

Starter for Ten

3. Bonding

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This resource was produced as part of the National HE STEM Programme





STARTER FOR 10...

3. BONDING

3.1. The nature of chemical bonds

- 3.1.1. Covalent dot and cross
- 3.1.2. Ionic dot and cross
- 3.1.3. Which type of chemical bond
- 3.1.4. Bonding summary

3.2. Covalent bonding

- 3.2.1. Co-ordinate bonding
- 3.2.2. Electronegativity and polarity
- 3.2.3. Intermolecular forces
- 3.2.4. Shapes of molecules

3.3. Properties and bonding

Bonding answers



STARTER FOR 10...

3.1.1. Covalent dot and cross

Draw dot and cross diagrams to illustrate the bonding in the following covalent compounds. If you wish you need only draw the outer shell electrons;

(2 marks for each correct diagram)

1. Water, H_2O

2. Carbon dioxide, CO_2

3. Ethyne, C_2H_2

4. Phosphoryl chloride, POCl_3

5. Sulfuric acid, H_2SO_4



STARTER FOR 10...

3.1.2. Ionic dot and cross

Draw dot and cross diagrams to illustrate the bonding in the following ionic compounds.

(2 marks for each correct diagram)

1. Lithium fluoride, LiF
2. Magnesium chloride, MgCl_2
3. Magnesium oxide, MgO
4. Lithium hydroxide, LiOH
5. Sodium cyanide, NaCN



STARTER FOR 10...

3.1.3. Which type of chemical bond

There are three types of strong chemical bonds; **ionic**, **covalent** and **metallic**.

