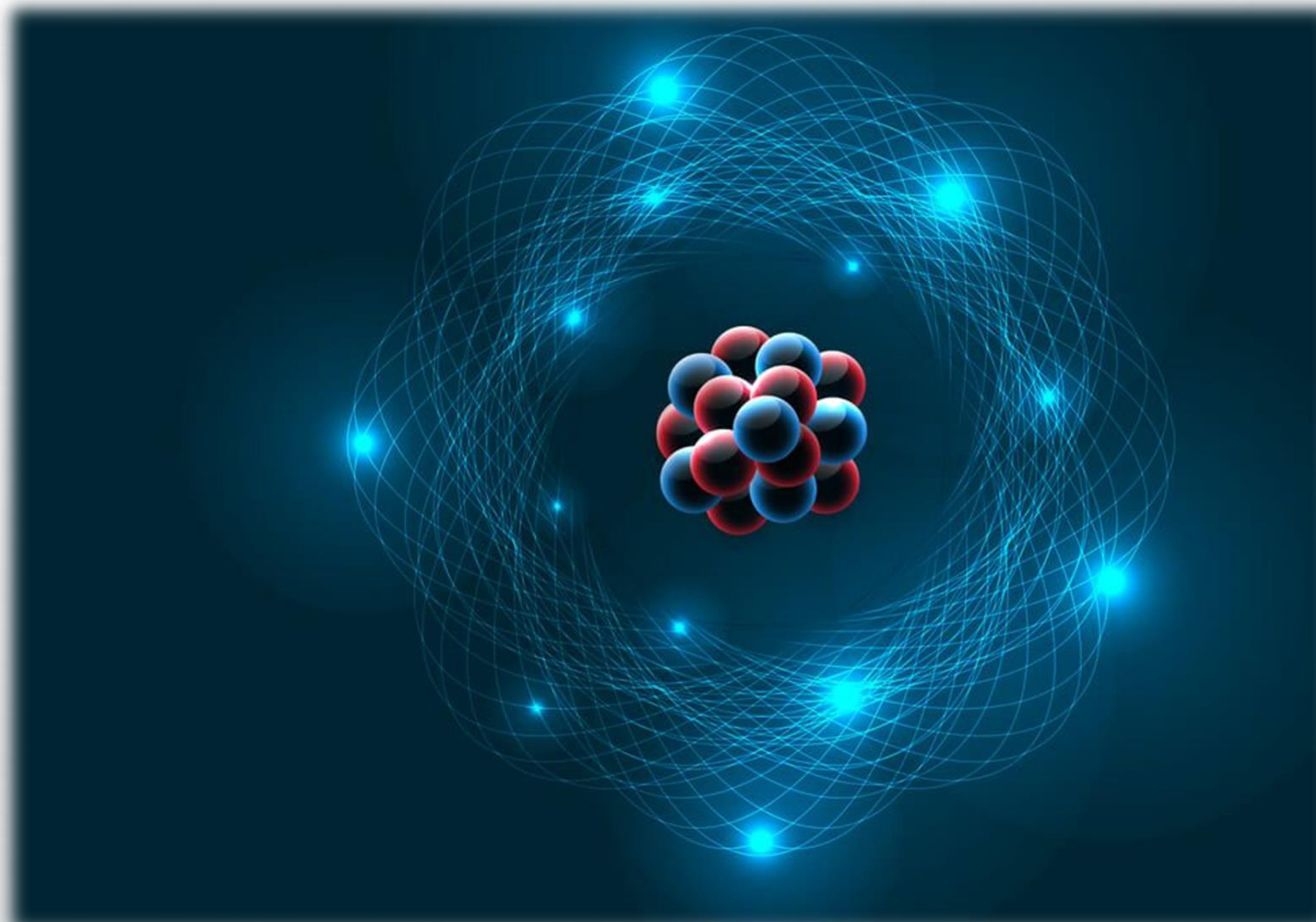
Covalent Bonds:

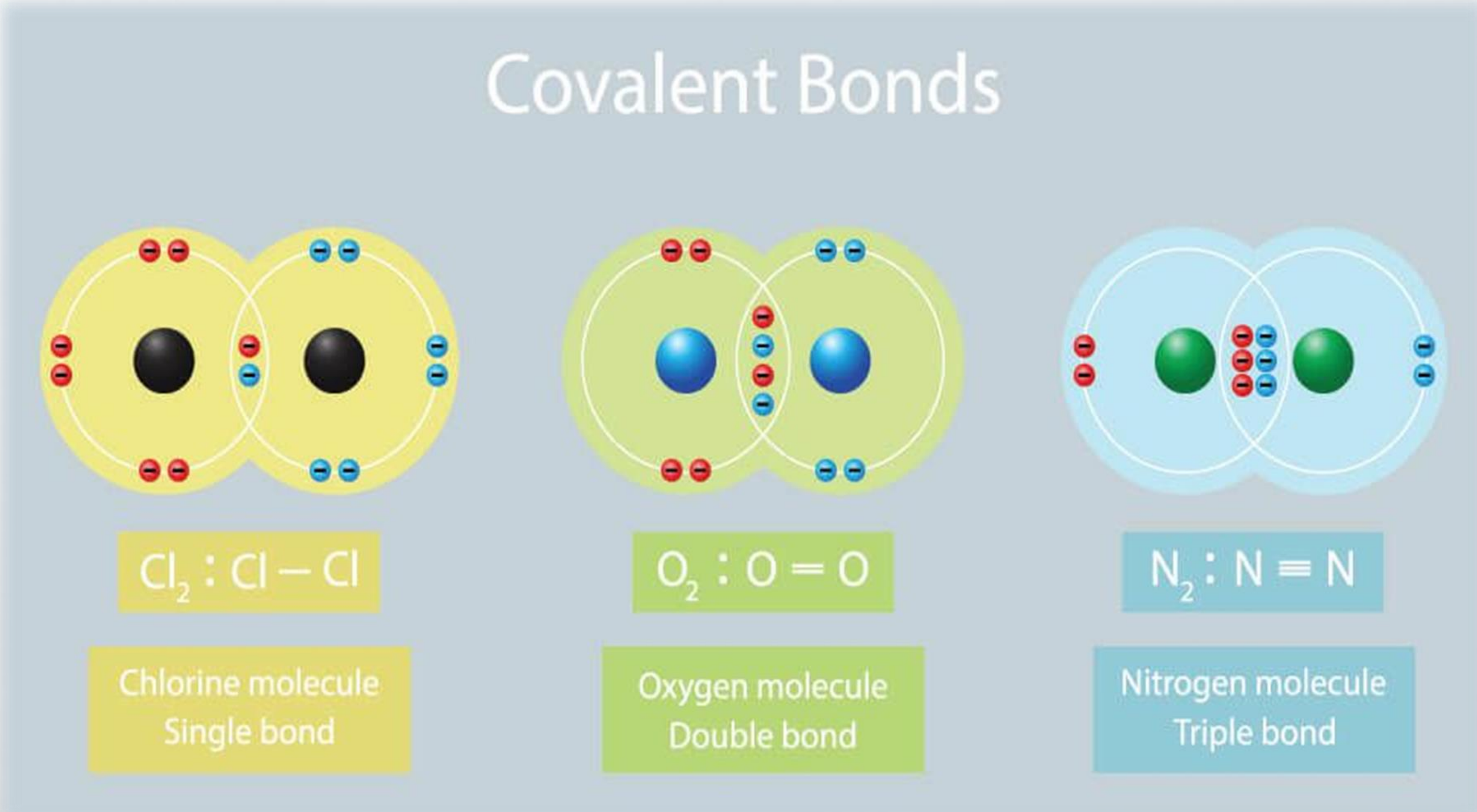
A covalent bond or molecular bond is a chemical link between two atoms where electron pairs are shared. Covalent bonds form between two non-metal atoms and non-metal compounds that possess the same or similar values of attraction (electronegativity). Electron pairs shared in a covalent bond are known as shared pairs or bonding pairs and increase the stability of the individual atoms as well as any molecule or compound they may form.

