Exercise walk-through

Intermolecular forces, electronegativity and bond properties ▪ 3.6

eXercise

You must be able to

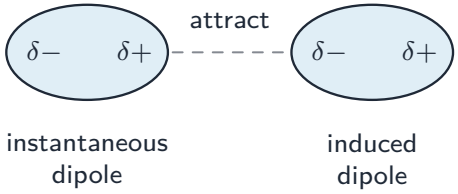
- explain bond polarity and dipole moments using electronegativity
- describe London (id–id) and permanent dipole (pd–pd) forces, and hydrogen bonding
- use hydrogen bonding to explain the anomalous properties of water

Method — 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

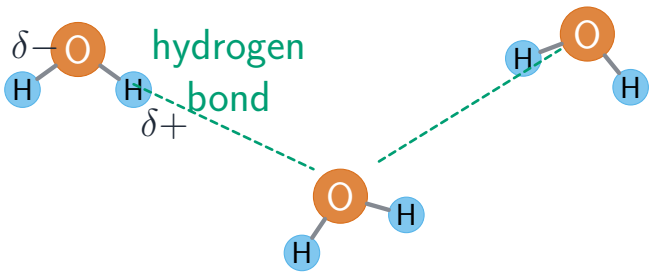
- **London (id–id)** force — acts between all molecules; stronger when there are more electrons.
- **permanent dipole (pd–pd)** force



Method — Hydrogen bonding and water

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.

Method — Hydrogen bonding and water



O is $\delta-$ (lone pairs),
H is $\delta+$

Three water molecules linked by dashed hydrogen bonds from $\delta+$ H to $\delta-$ O

Practice 2.1 ▪ 2 marks

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

Solution 2.1

Method: Hydrogen bonding and water

Worked steps

nitrogen, oxygen (and fluorine) B1 *for two correct.*

Practice 2.2 ▪ 1 mark

State which intermolecular force acts between all molecules.

Solution 2.2

Method: Polarity and van der Waals' forces

Worked steps

the London dispersion / instantaneous dipole–induced dipole force B1.

Exam-style 3.1 ▪ 1 mark

Why does ice float on water?

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

Solution 3.1

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

Worked steps

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

Exam-style 3.2 ▪ 1 mark

Which has the **strongest** intermolecular forces?

A CH

B Cl

C H O

D O

Solution 3.2

Method: Polarity and van der Waals' forces

A CH

B Cl

C H O ✓

D O

Worked steps

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

Exam-style 3.3 ▪ 2 marks

(a) Explain why water has a relatively high boiling point.
(b) Explain why the boiling points of the noble gases increase down the group.

Solution 3.3

Method: Hydrogen bonding and water

Worked steps

(a) water molecules are held by hydrogen bonds **M1**; much energy is needed to break these, so the boiling point is high **A1**.
(b) down the group atoms have more electrons **M1**, so stronger London forces, needing more energy to overcome — higher boiling points **A1**.

Exam-style 3.4 ▪ 3 marks

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

Solution 3.4

Method: Hydrogen bonding and water

Worked steps

a dashed hydrogen bond from a $\delta+$ H on one molecule to a lone pair on the $\delta-$ O of the other **B1**; both molecules drawn with $\delta+$ on H and $\delta-$ on O **B1**; a clear lone pair shown on the accepting oxygen **B1**.