C2: Bonding and Structure 1

ANSWER KEY

5.1	What are the three types of bonds?	Covalent, ionic and metallic
5.2	What happens to the electrons in an ionic bond?	They are transferred from a metal atom to a non-metal atom
5.3	If an atom has gained electrons, what charge will it have as an ion?	Negative
5.4	If an atom has lost electrons, what charge will it have as an ion?	Positive
5.5	**What type of elements will form ionic bonds?**	**Metal + non-metal**
5.6	What is the charge on ions from group one and two?	• Group 1: 1+ • Group 2: 2+
5.7	What is the charge on ions from group six and seven?	• Group 6: 2- • Group 7: 1-
5.8	Describe the structure and bonding in an ionic compound	Giant ionic lattice (repeating structure) held together by strong electrostatic forces of attraction between positive and negative ions
5.9	What kind of melting and boiling points do ionic compounds have?	High
5.10	Explain the melting and boiling points of ionic compounds	• High due to strong electrostatic forces of attraction • between the many ions • which require a lot of heat energy to break
5.11	Explain why ionic compounds do not conduct electricity when solid	The ions are not free to move and carry charge
5.12	Explain why ionic compounds conduct electricity when molten (melted) or in aqueous solution	The ions are free to move and carry charge

C2: Bonding and Structure 2

ANSWER KEY

6.1	What happens to the electrons in a covalent bond?	They are shared
6.2	**What type of elements will form covalent bonds?**	**Non-metal + non-metal**
6.3	What two types of substance have covalent bonds?	• Giant covalent substances (macromolecules) - like diamond and graphite • Small molecules (simple molecular) - like methane, CH_4, water, H_2O and ammonia NH_3
6.4	How many bonds does each carbon atom have in diamond? And in graphite?	4 3
6.5	**Explain why macromolecules like diamond, graphite and silicon dioxide have high melting points**	• **Giant (repeating) / lattice structures** • **Many strong covalent bonds between the atoms** • **Requires a lot of heat energy to break**
6.6	Explain why most covalent substances do not conduct electricity	There are no delocalised electrons or ions that are free to move and carry charge
6.7	**Making reference to structure and bonding in graphite, explain how it conducts electricity**	• **Each carbon has only 3 bonds** • **leaving 1 delocalised electron per atom** • **which is free to move through the structure** • **and carry charge**
6.8	**Explain why graphite can act as a lubricant and can be used in pencils**	• **Layered structure** • **with weak forces between layers** • **which are free to slide over each other**
6.9	What type of substance are methane and water?	Small covalent molecules (simple molecular)
6.10	**Describe the structure and bonding in small molecules**	• **Strong covalent bonds between atoms** • **weak forces between the molecules**
6.11	**Explain why small molecules have low melting points**	• **Weak forces of attraction** • **<u>between</u> the <u>molecules</u>** • **which are easy to break with only a little heat energy**

C2: Bonding and Structure 3

ANSWER KEY

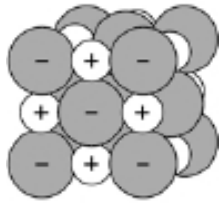
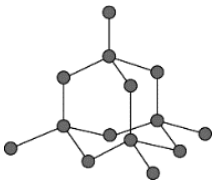
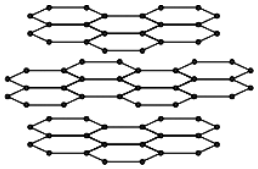
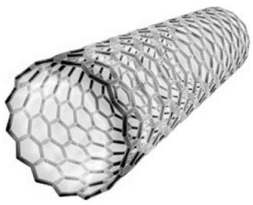
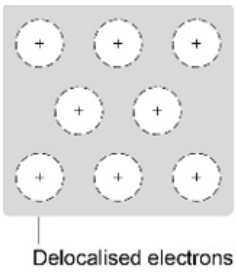
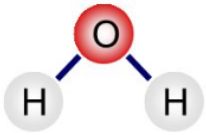
7.1	What is a polymer?	A long chain molecule made by joining many small molecules (monomers) together
7.2	Why do larger molecules have higher melting points than smaller ones?	• Bigger molecules have stronger forces of attraction • between the molecules • so need more heat energy to separate
7.3	What is graphene?	A single layer of graphite
7.4	What is graphene used for?	Electronics (as it is a good electrical conductor) and composites
7.5	**What is fullerene?**	**Molecule made of carbon atoms arranged in a cage or tube**
7.6	What is the formula of Buckminsterfullerene?	C_{60}
7.7	What are nanotubes?	Cylindrical fullerenes made from hexagonal rings of carbon
7.8	What are nanotubes used for?	Electronics (also nanotechnology and composite materials)
7.9	Describe the bonding in metals	• Lattice (repeating structure) of metal ions • surrounded by delocalised electrons
7.10	**Explain why metals generally have high melting points**	• **Strong attraction** • **between the metal ions and the delocalised electrons** • **which requires a lot of heat energy to break**
7.11	**Explain why metals conduct electricity**	• **Metals have delocalised electrons** • **which are free to move through the structure** • **and carry charge**
7.12	Explain why metals are malleable (bendable) and ductile (can be pulled into wires) without breaking	• Layers of ions • can slide past each other (and the) • delocalised electrons move with them
7.13	**Explain why alloys (mixtures of metals) are harder and stronger than pure metals**	• **Metal atoms are different sizes** • **layers of atoms are distorted** • **so layers can't slide past each other**

