C2 BULK AND SURFACE PROPERTIES INCLUDING NANOPARTICLES

Question Practice

Name: _____

Class: _____

Date: _____

Time: **68 minutes**

Marks: **68 marks**

Comments: **GCSE CHEMISTRY ONLY**

1 This question is about atoms, molecules and nanoparticles.

(a) Different atoms have different numbers of sub-atomic particles.

(i) An oxygen atom can be represented as $^{16}_{8}O$

Explain why the mass number of this atom is 16.

You should refer to the numbers of sub-atomic particles in the nucleus of the atom.

_____

_____

_____

_____

_____

_____

(2)

(ii) Explain why $^{12}_{6}C$ and $^{14}_{6}C$ are isotopes of carbon.

You should refer to the numbers of sub-atomic particles in the nucleus of each isotope.

_____

_____

_____

_____

_____

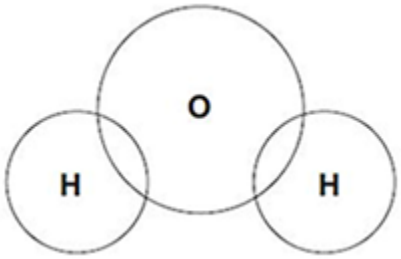
_____

(3)

(b) Hydrogen atoms and oxygen atoms chemically combine to produce water molecules.

(i) Complete the figure below to show the arrangement of the outer shell electrons of the hydrogen and oxygen atoms in a molecule of water.

Use dots (•) or crosses (×) to represent the electrons.



(2)

(ii) Name the type of bonding in a molecule of water.

_____

(1)

(iii) Why does pure water **not** conduct electricity?

_____

_____

(1)

(c) Nanoparticles of cobalt oxide can be used as catalysts in the production of hydrogen from water.

(i) How does the size of a nanoparticle compare with the size of an atom?

_____

_____

(1)

(ii) Suggest **one** reason why 1 g of cobalt oxide nanoparticles is a better catalyst than 1g of cobalt oxide powder.

_____

_____

(1)

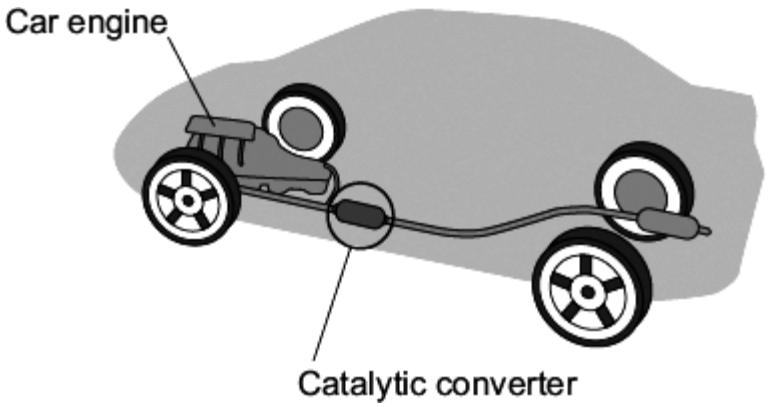
(Total 11 marks)

2 Read the information about car engines.

Burning petrol in air is an *exothermic* reaction. This reaction is used in car engines.

When petrol burns it produces harmful substances such as nitrogen oxides and carbon monoxide.

A catalytic converter stops these harmful substances being released into the air.



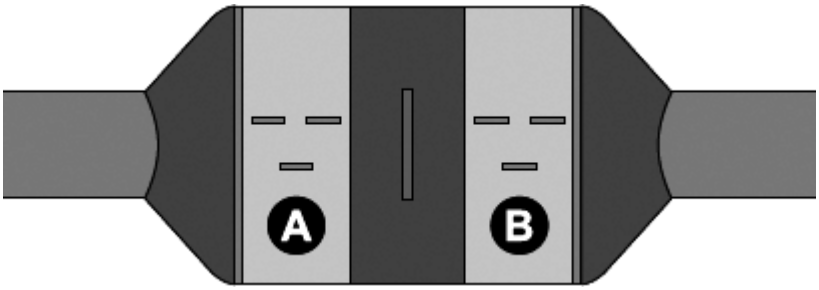
(a) The reaction is *exothermic*. What is the meaning of *exothermic*?

