Atoms, Bonds and Groups
Structure & Bonding

1. This question is about different models of bonding and molecular shapes.

Magnesium sulfide shows ionic bonding.

(i) What is meant by the term *ionic bonding*?

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[1]

(ii) Draw a '*dot-and-cross*' diagram to show the bonding in magnesium sulfide. Show outer electron shells only.

[2]

[Total 3 marks]

2. '*Dot-and-cross*' diagrams can be used to predict the shape of covalent molecules.

Fluorine has a covalent oxide called difluorine oxide, F_2O. The oxygen atom is covalently bonded to each fluorine atom.

(i) Draw a '*dot-and-cross*' diagram of a molecule of F_2O.
Show outer electron shells only.

[2]

(ii) Predict the bond angle in an F_2O molecule. Explain your answer.

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[3]

[Total 5 marks

3. Liquid ammonia, NH_3, and water, H_2O, both show hydrogen bonding.

(i) Draw a labelled diagram to show hydrogen bonding between two molecules of liquid **ammonia**.

[3]

(ii) Water has several anomalous properties as a result of its hydrogen bonding.

Describe and explain **one** anomalous property of water which results from hydrogen bonding.

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[2]

[Total 5 marks]

4. The third period of the Periodic Table features the elements magnesium and chlorine. The table below shows the melting points of these elements.

element	**melting point / °C**
magnesium	650
chlorine	–101

Describe the structure and bonding shown by these elements. Use your answer to explain the difference in melting points.

In your answer, you should use appropriate technical terms spelt correctly.

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[Total 6 marks]

5. One form of naturally occurring carbon is graphite.

The table below lists some properties of graphite.

electrical conductivity	good conductor
hardness	soft
melting point	very high

- Describe the bonding and structure in graphite.
- Explain, in terms of bonding and structure, the properties of graphite shown above.

In your answer, you should use appropriate technical terms, spelt correctly.

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[Total 5 marks]

6. Chemists have developed models for bonding and structure which are used to explain different properties.

Ammonia, NH_3, is a covalent compound.

(i) Explain what is meant by a *covalent bond*.

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[1]

(ii) Draw a '*dot-and-cross*' diagram to show the bonding in NH_3.

Show **outer** electrons only.

[1]

(iii) Name the shape of the ammonia molecule.

Explain, using your '*dot-and-cross*' diagram, why ammonia has this shape and has a bond angle of 107°.

shape: .....

explanation: .....

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[3]

[Total 5 marks]

7. Ammonia reacts with hydrogen chloride, HC*l*, to form ammonium chloride, NH_4Cl.

NH_4Cl is an ionic compound containing NH_4^+ and Cl^- ions.

(i) Complete the electron configuration of the Cl^- ion.

$1s^2$ .....

[1]

(ii) Draw a '*dot-and-cross*' diagram to show the bonding in NH_4^+.

Show **outer** electrons only.

[1]

(iii) State the shape of, and bond angle in, an NH_4^+ ion.

shape: .....

bond angle: .....

[2]

(iv) A student investigated the conductivity of ammonium chloride.

She noticed that when the ammonium chloride was solid it did **not** conduct electricity. However, when ammonium chloride was dissolved in water, the resulting solution did conduct electricity.

Explain these observations.

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[2]

[Total 6 marks]

8. This question compares the bonding, structure and properties of sodium and sodium oxide.

Sodium, Na, is a metallic element.

Explain, with the aid of a labelled diagram, what is meant by the term *metallic bonding*.

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[Total 3 marks]

9. Sodium reacts with oxygen to form sodium oxide, Na_2O, which is an ionic compound.

(i) Write the equation for the reaction of sodium with oxygen to form sodium oxide.

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[1]

(ii) State what is meant by the term *ionic bond*.

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[1]

(iii) Draw a '*dot-and-cross*' diagram to show the bonding in Na_2O.

Show **outer** electrons only.

