Energy Changes 4

Name: _____

Class: _____

Date: _____

Time: **63 minutes**

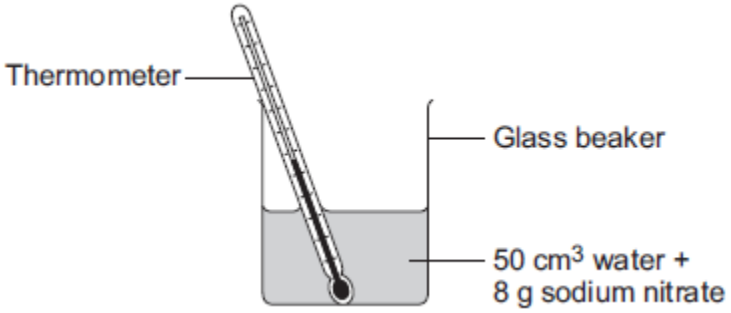
Marks: **63 marks**

Comments:

1. This question is about temperature changes.

(a) A student investigated the temperature change when 8 g of sodium nitrate dissolves in 50 cm^3 of water.

The diagram below shows the apparatus the student used.



The student did the experiment five times.
Table 1 shows the results.

Table 1

Experiment	Decrease in temperature of water in °C
1	5.9
2	5.7
3	7.2
4	5.6
5	5.8

(i) Calculate the mean decrease in temperature.
Do not use the anomalous result in your calculation.

_____

_____

Mean decrease in temperature = _____ °C

(2)

(ii) Suggest **one** change in the apparatus in the diagram above which would improve the accuracy of the results.
Give a reason for your answer.

_____

_____

_____

_____

(2)

(b) The student investigated the temperature change when different masses of sodium carbonate were added to 50 cm^3 of water at 20 °C.

Table 2 below shows the results.

Table 2

Mass of sodium carbonate in g	Final temperature of solution in °C
2.0	21.5
4.0	23.0
6.0	24.5
8.0	26.0
10.0	26.6
12.0	26.6
14.0	26.6

Describe the relationship between the mass of sodium carbonate added and the final temperature of the solution.

Use values from **Table 2** in your answer.

_____

_____

_____

_____

_____

_____

(3)

(Total 7 marks)

2. This question is about energy changes in chemical reactions.

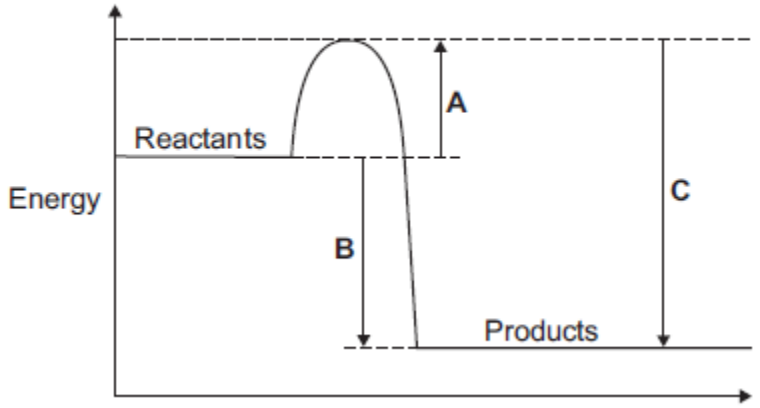
(a) Complete the word equation for the combustion of hydrogen.

hydrogen + oxygen → _____

(1)

(b) **Figure 1** shows a simple energy level diagram.

Figure 1



(i) Which arrow, **A**, **B** or **C**, shows the activation energy?

Tick (✓) **one** box.

A ☐

B ☐

C ☐

(1)

(ii) What type of reaction is shown by the energy level diagram in **Figure 1**?
Give a reason for your answer.

Type of reaction _____

Reason _____

_____

(2)

(iii) For a reaction, the value of **A** is 1370 kJ and **C** is 3230 kJ.
Calculate the value of **B**.

_____

_____

B = _____ kJ

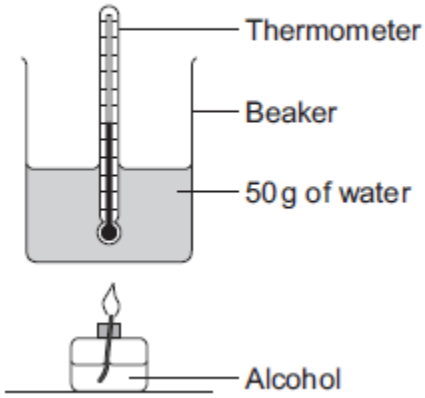
(1)

(c) Alcohols are used as fuels.

