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VCE Chemistry ½
Intermolecular Bonding [0.7]
Workshop

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Section A: Recap

[1.8.1] - Explain how dispersion forces form & identify molecules that can exhibit them

- Dispersion forces: when two or more temporary or **instantaneous** dipoles come together, arising from the **[symmetrical] / [asymmetrical]** distribution of electrons.
- This intermolecular bond occurs because electrons are **[fixed] / [randomly moving]** in molecules, and so they may temporarily group closely together on one side.
- Dispersion forces are the **[strongest] / [weakest]** type of intermolecular bonding that exists.
- Dispersion forces occur in **[polar] / [non-polar] / [all] / [specific]** molecules.
- Atoms/molecules with **more electrons** have a **[greater] / [same] / [lesser] chance for temporary dipoles** to be formed, and as such, have **[stronger] / [identical] / [weaker]** dispersion forces.

[1.8.2] - Explain how dipole-dipole attractive forces form & identify molecules that can exhibit them

- dipole-dipole bond are an intermolecular bond that occurs between **two dipoles**.
- While dispersion forces can occur in **all** molecules, dipole-dipole attractions only occur in polar **molecules**.
- As dipoles in polar molecules are **[temporary] / [permanent]**, these forces are **[stronger] / [weaker]** than dispersion forces, wherein the dipoles are only temporarily formed.

[1.8.3] - Explain how hydrogen bonds form & identify molecules that can exhibit them

- Hydrogen bonds are a **special type of dipole-dipole bond.** They are the strongest type of intermolecular bond out of the three major intermolecular bonds. This is due to:
- The **large** electronegativity difference.
- The hydrogen **atom** which is **[small] / [large] in nature** allows molecules to approach close to it as it is left exposed to the large electronegativity difference.
- For a H-bond to form:
  - A hydrogen atom has to be covalently **bonded** to one of FON (Fluorine, Oxygen or Nitrogen).

- That same H atom can form a **dipole-dipole** bond with **any** F O or N **atom** on a [redacted].

[1.8.4] - Apply intermolecular bonding to compare molecules' melting & boiling points

- Intramolecular bonding - happens **[within]** / **[between]** molecules.
- Intermolecular bonding - happens **[within]** / **[between]** molecules.
- Substances exist either as a [redacted] a given temperature.
- Their state depends on the **strength** of its [redacted] bonds.
- [redacted] is the phase change from Solid → Liquid: Intermolecular bonds are [redacted].
- [redacted] is the phase change from Liquid → Gas: Intermolecular bonds are [redacted].

Dispersion Forces	Dipole-dipole	Hydrogen Bonds
Weakest Intermolecular Bond.	Stronger Intermolecular Bond.	Strongest Intermolecular Bond.
Occurs in all molecules.	Only occurs in polar molecules.	Only occurs between one of FON and hydrogen which is covalently bonded to FON.
Formed by temporary/instantaneous dipoles which form temporary partial charges.	Formed from permanent dipoles due to polarity of molecules which results in electrostatic attraction.	Formed from the high electronegativity between hydrogen (H) and one of FON which exposes the hydrogen atom to even stronger electrostatic attraction.

Space for Personal Notes

Section B: Warm Up (18 Marks)

INSTRUCTION: 18 Marks. 12 Minutes Writing.

Question 1 (2 marks)

List all four types of intermolecular bonds.

Dispersion Ion – dipole bonds

Dipole – Dipole

Hydrogen

Question 2 (2 marks)

Nitrogen (N_2) exists as a gas at room temperature. What can you conclude about the relative strength of the intermolecular bonding in nitrogen gas compared to pure hydrogen chlorine gas (HCl)?

HCl → polar → dipole – dipole

N_2 → non-polar → dispersion

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Question 3 (7 marks)

Matthew is investigating the different types of intermolecular bonds.

a. Describe how dispersion forces form between molecules. (2 marks)

- e^- move randomly in a cloud
- this leads to instantaneous dipole formation
- these then attract each other

b. Describe how dipole-dipole interactions form between molecules. (2 marks)

- atoms join → unequal e^- distribution
- polar bonds → polar molecules
- this produces δ^- & δ^+ (dipoles)
- these are attracted to each other via electrostatic forces

c. Describe the conditions required for a hydrogen bond to form. (2 marks)

- H — F/O/N
  - this allows the H to be exposed.
- Dipole present

d. Rank these three types of intermolecular bonds from strongest to weakest. (1 mark)

H-bond, dipole-dipole, dispersion.

