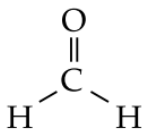
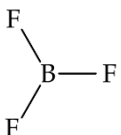
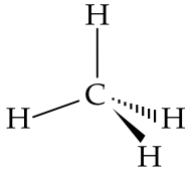
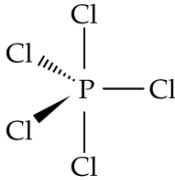
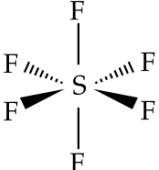
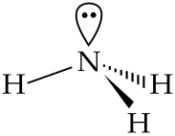



Molecular shape

Bond pair	Lone pair	Molecular shape	Example	
2	0	Linear	$\text{O} = \text{C} = \text{O}$ (Obeying octet rule)	$\text{F} - \text{Be} - \text{F}$ *(NOT obeying octet rule)
3	0	Trigonal planar	 (Obeying octet rule)	 (NOT obeying octet rule)
4	0	Tetrahedral	 (Obeying octet rule)	
5	0	Trigonal bipyramidal	 (NOT obeying octet rule)	
6	0	Octahedral	 (NOT obeying octet rule)	
3	1	Trigonal pyramidal	 (Obeying octet rule)	
2	2	V-shaped	 (Obeying octet rule)	

*For non-octet molecules:

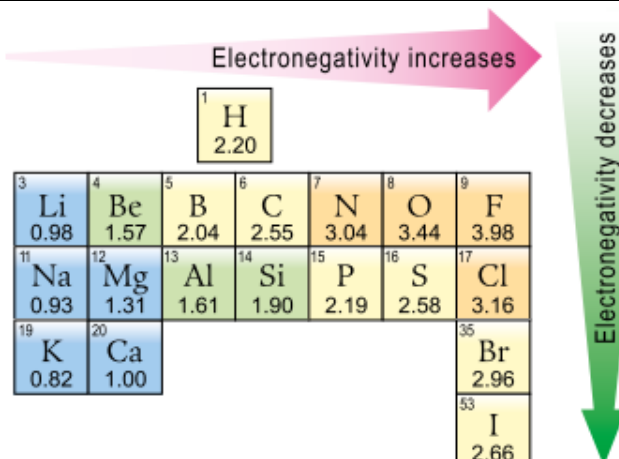
- Period 2 atoms can only have less than 8 outermost shell electrons (OF_6 , NF_5 do NOT exist)
- Period 3 or above atoms can have more than or less than 8 outermost shell electrons. (Usually more than 8)

Example

In a H_2O molecule, there are 2 bond pairs of electrons and 2 lone pairs of electrons around the central atom O. To minimize the repulsion between electron pairs, a H_2O molecule is V-shaped

Electronegativity

Electronegativity is a power of the atom to attract electrons to itself in a bonding situation



- Across a period, the electronegativity of the main group elements increases from left to right.
- Down a group, the electronegativity of the main group elements generally decreases.

Polar bond

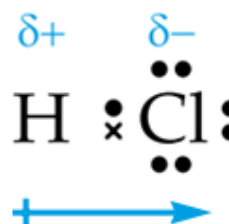
- A covalent bond is polar when the bonding electrons are not equally shared between the bonded atoms. This results when two bonded atoms have different electronegativities.

Non-polar bond



As both Cl atoms have the same electronegativity, Cl-Cl bond is a non-polar bond

Polar bond



As H and Cl have different electronegativities, H-Cl bond is a polar bond. Since Cl is more electronegative, the shared electrons are attracted more strongly towards Cl.