A group of students investigated the amount of energy released when different alcohols are burned.

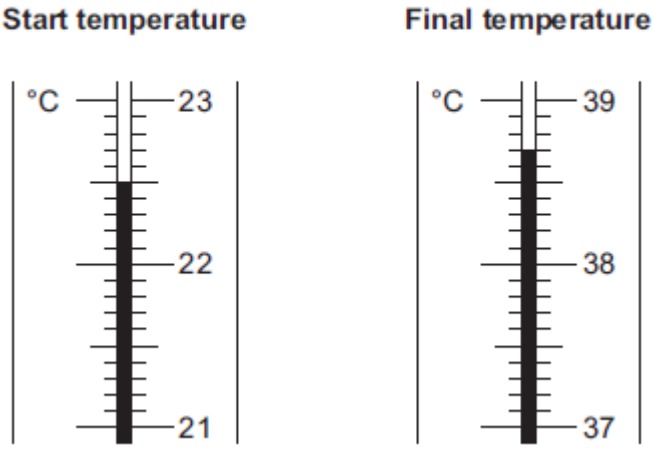
The students used the apparatus shown in **Figure 2**.

Figure 2



(i) **Figure 3** shows the start temperature and the final temperature of the water.

Figure 3



Write the start temperature and the final temperature of the water in **Table 1**.
Work out the increase in temperature to complete **Table 1**.

Table 1

Start temperature of the water in °C	
Final temperature of the water in °C	
Increase in temperature in °C	

(3)

(ii) The students worked out the heat energy released by burning 1 g of each alcohol.
The students used the equation:

Heat energy released = m × 4.2 × increase in temperature

Look at **Figure 2**. What is the value of m?

m = _____ g

(1)

(iii) **Table 2** shows the students' results.

Table 2

Name of alcohol	**Number of carbon atoms in one molecule of alcohol**	**Heat energy released when 1 g of alcohol is burned in kJ**
Methanol	1	11.4
Ethanol	2	13.5
Propanol	3	20.1
Butanol	4	16.8
Pentanol	5	17.2

Which value of heat energy released is anomalous?

_____

(1)

(iv) Look at **Table 2**.
What is the relationship between the number of carbon atoms in one molecule of alcohol and the heat energy released when 1 g of the alcohol is burned?

_____

_____

(1)

(v) The value in a data book for the amount of heat energy released when 1 g of butanol is burned completely is 36.2 kJ.

Suggest two reasons why the students' result for butanol is lower than the data book value.

1. _____

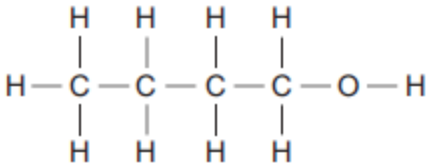
_____

2. _____

_____

(2)

(vi) The displayed structure of butanol is:



What is the functional group of the alcohol?

Tick (✓) **one** box.

−− C −− C ☐

−− C −− H ☐

−− O −− H ☐

(1)

(Total 14 marks)

3. This question is about energy changes in chemical reactions.

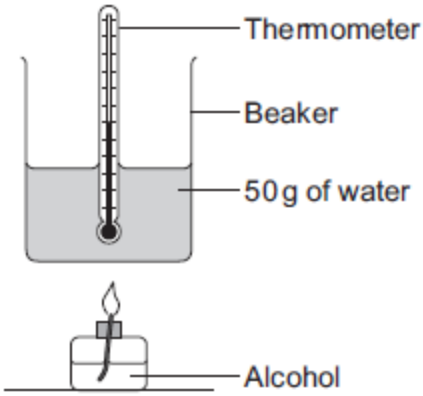
(a) Balance the chemical equation for the combustion of methane.

$$CH_4 \quad + \quad O_2 \quad \longrightarrow \quad CO_2 \quad + \quad H_2O$$

(1)

(b) Alcohols are used as fuels.

A group of students investigated the amount of energy released when an alcohol was burned. The students used the apparatus shown in the diagram below.



In one experiment the temperature of 50 g of water increased from 22.0 °C to 38.4 °C. The mass of alcohol burned was 0.8 g.

