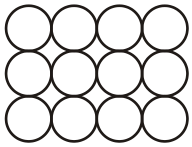
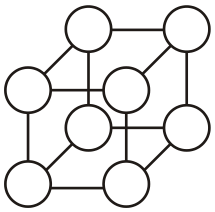
PRACTICE EXAMINATION QUESTIONS FOR TOPIC 3.1 BONDING
(includes some questions from 1.4 Periodicity)

1. At room temperature, both sodium metal and sodium chloride are crystalline solids which contain ions.

(a) On the diagrams for sodium metal and sodium chloride below, mark the charge for each ion.



Sodium metal



Sodium chloride

(2)

(b) (i) Explain how the ions are held together in solid sodium metal.

.....

.....

(ii) Explain how the ions are held together in solid sodium chloride.

.....

.....

(iii) The melting point of sodium chloride is much higher than that of sodium metal. What can be deduced from this information?

.....

.....

(3)

(c) Compare the electrical conductivity of solid sodium metal with that of solid sodium chloride. Explain your answer.

Comparison .....

.....

Explanation .....

.....

.....

(3)

(d) Explain why sodium metal is malleable (can be hammered into shape).

.....

.....

(1)

(Total 9 marks)

2. The equation below shows the reaction between boron trifluoride and a fluoride ion.

$$BF_3 + F^- \rightarrow BF_4^-$$

(i) Draw diagrams to show the shape of the BF_3 molecule and the shape of the BF_4^- ion. In each case, name the shape. Account for the shape of the BF_4^- ion and state the bond angle present.

(ii) In terms of the electrons involved, explain how the bond between the BF_3 molecule and the F^- ion is formed. Name the type of bond formed in this reaction.

(Total 9 marks)

3. Draw the shape of a molecule of $BeCl_2$ and the shape of a molecule of Cl_2O. Show any lone pairs of electrons on the central atom. Name the shape of each molecule.

$BeCl_2$ Cl_2O

Name of shape ..... *Name of shape* .....

(4)

(Total 4 marks)

4. Ammonia, NH_3, reacts with sodium to form sodium amide, $NaNH_2$, and hydrogen.

(a) Draw the shape of an ammonia molecule and that of an amide ion, NH_2^-

In each case show any lone pairs of electrons.

NH_3 NH_2^-

(b) State the bond angle found in an ammonia molecule.

.....

(c) Explain why the bond angle in an amide ion is smaller than that in an ammonia molecule.

.....

.....

.....

.....

(5)
(Total 5 marks)

5.

(a) Describe the bonding that is present in metals.

.....

.....

.....

.....

(3)

(b) Explain how the bonding and structure lead to the typical metallic properties of electrical conductivity and malleability.

Electrical conductivity .....

.....

.....

Malleability.....

.....

.....

(4)

(c) Suggest a reason why aluminium is a better conductor of electricity than magnesium.

.....

.....

.....

(2)
(Total 9 marks)

6. The table below shows the electronegativity values of some elements.

	Fluorine	Chlorine	Bromine	Iodine	Carbon	Hydrogen
Electronegativity	4.0	3.0	2.8	2.5	2.5	2.1

(a) Define the term *electronegativity*.

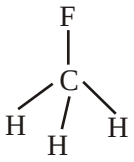
.....

.....

.....

(2)

(b) The table below shows the boiling points of fluorine, fluoromethane (CH_3F) and hydrogen fluoride.

	F–F		H–F
Boiling point/K	85	194	293

(i) Name the strongest type of intermolecular force present in:

Liquid F_2 .....

Liquid CH_3F .....

Liquid HF .....

(ii) Explain how the strongest type of intermolecular force in liquid HF arises.

.....

.....

.....

.....

(6)

(c) The table below shows the boiling points of some other hydrogen halides.

	HCl	HBr	HI
Boiling point / K	188	206	238

(i) Explain the trend in the boiling points of the hydrogen halides from HCl to HI.