1. Sort the compounds below into groups within the circles below according to their chemical bonding;

sodium chloride, NaCl

magnesium, Mg

magnesium oxide, MgO

methane, CH₄

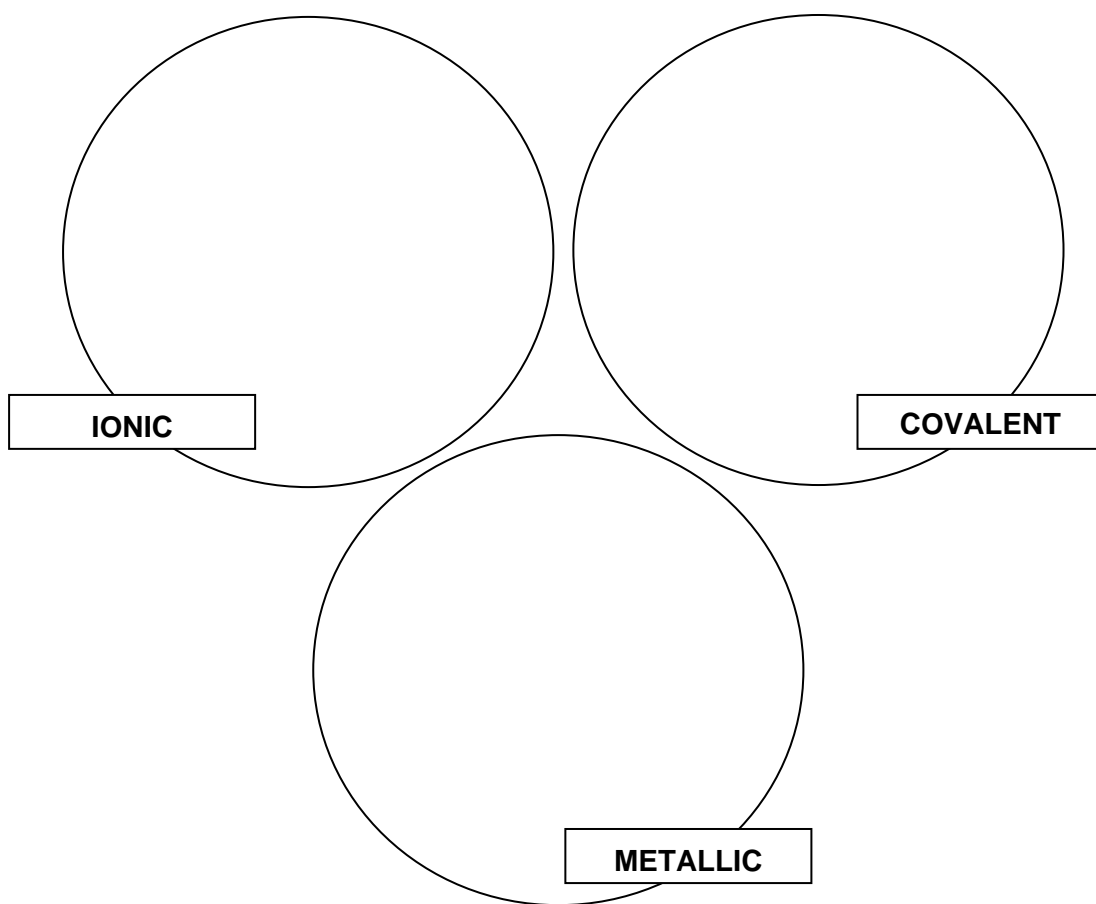
oxygen, O₂

barium iodide, BaI₂

aluminium, Al

ammonia, NH₃

caesium, Cs



2. For each of the types of compound, indicate if you would expect them to;
- (a) have a high or a low melting point
 - (b) conduct electricity



STARTER FOR 10...

3.1.4. Bonding summary

A student has written the revision cards below to help her prepare for the exam. However she has made a number of mistakes. Can you correct her cards to make sure she has accurate information to revise from;

(1 mark for each correct correction made)

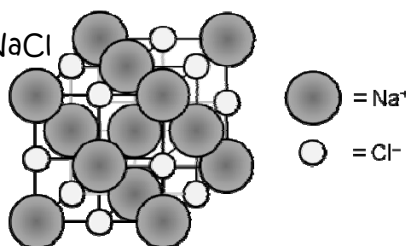
Ionic bonding

Between a metal and a non-metallic atom, e.g. NaCl

Electrons are shared between the atoms

The molecules have high melting points owing to the strong electrostatic attraction between the ions

Ionic compounds do not conduct electricity at all as the ions that carry the current are held in a fixed position in the lattice structure



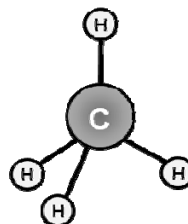
Covalent bonding

Between two non-metallic atoms, e.g. CO₂

Electrons are transferred between the atoms

Covalent molecules have high melting points because of the strong covalent bonds which must be broken

Covalent compounds do not conduct electricity at all as there are no free electrons



Metallic bonding

In metallic bonding, the outer electrons from the metal atoms merge to produce a lattice of negative metal ions in a sea of delocalised electrons

The strength of the metal depends on two things;

- the charge on the metal ion
- the size of the metal ion

Therefore sodium is stronger than magnesium

Metals have low melting points because of the repulsive forces between the negative electrons which need little energy to be broken

Metals conduct electricity because of the sea of delocalised electrons which can move through the structure to carry the charge



STARTER FOR 10...

3.2.1. Co-ordinate bonding

By drawing dot and cross diagrams, decide which of the species below contain a co-ordinate or dative covalent bond in which both electrons in one of the covalent bonds is provided by a single atom.

1. H_2S (2 marks)

2. NH_4^+ (2 marks)

3. H_3NBF_3 (2 marks)

4. CO (2 marks)

5. PF_3 (2 marks)



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3.2.2. Electronegativity and polarity

A **polar bond** is a bond in which the electrons between the atoms that are bonded together covalently are shared unequally. The unequal share of electrons is usually shown by a $\delta+$ and a $\delta-$ sign. If a molecule contains more than one polar bond, the effect of the polarity of all the bonds in the molecule may result in the molecule having a **dipole moment**.

Use the table of the Pauling electronegativity of different elements to identify any polar bonds in the molecules below. Then use these polar bonds to decide if the molecule has a dipole moment (this can be shown by an arrow with a line through it \rightarrow ; the head of the arrow points towards the negative end.)