_____

_____

(1)

(b) The catalytic converter has two parts shown as **A** and **B** in the diagram.



Part **A** contains a catalyst made from platinum and rhodium.

Part **B** contains a catalyst made from platinum and palladium.

(i) Why are catalysts used in chemical reactions?

_____

_____

(1)

(ii) One reaction in part **A** is shown by this equation.

$$2NO \rightarrow N_2 + O_2$$

Suggest why this reaction helps the environment.

_____

_____

(1)

(iii) The equation for one of the reactions in part **B** is shown below.

Balance this equation.

$$\_\_\_\_\ CO + O_2 \rightarrow \_\_\_\_\ CO_2$$

(1)

(iv) The catalytic converter works for many years without replacing the catalyst.

Explain why the catalyst does not need to be replaced.

_____

_____

(1)

(v) Suggest why different catalysts are used in parts **A** and **B**.

_____

_____

(1)

(c) Modern catalytic converters contain nanosized particles of catalyst. Using nanosized particles reduces the cost of the catalytic converter.

Suggest and explain why the use of nanosized catalyst particles reduces the cost of the catalytic converter.

Your answer should include information about the size and surface area of the particles.

_____

_____

_____

_____

_____

_____

_____

(3)

(Total 9 marks)

3 Read the article and then answer the questions that follow.

Nanotennis!

Tennis balls contain air under pressure, which gives them their bounce. Normal tennis balls are changed at regular intervals during tennis matches because they slowly lose some of the air. This means that a large number of balls are needed for a tennis tournament, using up a lot of materials.

'Nanocoated' tennis balls have a 'nanosize' layer of butyl rubber. This layer slows down the escape of air so that the ball does not lose its pressure as quickly. The 'nanocoated' tennis balls last much longer and do not need to be replaced as often.

(a) How does the 'nanosize' layer make the tennis balls last longer?

_____

_____

(1)

(b) Put a tick (✓) next to the best description of a 'nanosize' layer.

Description	(✓)
A layer one atom thick.	
A layer a few hundred atoms thick.	
A layer millions of atoms thick.	

(1)

(c) Suggest why using ‘nanocoated’ tennis balls would be good for the environment.

_____

_____

_____

_____

_____

(2)

(Total 4 marks)

4 Read the article and then answer the questions.

Nanotennis!

Tennis balls contain air under pressure, which gives them their bounce. Normal tennis balls are changed at regular intervals during tennis matches because they slowly lose some of the air.

‘Nanocoated’ tennis balls have a ‘nanosize’ layer of butyl rubber. This layer slows down the escape of air so that the ball does not lose its pressure as quickly.

(a) What is the meaning of *nanosize*?

_____

_____

(1)

(b) Suggest why using ‘nanocoated’ tennis balls would be good for the environment.

_____

_____

_____

_____

(2)