[2]

[Total 4 marks]

10. Compare and explain the electrical conductivities of sodium and sodium oxide in the solid and liquid states.

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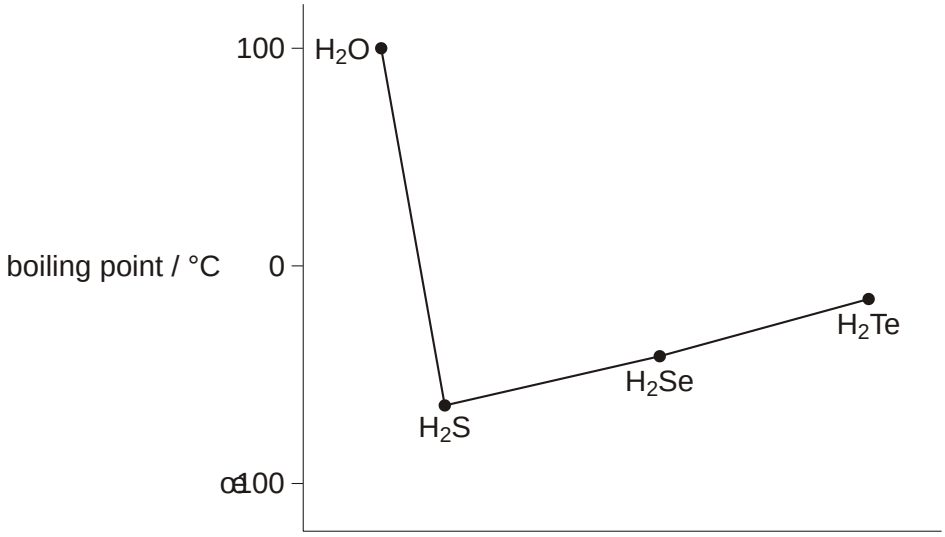
[Total 5 marks]

11. The figure below shows the boiling points of four hydrides of Group 6 elements.



(i) Explain, with the aid of a diagram, the intermolecular forces in H_2O that lead to the relatively high boiling point of H_2O.

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[3]

(ii) Suggest why H_2S has a much lower boiling point than H_2O.

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[1]

[Total 4 marks]

12. Chemists have developed models for bonding and structure. These models are used to explain different properties of metals and non-metals.

(i) Draw a labelled diagram to show the currently accepted model for *metallic bonding*.

[2]

(ii) What feature of this model allows metals to conduct electricity?

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[1]

[Total 3 marks]

13. The metal magnesium reacts with the non-metal chlorine to form a compound magnesium chloride, $MgCl_2$, which has ionic bonding.

(i) State what is meant by an *ionic bond*.

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[1]

(ii) '*Dot-and-cross*' diagrams are used to model which electrons are present in the ion.

Draw a '*dot-and-cross*' diagram, including outer electron shells only, to show the ions present in magnesium chloride, $MgCl_2$.

[2]

(iii) A student finds that solid magnesium chloride and pure water do not conduct electricity. The student dissolved the magnesium chloride in the water and the resulting solution **does** conduct electricity.

Explain these observations.

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[3]

[Total 6 marks]

14. The non-metals chlorine and carbon have very different boiling points. Chlorine is a gas at room temperature but carbon does not boil until well over 4500 °C.

Explain this difference, in terms of bonding and structure.

In your answer, you should use appropriate technical terms, spelled correctly.

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[Total 3 marks]

15. Water, ammonia and sulfur dioxide are simple molecular compounds.

Pairs of electrons in molecules may be present as *bonding pairs* or as *lone pairs*.

(i) Complete the table below for water, ammonia and sulfur dioxide.

molecule	H_2O	NH_3	SO_2
number of bonding pairs of electrons			4 (two double bonds)
number of lone pairs of electrons around central atom			1

[2]

(ii) Use your answers to (i) to help you draw the shape of, and bond angle in, a molecule of NH_3 and of SO_2.

molecule	NH_3	SO_2
shape of molecule with bond angles		

[4]

[Total 6 marks]

16. Water forms hydrogen bonds which influences its properties.

Explain, with a diagram, what is meant by *hydrogen bonding* and explain **two** anomalous properties of water resulting from hydrogen bonding.

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[Total 6 marks]

17. The ions present in $Ca(OH)_2$ are Ca^{2+} and OH^-.

(i) Complete the electronic configuration of a Ca^{2+} ion.

$1s^2$ .....

[1]

(ii) How many moles of ions are in one mole of $Ca(OH)_2$?

moles of ions = ...

[1]

(iii) How many moles of electrons are in one mole of OH^- ions?

moles of electrons = ...

[1]

(iv) Draw a *'dot-and-cross'* diagram of $Ca(OH)_2$. Show outer electron shells only.

[2]

[Total 5 marks]

18. Although compounds are usually classified as having ionic or covalent bonding, often the bonding is somewhere in between these two extremes.

State what is meant by the terms

(i) *ionic bond*,

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[1]

(ii) *covalent bond*.

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[2]

[Total 3 marks]

19. Compounds with covalent bonding often have polar bonds. Polarity can be explained in terms of electronegativity.

(i) Explain the term *electronegativity*.