*Formed by the sharing of electrons between atoms.

*Typically occurs between non-metal atoms.

*Involves the creation of a molecular bond, where atoms share one or more pairs of electrons to achieve a more stable electron configuration.




Covalent Bonds
Cl2 : Cl – Cl
Chlorine molecule
Single bond
O2 : O = O
Oxygen molecule
Double bond
N2 : N ≡ N
Nitrogen molecule
Triple bond

Valence Shells

The atomic number tells us how many protons are in the nucleus of that element. Hydrogen has an atomic number of one. This tells us that, in its non-ionic form, hydrogen has one proton. We can then conclude that hydrogen also has one electron. As the shells fill up from the inside outwards, this single hydrogen electron must sit on a K-shell.

Larger elements like krypton, with an atomic number of 36 (36 protons and 36 electrons), don't need a mathematical genius to calculate how many shells it has. Filling them up from the nucleus outwards we can calculate that krypton has enough electrons to fill three shells and partially fill a fourth.

Covalent bonds depend on the number of electrons in the outer shell(s) of an atom.

How many outer shells an element has depends on the number of electrons that atom has. The simplest element, hydrogen, has a single outer shell because it only has one electron.

Sodium metal has three electron shells; the first shell, closest to the nucleus, contains two electrons, and a second, outer shell hosts one electron.

Metallic Bonds:

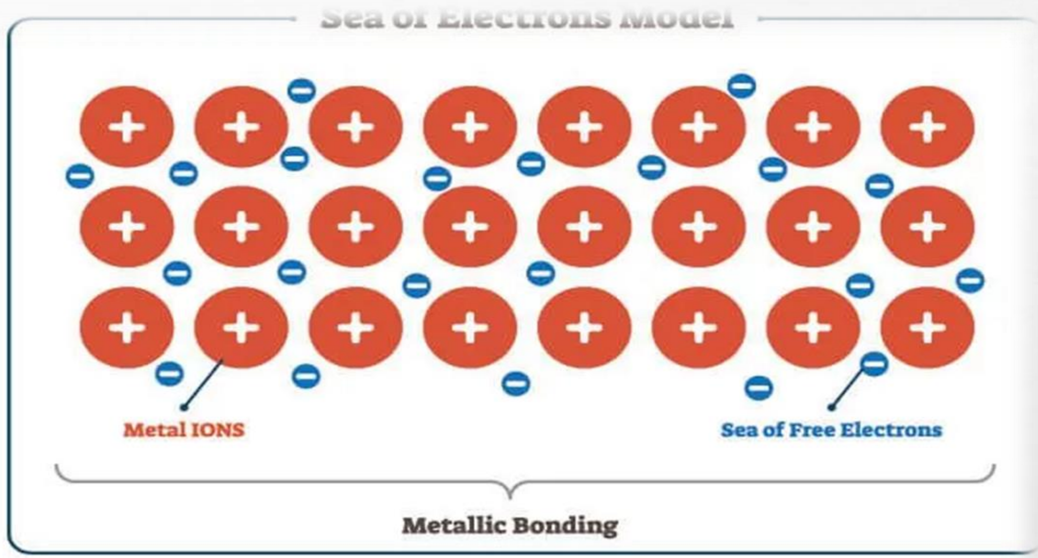
The positive charges of the multiple metal atom nuclei would repel one another; however, the cloud of surrounding negatively-charged electrons (conduction electrons) keeps these metal nuclei in close formation, thus the metallic bond are formed. It is the conduction electrons that give metals their high thermal and electrical conductivity properties.

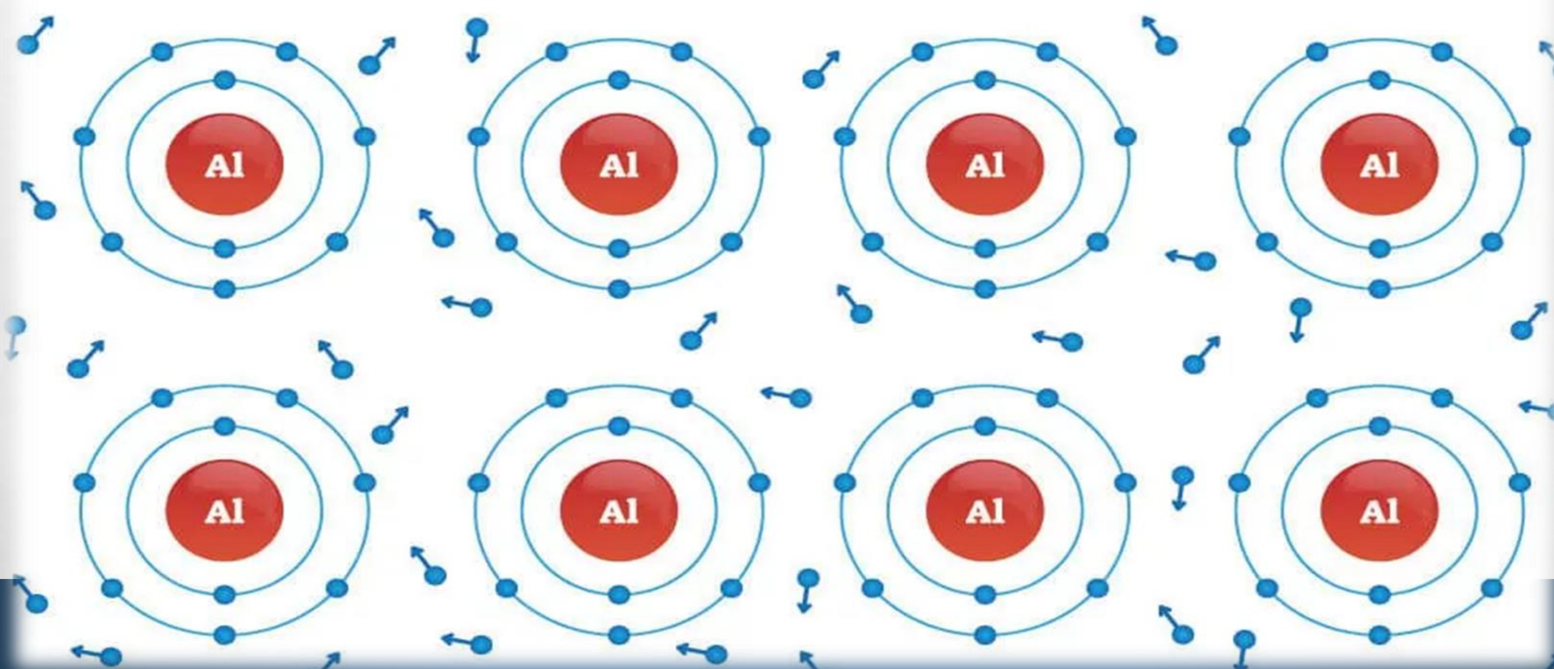
*Found in metals and alloys.

*Involves the delocalization of electrons, meaning electrons are free to move throughout the metal structure.

*Creates a sea of electrons that surround positively charged metal ions, holding them together in a metallic lattice.

METALLIC BONDING





Properties of Ionic Compounds

In an ionic lattice, the strong electrostatic attraction between the oppositely charged ions acts in all directions, giving them a unique set of properties.

Ionic Compounds Have High Melting and Boiling Points

Ionic compounds have high melting and boiling points. This is because it takes a lot of energy to break the ionic bonds,

Thanks to the strong electrostatic attraction between oppositely charged ions.

