C7: Energy Changes

Q1.

A student investigated the reactivity of metals with hydrochloric acid.

This is the method used.

1. Measure 50 cm^3 of hydrochloric acid into a polystyrene cup.
2. Measure the temperature of the hydrochloric acid.
3. Add one spatula of metal powder to the hydrochloric acid and stir.
4. Measure the highest temperature the mixture reaches.
5. Calculate the temperature increase for the reaction.
6. Repeat steps 1 to 5 three more times.
7. Repeat steps 1 to 6 with different metals.

The table below shows the student's results.

Metal	**Temperature increase in °C**				**Mean temperature increase in °C**
	Trial 1	**Trial 2**	**Trial 3**	**Trial 4**	
Cobalt	6	7	5	9	7
Magnesium	54	50	37	55	**X**
Zinc	18	16	18	20	18

(a) Calculate the mean temperature increase **X** for magnesium in the table above.

Do **not** include the anomalous result in your calculation.

____

____ X = __________ °C

(2)

(b) Determine the order of reactivity for the metals cobalt, magnesium and zinc.

Use the table above.

Most reactive _________________________

____

Least reactive _________________________

(1)

(c) The range of measurements either side of the mean shows the uncertainty in the mean temperature increase.

Complete the sentence.

Use the table above.

The mean temperature increase for zinc is 18 ± ___________°C

(1)

(d) What type of variable is the volume of hydrochloric acid in this investigation?

Tick (✓) **one** box.

Control	☐
Dependent	☐
Independent	☐

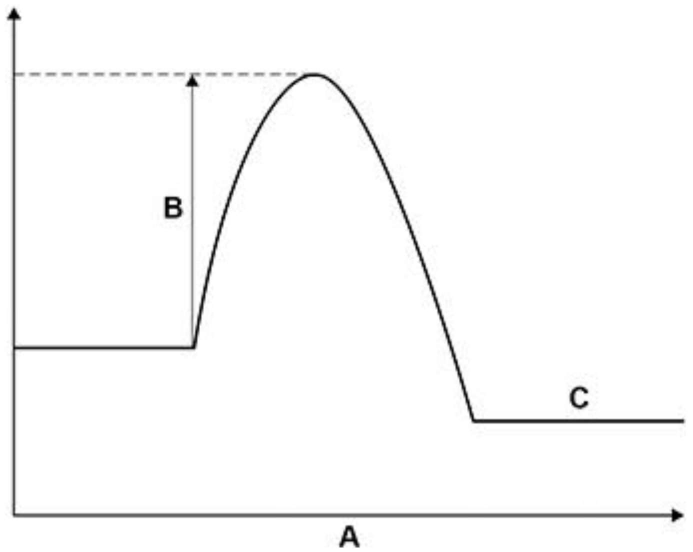
(1)

(e) Suggest **one** way of improving **step 3** in the method to give results which are more repeatable.

____

(1)

(f) The figure below shows a reaction profile for the reaction of magnesium with hydrochloric acid.



What do labels **A**, **B** and **C** represent on the figure above?

Choose answers from the box.

activation energy	**energy**	**overall energy change**
products	**progress of reaction**	**reactants**

A ____

B ____

C ____

(3)
(Total 9 marks)

Q2.

This question is about carbon and its compounds.

Fullerenes are molecules of carbon atoms.

The first fullerene to be discovered was Buckminsterfullerene (C_{60}).

(a) What shape is a Buckminsterfullerene molecule?

____

(1)

(b) Give **one** use of a fullerene.

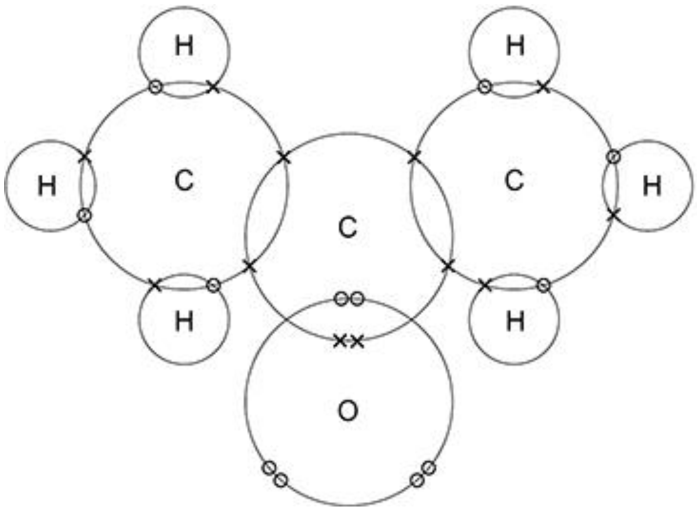
____

(1)

Propanone is a compound of carbon, hydrogen and oxygen.

Figure 1 shows the dot and cross for a propanone molecule.

Figure 1

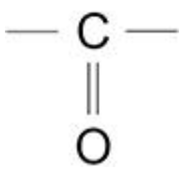


(c) Complete **Figure 2** to show a propanone molecule.

Use a line to represent each single bond.

Use **Figure 1**.