Calculate the heat energy (Q) in joules, released by burning 0.8 g of the alcohol.
Use the equation:

$$Q = m \times c \times \Delta T$$

Specific heat capacity (c) = 4.2 J / g / °C

_____

_____

_____

_____

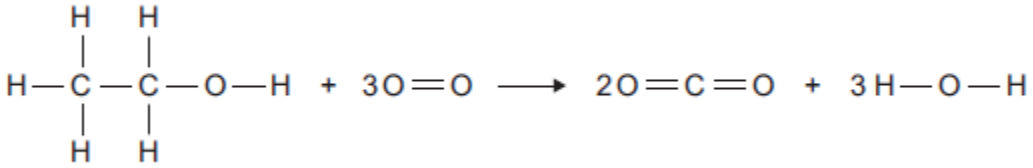
Heat energy (Q) = _____ J

(3)

(c) The chemical equation for the combustion of ethanol is:

$$C_2H_5OH + 3O_2 \longrightarrow 2CO_2 + 3H_2O$$

(i) The equation for the reaction can be shown as:



Bond	Bond energy in kJ per mole
C — H	413
C — C	347
C — O	358
C = O	799
O — H	467
O = O	495

Use the bond energies to calculate the overall energy change for this reaction.

Overall energy change = _____ kJ per mole

(3)

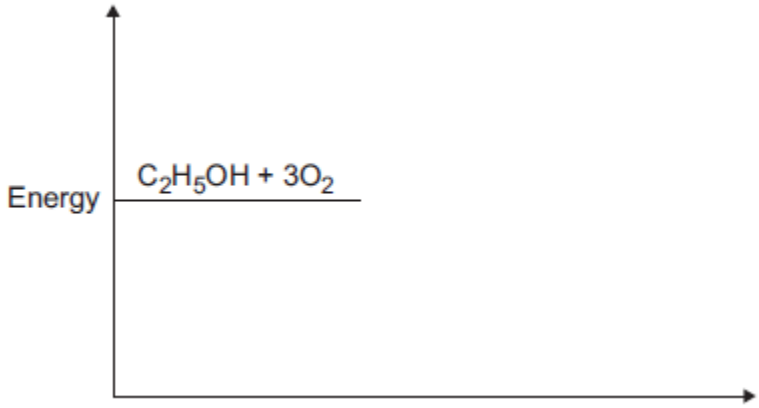
(ii) The reaction is exothermic.
Explain why, in terms of bonds broken and bonds formed.

(2)

(iii) Complete the energy level diagram for the combustion of ethanol.

On the completed diagram, label:

- activation energy
- overall energy change.

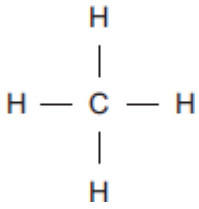


(3)

(Total 12 marks)

4. Methane (CH_4) is used as a fuel.

(a) The displayed structure of methane is:



Draw a ring around a part of the displayed structure that represents a covalent bond.

(1)

(b) Why is methane a compound?

Tick (✓) **one** box.

Methane contains atoms of two elements, combined chemically. ☐

Methane is not in the periodic table. ☐

Methane is a mixture of two different elements. ☐

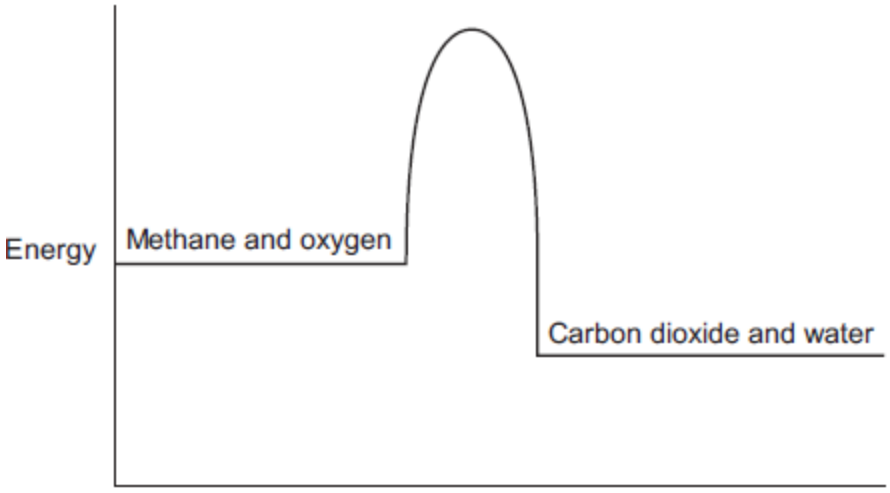
(1)

(c) Methane burns in oxygen.