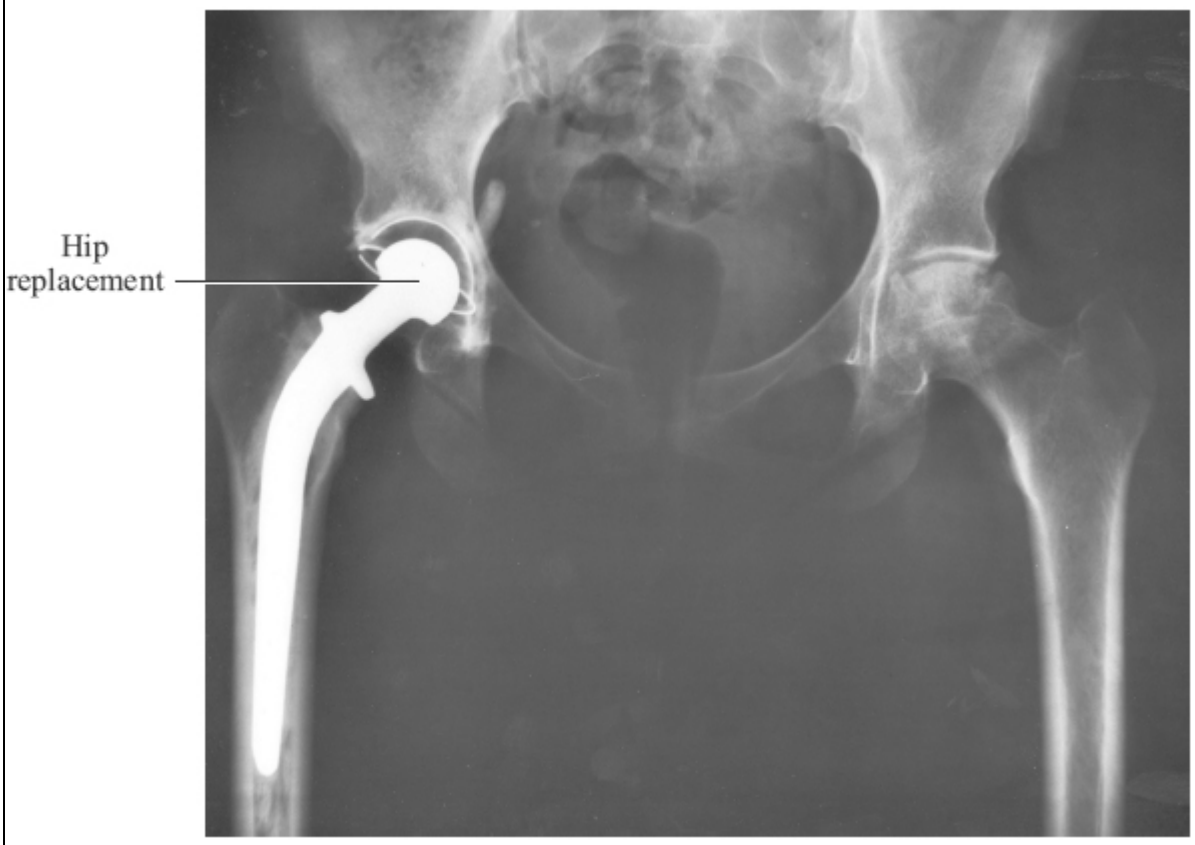
(Total 3 marks)

5 Read this passage about metals.

Metals are crystalline materials. The metal crystals are normally about 20 000 nm (nanometres) in diameter. The atoms inside these crystals are arranged in layers.

A new nanoscience process produces nanocrystalline metals. Nanocrystalline metals are stronger and harder than normal metals.

It is hoped that nanocrystalline metals can be used in hip replacements.



The use of nanocrystalline metals should give people better hip replacements which last longer.

(a) State why metals can be bent and hammered into different shapes.

_____

_____

(1)

(b) How is the size of the crystals in nanocrystalline metals different from the size of the crystals in normal metals?

_____

_____

(1)

(c) Hip joints are constantly moving when people walk.

Suggest and explain why the hip replacement made of nanocrystalline metal should last longer than one made of normal metals.

_____

_____

_____

_____

(2)

(Total 4 marks)

6 The article gives some information about graphene.

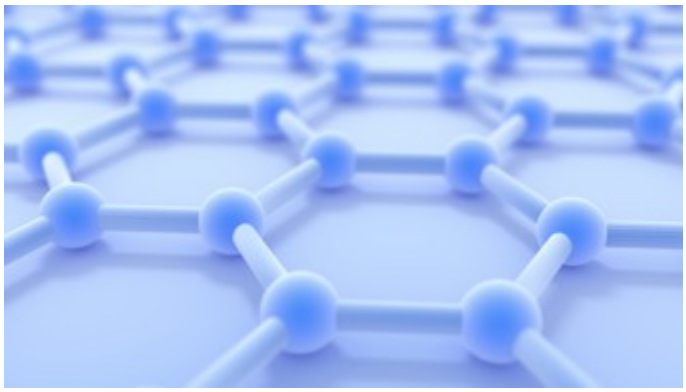
Nanotunes!

Carbon can be made into nano-thin, strong sheets called graphene.

A graphene sheet is a single layer of graphite.

Graphene conducts electricity and is used in loudspeakers.

The picture shows the structure of graphene.



(a) Use the picture and your knowledge of bonding in graphite to:

(i) explain why graphene is strong;

(3)

(ii) explain why graphene can conduct electricity.

(2)

(b) Graphite is made up of layers of graphene.