.....

.....

.....

(ii) Give **one** reason why the boiling point of HF is higher than that of all the other hydrogen halides.

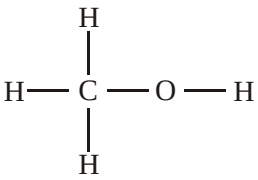
.....

.....

(3)

(Total 11 marks)

7. (a) Methanol has the structure



Explain why the O–H bond in a methanol molecule is polar.

.....

.....

.....

(2)

(b) The boiling point of methanol is +65 °C; the boiling point of oxygen is –183 °C. Methanol and oxygen each have an M_r value of 32. Explain, in terms of the intermolecular forces present in each case, why the boiling point of methanol is much higher than that of oxygen.

.....

.....

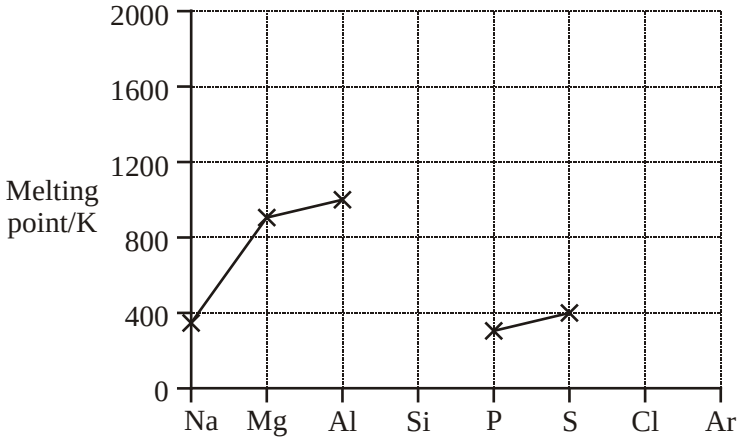
.....

.....

(3)

(Total 5 marks)

8. (a) The diagram below shows the melting points of some of the elements in Period 3.



(i) On the diagram, use crosses to mark the approximate positions of the melting points for the elements silicon, chlorine and argon. Complete the diagram by joining the crosses.

(ii) By referring to its structure and bonding, explain your choice of position for the melting point of silicon.

.....

.....

.....

(iii) Explain why the melting point of sulphur, S_8, is higher than that of phosphorus, P_4

.....

.....

(8)

(b) State and explain the trend in melting point of the Group II elements Ca–Ba.

Trend .....

Explanation .....

.....

.....

(3)

(Total 11 marks)

9. State and explain the trend in the melting points of the Period 3 metals Na, Mg and Al.

Trend .....

Explanation .....

.....

.....

(3)
(Total 3 marks)

10. (a) (i) Describe the bonding in a metal.

.....

.....

.....

(ii) Explain why magnesium has a higher melting point than sodium.

.....

.....

.....

(4)

(b) Why do diamond and graphite both have high melting points?

.....

.....

.....

.....

(3)

(c) Why is graphite a good conductor of electricity?

.....

(1)

(d) Why is graphite soft?

.....

.....

.....

(2)
(Total 10 marks)

11. Sodium sulphide, Na_2S, is a high melting point solid which conducts electricity when molten. Carbon disulphide, CS_2, is a liquid which does not conduct electricity.

(a) Deduce the type of bonding present in Na_2S and that present in CS_2

Bonding in Na_2S .....

Bonding in CS_2.....

(b) By reference to all the atoms involved explain, in terms of electrons, how Na_2S is formed from its atoms.

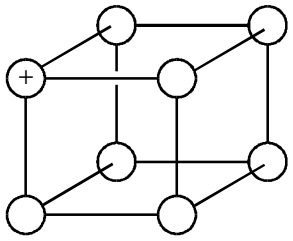
.....

.....

