Chemical Bonding

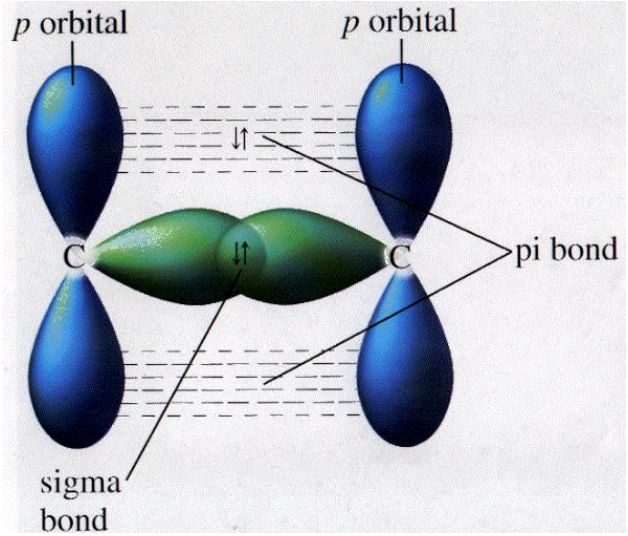
Chemical Bonding

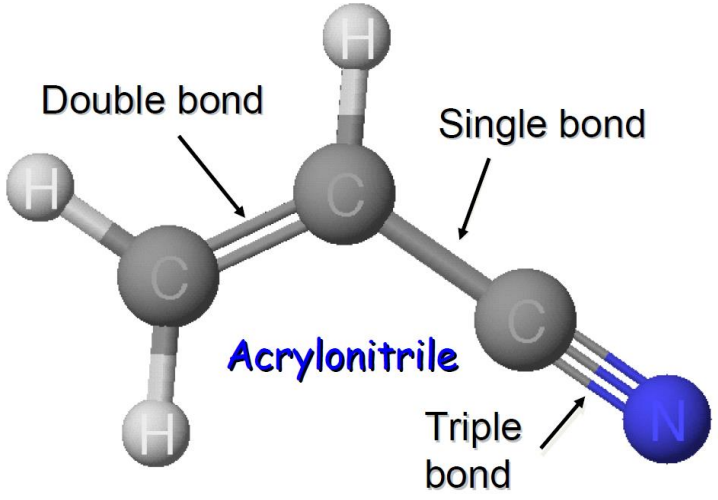
Chemical bond : The chemical force which keeps the atoms in any molecule together is commonly described as a chemical bond.

Covalent bond : The bond formed by mutual sharing of electrons between the combining atoms of the same or different elements is called covalent bonds.

Sigma (σ) Bond : A covalent bond formed due to the head-on overlap of orbitals of the two atoms along the line joining the two nuclei (orbital axis) is called **sigma (σ) bond.**

Pi (π) Bond : A pi-bond formed between the two atoms due to the sideways overlap of their *p*-orbitals is called a **pi (π) bond.**



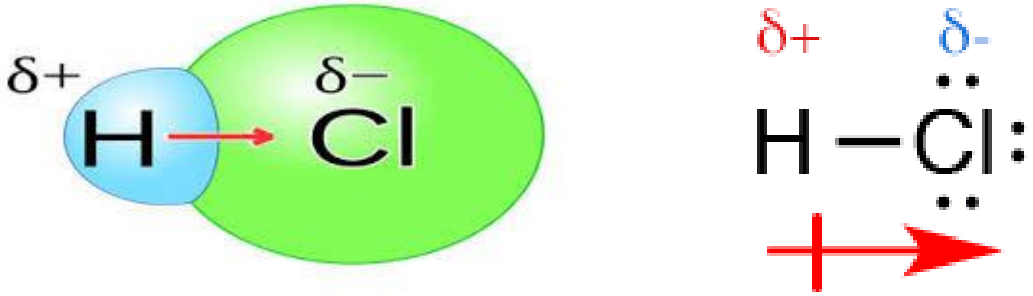


Polarity of Bonds

Non-polar Covalent Bond – between same element (e.g. H_2, O_2 etc)

Polar Covalent Bond - between different elements (e.g. HCl, H_2O etc)

Bond Dipole Moment (μ) : A covalent bond between two atoms of different elements is called a *polar covalent bond* . A polar bond is partly covalent bond and partly ionic. *The percentage of ionicity in a covalent bond is called percentage ionic character in that bond* . The ionic character in a bond is expressed in terms of **bond dipole moment** (μ).



- HCl is <u>polar</u> because it has a positive end and a negative end. Cl has slight negative charge (δ-) and H has slight positive charge (δ+).

Types of Chemical Bonding

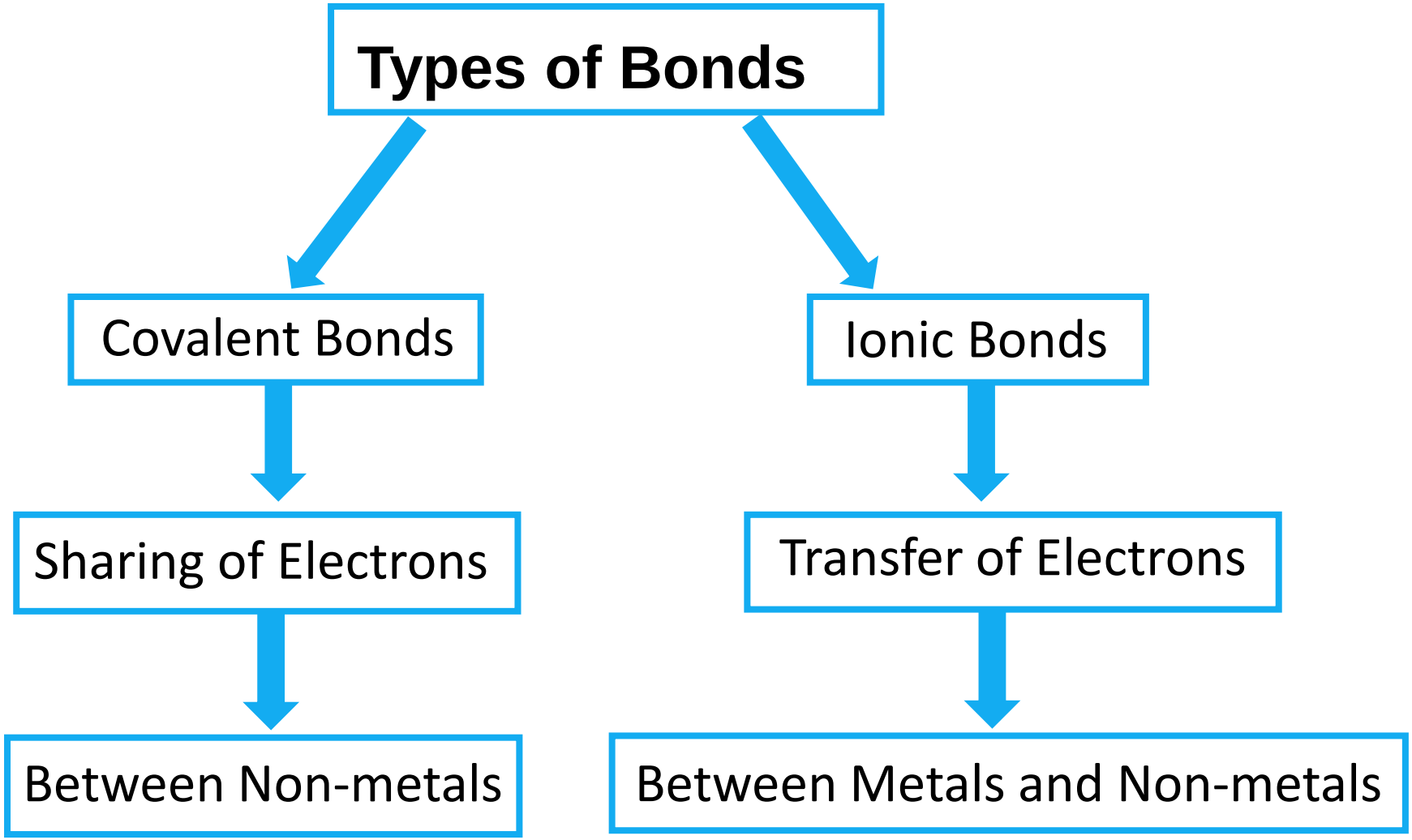
1. Ionic Bonding
2. Covalent Bonding
3. Hydrogen Bonding
4. Metallic Bonding