C2: Nanoparticles (Triple Content)

ANSWER KEY

1	What is a nanometre?	1 x 10^{-9} m
2	How big are nanoparticles?	1-100nm (a few hundred atoms)
3	**Calculate the surface area to volume ratio for a cube with each side of length 2 cm**	**Surface area = 2 x 2 x 6 = 24 cm^2** **Volume = 2 x 2 x 2 = 8 cm^3** **= 24:8 or 4:1**
4	**Why do nanoparticles have different properties to bulk materials?**	**Because of their high surface area to volume ratio**
5	Give two examples of what nanoparticles can be used for	Medical applications, sun creams, catalysts, deodorants, cosmetics, electronics
6	What are the possible risks associated with nanoparticles?	• Nanoparticles could get into our bloodstream through our lungs or our skin (as they are so small) • They could accumulate in important organs and have a negative effect on our health

Recognising Structures and Types of Bonding

Diagram	Type of bonding	How do we know?	Melting and boiling points	Electrical conductivity
	Ionic e.g. sodium chloride, NaCl	Has both positive <u>and</u> negative ions (metal and non-metal)	All the substances with ***giant repeating structures*** will have very ***high melting and boiling points*** This is because they contain a ***lot of strong bonds*** (ionic, covalent or metallic) so require a ***lot of heat energy to break these bonds*** If you can see a lot of atoms or ions in a lattice or large regular structure, ***high melting and boiling points***	Only when molten or dissolved in water, as the ions are then free to move and carry charge
	Macromolecular Covalent (giant covalent) Diamond	Has a giant repeating structure, but no ions		No – has no delocalised electrons Carbon atoms form 4 covalent bonds
	Macromolecular Covalent (giant covalent) Graphite	Has a giant repeating structure, but no ions, and is in hexagonal layers		Yes – has delocalised electrons Carbon atoms only form 3 covalent bonds
	Macromolecular Covalent (giant covalent) A fullerene	Has a giant repeating structure, but no ions		Yes – has delocalised electrons Carbon atoms only form 3 covalent bonds
	Metallic e.g. copper, Cu	Has positive ions surrounded by delocalised electrons in a giant repeating structure		Yes – has delocalised electrons that are free to move through the structure and carry charge
	Simple (molecular) covalent Made from small molecules e.g. water, H_2O	It has no ions (so must be covalent) and is only a small group of atoms	***Low melting and boiling points*** Strong covalent bonds between atoms but… ***Weak attraction <u>between</u> <u>molecules</u>*** so very little heat energy needed to separate the molecules	No – has no delocalised electrons

FOUNDATION TIER

Q1. Carbon can exist in a number of different structures.