H 2.1							He
Li 1.0	Be 1.5	B 2.0	C 2.5	N 3.0	O 3.5	F 4.0	Ne
Na 0.9	Mg 1.2	Al 1.5	Si 1.8	P 2.1	S 2.5	Cl 3.0	Ar

(2 marks per molecule)

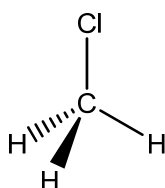
e.g. H_2O



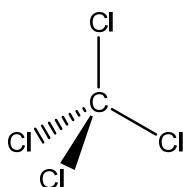
1. HCl $\text{H}-\text{Cl}$

2. CO_2 $\text{O}=\text{C}=\text{O}$

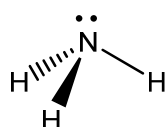
3. CH_3Cl



4. CCl_4



5. NH_3





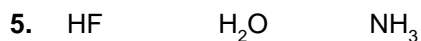
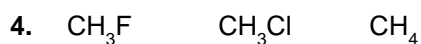
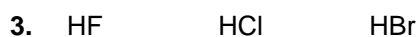
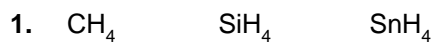
STARTER FOR 10...

3.2.3. Intermolecular forces

Molecules are attracted to each other by weak intermolecular forces. There are three types of intermolecular force;

- Van der Waal's forces
- Dipole-dipole forces
- Hydrogen bonding

For each group of molecules below, identify the strongest type of intermolecular force present in each molecule (1 mark) and then use this information to order the molecules according to their boiling point, from lowest to highest (1 mark).



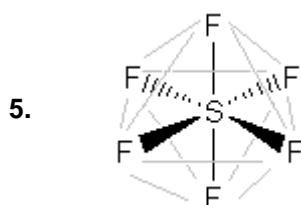
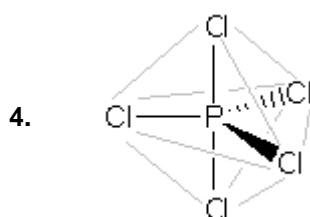
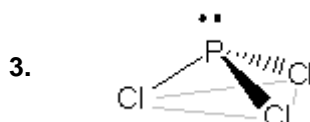
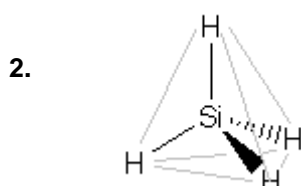
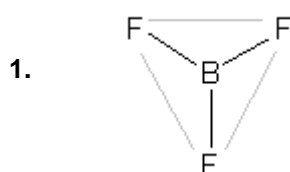


STARTER FOR 10...

3.2.4. Shapes of molecules

For this activity you need to work with a partner. The diagrams below show the 3 dimensional shapes of some different molecules. Your job is to describe the diagrams to your partner such that they can draw exact copies without seeing the original diagram. Good luck!

(2 marks awarded for each diagram your partner draws)





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3.3. Properties and bonding

Match the compound on the left to its correct structure from the middle bank of statements and one or more statements from the column on the right. Aluminium has been done for you

Compound	Structure	
aluminium	metal	Weak intermolecular forces are broken when it boils
		High melting point
diamond	simple covalent molecule	Conducts electricity when molten
		Conducts electricity when in solution
iodine	ionic compound	Conducts electricity when solid
		Low melting point
chlorine	molecular crystal	An ionic bond is broken when it melts
		A covalent bond must be broken to melt it
potassium fluoride	macromolecular crystal	

BONUS MARK Sketch the arrangement of molecules in a crystal of iodine



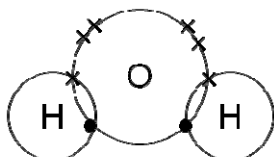
STARTER FOR 10...

3. Bonding answers

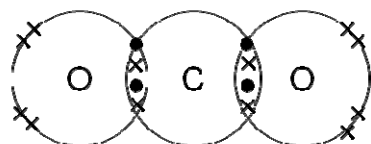
3.1. The nature of chemical bonds

3.1.1. Covalent dot and cross

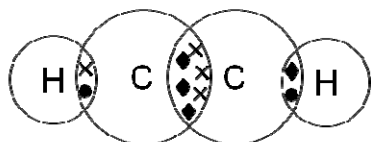
1.