1. Ionic Compounds Shatter Easily

Ionic compounds are hard but brittle. It takes a lot of force to break the ionic bonds that hold them together but, if enough force is applied, they shatter easily. This happens because breaking the ionic bonds brings ions of the same charge together. The strong repellent forces that exist between ions of the same charge makes them fly apart, causing the ionic compound to shatter.

2. Ionic Compounds Conduct Electricity

A substance can conduct electricity if it contains charged particles that are free to move about. All ionic compounds contain charged particles (ions), but they cannot conduct electricity in their solid form because the ions are not able to move.

**An ionic substance can only conduct electricity if it has melted or been dissolved in water, allowing the ions to move around.

Properties of Covalent Bonds

1. Physical State:

a. Covalent compounds often exist in various physical states, including gases, liquids, or solids.
b. Many covalent compounds have lower melting and boiling points compared to ionic compounds.

2. Solubility:

a. Covalent compounds generally have low solubility in water and other polar solvents.
b. Solubility depends on the polarity of the molecules and the ability of the solvent to interact with the compound's molecules.

3. Conductivity:

a. Covalent compounds are typically poor conductors of electricity.
b. This is because they do not contain charged particles (ions) that can move freely and carry an electric current.

4. Melting and Boiling Points:

a. Covalent compounds generally have lower melting and boiling points compared to ionic compounds.
b. The strength of covalent bonds is usually weaker than ionic bonds, resulting in lower energy requirements for phase changes.

5. Molecular Structure:

a. Covalent compounds often have complex and diverse molecular structures.

b. The arrangement of atoms within molecules is determined by the type and number of bonds formed.

6. Nonconductivity in the Solid State:

Covalent compounds in the solid state are generally non-conductive because there are no mobile charged particles.

7. Polarity:

a. Covalent molecules can be polar or nonpolar, depending on the electronegativity difference between the atoms.

b. Polar molecules have an uneven distribution of electrons, leading to the development of partial positive and negative charges.

8. Hardness:

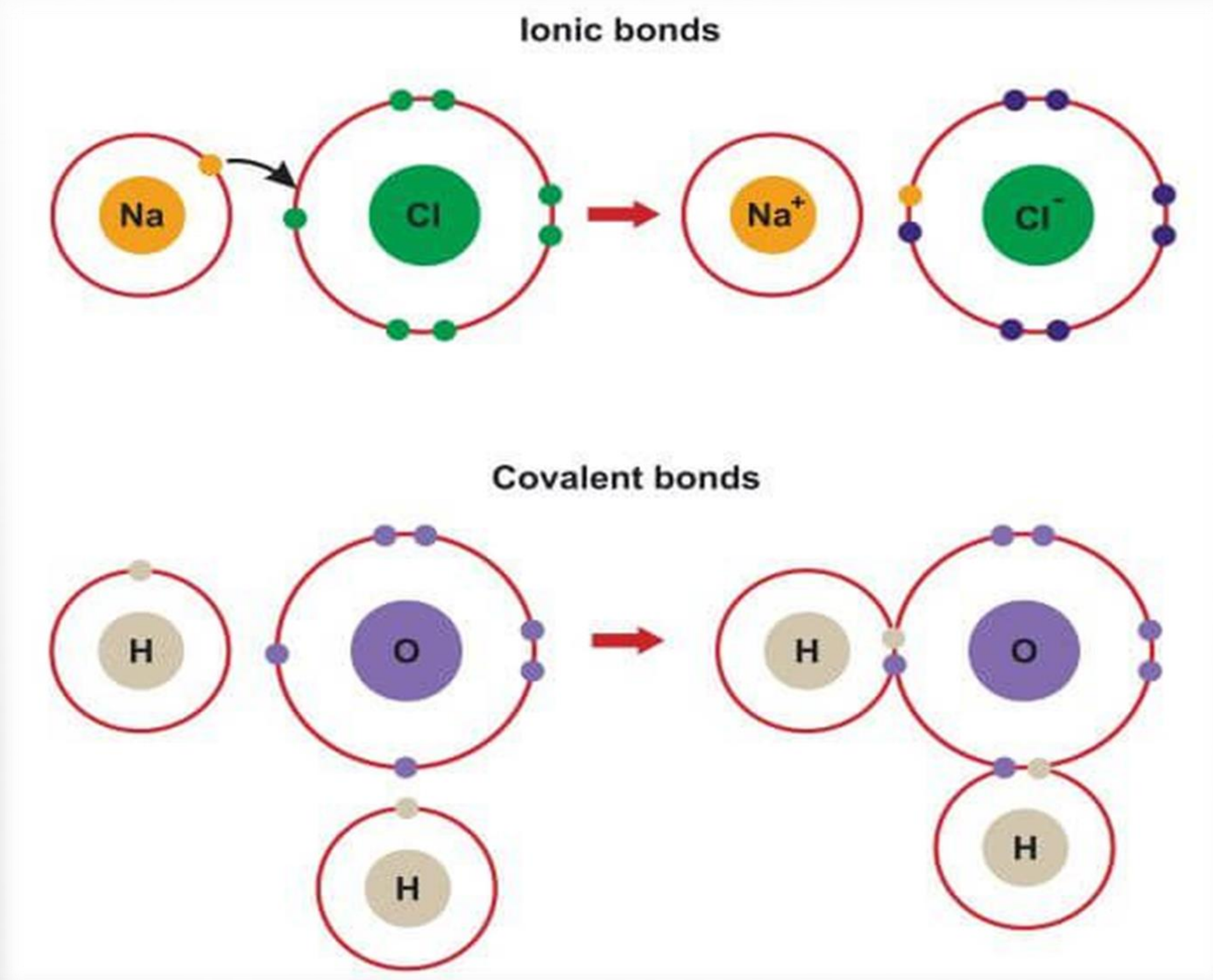
a. Covalent compounds tend to be relatively soft in comparison to many metallic and ionic solids.
b. The hardness is influenced by the strength of the covalent bonds within the molecules.

9. Electrical Conductivity in Solutions:

a. Covalent compounds in solution are generally non-conductive because they do not dissociate into ions.
b. Exceptions include certain covalent compounds that ionize in solution, such as acids.

What’s the Difference Between an Ionic Bond and a Covalent Bond?

The two main types of chemical bonds are ionic bonds and covalent bonds, but there are some key differences between the two.


Ionic bonds
Na
Cl
Na+
Cl-
Covalent bonds
H
O
H
H
O
H

Ionic bonds	Covalent bonds
Bond between metals and non-metals.	Bond between non-metals.
Involves complete transfer of electrons.	Involves sharing of electrons.
Occurs between ions with considerably different electronegativities.	Occurs between atoms with similar electronegativities.

Whereas ionic bonds involve the complete transfer of electrons between atoms, covalent bonds are formed when two atoms share electrons.

This usually takes place between atoms of the same element, or between two elements that are close to one another in the periodic table. Covalent bonds are most likely to form between two atoms with similar ***electronegativities*** (i.e. those with a similar ability to attract electrons).

They usually occur between two non-metals, though they may also be observed between metals and non-metals.

Ionic bonds are generally stronger than covalent bonds because of the electrostatic attraction that exists between oppositely charged ions.

Modern Approach's of Chemical Bond

The modern approach to understanding chemical bonding is primarily based on quantum mechanics and molecular orbital theory. This approach provides a more detailed and accurate description of chemical bonding compared to classical models.