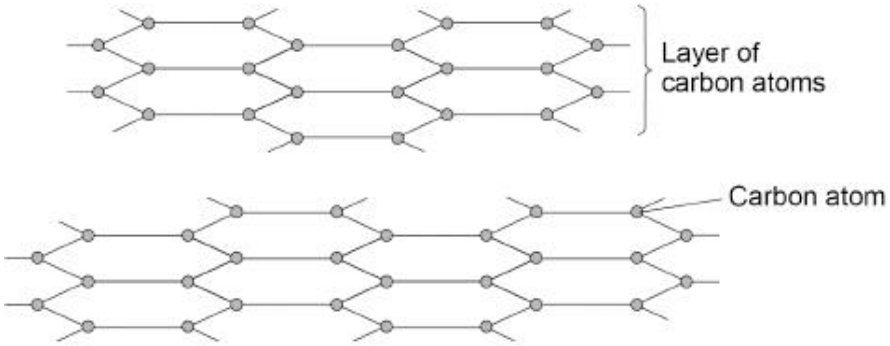
(a) What is the approximate radius of a carbon atom? Tick (✓) **one** box.

0.1 m ☐ 0.1 mm ☐ 0.1 nm ☐

(1)

In graphite the carbon atoms are held together by bonds.

Figure 1 represents part of the structure of graphite.



(b) How many bonds does each carbon atom have in graphite?

Use **Figure 1**. Tick (✓) **one** box.

1 ☐ 2 ☐ 3 ☐ 4 ☐

(1)

(c) What type of bonds hold the carbon atoms together in graphite? Tick (✓) **one** box.

Covalent ☐

Ionic ☐

Metallic ☐

(1)

(d) Lubricants allow objects to slide over each other easily.

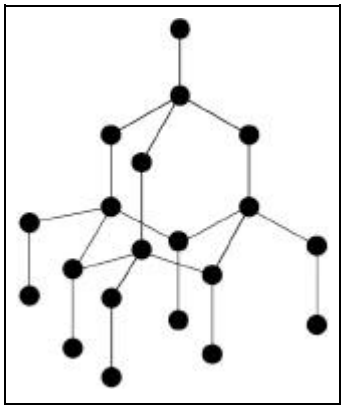
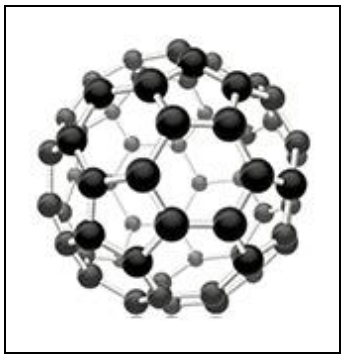
Suggest why graphite can be used as a lubricant. Use **Figure 1**.

_____

(1)

(e) The two structures represent different forms of carbon.

Draw **one** line from each structure to the form of carbon.

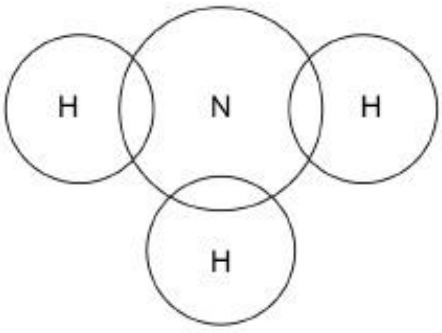
Structure	**Form of carbon**
	Buckminsterfullerene
	Diamond
	Graphene
	Nanotube

(2)

(f) The diagram below shows the outer electron shells in an ammonia molecule.

Complete the diagram to show a dot and cross diagram for an ammonia molecule.

Show the outer shell electrons only. Nitrogen is in group 5 of the periodic table.



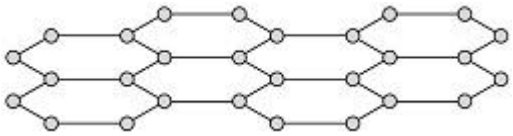
(2)
(Total 14 marks)

Q2. This question is about graphene and graphite.

Graphene is a single layer of graphite.

Figure 1 represents part of the structure of graphene.

Figure 1



(a) Graphene is one atom thick. The diameter of the atom is 3.4×10^{-10} m

What is the thickness of a graphene layer in nanometres?

1 nm = 10^{-9} m

Tick (✓) **one** box.

0.034 nm ☐

0.34 nm ☐

3.4 nm ☐

34 nm ☐

(1)

(b) Which is **one** use of graphene?

Tick (✓) **one** box.

As a detergent ☐

As a solvent ☐

In composites ☐

To produce polymers ☐

(1)

(c) Graphene and graphite are used in electronics.

