

Bonding and structure

1. The formulae of some ions are shown.

positive ions	negative ions
Al^{3+}	Br^{-}
Ca^{2+}	CO_3^{2-}
Cu^{2+}	NO_3^{-}
Fe^{3+}	S^{2-}
K^{+}	SO_4^{2-}

In which row is the formula **not** correct?

	compound	formula
A	aluminium sulfate	$Al_2(SO_4)_3$
B	calcium nitrate	$Ca(NO_3)_2$
C	iron(III) bromide	Fe_3Br
D	potassium sulfide	K_2S

2. Diamond and silicon(IV) oxide both have giant structures.

Which statements are correct?

- 1 Both substances are compounds.
- 2 There are strong covalent bonds in diamond.
- 3 Silicon(IV) oxide is bonded ionically.
- 4 Both substances have very high melting points.

A 1 and 2 **B** 2 and 3 **C** 2 and 4 **D** 3 and 4

3. Which statement about metals is correct?

- A** Layers of positive ions can slide over each other making metals malleable.
- B** Metallic bonding consists of a lattice of negative ions in a sea of delocalised electrons.
- C** Metallic bonding consists of a lattice of positive ions in a sea of delocalised negative ions.
- D** Metals conduct electricity because positive ions are free to move.

4. Sodium reacts with chlorine to form sodium chloride.

Which statements describe what happens to the sodium atoms in this reaction?

- 1 Sodium atoms form positive ions.
- 2 Sodium atoms form negative ions.
- 3 Sodium atoms gain electrons.
- 4 Sodium atoms lose electrons.

A 1 and 3 **B** 1 and 4 **C** 2 and 3 **D** 2 and 4

5. Diamond is extremely hard and does not conduct electricity.

Which statement explains these properties?

- A** It has a lattice of positive carbon ions in a 'sea of electrons'.
- B** It has delocalised electrons and each carbon atom forms three covalent bonds with other carbon atoms.
- C** It has no delocalised electrons and each carbon atom forms four covalent bonds with other carbon atoms.
- D** It has strong ionic bonds between each carbon atom.

6. Which statement about metals is **not** correct?

- A** Metals are malleable because the metal ions can slide over one another.
- B** Metals conduct electricity because electrons can move through the lattice.
- C** Metals consist of a giant lattice of metal ions in a 'sea of electrons'.
- D** Metals have high melting points because of the strong attraction between the metal ions.

7. Which element does **not** form a stable ion with the same electronic structure as argon?

- A** aluminium
- B** chlorine
- C** phosphorus
- D** potassium

8. Graphite and diamond are both forms of the element carbon.

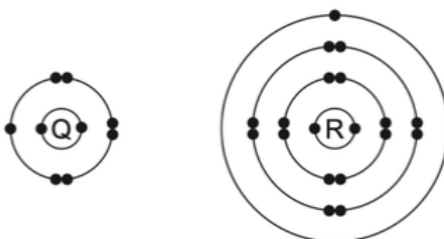
Which row shows the number of other carbon atoms that each carbon atom is covalently bonded to in graphite and diamond?

	graphite	diamond
A	3	3
B	3	4
C	4	3
D	4	4

9. Which statement describes metallic bonding?

- A The attraction between a lattice of negative ions and delocalised protons.
- B The attraction between a lattice of positive ions and delocalised electrons.
- C The attraction between delocalised protons and electrons.
- D The attraction between oppositely charged ions.

10. The electronic structures of atoms Q and R are shown.



Q and R form an ionic compound.

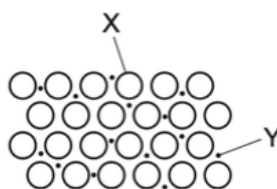
What is the formula of the compound?

- A QR_7
- B Q_2R_4
- C QR
- D Q_7R

11. Which substance is a macromolecule?

- A ammonia
- B carbon dioxide
- C diamond
- D water

12. The diagram shows metallic bonding.



Which labels are correct?

	X	Y
A	atomic nucleus	outer electron
B	metal atom	mobile electron
C	metal ion	mobile electron
D	positive ion	negative ion

13. Two statements about silicon(IV) oxide are given.

- 1 It is a hard substance.
- 2 It has a macromolecular structure with strong covalent bonds.

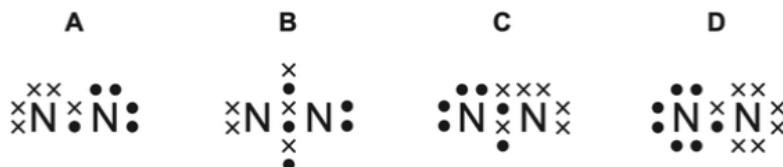
Which is correct?

- A Both statements are correct and statement 2 explains statement 1.
- B Both statements are correct but statement 2 does not explain statement 1.
- C Statement 1 is correct but statement 2 is not correct.
- D Statement 2 is correct but statement 1 is not correct.