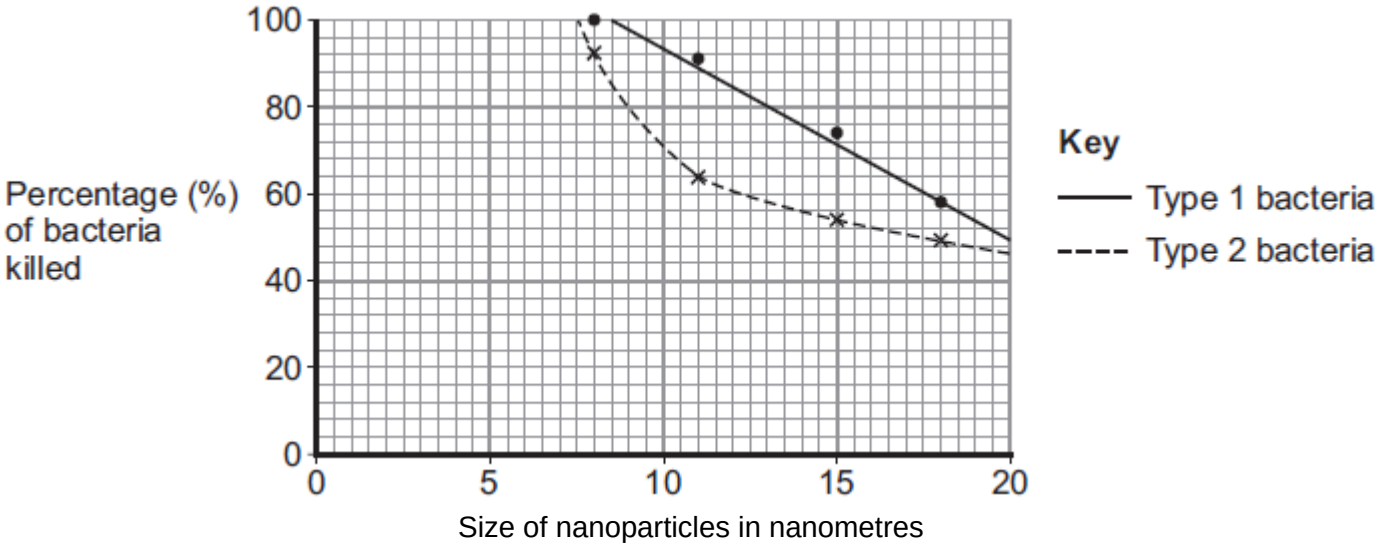
Explain why graphite is a lubricant.

(2)

(Total 7 marks)

7 Magnesium oxide nanoparticles can kill bacteria.

The figure below shows the percentage of bacteria killed by different sized nanoparticles.



(a) (i) Give **two** conclusions that can be made from the figure above.

_____

_____

_____

_____

_____

_____

(2)

(ii) Points are plotted for only some sizes of nanoparticles.

Would collecting and plotting data for more sizes of nanoparticles improve the conclusions?

Give a reason for your answer.

_____

_____

(1)

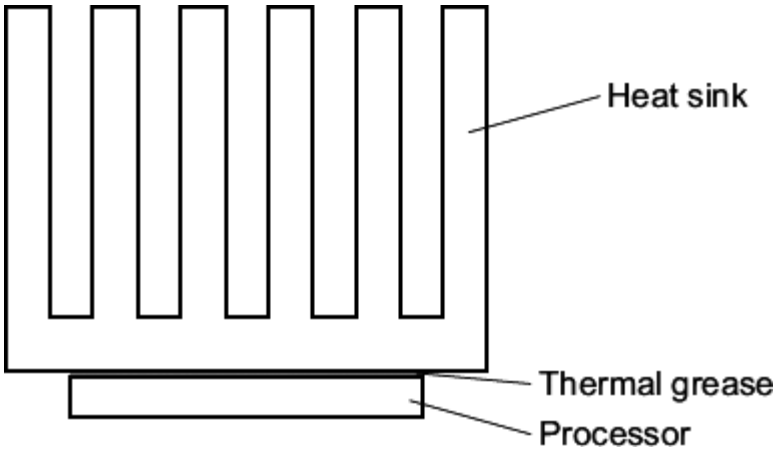
(b) Magnesium oxide contains magnesium ions (Mg^{2+}) and oxide ions (O^{2-}).