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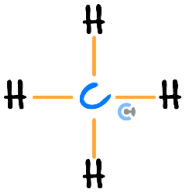
Question 4 (4.5 marks)

Which one of the following molecules can form hydrogen bonds with itself?

a. (0.5 marks)



[Yes] / [No]

b. (0.5 marks)

[Yes] / [No]

c. (0.5 marks)

[Yes] / [No]

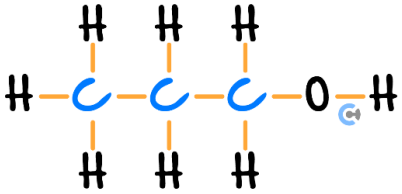
d. (0.5 marks)

[Yes] / [No]

e. (0.5 marks)

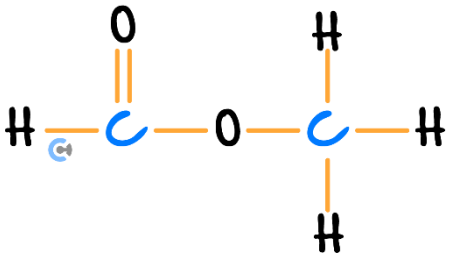
[Yes] / [No]

f. (0.5 marks)



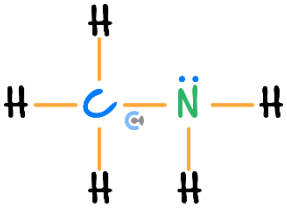
[Yes] / [No]

g. (0.5 marks)



[Yes] / [No]

h. (0.5 marks)



[Yes] / [No]

i. (0.5 marks)

[Yes] / [No]

Question 5 (2.5 marks)

Name the type(s) of intermolecular forces that exist between molecules in each of the following species.

a. CH_4. (0.5 marks)

disp forces

b. Cl_2 (0.5 marks)

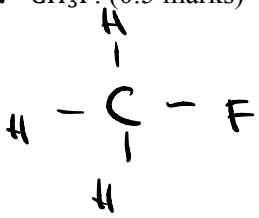
disp forces

c. HCl. (0.5 marks)

Dispersion, dipole-dipole

dipole

d. CH_3F. (0.5 marks)



Dispersion, dipole-dipole

dipole

e. NH_3. (0.5 marks)

Dispersion, dipole-dipole, hydrogen bonding

hydrogen

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Section C: Ramping Up (16 Marks)

INSTRUCTION: 16 Marks. 11 Minutes Writing.

Question 6 (1 mark)

Which one of these options correctly describes a hydrogen bond?

A. The partially positive hydrogen is attracted to an electronegative atom in another molecule, thereby forming a hydrogen bond.

B. The partially positive hydrogen that can be attached to an electronegative atom forms a hydrogen bond with an electronegative atom that must be attached to another hydrogen.

C. The partially positive hydrogen forms a bond with another hydrogen that is attached to an electronegative atom.

D. The partially positive hydrogen that must be attached to an electronegative atom forms a hydrogen bond with an electronegative atom that can be attached to another hydrogen.

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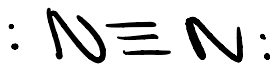
Question 7 (6 marks)

Reina is considering the element of nitrogen and the molecules it can form. The two molecules, nitrogen gas (N_2) and ammonia (NH_3) are used.

a. Draw the Lewis Structure of:

i. Nitrogen gas (N_2). (1.5 marks)



ii. Ammonia (NH_3). (1.5 marks)

b. Which of N_2 and NH_3 will have stronger intermolecular bonding? Justify your answer. (2 marks)

- NH_3 → polar / also has a H–N
- ∴ NH_3 forms strong hydrogen bonds
- N_2 → nonpolar → weak dispersion forces

c. As such, which of the molecules will have a higher boiling point? (1 mark)

NH_3

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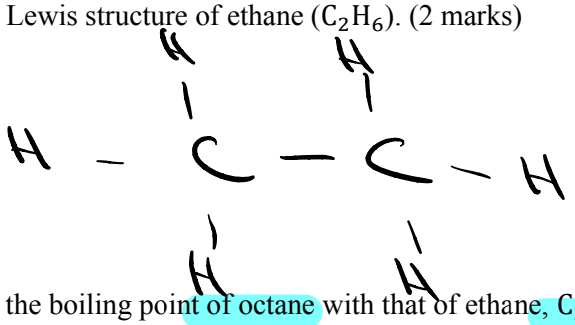
Question 8 (9 marks)

Consider a molecule of octane which has a molecular formula of C_8H_{18}.

a. This octane is compared with ethane, C_2H_6.