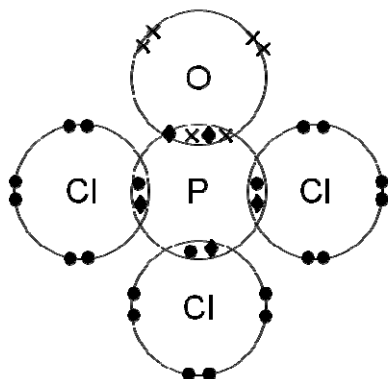
2.



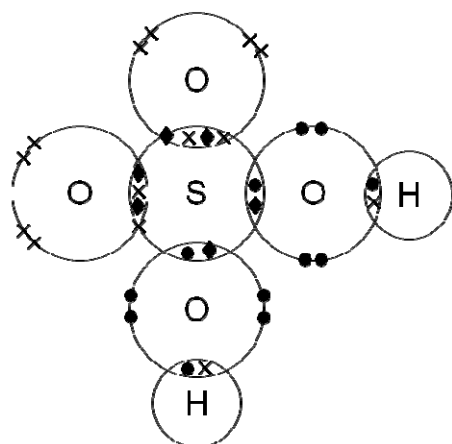
3.



4.

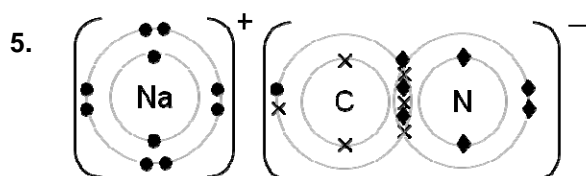
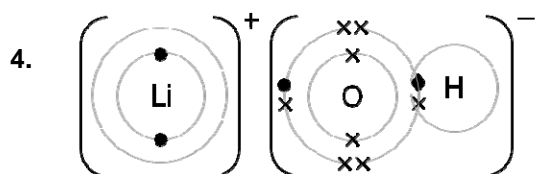
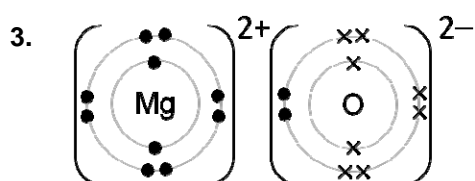
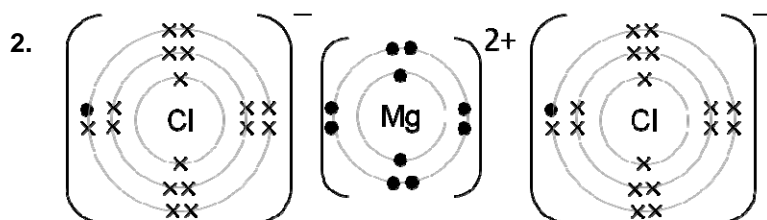
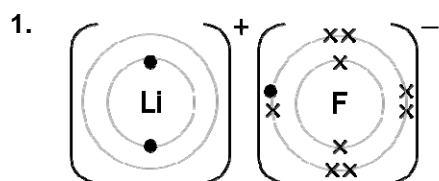


5.