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[2]

(ii) Use a suitable example to show how the presence of a polar bond can be explained in terms of electronegativity.

You may find it useful to draw a diagram in your answer.

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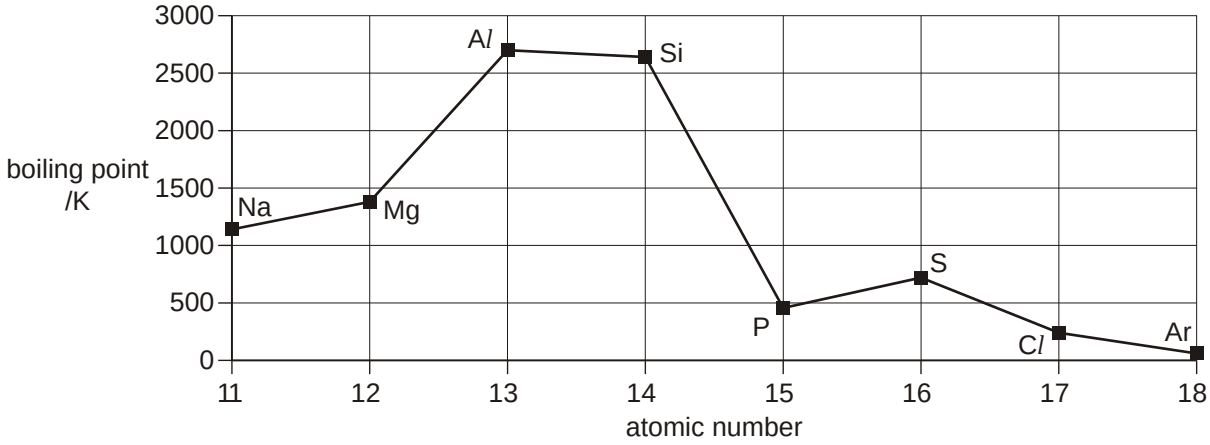
[2]

[Total 4 marks]

20. Some polar molecules are able to form hydrogen bonds.
Draw a diagram to show an example of hydrogen bonding.

[Total 2 marks]

21. The diagram below shows the variation in the boiling points of elements across Period 3 of the Periodic Table.



(a) In the table below for the elements Mg, Si and S,

- complete the structure column using the word *giant* or *simple*.
- complete the bonding column using the word *metallic*, *ionic* or *covalent*.

element	structure	bonding
Mg		
Si		
S		

[3]

(b) Explain why silicon has a much **higher** boiling point than phosphorus.

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[2]

(c) Explain why the boiling point **increases** from sodium to aluminium.

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[2]

[Total 7 marks]

22. Sodium reacts with chlorine forming the ionic compound sodium chloride, NaC*l*.

(i) Write an equation, including state symbols, for this reaction.

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[2]

(ii) Describe the structure of sodium chloride in the solid state. You may find it useful to draw a diagram.

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[2]

[Total 4 marks]

23. Sodium reacts with oxygen to form sodium oxide, Na_2O.

Draw a '*dot-and-cross*' diagram for Na_2O. Show outer electrons only.

[Total 2 marks]

24. Sodium reacts with excess oxygen to form sodium peroxide, Na_2O_2.

Na_2O_2 is used in laundry bleaches. When added to water a reaction takes place forming an alkaline solution and hydrogen peroxide, H_2O_2.

(i) Construct a balanced equation for the formation of sodium peroxide from sodium.

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[1]

(ii) Construct a balanced equation for the reaction of sodium peroxide with water.

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[1]

(iii) Draw a 'dot-and-cross' diagram for a molecule of H_2O_2. Show outer electrons only.

[2]

[Total 4 marks]

25. In water treatment plants, care must be taken as chlorine can react with nitrogen compounds to form the highly explosive compound, nitrogen trichloride, NCl_3. Molecules of NCl_3 have a bond angle of 107°.

(i) Name the shape of an NCl_3 molecule.

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[1]

(ii) Explain why a molecule of NCl_3 has this shape and a bond angle of 107°.

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[3]

[Total 4 marks]

26. Sulphuric acid was added to aqueous barium hydroxide until the solution was just neutralised, forming the insoluble salt, $BaSO_4$, and water.

$Ba(OH)_2(aq) + H_2SO_4(aq) \rightarrow BaSO_4(s) + 2H_2O(l)$

The electrical conductivity of the solution steadily decreased as the sulphuric acid was added.

Explain why the electrical conductivity decreased.