5. van der Wall interaction

The Electronic Structure of the Noble Gases

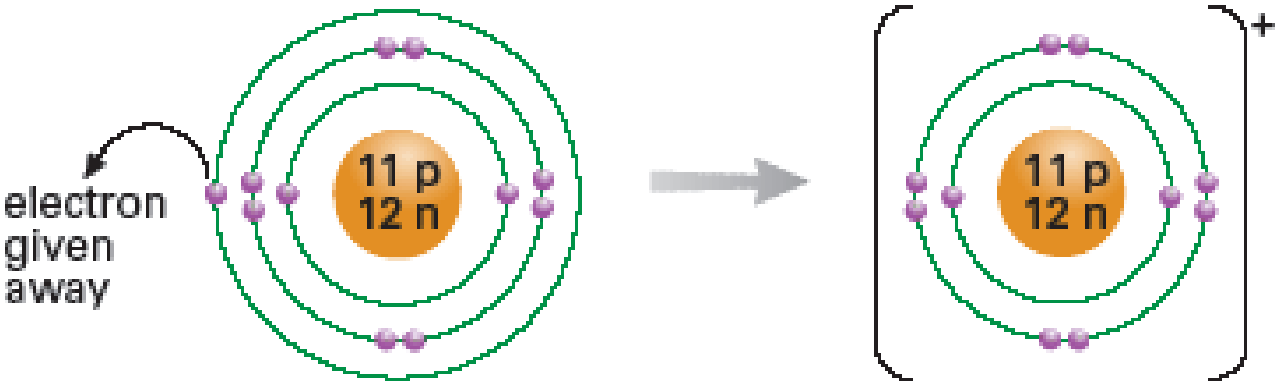
- The noble gases like helium, neon and argon, which are in Group 18 of the Periodic Table, are very unreactive.
- They do not form bonds with other atoms.
- They have fully filled outermost (valence) shells.
- Except for helium, which has 2 outer electrons, all the other noble gases have 8 outer electrons.

- The outer shell of 8 electrons is called an octet structure and it makes the atom very stable. e.g. helium, neon, argon etc
- Atoms of other elements become stable like the noble gases by losing or gaining electrons or by sharing electrons.
- They achieve this by forming chemical bonds with other atoms.


Types of Bonds
Covalent Bonds
Ionic Bonds
Sharing of Electrons
Transfer of Electrons
Between Non-metals
Between Metals and Non-metals

Ionic Bonds – Sodium Chloride

- When sodium reacts with chlorine, the sodium atom loses an electron to become a positively charged sodium ion:



$1s^2, 2s^2, 2p^6, 3s^1$

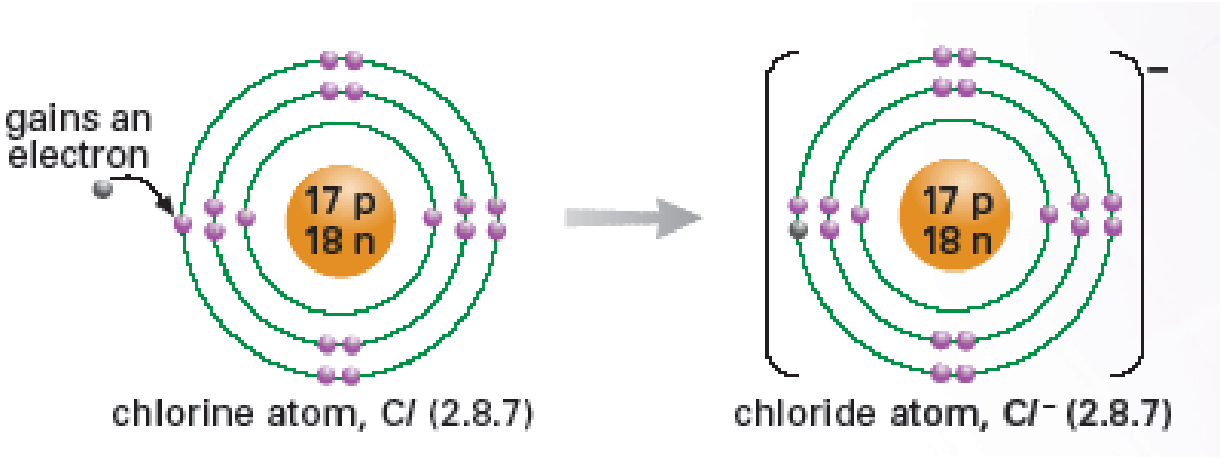
One electron is more than nearest noble gas configuration

$1s^2, 2s^2, 2p^6$

- Valence shell – octoate full.
- Same as neon

Ionic Bonds – Sodium Chloride

- The chlorine atom gains an electron to become a negatively charged chloride ion:



$1s^2, 2s^2, 2p^6, 3s^2, 3p^5$

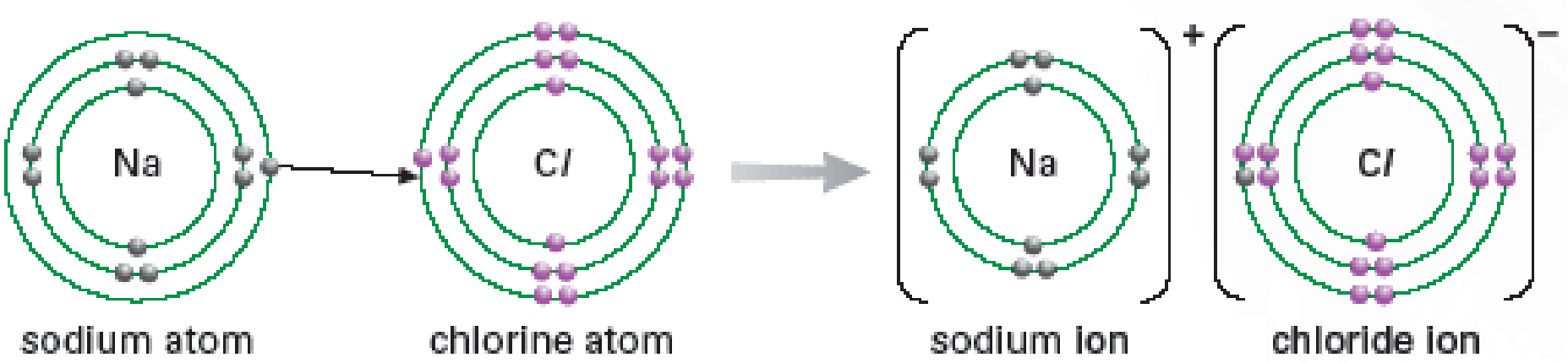
$1s^2, 2s^2, 2p^6, 3s^2, 3p^6$

One electron is less than nearest noble gas configuration

- Valence shell – octoate full.
- Same as argon

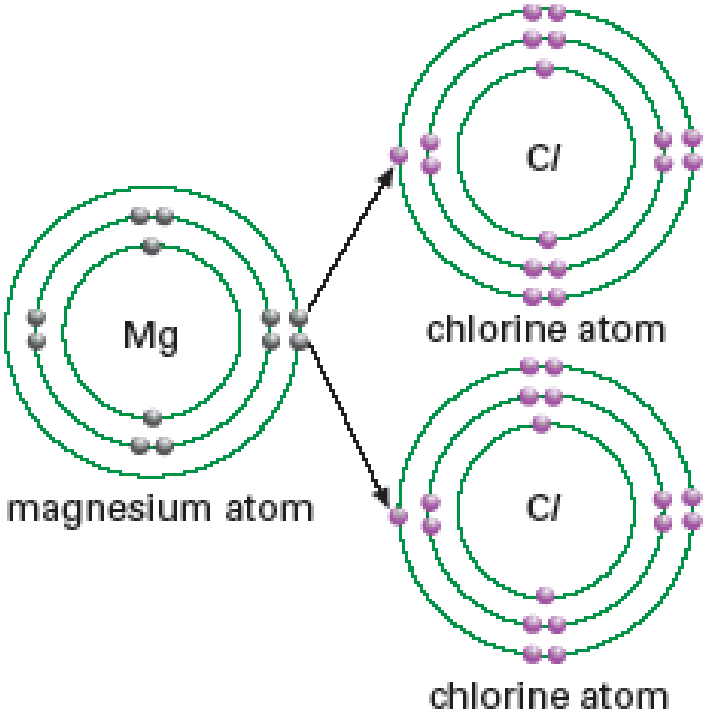
Ionic Bonds – Sodium Chloride

- The positive sodium ion and the negative chloride ion then attract each other to form sodium chloride.

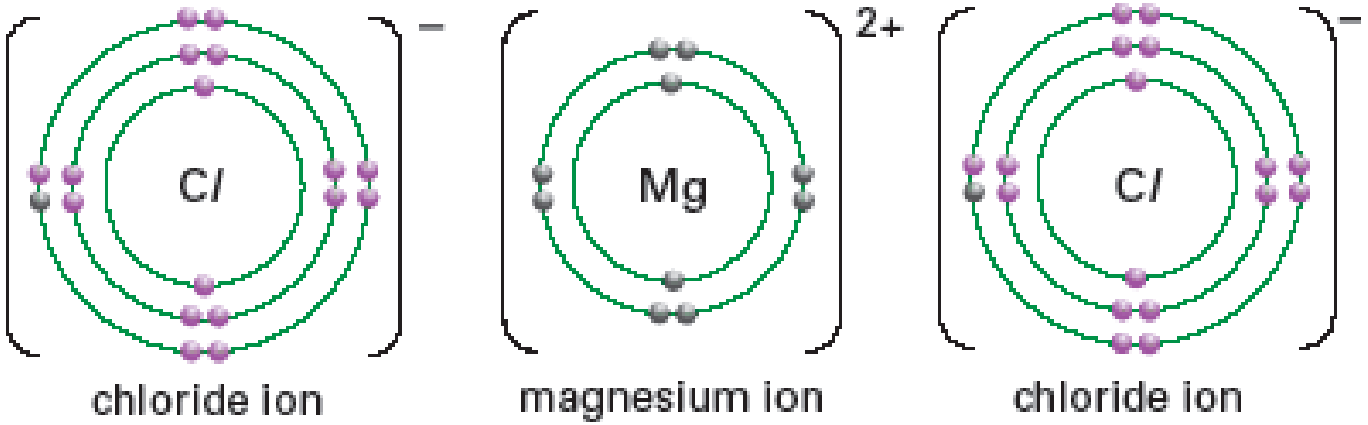


- Hence, sodium chloride is an ionic compound.

Other Ionic Compounds – $MgCl_2$

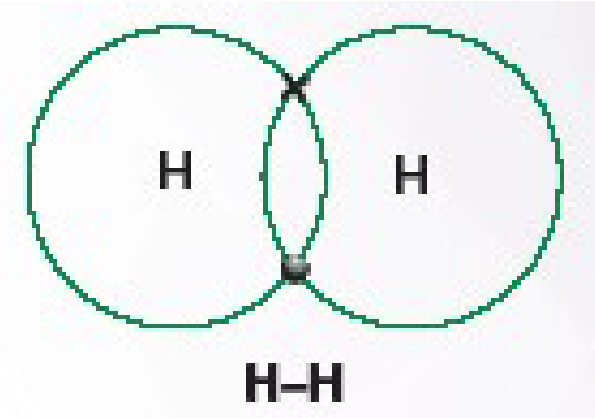


- Magnesium : $1s^2$, $2s^2$, $2p^6$, $3s^2$ or $[Ne]3s^2$ has two extra from nearest noble gas configuration (Neon).
- Magnesium, thus, lose two electron to attain noble gas configuration.
- Each magnesium atom transfers two electrons, one to each chlorine atom, to form magnesium chloride.