(i) The diagram below shows the energy level diagram for the complete combustion of methane.

Draw and label arrows on the diagram to show:

- the activation energy
- the enthalpy change, ΔH.



(2)

(ii) Complete and balance the symbol equation for the complete combustion of methane.

$$CH_4 + \_\_\_\_\_ \longrightarrow CO_2 + \_\_\_\_\_$$

(2)

(iii) Explain why the **incomplete** combustion of methane is dangerous.

_____

_____

_____

_____

(2)

(iv) Explain why, in terms of the energy involved in bond breaking and bond making, the combustion of methane is exothermic.

(3)

(d) Methane reacts with chlorine in the presence of sunlight.

The equation for this reaction is:

Some bond dissociation energies are given in the table.

Bond	**Bond dissociation energy in kJ per mole**
C−H	413
C−Cl	327
Cl−Cl	243
H−Cl	432

(i) Show that the enthalpy change, ΔH, for this reaction is −103 kJ per mole.

(3)

(ii) Methane also reacts with bromine in the presence of sunlight.

This reaction is less exothermic than the reaction between methane and chlorine.

The enthalpy change, ΔH, is −45 kJ per mole.

What is a possible reason for this?

Tick (✓) **one** box.

CH_3Br has a lower boiling point than CH_3Cl ☐

The C−Br bond is weaker than the C−Cl bond. ☐

The H−Cl bond is weaker than the H−Br bond. ☐

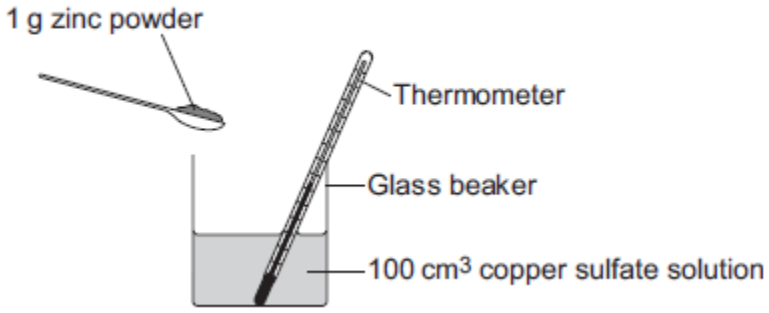
Chlorine is more reactive than bromine. ☐

(1)

(Total 15 marks)

5. A student investigates the energy released when zinc powder reacts with copper sulfate solution.
The student uses the apparatus shown in **Figure 1**.

Figure 1



The student:

- measures 100 cm^3 copper sulfate solution into a beaker
- measures the temperature of the copper sulfate solution
- puts 1 g zinc powder into the beaker
- stirs the mixture with a thermometer
- measures the highest temperature.

The student's results were:

Starting temperature = 21 °C
Highest temperature = 32 °C

(a) (i) Calculate the change in temperature.

_____

Change in temperature = _____ °C

(1)

(ii) Calculate the energy released in the reaction.

Use the equation

$$\text{energy released in J} = \text{volume of solution in } cm^3 \times 4.2 \times \text{temperature change in °C}$$

_____

_____

Energy released = _____ J

(2)

(b) The reaction of zinc with copper sulfate is exothermic.

How can you tell from the student's results that the reaction is exothermic?

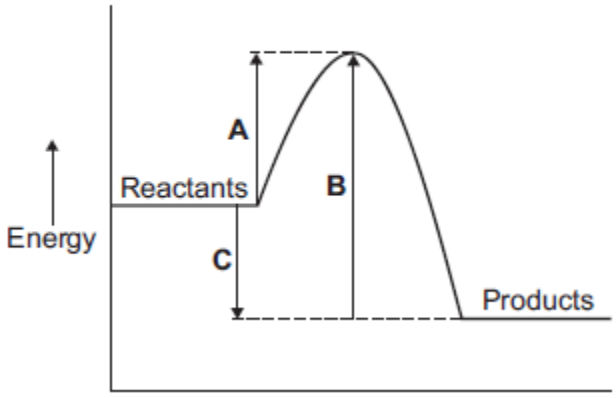
_____

_____

(1)

(c) The energy diagram for the reaction is shown in **Figure 2**.

Figure 2



(i) How can you tell from the energy diagram that the reaction is exothermic?

_____

_____

(1)

(ii) Which arrow shows the activation energy in **Figure 2**?