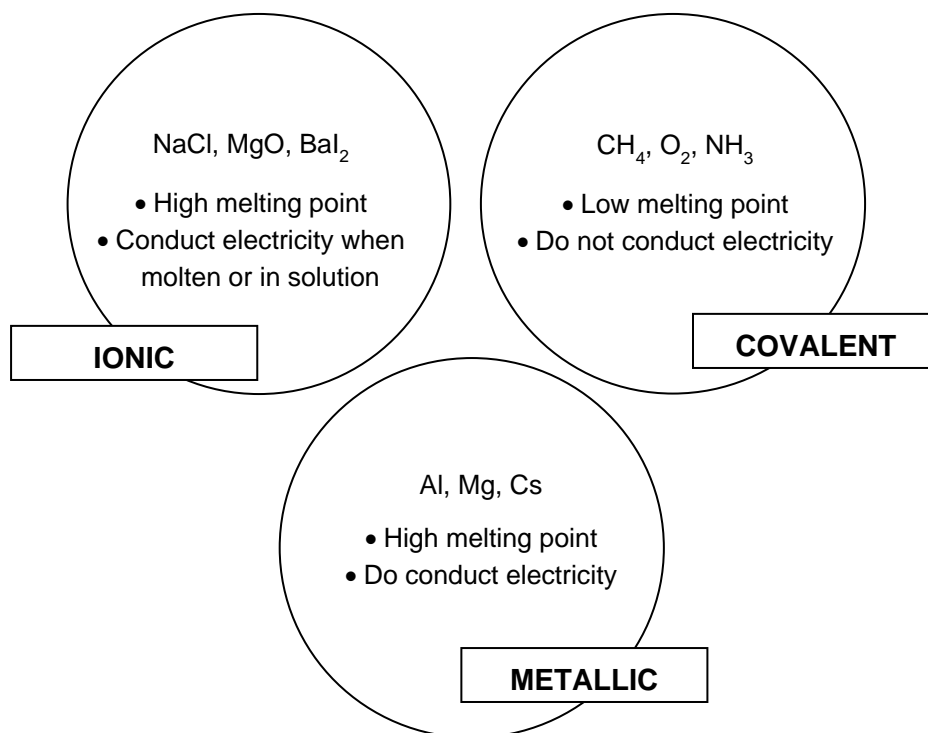
(2 marks for each diagram)

3.1.2. Ionic dot and cross



(2 marks for each diagram)

3.1.3. Types of chemical bond



(1 mark for all three of each type correctly identified;
1 mark for each of the six comments relating to melting point / conductivity;
1 bonus mark for clarifying that ionic compounds only conduct when molten or in solution)

3.1.4. Bonding summary

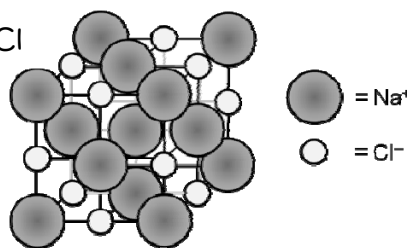
Ionic bonding

Between a metal and a non-metallic atom, e.g. NaCl

Electrons are shared between the atoms

The molecules have high melting points
owing to the strong electrostatic attraction
between the ions

Ionic compounds do not conduct electricity at all as the ions that carry the
current are held in a fixed position in the lattice structure



Corrections;

- (1 mark) In the diagram the Na⁺ ion should be smaller than the Cl⁻ ion
- (1 mark) Electrons are not shared but transferred between the atoms
- (1 mark) Ionic compounds are NOT molecules
- (1 mark) Ionic compounds can conduct electricity when molten or in solution

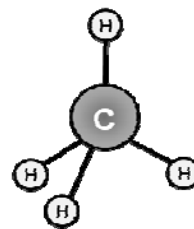
Covalent bonding

Between two non-metallic atoms, e.g. CH_4

Electrons are transferred between the atoms

Covalent molecules have high melting points because of the strong covalent bonds which must be broken

Covalent compounds do not conduct electricity at all as there are no free electrons



Corrections;

- (1 mark) Electrons are shared between atoms not transferred
- (1 mark) Covalent molecules have low melting points because.....
- (1 mark) Only weak intermolecular forces need to be broken (clarification of correction above)

Metallic bonding

In metallic bonding, the outer electrons from the metal atoms merge to produce a lattice of negative metal ions in a sea of delocalised electrons

The strength of the metal depends on two things;

- the charge on the metal ion
- the size of the metal ion

Therefore sodium is stronger than magnesium

Metals have low melting points because of the repulsive forces between the negative electrons which need little energy to be broken

Metals conduct electricity because of the sea of delocalised electrons which can move through the structure to carry the charge

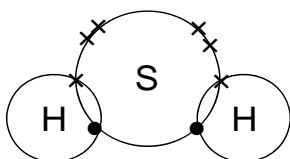
Corrections;

- (1 mark) The metal ions are positive not negative
- (1 mark) Sodium is weaker than magnesium (following on from the points raised)
- (1 mark) Metals have high melting points because of the attractive forces between the positive metal ions and the delocalised sea of electrons

3.2. Covalent bonding

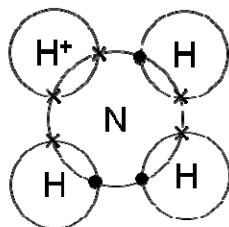
3.2.1. Coordinate bonding

1.



