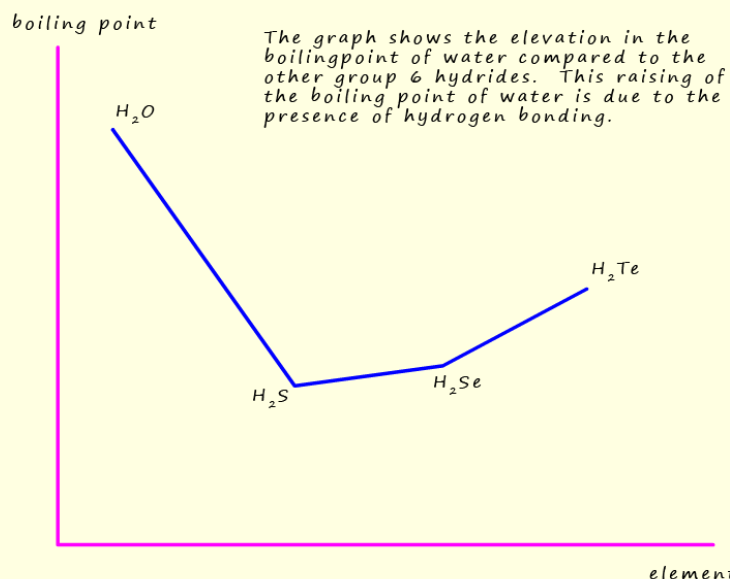


Answer the questions below then check your answers.

1. Which type of intermolecular bonding is the strongest?
 - a. What is a hydrogen bond?
 - b. What atoms must a hydrogen atom be bonded to before it can form hydrogen bonds?
 - c. Explain why ammonia (NH_3) can form hydrogen bonds but methane (CH_4) cannot.
2. Draw a diagram to show how hydrogen bonds form in water and ammonia.
 - a. How many atoms are involved in forming a hydrogen bond in water?
 - b. How are the atoms which form the hydrogen bonds in water arranged?
 - c. Why are alcohols generally more soluble in water than alkanes of similar size?
3. The graph opposite shows the trends in the boiling points of the group 6 hydrides.
 - a. What is unusual about the boiling point of water when



compared to the other hydrides in group 6?

- b. Account for the high boiling point of water.
5. Ethanol (C_2H_5OH) has a boiling point of $78^\circ C$, while butane (C_4H_8) has a boiling point of $-1^\circ C$ despite the fact it is a larger molecule. Suggest why the boiling point of ethanol is higher than butane.
 - a. Draw a diagram to show how 3 ethanol molecules can form hydrogen bonds to each other. Draw a similar diagram to show how ethanoic acid molecules can form a dimer.
6. Ammonia gas is very soluble in water. Suggest a reason for this.
7. Why is ice less dense than water?

Answers

1. Which type of intermolecular bonding is the strongest?

Hydrogen bonding

b. What is a hydrogen bond?

A special type of dipole-dipole interaction where a hydrogen atom bonded to a highly electronegative atom (N, O, F) experiences attraction towards a lone pair on another highly electronegative atom (N, O, F)

2. What atoms must a hydrogen atom be bonded to before it can form hydrogen bonds?

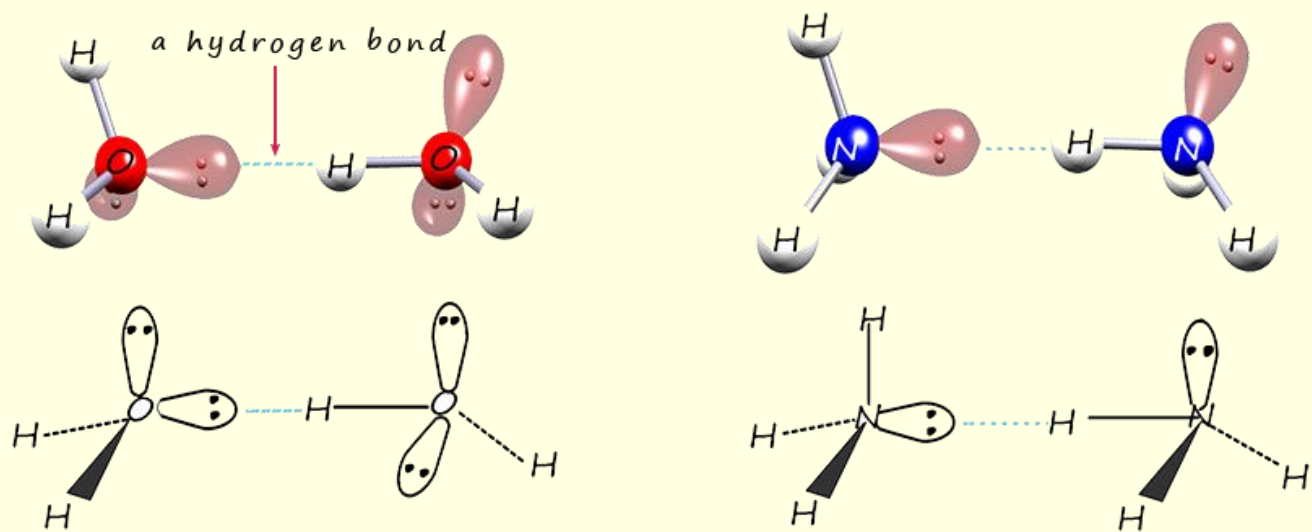
N,O,F - nitrogen, oxygen or fluorine atoms

b. Explain why ammonia (NH_3) can form hydrogen bonds but methane (CH_4) cannot.

Ammonia has a highly electronegative nitrogen atom bonded to hydrogen, creating a significant dipole.