Note: If the electronegativity difference between 2 atoms are very large, ionic bond will be formed (Transfer of electron)

Polar molecule

Criteria of being a non-polar molecule (DSE syllabus only)

A. Molecules without polar bonds

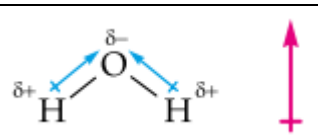
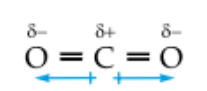
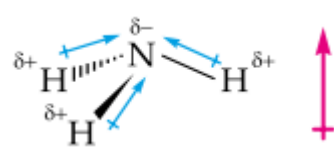
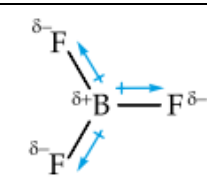
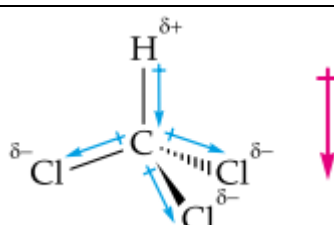
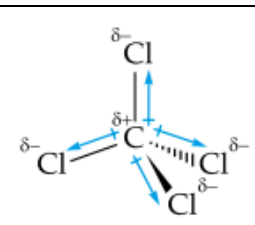

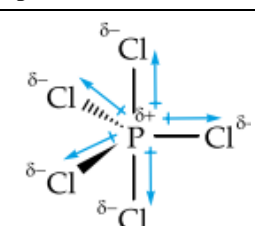
e.g. H₂, N₂, O₂, F₂, Cl₂, Br₂, I₂, P₄, S₈, Ne, Ar, He

B. Molecules with polar bonds but fulfilling the followings:

1. No lone pair of electrons on central atom
2. All polar bonds are the same

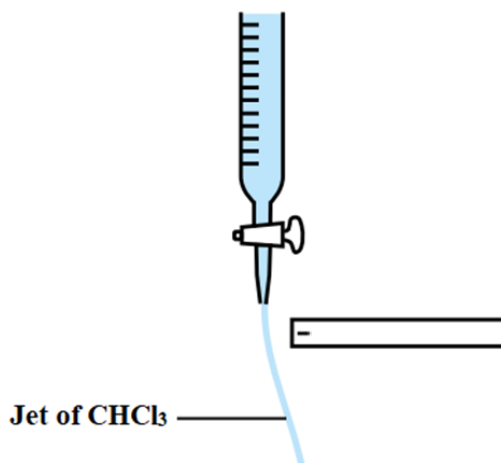
e.g. CO₂, BF₃, CH₄, PCl₅, SF₆

Intensive note (Topic 6: Microscopic world II)

Polar molecules	Non-polar molecules
	
Molecular shape of H ₂ O is V-shape Polar O-H bonds are not arranged symmetrically Polarities of polar O-H bonds cannot cancel out.	Molecular shape of CO ₂ is linear Polar C=O bonds are arranged symmetrically Polarities of polar C=O bonds can cancel out
	
Molecular shape of NH ₃ is trigonal pyramidal Polar N-H bonds are not arranged symmetrically Polarities of polar N-H bonds cannot cancel out.	Molecular shape of BF ₃ is trigonal planar Polar B-F bonds are arranged symmetrically Polarities of polar B-F bonds can cancel out
	
Molecular shape of CHCl ₃ is tetrahedral Polarities of polar C-H and C-Cl bonds are different Polarities of polar C-H and C-Cl bonds cannot cancel out	Molecular shape of CCl ₄ is tetrahedral Polar C-Cl bonds are arranged symmetrically Polarities of polar C-Cl bonds can cancel out
	
Each HF molecule has only one polar H-F bond.	Molecular shape of PCl ₅ is trigonal bipyramidal Polar P-Cl bonds are arranged symmetrically Polarities of polar P-Cl bonds can cancel out

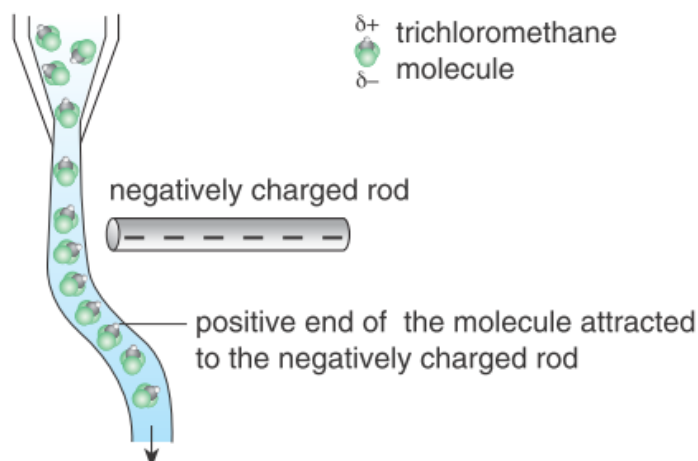
Charged rod experiment

A negatively charged rod is brought near a jet of water running out from a burette. The jet of CHCl_3 is deflected as shown:



- (a) With reference to the structure of CHCl_3 , explain why the jet of CHCl_3 was deflected.