Covalent Bonds – Hydrogen

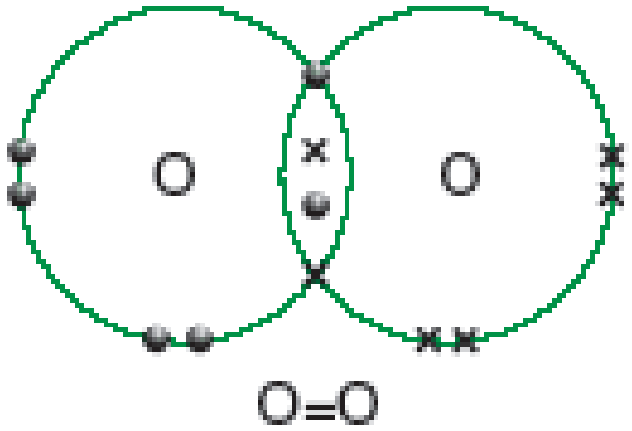
- A hydrogen atom has only one electron in its first shell.
- To achieve a more stable structure like helium, it needs one more electron in the first shell.
- So two hydrogen atoms join together and share their electrons. Thus, a hydrogen molecule is formed.
- This sharing of electrons is called covalent bonding.



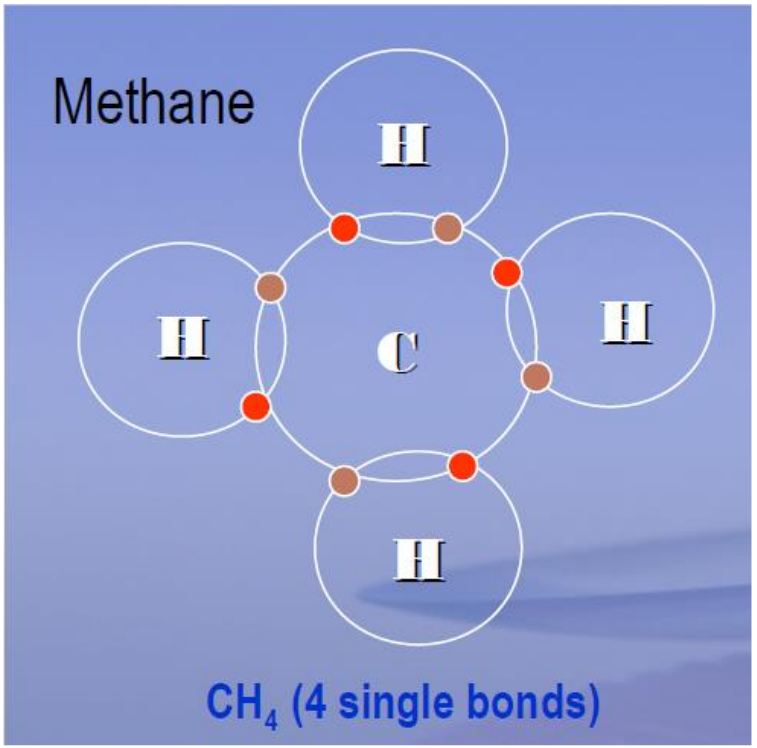
Covalent Bonds – Oxygen

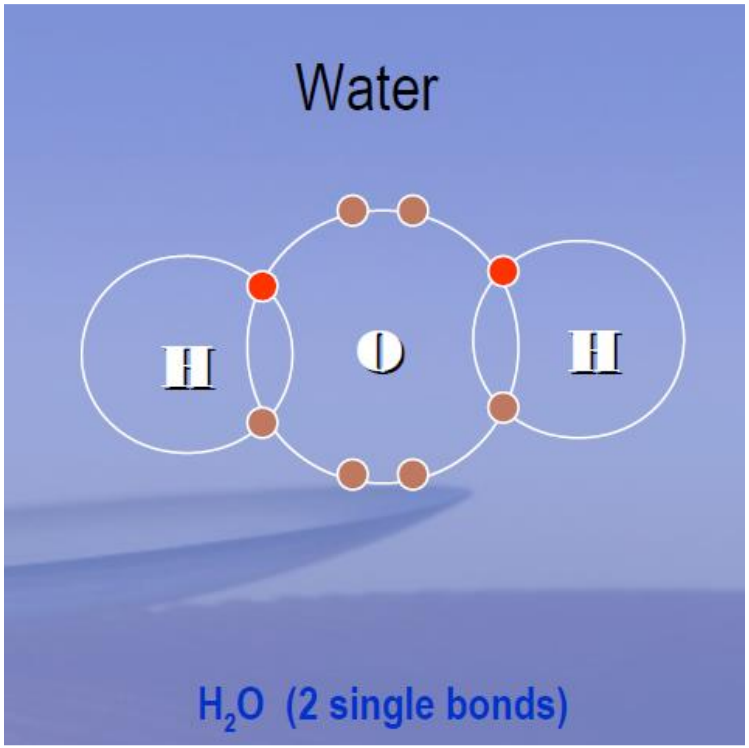
- In an oxygen atom, the outer shell has 6 electrons, so to achieve an octet structure of 8 electrons like neon, two extra electrons are needed. So, two oxygen atoms combine to share 4 electrons (two from each).

- This is called double bond



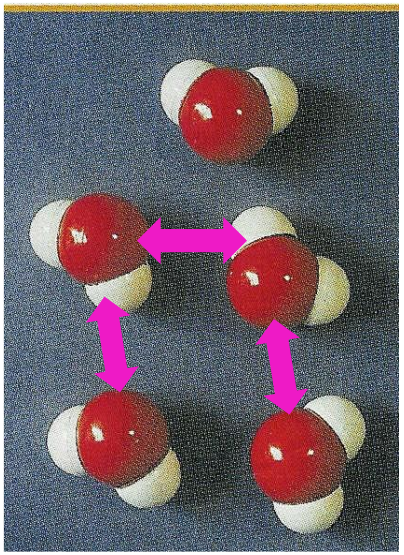
Other Covalent Molecules





Properties of Covalent Compounds

- The intermolecular forces between the molecules are weak so covalent compounds have low melting and low boiling points.
- For example, water, a covalent compound, has a melting point of 0 °C and a boiling point of 100 °C.
- Covalent compounds do not conduct electricity in any state.

