

REVISION BOOKLET

Grade 11 • Chemistry

INTERMOLECULAR FORCES

MATTER & MATERIAL



Subject: Physical Science

Grade: 11

Content area: Matter and Materials

Topic: Intermolecular forces

In this unit we will focus on the following concepts and skills:

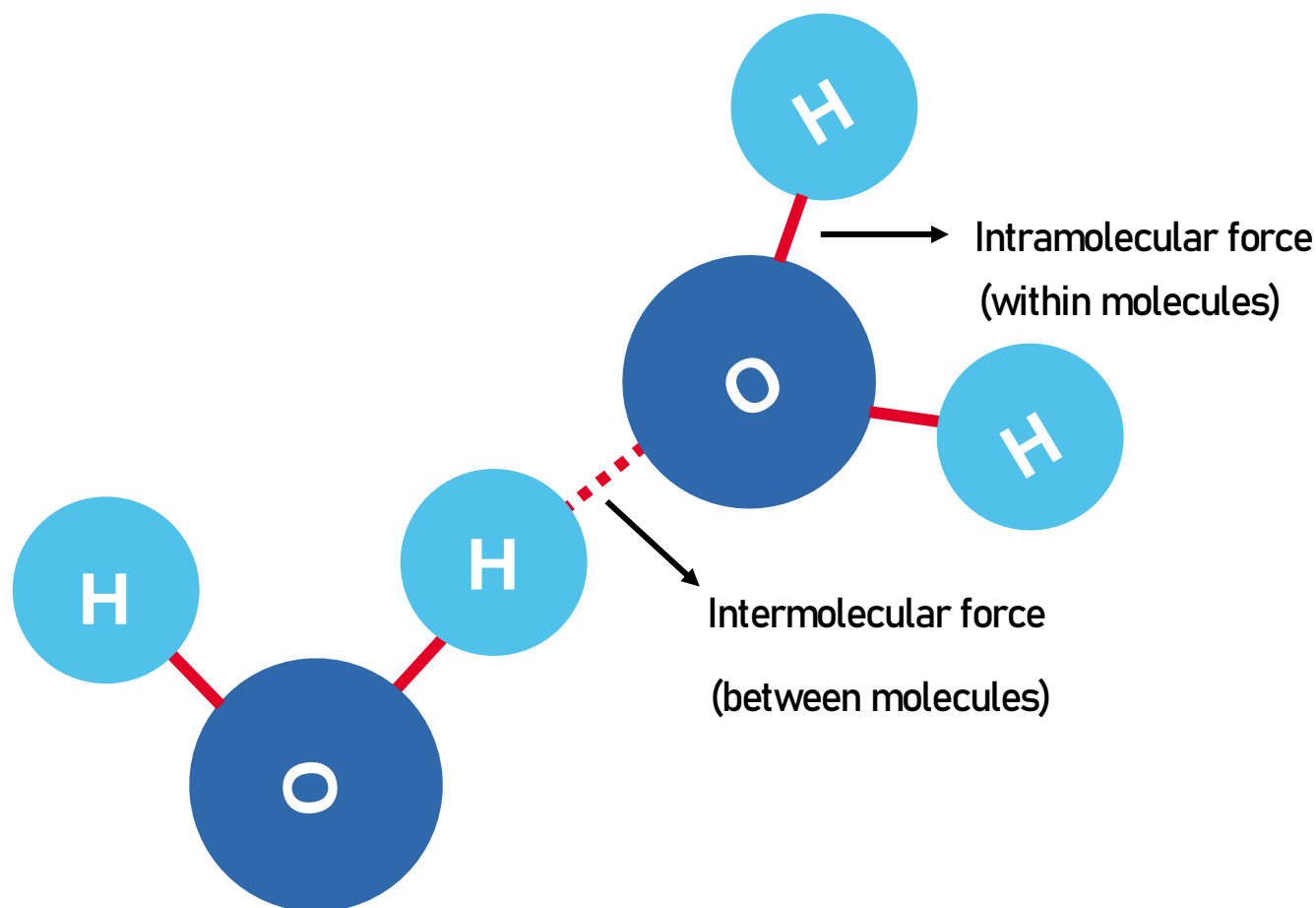
- Describe the difference between intermolecular forces and interatomic forces (intramolecular forces)
- Name and explain the different inter-molecular forces

INTRAMOLECULAR AND INTERMOLECULAR FORCES

INTRAmolecular/Interatomic forces are forces that hold atoms together within a molecule, whereas INTERmolecular forces are forces that exist between different molecules.