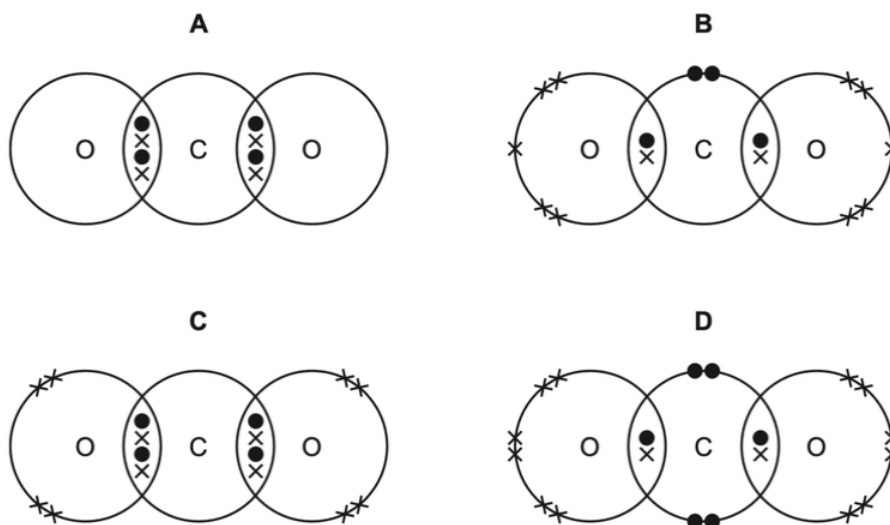
14. Which statement explains why isotopes of the same element have the same chemical properties?

- A They have a different number of neutrons in the nucleus.
- B They have the same number of neutrons in the nucleus.
- C They have the same number of outer shell electrons.
- D They have the same number of protons as neutrons.

15. Which dot-and-cross diagram shows the outer shell electron arrangement in a molecule of nitrogen?



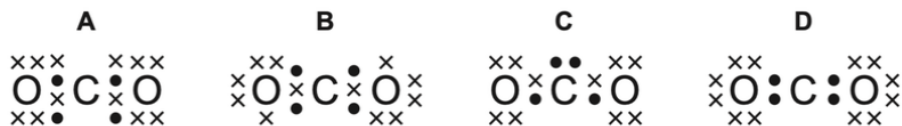
16. Which dot-and-cross diagram shows the outer shell electron arrangement in a molecule of carbon dioxide?



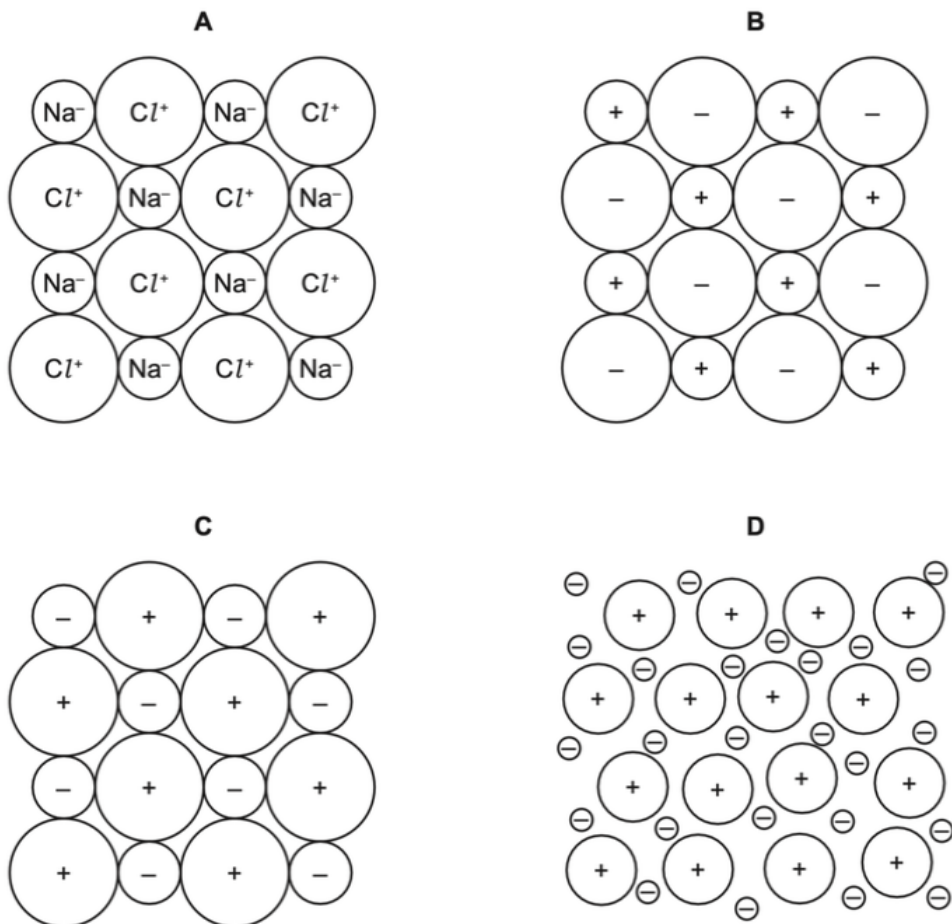
17. Which molecule contains only single covalent bonds?

- A Cl_2
- B CO_2
- C N_2
- D O_2

18. Which dot-and-cross diagram shows the outer shell electron arrangement in a molecule of carbon dioxide?



19. Which structure represents the sodium chloride lattice?



20. Magnesium nitride is formed when magnesium burns in air. Magnesium nitride is an ionic compound.

What is the formula of magnesium nitride?

- A** MgN_2
B Mg_2N_2
C Mg_2N_3
D Mg_3N_2

21. Metals consist of a lattice of positive ions in a 'sea of electrons'.

Why is aluminium malleable?

- A** Its ions are attracted to the 'sea of electrons'.
B Its ions are tightly packed together.
C Its ions repel each other.
D Its layers of ions can slide over each other.

22. The table shows the electronic structure of four atoms.

atom	electronic structure
W	2,8,1
X	2,8,4
Y	2,8,7
Z	2,8,8

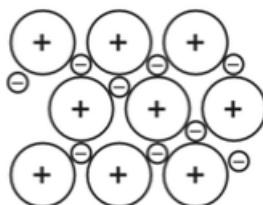
Which two atoms combine to form a covalent compound?