(c) Draw a diagram, including all the outer electrons, to represent the bonding present in CS_2

(6)
(Total 6 narks)

12. (a) The diagram below represents a part of the structure of sodium chloride. The ionic charge is shown on the centre of only one of the ions.



(i) On the diagram, mark the charges on the four negative ions.

(ii) What change occurs to the motion of the ions in sodium chloride when it is heated from room temperature to a temperature below its melting point?

.....

(2)

(b) Sodium chloride can be formed by reacting sodium with chlorine.

(ii) A chloride ion has one more electron than a chlorine atom. In the formation of sodium chloride, from where does this electron come?

.....

(ii) What property of the atoms joined by a covalent bond causes the bond to be polar?

.....

(2)
(Total 4 marks)

13. Phosphorus and nitrogen are in Group V of the Periodic Table and both elements form hydrides. Phosphine, PH_3, reacts to form phosphonium ions, PH_4^+, in a similar way to that by which ammonia, NH_3, forms ammonium ions, NH_4^+

(a) Give the name of the type of bond formed when phosphine reacts with an H^+ ion. Explain how this bond is formed.

Type of bond .....

Explanation .....

.....

.....

(3)

(b) Draw the shapes, including any lone pairs of electrons, of a phosphine molecule and of a phosphonium ion.
Give the name of the shape of the phosphine molecule and state the bond angle found in the phosphonium ion.

PH_3 PH_4^+

Shape of PH_3 …… *Bond angle in PH_4^+* …….....

(4)
(Total 7 marks)

14. (a) State the meaning of the term *electronegativity*.

.....

.....

(2)

(b) State and explain the trend in electronegativity values across Period 3 from sodium to chlorine.

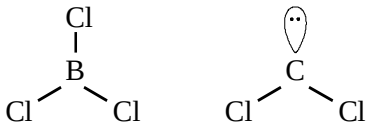
Trend.....

Explanation.....

.....

(3)
(Total 5 marks)

15. (a) The shape of the molecule BCl_3 and that of the unstable molecule CCl_2 are shown below.



(i) Why is each bond angle exactly 120° in BCl_3?

.....

.....

(ii) Predict the bond angle in CCl_2 and explain why this angle is different from that in BCl_3

Predicted bond angle .....

Explanation .....

.....

(5)

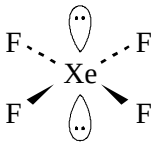
(b) Give the name which describes the shape of molecules having bond angles of 109° 28'. Give an example of one such molecule.

Name of shape .....

Example.....

(2)

(c) The shape of the XeF_4 molecule is shown below.



(i) State the bond angle in XeF_4

.....

(ii) Suggest why the lone pairs of electrons are opposite each other in this molecule.

.....

.....

(iii) Name the shape of this molecule, given that the shape describes the positions of the Xe and F atoms only.

.....

(4)

(d) Draw a sketch of the NF_3 molecule. Indicate in your sketch any lone pairs of electrons on nitrogen.

(2)
(Total 13 marks)

16. (a) Describe the motion of the particles in solid iodine and in iodine vapour.

Motion in solid iodine.....

.....

Motion in iodine vapour.....

.....

(3)

(b) Explain why solid iodine vaporises when warmed gently.

.....

.....

.....

(2)

(c) Silver and sodium chloride melt at similar temperatures. Give two physical properties of silver which are different from those of sodium chloride and, in each case, give one reason why the property of silver is different from that of sodium chloride.

First property of silver.....

Reason for difference.....

.....

Second property of silver.....

Reason for difference.....

.....

(4)

(d) Draw the shapes of $BeCl_2$, NCl_3 and $BeCl_4^{2-}$. In each case, show any lone-pair electrons on the central atom and state the value of the bond angle.

$BeCl_2$ *NCl_3* *$BeCl_4^{2-}$*

(6)
(Total 15 marks)

17. Silicon dioxide has a macromolecular structure. Draw a diagram to show the arrangement of atoms around a silicon atom in silicon dioxide. Give the name of the shape of this arrangement of atoms and state the bond angle.

