MEGA LECTURE · A LEVEL CHEMISTRY

Chapter 6: Intermolecular Forces, Structures and Properties

OCR A Level Chemistry A (H432) — Structured Practice Worksheet

SPECIFICATION	TOTAL MARKS	SUGGESTED TIME
Van der Waals, dipole–dipole & hydrogen bonding · Giant structures · Physical properties	89	2 hours

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Instructions to candidates

- Answer **all** questions in the spaces provided.
- Where a diagram is requested, show partial charges (δ+/δ−) and any dotted lines representing intermolecular forces.
- Marks are shown in brackets [ ] at the end of each part.

Question 1 — Types of intermolecular force

2.1.4

a. Name the three types of intermolecular force studied at A Level and state which is generally the weakest and which is generally the strongest. **[3]**

b. Explain, in terms of electron movement, how instantaneous dipole–induced dipole (van der Waals) forces arise between two argon atoms. **[3]**

c. State two factors that increase the strength of van der Waals forces between molecules. **[2]**

d. Explain why permanent dipole–dipole forces only occur between polar molecules. **[2]**

Question 1 total: 10 marks

Question 2 — Boiling points of the halogens and noble gases 2.1.4

Boiling points: F_2 = −188 °C, Cl_2 = −34 °C, Br_2 = 59 °C, I_2 = 184 °C.

a. Explain the increase in boiling point down Group 7, referring to the number of electrons and the strength of intermolecular forces. **[4]**

b. Explain why, to boil liquid bromine, only the intermolecular forces need to be overcome, not the covalent Br–Br bond. **[2]**

c. Explain why the boiling point of neon is lower than that of argon. **[3]**

Question 2 total: 9 marks

Question 3 — Hydrogen bonding 2.1.4

a. State the two structural conditions necessary for hydrogen bonding to occur between molecules. **[3]**

b. Draw a diagram showing hydrogen bonding between two water molecules. Show all relevant lone pairs, partial charges and the hydrogen bond itself. **[3]**

Draw two H_2O molecules hydrogen bonded together

c. The boiling point of NH_3 (−33 °C) is much higher than that of PH_3 (−88 °C), even though both are Group 15 hydrides of similar molecular mass. Explain this difference. **[4]**

d. Explain why ice is less dense than liquid water, in terms of hydrogen bonding. **[3]**

Question 3 total: 13 marks

Question 4 — Solubility 2.1.4

a. Explain why ethanol, CH_3CH_2OH, is completely miscible with water. **[3]**

b. Explain why long-chain alcohols, such as octan-1-ol, are much less soluble in water than ethanol. **[2]**

c. Explain why iodine is much more soluble in hexane than in water. **[2]**

Question 4 total: 7 marks

Question 5 — Giant covalent (macromolecular) structures 2.1.4

a. Describe the structure and bonding in diamond, and explain why diamond has a very high melting point. **[3]**

b. Describe the structure and bonding in graphite. Explain why graphite conducts electricity but diamond does not. **[4]**

c. Explain why graphite is soft and slippery, making it useful as a lubricant. **[2]**

d. Silicon dioxide, SiO_2, has a giant covalent structure similar to diamond. State one physical property you would predict for SiO_2 and justify your answer. **[2]**

Question 5 total: 11 marks

Question 6 — Comparing structures: melting points 2.1.4

Melting points: NaCl = 801 °C, SiO_2 = 1710 °C, Cl_2 = −101 °C, Fe = 1538 °C.

a. For each substance, identify the structure type (giant ionic, giant covalent, giant metallic, or simple molecular) and the particles present. **[8]**

Substance	Structure type	Particles present
NaCl		
SiO_2		
Cl_2		
Fe		

b. Explain why SiO_2 has a much higher melting point than NaCl. **[4]**

c. Explain why Cl_2 has a much lower melting point than all three other substances. **[3]**

Question 6 total: 15 marks

Question 7 — Predicting and explaining trends 2.1.4

a. The boiling points of the straight-chain alkanes increase steadily from methane to decane. Explain this trend. **[4]**

b. Branched alkanes have lower boiling points than their straight-chain isomers of the same molecular formula (e.g. 2,2-dimethylpropane compared with pentane). Explain why. **[3]**

c. Butan-1-ol has a considerably higher boiling point than butane, despite having a similar relative molecular mass. Explain why. **[3]**

Question 7 total: 10 marks

Question 8 — Practical and applied contexts 2.1.4

a. DNA base pairs (adenine–thymine and guanine–cytosine) are held together by hydrogen bonds. Suggest why hydrogen bonding, rather than covalent bonding, is important for DNA's biological function. **[3]**

b. Explain, in terms of intermolecular forces, why propan-1-ol evaporates faster than propane-1,2,3-triol (glycerol) at room temperature. **[3]**

c. Suggest why fullerene (C_{60}), a simple molecular form of carbon, has a much lower melting point than diamond or graphite. **[2]**

Question 8 total: 8 marks

Question 9 — Extended response

Synoptic

Water (boiling point 100 °C) and hydrogen sulfide, H_2S (boiling point −60 °C), are both simple molecular hydrides with a bent shape, yet their boiling points differ enormously. Explain this difference fully, referring to the types of intermolecular force present in each substance and the relative strength of these forces. **[6]**

This question is marked using a level of response.