- A** W and X **B** W and Y **C** X and Y **D** X and Z

23. Which statement describes the attractive forces between molecules (intermolecular forces)?

- A** They are strong covalent bonds which hold molecules together.
B They are strong ionic bonds which hold molecules together.
C They are weak forces formed between covalently-bonded molecules.
D They are weak forces which hold ions together in a lattice.

24. The diagram represents the general structure of a solid Z.



What is Z?

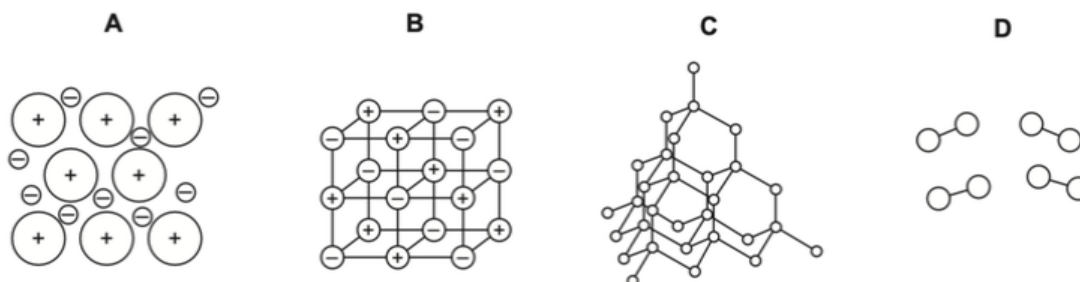
- A** aluminium
B iodine
C silicon dioxide
D sulfur
25. Which substance exists as a lattice of positive ions in a 'sea of electrons'?
- A** liquid potassium chloride
B solid graphite
C solid magnesium
D solid silicon(IV) oxide

28. X is a solid at room temperature.

X has a high melting point.

Solid X conducts electricity.

Which diagram shows how the particles are arranged in solid X?



29. Which substance is an ionic compound?

	volatility	electrical conductivity when molten	solubility in water
A	high	good	soluble
B	high	poor	insoluble
C	low	good	soluble
D	low	poor	insoluble

30. Covalent bonds are formed when electrons are1..... .

Most covalent compounds have2..... electrical conductivity.

Which words correctly complete gaps 1 and 2?

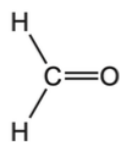
	1	2
A	shared	high
B	shared	low
C	transferred	high
D	transferred	low

31. In which compounds are pairs of electrons shared between atoms?

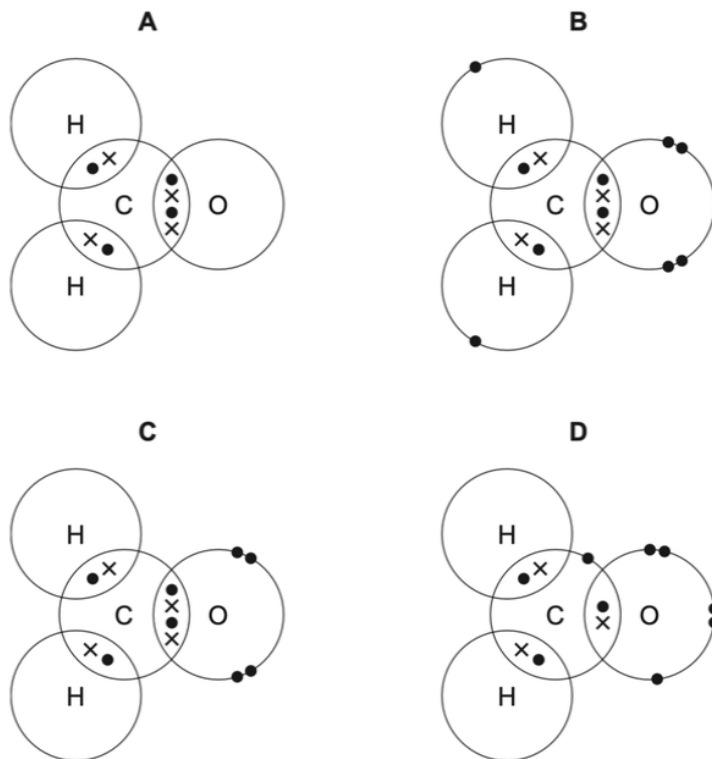
- 1 methane
- 2 lead bromide
- 3 sodium chloride

A 1 only **B** 2 only **C** 1 and 3 **D** 1, 2 and 3

32. The structure of methanal is shown.



Which diagram shows the arrangement of outer shell electrons in a molecule of methanal?



33. Iron is a metal. Its structure consists of a giant lattice of positive ions in a 'sea of electrons'.

Which statements about solid iron are correct?

- 1 Iron conducts electricity because the electrons are free to move.
- 2 Iron conducts heat because the positive ions are free to move.
- 3 Iron has a high melting point due to the strong covalent bonds.
- 4 Iron is malleable because the layers of ions can slide over one another.

A 1 and 3 **B** 1 and 4 **C** 1 only **D** 2, 3 and 4

34. Ethanol is a liquid at room temperature and boils at 78 °C.

Sodium chloride is a solid at room temperature.

Which statement about the bonding in ethanol and sodium chloride is **not** correct?

- A** Each ethanol molecule is held together by weak covalent bonds.
- B** The ethanol molecules are held together by weak attractive forces.
- C** The sodium ions and chloride ions are held together by strong attractive forces.
- D** The sodium ions and chloride ions are held together in a giant lattice.

