

# Energy Changes 3

Name: \_\_\_\_\_

Class: \_\_\_\_\_

Date: \_\_\_\_\_

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Time: **80 minutes**

Marks: **74 marks**

Comments:

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1.

A student investigated the temperature change when magnesium was added to copper sulfate solution.

This is the method used.

1. Pour 30 cm<sup>3</sup> of copper sulfate solution into a polystyrene cup.
2. Measure the temperature of copper sulfate solution every minute for 3 minutes.
3. Add magnesium on the fourth minute.
4. Measure the temperature of the mixture at 5 minutes and then every minute up to 14 minutes.

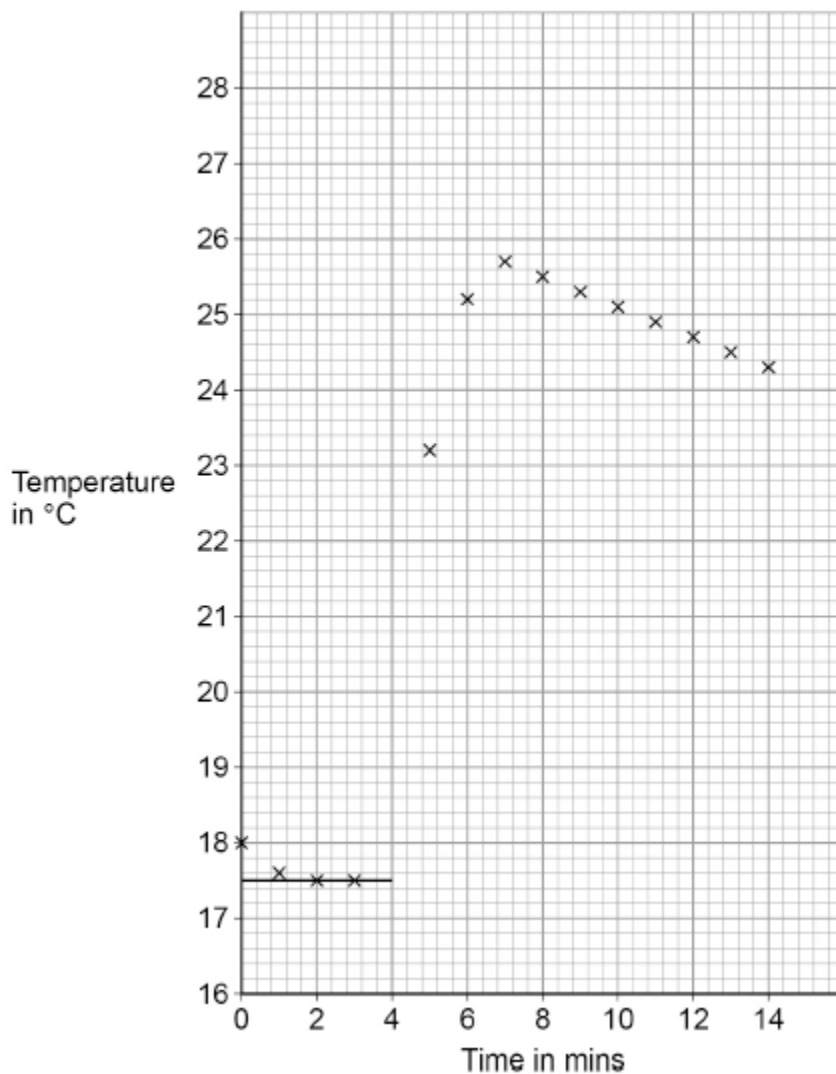
(a) What is the dependent variable in this investigation?

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(1)

The student used the results to plot a graph.

The image below shows the graph.



- (b) Suggest why the copper sulfate solution was left for four minutes before adding the magnesium.

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(1)

- (c) Complete the graph above by:
- drawing a line of best fit through all the points after 7 minutes
  - extending the line back to 4 minutes.

(2)

- (d) The temperature change for the reaction is the temperature difference between the two graph lines at 4 minutes.

Determine the temperature change for the reaction.

Use the graph above.