Diagram

Name of shape .....

Bond angle .....

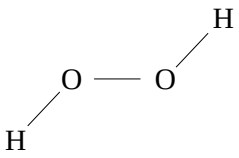
(3)
(Total 3 marks)

18. (a) When considering electron pair repulsions in molecules, why does a lone pair of electrons repel more strongly than a bonding pair?

.....

(1)

(b) The diagram below shows a hydrogen peroxide molecule.



(i) On the diagram above, draw the lone pairs, in appropriate positions, on the oxygen atoms.

(ii) Indicate, on the diagram, the magnitude of one of the bond angles.

(iii) Name the strongest type of intermolecular force which exists between molecules of hydrogen peroxide in the pure liquid.

.....

(4)

(c) Draw a diagram to illustrate the shape of a molecule of SF_4 and predict the bond angle(s).

Diagram of shape

Bond angle(s).....

(4)

(d) Name two types of intermolecular force which exist between molecules in liquid SF_4

Type I.....

Type2.....

(2)

(Total 11 marks)

19. (a) Name the type of force that holds the particles together in an ionic crystal.

.....

(1)

(b) What is a covalent bond?

.....

(1)

(c) State how a co-ordinate bond is formed.

.....

.....

(2)

(d) Describe the bonding in a metal.

.....

.....

.....

(2)

(e) A molecule of hydrogen chloride has a dipole and molecules of hydrogen chloride attract each other by permanent dipole-dipole forces. Molecules ot chlorine are non-polar.

(i) What is a permanent dipole?

.....

.....

.....

(ii) Explain why a molecule of hydrogen chloride is polar.

.....

.....

.....

(iii) Name the type of force which exists between molecules of chlorine.

.....

(5)

(f) Show, by means of a diagram, how two molecules of hydrogen fluoride are attracted to each other by hydrogen bonding; include all lone-pair electrons and partial charges in your diagram.

(3)

(g) Why is there no hydrogen bonding between molecules of hydrogen bromide?

.....

.....

(1)
(Total 15 marks)

20. The table below gives the boiling points, T_b, of some hydrogen halides.

Hydrogen halide	HF	HCl	HBr	HI
T_b /K	293	188	206	238

(a) By referring to the types of intermolecular force involved, explain why energy must be supplied in order to boil liquid hydrogen chloride.

.....

.....

.....

.....

(3)

(b) Explain why the boiling point of hydrogen bromide lies between those of hydrogen chloride and hydrogen iodide.

.....

.....

.....

(2)

(c) Explain why the boiling point of hydrogen fluoride is higher than that of hydrogen chloride.

.....

.....

.....

(2)

(d) Draw a sketch to illustrate how two molecules of hydrogen fluoride interact in liquid hydrogen fluoride.

(2)
(Total 9 marks)

21. Sulphur will combine separately with carbon, hydrogen and sodium to form carbon disulphide (CS_2), hydrogen sulphide (H_2S) and sodium sulphide (Na_2S) respectively. The bonding in these compounds is similar to that in CO_2, H_2O and Na_2O .

(a) Complete the table in **Figure 2** by classifying the compounds as either ionic or covalent.

	Melting point/K	Ionic or covalent
Carbon disulphide	162	
Hydrogen sulphide	187	
Sodium sulphide	1450	

Figure 2

(3)

(b) One of the compounds in **Figure 2** shows high electrical conductivity under appropriate conditions. Identify the compound, by name or formula, and state **one** condition under which it shows high electrical conductivity.

Name or formula of compound .....

Condition .....

(2)

(Total 5 marks)

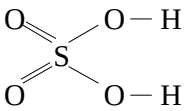
22. (a) State what is meant by the term *polar bond.*

.....

.....