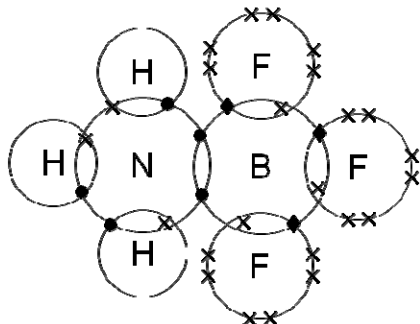
No coordinate bonds

2.



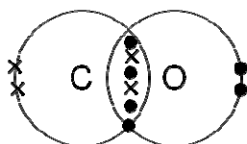
One coordinate bond in which both electrons are donated from the N atom to the H

3.



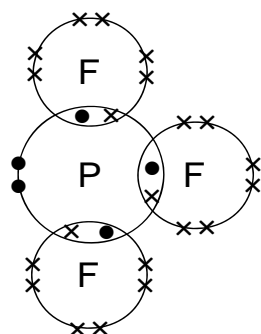
One coordinate bond in which both electrons are donated from the N atom to the B atom

4.



One coordinate bond in which both electrons are donated from the O atom to the C atom

5.



No coordinate bonds

(1 mark for each correct dot and cross diagram;

1 mark for correct identification of the coordinate bond or the lack of coordinate bond)

3.2.2. Electronegativity and polarity

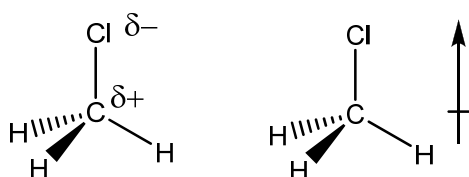
1.

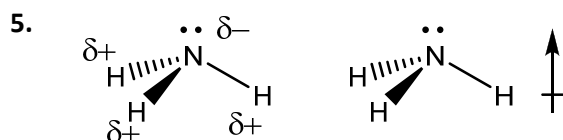
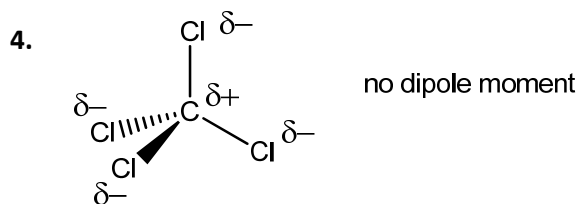


2.



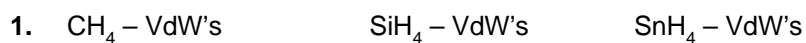
3.



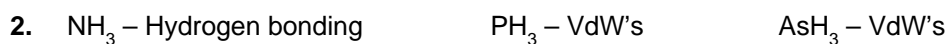


(1 mark for the correct placement of the $\delta+$ and $\delta-$;
1 mark for correct identification of the dipole moment)

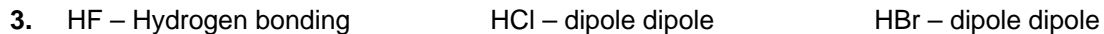
3.2.3. Intermolecular forces



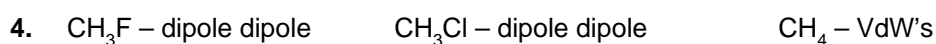
\therefore B.p. $\text{CH}_4 < \text{SiH}_4 < \text{SnH}_4$