Four separate atoms with no Intermolecular or Intramolecular forces



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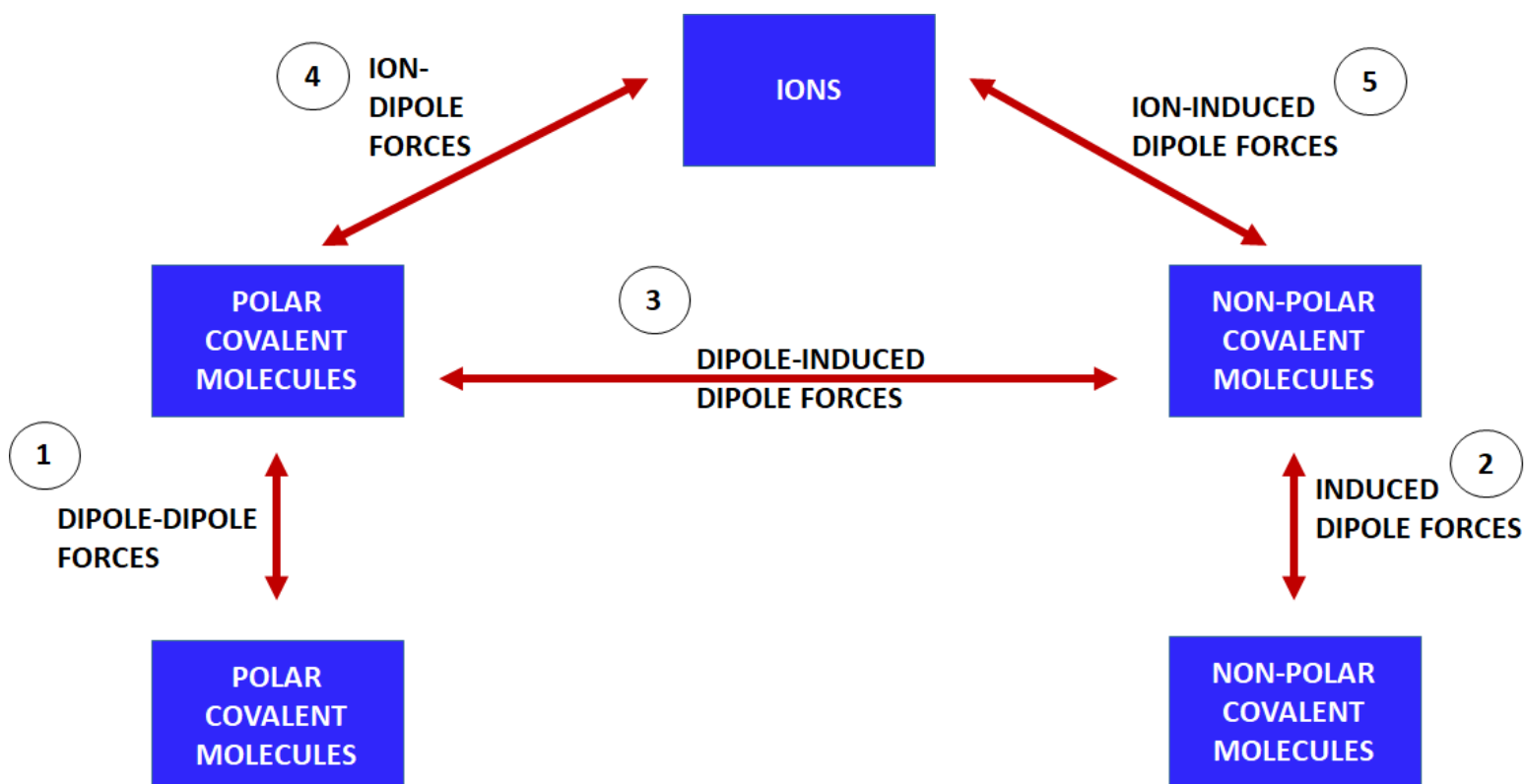
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INTRAMOLECULAR AND INTERMOLECULAR FORCES

These are the 5 types of Intermolecular forces we will focus on:

1. Dipole-dipole forces
2. Mutually induced dipole forces (London forces)
3. Dipole-induced dipole forces
4. Ion-dipole forces
5. Ion- induced-dipole forces



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INTRAMOLECULAR AND INTERMOLECULAR FORCES

1. Dipole-dipole forces

When 2 Dipole molecules come into contact, the positive pole of one molecule will be attracted to the negative pole of the other molecule and both molecules will be held together by this attraction. These interactions are the strong intermolecular force of attraction.