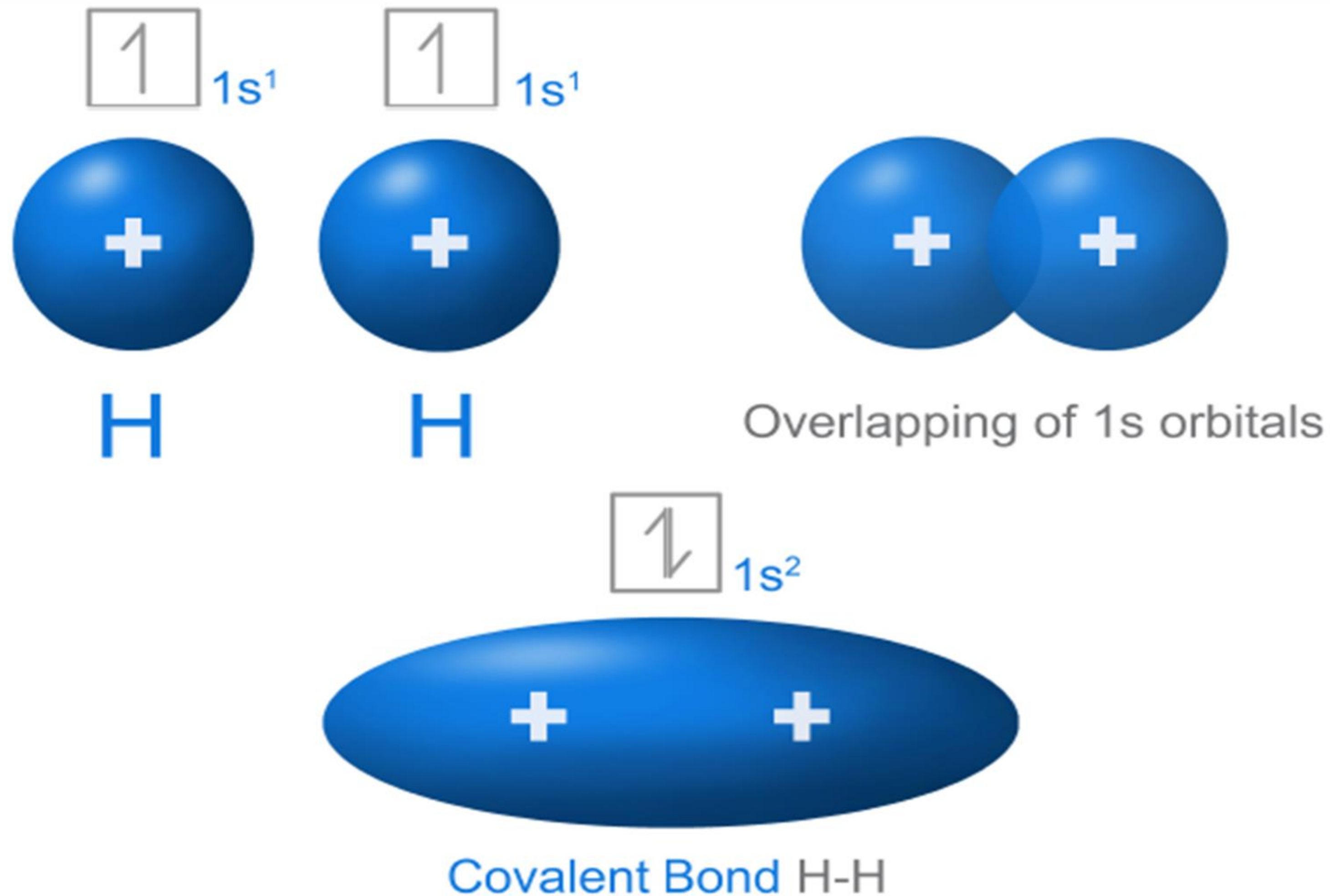
Quantum Mechanics
Molecular Orbital Theory
Valence Bond Theory
Hybridization

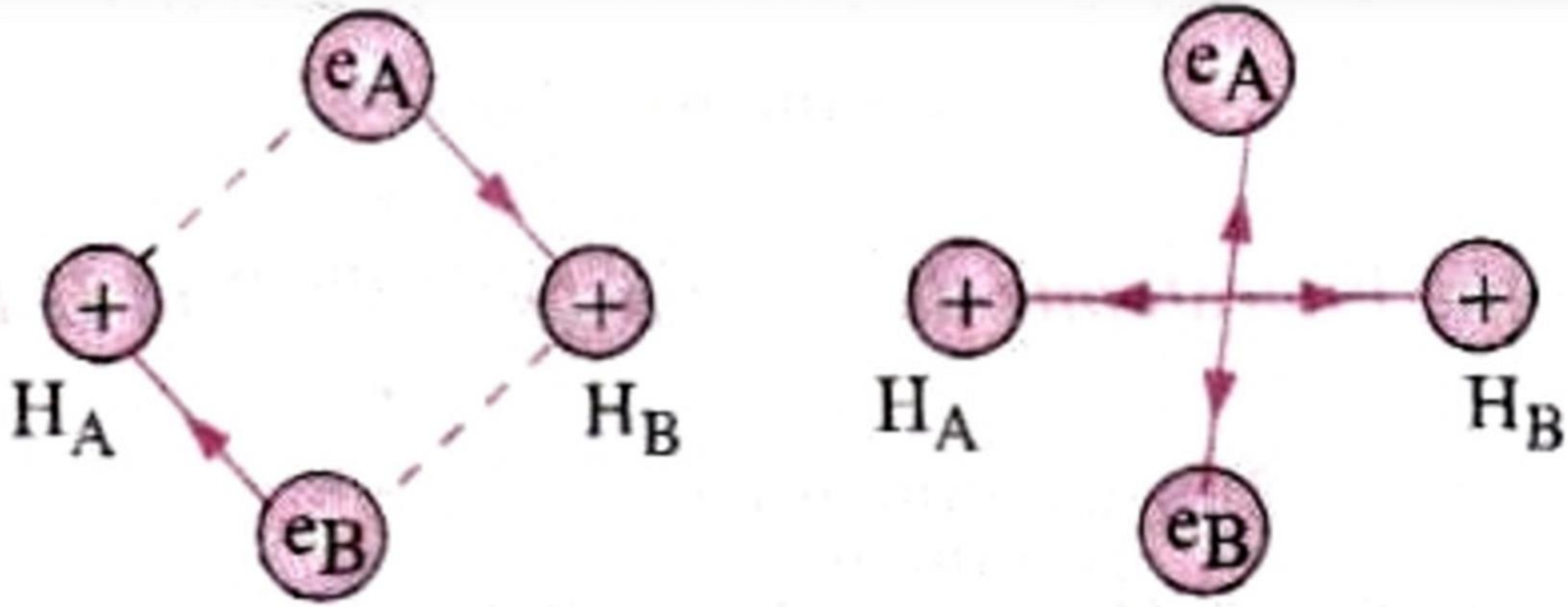
Electronegativity
Resonance
Molecular Geometry
Intermolecular Forces

