Higher Chemistry: Unit 1 – Chemical Changes and Structure

Part B – Bonding, Structure and Properties

Lesson 5 – Van der Waals Forces: Pd-Pd and H Bonds

Learning Outcomes

By the end of this lesson you should know:

1. How permanent dipole to permanent dipole interactions arise.
2. How hydrogen bonds arise.
3. How to identify whether a molecule will display Pd-Pd interactions, H bonds, or neither.

Success Criteria

You will have been successful in this lesson if you:

1. Watch Ms Hastie's screencast of today's lesson
2. Read and learn the material given
3. Watch the links provided
4. Complete Exercise 1.9 and check your answers.

There is also a further reading section to help you gain more depth of understanding for this section.

MS Teams will be monitored throughout the week by a chemistry teacher. If you need help or clarification with either the task or the content of the lesson, just ask.

Links to Prior Knowledge

You may wish to revise the following to help you understand this lesson:

- Higher Chemistry – Polarity in molecules

- Data booklet https://www.sqa.org.uk/sqa/files_ccc/ChemistryDataBooklet_NewH_AH-Sep2016.pdf

Introduction - You don't need to write this part down, just read it, or watch Ms Hastie's lesson below…

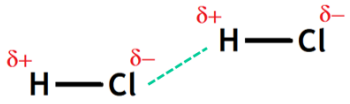
WATCH – Ms Hastie's screencast of this lesson: Pd-Pds and H bonds

Moving on from the last lesson, which focused on the weakest Van der Waals force, London Dispersion Forces (LDFs), this lesson will focus other important Van der Waals forces:

2. Permanent Dipole to Permanent dipole interactions (Pd-Pd Interactions)

3. Hydrogen bonds (H bonds)

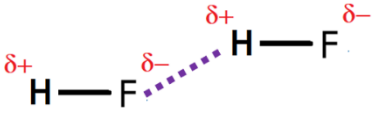
In a previous lesson, we learned about polar molecules. Polar molecules have permanent dipoles, ie one end of the molecule is slightly positive (δ+) and the other end is slightly negative (δ-). When two polar molecules are near each other there is an attraction between the negative end of one of the molecules and positive end of the other.



This called a **permanent dipole to permanent dipole interaction** and is stronger than LDFs.

Some polar molecules contain highly polar bonds. Specifically, molecules that contain either N-H, O-H or F-H bonds. The extreme polarity of these bonds, means that the Pd-Pd interactions are stronger than normal.

These molecules display a special type of Pd-Pd interaction called **hydrogen bonds**.



Hydrogen bonds are incredibly important in nature, they hold proteins and DNA in the correct shape and cause ice to float on water.

More than one kind of Van der Waals

It is important to understand that covalent molecular substances can display more than one Van der Waals force at the same time. ALL substances have LDFs, but some substances also have Pd-Pd interactions or H bonds.

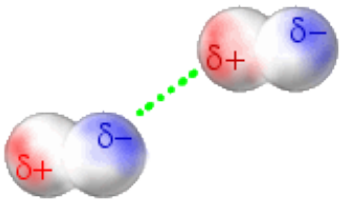
Non-polar molecules and monatomic substances display only LDFs and therefore have very low melting and boiling points. Polar molecules display Pd-Pds and those with N-H O-H or F-H bonds display hydrogen bonding.

When more than one Van der Waals force exists, we tend to focus on the strongest force because it is the strongest forces that determine the physical properties of a substance, eg melting and boiling points.

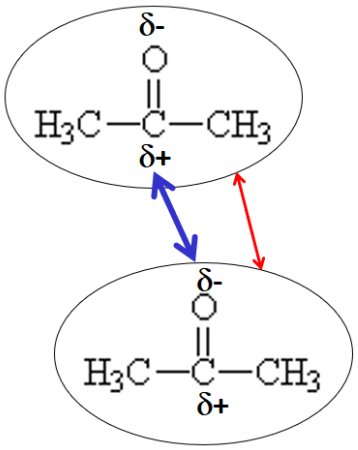
Notes - Below is the summary you should write/ save / print a stick into your notes

2. Permanent Dipole- Permanent Dipole Interactions

Permanent dipole to permanent dipole interactions are forces of attractions **between polar covalent molecules.**



e.g. propanone



↔ Permanent dipole to permanent dipole interactions

↔ LDFs

Pd-pd interactions are **Stronger than London dispersion forces**

Pd-Pd interactions arise due to the permanent dipole caused by the difference in electronegativity between atoms in polar molecule.