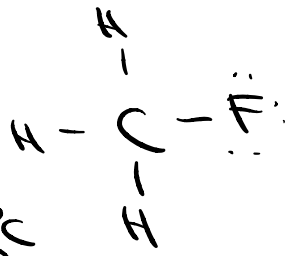
i. Draw the Lewis structure of ethane (C_2H_6). (2 marks)



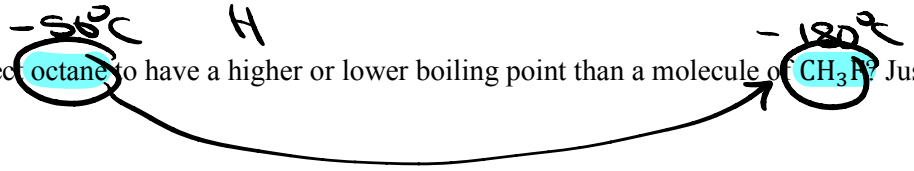
ii. Compare the boiling point of octane with that of ethane, C_2H_6. (2 marks)

- octane ↑ B.P than ethane
- octane bigger ∴ ↑ e⁻ ∴ ↑ instantaneous dipoles ∴ forms more dispersion forces.

b. The octane is also compared with fluoromethane (CH_3F). Draw the Lewis structure of fluoromethane. (2 marks)



c. Do you expect octane to have a higher or lower boiling point than a molecule of CH_3F? Justify your answer. (3 marks)



- octane
- Although CH_3F has dipole-dipole bonds octane is almost 8x bigger
- ∴ octane has a lot more dispersion forces → outweighs the the dipole-dipole bond.

Section D: Getting Trickier I (11 Marks)

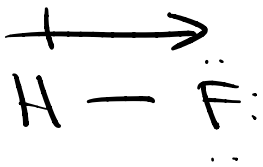
INSTRUCTION: 11 Marks. 9 Minutes Writing.

Question 9 (11 marks)

Hydrofluoric acid also known as HF is an acidic substance. We usually dilute it in several ways to make it safer for human handling.

a. The structure of HF is to be investigated.

i. Draw the Lewis Structure of HF. (1 mark)



ii. Draw the polarity arrow on the HF above. (1 mark)

b. Explain whether HF is polar or non-polar. (2 marks)

- Polar
- Electronegativity difference is 1.8

$0.4 < x < 1.8$ ∴ $F\delta^-$ & $H\delta^+$

c. What sort of intermolecular bonds can HF make? (1 mark)

Hydrogen Bonds Dispersion, Dipole Dipole,

d. Would we expect HF to have a higher boiling point than HBr? Justify your answer. (2 marks)

- HF
- H–F bond has a high e-neg difference H–Br bond
- HF is more polar → Stronger dipole-dipole

BUT IT ALSO FORMS H-BONDS THESE ARE STRONGER

e. How would the intermolecular bonding of HF differ from another molecule such as CH_4? (2 marks)

HF → disp, dipole – dipole, hydrogen

CH_4 → dispersion

f. When we drop HF into a solution of H_2O, we see that the two substances mix with each other pretty well. However, when we drop CH_4 into H_2O, we see that they do not mix at all. What does H_2O have in common with HF but not CH_4? (1 mark)

Both have hydrogen bonds

OR both polar.

g. As such, what sort of conclusion can we draw in terms of molecules mixing with each other? (1 mark)

polar items will dissolve in other polar items → similar intermolecular bonds

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CH_4 H_2O

Section E: Getting Trickier II (10 Marks)

INSTRUCTION: 10 Marks. 9 Minutes Writing.

