

**Q16.**

The following equation shows the reaction of a phosphine molecule (PH<sub>3</sub>) with an H<sup>+</sup> ion.



- (a) Draw the shape of the PH<sub>3</sub> molecule. Include any lone pairs of electrons that influence the shape.

(1)

- (b) State the type of bond that is formed between the PH<sub>3</sub> molecule and the H<sup>+</sup> ion. Explain how this bond is formed.

Name of bond \_\_\_\_\_

How bond is formed \_\_\_\_\_

\_\_\_\_\_

(2)

- (c) Predict the bond angle in the PH<sub>4</sub><sup>+</sup> ion.

\_\_\_\_\_

(1)

- (d) Although phosphine molecules contain hydrogen atoms, there is no hydrogen bonding between phosphine molecules. Suggest an explanation for this.

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

(1)

**(Total 5 marks)**

**Q17.**

Fluorine forms compounds with many other elements.

- (a) Fluorine reacts with bromine to form liquid bromine trifluoride ( $\text{BrF}_3$ ).  
State the type of bond between Br and F in  $\text{BrF}_3$  and state how this bond is formed.

Type of bond \_\_\_\_\_

How bond is formed \_\_\_\_\_

\_\_\_\_\_

(2)

- (b) Two molecules of  $\text{BrF}_3$  react to form ions as shown by the following equation.



- (i) Draw the shape of  $\text{BrF}_3$  and predict its bond angle.  
Include any lone pairs of electrons that influence the shape.

Shape of  $\text{BrF}_3$

Bond angle \_\_\_\_\_

(2)

- (ii) Draw the shape of  $\text{BrF}_4^-$  and predict its bond angle.  
Include any lone pairs of electrons that influence the shape.

Shape of  $\text{BrF}_4^-$

Bond angle \_\_\_\_\_

(2)

- (c)  $\text{BrF}_4^-$  ions are also formed when potassium fluoride dissolves in liquid  $\text{BrF}_3$  to form  $\text{KBrF}_4$ .  
Explain, in terms of bonding, why  $\text{KBrF}_4$  has a high melting point.

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

**(3)**

(d) Fluorine reacts with hydrogen to form hydrogen fluoride (HF).

(i) State the strongest type of intermolecular force between hydrogen fluoride molecules.

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**(1)**

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

**(3)**

(e) The boiling points of fluorine and hydrogen fluoride are  $-188\text{ }^{\circ}\text{C}$  and  $19.5\text{ }^{\circ}\text{C}$  respectively. Explain, in terms of bonding, why the boiling point of fluorine is very low.

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**(2)****(Total 15 marks)****Q18.**

Fluorine and iodine are elements in Group 7 of the Periodic Table.

(a) Explain why iodine has a higher melting point than fluorine.

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**(2)**



- (b) (i) Draw the shape of the  $\text{NHF}_2$  molecule and the shape of the  $\text{BF}_3$  molecule.

Include any lone pairs of electrons that influence the shape. In each case name the shape.

Shape of  $\text{NHF}_2$

Shape of  $\text{BF}_3$

Name of shape of  $\text{NHF}_2$  \_\_\_\_\_

Name of shape of  $\text{BF}_3$  \_\_\_\_\_

(4)

- (ii) Suggest a value for the  $\text{F—N—F}$  bond angle in  $\text{NHF}_2$

\_\_\_\_\_

(1)

- (c) State the strongest type of intermolecular force in a sample of  $\text{NHF}_2$

\_\_\_\_\_

(1)

- (d) A molecule of  $\text{NHF}_2$  reacts with a molecule of  $\text{BF}_3$  as shown in the following equation.



State the type of bond formed between the N atom and the B atom in  $\text{F}_2\text{HNBF}_3$ .

Explain how this bond is formed.