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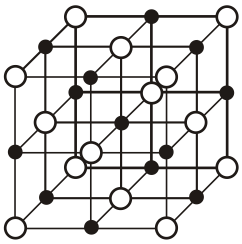
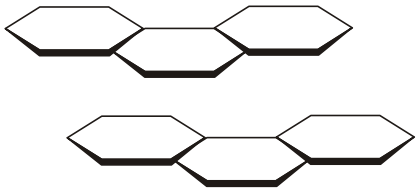
[Total 2 marks]

27. In this question, one mark is available for the quality of spelling, punctuation and grammar.

Many physical properties can be explained in terms of bonding and structure. The table below shows the structures and some properties of sodium chloride and graphite in the solid state.

substance	sodium chloride	graphite
structure		
electrical conductivity of solid	poor	good
melting and boiling point	high	high
solubility in water	good	insoluble

Explain these properties in terms of bonding and structure.

[7]

Quality of Written Communication [1]

[Total 8 marks]

28. Magnesium has a giant metallic structure held together by metallic bonding.

(i) Draw a **labelled** diagram to show metallic bonding.

[2]

(ii) Use your diagram to explain how magnesium conducts electricity.

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[1]

[Total 3 marks]

29. Magnesium reacts with oxygen to form magnesium oxide.

$$2Mg(s) + O_2(g) \rightarrow 2MgO(s)$$

(i) Use oxidation numbers to show that oxygen has been reduced in its reaction with magnesium.

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[2]

(ii) Draw a '*dot-and-cross*' diagram to show the arrangement of electrons in magnesium oxide. Show outer electron shells only and include any charges.

[2]

[Total 4 marks]

30. This question is about the simple molecular compounds water, ammonia and sulphur dioxide.

Pairs of electrons in molecules may be present as *bonding pairs* or as *lone pairs*.

(i) Complete the table below for water, ammonia and sulphur dioxide.

molecule	H_2O	NH_3	SO_2
number of bonding pairs of electrons			4 (2 double bonds)
number of lone pairs of electrons around central atom			1

[2]

(ii) Use your answers to (a)(i) to help you draw the shape of a molecule of NH_3 and of SO_2. Clearly show values of the bond angles in your diagrams.

molecule	NH_3	SO_2
shape of molecule with bond angles		

[4]

[Total 6 marks]

31. The O–H bonds in water and the N–H bonds in ammonia have dipoles.

(i) Why do these bonds have dipoles?

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[1]

(ii) Molecules of NH_3 are able to form hydrogen bonds. Draw a diagram to show the hydrogen bonding in ammonia. Include any relevant lone pairs and dipoles.

[2]

[Total 3 marks]

32. Describe and explain the density of ice compared with water.

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[Total 2 marks]

33. Antimony is in Group 5 of the Periodic Table. It forms a compound with hydrogen that has the formula SbH_3.

(i) Predict the bond angle in SbH_3.

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[1]

(ii) Explain why a molecule of SbH_3 has this bond angle.

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[2]

[Total 3 marks]

34. Limestone contains the ionic compound, $CaCO_3$. Limestone decomposes when it is heated strongly, forming an ionic compound, CaO and a covalent compound, CO_2.

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$$

(a) State what is meant by *ionic bonding*.

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[1]

(b) Draw '*dot and cross*' diagrams to show the bonding in CaO and CO_2. Show outer electron shells only.

CaO	CO_2

[3]

(c) Complete the electronic configuration in terms of sub-shells for calcium in CaO.

$1s^2$ .....

[1]

[Total 5 marks]

35. The nitrate ion, NO_3^-, in $Ca(NO_3)_2$ contains both covalent and dative covalent bonds.

(i) What is the difference between a covalent bond and a dative covalent bond?

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[1]

(ii) Calcium nitrate decomposes on heating to form calcium oxide, oxygen and nitrogen(IV) oxide, NO_2.

Construct a balanced equation for this reaction.

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[1]

[Total 2 marks]

36. In this question, one mark is available for the quality of spelling, punctuation and grammar.

Many physical properties can be explained in terms of bonding and structure. The table below show some properties of elements in Period 2 of the Periodic Table.

element	Li	C (graphite)	N
electrical conductivity of solid	good	good	poor
boiling point / °C	1342	4000	–196

Explain these properties in terms of bonding and structure.

[11]

Quality of Written Communication [1]

[Total 12 marks]

37. The burning of fossil fuels containing carbon produces carbon dioxide. Draw a *'dot-and-cross'* diagram of carbon dioxide, showing outer shell electrons only.