35. The molecules N_2 , C_2H_4 , CO_2 and CH_3OH all have covalent bonds.

These bonds consist of shared pairs of electrons.

Which row gives the total number of shared pairs of electrons in the molecules shown?

	molecule	total number of shared pairs of electrons
A	N_2	2
B	C_2H_4	6
C	CO_2	2
D	CH_3OH	4

36. Metals are malleable.

Which statement explains why metals are malleable?

- A** Metallic bonding is very strong.
- B** Metals are good conductors of electricity.
- C** Positive metal ions are arranged in a regular lattice structure.
- D** The layers of positive metal ions can slide over each other.

37. Iron is a metal. The structure of iron is described as a lattice of positive ions in a sea of electrons.

Which of the following statements about iron are correct?

- 1 iron conducts electricity because the electrons are free to move
- 2 iron has a high melting point due to the strong covalent bonds
- 3 iron is an alloy
- 4 iron is malleable because the layers of atoms can slide over one another

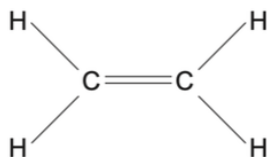
- A** 1 only
- B** 1 and 3
- C** 1 and 4
- D** 2, 3 and 4

38. Which two elements react together to form an ionic compound?

element	electronic structure
R	2,4
T	2,8
X	2,8,1
Z	2,8,7

- A** R and T
- B** T and X
- C** X and Z
- D** Z and R

39. Ethene is an unsaturated hydrocarbon.



Which description of the bonding in ethene is correct?

- A All atoms in the molecule have a share of eight electrons.
 - B Each carbon atom shares two of its electrons with hydrogen atoms and two of its electrons with a carbon atom.
 - C Each carbon atom shares two of its electrons with hydrogen atoms and one of its electrons with a carbon atom.
 - D The two carbon atoms share a total of six electrons with other atoms.
40. Rescuers are drilling through fallen rock in order to rescue some men trapped in a cave. The drill needs lubricating from time to time.

The following statements were made about the materials used for the drill tip and the lubricant and the reasons for their use.

- 1 Diamond was used for the drill tip as it does not conduct electricity.
- 2 Diamond was used for the drill tip as it is very hard.
- 3 Graphite was used as the lubricant as it conducts electricity.
- 4 Graphite was used as the lubricant as it is soft and flaky.

Which statements are correct?

- A 1 and 3 B 1 and 4 C 2 and 3 D 2 and 4
41. Graphite is a form of carbon.

Why can graphite be used as a lubricant?

- A Graphite contains delocalised electrons which move throughout the structure.
 - B Graphite contains weak covalent bonds so the atoms move easily.
 - C Graphite has a low melting point so it easily turns into a liquid.
 - D Graphite has weak forces of attraction between layers so they can move.
42. In which compounds are pairs of electrons shared between atoms?

- 1 methane
- 2 lead bromide
- 3 sodium chloride

- A 1 only B 2 only C 1 and 3 D 1, 2 and 3

43. Diamond and graphite are both macromolecules.

Which statement is **not** correct?

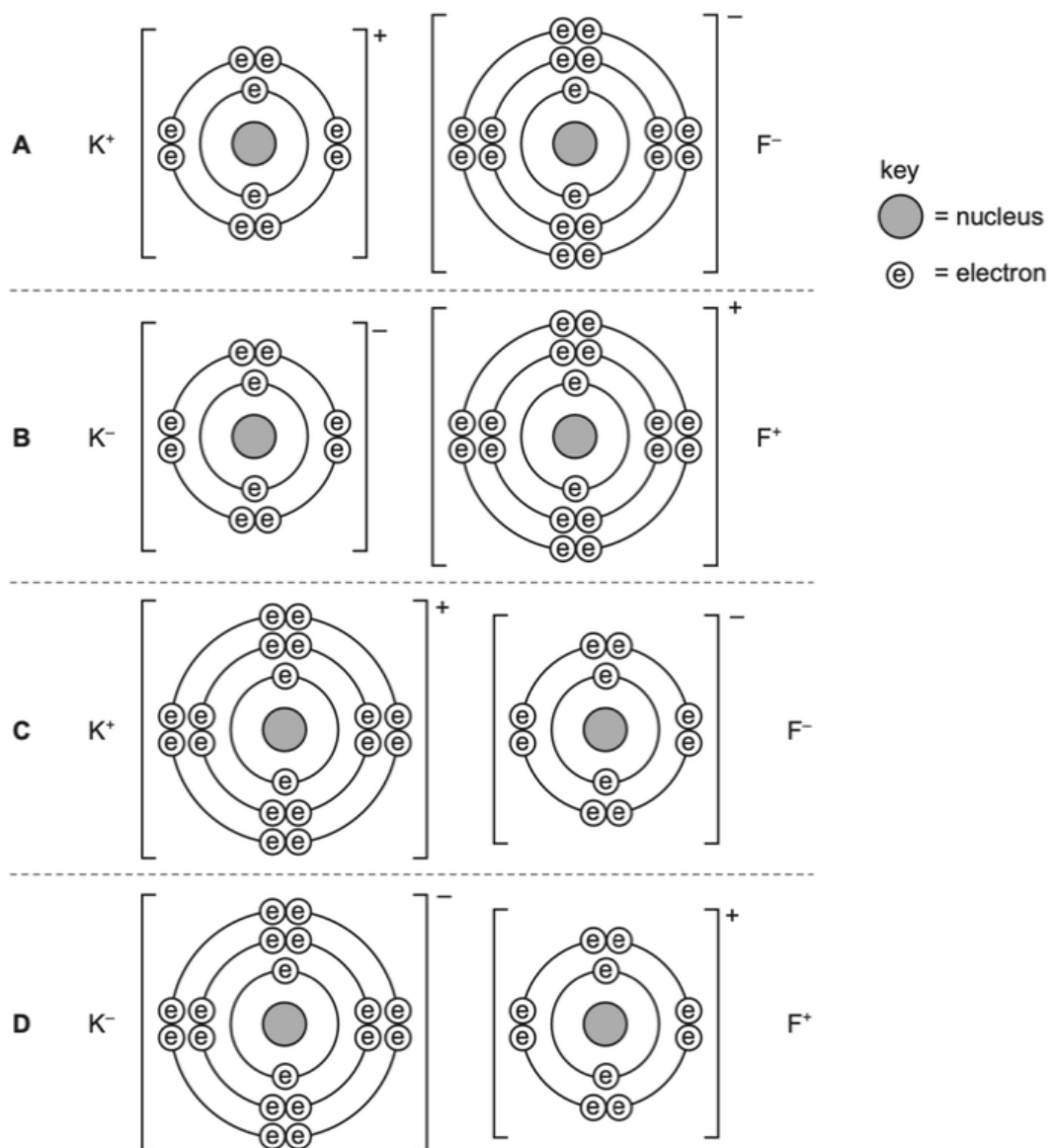
- A Diamond and graphite contain carbon atoms only.
- B Diamond and graphite contain charged ions.
- C Diamond and graphite have high melting points.
- D The atoms in diamond and graphite are held together by covalent bonds.