Name of type of bond \_\_\_\_\_

How bond is formed \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

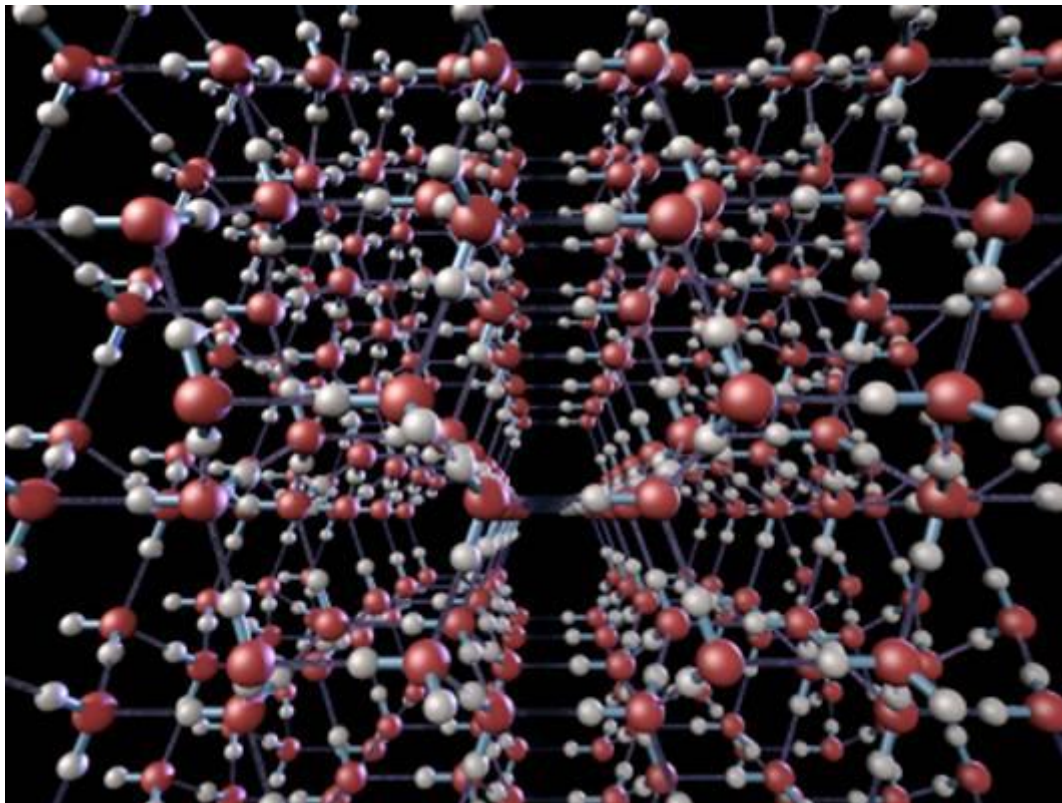
(2)

(Total 10 marks)

**Q19.**

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.

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(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>
$M_r$	18.0	16.0
Melting point / K	273	91



- (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)

**Q20.**

Fluorine forms many compounds that contain covalent bonds.

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

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(1)

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

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(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.

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(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 \_\_\_\_\_

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(3)

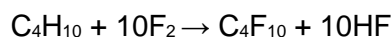


- (ii) State the bond angle in the  $\text{BF}_4^-$  ion

\_\_\_\_\_

(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.

\_\_\_\_\_

\_\_\_\_\_

(2)

(Total 11 marks)

### Q21.

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

	$\text{H}_2\text{O}$	$\text{H}_2\text{S}$	$\text{H}_2\text{Se}$	$\text{H}_2\text{Te}$
Boiling point / K	373	212	232	271

- (a) State the strongest type of intermolecular force in water and in hydrogen sulfide ( $\text{H}_2\text{S}$ ).

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.

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(1)

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

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(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 \_\_\_\_\_

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(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 \_\_\_\_\_

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(3)

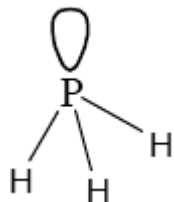
(Total 13 marks)



## Mark Scheme

### Q16.

(a)



*Need to see 3 P–H bonds and one lone pair (ignore shape).*

1

(b) Coordinate / dative

*If not coordinate / dative then chemical error CE=0 unless blank or covalent then M1 = 0 and mark on.*

1

Pair of electrons on P(H<sub>3</sub>) donated (to H<sup>+</sup>)