3. Hydrogen Bonds

Hydrogen bonds are special permanent dipole interactions which only exist between molecules that contain one or more of the following bonds:

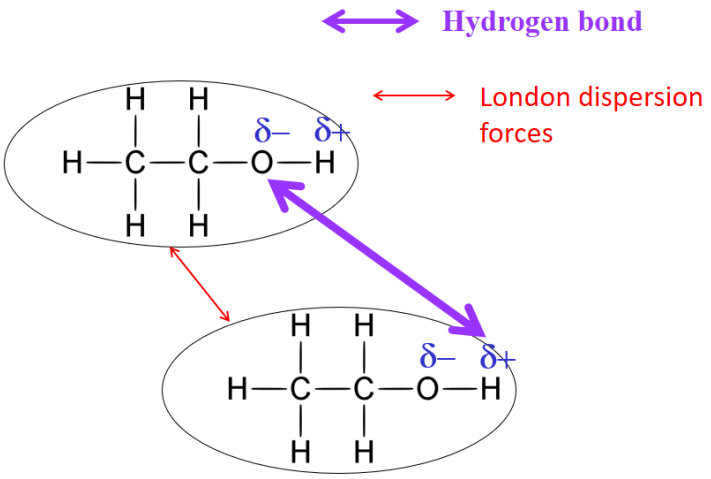
- Nitrogen (N-H)
- Oxygen (O-H)
- Fluorine (F-H)

} HIGHLY POLAR

These bonds are highly polar due to the large difference in electronegativity between the two atoms.

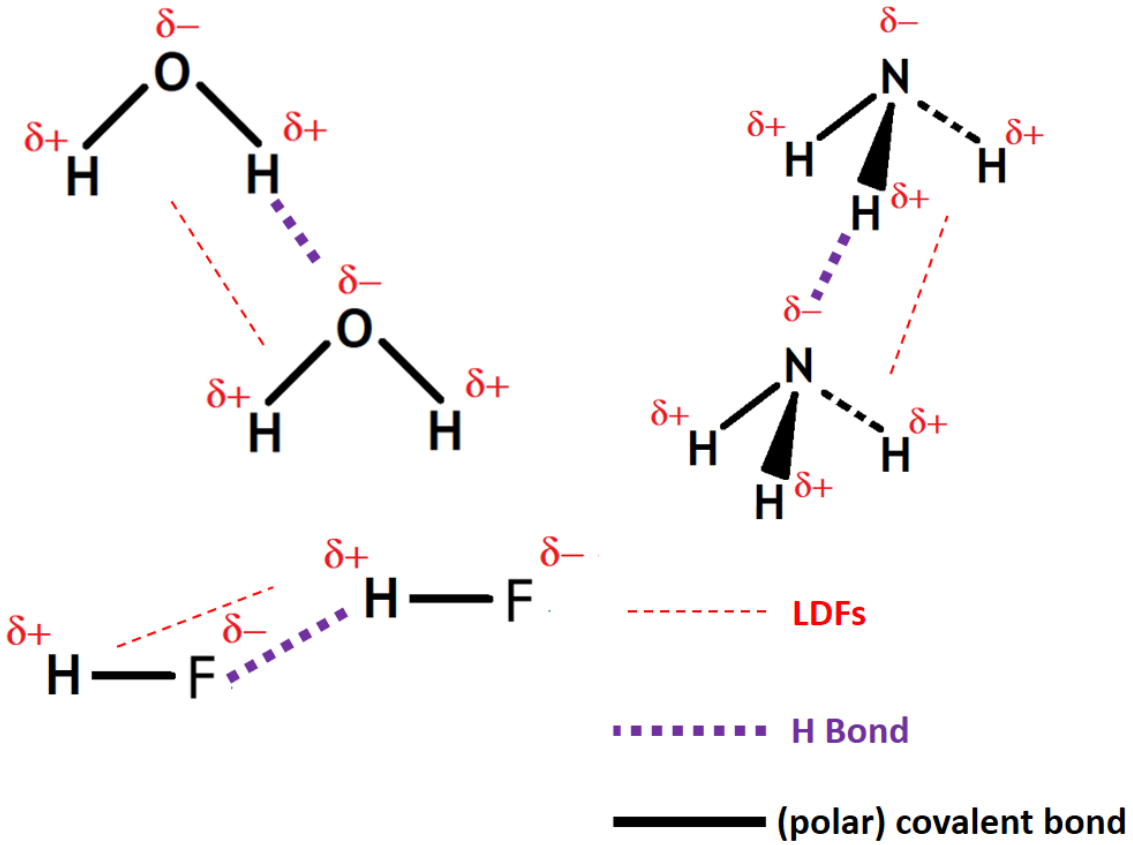
H bonds are the stronger than regular Pd-Pd interactions.