Question 9 total: 6 marks

PAPER TOTAL: 89 MARKS

MARK SCHEME — Chapter 6: Intermolecular Forces, Structures and Properties

Award marks independently unless stated.

Q1 (a) [3]

- Van der Waals (induced dipole–dipole), permanent dipole–dipole, and hydrogen bonding. (1)
- Van der Waals forces are generally the weakest. (1)
- Hydrogen bonding is generally the strongest. (1)

Q1 (b) [3]

- Electrons in the electron cloud are in constant, random motion. (1)
- At any instant this creates an uneven distribution of charge — a temporary/instantaneous dipole. (1)
- This induces a dipole in a neighbouring atom, and the resulting attraction between the (opposite) dipoles is the van der Waals force. (1)

Q1 (c) [2]

- Increasing number of electrons (larger Mr / more electrons). (1)
- Larger surface area of contact between molecules (e.g. straight chain vs branched). (1)

Q1 (d) [2]

- Permanent dipole–dipole forces need a permanent bond dipole that does not cancel over the molecule. (1)
- Only polar molecules have such a permanent uneven charge distribution / net dipole. (1)

Q2 (a) [4]

- Down the group, the number of electrons per molecule increases. (1)
- This increases the strength of the (instantaneous dipole–induced dipole) van der Waals forces between molecules. (1)
- More energy is required to overcome these stronger forces. (1)
- So boiling point increases down the group. (1)

Q2 (b) [2]

- Boiling only involves separating molecules from each other, breaking the weaker intermolecular forces. (1)
- The strong covalent bond within each Br_2 molecule remains intact (much more energy would be needed to break it). (1)

Q2 (c) [3]

- Neon has fewer electrons than argon. (1)
- Weaker van der Waals forces between neon atoms. (1)
- Less energy is needed to separate the atoms, so neon has a lower boiling point. (1)

Q3 (a) [3]

- A hydrogen atom must be covalently bonded to a small, highly electronegative atom (N, O or F). (2)
- A lone pair of electrons must be present on an N, O or F atom of a neighbouring molecule. (1)

Q3 (b) [3]

- δ+ shown on H, δ− shown on O of each water molecule. (1)
- Hydrogen bond shown as a dotted/dashed line between the δ+ H of one molecule and a lone pair on the δ− O of the other. (1)
- Correct roughly linear (O–H···O) arrangement of the hydrogen bond. (1)

Q3 (c) [4]

- N is small and highly electronegative; P is larger and less electronegative. (1)
- N–H bonds are polar enough, and N has a lone pair, so NH_3 molecules form hydrogen bonds with each other. (1)
- P–H bonds are much less polar and P is too large/not electronegative enough, so PH_3 only has (weaker) van der Waals and permanent dipole–dipole forces. (1)
- Hydrogen bonds are stronger than van der Waals/dipole–dipole forces, so more energy is needed to separate NH_3 molecules — higher boiling point. (1)

Q3 (d) [3]

- In ice, water molecules are held in a rigid, open (hexagonal) lattice by hydrogen bonds. (1)
- Each water molecule is hydrogen bonded to four others, creating an open structure with empty space. (1)
- When ice melts, some hydrogen bonds break and molecules pack more closely together, increasing the density. (1)

Q4 (a) [3]

- Both ethanol and water can form hydrogen bonds. (1)
- Ethanol's –OH group can hydrogen bond with water molecules. (1)
- New hydrogen bonds formed between ethanol and water are of similar strength to those broken (water–water and ethanol–ethanol), so they mix completely. (1)

Q4 (b) [2]

- Long-chain alcohols have a much larger non-polar hydrocarbon chain relative to the single –OH group. (1)
- The hydrocarbon chain cannot hydrogen bond with water and disrupts the hydrogen-bonded water structure, reducing solubility. (1)

Q4 (c) [2]

- Iodine is non-polar and can only form van der Waals forces, matching the non-polar forces in hexane ("like dissolves like"). (1)
- Iodine cannot form hydrogen bonds with water, and would disrupt water's hydrogen-bonded structure, so it does not dissolve well in water. (1)

Q5 (a) [3]

- Each carbon atom is covalently bonded to four other carbon atoms in a tetrahedral arrangement. (1)
- This forms a rigid, giant covalent (macromolecular) lattice extending throughout the structure. (1)
- Very high melting point because many strong covalent bonds must be broken throughout the giant structure. (1)