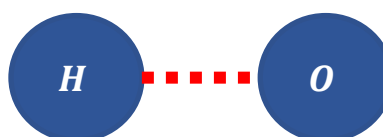
Special Case – Hydrogen Bonding

Is a special dipole-dipole interaction that occurs SPECIFICALLY between a Hydrogen atom bonded to either an Oxygen, Nitrogen or Fluorine atom. Hydrogen bonding is the strongest of the dipole-dipole attractions and requires considerable energy to break these bonds which results in compounds containing these bonds having exceptionally high boiling and melting points.

DIPOLE-DIPOLE
FORCES



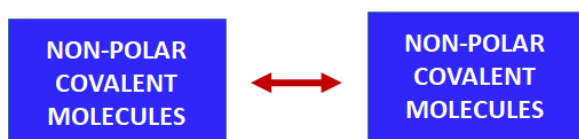
Example:



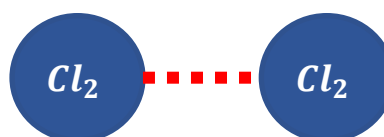
2. Mutually induced dipole forces (London forces):

These Intermolecular forces exist between all types of molecules but are the weakest of forces. Molecules with more electrons will have the stronger London dispersion forces. Breaking London dispersion forces do NOT require much energy which explains why Non-polar covalent compounds will freeze at very low temperatures.

INDUCED
DIPOLE FORCES



Example:



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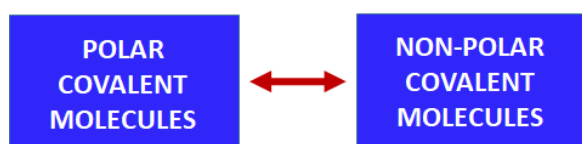
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INTRAMOLECULAR AND INTERMOLECULAR FORCES

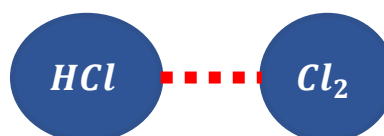
3. Dipole-induced dipole forces

This type of force occurs when a polar molecule induces a dipole in a non-polar molecule.

DIPOLE-INDUCED
DIPOLE FORCES



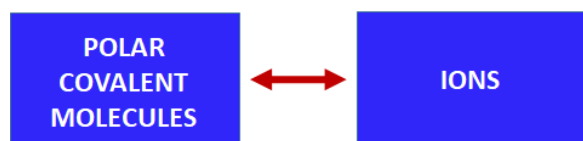
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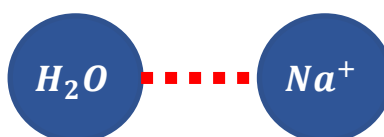
4. Ion-dipole forces

Forces between ions and polar molecules. An ion is a charged atom, therefore will be attracted to one of the poles of the polar molecule.

ION-
DIPOLE
FORCES



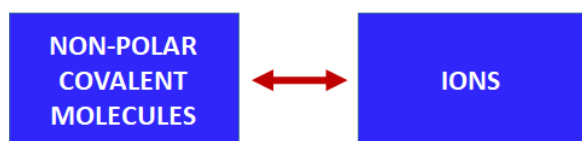
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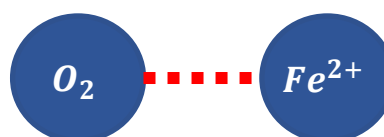
5. Ion-induced-dipole forces

Forces between ions and non-polar molecules, the ion induces a dipole leading to a weak force that holds the compound together.