Valence Bond Theory

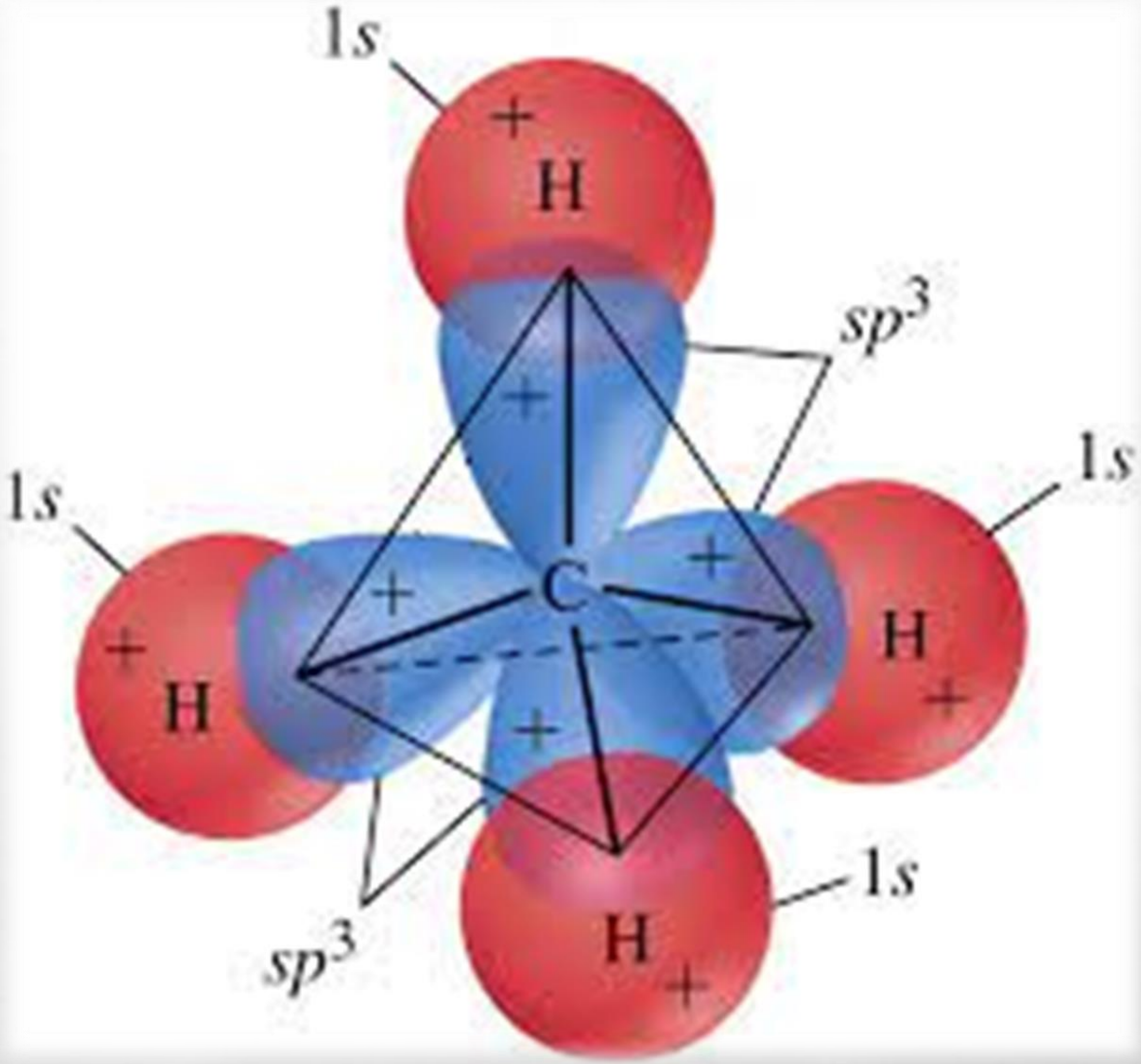
Valence Bond Theory is a fundamental concept in chemistry that explains chemical bonding in molecules. Proposed by Linus Pauling and others in the early 20th century, it provides a qualitative understanding of how atoms combine to form molecules through the overlap of atomic orbitals.

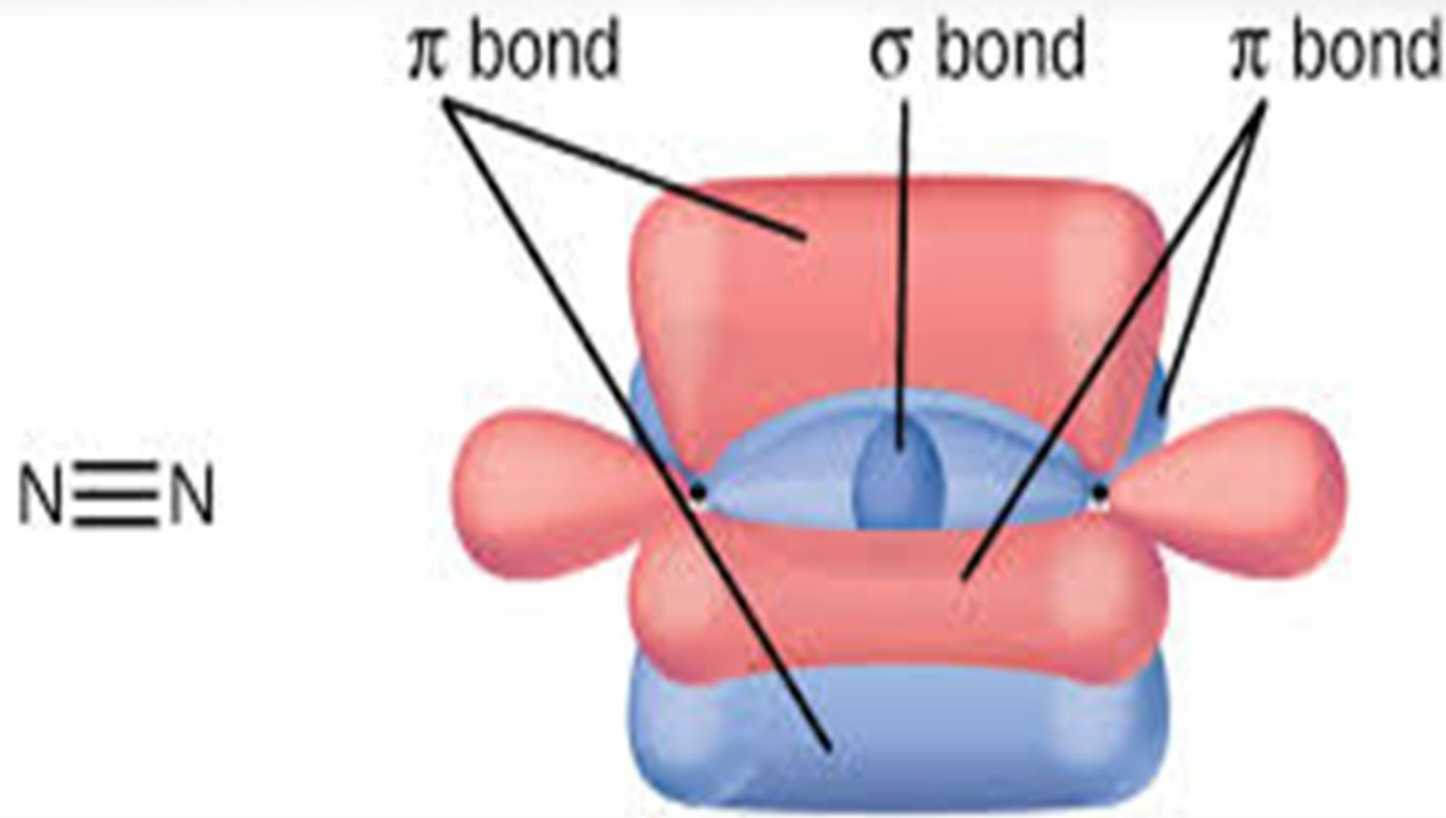
According to this theory, atoms form covalent bonds by sharing electrons when their atomic orbitals overlap. The key principles of valence bond theory include the concept of hybridization, where atomic orbitals mix to form hybrid orbitals with specific geometries, and the idea of localized electron pairs between bonded atoms.