44. In which compounds are pairs of electrons shared between atoms?

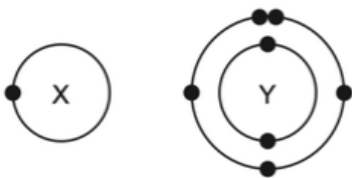
- 1 methane
- 2 lead bromide
- 3 sodium chloride

- A 1 only
- B 2 only
- C 1 and 3
- D 1, 2 and 3

45. Which diagram correctly shows the ions present in the compound potassium fluoride?



46. The electronic structures of atoms X and Y are shown.



X and Y form a covalent compound.

What is its formula?

- A XY_5 B XY_3 C XY D X_3Y

47. Two atoms of magnesium, Mg, react with one molecule of oxygen, O_2 .

What is the formula of the product?

- A MgO B MgO_2 C Mg_2O D Mg_2O_2

48. Compound X melts at $801^\circ C$ and is a good electrical conductor when dissolved in water.

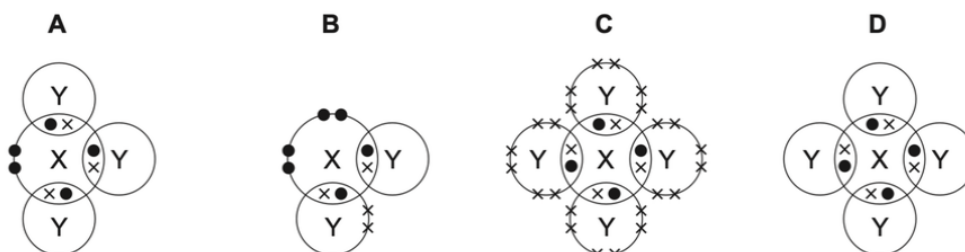
Compound Y boils at $77^\circ C$, is insoluble in water and is a non-conductor of electricity.

Which type of bonding is present in X and in Y?

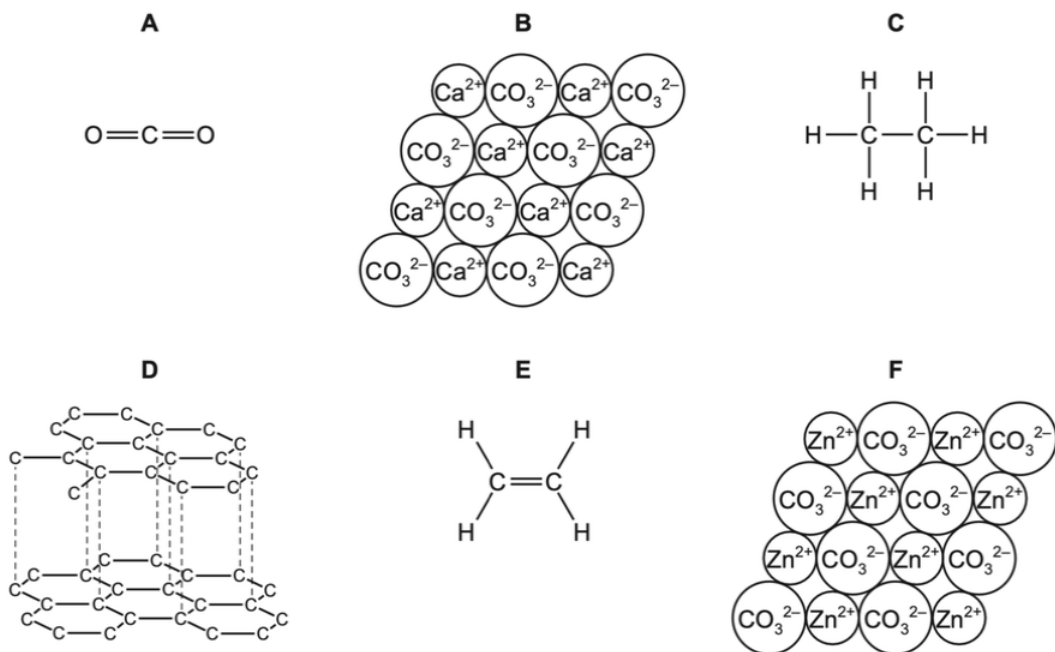
	X	Y
A	covalent	covalent
B	covalent	ionic
C	ionic	covalent
D	ionic	ionic

49. In the following diagrams, X and Y are atoms of different elements.

Which diagram correctly shows the arrangement of outer electrons in a molecule of methane?



