♦ Chemical Bonding

I. TYPES OF BONDING

Metallic bonding : Li vs Na

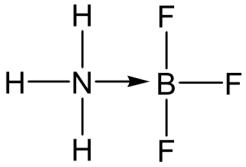
Both Li and Na have a giant metallic lattice structure.
Both contribute 1 valence electron per atom to their sea of delocalised electrons.
Li^+ ion has a smaller ionic radius than Na^+ ion.
Hence, Li^+ ions have a stronger attraction for the sea of delocalised electrons. More energy is needed to break the stronger metallic bonds in Li, thus Li has a higher melting point.

Ionic bonding : NaCl vs MgO

Both NaCl and MgO are ionic compounds with a giant ionic lattice structure.
Mg^{2+} and O^{2-} are doubly charged while Na^+ and Cl^- are singly charged. The product of charges in MgO is greater than in NaCl.
The interionic distance in MgO is shorter than that of NaCl.
By
$|\text{L.E.}| \propto |\frac{q_+ \times q_-}{r_+ + r_-}|$Hence, the magnitude of lattice energy of MgO is greater than that of NaCl, and the ionic bond in MgO is stronger.

Dative bonding : NH_3 donating to BF_3

NH_3 has a lone pair of electrons on the nitrogen atom that is readily available to be donated, hence it is a donor atom.
BF_3 has a low-lying vacant p orbital and can readily accept a lone pair of electrons, hence it is an acceptor atom.
NH_3 will donate its lone pair to BF_3, forming a dative bond.



Effectiveness of orbital overlap : Cl_2 vs Br_2

Bromine has a larger orbital than chlorine. Larger orbitals are more diffused.
The effectiveness of orbital overlap in Br_2 is less effective than in Cl_2. Hence, the covalent bond in Cl_2 is stronger.

Covalent character in ionic compounds : Why $AlCl_3$ is covalent

Al^{3+} has a high charge/size ratio. Hence, it has high polarising power. Al^{3+} will distort and polarise the electron cloud of Cl^-. This causes $AlCl_3$ to have covalent character.

II. SHAPES OF MOLECULES (VSEPR)

The 2 laws of VSEPR theory

(1) The electron regions around the central atom will arrange themselves as far apart as possible to minimise mutual repulsion.
(2) lp–lp > bp–lp > bp–bp repulsion.

Answering shape questions: Framework

State the number of electron regions, bond pairs, and lone pairs around the central atom for each molecule.
Apply law (1) if number of electron regions are **DIFFERENT**
Apply law(1) **AND** law(2) if number of electron regions are the **SAME**

Answering shape questions: NH_3 vs CH_4

NH_3 has 3 bond pairs and 1 lone pair around the central atom N.
CH_4 has 4 bond pairs, 0 lone pairs around central atom C.
By VSEPR theory **[STATE BOTH LAW(1) AND LAW(2)]**
Hence, NH_3 has a trigonal pyramidal shape with a bond angle of 107 with respect to the central atom N while CH_4 has a tetrahedral shape and a bond angle of 109.5 with respect to the central atom C.

Effect of electronegativity on bond angle: CH_4 vs CCl_4

Both CH_4 and CCl_4 have 4 bond pairs, 0 lone pairs around central atom C.
However, Cl is more electronegative than H. Hence, Cl attracts the bonding pair of electrons away from the central atom to a greater extent.
This results in less bp–bp repulsion in CCl_4 compared to CH_4.
CCl_4 has a smaller bond angle than CH_4.

III. INTERMOLECULAR FORCES

How id-id interactions are formed

Id-id interactions are formed due to the constant motion of electrons.
There is a temporary shift of electrons to one side of the atom, resulting in an induced dipole which induces a similar dipole in an adjacent atom, forming id-id interactions.

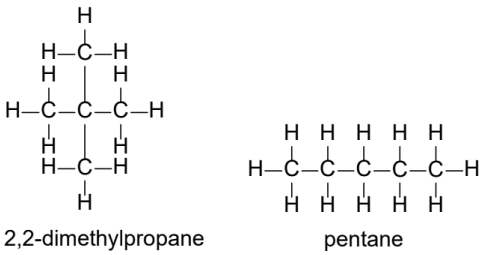
How pd-pd interactions are formed

Pd-pd interactions arise due to the overall net dipole moment of the molecule. Electronegativity differences between bonds create bond dipoles that do not cancel out completely, resulting in a net dipole moment. This results in pd-pd interactions.

Comparing mp/bp: different number of electrons, non-polar : I_2 vs CH_4

Both CH_4 and I_2 are covalent compounds with a simple molecular structure.
They are both non-polar and form only id-id interactions between the molecules.
I_2 has more electrons and hence a larger electron cloud. A larger electron cloud is more easily polarised, dipoles are more easily induced and I_2 forms stronger id-id interactions between the molecules.
More energy is required to overcome the id-id interactions in I_2 than in CH_4.