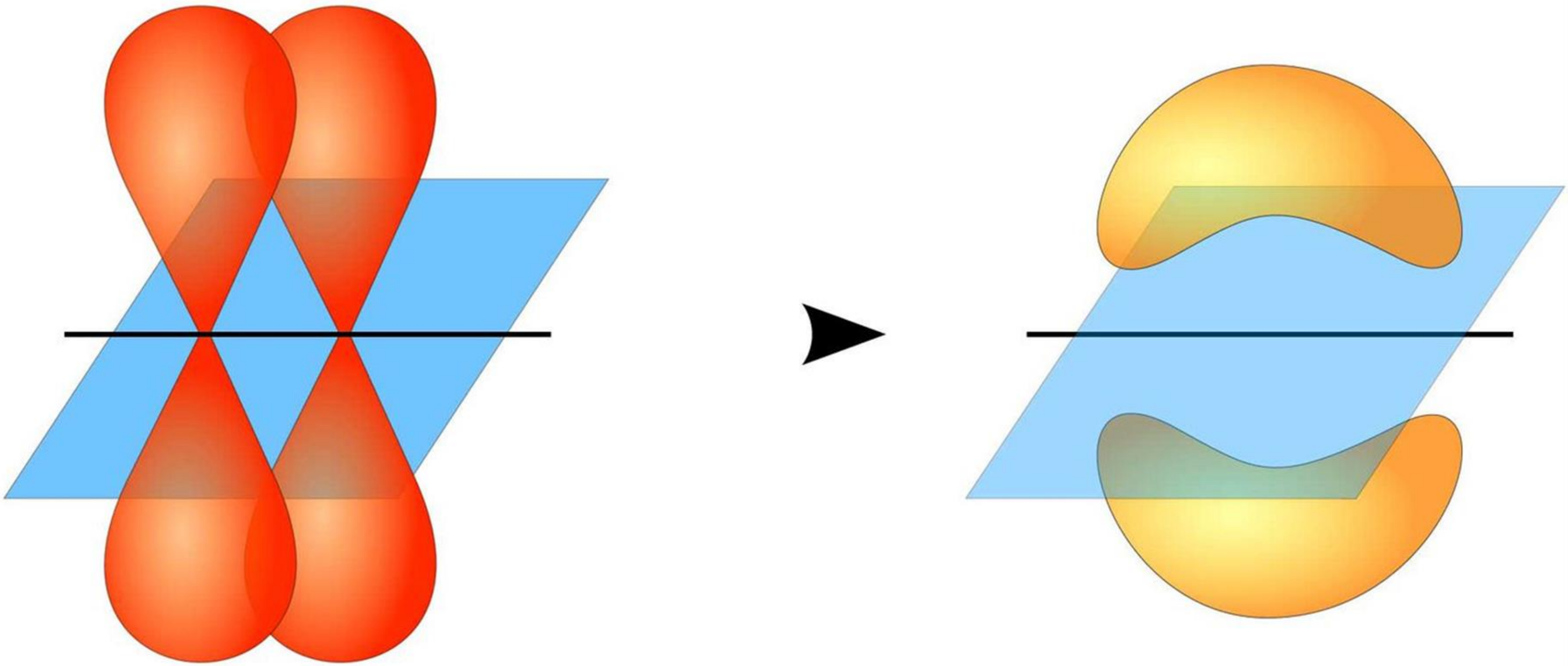

1s1
1s1
H
H
Overlapping of 1s orbitals
1s2
Covalent Bond H-H

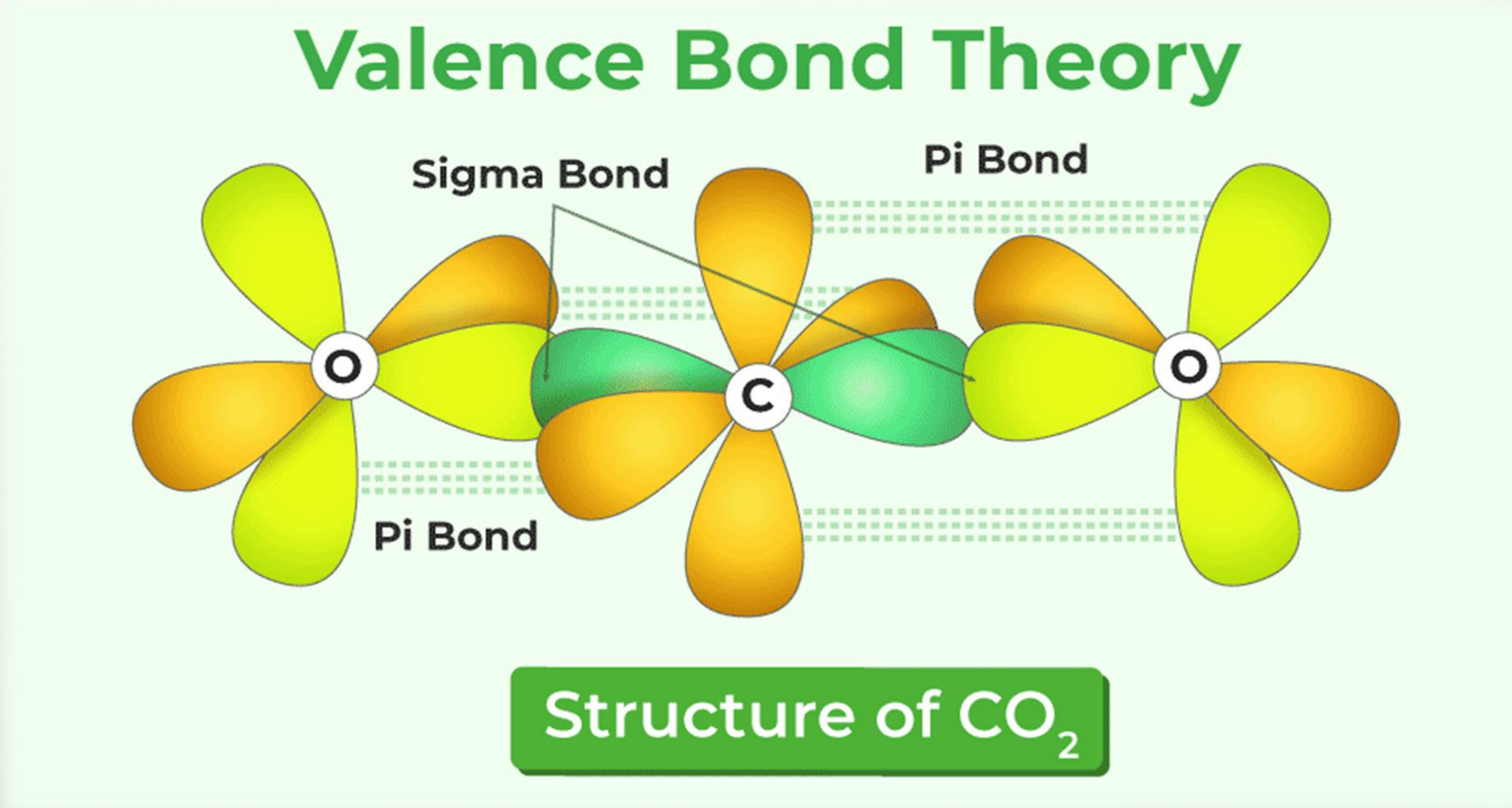


(a) Attractive forces (b) Repulsive forces


1s
H
sp3
1s
1s
H
C
H
H
1s
sp3


N≡N
π bond
σ bond
π bond



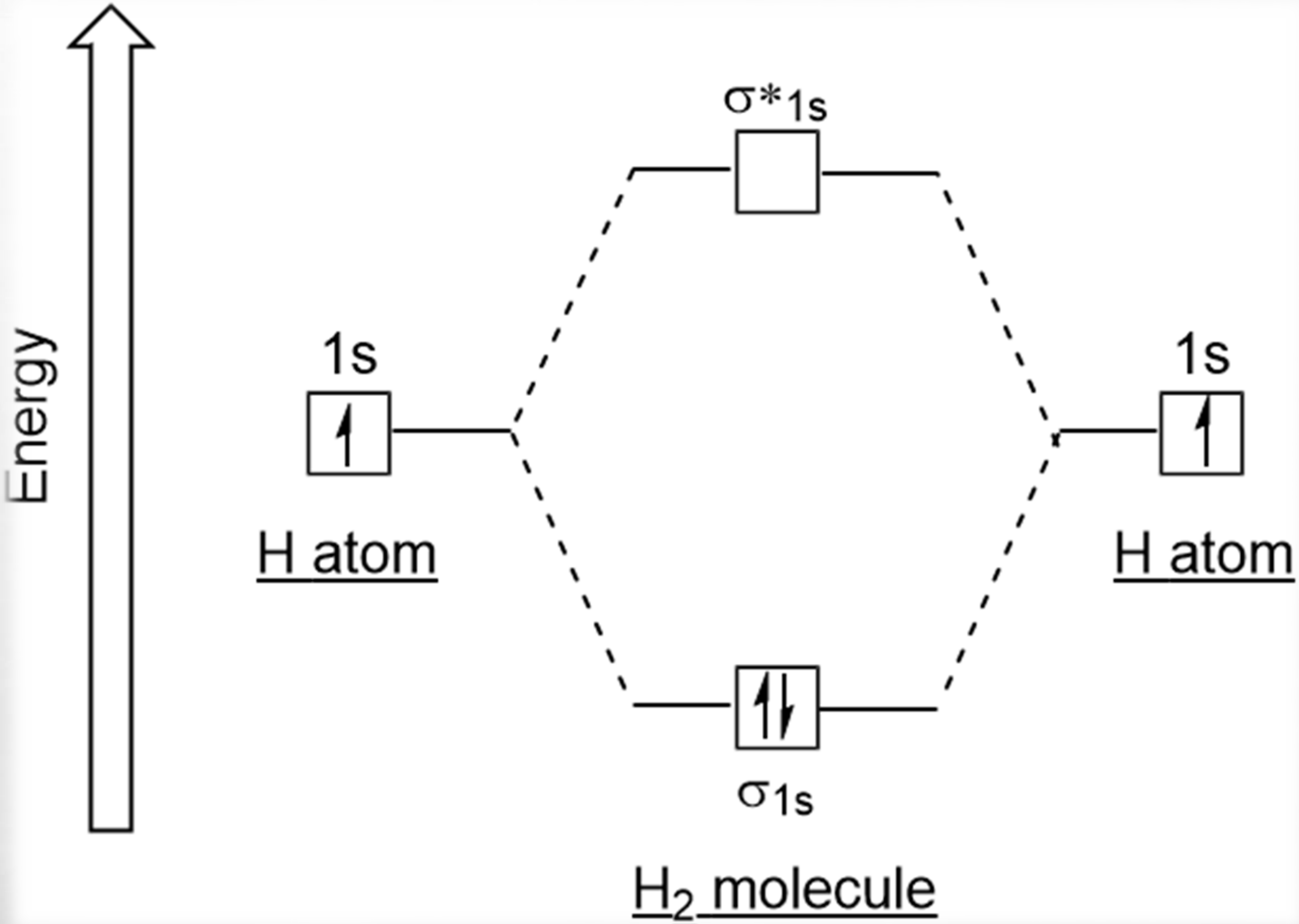

Valence Bond Theory
Sigma Bond
Pi Bond
O
C
O
Pi Bond
Structure of CO_2