Suggest **one** reason why graphene is a more suitable material for use in electronics than graphite.

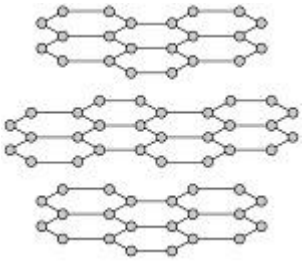
_____

_____

(1)

(d) **Figure 2** represents part of the structure of graphite.

Figure 2



Graphite is used as a contact in electric motors because graphite:

- conducts electricity
- is slippery

Explain why graphite has these properties.

You should refer to the structure and bonding of graphite in your answer.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

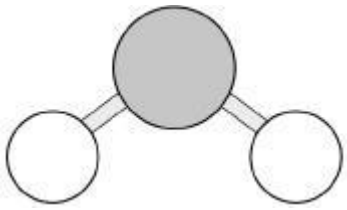
_____

(6)

(Total 9 marks)

Q3. This question is about substances with covalent bonding.

(a) The diagram below shows a ball and stick model of a water molecule (H_2O).



Suggest **one** limitation of using a ball and stick model for a water molecule.

_____

_____

_____

(1)

(b) Ice has a low melting point.

Water molecules in ice are held together by intermolecular forces.

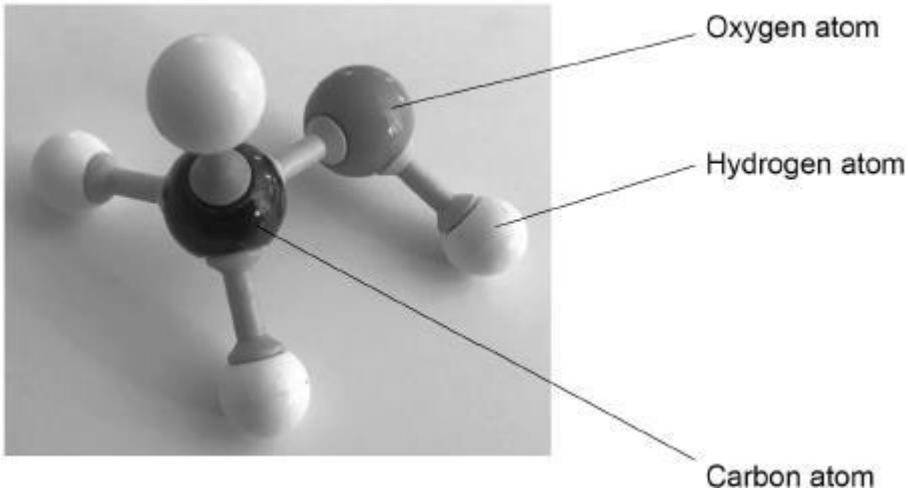
Complete the sentence.

Ice has a low melting point because the intermolecular forces are

_____.

(1)

(c) The image below shows the structure of a molecule.



What is the molecular formula of the molecule in the above image?

_____

_____

(1)

Diamond has a giant covalent structure.

(d) What is the number of bonds formed by each carbon atom in diamond?

Tick (✓) **one** box.

2 ☐ 3 ☐ 4 ☐ 8 ☐

(1)

(e) Give **two** physical properties of diamond.

1. _____

2. _____

(2)

(f) Name **two** other substances with giant covalent structures.

1. _____

2. _____

(2)

(Total 8 marks)

HIGHER TIER

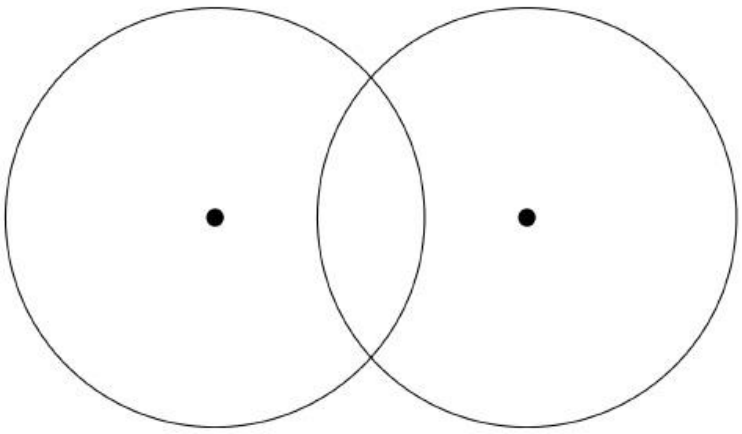
Q4. This question is about structure and bonding.