Describe, as fully as you can, what happens when magnesium atoms react with oxygen atoms to produce magnesium oxide.

(4)

(Total 7 marks)

8 The diagram shows how a heat sink is placed on top of a processor in a computer.
The heat sink is a large piece of metal which conducts heat away from the processor.
If the processor gets too hot it may be damaged.



(a) (i) Describe the structure of a metal.

(3)

(ii) Why are metals very good conductors of heat?

(1)

(b) When viewed under a microscope, it can be seen that the surfaces of the processor and the heat sink that are in contact are not flat.
There are lots of tiny gaps between the two surfaces.
The gaps contain air, which does not conduct heat very well.
Thermal grease is used to fill the gaps between the processor and the heat sink to improve the transfer of heat from the processor to the heat sink.

One type of thermal grease contains nanosized particles of silver.
The manufacturer claims that the nanosized particles help to transfer heat better than normal sized particles.

(i) How are nanosized particles different from normal sized particles?

_____

_____

(1)

(ii) Suggest **one** reason why nanosized particles of silver might help to transfer heat better than normal sized particles.

_____

_____

(1)

(Total 6 marks)

9 This question is about calcium hydroxide.

Ancient artworks and monuments can be protected from acid rain if the surface is sprayed with calcium hydroxide nanoparticles.

By Svilen Enev (Own work) [GFDL or CC-BY-SA-3.0], via Wikimedia Commons

(a) Calcium hydroxide has the formula $Ca(OH)_2$

Why are there two hydroxide ions for each calcium ion in the formula?

_____

_____

_____

(1)

(b) The calcium hydroxide is used in the form of *nanoparticles*.

What are *nanoparticles*?

_____

_____

(1)

(c) A student added water to calcium oxide to make calcium hydroxide.

The equation for the reaction is shown below.

$$CaO + H_2O \rightarrow Ca(OH)_2$$

Calculate the maximum mass of calcium hydroxide which could be made from 2.00 g of calcium oxide.

Relative atomic masses (A_r): H = 1; O = 16; Ca = 40.

Maximum mass of calcium hydroxide = _____ g

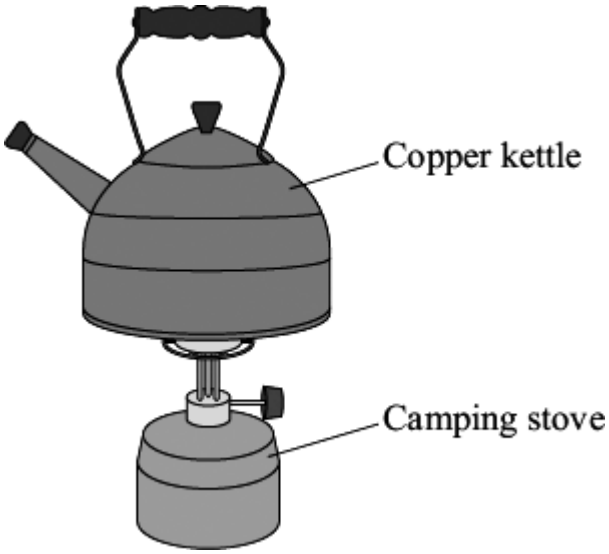
(3)

(Total 5 marks)

10 The picture shows a copper kettle being heated on a camping stove.

Copper is a good material for making a kettle because:

- it has a high melting point
- it is a very good conductor of heat.