\therefore B.p. $\text{PH}_3 < \text{AsH}_3 < \text{NH}_3$ – Hydrogen bonding



\therefore B.p. $\text{HBr} < \text{HCl} < \text{HF}$



\therefore B.p. $\text{CH}_4 < \text{CH}_3\text{F} < \text{CH}_3\text{Cl}$



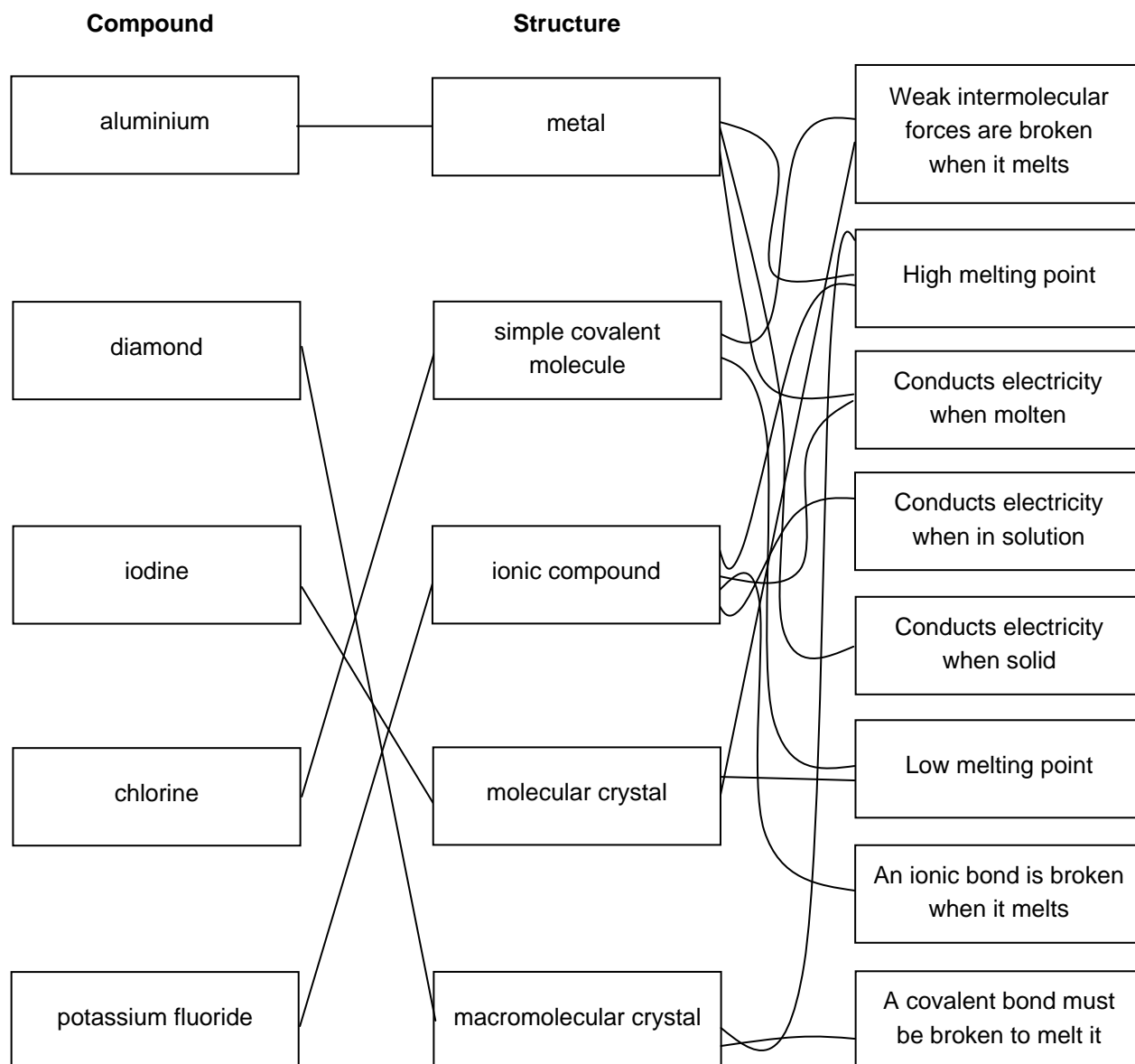
\therefore B.p. $\text{NH}_3 < \text{HF} < \text{H}_2\text{O}$

(1 mark for correct identification of strongest intermolecular force in all three molecules;
1 mark for the correctly predicting the correct order of the molecules based on their boiling points)

3.2.4. Shapes of molecules

2 marks allocated for the drawing of each molecule

3.3. Properties and bonding



4 marks for the correct identification of the structure of each compound

5 marks for the correct statements (1 mark each for the correct identification of 2 correct statements for diamond, iodine and chlorine, 2 marks for the 4 correct statements for potassium fluoride)

1 Bonus mark;