*Do not allow a generic description of a coordinate bond.*

1

(c) 109.5° / 109½° / 109° 28'

*Allow answers in range between 109° to 109.5°*

1

(d) Difference in electronegativity between P and H is too small

*Allow P not very electronegative / P not as electronegative as N, O and F / P not electronegative enough / P not one of the 3 most electronegative elements.*

*Do not allow phosphine is not very electronegative.*

1

[5]

### Q17.

(a) Covalent

*If not covalent CE = 0/2*

*If dative covalent CE = 0/2*

*If blank mark on*

*Ignore polar*

*If number of pairs of electrons specified, must be 3*

1

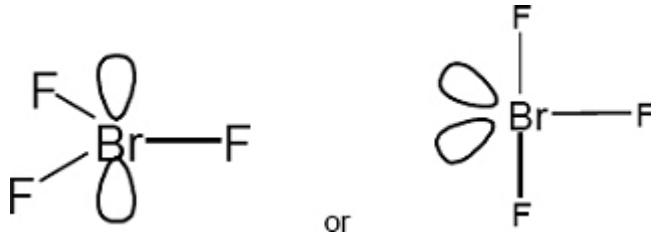
Shared pair(s) of electrons / one electron from Br and one electron from F

*Not 2 electrons from 1 atom*

*Not shared pair between ions/molecules*

1

(b) (i)



or

$BrF_3$  should have 3 bp and 2 lp and correct atoms for the mark

Penalise Fl

1

$BrF_3$  if trigonal planar shown =  $120^\circ$

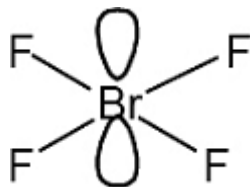
Allow  $84 - 90^\circ$  or  $120^\circ$  and ignore  $180^\circ$

or if T shape shown  $84 - 90^\circ$

Irrespective of shape drawn

1

(ii)



$BrF_4^-$  should have 4 bp and 2 lp and all atoms for the mark (ignore sign)

Allow Fl

1

$BrF_4^-$   $90^\circ$

Only

Ignore  $180^\circ$

1

(c) Ionic or (forces of) attraction between ions / bonds between ions

If molecules, IMF, metallic, CE = 0

If covalent bonds mentioned, 0/3, unless specified within the  $BrF_4^-$  ion and not broken

Ignore atoms

1

Strong (electrostatic) attraction / strong bonds / lots of energy needed to break bonds

1

Between  $K^+$  and  $BrF_4^-$  ions/oppositely charged ions / + and - ions

If ions mentioned they must be correct

Strong bonds between + and - ions = 3/3

1

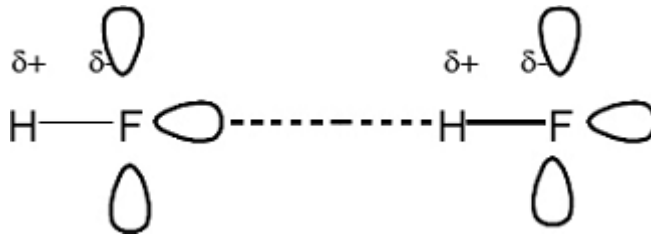
(d) (i) Hydrogen bonds/hydrogen bonding/H bonds/H bonding



Not just hydrogen

1

(ii)



One mark for 4 partial charges

One mark for 6 lone pairs

One mark for H bond from the lone pair to the H $\delta^+$

Allow FI

If more than 2 molecules are shown they must all be correct.

Treat any errors as contradictions within each marking point.

CE = 0/3 if incorrect molecules shown.