Q5 (b) [4]

- Each carbon atom is covalently bonded to three others in hexagonal layers/sheets. (1)
- The layers are held together by weak van der Waals forces (allowing them to slide). (1)
- Each carbon has one delocalised electron (from the 4th outer electron) which is free to move within the layers, allowing graphite to conduct electricity. (1)
- In diamond every outer electron is used in a covalent bond, so there are no delocalised/free electrons and it does not conduct. (1)

Q5 (c) [2]

- The layers are held together only by weak van der Waals forces. (1)
- These weak forces allow the layers to slide over each other easily. (1)

Q5 (d) [2]

- Very high melting point (accept: hard/does not conduct electricity). (1)
- Justification: like diamond, it is a giant covalent structure with strong covalent bonds throughout that require a large amount of energy to break. (1)

Q6 (a) [8] — 1 mark each cell

- NaCl: giant ionic — ions (Na^+, Cl^-).
- SiO_2: giant covalent (macromolecular) — atoms (Si, O), covalently bonded throughout.
- Cl_2: simple molecular — Cl_2 molecules.
- Fe: giant metallic — metal ions and delocalised electrons.

Q6 (b) [4]

- Both are giant structures, but SiO_2 is held together by strong covalent bonds throughout the whole structure. (1)
- NaCl is held together by strong ionic (electrostatic) bonds. (1)
- Covalent bonds in SiO_2 are generally stronger/more directional and require more energy to break on melting than the ionic attractions in NaCl. (1)
- So more energy (higher temperature) is needed to melt SiO_2 than NaCl. (1)

Q6 (c) [3]

- Cl_2 is a simple molecular substance. (1)
- Only weak van der Waals forces exist between Cl_2 molecules, and these are broken on melting (not the strong Cl–Cl covalent bond). (1)
- Much less energy is needed to overcome van der Waals forces than the strong ionic/covalent/metallic bonding in the other three substances. (1)

Q7 (a) [4]

- As chain length increases, the number of electrons per molecule increases. (1)
- This increases the strength of the van der Waals forces between molecules. (1)
- More energy is required to overcome these stronger forces. (1)
- So boiling point increases steadily with chain length. (1)

Q7 (b) [3]

- Branched molecules are more spherical / compact, with a smaller surface area of contact between molecules than the straight-chain isomer. (1)
- Weaker van der Waals forces can form between branched molecules. (1)
- Less energy is needed to separate them, so the boiling point is lower. (1)

Q7 (c) [3]

- Butan-1-ol has an –OH group and can form hydrogen bonds between molecules; butane cannot. (1)
- Butane only has (weaker) van der Waals forces between molecules. (1)
- Hydrogen bonds are stronger, needing more energy to overcome, giving butan-1-ol the higher boiling point. (1)

Q8 (a) [3]

- Hydrogen bonds are strong enough to hold the two DNA strands together in a stable double helix. (1)
- But they are much weaker than covalent bonds, so the strands can be separated (unzipped) without breaking the sugar-phosphate backbone. (1)
- This allows the DNA to be "read"/replicated during cell processes such as transcription and replication. (1)

Q8 (b) [3]

- Glycerol has three –OH groups per molecule compared with one in propan-1-ol. (1)
- Glycerol can form many more hydrogen bonds per molecule than propan-1-ol. (1)
- More energy is needed to overcome the greater number/total strength of hydrogen bonds, so glycerol evaporates (much) more slowly. (1)

Q8 (c) [2]

- C_{60} exists as discrete (simple) molecules, unlike the giant covalent lattices of diamond and graphite. (1)
- Only weak van der Waals forces need to be overcome between C_{60} molecules to melt it, rather than breaking strong covalent bonds. (1)

Q9 [6] — Level of response

- **Level 3 (5–6):** Correctly identifies hydrogen bonding in water and explains its absence/weakness in H_2S, linking bond strength directly to the boiling point difference, in a well-organised answer.
- **Level 2 (3–4):** Identifies the correct forces in both substances but the explanation of the link to boiling point is incomplete.
- **Level 1 (1–2):** Some relevant, isolated points; forces not clearly linked to both substances.

Indicative content: *O is small and highly electronegative, so O–H bonds are very polar and O has lone pairs — water molecules form strong hydrogen bonds with each other. S is larger and less electronegative than O, so S–H bonds are much less polar and hydrogen bonding does not occur (or is negligible) in H_2S — only weaker van der Waals and permanent dipole–dipole forces exist between H_2S molecules. Hydrogen bonds are considerably stronger than van der Waals/dipole–dipole forces, so much more energy is required to separate water molecules than H_2S molecules, giving water a far higher boiling point.*

END OF MARK SCHEME · 89 marks