ION-INDUCED
DIPOLE FORCES



Example:



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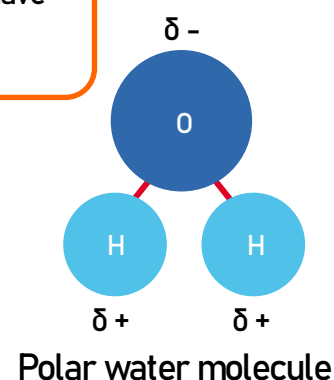
In this unit we will focus on the following concepts and skills:

- Describe the relationship between intermolecular forces and molecular mass
- Explain the effect intermolecular forces have on boiling point, melting point, vapour pressure and solubility

INTERMOLECULAR FORCE AND MOLECULAR MASS

The larger the molecule, the more electrons it contains and therefore the molecule will be more polar and thus the intermolecular forces between the molecules would be stronger. To summarise, as the molecular mass increases so does the intermolecular force. This can be illustrated using alkanes which is shown in the table below. The longer the alkane chain, i.e. the greater the molecular mass, the higher the boiling point of the alkane which indicates a stronger intermolecular force.

Polar: Separation of electric charge, i.e. a molecule will have a positively and negatively charged side.



Alkane	Molecular Mass (g/mol)	Boiling Point (°C)
Methane (CH ₄)	16	-161
Ethane (C ₂ H ₆)	30	-89
Propane (C ₃ H ₈)	44	-42
Butane (C ₄ H ₁₀)	58	-1
Pentane (C ₅ H ₁₂)	72	36
Hexane (C ₆ H ₁₄)	86	69

Increasing
Intermolecular
Strength

THE EFFECT OF INTERMOLECULAR FORCES ON BOILING POINT, MELTING POINT, VAPOUR PRESSURE AND SOLUBILITY

Boiling point

Boiling point is the temperature at which the vapour pressure of a substance is equal to the atmospheric pressure.

Stronger
Intermolecular
Force



Higher Boiling
Point

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THE EFFECT OF INTERMOLECULAR FORCES ON BOILING POINT, MELTING POINT, VAPOUR PRESSURE AND SOLUBILITY

Melting Point

Melting point is the temperature at which the solid and liquid phases of a substance is at equilibrium.



Vapour Pressure

Vapour pressure is the pressure exerted on a container when the vapour and liquid phases of a substance is at equilibrium.



Solubility

Solubility is the ability of a certain substance to dissolve in another substance, for example sugar dissolving in water.

Polar molecules are only soluble in polar solvents and non-polar molecules are only soluble in non-polar solvents.



Note: Size of molecule also affects the boiling/melting point, vapour pressure and solubility!

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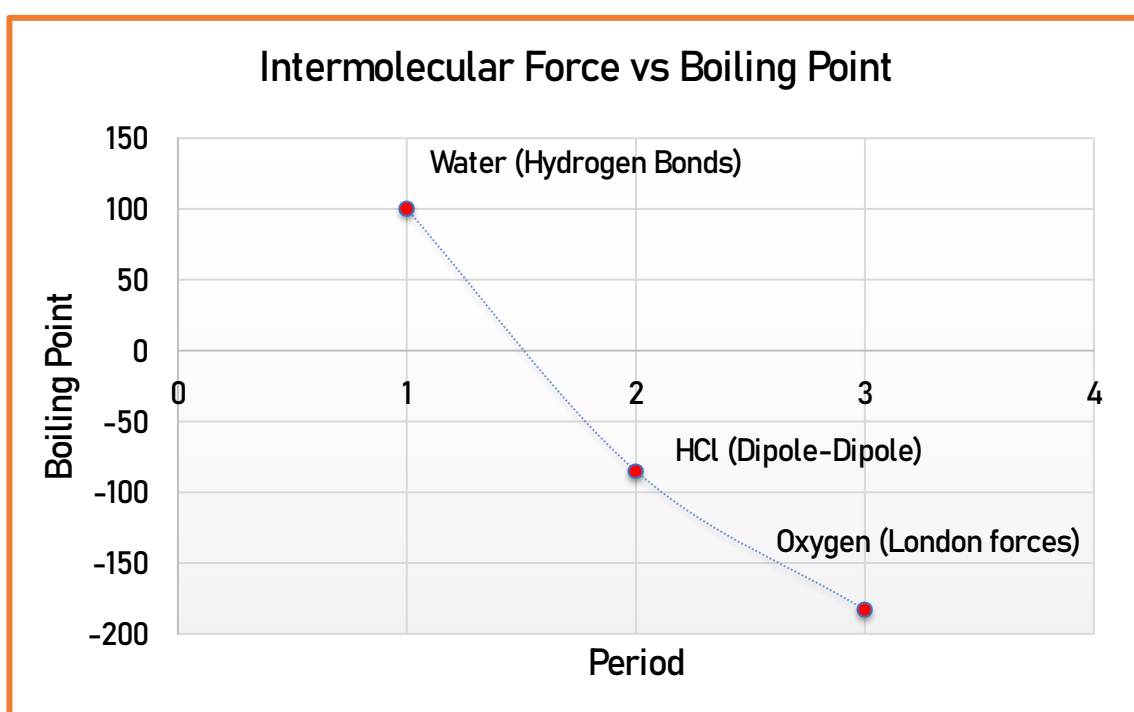
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THE EFFECT OF INTERMOLECULAR FORCES ON BOILING POINT, MELTING POINT, VAPOUR PRESSURE AND SOLUBILITY