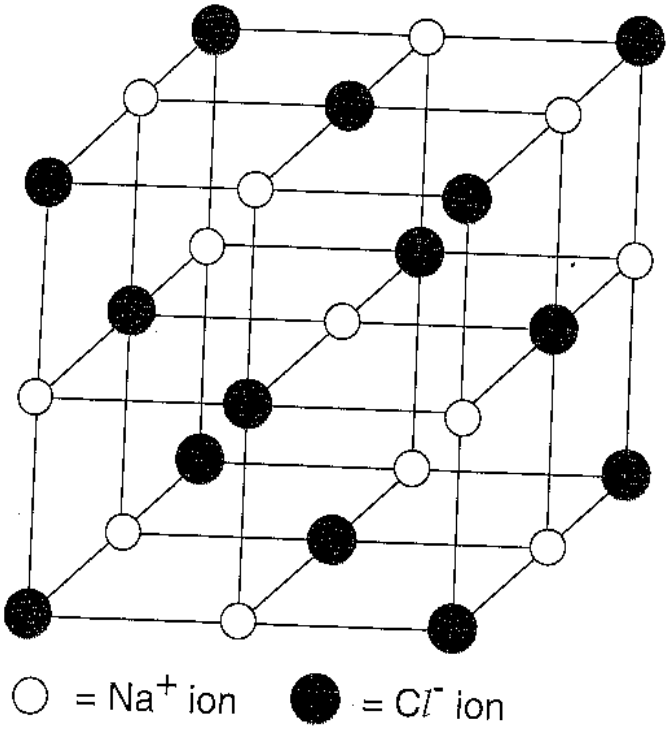


Question: Sugar is a covalent compound but it is soluble in water. State one test you would use to show that sugar is a covalent compound.

Answer: measurement of conductivity.

Properties of Ionic Compounds

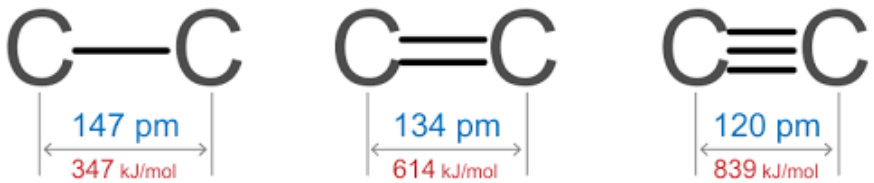
- The electrostatic forces between the oppositely charged ions are very strong, so ionic compounds have very high melting points and boiling points.
- For example, sodium chloride, an ionic compound, has a melting point of 801 °C and a boiling point of 1517 °C.
- Ionic compounds conduct electricity when molten or dissolved in water. This is because the ions can move about and conduct electricity.

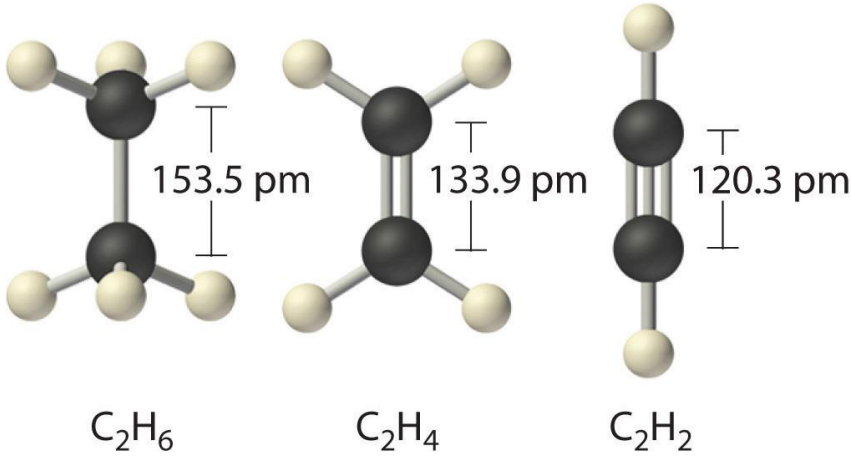


- Most ionic compounds are soluble in water, but insoluble in organic solvents.
- For example, sodium chloride is soluble in water, but insoluble in oil or petrol.

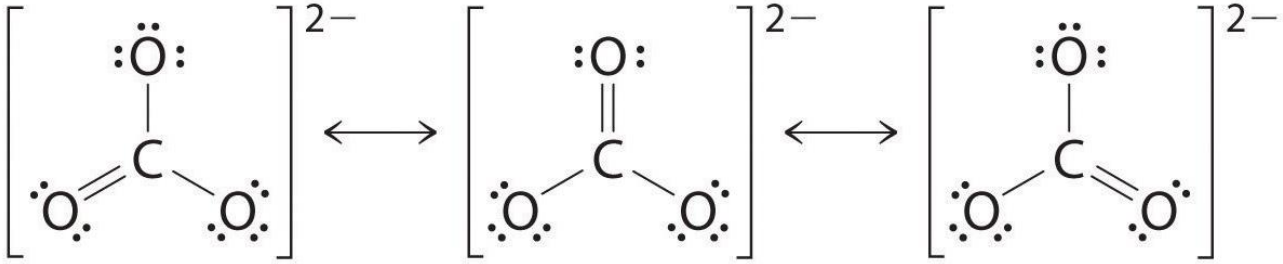
Bond Order

- Bond strength increases with bond order.
- Bond length decreases with bond order





Fractional Bond Order



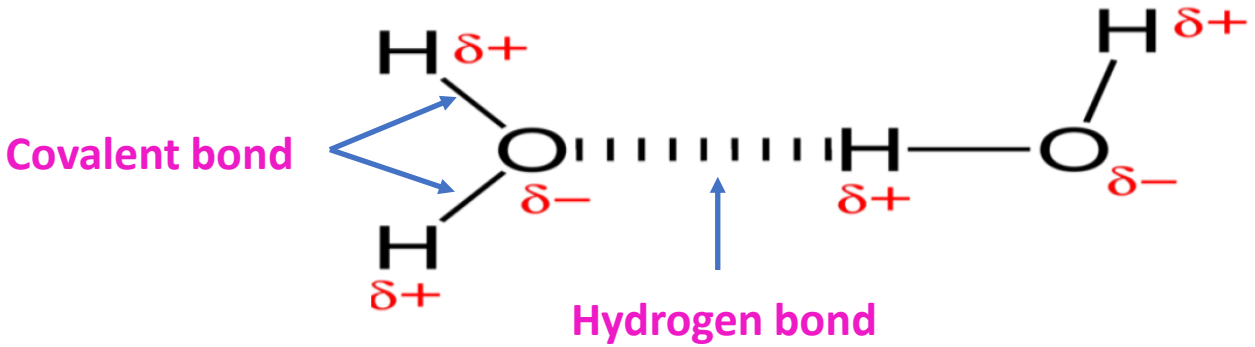
Resonance structure

Bond order of carbonate ion is 1.33.