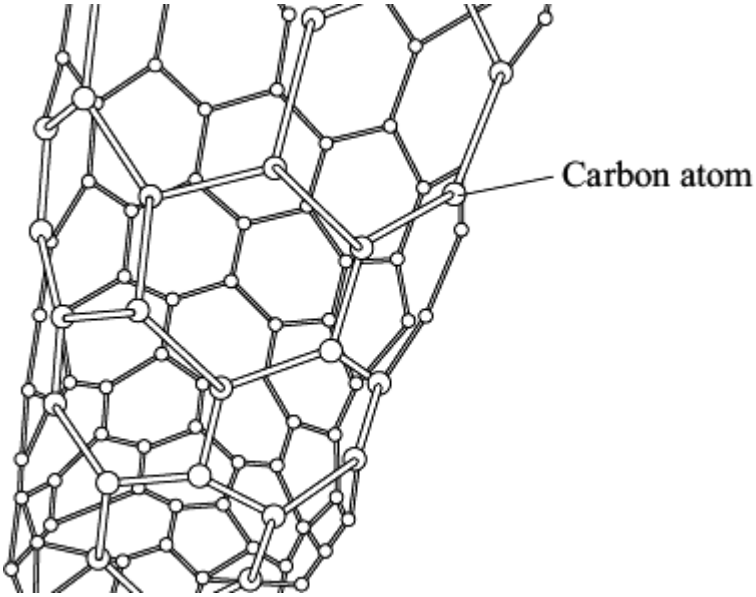
(a) Explain why copper, like many other metals, has a high melting point.
You should describe the structure and bonding of a metal in your answer.

(4)

(b) An aeroplane contains many miles of electrical wiring made from copper. This adds to the mass of the aeroplane.

It has been suggested that the electrical wiring made from copper could be replaced by lighter carbon nanotubes.

The diagram shows the structure of a carbon nanotube.



(i) What does the term ‘nano’ tell you about the carbon nanotubes?

_____

_____

(1)

(ii) Like graphite, each carbon atom is joined to three other carbon atoms.

Explain why the carbon nanotube can conduct electricity.

_____

_____

_____

_____

(2)

(Total 7 marks)

11 Read the article about the use of nanoparticles in sun creams.

Sun creams

Many sun creams use nanoparticles. These sun creams are very good at absorbing radiation, especially ultraviolet radiation. Owing to the particle size, the sun creams spread more easily, cover better and save money because you use less. The new sun creams are also transparent, unlike traditional sun creams which are white. The use of nanoparticles is so successful that they are now used in more than 300 sun cream products.

Some sun creams contain nanoparticles of titanium oxide. Normal-sized particles of titanium oxide are safe to put on the skin.

It is thought that nanoparticles can pass through the skin and travel around the body more easily than normal-sized particles. It is also thought that nanoparticles might be toxic to some types of cell, such as skin, bone, brain and liver cells.

(a) Explain why nanoparticles pass through the skin and travel around the body more easily than normal-sized particles of titanium oxide.

_____

_____

_____

_____

(2)

(b) Explain why sun creams containing nanoparticles should be tested further.

_____

_____

(1)

(c) Suggest why some companies that make sun creams might not want to do more tests.

_____

_____

_____

_____

(2)

(Total 5 marks)

1

(a) (i) (mass number = 16) because there are 8 protons and 8 neutrons (in the nucleus)

*accept mass number is total number of protons and neutrons for **1** mark*

2

(ii) same number of protons **or** both have 6 protons

accept same atomic number

1

^{12}C has 6 neutrons

1

^{14}C has 8 neutrons

1

*accept different number of neutrons for **1** mark*

numbers, if given, must be correct

*incorrect reference to electrons = **max 2** marks*

(b) (i) 2 bonding pairs

1

additional unbonded electrons negates this mark

4 unbonded electrons around oxygen

1

accept dot, cross or e or – or any combination

(ii) covalent

1

(iii) any **one** from:

- no delocalised / free electrons
  ignore mobile electrons
- no overall electric charge
  accept no charge (carriers)
- no ions

1

*do **not** accept any implications of the presence of ions*

(c) (i) larger

accept the size of a few hundred atoms

accept atoms are smaller (than nanoparticles)

allow up to 1000 atoms)

1

(ii) (nanoparticles have) large(r) surface area

1

[11]

2

(a) gives out heat / energy

allow release / loses

allow the products have less energy

or

energy / heat transferred to the surroundings

ignore temperature rises

allow more energy given out in forming bonds than taken in to break bonds

1

(b) (i) speed up the reaction (owtte)

accept changes the rate

accept lowers activation energy

accept increases <u>successful</u> collisions

accept allows reaction to take place at a lower temperature

1

(ii) nitrogen (N_2) / oxygen (O_2) / products are safe **or** not harmful / pollutant / toxic / dangerous / damaging

ignore releases nitrogen / oxygen unless qualified

or

(harmful) nitrogen monoxide / NO is not released into the air.