(a) Oxygen is in Group 6.

The diagram shows the outer shells in an oxygen molecule.

Complete the dot and cross diagram.

You should show only the electrons in the outer shell.



(2)

(b) Explain why oxygen is a gas at room temperature.

(3)

(c) Oxygen forms many compounds.

Which **two** compounds of oxygen are small molecules? Tick **two** boxes.

- Carbon dioxide ☐
- Magnesium oxide ☐
- Potassium oxide ☐
- Silicon dioxide ☐
- Water ☐

(2)

(d) Explain why metals conduct electricity.

Refer to structure and bonding in your answer.

(4)

(Total 11 marks)

Q5. This question is about sodium chloride and iodine.

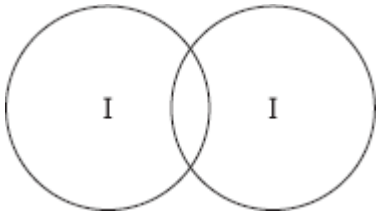
(a) Describe the structure and bonding in sodium chloride.

(4)

(b) The bonding in iodine is similar to the bonding in chlorine.

(i) Complete the diagram below to show the bonding in iodine.

Show the outer electrons only.



(2)

(ii) Explain why iodine has a low melting point.

(3)

(iii) Explain, in terms of particles, why liquid iodine does not conduct electricity.

(2)

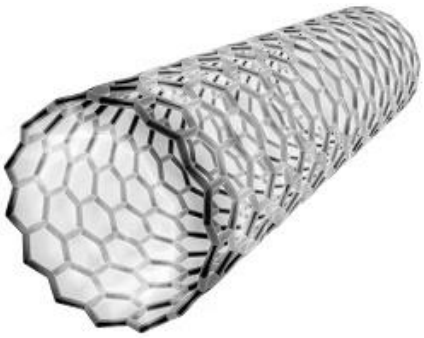
(Total 11 marks)

SEPARATE SCIENCE

Q6. This question is about materials and their properties.

(a) **Figure 1** shows a carbon nanotube.

Figure 1



The structure and bonding in a carbon nanotube are similar to graphene.

Carbon nanotubes are used in electronics because they conduct electricity.

Explain why carbon nanotubes conduct electricity.

_____

_____

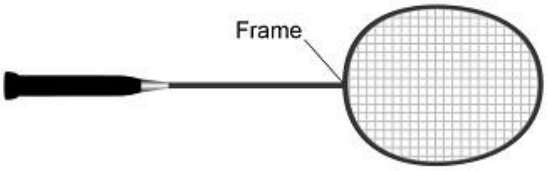
_____

_____

(2)

(b) **Figure 2** shows a badminton racket.

Figure 2



The following table shows some properties of materials.

The materials could be used to make badminton racket frames.

Material	Density in g/cm^3	Relative strength	Relative stiffness
Aluminium	2.7	0.3	69
Carbon nanotube	1.5	60	1000
Wood	0.71	0.1	10

Evaluate the use of the materials to make badminton racket frames.

Use the table above.

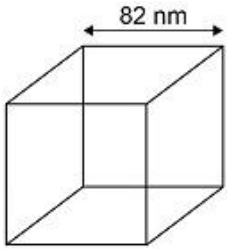
(4)

Zinc oxide can be produced as nanoparticles and as fine particles.

(c) A nanoparticle of zinc oxide is a cube of side 82 nm

Figure 3 represents a nanoparticle of zinc oxide.

Figure 3



Calculate the surface area of a nanoparticle of zinc oxide.

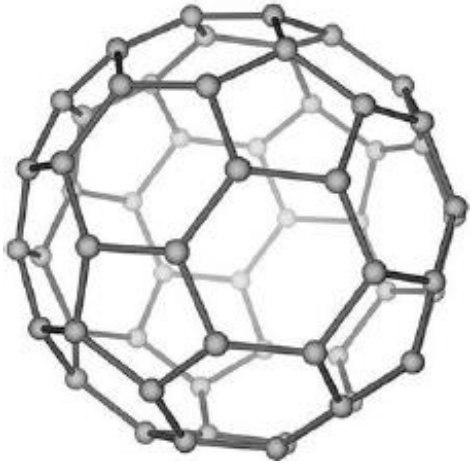
Give your answer in standard form.