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Temperature change = \_\_\_\_\_ °C

(2)

- (e) Explain why the temperature of the mixture decreases after 7 minutes.

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(2)

- (f) The student repeated the experiment with an unknown metal **Q** instead of magnesium.

All the other variables were kept the same.

The student recorded a smaller temperature change.

Suggest the identity of metal **Q**.

Give **one** reason for your answer.

Metal **Q** \_\_\_\_\_

Reason \_\_\_\_\_  
\_\_\_\_\_

(2)

- (g) A copper sulfate solution contained 0.100 moles of copper sulfate dissolved in 0.500 dm<sup>3</sup> of water.

Calculate the mass of copper sulfate in 30.0 cm<sup>3</sup> of this solution.

Relative formula mass ( $M_r$ ): CuSO<sub>4</sub> = 159.5

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Mass = \_\_\_\_\_ g

(4)

(Total 14 marks)

2.

This question is about energy changes.

- (a) Which of these items uses an endothermic reaction?

Tick (✓) **one** box.

Hand warmer

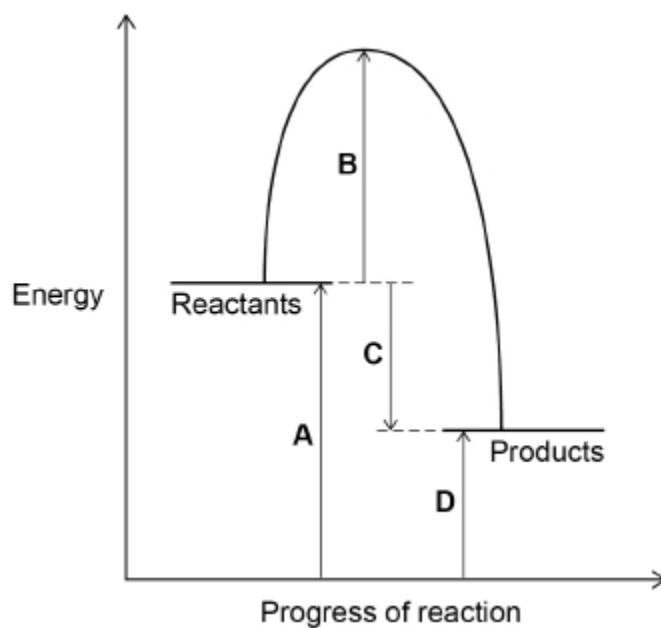
Sports injury pack

Self-heating can

(1)

Figure 1 shows the reaction profile for an exothermic reaction.

Figure 1



(b) Which letter represents the activation energy for the reaction?

Tick (✓) **one** box.

A       B       C       D

(1)

(c) Which letter represents the overall energy change for the reaction?

Tick (✓) **one** box.

A       B       C       D

(1)

(d) Complete the sentence.

Choose the answer from the box.

lower than	the same as	higher than
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In an exothermic reaction the energy of the products

is \_\_\_\_\_ the energy of the reactants.

(1)

(e) A student measured the temperature at the start and at the end of a reaction.

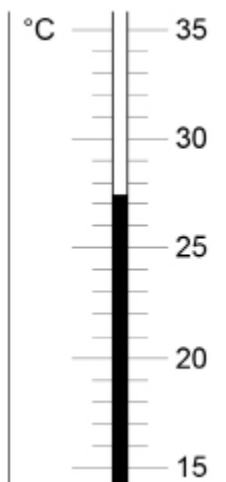
Name the apparatus used to measure the temperature.

\_\_\_\_\_

(1)

(f) **Figure 2** shows the temperature at the end of the reaction.

**Figure 2**



Complete the table below.

Use **Figure 2**.

Temperature at start in °C	14.3
Temperature at end in °C	
Change in temperature in °C	

(2)

(Total 7 marks)

**3.** This question is about compounds of oxygen.

The reaction between carbon and oxygen is exothermic.

(a) What does exothermic reaction mean?

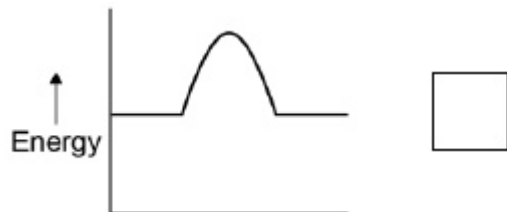
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(1)

(b) Which is the correct reaction profile (energy level diagram) for an exothermic reaction?