accept prevents / less acid rain

ignore greenhouse gas / ozone layer

1

(iii) 2 and 2

accept correct multiples or fractions

1

(iv) idea of catalyst not being used up

allow not changed by reaction

ignore catalyst does not take part

ignore catalyst not used in the reaction

1

(v) idea of different reactions (require different catalysts)

accept catalysts work for specific reactions

allow different gases

1

(c) • smaller / very small / or any indication of very small / 1–100 nanometres / a few (hundred) atoms

ignore just small

ignore size of the converter

1

- big(ger) surface area

1

- less (catalyst) needed / small amount of catalyst needed

1

[9]

3 (a) Stops / reduces air from escaping (owtte)

*allow keeping shape **or** keeping it hard*

1

(b) a layer a few hundred atoms thick

1

(c) any **two** from:

- last longer
- use fewer balls
- less materials **or** save resources
- less manufactured

  accept less factories
- less energy
- less fuel
- less pollution / greenhouse effect / global warming
- less waste

  ignore references to cost / recycling

  *any **two** ideas*

2

[4]

4 (a) 1-100 nm in size

or

a few (hundred) atoms in size

accept very / really small / tiny

or 10^{-9}

*accept billionth of a metre **or** any number that implies very small*

accept measured in nanometers

if answer 'very small' ignore incorrect numerical values

1

(b) any **two** from:

- less tennis balls need to be made
- tennis balls last longer **or** don't have to replace as often
- less materials / resources / fuel used up / saves resources
  accept saving materials
- less energy used **or** making tennis balls uses energy
  accept saving energy
- less pollution caused
  accept named pollutant
  accept global warming / greenhouse effect
- less waste
  eg fewer tennis balls going to landfill

2

[3]

5 (a) any **one** from:

- they are made of layers
  *do **not** accept line / rows / lattice*
- atoms / ions / particles / layers (of atoms) can slide over each other

1

(b) any **one** from:

- smaller / tiny **or** very small
  *do **not** allow small alone*
- correct size range 1 to 100 nanometres
- a few hundred atoms in size
  if they state smaller and give a size outside range ignore size if it is less than 20,000

1

(c) harder

1

plus **one** from:

- so does not wear as quickly / erode as quickly
  ignore corrode
- less vulnerable to damage owtte
  *harder to wear down = **1** mark*
- because they have a high surface area to volume ratio

or

stronger (1)

plus **one** from: (1)

- less likely to break / do not break
  accept withstand pressure
- not as vulnerable to damage owtte
  *harder and stronger alone gains **1** mark*
- do not bend out of shape
- because they have a high surface area to volume ratio

1

[4]

6 (a) (i) giant lattice
allow each carbon atom is joined to three others

1

atoms in graphene are covalently bonded
*max. **2** marks if any reference to wrong type of bonding*

1

and covalent bonds are strong **or** need a lot of energy to be broken
allow difficult to break

1

(ii) because graphene has delocalised electrons
allow each carbon atom has one free electron

1

which can move throughout the structure
*do **not** accept just electrons can move.*

1

(b) because there are weak forces between molecules
allow no bonds between the layers

1

so layers / molecules can slip / slide.

1

[7]

7 (a) (i) any **two** from:

ignore any conclusion drawn referring to data below 7.5 nm or above 20 nm

- *100% of (type 1 and type 2) bacteria are killed with a particle size of 7.5 to 8.5 nm*

  accept nanoparticles in the range of 7.5 to 8.5 nm are most effective at killing (type 1 and type 2) bacteria
- *as the size increases (beyond 8.5 nm), nanoparticles are less effective at killing (type 1 and type 2) bacteria*
- *type 1 shows a linear relationship **or** type 2 is non-linear*
- type 1 bacteria more susceptible than type 2 (at all sizes of nanoparticles shown on the graph)

  allow type 2 bacteria are harder to kill

2

(ii) (yes) because you *could confirm the pattern that has been observed*

allow would reduce the effect of anomalous points / random errors

allow would give better line of best fit

ignore references to reliability / precision / accuracy / reproducibility / repeatability / validity

or

(no) because trend / *conclusion* is already clear

1

(b) magnesium loses electron(s)

1

oxygen gains electron(s)

1

<u>two</u> electrons (per atom)

1

gives full outer shells (of electrons) **or** *eight electrons in highest energy level*