[Total 2 marks]

38. Draw a '*dot-and-cross*' diagram for $CaCl_2$.

[Total 2 marks]

39. In this question, one mark is available for the quality of spelling, punctuation and grammar.

The halogens chlorine, bromine and iodine each exist as diatomic molecules at room temperature and pressure.

The halogens all have van der Waals' forces.

- Explain how van der Waals' forces are formed.
- Explain the trend in volatilities of the halogens chlorine, bromine and iodine.

[Total 6 marks]

40. Titanium has metallic bonding.

(i) Explain what is meant by *metallic bonding*. Use a diagram in your answer.

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[2]

(ii) How does metallic bonding allow titanium to conduct electricity?

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[1]

[Total 3 marks]

41. At room temperature, **X** is a liquid which does **not** conduct electricity. What does this information suggest about the bonding and structure in **X**?

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[Total 2 marks]

42. Iodine is extracted commercially from seawater with chlorine gas. Seawater contains very small quantities of dissolved iodide ions, which are oxidised to iodine by the chlorine gas.

(i) Write an ionic equation for the reaction that has taken place.

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[2]

(ii) Use your understanding of electronic structure to explain why chlorine is a stronger oxidising agent than iodine.

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[2]

[Total 4 marks]

43. In this question, one mark is available for the quality of use and organisation of scientific terms.

Nitrogen and oxygen are elements in Period 2 of the Periodic Table. The hydrogen compounds of oxygen and nitrogen, H_2O and NH_3, both form hydrogen bonds.

(i) Draw a diagram containing two H_2O molecules to show what is meant by *hydrogen bonding*. On your diagram, show any lone pairs present and relevant dipoles.

[3]

(ii) State and explain **two** anomalous properties of water resulting from hydrogen bonding.

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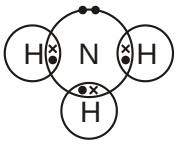
[4]

[Total 7 marks]

44. The *'dot-and-cross'* diagram of an ammonia molecule is shown below.



Predict, with reasons, the bond angle in an ammonia molecule.

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[Total 4 marks]

45. Water and carbon dioxide both consist of covalent molecules.

State what is meant by a *covalent* bond.

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[Total 2 marks]

46. Draw '*dot-and-cross*' diagrams for a molecule of water and a molecule of carbon dioxide. Show outer electron shells only.

water	carbon dioxide

[Total 3 marks]

47. The shape of a water molecule is different from the shape of a carbon dioxide molecule.

(i) Draw the shapes of these molecules and state the bond angles.

water	carbon dioxide
bond angle in water = ...	bond angle in carbon dioxide = ...

[4]

(ii) Explain why a water molecule has a different shape from a carbon dioxide molecule.

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[2]

[Total 6 marks]

48. An understanding of electronegativity helps to explain why some covalent bonds are polar.

(i) Define the term *electronegativity*.

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[2]

(ii) Water and carbon dioxide both have polar bonds. Explain why water has polar molecules but carbon dioxide has non-polar molecules.

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[2]

[Total 4 marks]

49. Magnesium, fluorine and magnesium fluoride have different types of bonding and different properties.

Magnesium has metallic bonding.

(i) Draw a diagram to show what is meant by *metallic* bonding.

Label the diagram.

[2]

(ii) Why is magnesium a good conductor of electricity?

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[1]

[Total 3 marks]

50. Fluorine, F_2, has covalent bonding.

(i) State what is meant by a *covalent* bond.

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[2]

(ii) Draw a '*dot-and-cross*' diagram to show the covalent bonding in fluorine. Show outer electron shells only.

[1]

[Total 3 marks]

51. Magnesium fluoride, MgF_2, has ionic bonding.

(i) How does *ionic bonding* hold particles in MgF_2 together?

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[2]

(ii) Draw a '*dot-and-cross*' diagram for magnesium fluoride, MgF_2. Show outer electron shells only.

[2]

(iii) Magnesium fluoride is produced when magnesium reacts with fluorine.

Complete the half-equations below to show the formation of the ions in magnesium fluoride in this reaction.

Mg → ..... + ...

F_2 + ... → .....

[2]

(iv) A student found that magnesium fluoride has different electrical conductivities when solid and when dissolved in water.

Explain these **two** observations.

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[2]

[Total 8 marks]

52. In this question, one mark is available for the quality of written communication.

Describe the intermolecular bonding in CH_4 and in H_2O.

Use clear diagrams in your answer.

[Total 6 marks]

53. State and explain **two anomalous** properties of H_2O that depend on its intermolecular forces.

[4]

Quality of Written Communication [1]

[Total 5 marks]