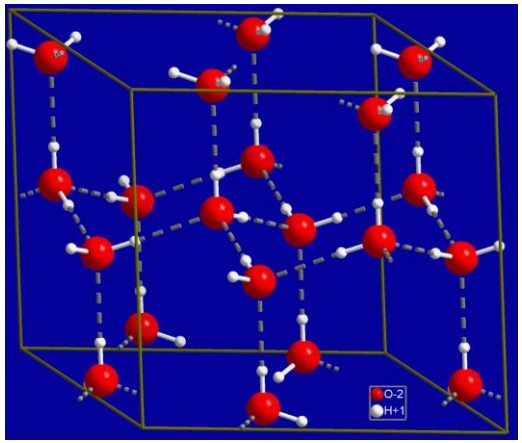
Hydrogen Bonding

- A hydrogen bond is the attractive force between the hydrogen attached to an electronegative atom of one molecule and an electronegative atom of the same or another molecule.

- Usually the electronegative atom is oxygen, nitrogen, or fluorine, which has a partial negative charge.



Hydrogen bonding in hexagonal ice crystal



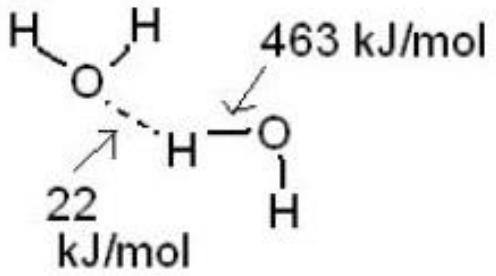
Order of Strength of Hydrogen Bonding

- The strength of hydrogen bonding depends on the electronegativity of the hetero-atom.

$HF > H_2O > NH_3$

$HF > HCl > HBr > HI$

$H_2O > H_2S$

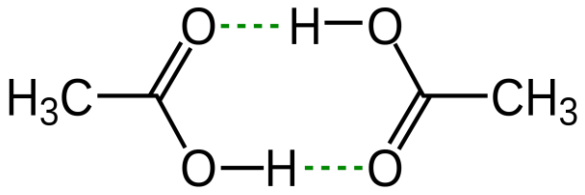


Strongest case is in HF_2^- bifluoride anion

$[F - H - F]^-$

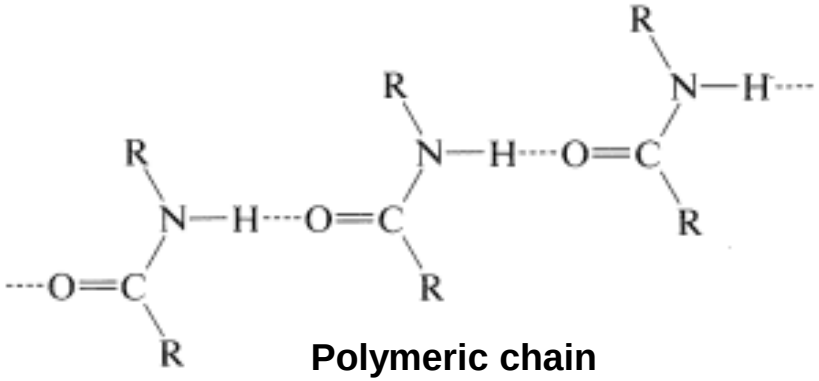
B(H-F) = 165 kJ/mol

Hydrogen Bonding in Organic Compounds

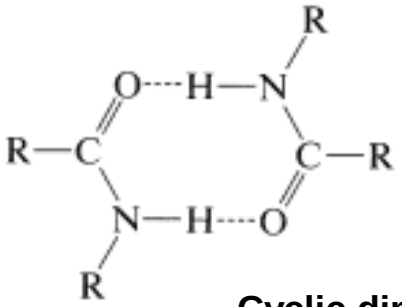


Hydrogen Bonding between carboxylic acids - Cyclic dimer

Hydrogen bonding between amide compounds

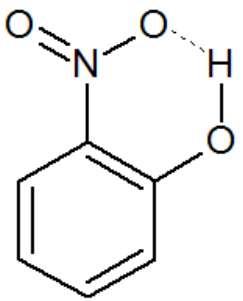


Polymeric chain



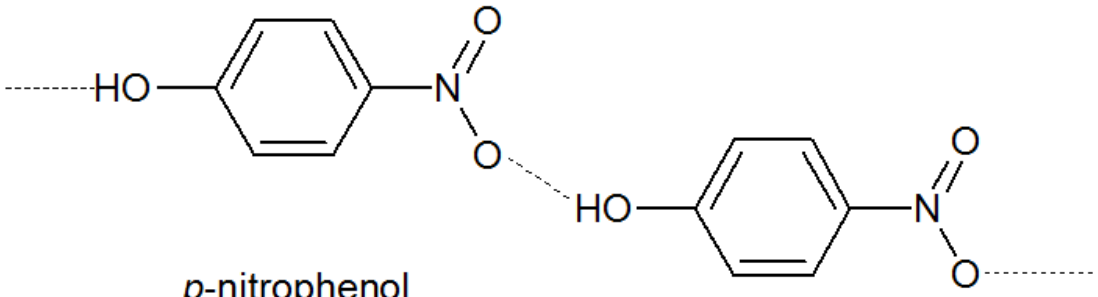
Cyclic dimer

Intramolecular Hydrogen Bonding



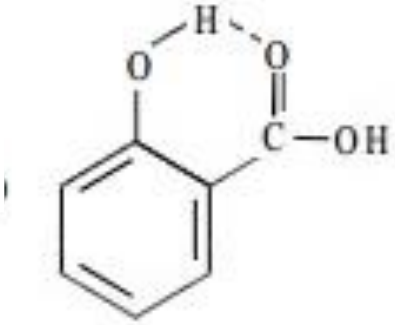
o-nitrophenol

(intramolecular hydrogen bonding)