50. The structures of six substances containing carbon are shown below.



Answer the following questions about these substances.
Each substance may be used once, more than once or not at all.

- (a) Which substance, **A**, **B**, **C**, **D**, **E** or **F**,
- (i) is an element, [1]
 - (ii) is a saturated hydrocarbon, [1]
 - (iii) is added to the blast furnace to help in the extraction of iron, [1]
 - (iv) has a giant covalent structure, [1]
 - (v) is a product of respiration, [1]
 - (vi) contains a metal ion with 20 protons? [1]

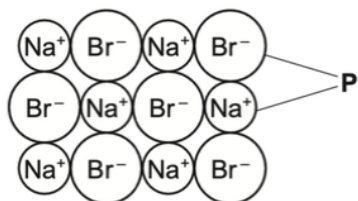
(c) (i) Draw a diagram to show the electron arrangement in a molecule of hydrogen.

[1]

(ii) What type of bonding is present in a hydrogen molecule?

..... [1]

5]. (d) The diagram below shows the arrangement of the particles in sodium bromide at room temperature.



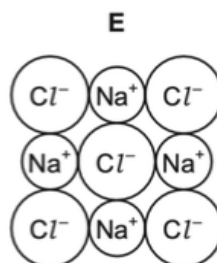
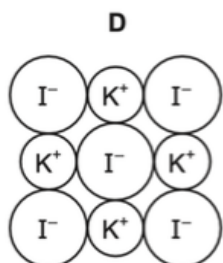
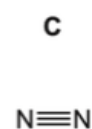
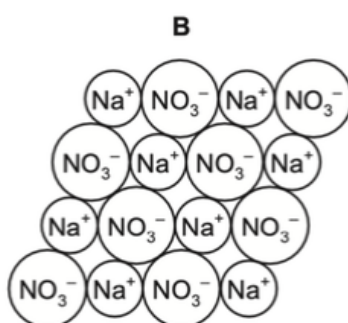
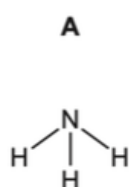
(i) Give the name of the type of particles, **P**, present in sodium bromide.

..... [1]

(ii) What is the state of sodium bromide at room temperature?
Use the information in the diagram to explain your answer.

.....
.....
..... [2]

52. The structures of five substances are shown below.



Answer the following questions about these substances.
Each substance may be used once, more than once or not at all.

- (a) Which substance, **A**, **B**, **C**, **D** or **E**,
- (i) is an element, [1]
 - (ii) turns damp red litmus paper blue, [1]
 - (iii) is a salt which contains atoms of three different elements, [1]
 - (iv) is a compound, whose aqueous solution gives a white precipitate on addition of aqueous silver nitrate, [1]
 - (v) is an ionic compound, whose aqueous solution gives off ammonia when warmed with aluminium powder and aqueous sodium hydroxide? [1]

(b) (i) Give the name of compound **B**.
..... [1]

(ii) Complete the following sentences about compounds **A** and **E** using words from the list below.

atoms gas giant ions liquid molecular polymer solid

Compound **A** is a at room temperature. It does not conduct electricity because it has a simple structure. Compound **E** does not conduct electricity when it is because its cannot move. [4]

[Total: 10]

53. The table shows the melting points, boiling points and electrical properties of five substances, A to E.

substance	melting point /°C	boiling point /°C	electrical conductivity of solid	electrical conductivity of liquid
A	-7	59	poor	poor
B	1083	2567	good	good
C	755	1387	poor	good
D	43	181	poor	poor
E	1607	2227	poor	poor

Choose a substance from the table above to match each of the following descriptions. A substance may be used once, more than once or not at all. Justify each choice with evidence from the table.

One has been completed as an example.

This substance is covalent and is a solid at room temperature (25°C).**D**.....
 evidence *Its melting point is above room temperature. It has a low melting point and it does not conduct as a liquid, so it is covalent.*

(a) This substance has a giant covalent structure.
 evidence [3]

(b) This substance is a metal.
 evidence [2]

(c) This substance is a liquid at room temperature (25°C).
 evidence [3]

(d) This substance is an ionic solid.
 evidence [3]

[Total: 11]

54. Calcium reacts with nitrogen to form the ionic compound calcium nitride, Ca_3N_2 .

- (a) Draw a diagram, based on the correct formula, which shows the charges on the ions and the arrangement of the electrons around the negative ion.

Use o to represent an electron from a calcium atom.

Use x to represent an electron from a nitrogen atom.

[3]

- (b) In the lattice of calcium nitride, the ratio of calcium ions to nitride ions is 3:2.

- (i) What is meant by the term *lattice*?

.....
..... [2]

- (ii) In terms of ionic charges, explain why the ratio of ions is 3:2.

.....
..... [2]

55. Use your copy of the Periodic Table to help you answer these questions.

(a) Predict the formula of each of the following compounds.

(i) aluminium fluoride [1]

(ii) arsenic oxide [1]

(iii) silicon bromide [1]

(b) Deduce the formula of each of the following ions.

(i) phosphide [1]

(ii) barium [1]

(iii) francium [1]

(c) Draw a diagram showing the arrangement of the valency electrons in one molecule of the covalent compound carbon dioxide.

Use x to represent an electron from a carbon atom.

Use o to represent an electron from an oxygen atom.