Below are some common molecules that contain hydrogen bonds.



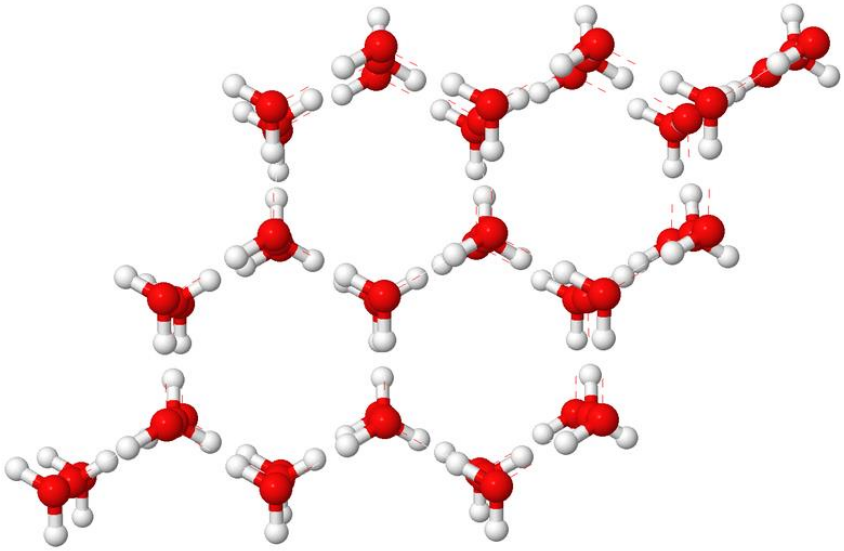
Remember that H bond is the bond between the molecules

- **not** the N-H, O-H or F-H bond.



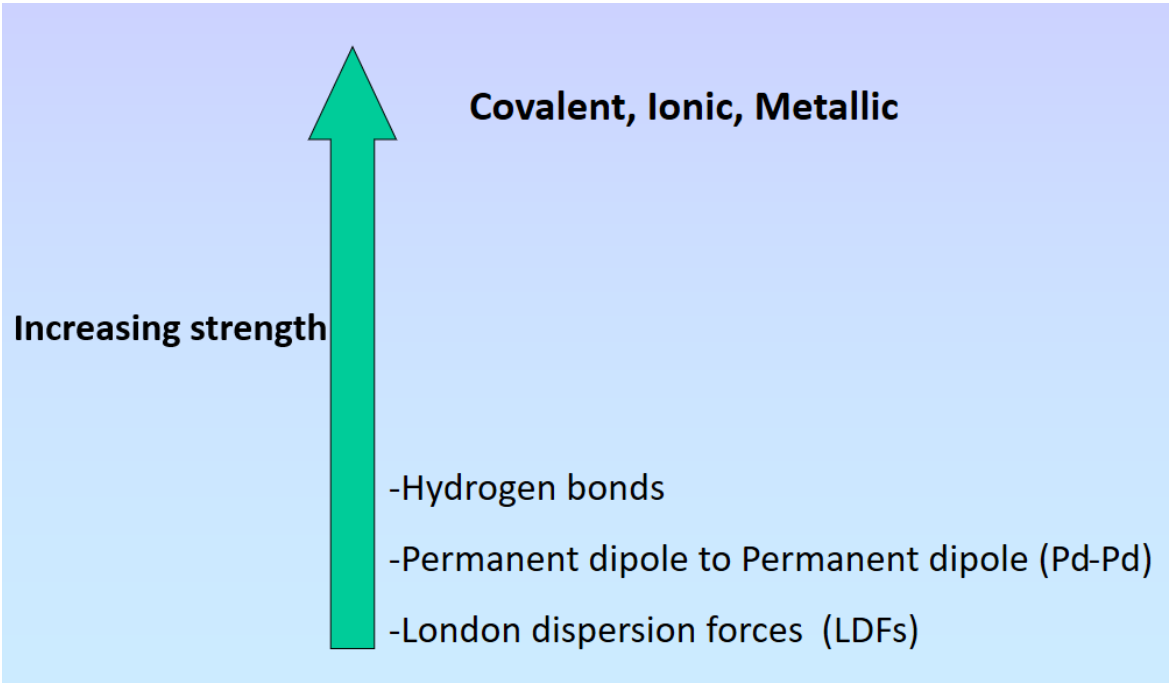
Density of Ice

When water changes to ice it becomes less dense as the molecules produce an open, expanded structure due to the presence of hydrogen bonds.



