

PHYSICAL SCIENCES: CHEMISTRY

Grade 11 • Matter & Materials: Intermolecular Forces & Physical Properties

Topic: Intermolecular Forces (IMFs) **Target:** Grade 11 CAPS / IEB**Focus:** Concepts, Graphs & Calculations**INSTRUCTIONS AND INFORMATION**

- Answer ALL questions in Section A and Section B.
- Non-programmable calculators may be used where appropriate.
- Where applicable, show all working and explain answers using relevant chemical principles (molecular structure, surface area, polarizability, and energy).
- A detailed marking guidelines (memorandum) is provided at the end of this paper for self-assessment.

SECTION A: MULTIPLE-CHOICE QUESTIONS

Four options are provided as possible answers to the following questions. Each question has only ONE correct answer.

1.1 Which ONE of the following compounds exhibits the WEAKEST intermolecular forces in the liquid state? [2]

- A. Water (H_2O)
- B. Ammonia (NH_3)
- C. Methane (CH_4)
- D. Hydrogen fluoride (HF)

1.2 What type of intermolecular force is primarily responsible for the interaction between an ion (such as Na^+) and water molecules during dissolution? [2]

- A. Hydrogen bonding
- B. London dispersion forces
- C. Dipole-dipole forces
- D. Ion-dipole forces

1.3 Which ONE of the following physical properties DECREASES as the strength of intermolecular forces increases? [2]

- A. Boiling point
- B. Vapor pressure
- C. Viscosity
- D. Surface tension

1.4 Consider two non-polar substances: Iodine (I_2) and Chlorine (Cl_2). At room temperature, I_2 is a solid while Cl_2 is a gas. The best explanation for this difference is that: [2]

- A. Iodine has covalent bonds between its molecules, whereas chlorine has London forces.
- B. Iodine has a larger electron cloud, leading to stronger induced dipoles (London forces).
- C. Chlorine molecules are polar, resulting in dipole-dipole repulsion.
- D. Iodine molecules form hydrogen bonds with neighboring iodine molecules.

1.5 When a liquid reaches its normal boiling point, its vapor pressure is equal to:

[2]

- A. Zero
- B. 50 kPa
- C. Standard atmospheric pressure (101,3 kPa)
- D. Twice the atmospheric pressure

TOTAL SECTION A: [10]

SECTION B: STRUCTURED QUESTIONS

QUESTION 2: MOLECULAR STRUCTURE & INTERMOLECULAR FORCES

The physical properties of substances depend significantly on the type and strength of intermolecular forces present between their molecules. Consider the three compounds given below:

Compound Name	Chemical Formula	Molar Mass ($\text{g}\cdot\text{mol}^{-1}$)	Boiling Point ($^{\circ}\text{C}$)
Water	H_2O	18	100
Hydrogen sulfide	H_2S	34	-60
Hydrogen selenide	H_2Se	81	-41