Question 10 (1 mark)

Which of the following substances might one expect to exhibit the weakest intermolecular forces?

A. HCl

B. He

C. NH_3

D. H_2O

Question 11 (1 mark)

Rank HCl, He, NH_3 and H_2O in increasing the strength of intermolecular bonds.

He < HCl < NH_3 < H_2O

Question 12 (1 mark)

What do you think is the difference between H_2O is a liquid versus when it's a gas, such as in steam, with regards to its intermolecular bonds?

A. The intermolecular bonding between H_2O molecules in liquid form will be weaker than when it's a gas, as the gas expands to a larger volume.

B. There is no difference with regard to its intermolecular bonds since the change is a physical change.

C. The intermolecular bonding between H_2O molecules will overall be much weaker when it's a gas compared to when it's a liquid.

D. The dispersion forces will remain in H_2O when it's a gas, but all the hydrogen bonds and dipole-dipole attractions will disappear because of the change of state.

Question 13 (7 marks)

Andrew is analysing several pairs of molecules and is a bit confused when he sees that they have different boiling points.

a. He notices that two noble gases, helium and argon, have boiling points of −269°C and −186°C respectively. Explain the large difference in their boiling points. (3 marks)

- He & Ar can only have dispersion forces
- Ar is larger than He ∴ more electrons → Ar has stronger disp forces
- ∴ Ar has more thermal energy to break bonds
- ∴ Ar has higher B.P (−186°C)

b. Both Kr (boiling point −152°C) and HBr (boiling point −67°C) have the same number of electrons. Explain what factors could affect intermolecular forces to cause the difference in boiling points between Kr and HBr. (2 marks)

- Kr only has dispersion forces
- HBr → polar → it also has dipole–dipole → these are stronger
- ∴ HBr has more thermal energy to break bonds.

c. He also notices that HCl has more electrons than HF so we would expect it to have a higher boiling point. However, this is not the case, as the boiling points of HCl and HF are −83.7°C and 19.4°C respectively. Explain what factors could account for this reversal in trend. (2 marks)

- HF → more polar ↑ e- neg difference
- ∴ HF stronger dipole-dipole
& HF also form H-bonds, stronger...
- ∴ HF ↑ thermal energy.

Let's take a BREAK!

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Section F: VCAA-Level Questions I (15 Marks)

INSTRUCTION: 15 Marks. 30 Seconds Reading. 14 Minutes Writing.

Question 14 (8 marks)

a. Compare the intermolecular bonding strength of CH_3Cl and CH_3OH, stating their similarities and differences. (3 marks)

Similarities:

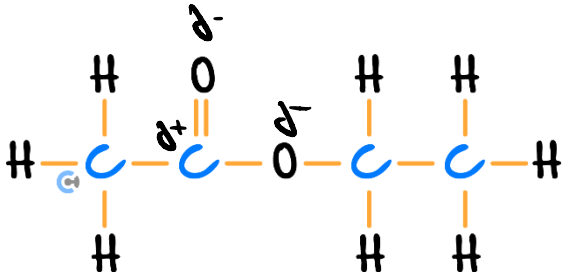
- Polar → dipole-dipole.

Differences

- CH_3OH has hydrogen bonds, CH_3Cl won't

∴ CH_3OH has stronger intermolecular bonds

b. Below is a molecule of ethyl ethanoate. What sort of intermolecular bonds can it make with itself? (1 mark)



dispersion forces, dipole-dipole

c. Explain why it can or cannot make hydrogen bonds with itself. (2 marks)

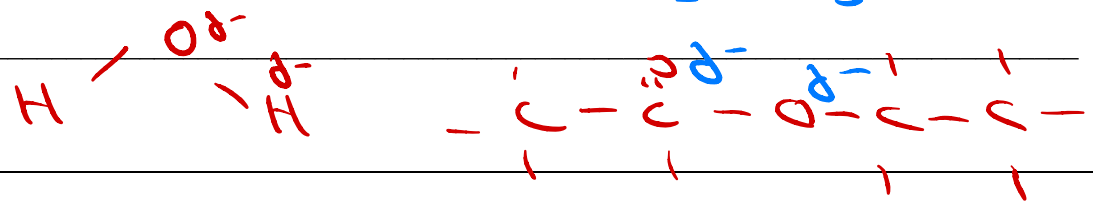
- there is NO H covalently bonded to F, O, N