Molecular Orbital Theory

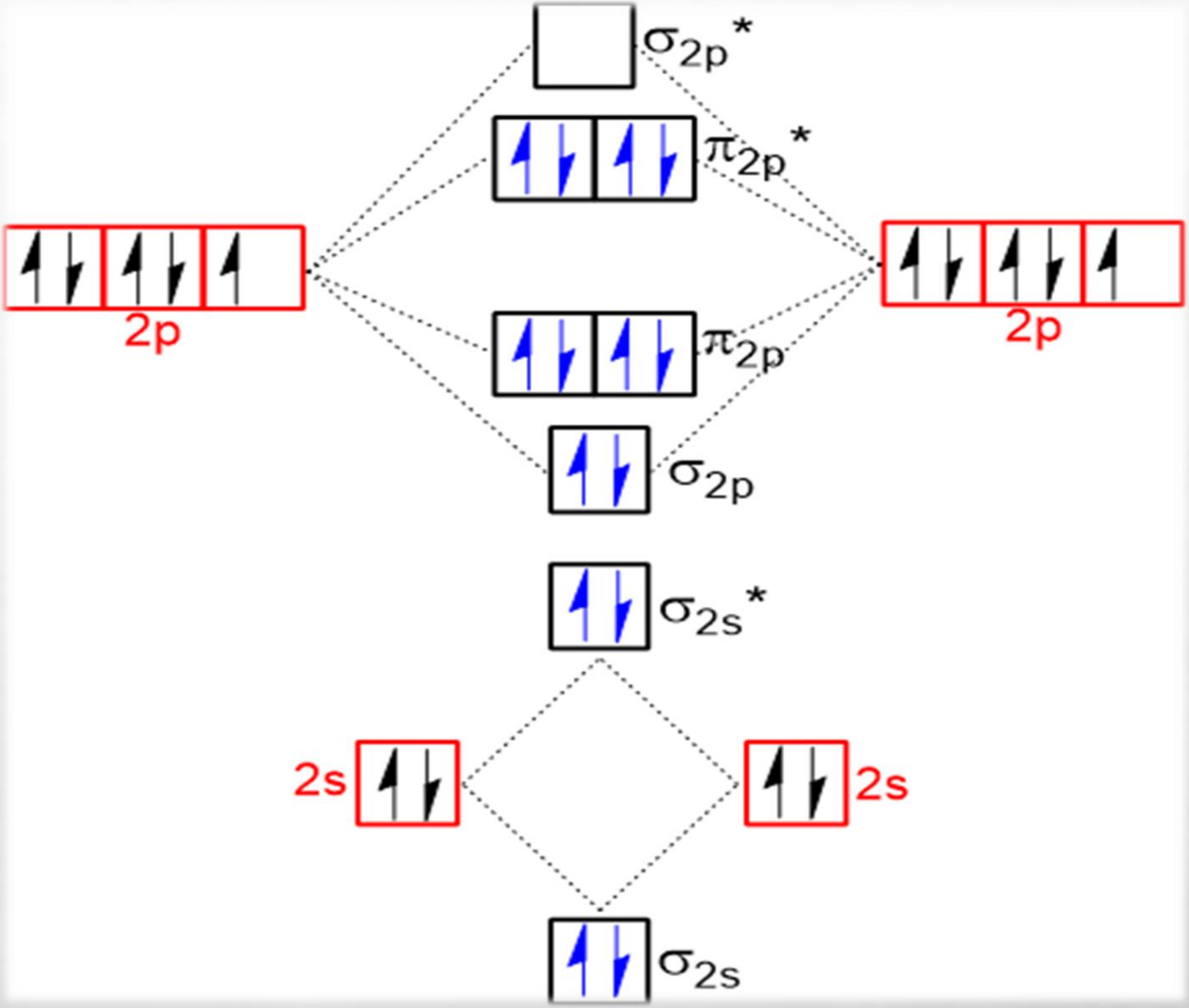
Molecular Orbital (MO) Theory is a quantum mechanical model that describes the behavior of electrons in molecules. Proposed by **Robert Mulliken, Friedrich Hund, and Linus Pauling** in the 1930s, this theory extends the principles of quantum mechanics to explain how atomic orbitals combine to form molecular orbitals.