2.1 Define the term *intermolecular force*. (2)

2.2 Name the dominant type of intermolecular force found in:

2.2.1 Pure water (H_2O) (1)

2.2.2 Hydrogen sulfide (H_2S) (1)

2.3 Draw the Lewis electron dot structure for a water molecule (H_2O) and state its molecular shape. (3)

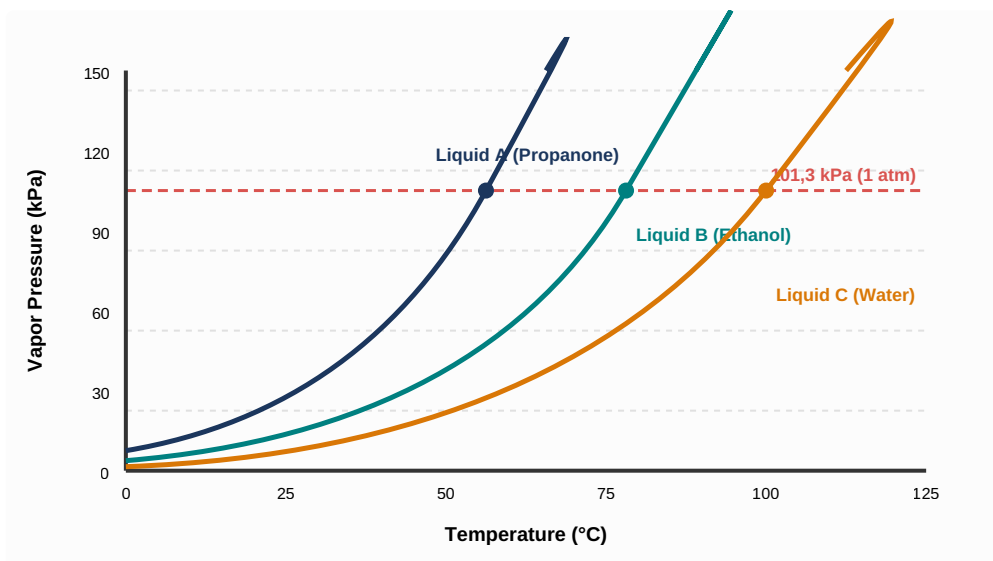
2.4 Fully explain why water (H_2O) has a significantly higher boiling point than hydrogen sulfide (H_2S), despite H_2S having a greater molar mass. Refer to polarity, force types, and energy in your explanation. (4)

2.5 Explain why H_2Se has a slightly higher boiling point than H_2S . (3)

[14]

QUESTION 3: VAPOR PRESSURE & GRAPH INTERPRETATION

A group of Grade 11 learners investigated how vapor pressure changes with temperature for three different pure liquids: **Propanone**, **Ethanol**, and **Water**. Their experimental results are illustrated in the graph below:



3.1 Define *vapor pressure*. (2)

3.2 From the graph, write down the approximate normal boiling point of:
3.2.1 Liquid B (Ethanol) (1)

3.2.2 Liquid C (Water) (1)

3.3 Identify the independent variable for this investigation. (1)

3.4 At a temperature of 50 °C, which liquid (A, B, or C) has the highest vapor pressure? (1)

3.5 Which liquid (A, B, or C) exhibits the **strongest** net intermolecular forces? Fully justify your choice using information from the graph. (3)

3.6 How will the boiling point of Liquid B change if the experiment is conducted on top of Table Mountain in Cape Town, where atmospheric pressure is lower than 101,3 kPa? Write only **INCREASES**, **DECREASES**, or **REMAINS THE SAME**. Briefly explain your answer. (3)

[12]

QUESTION 4: HOMOLOGOUS SERIES & PHYSICAL PROPERTIES

The boiling points of five straight-chain alkanes were determined and recorded in the table below:

Alkane Name	Molecular Formula	Number of Carbon Atoms	Boiling Point (°C)
Methane	CH ₄	1	-161,5
Ethane	C ₂ H ₆	2	-88,6
Propane	C ₃ H ₈	3	-42,1
Butane	C ₄ H ₁₀	4	-0,5
Pentane	C ₅ H ₁₂	5	36,1

4.1 State the general trend in boiling points as the number of carbon atoms increases from 1 to 5. (1)

4.2 Name the specific type of intermolecular force present between alkane molecules. (1)

4.3 Explain the trend stated in Question 4.1 in terms of molecular size, surface area, and intermolecular forces. (4)

4.4 Consider 2-methylpropane (an isomer of butane with formula C₄H₁₀).

4.4.1 Will the boiling point of 2-methylpropane be **HIGHER THAN**, **LOWER THAN**, or **EQUAL TO** that of butane (-0,5 °C)? (1)

4.4.2 Fully explain your answer to Question 4.4.1 by comparing the molecular structures of the two branched/unbranched molecules. (3)

[10]

TOTAL SECTION B: [36]

GRAND TOTAL: [46] + 4 (Bonus/Format) = 50 MARKS

MEMORANDUM & MARKING GUIDELINES

Note to Educators/Learners: Tick marks (✓) indicate distribution of marks as per DBE CAPS marking standard.

SECTION A: MULTIPLE-CHOICE

1.1 C (Methane / CH₄) ✓✓ [2 marks]

(Methane is non-polar and held only by weak London dispersion forces, whereas H₂O, NH₃, HF exhibit strong hydrogen bonding.)

1.2 D (Ion-dipole forces) ✓✓ [2 marks]

(Interactions between charged ions and polar solvent molecules like water are ion-dipole forces.)