3

(e) vdw / van der Waals forces between molecules

QoL

Not vdw between HF molecules, CE = 0/2

vdw between atoms, CE = 0/2

If covalent, ionic, metallic, CE=0/2

1

IMF are weak / need little energy to break IMF / easy to overcome IMF

1

[15]

**Q18.**

(a) Iodine has more electrons / iodine is bigger (atom or molecule) / iodine has bigger  $M_r$  / bigger surface area

1

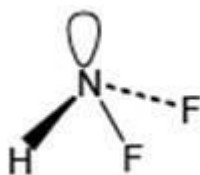
Stronger / more van der Waals forces / vdw / London / temporarily induced dipole / dispersion forces between molecules

1

Stronger VdW intermolecular forces = M2

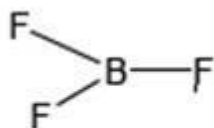
If stated VdW between atoms lose M2

(b) (i)



Mark is for 3 bp and 1 lp attached to N (irrespective of shape)

1



Mark is for 3 bp and 0 lp attached to B (irrespective of shape)

1

NHF<sub>2</sub> shape - pyramidal / trigonal pyramid  
Accept tetrahedral / triangular pyramid

1

BF<sub>3</sub> shape - trigonal planar  
Not triangular or triangular planar

1

(ii) 107°  
Allow 106-108°

1

(c) Hydrogen bonds  
Allow H-Bonds  
Not just Hydrogen  
Apply list principle eg Hydrogen bonding and dipole-dipole = 0

1

(d) Coordinate / dative covalent / dative  
If covalent mark on  
If ionic / metallic CE = 0

1

Lone pair / both electrons/ 2 electrons on N(HF<sub>2</sub>) donated (to BF<sub>3</sub>)  
Direction of donation needed here

1

[10]

### Q19.

(a) Water or H<sub>2</sub>O or molecules (in ice) are held further apart  
(than in liquid water)/(more) space/gaps/holes in structure/Water  
or H<sub>2</sub>O or molecules (in ice) are more spread out  
Allow water (liquid) is more compact/less space/gaps/holes  
CE if holes filled with air, O<sub>2</sub> etc  
CE if macromolecule  
CE if atoms further apart (since ambiguous)  
Ignore spaces filled with H<sub>2</sub>O  
Ignore reference to H bonds  
Allow better tessellation in liquid water

1

(b) (i) Hydrogen bonding  
Allow H bonds



- Do not allow 'hydrogen' only but mark on*
- 1
- (ii) Van der Waals'/VdW  
*Allow London forces, dispersion forces, temporary induced dipole forces*
- 1
- (iii) Hydrogen bonding is stronger (than van der Waals forces)/IMF in ice stronger (than IMF in methane)/H bonds take more energy to break  
*Not H Bonds are strong (needs comparison)  
If (b)(i) OR (ii) is incorrect, cannot award (b)(iii)  
If (b)(i) and/or (ii) is blank, can score (b)(iii)*
- 1
- (c) (i) Structure showing 3 bonds to H and 1 lone pair
- 1
- (trigonal) pyramid(al)/(distorted) tetrahedral  
*do not insist on the + sign  
Allow triangular pyramid  
Not square pyramid  
Ignore bond angles in structure  
M2 independent of M1*
- 1
- (ii) 107°  
*Allow range 106 – 108°  
Ignore °(C)*
- 1
- (iii) NH<sub>3</sub>/ammonia  
*Contradictions (eg NH<sub>4</sub> ammonia) CE = 0*
- 1
- (d) 3  
*Allow three/III/3 lone pairs/3lp/3 lone pairs of electrons*
- 1

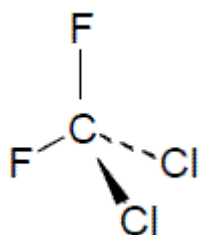
[9]

**Q20.**

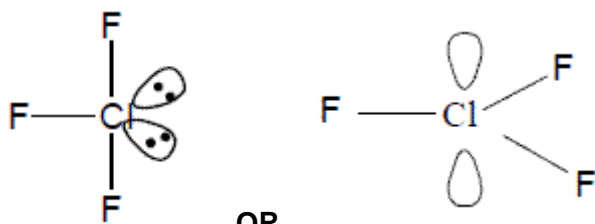
- (a) (i) shared pair of electrons  
*Can have one electron from each atom contributes to the bond  
Not both electrons from one atom*
- 1
- (ii)  $\frac{1}{2} \text{Cl}_2 + \frac{3}{2} \text{F}_2 \rightarrow \text{ClF}_3$
- 1
- Only  
Ignore state symbols even if wrong*