Answer: Molecular shape of CHCl_3 is tetrahedral. Polarities of polar C-H and C-Cl bonds are different. Polarities of polar C-H and C-Cl bonds cannot cancel out. Hence, CHCl_3 molecules are polar and are attracted by the electric field.



- (b) State the effect on the jet if the negatively charged rod is replaced by a positively charged rod. Explain your answer

Answer: The jet of CHCl_3 will be attracted towards the rod. The CHCl_3 molecules will orientate themselves so that their negative ends are attracted to the positively charged rod.

- (c) If CCl_4 is used instead of CHCl_3 and a negatively charged rod is brought near the liquid jet, would the liquid jet be deflected? Explain your answer.

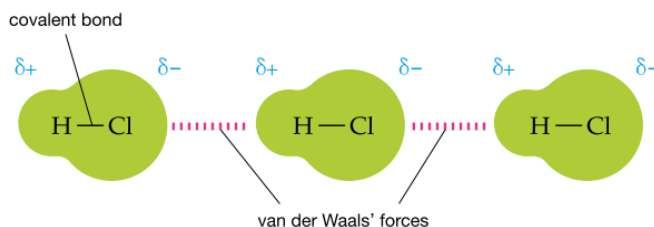
Answer: The jet of CCl_4 does not deflect. Molecular shape of CCl_4 is tetrahedral. Polar C-Cl bonds are arranged symmetrically. Polarities of polar C-Cl bonds can cancel out. CCl_4 molecules are non-polar and they are not attracted by the charged rod.

Van der Waals' forces

- An electrostatic attraction that exist between ALL molecules.

Van der Waals' forces in polar molecules

In a HCl molecule, uneven distribution of shared electrons is permanent as HCl is a polar molecule. The attraction between the positive end of a HCl molecule and the negative end of a HCl molecule belongs to one kind of van der Waals' forces

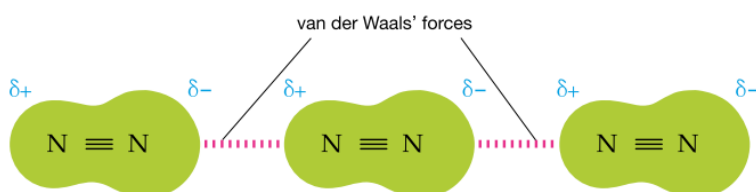


Van der Waals' forces in non-polar molecules

N_2 is a non-polar molecule. Electrons are in constant motion. At a given instant of time, the electron distribution may be uneven. The side with more electrons forms a partial negative charge ($\delta-$) and the side with fewer electrons forms a partial positive charge ($\delta+$). These charges are not permanent. They continue to arise and disappear all the time.



The partial charges on one molecule can affect the electron distribution in neighbouring molecules, inducing a separation of charge on the neighbouring molecules. The attraction between the positive end of a N_2 molecule and the negative end of a N_2 molecule belongs to another kind of van der Waals' forces



Factors affecting strength of van der Waals' forces

1. Molecular size

- When there are more electrons in a molecule, there is a higher chance of uneven distribution of electrons in the molecule
- The **larger the molecular size, the stronger is the van der Waals' forces** between molecules



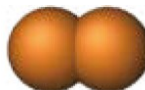
F₂

Boiling point = -188°C



Cl₂

Boiling point = -35°C



Br₂

Boiling point = 59°C



I₂

Boiling point = 184°C

2. Molecular shape (usually applicable to carbon compounds)



Pentane [CH₃CH₂CH₂CH₂CH₃]

Boiling point = 36.1 °C



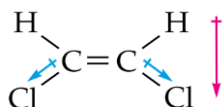
Dimethylpropane [CH₃C(CH₃)₂CH₃]

Boiling point = 9.5 °C

- Carbon atoms in pentane molecule are arranged in straight chain. Pentane is a rod-shaped molecule.
- Carbon atoms in dimethylpropane molecule are arranged in a branched chain. Dimethylpropane is a spherical molecule.
- Pentane has a **higher area of contact between molecules**. Van der Waals' forces between pentane molecules are **stronger**.