Tick (✓) **one** box.

A ☐

B ☐

C ☐

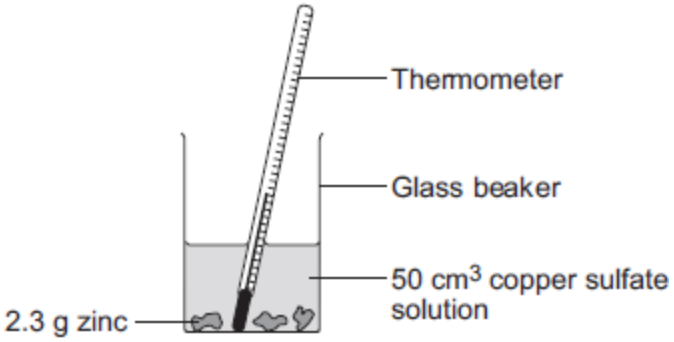
(1)

(Total 6 marks)

6. A student investigated the temperature change when zinc reacts with copper sulfate solution.

The student used a different concentration of copper sulfate solution for each experiment.

The student used the apparatus shown below.



The student:

- measured 50 cm^3 copper sulfate solution into a glass beaker
- measured the temperature of the copper sulfate solution
- added 2.3 g zinc
- measured the highest temperature
- repeated the experiment using copper sulfate solution with different concentrations.

The equation for the reaction is:

$Zn(s) + CuSO_4(aq) \longrightarrow Cu(s) + ZnSO_4(aq)$

zinc + copper sulfate solution $\longrightarrow$ copper + zinc sulfate solution

(a) The thermometer reading changes during the reaction.

Give **one** other change the student could **see** during the reaction.

_____

_____

(1)

(b) Suggest **one** improvement the student could make to the apparatus.

Give a reason why this improves the investigation.

Improvement _____

_____

Reason _____

_____

(2)

(c) **In this question you will be assessed on using good English, organising information clearly and using specialist terms where appropriate.**

The student's results are shown in the table below.

Experiment number	**Concentration of copper sulfate in moles per dm^3**	**Increase in temperature in °C**
1	0.1	5
2	0.2	10
3	0.3	12
4	0.4	20
5	0.5	25
6	0.6	30
7	0.7	35
8	0.8	35
9	0.9	35
10	1.0	35

Describe **and** explain the trends shown in the student's results.

(6)

(Total 9 marks)

1. (a) (i) 5.75 **or** 5.8

*correct answer with or without working gains **2** marks*

*correct working showing addition of any four results and division by 4 gains **1** mark*

OR

*6(.04) for **1** mark*

2

(ii) use a polystyrene cup **or** lid

accept insulate the beaker

1

to prevent energy/heat gain

accept to prevent energy/heat transfer

*do **not** accept energy/heat loss*

OR

use a digital thermometer

allow use a data logger

easier to read (to 0.1°C)

1

(b) (as mass increases) the final temperature increases

1

then stays constant

1

correct reference to a value above 8 g up to and including 10 g as mass when the trend changes

1

[7]

2. (a) water / H_2O

allow steam or hydrogen oxide

1

(b) (i) A

1

(ii) exothermic

1

products (energy) lower than reactants (energy)

1

(iii) 1860 (kJ)

1

(c) (i) 22.5

1

38.7

1

16.2

allow ecf for correct subtraction

1

(ii) 50 (g)

1

(iii) 20.1 (kJ)

allow propanol

ignore 3

1

(iv) as the number of carbon atoms (in one molecule of alcohol) increases the heat energy given out increases (when the alcohol is burned)

1

(v) any **two** from:

- no lid
- no insulation
- no draught shield

Allow heat / energy loss to surroundings for any one of these marks

- incomplete combustion
- inaccurate measurement
- no repeats (to calculate a mean)

2

(iv) -O-H

1

[14]

3. (a) $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

allow multiples

1

(b) 3444 J

if answer incorrect:

one mark for temperature increase = 16.4 °C

one mark for mass of water = 50 g

ecf for one incorrect value gains two marks for correct calculation

no ecf for two incorrect values

3

(c) (i) 1276 (kJ per mole)

ignore + or -

if answer incorrect:

[(5 × 413) + 347 + 358 + 467] + [(3 × 495)] = 4722 (1 mark)

[(4 × 799) + (6 × 467)] = 5998 (1 mark)

correct subtraction of calculated energy values (1 mark)