[3]

56. Carbon and silicon are elements in Group IV. They both form oxides of the type XO_2 .

(a) Silicon(IV) oxide, SiO_2 , has a macromolecular structure.

(i) Describe the structure of silicon(IV) oxide.

.....
.....
.....
.....
..... [3]

(ii) State **three** properties which silicon(IV) oxide and diamond have in common.

.....
.....
..... [3]

(b) Explain why the physical properties of carbon dioxide are different from those of diamond and silicon(IV) oxide.

.....
..... [1]

57. The table below shows the elements in the third period of the Periodic Table, the number of electrons in their outer energy level, their oxidation state in their common compounds and their melting points.

element	Na	Mg	Al	Si	P	S	Cl	Ar
number of outer electrons	1	2	3	4	5	6	7	8
oxidation state	+1	+2	+3	+4/-4	-3	-2	-1	0
melting point/°C	98	650	660	1414	317	115	-101	-189

- (a) Describe and explain the variation in oxidation state across the period.

.....

 [3]

- (b) The first three elements, Na, Mg and Al, are metals.

Describe the structure of a typical metal.

.....

 [3]

- (c) Explain why Na, Mg and Al are good conductors of electricity.

..... [1]

- (d) Which element exists as diatomic molecules of the type X₂?

..... [1]

- (e) Silicon has a similar structure to diamond.

Explain why silicon has the highest melting point in the period.

.....
 [2]

58. Lithium bromide is an ionic compound. It can be electrolysed when it is molten or in aqueous solution. It cannot be electrolysed as a solid.

(a) Solid lithium bromide is a poor conductor of electricity. The ions cannot move to the electrodes, they are held in an ionic lattice by strong forces.

(i) Describe the motion of the ions in the solid state.

..... [1]

(ii) Define the term *ionic bonding*.

.....
..... [2]

(iii) What is meant by the term *ionic lattice*?

.....
..... [2]

59. Carbon dioxide and silicon(IV) oxide are oxides of Group IV elements.

(a) Complete the following table.

	carbon dioxide	silicon(IV) oxide
formula		SiO ₂
melting point/°C	-56	1610
physical state at 25 °C	gas	
conduction of electricity	non-conductor	
structure		macromolecular

[4]

(b) (i) Name the type of bonds that exist between the atoms in silicon(IV) oxide.

..... [1]

(ii) Explain why silicon(IV) oxide has a very high melting point.

.....
..... [1]

(iii) Explain, in terms of attractive forces between particles, why carbon dioxide has a very low melting point.

.....
..... [1]

(iv) Explain, in terms of particles, why carbon dioxide is a non-conductor of electricity.

.....
..... [1]

60. (d) Silicon(IV) oxide has a giant structure.

(i) Name the type of bonding in silicon(IV) oxide.

..... [1]

(ii) Give two **physical** properties of silicon(IV) oxide.

.....
..... [2]

(e) Calcium phosphate is used in fertilisers. The bonding in calcium phosphate is ionic. Calcium phosphate contains the phosphate ion, PO_4^{3-} .

(i) What is ionic bonding?

.....
..... [2]

(ii) Deduce the formula of calcium phosphate.

..... [1]

Gallium is a metallic element in Group III. It has similar properties to aluminium.

(a) (i) Describe the structure and bonding in a metallic element. You should include a labelled diagram in your answer.

.....
..... [3]

(ii) Explain why metallic elements such as gallium are good conductors of electricity.

..... [1]

(b) Give the formula of

gallium(III) chloride,

gallium(III) sulfate.

[2]

61. (a) Potassium iodide is an ionic compound.

(i) Describe what happens, in terms of electron loss and gain, when a potassium atom reacts with an iodine atom.

.....
.....
.....
..... [2]

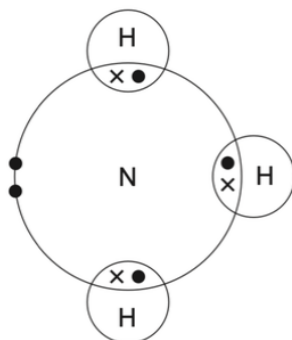
(ii) Describe the structure of solid potassium iodide. You may draw a diagram.

.....
.....
..... [2]

(iii) Explain why potassium iodide has a high melting point.

.....
.....
..... [2]

62. (c) The diagram shows the electron arrangement in a molecule of ammonia, showing only outer shell electrons.

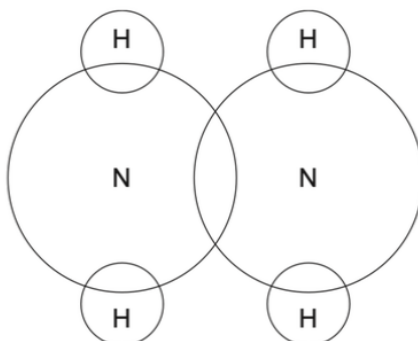


(i) State the type of bonding in ammonia.

..... [1]

(ii) Hydrazine, N_2H_4 , is another compound of nitrogen and hydrogen.

Complete the diagram to show the electron arrangement in a molecule of hydrazine, showing only outer shell electrons.



[3]

63. Beryllium is a metallic element in Group II.

(a) Give the electronic structure of a beryllium atom.

..... [1]

(b) Give the formula of beryllium oxide.

..... [1]

(c) (i) Describe the bonding in a metallic element such as beryllium.
Include a labelled diagram and any appropriate charges in your answer.

.....
.....
..... [3]

(ii) Explain why metallic elements, such as beryllium, are good conductors of electricity.

.....
..... [1]

64. Silicon(IV) oxide and sodium chloride have different types of bonding and structure.

(a) Name the type of bonding present in

silicon(IV) oxide,

sodium chloride.

