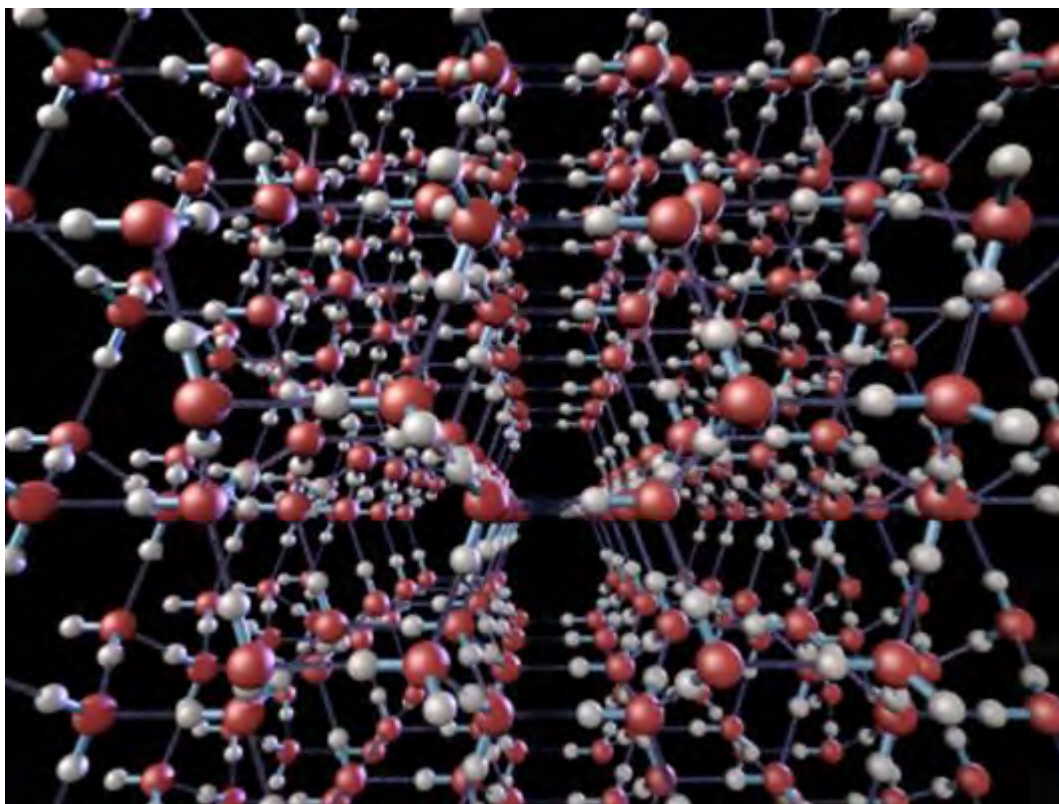


**Q1.** Water can be found as ice, water and steam.

- (a) The following diagram shows the arrangement of some of the water molecules in a crystal of ice.



With reference to the structure shown above give **one** reason why ice is less dense than water.

.....

.....

.....

(1)

- (b) Water and methane have similar relative molecular masses and both contain the element hydrogen.  
The table below gives some information about water and methane.

	H <sub>2</sub> O	CH <sub>4</sub>
<i>M<sub>r</sub></i>	18.0	16.0

Melting point / K	273	91
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- (i) State the strongest type of intermolecular force holding the water molecules together in the ice crystal.

.....

(1)

- (ii) State the strongest type of intermolecular force in methane.

.....

(1)

- (iii) Give **one** reason why the melting point of ice is higher than the melting point of methane.

.....

.....

.....

(1)

- (c) A molecule of  $\text{H}_2\text{O}$  can react with an  $\text{H}^+$  ion to form an  $\text{H}_3\text{O}^+$  ion.

- (i) Draw and name the shape of the  $\text{H}_3\text{O}^+$  ion. Include any lone pairs of electrons.

Shape of the  $\text{H}_3\text{O}^+$  ion

Name of shape .....

(2)

- (ii) Suggest a value for the bond angle in the  $\text{H}_3\text{O}^+$  ion.

.....

(1)

- (iii) Identify **one** molecule with the same number of atoms, the same number of electrons and the same shape as the  $\text{H}_3\text{O}^+$  ion.

.....

(1)

- (d) Water can also form the hydroxide ion.  
State the number of lone pairs of electrons in the hydroxide ion.

.....

(1)

(Total 9 marks)

**Q2.** Fluorine forms many compounds that contain covalent bonds.

- (a) (i) State the meaning of the term *covalent bond*.

.....

.....

(1)

- (ii) Write an equation to show the formation of one molecule of  $\text{ClF}_3$  from chlorine and fluorine molecules.

.....

(1)

- (b) Draw the shape of a dichlorodifluoromethane molecule ( $\text{CCl}_2\text{F}_2$ ) and the shape of a chlorine trifluoride molecule ( $\text{ClF}_3$ ). Include any lone pairs of electrons that influence the shape.