Bond Strengths

Although hydrogen bonds are the strongest Van der Waals force, there are still much weaker than ionic, covalent or metallic bonds.



More than one kind of Van der Waals

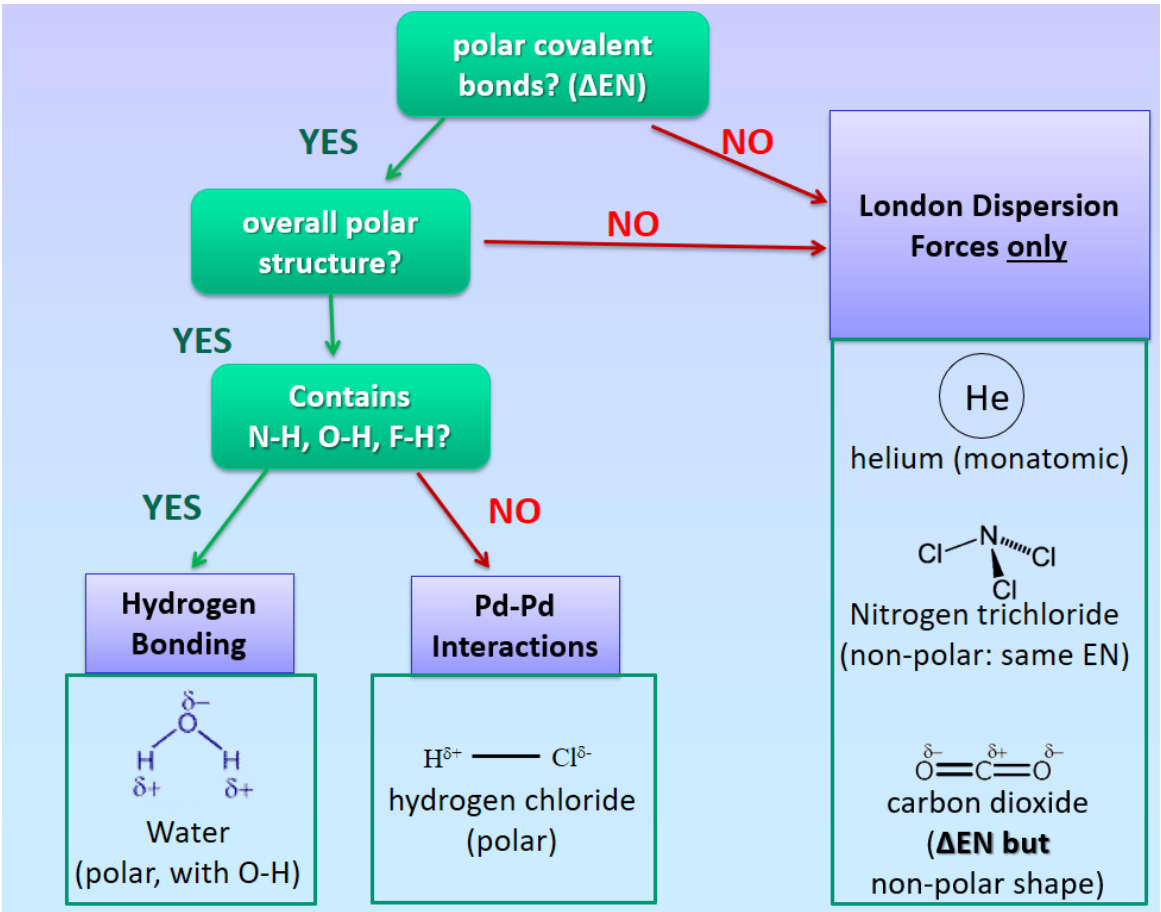
ALL substances display LDFs

Non-polar and monatomic substances display **LDFs only**

Polar molecules display **Pd-Pd interactions** (and LDFs)

Polar molecules that contain N-H, F-H or O-H display **hydrogen bonds** (and LDFs)

SUMMARY

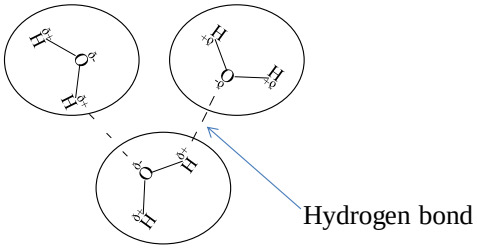


Learning Outcomes

You should now know:

1. Permanent dipole-permanent dipole interactions occur between polar molecules and are stronger than London dispersion forces for molecules with similar numbers of electrons.