Type of Compound	Intermolecular Forces	Relative Order of Boiling/Melting Point	Relative Order of Vapour Pressure
Ionic compound	Ion to ion attraction between ions, London dispersion forces.	1 (Highest)	4 (Lowest)
Covalent compound with hydrogen bonds	Hydrogen bonds, London dispersion forces	2	3
Polar covalent compound	Dipole-dipole attraction, London dispersion forces	3	2
Non-polar covalent compound	London dispersion forces	4 (Lowest)	1 (Highest)



MULTIPLE CHOICE QUESTIONS FROM FINAL EXAMS (2015-2018)

1) Hydrogen bonds and London forces (induced dipole forces) have a common characteristic in that they ...

- A are both stronger than chemical bonds.
- B both occur between non-polar molecules.
- C both occur between polar molecules.
- D are both intermolecular forces.

(2)

In-depth answering of a multiple-choice question

Option A states that both Hydrogen bonds and London forces are stronger than chemical bond which we know is false because interatomic forces are stronger than intermolecular forces.

Option B and C states that they occur between Non-polar molecules and Polar molecules, respectively. We know these two options are false because Hydrogen bonding only occurs between polar molecules and not Non-polar molecules.

Option D states That both these are Intermolecular forces which is correct, therefore the correct answer is d.

2) Solid iodine sublimes easily. The intermolecular forces present in iodine are ...

- A London forces.
- B ion-dipole forces.
- C dipole-dipole forces.

(2)

MULTIPLE CHOICE QUESTIONS FROM FINAL EXAMS (2015-2018)

- 3) The intermolecular forces in dry ice (CO_2) are ...
- A ion-induced dipole forces.
 - B hydrogen bonding.
 - C ion-dipole forces.
 - D London forces.
- 4) Which ONE of the following has the strongest forces between its molecules?
- A F_2
 - B Cl_2
 - C Br_2
 - D I_2

In-depth answering of a multiple-choice question

All of our options are Non-polar covalent therefore all of our options have London forces acting upon them. To differentiate between them, the molecule with the most valence electrons will have the stronger London forces.

Once again all of our options have 8 Valence electron so to determine which option has the strongest force, we will have to refer to atomic mass.

Option D (I_2) has the highest atomic mass therefore has the strongest forces between the molecules.

Worked Exam Questions

Question 3 November 2015

3.1 The boiling point of compounds A to E are given in the table below.

COMPOUND	FORMULA	BOILING POINT (°C)
A	CH ₄	-164
B	C ₂ H ₆	-89
C	C ₅ H ₁₂	36
D	C ₆ H ₁₄	69
E	C ₂₀ H ₄₂	343

3.1.1 Define the term boiling point. (2)

The temperature at which the vapour pressure equals the atmospheric temperature.

3.1.2 Calculate the molecular mass of compound D. (1)

Carbon molecular mass = 12, Hydrogen molecular mass = 1.

Compound D has 6 carbons and 14 hydrogens, therefore:

$$M = 6(12) + 14(1)$$

$$M = 86 \text{ g/mol}$$

3.1.3 In what phase is compound B at 25 °C? (1)

The boiling point of compound B is -89 °C, therefore at 25 °C it will be a gas. (When a substance boils it undergoes a phase change into the gaseous state).