(b)



1



OR

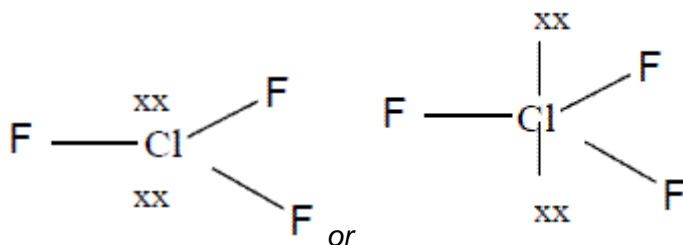
Allow any structure with 4 bp

In  $CCl_2F_2$ , watch for Cl in centre- it must be C

Ignore wrong bond angles

Representations of lone pairs allowed are the two examples shown with or without the electrons in the lobe.

Also they can show the lone pair for either structure by two crosses/dots or a line with two crosses/dots on it e.g.



Or a structure with 3 bp and 2 lp

1

(c) Dipole – dipole

Allow van der Waals/vdw/London/dispersion/temporary dipole – induced dipole

Not dipole alone

1

(d) (i) Coordinate/dative (covalent)

If wrong CE = 0/3 but if 'covalent' or left top line blank, mark on.

1

(Lone) pair of electrons/both electrons (on  $F^-$ )

CE if lone pair is from B

1

Donated from  $F^-$ /fluoride or donated to the  $BF_3$

Must have the – sign on the F ie  $F^-$

Ignore  $F^+$



*M3 dependent on M2*

1

(ii)  $109^\circ$  to  $109.5^\circ$

1

(e) 
$$\frac{238 \times 100}{438}$$

*For 1 mark allow 238 as numerator and 438 as denominator or correct strings*

1

= 54.3%

*2 marks if correct answer to 3 sig figs.  
54% or greater than 3 sig figs = 1 mark*

1

[11]

### Q21.

(a) Hydrogen/H bonds

*Not just hydrogen*

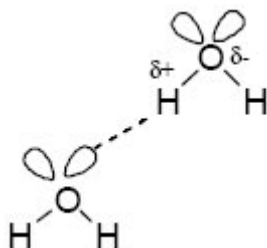
1

van der Waals/vdw/dipole-dipole/London/temporarily induced dipole/dispersion forces

*Not just dipole*

1

(b)



*M1 for partial charges as indicated in diagram (correct minimum)*

*M2 for all four lone pairs*

*M3 for H bond from the lp to the H ( $\delta^+$ ) on the other molecule*

*Lone pair on hydrogen CE = 0*

*OHO CE = 0*

*If only one molecule of water shown*

*CE = 0*

3

(c) Hydrogen bonds/IMF (in water) stronger

**OR**

IMF/VDW/dipole-dipole forces (in  $H_2S$ ) are weaker

**OR**

H bonding is the strongest IMF



	<i>Ignore energy references</i> <i>Comparison must be stated or implied</i>	1
(d)	Atoms/molecules get larger/more shells/more electrons/more surface area <i>Not heavier/greater Mr</i>	1
	therefore increased <u>Van der Waals/IMF</u> forces <i>Ignore references to dipole-dipole forces</i>	1
(e)	Dative (covalent)/coordinate <i>If not dative/coordinate CE = 0/2</i> <i>If covalent or blank read on</i>	1
	(Lone) pair/both electrons/two electrons on O(H <sub>2</sub> ) donated (to H <sup>+</sup> ) OR pair/both electrons come from O(H <sub>2</sub> ) <i>Explanation of a coordinate bond specific to oxygen or water required</i> <i>Not just H<sup>+</sup> attracted to lone pair since that is nearer to a H bond</i>	1
(f)	ionic	1
	<i>if not ionic CE = 0</i>	
	oppositely charged <u>ions/+</u> and – <u>ions or particles</u> <i>atoms or molecules loses M2 and M3</i>	1
	ions attract <u>strongly</u> OR strong/many (ionic) bonds must be broken <i>S<sup>-</sup> loses M2</i> <i>Reference to IMF loses M2 and M3</i>	1

[13]