Shape of  $\text{CCl}_2\text{F}_2$

Shape of  $\text{ClF}_3$

(2)

(c) Suggest the strongest type of intermolecular force between  $\text{CCl}_2\text{F}_2$  molecules.

.....

(1)

(d)  $\text{BF}_3$  is a covalent molecule that reacts with an  $\text{F}^-$  ion to form a  $\text{BF}_4^-$  ion.

(i) Name the type of bond formed when a molecule of  $\text{BF}_3$  reacts with an  $\text{F}^-$  ion. Explain how this bond is formed.

Type of bond .....

Explanation .....

.....

.....

.....

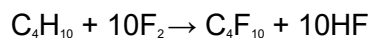
(3)

(ii) State the bond angle in the  $\text{BF}_4^-$  ion

.....

(1)

(e) An ultrasound imaging agent has the formula  $\text{C}_4\text{F}_{10}$ . It can be made by the reaction of butane and fluorine as shown in the following equation.



Calculate the percentage atom economy for the formation of  $\text{C}_4\text{F}_{10}$  in this reaction. Give your answer to three significant figures.

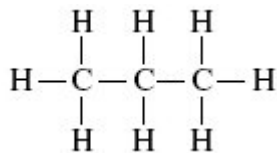
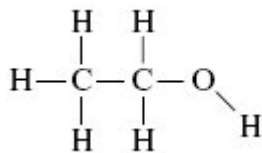
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(2)

(Total 11 marks)

- Q3.** (a) Two organic compounds with similar relative molecular masses are shown below.



Ethanol

Propane

- (i) State the type of bond present between the C and H atoms in both of these molecules. Explain how this type of bond is formed.

Type of bond .....

Explanation .....

(2)

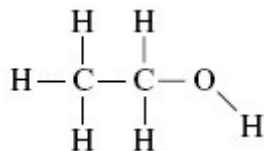
- (ii) State the strongest type of intermolecular force present in each compound.

Liquid ethanol .....

Liquid propane .....

(2)

- (b) Ethanol dissolves in water. Draw a diagram to show how one molecule of ethanol interacts with one molecule of water in the solution. Include partial charges and all lone pairs. The ethanol molecule has been drawn for you.



(3)

(c) Ethanol was the fuel used in the first mass-produced car, the Model T Ford.

(i) Write an equation which shows how ethanol burns completely in air to form carbon dioxide and water as the only products.

.....

(1)

(ii) Suggest **one** environmental problem caused by incomplete combustion of ethanol in a car engine.

.....

.....

(1)

(iii) Suggest **one** economic problem for the car user caused by incomplete combustion of ethanol in the car engine.

.....

.....

(1)

(d) Propane is also used as a fuel, although sometimes it can be contaminated with sulfur-containing impurities. When this propane burns, these impurities form sulfur dioxide.

(i) State how the sulfur dioxide can be removed from the waste gases produced when this propane is burned on a large scale in industry. Suggest a reason why the method you have stated may not be 100% efficient.

How removed .....

.....

Reason for less than 100% efficiency .....

.....

(2)

(ii) Although propane has a boiling point of  $-42\text{ }^{\circ}\text{C}$ , it is usually supplied as a liquid for use in camping stoves. Suggest why it is supplied as a liquid.

.....

**Q4.** The table below shows the boiling points of some hydrogen compounds formed by Group 6 elements.

	H <sub>2</sub> O	H <sub>2</sub> S	H <sub>2</sub> Se	H <sub>2</sub> Te
Boiling point / K	373	212	232	271

(a) State the strongest type of intermolecular force in water and in hydrogen sulfide (H<sub>2</sub>S).

Water .....

Hydrogen sulfide .....

.....

(2)

(b) Draw a diagram to show how two molecules of water are attracted to each other by the type of intermolecular force you stated in part (a). Include partial charges and all lone pairs of electrons in your diagram.

(3)

(c) Explain why the boiling point of water is much higher than the boiling point of hydrogen sulfide.

.....

.....

(1)

(d) Explain why the boiling points increase from  $\text{H}_2\text{S}$  to  $\text{H}_2\text{Te}$

.....  
.....

(2)

(e) When  $\text{H}^+$  ions react with  $\text{H}_2\text{O}$  molecules,  $\text{H}_3\text{O}^+$  ions are formed.

Name the type of bond formed when  $\text{H}^+$  ions react with  $\text{H}_2\text{O}$  molecules.  
Explain how this type of bond is formed in the  $\text{H}_3\text{O}^+$  ion.

Type of bond .....

Explanation .....

.....

(2)

(f) Sodium sulfide ( $\text{Na}_2\text{S}$ ) has a melting point of 1223 K.  
Predict the type of bonding in sodium sulfide and explain why its melting point is high.

Type of bonding .....

Explanation .....

.....

.....

(3)

(Total 13 marks)