- ∴ there are no exposed hydrogens

d. Is there a situation in which it can actually form hydrogen bonds? Justify your answer with an example. (2 marks)

• Yes → ethyl ethanoate can interact with a molecule that has H - FON

• e.g bond with H_2O, NH_3, CH_3OH

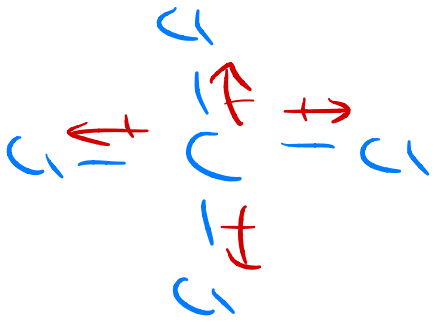


Question 15 (7 marks)

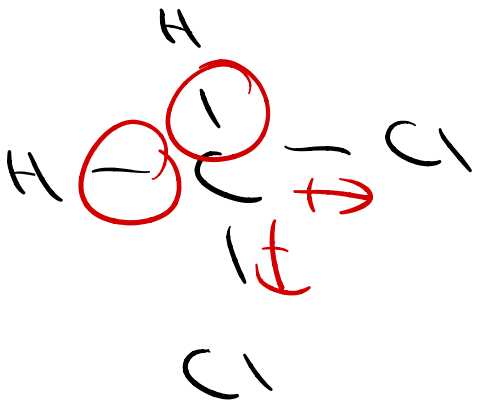
Dichloromethane (CH_2Cl_2) and carbon tetrachloride (CCl_4) both contain carbon-chlorine bonds.

a. Draw the structure of:

i. Carbon tetrachloride (CCl_4), and draw the polarity arrows, if any. (2 marks)



ii. Dichloromethane (CH_2Cl_2), and draw the polarity arrows, if any. (2 marks)



b. Explain which substance is likely to have a greater melting point. (3 marks)

- CH_3Cl → polar ∴ strong dipole-dipole
- CCl_4 → non-polar ∴ weak disp forces
- ∴ CH_3Cl ↑ thermal energy to weaken bonds.

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Section G: Multiple Choice Questions (8 Marks)

INSTRUCTION: 8 Marks. 8 Minutes Writing.

Question 16 (1 mark)

What is false about dispersion forces?

A. Dispersion forces occur when dipoles form in molecules from the electrons fixed on one side more than the other side.

B. Dispersion forces occur when instantaneous dipoles form in molecules from the electrons gathering more to one side.

C. Dispersion forces exist in all molecules.

D. Dispersion forces are the weakest form of intermolecular bonding.

Question 17 (1 mark)

Dipole-dipole attractions are one type of intermolecular bonding that can exist between molecules. Which one of the following statements is true?

A. Dipole-dipole attractions occur between temporary dipoles caused by the electronegativity difference between the molecules involved.

B. The strength of dipole-dipole attractions depends on the size or length of the molecules involved.

C. Dipole-dipole attractions are formed using at least one dipole.

D. The strength of dipole-dipole attractions depends on the polarity of the molecules involved.

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Question 18 (1 mark)

Which of the following molecules does not form hydrogen bonds with itself?

A. NH_3

B. HF

C. HCl

D. HCOOH

Question 19 (1 mark)

Which one of the following explanations is the most correct as to why CH_4 has weaker intermolecular bonding than CH_3OH?

A. CH_3OH has a larger size than CH_4 there it will have stronger dispersion forces

B. CH_3OH can form dipole-dipole attractions, whereas CH_4 cannot, therefore CH_3OH will have stronger intermolecular bonding.

C. The CH_3OH molecule can form dipole-dipole attractions and hydrogen bonds on top of dispersion forces, therefore it will have stronger intermolecular bonding than CH_4 which can only form dispersion forces.

D. The CH_3OH molecule can form hydrogen bonds with itself, whereas CH_4 can only form dispersion forces, therefore CH_3OH will have stronger intermolecular bonding.

Question 20 (1 mark)

When we are comparing the intermolecular bonding strengths of two non-polar molecules, what factors do we need to consider?