Figure 2



(1)

(d) Determine the molecular formula of propanone.

Use **Figure 1**.

Molecular formula = ____________________

(1)

(e) Propanone is a liquid with a low boiling point.

Why does propanone have a low boiling point?

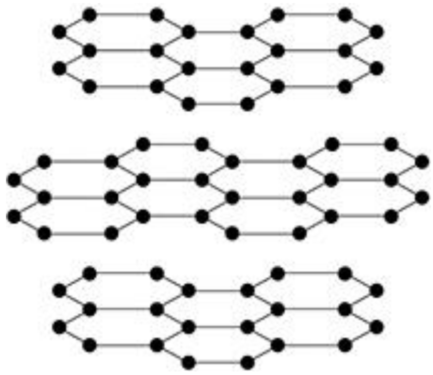
Tick (✓) **one** box.

The covalent bonds are strong.	☐
The covalent bonds are weak.	☐
The intermolecular forces are strong.	☐
The intermolecular forces are weak.	☐

(1)

(f) **Figure 3** represents the structure of graphite.

Figure 3



Explain why graphite is:

- a good electrical conductor
- soft and slippery.

You should answer in terms of structure and bonding.

____

____

____

____

____

____

____

(6)
(Total 11 marks)

HIGHER TIER

Q3.

This question is about displacement reactions.

(a) The displacement reaction between aluminium and iron oxide has a high activation energy.

What is meant by 'activation energy'?

____

____

(1)

(b) A mixture contains 1.00 kg of aluminium and 3.00 kg of iron oxide.

The equation for the reaction is:

$$2\ Al + Fe_2O_3 \rightarrow 2\ Fe + Al_2O_3$$

Show that aluminium is the limiting reactant.

Relative atomic masses (A_r): O = 16   Al = 27   Fe = 56

____

____

____

____

____

____

____

____

____

____

(4)

Magnesium displaces zinc from zinc sulfate solution.

(c) Complete the ionic equation for the reaction.

You should include state symbols.

$$Mg(s) + Zn^{2+}(aq) \rightarrow \_\_\_\_\_\_\_\_\_\_ + \_\_\_\_\_\_\_\_\_\_$$

(2)

(d) Explain why the reaction between magnesium atoms and zinc ions is both oxidation and reduction.

___

___

___

___

(2)

(Total 9 marks)

Q4.

This question is about fertilisers.

Some fertilisers are described as NPK fertilisers because they contain three elements needed for healthy plant growth.

(a) Which **two** compounds each contain **two** of these elements?

Tick (✓) **two** boxes.

Ammonium nitrate	☐
Ammonium phosphate	☐
Calcium chloride	☐
Calcium phosphate	☐
Potassium chloride	☐
Potassium nitrate	☐

(2)

(b) Rocks containing calcium phosphate are treated with acid to produce soluble salts that can be used as fertilisers.

Name the soluble salts produced when calcium phosphate reacts with:

- nitric acid
- phosphoric acid.

Nitric acid ____

Phosphoric acid ____

(2)

(c) Ammonium sulfate is a compound in fertilisers.

Ammonium sulfate can be made using an industrial process or in the laboratory.

In the industrial process, the following steps are used.

1. React streams of ammonia solution and sulfuric acid together.
2. Evaporate the water by passing the solution down a warm column.
3. Collect dry crystals continuously at the bottom of the column.

In the laboratory, the following steps are used.

1. React ammonia solution and sulfuric acid in a conical flask.
2. Evaporate water from the solution until crystals start to form.
3. Leave to cool and crystallise further.
4. Separate the crystals using filtration.
5. Dry the crystals between pieces of filter paper.

Evaluate the two methods for producing a large mass of ammonium sulfate.

(4)

(Total 8 marks)

Mark schemes

Q1.

(a) $\frac{54 + 50 + 55}{3}$

1

= 53 (°C)

*if no other mark awarded allow **1** mark for*

$\frac{54 + 50 + 37 + 55}{4}$ = 49 (°C)

1

(b) (most reactive) magnesium zinc
(least reactive) cobalt

*allow ecf from question **(a)***

1

(c) (18 ±) 2 (°C)

1

(d) control

1

(e) use the same mass of metal / powder

1

(f) (A) progress of reaction

1

(B) activation energy

1

(C) products

1

[9]

Q2.

(a) spherical

allow ball-shaped

ignore round / circular

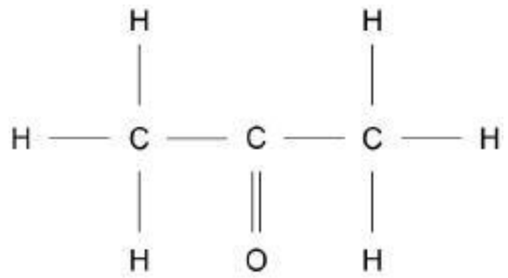
1

(b) any **one** from:

- drug delivery (round the body)
- hydrogen storage
- anti-oxidants
- reduction of bacterial growth
- catalysts
- (cylindrical fullerenes for) strengthening materials
- (spherical fullerenes for) lubricants

1

(c)



1

(d) C_3H_6O

allow CH_3COCH_3
allow elements in any order

1

(e) the intermolecular forces are weak

1

(f) **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

No relevant content

0

Indicative content

- bonds are covalent
- giant / macromolecular structure

- three (covalent) bonds per carbon atom
  or
  only three electrons per carbon atom used in (covalent) bonds
- so one electron per carbon atom (is delocalised)
- these delocalised electrons
- can move through the structure
- carrying (electrical) charge
- so graphite conducts electricity

- layered structure
- of (interlocking) hexagonal rings
- with weak (intermolecular) forces between layers
  or
  no (covalent) bonds between layers
- so the layers can slide over each other
- so graphite is soft and slippery

[11]

Q3.