(1)

(b) Sulphuric acid is a liquid that can be represented by the formula drawn below.



Given that the electronegativity values for hydrogen, sulphur and oxygen are 2.1, 2.5 and 3.5 respectively, clearly indicate the polarity of each bond present in the formula given.

(2)

(c) Suggest the strongest type of intermolecular force present in pure sulphuric acid.

Briefly explain how this type of intermolecular force arises.

.....

.....

.....

(2)
(Total 5 marks)

23. (a) Sketch the shapes of each of the following molecules, showing any lone pairs of electrons. In each case, state the bond angle(s) present in the molecule and name the shape.

Molecule	Sketch of shape	Bond angle(s)	Name of shape
BF_3			
NF_3			
ClF_3			

(9)

(b) State the types of intermolecular force which exist, in the liquid state, between pairs of BF_3 molecules and between pairs of NF_3 molecules.

BF_3 .....

NF_3 .....

(3)

(c) Name the type of bond which you would expect to be formed between a molecule of BF_3 and a molecule of NF_3. Explain how this bond is able to form.

Name of bond .....

Explanation .....

.....

(3)
(Total 15 marks)

24. Sketch a diagram to show the shape of a molecule of NH_3 and indicate on your diagram how this molecule is attracted to another NH_3 molecule in liquid ammonia.

(3)
(Total 3 marks)

25. (a) Define the term *electronegativity.*

.....

.....

(2)

(b) State and explain the trend in electronegativity of the elements across Period 3 from sodium to chlorine.

Trend. .....

Explanation. .....

.....

.....

(3)

(c) State the bond type in sodium oxide and the bond type in sulphur dioxide. In each case, explain the link between the bond type and the electronegativity of the elements involved.

Bond type in sodium oxide. .....

Explanation. .....

.....

.....

Bond type in sulphur dioxide. .....

Explanation. .....

(4)
(Total 9 marks)

26. (a) Co-ordinate bonding can be described as dative covalency. In this context, what is the meaning of each of the terms *covalency* and *dative?*

Covalency.....

Dative .....

(2)

(b) Write an equation for a reaction in which a co-ordinate bond is formed.

.....

(2)

(c) Why is sodium chloride ionic rather than covalent?

.....

.....

.....

(2)

(d) Why is aluminium chloride covalent rather than ionic?

.....

.....

.....

(2)

(e) Why is molten sodium chloride a good conductor of electricity?

.....

(1)

(f) Explain, in terms of covalent bonding, why the element iodine exists as simple molecules whereas the element carbon does not.

.....

.....

.....

.....

(3)

(Total 12 marks)

27. (a) Describe the nature and strength of the bonding in solid calcium oxide.

.....

.....

.....

.....

(3)

(b) Use the kinetic theory to describe the changes that take place as calcium oxide is heated from 25°C to a temperature above its melting point.

.....

.....

.....

.....

(3)

(c) State **two** properties of calcium oxide that depend on its bonding.

.....

.....

.....

(2)

(Total 8 marks)

28. What is a covalent bond?

.....

(1)

(Total 1 mark)

29. (a) **Figure 1** shows some data concerned with halogens.

Element	Electronegativity	Boiling point of hydride / K
Fluorine	4.0	293
Chlorine	3.0	188
Bromine	2.8	206
Iodine	2.5	238

Figure 1

(i) Define the term *electronegativity*.

.....

.....

.....

(2)

(ii) Explain the trend in boiling points from hydrogen chloride to hydrogen iodide.

.....

.....

.....

.....

(2)

(iii) Explain why hydrogen fluoride does not fit this trend.

.....

.....

.....

(2)

(b) The oxygen atoms in the sulphate ion surround the sulphur in a regular tetrahedral shape.

(i) Write the formula of the ion.

.....

(1)

(ii) State the O–S–O. bond angle.

.....

(1)

(Total 8 marks)

30. (a) State the type of bonding in a crystal of potassium bromide.