2. Hydrogen bonding occurs between molecules where there is an atom of H bonded to an atom of a strongly electronegative element such as N, O or F. e.g. water.



3. Hydrogen bonding is the strongest type of intermolecular force but note that it is still weaker than a covalent bond.

4. Hydrogen bonding between molecules in ice results in an expanded structure that causes the density of ice to be less than that of water at low temperatures.

5. LDFs are the only intermolecular force present in non-polar molecules or monatomic gases.

Further Reading

To learn more about the bonding continuum. Follow the links below:

BBC Bitesize: https://www.bbc.co.uk/bitesize/guides/zt9887h

Read page 6 & 10

Evans2 chem web: https://www.evans2chemweb.co.uk/login/index.php#

Username: snhs password: giffnock

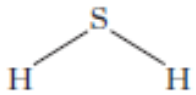
Select any teacher → revision material → CfE Higher → Structure and Bonding

Questions

Complete Exercise 1.9 and check your answers

Exercise 1.9 – Pd-Pd Interactions and H Bonds

1. Hydrogen sulfide (shown opposite) displays two types of Van der Waals forces, namely, London Dispersion Forces and Permanent Dipole to Permanent Dipole Interactions.



Explain how Permanent Dipole to Permanent Dipole Interactions arise in hydrogen sulfide.

2. A pupil compared the boiling points of alcohols and alkanes to examine the influence of hydrogen bonding on intermolecular forces.

(a) Why do the boiling points of the alkanes increase as we move from methane to pentane?

(b) Which of the homologous series mentioned above displays hydrogen bonding? Explain how this arises.

3. Whilst methane (CH_4) and ammonia (NH_3) both contain polar bonds, the methane molecule is non-polar and the ammonia molecule is polar.

(a) (i) Draw diagrams showing the molecular shape of methane and ammonia.
(ii) Explain using the diagrams why methane is a non-polar molecule and ammonia is a polar molecule.

(b) Name the strongest type of Van der Waals present in each molecule.

4. Hydrogen bromide and hydrogen fluoride are two diatomic polar molecules.

(a) Draw both molecules, using δ+ and δ- to show the polarity in the bonds.

(b) Name the strongest type of Van der Waals forces in hydrogen bromide.

(c) Explain why HF contains hydrogen bonding.

5.(a) What effect does hydrogen bonding have on the density of ice?

(b) Describe a simple experiment that could be carried out to show the effect that hydrogen bonding has on the density of ice.

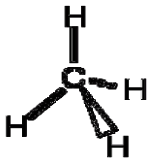
Exercise 1.9 – ANSWERS

1. Pd-Pd interactions arise in hydrogen sulfide because it has a permanent dipole caused by the difference in electronegativity between the sulfur and hydrogen atoms.

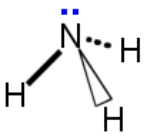
2. (a) An increase in numbers of electrons results in an increase in the strength of London dispersion forces between the molecules.

(b) The alcohols display hydrogen bonds, as they contain an O-H bond.

3. (a)(i)



methane



ammonia

(ii) Although both molecules have polar bonds the tetrahedral shape of methane results in a non-polar structure.

(b) Methane has only LDFs and ammonia has hydrogen bonds.

4. (a) $\delta+ \quad \delta-$ *H-Br* $\qquad \delta+ \quad \delta-$ *H-F*

(b) Pd-Pd interactions.

(c) Hydrogen fluoride contains an H-F bond which is highly polar due to the large difference in electronegativity between fluorine (4.0) and hydrogen (2.2). This results in the formation of hydrogen bonds.

5. (a) Hydrogen bonding causes water to form an open-expanded structure, which decreases the density of solid ice. (Hence why ice floats on water).

(b) Drop ice(solid) in water(liquid) and it will float.