3

(ii) because energy released when bonds form is greater than energy used when bonds broken

allow converse

if no mark awarded allow one mark for energy is used to break bonds

or

one mark for energy is released when bonds form

2

(iii) products line lower than reactants

1

activation energy labelled

1

overall energy change labelled

1

[12]

4. (a) circle round any one (or more) of the covalent bonds

any correct indication of the bond − the line between letters

1

(b) Methane contains atoms of two elements, combined chemically

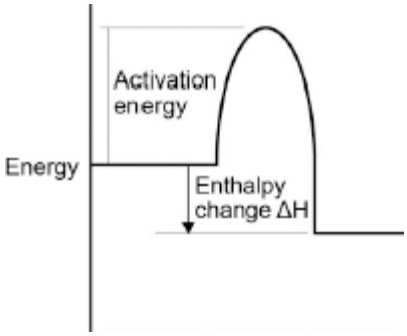
1

(c) (i) activation energy labelled from level of reagents to highest point of curve

ignore arrowheads

1

enthalpy change labelled from reagents to products



*arrowhead **must** go from reagents to products only*

1

(ii) $2\ O_2$

1

$2\ H_2O$

*if not fully correct, award **1** mark for all formulae correct.*

ignore state symbols

1

(iii) carbon monoxide is made

1

this combines with the blood / haemoglobin **or** prevents oxygen being carried in the blood / round body **or** kills you **or** is toxic **or** poisonous

dependent on first marking point

1

(iv) energy is taken in / required to break bonds

accept bond breaking is endothermic

1

energy is given out when bonds are made

accept bond making is exothermic

1

the energy given out is greater than the energy taken in

this mark only awarded if both of previous marks awarded

1

(d) (i) energy to break bonds = 1895

calculation with no explanation max = 2

1

energy from making bonds = 1998

1

1895 − 1998 (= −103)
or
energy to break bonds = 656
energy from making bonds = 759
656 − 759 (= −103)

allow:

bonds broken − bonds made =

413 + 243 − 327 − 432 = -103 for 3 marks.

1

(ii) The C — Br bond is weaker than the C — Cl bon

1

[15]

5. (a) (i) 11

1

(ii) 4620 (J)

*correct answer gains **2** marks with or without working*

*allow 4.62kJ for **2** marks*

if answer is incorrect:

*100 × 4.2 × 11 gains **1** mark*

or

*100 × 4.2 × (their temp. rise) gains **1** mark*

or

*100 × 4.2 × (their temp. rise) correctly calculated gains **2** marks*

2

(b) the temperature increases

allow gets hotter

allow heat / energy is given off

1

(c) (i) (energy of) products lower than (energy of) reactants

allow converse

allow arrow C points downwards

1

(ii) A

1

[6]

6. (a) any **one** from:

- solution becomes colourless or colour fades
- zinc becomes bronze / copper coloured

allow copper (forms) or a solid (forms)

- zinc gets smaller

allow zinc dissolves

- bubbles or fizzing.

ignore precipitate

1

(b) improvement:
use a plastic / polystyrene cup or add a lid

accept use lagging / insulation

1

reason - must be linked
reduce / stop heat loss
OR
improvement:
use a digital thermometer

allow use a data logger

reason - must be linked
more accurate or easy to read or stores data

allow more precise or more sensitive

ignore more reliable

ignore improvements to method, eg take more readings

1

(c) Marks awarded for this answer will be determined by the Quality of Written Communication (QWC) as well as the standard of the scientific response. Examiners should also refer to the information in the Marking Guidance and apply a 'best–fit' approach to the marking.

0 marks
No relevant content

Level 1 (1−2 marks)
There is a statement about the results.

Level 2 (3−4 marks)
There are statements about the results. These statements may be linked or may include data.

Level 3 (5−6 marks)
There are statements about the results with at least one link and an attempt at an explanation.

Examples of chemistry points made in the response:
Description:
Statements
Concentration of copper sulfate increases
Temperature change increases
There is an anomalous result
The temperature change levels off
Reaction is exothermic

Linked Statements
Temperature change increases as concentration of copper sulfate increases
The temperature change increases, and then remains constant
After experiment 7 the temperature change remains constant

Statements including data
The trend changes at experiment 7
Experiment 3 is anomalous

Attempted Explanation
Temperature change increases because rate increases
Temperature change levels off because the reaction is complete

Explanation
As more copper sulfate reacts, more heat energy is given off
Once copper sulfate is in excess, no further heat energy produced

6

[9]