Type of bonding.....

(1)

(b) Sketch a diagram to show the shape of a BrF_3 molecule. Show on your sketch any lone pairs of electrons in the outermost shell of bromine and name the shape.

Sketch

Name of shape.....

(3)
(Total 4 marks)

31. (a) (i) State **one** feature which molecules must have in order for hydrogen bonding to occur between them.

.....

.....

(1)

(ii) Give the name of the type of intermolecular bonding present in hydrogen sulphide, H_2S, and explain why hydrogen bonding does not occur.

.....

.....

(2)

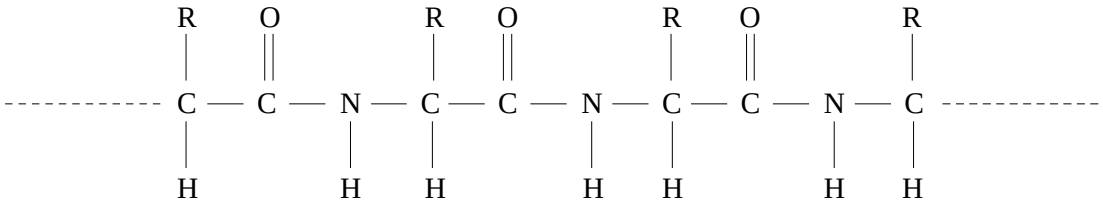
(iii) Account for the much lower boiling point of hydrogen sulphide (–61 °C) compared with that of water(100 °C).

.....

.....

(2)

(b) Protein molecules are composed of sequences of amino acid molecules that have joined together, with the elimination of water, to form long chains. Part of a protein chain is represented by the graphical formula given below.



Explain the formation of hydrogen bonding between protein molecules.

.....

.....

.....

.....

.....

.....

(4)

(Total 9 marks)

32. (a) Describe the bonding found in metals.

.....

.....

.....

.....

(3)

(b) Use data from **table above** and your knowledge of the bonding in these metals to explain why the melting point of magnesium is higher than that of sodium.

.....

.....

.....

.....

(3)

(c) State and explain the similarities and differences in electrical conductivity of sodium, graphite and diamond.

.....

.....

.....

.....

.....

.....

(4)
(Total 10 marks)

33. The table below contains electronegativity values for the Period 3 elements, except chlorine.

Element	Na	Mg	Al	Si	P	S	Cl	Ar
Electronegativity	0.9	1.2	1.5	1.8	2.1	2.5		no value

(a) How can electronegativity values be used to predict whether a given chloride is likely to be ionic or covalent?

.....

.....

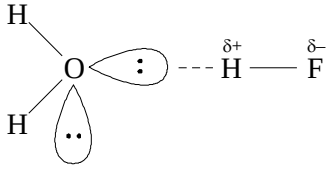
(2)

(b) State the type of bonding in sodium oxide.

.....

(1)
(Total 3 marks)

34. The diagram below shows how a water molecule interacts with a hydrogen fluoride molecule.



(a) What is the value of the bond angle in a single molecule of water?

.....

(1)

(b) Explain your answer to part (a) by using the concept of electron pair repulsion.

.....

.....

.....

.....

(4)

(c) Name the type of interaction between a water molecule and a hydrogen fluoride molecule shown in the diagram above.

.....

(1)

(d) Explain the origin of the δ+ charge shown on the hydrogen atom in the diagram.

.....

.....

(2)

(e) When water interacts with hydrogen fluoride, the value of the bond angle in water changes slightly. Predict how the angle is different from that in a single molecule of water and explain your answer.

Prediction .....

Explanation .....

.....

(2)

(Total 10 marks)

35. (a) State which one of the elements neon, sodium, magnesium, aluminium and silicon has the lowest melting point and explain your answer in terms of the structure and bonding present in that element.

Element with lowest melting point .....

Explanation .....

.....

.....