*reference to incorrect particles **or** incorrect bonding **or** incorrect structure = max **3***

1

or

(electrostatic) attraction between ions **or** forms ionic bonds

accept noble gas structure

[7]

8 (a) (i) *mention of molecules / intermolecular / ionic / covalent =* ***max 2***

atoms / positive ions

1

any **two** from:

- (atoms / positive ions) in regular pattern / lattice / layer / giant structure (or diagram)
- delocalised electrons
  accept electrons move within / through the structure
  allow free (moving) electrons
  allow sea of electrons
- (atoms / positive ions) held together by strong / electrostatic attractions
  allow strong (metallic) bonds

2

(ii) delocalised electrons
accept electrons move within / through the structure
allow free electrons

1

(b) (i) smaller / very small
accept converse
accept 1 - 100 nanometres in size
accept a few hundred atoms
accept larger surface area ***or***
large surface area for their size

1

(ii) nanoparticles / more can fit into (tiny) gaps
allow nanosize particles have large(r) surface area

1

[6]

9 (a) because calcium is +2 and hydroxide is –1
accept to balance the charges

or
to make the compound neutral (in terms of charges)
allow calcium needs to lose 2 electrons and hydroxide needs to gain one electron

1

(b) particles of size 1-100 nm

allow clear comparison to 'normal' size particles

or particles with a few hundred atoms / ions

or particles with a high surface area (to volume ratio)

or as different properties to 'normal' size particles of the same substance

1

(c) $\mathbf{M_r}$ CaO = 56
and

$\mathbf{M_r}$ $Ca(OH)_2$= 74

1

2/56 (x74) **or** 0.036 (x74)
or

allow ecf from step 1

74/56 (x2) **or** 1.3(214…) (x2)

1

2.6(428…) in range 2.6 to 2.96

*correct answer with or without working gains **3** marks*
allow ecf carried through from step 1
ignore final rounding to 3

1

[5]

10 (a) any **four** from:

*max **3** marks if any reference made to covalent / ionic bonding / molecules or intermolecular forces **or** graphite / diamond **or** forces of attraction between electrons and then ignore throughout*

- giant structure / lattice
  ignore layers
- positive ions
- sea of electrons **or** delocalised / free electrons
  ignore electrons can move
- awareness of outer shell / highest energy level electrons are involved
- (electrostatic) attractions / bonds between electrons and positive ions
- bonds / attractions (between atoms/ ions) are strong
  allow hard to break for strong
  ignore forces unqualified
- a lot of energy / heat is needed to break these bonds / attractions
  ignore high temperature

4

(b) (i) that they are very small

accept tiny / really small / a lot smaller / any indication of very small
eg microscopic, smaller than the eye can see

or

1–100 nanometres **or** a few (hundred) atoms
ignore incorrect numerical values if very small is given

1

(ii) any **2** from:

- one (non-bonded) electron from each atom
- delocalised / free electrons
  allow sea of electrons
  ignore electrons can move
- electron carry / form / pass current / charge
  ignore carry electricity

2

[7]

11 (a) nanoparticles / they are small(er)

accept 1–100 nm or a few atoms in size

1

so can easily pass through pores / skin / cell / membranes / arteries / veins / capillaries / into blood stream owtte

must be a comparative statement

can be inferred from smaller particles

allow absorbed for pass through

1

(b) any **one** from:

- may be toxic (to cells / specific cells)

  *allow may harm / damage / kill cells / organs / tissues **or** may cause cancer*

- to ensure safety **or** reduce risk **or** risk of litigation

  allow may cause allergies / side effects

  ignore harmful / dangerous unqualified eg harmful to body / people

- nanoparticles may have different properties

- to see if they pass into the body

1

(c) any **two** sensible ideas from eg:

- testing is expensive **or** testing costs money

  allow it costs money

  ignore litigation

- testing is time consuming

- don't see any reason to test since normal sized particles (of titanium oxide) do not cause harm

  *accept normal sun cream does **not** cause harm owtte*

- don't want to risk not producing a popular product (owtte)

  *eg if unsafe will have to stop production **or** have to remove product if toxic*

- testing process / unfavourable results might cause alarm / reduce sales / reduce profit (less money)

- do not want to be seen doing animal testing

2

[5]