Surface area = _____ nm^2

(3)

(d) **Figure 1** shows a model of a Buckminsterfullerene molecule.

Figure 1



A lubricant is a substance that allows materials to move over each other easily.

Suggest why Buckminsterfullerene is a good lubricant.

Use **Figure 1**.

_____

_____

_____

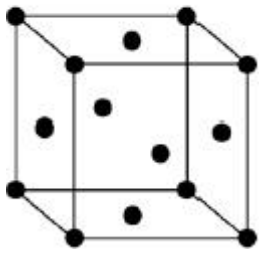
_____

(2)

Silver can form cubic nanocrystals.

Figure 2 represents a silver nanocrystal.

Figure 2



(e) A silver nanocrystal is a cube of side 20 nm

Calculate the surface area to volume ratio of the nanocrystal.

Surface area to volume ratio = _____

(3)

(f) Silver nanoparticles are sometimes used in socks to prevent foot odour.

Suggest why it is cheaper to use nanoparticles of silver rather than coarse particles of silver.

(2)

(Total 16 marks)

Q1.

(a) 0.1 nm

1

(b) 3

1

(c) covalent

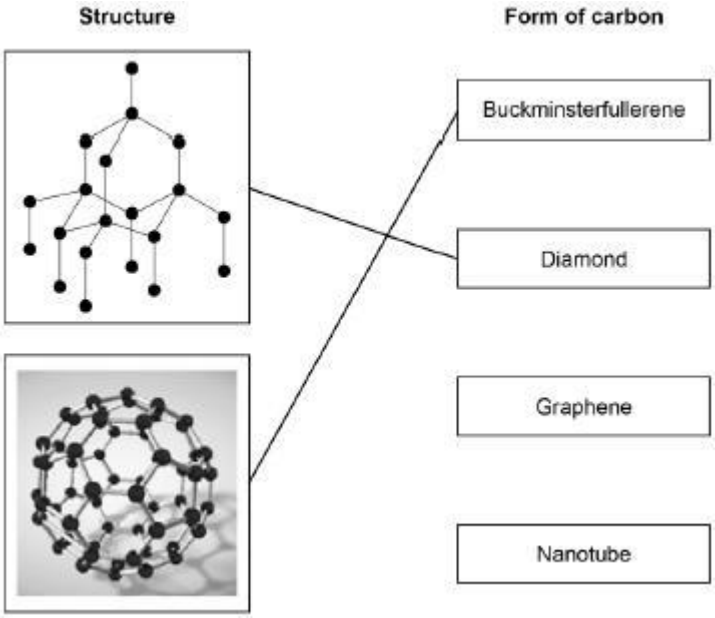
1

(d) layers slide (over each other)

allow atoms slide over each other

1

(e)



do **not** accept more than **one** line from a box on the left

1
1

(f) 3 bonding pairs of electrons

1

lone pair of electrons on the nitrogen atom

1

[14]

Q2.

(a) 0.34 nm

1

(b) in composites

1

(c) *must be a comparison*

graphene is any **one** from:
- better conductor (of electricity)
- allows greater miniaturisation of electronic circuits

  allow thinner
- stronger
- harder
- more flexible

  allow converse for graphite

1

(d) **Level 3**: Relevant points (reasons / causes) are identified, given in detail and logically linked to form a clear account.

5–6

Level 2: Relevant points (reasons / causes) are identified, and there are attempts at logical linking. The resulting account is not fully clear.

3–4

Level 1: Points are identified and stated simply, but their relevance is not clear and there is no attempt at logical linking.

1–2

Indicative content

Structure and bonding
- giant structure / lattice / repeating structure
- of carbon atoms
- in layers of hexagonal rings

- covalent (bonds)
- strong (covalent) bonds

- where each (carbon) atom bonded to three other (carbon) atoms
- one electron on each atom is delocalised

Explanation for conductivity
- has delocalised electrons
- (which) are free to move
- and carry charge through the structure

Explanation for graphite being slippery
- layers free to slide over each other
- (because) only weak (intermolecular) forces between layers

[9]

Q3.