(3)

(b) State which one of the elements neon, sodium, magnesium, aluminium and silicon has the highest melting point and explain your answer in terms of the structure and bonding present in that element.

Element with highest melting point .....

Explanation .....

.....

.....

(3)

(Total 6 marks)

36. Diamond and graphite are both forms of carbon.
Diamond is able to scratch almost all other substances, whereas graphite may be used as a lubricant. Diamond and graphite both have high melting points.

Explain each of these properties of diamond and graphite in terms of structure and bonding.
Give **one** other difference in the properties of diamond and graphite.

(Total 9 marks)

37. Iodine and diamond are both crystalline solids at room temperature. Identify one similarity in the bonding, and one difference in the structures, of these two solids.
Explain why these two solids have very different melting points.

(Total 6 marks)

38. Phosphorus exists in several different forms, two of which are white phosphorus and red phosphorus. White phosphorus consists of P_4 molecules, and melts at 44°C. Red phosphorus is macromolecular, and has a melting point above 550°C.

Explain what is meant by the term *macromolecular*. By considering the structure and bonding present in these two forms of phosphorus, explain why their melting points are so different.

(Total 5 marks)

39. (a) Predict the shapes of the SF_6 molecule and the $AlCl_4^-$ ion. Draw diagrams of these species to show their three-dimensional shapes. Name the shapes and suggest values for the bond angles. Explain your reasoning.

(8)

(b) Perfume is a mixture of fragrant compounds dissolved in a volatile solvent.

When applied to the skin the solvent evaporates, causing the skin to cool for a short time. After a while, the fragrance may be detected some distance away. Explain these observations.

(4)

(Total 12 marks)

40. (a) Iodine and graphite crystals both contain covalent bonds and yet the physical properties of their crystals are very different.
For iodine and graphite, state and explain the differences in their melting points and in their electrical conductivities.

(9)

(b) Draw the shape of the $BeCl_2$ molecule and explain why it has this shape.

(2)
(Total 11marks)

41. (a) The table below gives the melting point for each of the Period 3 elements Na – Ar.

Element	Na	Mg	Al	Si	P	S	Cl	Ar
Melting point / K	371	923	933	1680	317	392	172	84

In terms of structure and bonding, explain why silicon has a high melting point, and why the melting point of sulphur is higher than that of phosphorus.

(7)

(b) Draw a diagram to show the structure of sodium chloride. Explain, in terms of bonding, why sodium chloride has a high melting point.

(4)
(Total 11 marks)

42. Explain the meaning of the term *periodicity* as applied to the properties of rows of elements in the Periodic Table. Describe and explain the trends in atomic radius, in electronegativity and in conductivity for the elements sodium to argon.

(13)
(Total 13 marks)

43. (a) Describe the structure of, and bonding in, three different types of crystal. Illustrate your answer with a specific example of each type of crystal and sketch labelled diagrams of the structures. In each case, explain how the ability to conduct electricity is influenced by the type of bonding.

(18)

(b) Explain how the concept of bonding and lone (non-bonding) pairs of electrons can be used to predict the shape of, and bond angles in, a molecule of sulphur tetrafluoride, SF_4.
Illustrate your answer with a sketch of the structure.

(8)
(Total 26 marks)

44. Sketch a graph to show how the melting points of the elements vary across Period 3 from sodium to argon. Account for the shape of the graph in terms of the structure of, and the bonding in, the elements.

(Total 21 marks)

45. (a) With the aid of diagrams, describe the structure of, and bonding in, crystals of sodium chloride, graphite and magnesium. In each case, explain how the melting point and the ability to conduct electricity of these substances can be understood by a consideration of the structure and bonding involved.

(23)

(b) Explain how the electron-pair repulsion theory can be used to predict the shapes of the molecules H_2O and PF_5. Illustrate your answer with diagrams of the molecules on which the bond angles are shown.

(7)

(Total 30 marks)