A-LEVEL CHEMISTRY • EXERCISE SHEET

3.6 Intermolecular forces, electronegativity and bond properties

Name: _____ Class: _____ Date: _____ **Total: 12 marks**

Objective

Build the skills to answer exam questions on **intermolecular forces** —**bond polarity** 键极性 and dipoles, **van der Waals' forces** 范德华力, **hydrogen bonding** 氢键, and the anomalous properties of water.

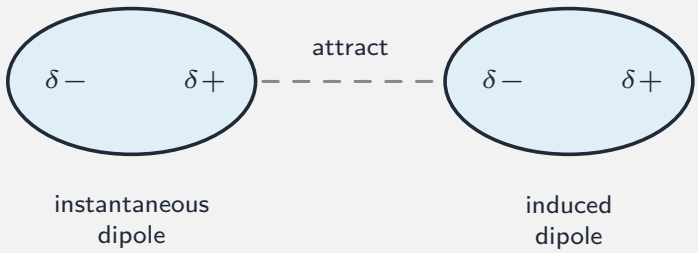
You must be able to:

- explain bond polarity and dipole moments using electronegativity
- describe London (id–id) and permanent dipole (pd–pd) forces, and hydrogen bonding
- use hydrogen bonding to explain the anomalous properties of water

1 Worked examples

Polarity and van der Waals' forces

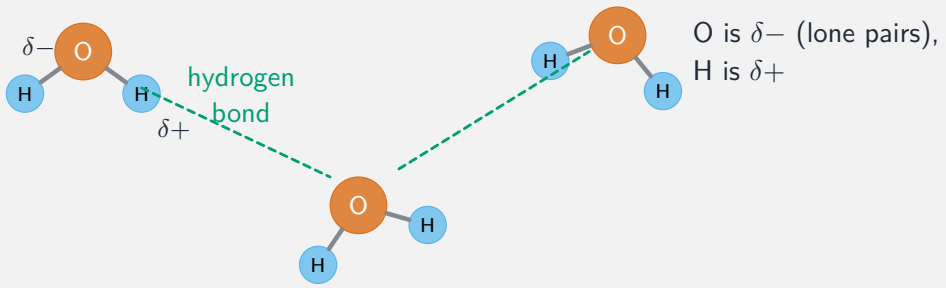
A bond between atoms of different electronegativity has a **dipole** 偶极 ($\delta-$ / $\delta+$). If the dipoles do not cancel, the molecule is **polar**. **Van der Waals' forces** is the general term for all intermolecular forces.



London (id–id) force: a momentary dipole induces one in a neighbour —acts between all molecules, stronger with more electrons

- **London (id–id)** force —acts between all molecules; stronger when there are more electrons.
- **permanent dipole (pd–pd)** force —between always-polar molecules.

Hydrogen bonding and water



Hydrogen bonding: a δ+ H (bonded to N, O or F) is attracted to a lone pair on a δ− N, O or F

Hydrogen bonding (a strong pd–pd case) explains water's anomalies: high melting/boiling point (many H-bonds to break); high surface tension; and **ice is less dense** than water (H-bonds hold an open structure), so ice floats.

2 Practice

2.1 Name the **two** atoms (besides hydrogen) that must be present for hydrogen bonding in water and ammonia. [2]

2.2 State which intermolecular force acts between all molecules. [1]

3 Exam-style questions

3.1 Why does ice float on water? [1]

- **A** ice is warmer
- **B** hydrogen bonds hold ice in an open structure, so it is less dense
- **C** ice has no hydrogen bonds
- **D** ice contains air

3.2 Which has the **strongest** intermolecular forces? [1]

- **A** CH
- **B** Cl
- **C** H O
- **D** O

3.3 (a) Explain why water has a relatively high boiling point. [2]

(b) Explain why the boiling points of the noble gases increase down the group. [2]

3.4 Draw and label a diagram to show hydrogen bonding between two water molecules (show the δ charges and the lone pair). [3]

4 Go further

You are now ready for the real exam questions on this subtopic. Open the **3.6 Intermolecular forces** past-paper sheet in the Library, or try these in **Practice mode**:

- 9701/14 N25 —Q7 (intermolecular forces)
- 9701/22 N25 —Q3 (bonding and forces, structured)

Solutions

2.1 nitrogen, oxygen (and fluorine).

2.2 the London dispersion / instantaneous dipole–induced dipole force.

3.1 B. Hydrogen bonds hold ice in an open lattice, making it less dense than water.

3.2 C. Water has hydrogen bonding, the strongest of the four.

3.3 (a) water molecules are held by hydrogen bonds; much energy is needed to break these, so the boiling point is high.
(b) down the group atoms have more electrons, so stronger London forces, needing more energy to overcome —higher boiling points.

3.4 a dashed hydrogen bond from a $\delta+$ H on one molecule to a lone pair on the $\delta-$ O of the other; both molecules drawn with $\delta+$ on H and $\delta-$ on O; a clear lone pair shown on the accepting oxygen.