[2]

(b) Name the type of structure present in silicon(IV) oxide.

..... [1]

(c) (i) Silicon(IV) oxide has a high melting point. Explain why.

.....

..... [2]

(ii) Silicon(IV) oxide is a poor conductor of electricity. Explain why.

..... [1]

(d) Solid sodium chloride does not conduct electricity. However, it conducts electricity when molten.

Explain why solid sodium chloride does **not** conduct electricity, whereas molten sodium chloride does conduct electricity.

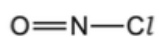
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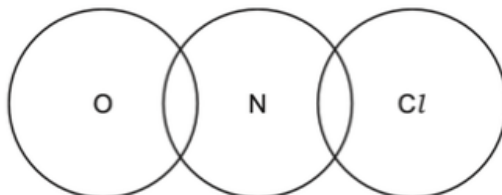
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..... [3]

b5. (e) Nitrosyl chloride, NOCl , is a gas at room temperature. It has the structure shown.



- (i) Complete the dot-and-cross diagram to show the arrangement of the outer shell electrons in nitrosyl chloride.



[2]

- (ii) Nitrosyl chloride has a boiling point of -6°C .

Explain why nitrosyl chloride has a low boiling point.

.....

.....

..... [2]

6b. Magnesium is a metal.

(a) Describe the structure and bonding in magnesium.

.....
.....
.....
..... [3]

(b) Why can magnesium conduct electricity when solid?

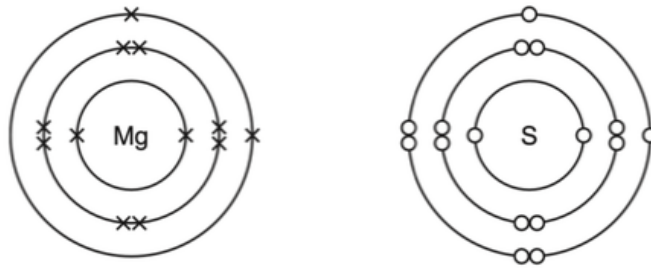
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(c) Why is magnesium malleable?

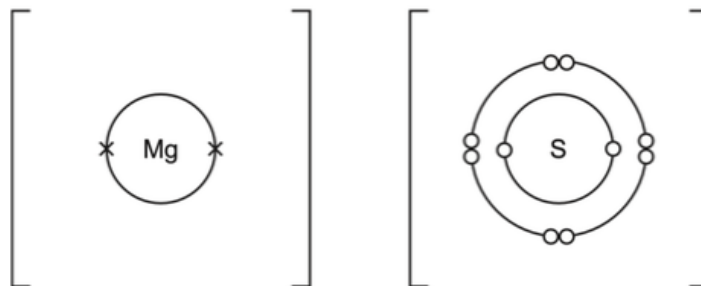
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67. (d) Magnesium reacts with sulfur to form the ionic compound magnesium sulfide, MgS.

The diagrams show the electronic structures of atoms of magnesium and sulfur.



(i) Complete the diagrams to show the electronic structures of the ions in magnesium sulfide. Show the charges on the ions.



[3]

(ii) Ionic compounds, such as magnesium sulfide, do **not** conduct electricity when solid. Magnesium sulfide does **not** dissolve in water. Magnesium sulfide **does** conduct electricity under certain conditions.

State the conditions needed for magnesium sulfide to conduct electricity. Explain why magnesium sulfide conducts electricity under these conditions.

.....

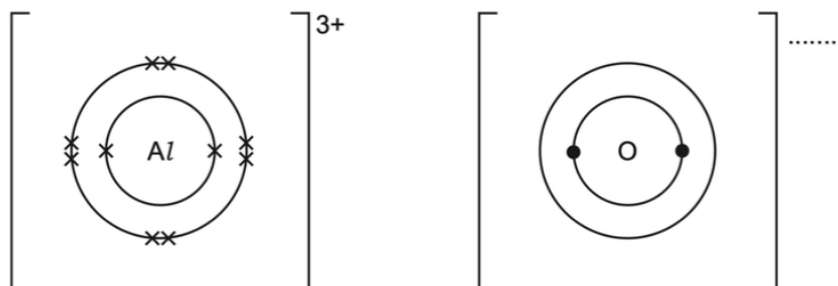
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..... [2]

68.(b) Aluminium oxide is an ionic compound with a high melting point.

- (i) Complete the dot-and-cross diagram to show the electron arrangement in **one** of the oxide ions present in aluminium oxide. Include the charge on the oxide ion. One of the aluminium ions is shown.



[2]

- (ii) The melting point of aluminium oxide is above 2000 °C.

Explain why aluminium oxide has a high melting point.

.....
.....
..... [2]

69. (a) Complete the table to show the electronic structure of the atoms and ions.

	electronic structure
F	2,7
Si	
Ca ²⁺	
N ³⁻	

[3]

(b) Predict the formula of the compound formed between Ca²⁺ and N³⁻.

..... [1]

(c) Draw a dot-and-cross diagram to show the electron arrangements in the **two** ions present in lithium chloride, LiCl.

Show outer shell electrons only. Include the charges on the ions.

[3]

(d) Sulfur dichloride, SCl₂, is a covalent compound. It has the structure Cl-S-Cl.

Draw a dot-and-cross diagram to show the electron arrangement in a molecule of sulfur dichloride.

Show outer shell electrons only.

[3]

(e) In terms of attractive forces, explain why LiCl has a higher melting point than SCl_2 .

.....
.....
.....
.....
..... [3]

(f) Suggest the identity of a **covalent compound** with a higher melting point than LiCl .

..... [1]