(a) the (minimum) energy needed for particles to react
or
the (minimum) energy needed for a reaction to occur

allow the (minimum) energy needed to start a reaction

1

(b) (M_r of Fe_2O_3 =) 160

1

(moles Fe_2O_3 = $\frac{3000}{160}$ =)
18.75 (mol)

allow correct use of incorrectly calculated M_r

1

(moles Al = $\frac{1000}{27}$ =) 37.0 (mol)

allow 37.037037 (mol) correctly rounded to at least 2 significant figures

*if both MP2 and MP3 are not awarded allow **1** mark for 0.01875 mol Fe_2O_3 **and** 0.037 mol Al*

1

(aluminium is limiting because)
37.0 mol is less than the (2 x 18.75 =) 37.5 mol (aluminium needed)
or
iron oxide is in excess because 18.75 mol is more than the ($\frac{37.0}{2}$ =) 18.5 mol (iron oxide needed)

allow correct use of incorrect number of moles from steps 2 and/or 3

alternative approaches:

approach 1:

(finding required mass of aluminium by moles method)

(M_r of Fe_2O_3 =) 160 (1)

(moles Fe_2O_3 = $\frac{3000}{160}$ =)
18.75 (mol) (1)

allow correct use of incorrectly calculated M_r

(moles Al needed =18.75 × 2 =) 37.5 (mol)
and

(mass Al needed = 37.5 × 27 =) 1012.5 (g) **or** 1.0125 kg (1)

allow correct use of incorrectly calculated moles of iron oxide

allow correct use of incorrectly calculated moles of aluminium needed

(so) 1.00 kg of aluminium is not enough (1) *dependent on calculated mass of aluminium needed being greater than 1.00 (kg)*

approach 2:
(finding required mass of aluminium by proportion method)

(*M_r* of Fe_2O_3 =) 160 (1)

(3.00 kg Fe_2O_3 needs)
$\frac{3.00}{160}$ × 2 × 27 (kg Al) (1)

allow correct use of incorrectly calculated M_r

(=) 1.0125 (kg) (1)

(so) 1.00 kg of aluminium is not enough (1)

dependent on calculated mass of aluminium needed being greater than 1.00 (kg)

alternative approaches:

approach 3:
(finding required mass of iron oxide by moles method)

M_r of Fe_2O_3 =) 160 (1)

(moles Al = $\frac{1000}{27}$ =) 37.0 (mol) (1)

allow 37.037037 (mol) correctly rounded to at least 2 significant figures

(moles Fe_2O_3 needed) = $\frac{37.0}{2}$) = 18.5 (mol)
and
(mass Fe_2O_3 needed = 18.5 × 160 =) 2960 (g) **or** 2.96 (kg) (1)

allow correct use of incorrectly calculated moles of aluminium

allow correct use of incorrectly calculated moles of iron oxide needed
allow correct use of incorrectly calculated M_r

(so) 3.00 kg of iron oxide is an excess (1)

dependent on calculated mass of iron oxide needed being less than 3.00 (kg)

approach 4:
(finding required mass of iron oxide by proportion method)

(M_r of Fe_2O_3 =) 160 (1)

(1.00 kg Al needs) $\frac{1.00}{2 \times 27}$ (kg Fe_2O_3) (1)

allow correct use of incorrectly calculated M_r

(=) 2.96 (kg) (1)

(so) 3.00 kg of iron oxide is an excess (1)

dependent on calculated mass of iron oxide needed being less than 3.00 (kg)

1

(c) $Mg(s) + Zn^{2+}(aq) \rightarrow Mg^{2+}(aq) + Zn(s)$

allow multiples

*allow **1** mark for Mg^{2+} + Zn with missing or incorrect state symbols*

2

(d) magnesium (atoms) are oxidised because they lose electrons

1

(and) zinc (ions) are reduced because they gain electrons

*if no other marks awarded allow **1** mark for magnesium (atoms) lose electrons and zinc (ions) gain electrons 1*

1

[9]

Q4.

(a) ammonium phosphate

1

potassium nitrate

1

(b) (nitric acid) calcium nitrate

1

(phosphoric acid)
(calcium) triple superphosphate
or
calcium dihydrogenphosphate

1

(c) (industrial process)
(is) large(er) scale

allow converse for laboratory process

ignore references to cost / energy

ignore large mass produced

1

(is) quicker

1

(is a) continuous process

allow does not need to be repeated

1

reasoned judgement

1

[8]