Comparing mp/bp: same electrons, different shape : pentane vs 2,2-dimethylpropane



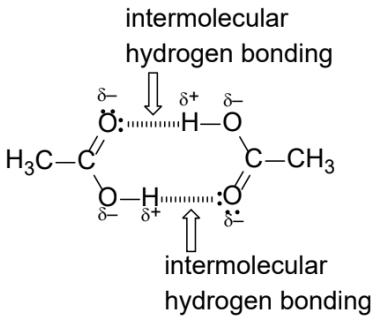
Both pentane and 2,2-dimethylpropane are covalent compounds with a simple molecular structure.
Both are non-polar and only form id-id interactions between the molecules.
They are both isomers with the same number of electrons and hence the same electron cloud size.
Pentane has a larger surface area of contact between its molecules as compared to 2,2-dimethylpropane.
Dipoles are more easily induced in pentane and more energy is required to overcome the stronger id-id interactions in pentane.

Comparing mp/bp: hydrogen bonding : H_2O vs HF

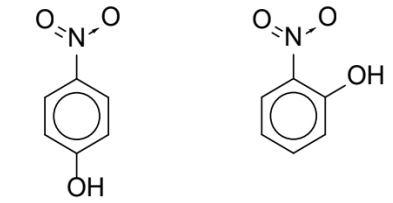
H_2O and HF are covalent compounds with a simple molecular structure.
They are both polar and form id-id, and additional hydrogen bonding.
H_2O forms an average of 2 hydrogen bonds per molecule while HF forms only 1.
Hence, more energy is required to overcome the more extensive hydrogen bonding in H_2O than in HF.
Number of hydrogen bonds is the **MINIMUM** of…
1) Number of protonic H
2) Number of lone pair of electrons on O,N,F

Dimerisation via hydrogen bonding : ethanoic acid

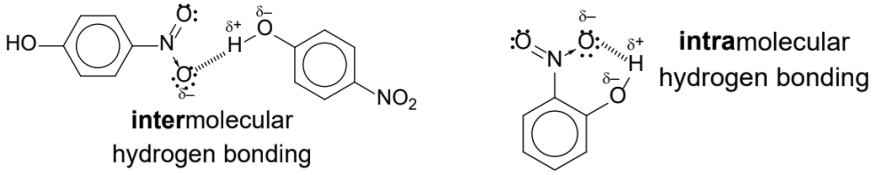
Each ethanoic acid molecule has a lone pair of electrons on the C=O group and a $\delta+$ H on the O-H group. Two ethanoic acid molecules form two intermolecular hydrogen bonds between their C=O and O-H groups, forming a cyclic dimer.
This results in the doubling of the molecular mass in gaseous state.



Intramolecular H bonding effect on boiling point : 2-nitrophenol vs 4-nitrophenol



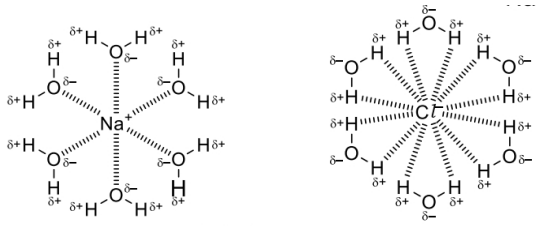
Due to the close proximity of the NO_2 and OH groups, 2-nitrophenol forms intramolecular hydrogen bonds. However, 4-nitrophenol forms only intermolecular hydrogen bonding. Less sites on 2-nitrophenol are available for intermolecular hydrogen bonding. More energy is required to overcome the intermolecular hydrogen bonding in 4-nitrophenol, resulting in it having a higher boiling point.



IV. SOLUBILITY

Ionic compound in water : NaCl

When NaCl is added to water, Na^+ and Cl^- form ion-dipole interactions with water. The energy released in the formation of ion-dipole interactions is sufficient to overcome the hydrogen bonding in H_2O and the strong ionic bonds in NaCl. Thus, NaCl is soluble in water.



Solubility of ethanol in $CHCl_3$

Ethanol : id-id interactions , pd-pd interactions , Hydrogen Bonding
$CHCl_3$: id-id interactions , pd-pd interactions
Take the common + strongest interaction
The energy released in the formation of **pd-pd interactions** between ethanol and $CHCl_3$ is sufficient to overcome the pd-pd interactions between ethanol molecules and between $CHCl_3$ molecules. Ethanol is soluble in $CHCl_3$.

Solubility of ethanol in H_2O

Ethanol : id-id interactions , pd-pd interactions , Hydrogen Bonding
H_2O : id-id interactions , pd-pd interactions , Hydrogen Bonding
Take the common + strongest interaction
The energy released in the formation of hydrogen bonding between ethanol and water is sufficient to overcome the pd-pd interactions between ethanol molecules and the hydrogen bonding between H_2O molecules. Ethanol is soluble in H_2O.