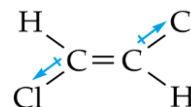
3. Molecular polarity (usually applicable to molecules with comparable sizes)

- Both cis-1,2-dichloroethene and trans-1,2-dichloroethene have 2 polar C-Cl bonds. Since the C-H bonds have a very low polarity, the molecular polarity is mainly determined by the polarity of the C-Cl bonds.



Cis-1,2-dichloroethene

Boiling point = 60.1 °C



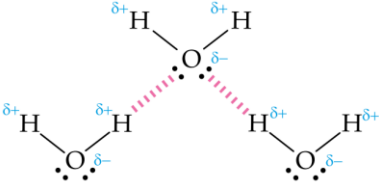
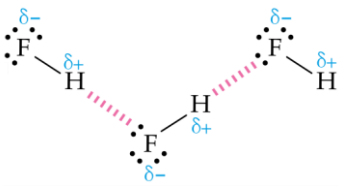
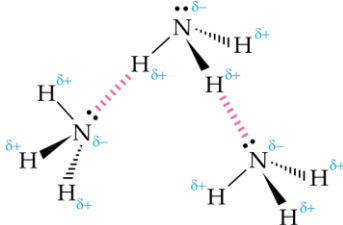
Trans-1,2-dichloroethene

Boiling point = 48.7 °C

- The two polar C-Cl bonds in the cis-1,2-dichloroethene have same polarities and are on the same side of the double bond. As the polarities of these two polar bonds do not cancel out each other, the cis-1,2-dichloroethene molecule is polar.
- The two polar C-Cl bonds in the trans-1,2-dichloroethene have same polarities but are on the opposite sides of the double bond. As the polarities of these two polar bonds cancel out each other, the trans-1,2-dichloroethene molecule is non-polar.
- The van der Waals' forces between **polar** cis-1,2-dichloroethene molecules are **stronger** than those between **non-polar** trans-1,2-dichloroethene molecules.