A. Dispersion forces, ion-dipole attractions.

B. How many F, O, N it has, the difference in electronegativity, the size/length of the molecule.

C. The size/length of the molecule.

D. The size/length of the molecule, how many F, O, N it has.

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Question 21 (1 mark)

Which of the following statements is completely false about any molecule that contains oxygen, given that it is polar?

A. The molecule will form dispersion forces with itself.

B. The molecule will form dispersion forces and dipole-dipole attractions with itself.

C. The molecule will form dispersion forces, dipole-dipole attractions and hydrogen bonding with itself.

D. The molecule has a net dipole.

Question 22 (1 mark)

Is it possible for a non-polar molecule with only dispersion forces to have stronger intermolecular bonding than another polar molecule with dipole-dipole attraction?

A. Yes, because if the non-polar molecule has an electronegative atom it could rival the polar molecule in its electronegativity.

B. Yes, because if the dispersion forces are much, much stronger than the dipole-dipole attractions, such as if the non-polar molecule is a lot larger than the polar molecule.

C. No, because the magnitude of the difference between dispersion forces and dipole-dipole attractions is too great, as such the dispersion forces would never catch up.

D. No, because the polar molecule has dispersion forces on top of its dipole-dipole attractions, therefore it would overtake the non-polar molecule every time.

Question 23 (1 mark)

What's the most plausible reason that hydrogen bonds are only formed when fluorine, oxygen or nitrogen is involved?

A. The other elements don't have enough valence electron shells that are required to create a strong hydrogen bond.

B. The other elements don't have a large enough electronegativity that is required to create the strong hydrogen bond.

C. For a hydrogen bond to be created, only the non-metals in that period can bond with hydrogen to create them.

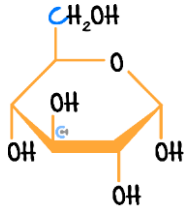
D. The other elements don't have the same effective nuclear charge that is required to create the strong hydrogen bond.

Section H: VCAA-Level Questions II (10 Marks)

INSTRUCTION: 10 Marks. 30 Seconds Reading. 9 Minutes Writing.

Question 24 (6 marks)

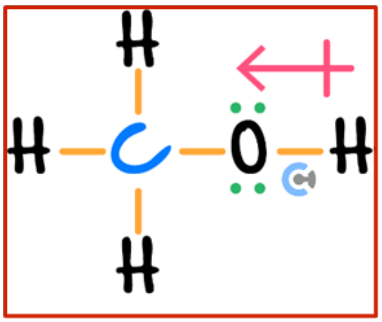
Consider the following molecule of glucose, the simplest carbohydrate, or sugar, that you can eat. Below is a skeletal structure of glucose, where each intersection of the line represents a carbon.



a. Would you expect glucose to be polar or non-polar? Justify your answer with reference to the structure of glucose. (2 marks)

Glucose would be polar as it has multiple groups of electronegative oxygens attached to hydrogens, meaning it would pull electrons closer towards itself, and as this occurs numerous times, there would be a net dipole occurring for glucose. Hence it is polar.

b. Methanol is also compared, which has the following Lewis Structure.



i. Draw the polarity arrow on methanol. (1 mark)

ii. Compare the intermolecular bonding strength of glucose compared to methanol CH_3OH, nothing down both similarities and differences. (3 marks)

Both molecules have the ability to form dispersion forces, dipole dipole attractions and hydrogen bonds because of the presence of the polar O-H bond. However, as glucose is a larger molecule than methanol, we see that glucose has stronger dispersion forces than methanol.

In addition, as glucose has multiple O-H bonds, this would give glucose to form more dipole dipole attractions and hydrogen bonds when compared to the CH_3OH with just one O-H bond. As such, we see that overall, glucose has a much stronger intermolecular bond strength compared to methanol.