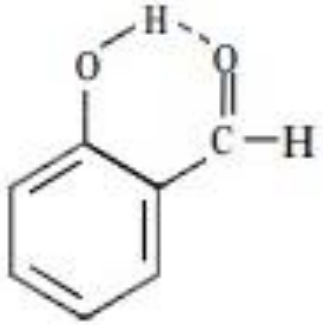


p-nitrophenol

(intermolecular hydrogen bonding)



Salicylic Acid

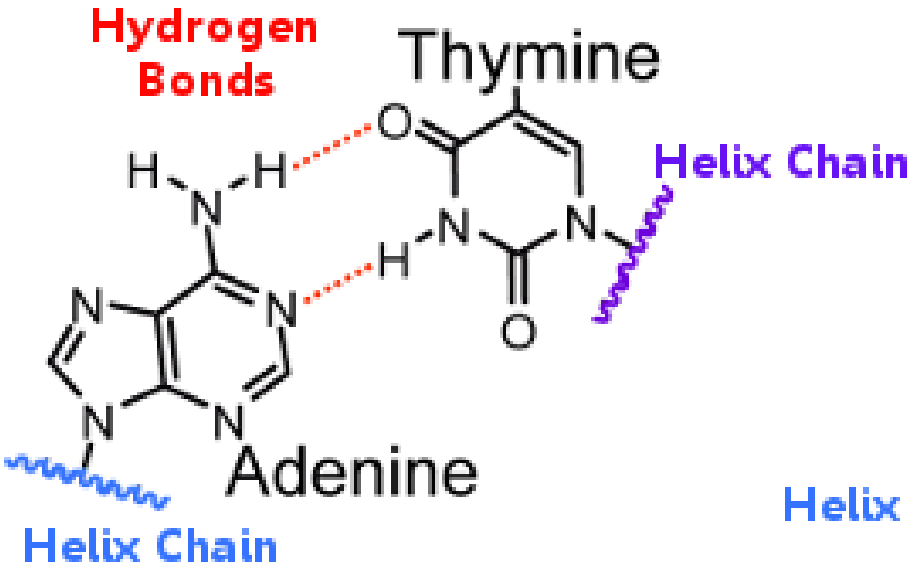


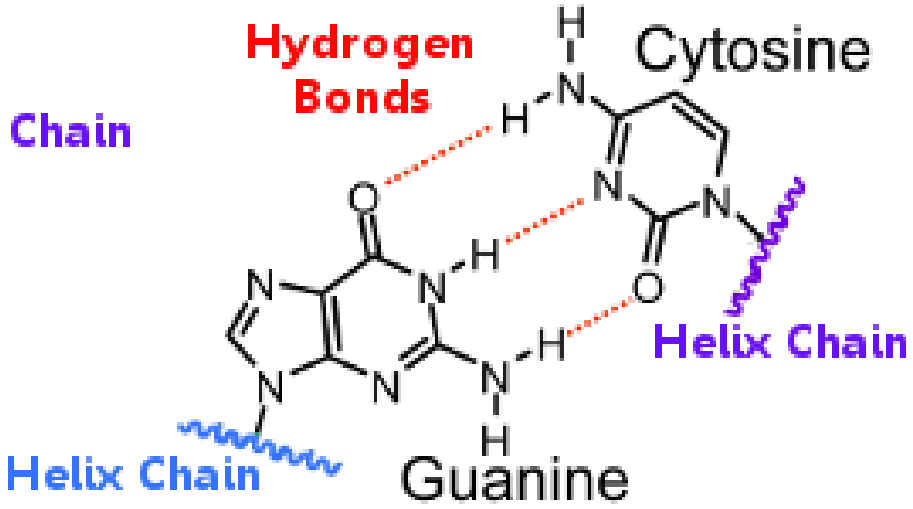
Salicylaldehyde

Hydrogen Bonding in Biology

- **Base pairs in DNA**

- **Adenine (A)**
- **Thymine (T)**
- **Guanine (G)**
- **Cytosine (C)**



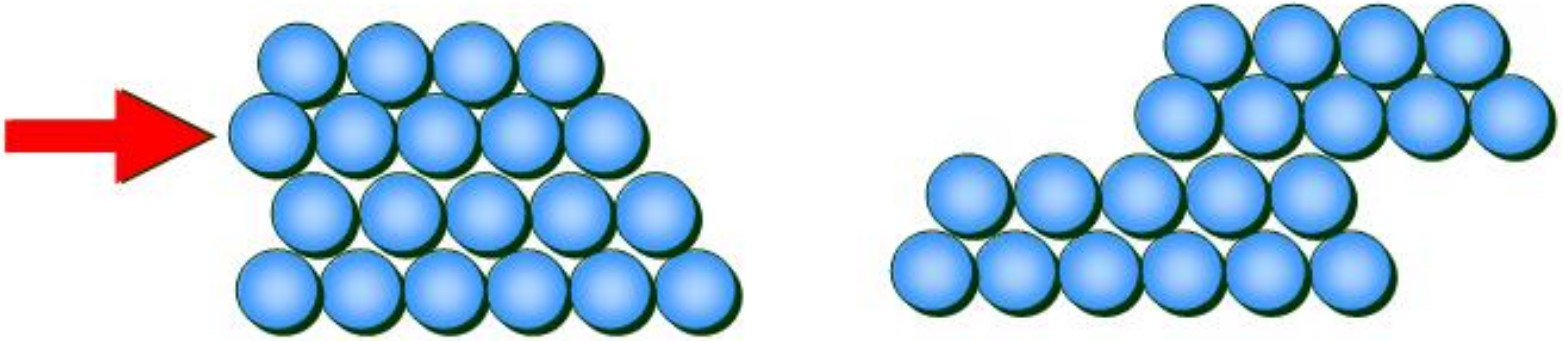


Metallic bonding

- Metals are also made up of very large lattice structures.
- The metallic structure consists of a lattice of positive ions in a "sea of electrons".

- This is the electrostatic force of attraction between positively charged ions and delocalized outer electrons.

- Metals are malleable because the layers of atoms can slide over one another easily as they are being arranged in neat layers.