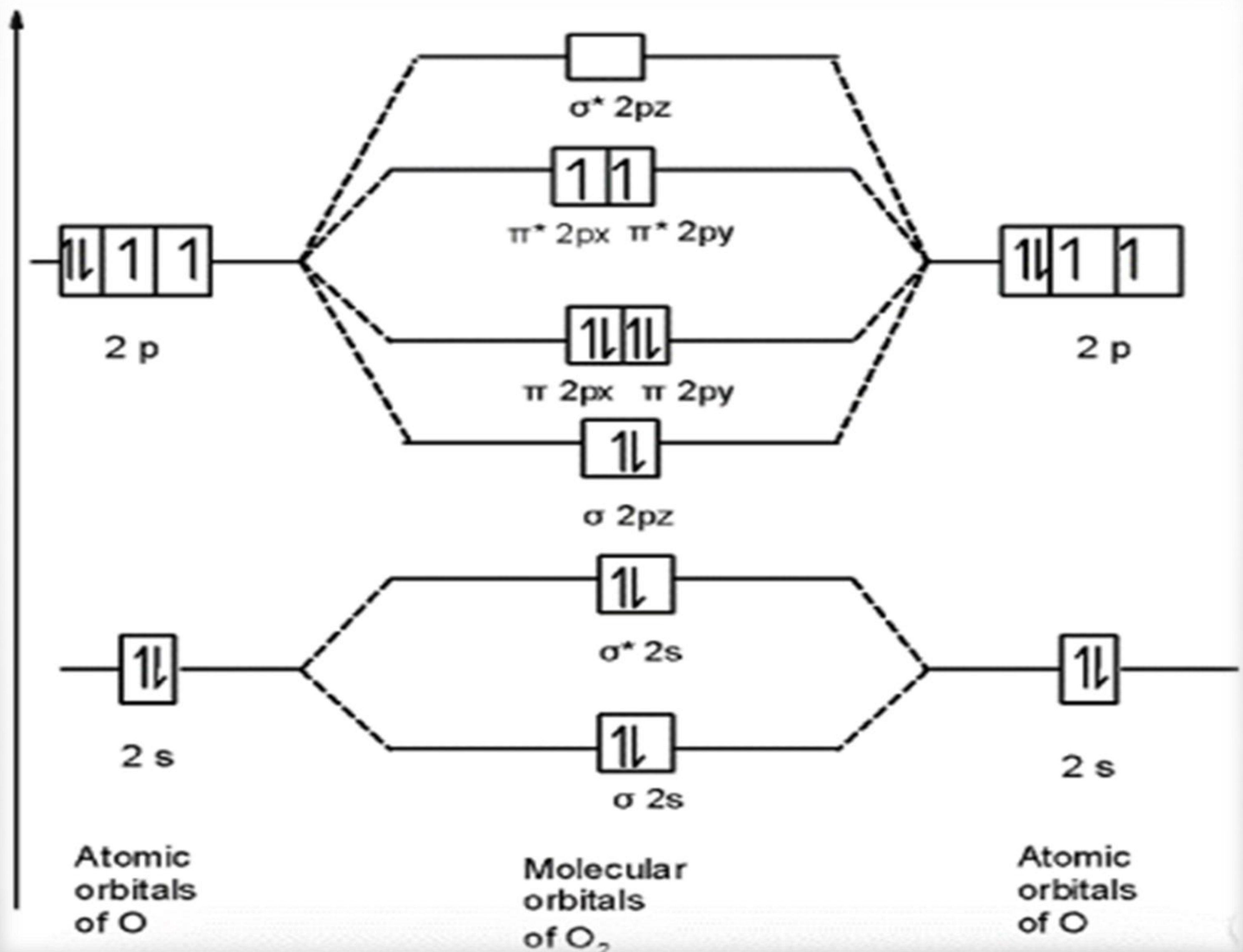
In MO theory, molecular orbitals are mathematical functions representing the distribution of electrons in a molecule. When atomic orbitals overlap, they combine to form molecular orbitals, which can be bonding, antibonding, or nonbonding.

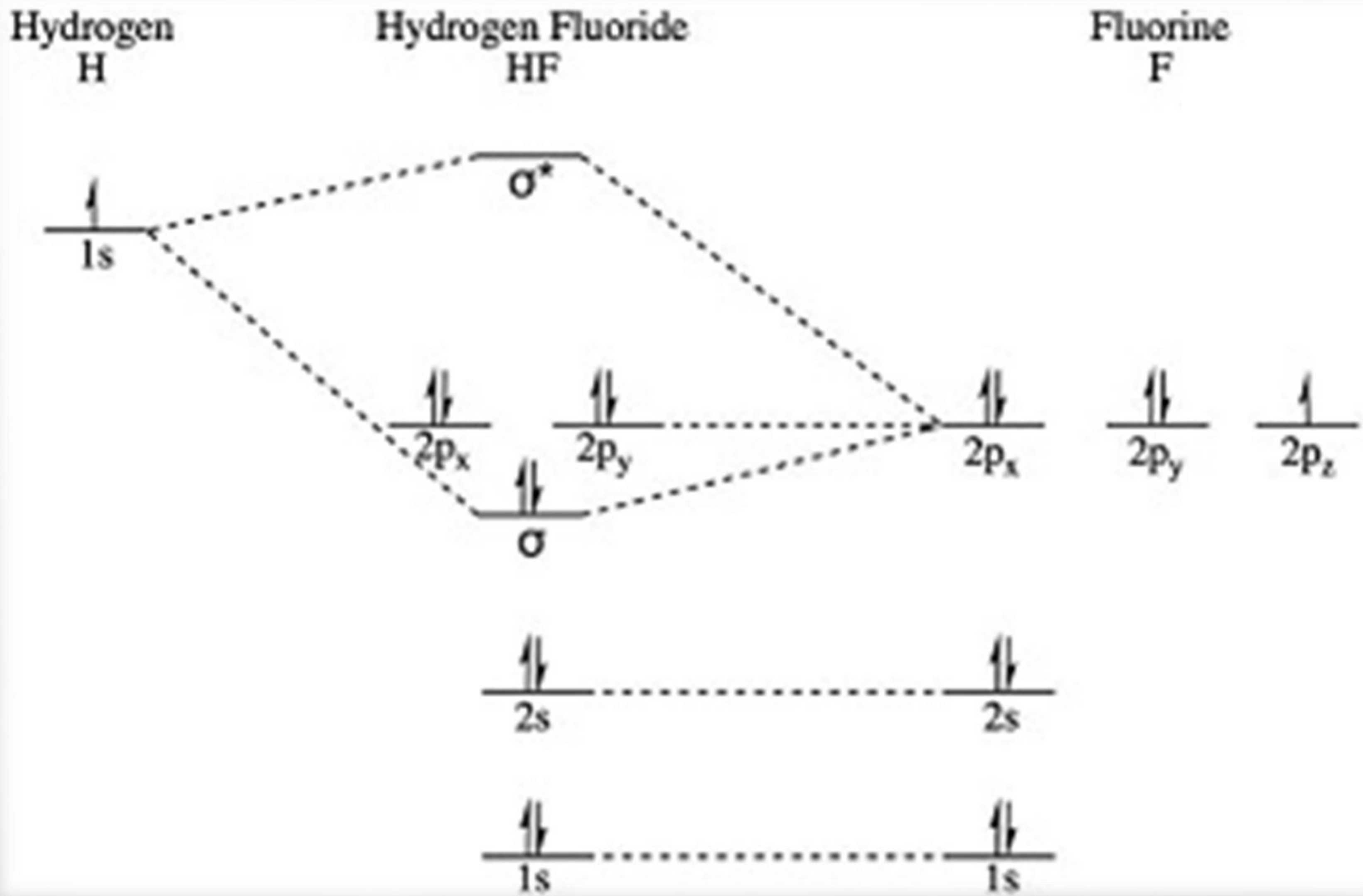
Bonding orbitals stabilize a molecule, while antibonding orbitals increase its energy. Electrons fill these molecular orbitals in accordance with the Pauli Exclusion Principle and Hund's Rule.


Energy
σ*1s
1s
1s
H atom
H atom
σ1s
H2 molecule

F_2




σ* 2pz
π* 2px π* 2py
2 p
π 2px π 2py
2 p
σ 2pz
σ* 2s
2 s
σ 2s
2 s
Atomic orbitals of O
Molecular orbitals of O_2
Atomic orbitals of O


Hydrogen
H
Hydrogen Fluoride
HF
Fluorine
F
σ*
1s
2px
2py
2px
2py
2pz
σ
2s
2s
1s
1s