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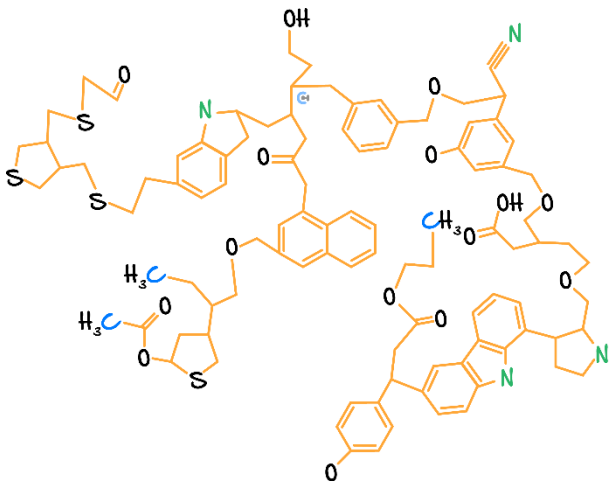
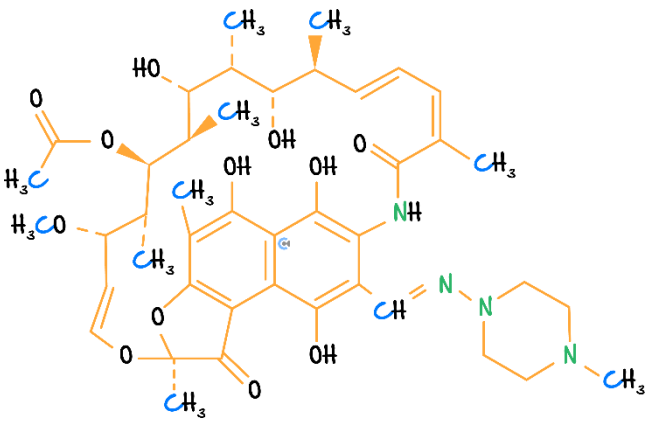
Question 25 (4 marks)

The two molecules are observed below.

Molecule *A*	Molecule *B*
	

Which one of these molecules is likely to have a greater melting point, given that they have roughly the same number of electrons? Justify your answer.

Molecule B – if they both have the same amount of electrons ,they have roughly the same strength of dispersion forces. However, molecule B contains a lot of OH and O, which can undergo stronger hydrogen bonding. As a result, more energy is required to vibrate and weaken the intermolecular bonds in molecule B, thus leading to its greater melting point.

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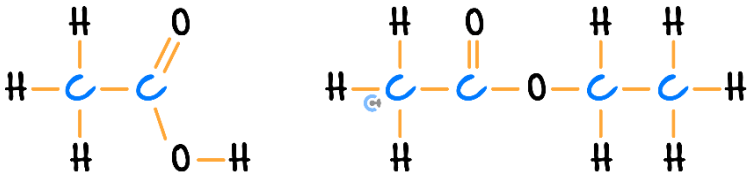
Section I: Extension Questions (9 Marks)

Question 26 (7 marks)

Consider the molecule of ethanoic acid (left) and ethyl ethanoate (right).



a. The types of intermolecular bonds within each of the two molecules are investigated.

i. Which molecule would have stronger **dispersion forces** with itself? Justify your answer. (2 marks)

Ethyl ethanoate would have stronger dispersion forces as it is a larger molecule than ethanoic acid.

ii. Which molecule would have stronger **dipole-dipole attractions** and **hydrogen bonds** with itself? Justify your answer. (2 marks)

Ethanoic acid would have stronger dipole-diople attractions and hydrogen bonds with itself. Ethanoic acid can form both hydrogen bonds and dipole dipole attractions with itself due to the O-H bond whereas ethyl ethanoate can only form dipole dipole attractions but not hydrogen bonds due to a lack of H bonded to an electronegative atom.

b. Is the difference in the strength of the dispersion forces between ethanoic acid and ethyl ethanoate more significant than the difference in the strength of the polar intermolecular bonding between the two molecules? (2 marks)

As ethyl ethanoate does have stronger dispersion forces, they are inherently very weak and so this difference is fairly insignificant. Hence it would not make a difference since the difference in dipole dipole attractions and hydrogen bond is much greater.

c. Hence, which molecule would have an overall stronger intermolecular bond strength? (1 mark)

Ethanoic Acid

Question 27 (2 marks)

Methanol and ethanol have the formulas CH_3OH and CH_3CH_2OH. Predict which has the higher boiling point and give clear reasons why.

Ethanol - even though CH_3OH is more polar overall, ethanol is a bigger molecule, and thus undergoes stronger dispersion forces overall. As such, more heat energy is required to vibrate and break the bonds, resulting in a higher boiling point

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