1.3 B (Vapor pressure) ✓✓ [2 marks]

(Stronger IMFs prevent molecules from escaping into the gas phase, reducing vapor pressure.)

1.4 B (Iodine has a larger electron cloud, leading to stronger induced dipoles) ✓✓ [2 marks]

(I₂ has more electrons / larger atomic mass, producing larger temporary dipoles and stronger London forces.)

1.5 C (Standard atmospheric pressure - 101,3 kPa) ✓✓ [2 marks]

QUESTION 2: MOLECULAR STRUCTURE & IMFs

2.1 Intermolecular force: A force of attraction that exists between neighboring molecules (or atoms/ions). ✓✓ (2)

2.2.1 Pure water: Hydrogen bonds (or hydrogen bonding) ✓ (1)

2.2.2 Hydrogen sulfide: Dipole-dipole forces ✓ (1)

2.3 Lewis Structure & Shape:

- Central oxygen atom with 2 bonding pairs and 2 lone pairs correctly drawn ✓✓
- Shape: Angular / Bent ✓ (3)

2.4 Explanation of Boiling Point Difference (H₂O vs H₂S):

- H₂O molecules are held together by **strong hydrogen bonds** (due to highly electronegative O bonded to H) ✓
- H₂S molecules are held together by weaker **dipole-dipole forces** ✓
- Hydrogen bonds require significantly more thermal energy to overcome/break than dipole-dipole forces ✓
- Therefore, water has a much higher boiling point than H₂S ✓ (4)

2.5 Explanation (H₂Se vs H₂S):

- Both molecules have dipole-dipole forces and London forces.
- H₂Se has a larger molecular size / larger electron cloud / greater molar mass than H₂S ✓
- This results in stronger induced dipoles / stronger London dispersion forces in H₂Se ✓
- More energy is required to overcome these total intermolecular forces, giving H₂Se a higher boiling point ✓ (3)

QUESTION 3: VAPOR PRESSURE & GRAPH INTERPRETATION

3.1 Vapor pressure: The pressure exerted by a vapor in thermodynamic equilibrium with its liquid phase in a closed system at a given temperature. ✓✓ (2)

3.2.1 Liquid B (Ethanol): 78 °C (accept 77 °C – 79 °C) ✓ (1)

3.2.2 Liquid C (Water): 100 °C ✓ (1)

3.3 Independent variable: Temperature (°C) ✓ (1)

3.4 Liquid A (Propanone) ✓ (1)

3.5 Liquid C (Water):

- Liquid C has the lowest vapor pressure at any given temperature / highest normal boiling point (100 °C) ✓
- Lower vapor pressure indicates fewer molecules escape into gas phase, meaning **stronger net intermolecular forces** hold the liquid together ✓
- Requires the highest amount of thermal energy to reach 101,3 kPa ✓ (3)

3.6 Effect of Altitude (Table Mountain):

- **DECREASES** ✓
- Atmospheric pressure on Table Mountain is lower than standard atmospheric pressure (101,3 kPa) ✓
- Liquid B will reach a vapor pressure equal to the lower atmospheric pressure at a lower temperature ✓ (3)

QUESTION 4: HOMOLOGOUS SERIES & PHYSICAL PROPERTIES

4.1 Trend: The boiling point increases as the number of carbon atoms / chain length increases. ✓ (1)

4.2 Intermolecular force: London forces / dispersion forces / induced dipole forces ✓ (1)

4.3 Explanation of Alkane Boiling Points:

- As chain length / number of C atoms increases, the molecular mass and surface area increase ✓
- Larger surface area leads to greater electron cloud polarizability ✓
- Stronger / more London dispersion forces are formed between molecules ✓
- More thermal energy is required to overcome these stronger forces ✓ (4)

4.4.1 Prediction: LOWER THAN ✓ (1)

4.4.2 Explanation (2-methylpropane vs butane):

- 2-methylpropane is a branched molecule, making its shape more spherical compared to the straight-chain butane molecule ✓
- Branching decreases the effective surface area available for contact between molecules ✓
- This results in weaker London dispersion forces requiring less energy to overcome ✓ (3)