(a) any **one** from:

- not to scale

  allow size of atoms incorrect
- not 3 dimensional / D
- incorrect arrangement in space

  allow atoms are separated
- electrons / shells not shown

ignore properties of water

1

(b) weak

allow weaker

1

(c) CH_4O

allow CH_3OH

1

(d) 4

1

(e) any **two** from:

- (very) hard
  allow strong
- (very) high melting point
- does not conduct electricity
  allow high thermal conductivity
  ignore shiny

2

(f) graphite

allow graphene

1

silicon dioxide

allow silica
allow silicon
allow polymer(s) ***or*** *allow (named) polymer(s)*
allow fullerene ***or*** *allow carbon nanotubes*
ignore buckminsterfullerene

1

[8]

Q4.

(a) 4 electrons shared

1

each atom has 4 unshared electrons outside the bond

1

(b) small molecules

allow simple / small molecular structure

1

with weak intermolecular forces

allow weak forces between molecules

1

(which) require little energy to overcome

must be linked to second marking point

1

(c) carbon dioxide

1

water

1

(d) giant structure / lattice / repeating structure of metal ions

1

delocalised electrons

1

(delocalised electrons) are free to move through the whole structure

1

and carry charge

1

[11]

Q5.

(a) lattice / giant / repeating structure

*max **3** if incorrect structure or bonding or particles*

1

ionic **or** (contains) ions

1

Na^+ **and** Cl^-

accept in words or dot and cross diagram: must include type and magnitude of charge for each ion

1

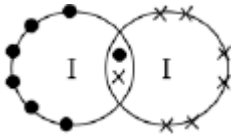
electrostatic attraction

allow attraction between opposite charges

1

(b) (i) one bonding pair of electrons

accept dot, cross or e or − or any combination, eg



1

6 un-bonded electrons on each atom

1

(ii) simple molecules

*max **2** if incorrect structure or bonding or particles*

accept small molecules

accept simple / small molecular structure

1

with intermolecular forces

accept forces between molecules

must be no contradictory particles

1

which are weak **or** which require little energy to overcome − must be linked to second marking point

reference to weak covalent bonds loses second and third marking points

1

(iii) iodine has no delocalised / free / mobile electrons or ions

1

so cannot carry charge

*if no mark awarded iodine molecules have no charge gains **1** mark*

1

[11]

Q6.

(a) contain delocalised electrons

allow contain free electrons

1

(so) electrons can move through the structure / nanotube

allow (so) electrons can carry charge through the structure / nanotube

ignore throughout for through

ignore current / electricity for charge

1

(b) **Level 2:** Some logically linked reasons are given. There may also be a simple judgement.

3–4

Level 1: Relevant points are made. They are not logically linked.

1–2

No relevant content

0

Indicative content

- wood is the least dense so lightest to use
- aluminium is the most dense so will make the racket too heavy

- carbon nanotube is the strongest so least likely to break
- wood / aluminium are too weak so the racket will break more easily

- carbon nanotube is the stiffest so least likely to bend out of shape
- wood / aluminium are not very stiff so could bend out of shape

- justified conclusion

(c)

*an answer of 4.0×10^4 (nm^2) scores **3** marks*

*an answer of 40344 (nm^2) scores **2** marks*

(822 =) 6724 (nm^2)

1

(6 x 6724 =) 40344 (nm^2)

allow 40344 (nm^2) correctly rounded to any number of significant figures
allow correct calculation using incorrectly calculated value of area of one face from step1

1

= 4.0 x 10^4 (nm^2)

allow 4.0344 x 10^4 (nm^2) correctly rounded to 1 or more significant figures
allow a correctly calculated and rounded conversion to standard form of an incorrect calculation of surface area

1

(d) molecules are spherical

1

(so molecules) will roll

1

(e) surface area (= 20 × 20 × 6) = 2400 (nm^2)

1

volume (= 20^3) = 8000 (nm^3)

1

ratio = 0.3 (nm^3): 1 (nm^3)
ratio = 0.3 (nm^3): 1 (nm^3)
or
1 (nm^3): 3.33 (nm^3)

1

(f) (nanoparticles) have a larger surface area to volume ratio

1

so less can be used for the same effect

1

[16]