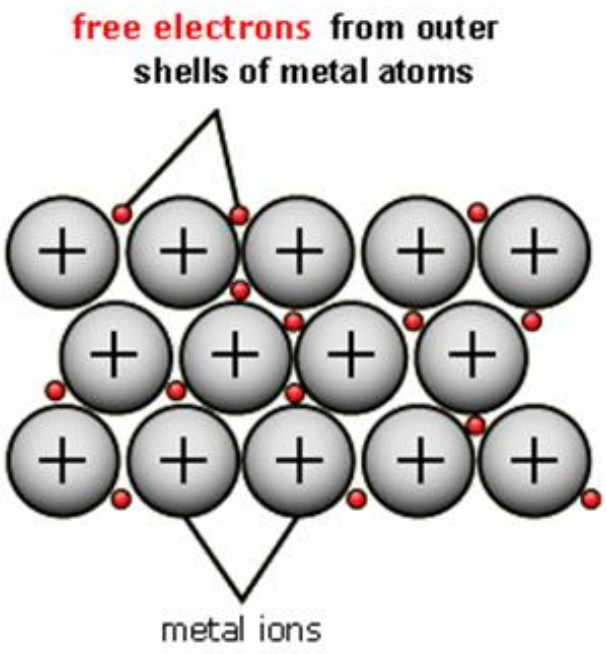


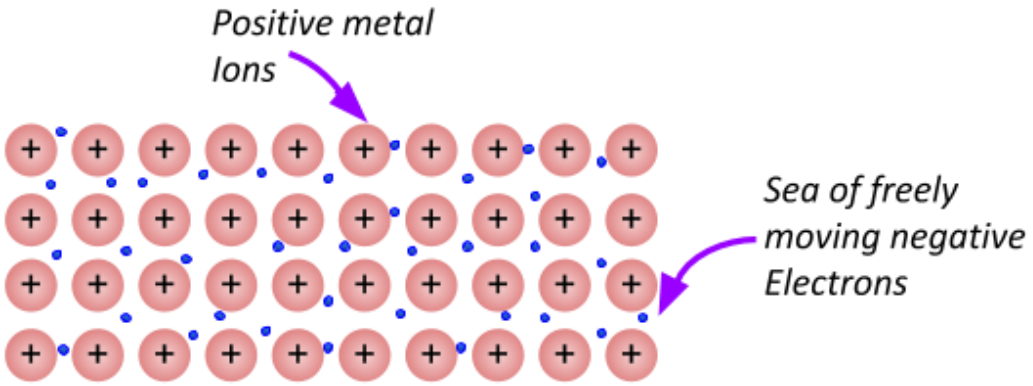
pure metals are soft because layers of "atoms" can slide over one another

Properties of Metallic structure

- The closely packed positively charged metallic ions form a lattice structure with the outer electrons moving freely around the whole metallic structure.

- The electrostatic attraction between the metallic ions and the electrons holds the metallic ions tightly in the lattice and this gives the metal a high melting point.
- The free electrons are able to move and conduct electricity and heat.

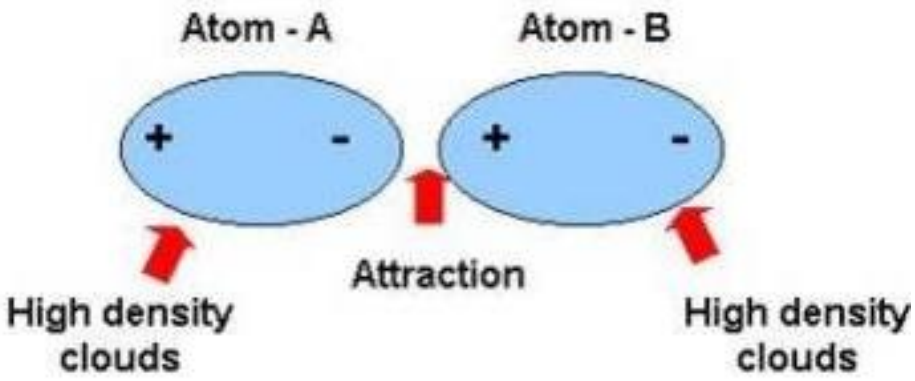


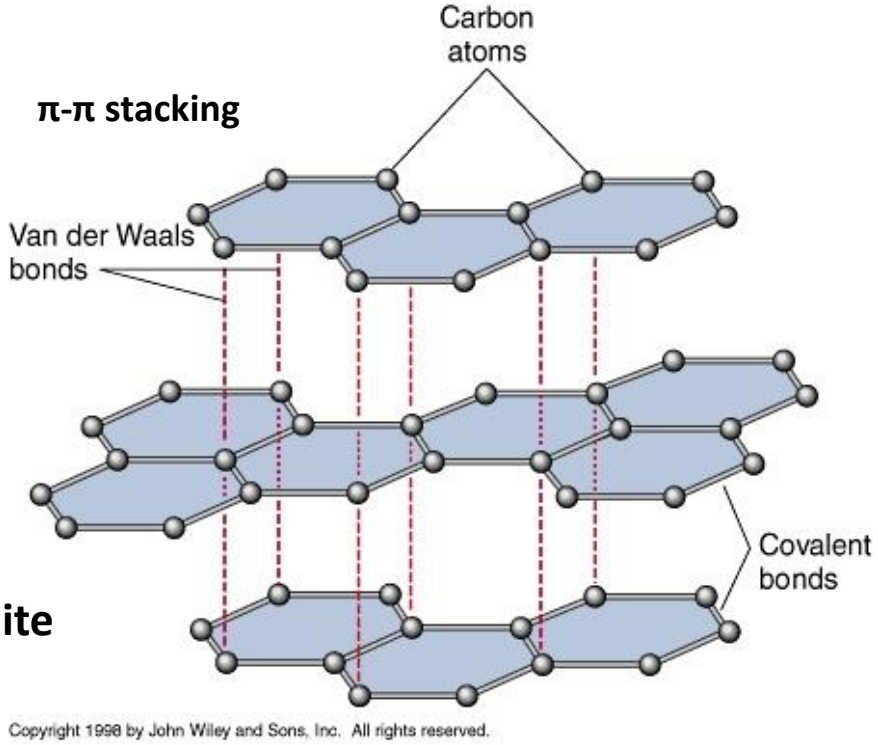


van der Waal's Forces

- Van der Waals forces include attraction and repulsions between atoms, molecules, and surfaces, as well as other intermolecular forces.
- They differ from covalent and ionic bonding in that they are caused by correlations in the fluctuating polarizations of nearby particles.

- van der Waal interaction is one kind of **non-covalent interaction**, which differs from a covalent bond in that it does not involve the sharing of electrons.





Questions

1. What is a covalent bond and how is it formed?
2. What is an ionic bond and how is it formed?
3. What is bond order and how it is related to bond length and bond energy? Calculate the bond order in carbonate ion (CO_3^{2-}).
4. What are the characteristics of covalent compounds?
5. What are the characteristics of ionic compounds?
6. What is hydrogen bonding? Which parameter decides the strength of hydrogen bonding? Describe hydrogen bonding in water.
7. Describe the structure and bonding in graphite.

Thank you for your Attention