3.1.4 Name the type of intermolecular force present in compound A. (1)

Compound A is a non-polar molecule, therefore the intermolecular force present is London/dispersion/induced dipole forces.

3.1.5 Explain why the boiling point increases from compound A to E. (3)

- The molecular mass increases from A to E
- The intermolecular forces become stronger from A to E
- More energy is required to break the intermolecular forces between the molecules.

3.1.6 How does the vapour pressure of compound B compare to the vapour pressure of compound C? Write down only HIGHER THAN, LOWER THAN or EQUAL TO. (1)

Higher than. (Compound B has the weaker intermolecular forces therefore more vapour would be present at equilibrium and therefore a greater vapour pressure would be exerted)

Worked Exam Questions

Question 3 November 2015

3.2 Consider the boiling points of the compounds in the table below.

SUBSTANCE	BOILING POINT (°C)
H ₂ S	-60
NH ₃	-33
H ₂ O	100

3.2.1 Which ONE of the substances in the table above has the weakest forces between its molecules? (1)

H₂S. (H₂S has the lowest boiling point which indicates that it has the weakest intermolecular forces between its molecules)

3.2.2 Name the type of intermolecular force found between NH₃ molecules. (1)

Hydrogen bonding. (The NH₃ molecules are polar and have a hydrogen atom bonded to a nitrogen atom, therefore the intermolecular forces occurring between two NH₃ molecules will be hydrogen bonding.)

3.2.3 Explain the following statement:

Although the shape of the molecules of H₂S and H₂O is similar, there is a remarkable difference in their boiling points. (4)

The hydrogen bonds between H₂O molecules are stronger than the London/dispersion/induced dipole forces between H₂S molecules. More energy is required to break the intermolecular forces between the H₂O molecules which results in a significantly higher boiling point.

Exam Questions

Question 3 November 2016

Learners conduct an experiment to investigate the effects of intermolecular forces on boiling points. They use 20 mL of each of the following compounds in their investigation: water, sunflower oil, nail polish remover, glycerine and methylated spirits. The results are shown in the table below.

NAME OF COMPOUND	BOILING POINT (°C)
water	93
sunflower oil	230
nail polish remover	56
glycerine	290
methylated spirits	62

- 3.1 Define the term boiling point. (2)
- 3.2 Formulate an investigative question for this experiment. (2)
- 3.3 In which compound in the table above will the strongest intermolecular forces occur? Give a reason for the answer. (2)
- 3.4 The learners now use 40 mL of each of the compounds above in the experiment. Will it affect the boiling points? Choose YES or NO. Give a reason for the answer. (2)
- 3.5 Methylated spirits is highly flammable. State TWO safety precautions that should be taken when using methylated spirits in the laboratory. (2)
- 3.6 Which compound in the table above will have the highest rate of evaporation? Give a reason for the answer. (2)
- 3.7 Sunflower oil is a non-polar compound with induced dipole forces between the molecules, while water is a polar molecule with hydrogen bonds between its molecules. Explain why the boiling point of sunflower oil is higher than the boiling point of water. (2)

Exam Questions

Question 3 November 2017

Consider the list of six substances with their formulae and boiling points in the table below.

NAME OF SUBSTANCE	FORMULA	BOILING POINT (°C)
Water	H ₂ O	100
Ethanol	CH ₃ CH ₂ OH	78
Bromine	Br ₂	58,8
Iodine	I ₂	184,3
Ammonia	NH ₃	-33,3
Phosphine	PH ₃	-87,7

- 3.1 Explain why ethanol is soluble in water. Refer to the relative strength of the intermolecular forces in ethanol and water. (3)
- 3.2 Explain why the boiling point of iodine is higher than that of bromine. Refer to the intermolecular forces present in EACH substance in the explanation. (3)
- 3.3 Explain why phosphine will evaporate faster than ammonia by referring to the types of intermolecular forces present in EACH substance. (4)
- 3.4 Water, ethanol and bromine are all liquids at room temperature .
Which ONE will have the highest vapour pressure? (1)
- 3.5 Give a reason for the answer to QUESTION 3.4 by referring to the relative strength of the intermolecular forces and boiling points . (2)