Methane lacks a highly electronegative atom; the C-H bond has minimal polarity.

3. Draw a diagram to show how hydrogen bonds form in water and ammonia.



a. How many atoms are involved in forming a hydrogen bond in water?

3 atoms and 1 lone pair of electrons

b. How are the atoms which form the hydrogen bonds in water arranged?

The 3 atoms and the lone pair involved in forming the hydrogen bond must all be in a straight line with each other.

c. Why are alcohols generally more soluble in water than alkanes of similar size?

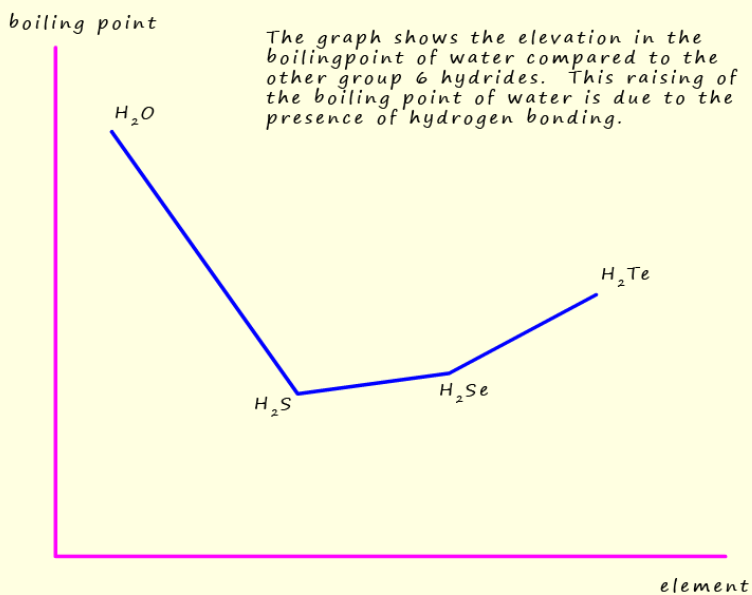
Alcohols can form hydrogen bonds with water molecules, increasing their interaction and solubility.

Alkanes can only experience weaker van der Waals forces with water, leading to lower solubility.

4. The graph opposite shows the trends in the boiling points of the group 6 hydrides.

a. What is unusual about the boiling point of water when compared to the other hydrides in group 6?

Having the smallest hydride molecule in group 6 we would expect water to have the lowest boiling point, not the highest.



b. Account for the high boiling point of water.

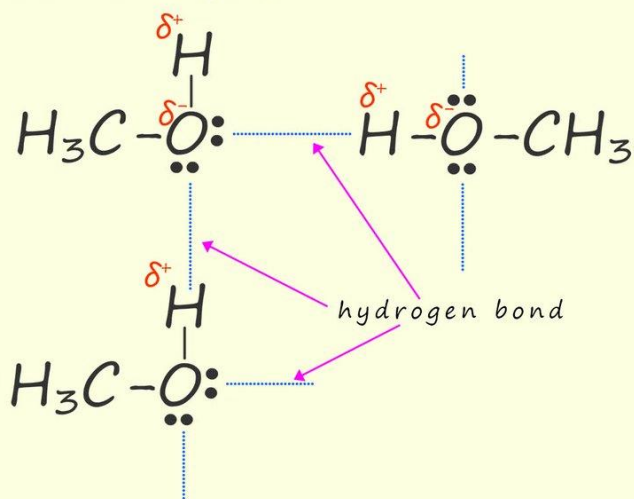
Water has hydrogen bonding present between the molecules, the other hydrides will have Van der Waals (London dispersion forces) or dipole-dipole bonding between the molecules.

5. Ethanol (C₂H₅OH) has a boiling point of 78°C, while butane (C₄H₈) has a boiling point of -1°C despite the fact it is a larger molecule. Suggest why the boiling point of ethanol is higher than butane.

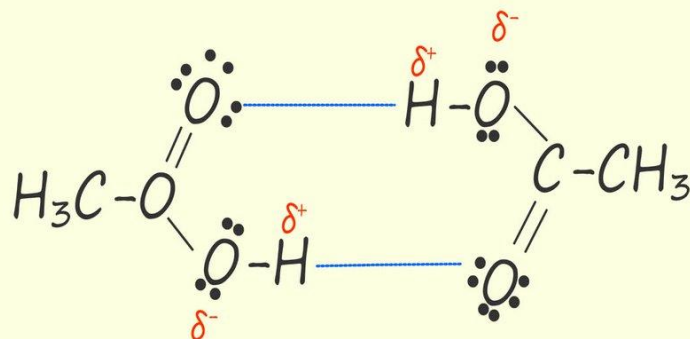
Ethanol molecules have hydrogen bonding between them, butane being a hydrocarbon has non-polar C-H bonds, so will have weak Van der Waals (dispersion forces) bonding between the molecules

a. Draw a diagram to show how 3 ethanol molecules can form hydrogen bonds to each other. Draw a similar diagram to show how ethanoic acid molecules can form a dimer.

Hydrogen bonding in the alcohol
methanol (CH_3OH)



hydrogen bonding in ethanoic acid



Alcohols and carboxylic acids both contain a $-\text{OH}$ group and so both these molecules can exhibit hydrogen bonding.

6. Ammonia gas is very very soluble in water. Suggest a reason for this.

In order for a solute to dissolve it must be able to interact with the solvent in some way, the ammonia molecule can form strong hydrogen bonds to the water molecules.

7. Why is ice less dense than water?

In order to form the ice structure the water molecules are not as densely packed as they are in water, this explains why ice is less dense than water and floats on it. It is easy to see when you look at the ice structure how open it is. This is a very unusual property since for most substances the solid state is more dense than the liquid state.