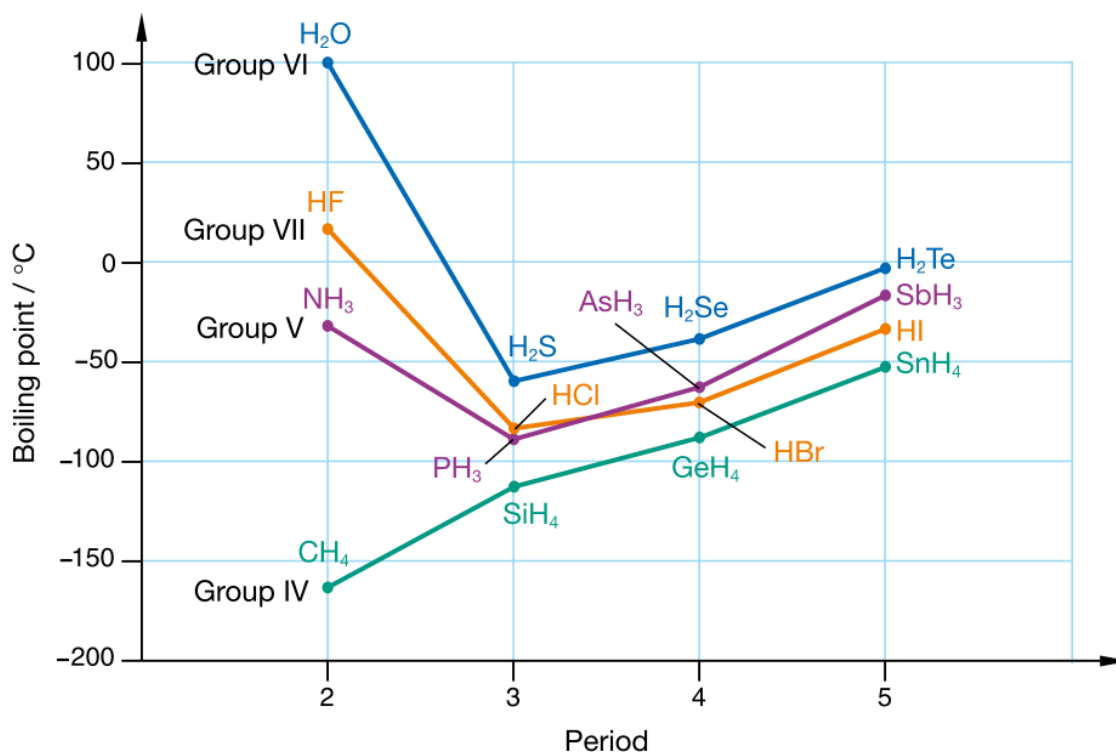
Hydrogen bonds

- When a H atom is bonded to a highly electronegative atom (e.g. N, O, F), a highly polar bond forms.
- Hydrogen bonding forms between the H atom bonded to N / O / F and the lone pair electrons of N / O / F

		
<p>In each H₂O molecule, there are 2 lone pair electrons on O and 2 O-H bonds. Each H₂O molecule can form 2 hydrogen bonds on average</p>	<p>In each HF molecule, there are 3 lone pair electrons on F and 1 F-H bonds. Each HF molecule can form 1 hydrogen bonds on average</p>	<p>In each NH₃ molecule, there are 1 lone pair electron on N and 3 N-H bonds. Each NH₃ molecule can form 1 hydrogen bonds on average</p>

Note: van der Waals' forces also exist between molecule of H₂O, HF and NH₃

Boiling points of hydrides



Explanation on the ascending order of boiling points of HF, HCl and HBr:

- Both molecules of HCl and HBr are held by weak van der Waals' forces.
- The molecular size of HBr is larger than that of HCl, therefore the van der Waals' forces between HBr molecules are stronger than those between HCl molecules
- Stronger hydrogen bonds exist between HF molecules

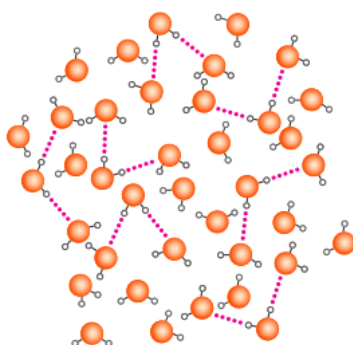
Effect of hydrogen bonding on physical properties of water and ethanol

Water	Ethanol
1. High boiling point - Extensive hydrogen bonds between water molecules	1. High boiling point - Extensive hydrogen bonds between ethanol molecules
2. High viscosity [liquid flows slowly] - Extensive hydrogen bonds between water molecules	2. High viscosity [liquid flows slowly] - Extensive hydrogen bonds between ethanol molecules - Less viscous than water
3. High surface tension [Liquid surface to be tightened like an elastic film] - Extensive hydrogen bonds between water molecules	3. Soluble in water - Hydroxyl group (-OH) of ethanol can form hydrogen bonds with water molecules

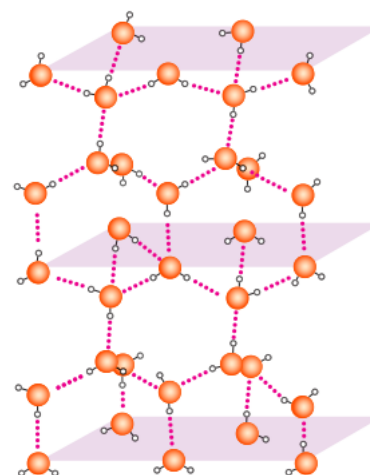
Density of ice and water

- H₂O molecules are mainly held by strong hydrogen bonds
- In ice, water molecules are arranged tetrahedrally in an open structure because of the extensive hydrogen bonding between them. Thus, they take up a larger volume.
- When ice melts, the water molecules have relative motion and the open structure collapses. The water molecules become more closely packed and they take up a smaller volume.

key: ● oxygen atom
○ hydrogen atom
⋯ hydrogen bond



Arrangement of H₂O molecules in water



Arrangement of H₂O molecules in ice