Tick **one** box.



(1)

(c) The percentage by mass of oxygen in carbon dioxide (CO<sub>2</sub>) is calculated by the equation:

$$\text{percentage by mass} = \frac{\text{number of atoms of O} \times \text{Relative atomic mass of oxygen (O)}}{\text{relative molecular mass of carbon dioxide (CO}_2\text{)}} \times 100$$

Relative atomic masses (A<sub>r</sub>): C = 12 O = 16

Calculate the percentage by mass of oxygen in carbon dioxide (CO<sub>2</sub>).

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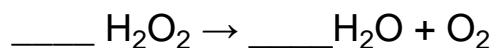
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Percentage by mass of oxygen = \_\_\_\_\_ %

**(3)**

Hydrogen peroxide decomposes to produce water and oxygen.

(d) Balance the chemical equation.



**(1)**

(e) 6.8 g of hydrogen peroxide decomposes to produce 3.6 g of water.

Calculate the mass of oxygen produced when 68 g of hydrogen peroxide decomposes.

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Mass of oxygen = \_\_\_\_\_ g

**(2)**

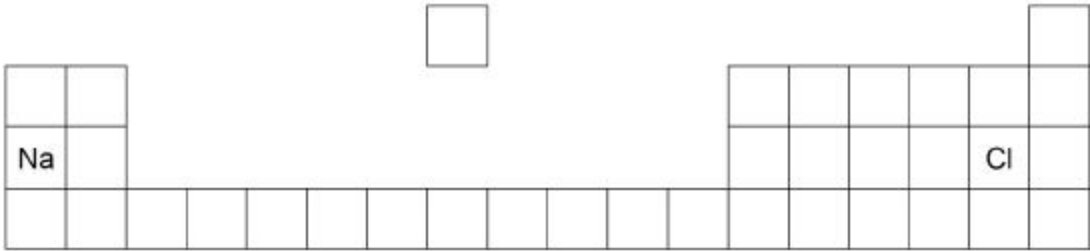
**(Total 8 marks)**

4.

This question is about sodium and chlorine.

Figure 1 shows the positions of sodium and chlorine in the periodic table.

Figure 1



(a) State **one** difference and **one** similarity in the electronic structure of sodium and of chlorine.

Difference \_\_\_\_\_

\_\_\_\_\_

Similarity \_\_\_\_\_

\_\_\_\_\_

(2)

(b) Sodium atoms react with chlorine atoms to produce sodium chloride (NaCl).

Describe what happens when a sodium atom reacts with a chlorine atom.

Write about electron transfer in your answer.

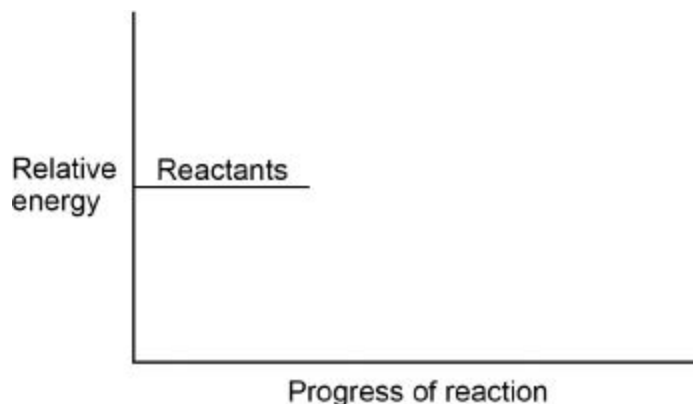
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\_\_\_\_\_

(4)

(c) The reaction between sodium and chlorine is an exothermic reaction.

Complete the reaction profile for the reaction between sodium and chlorine.

**Figure 2**



(2)

(Total 8 marks)

5.

Some students investigated the reactivity of four unknown metals, **W**, **X**, **Y** and **Z**.

The letters are not the symbols of these elements.

The students used metal salt solutions of copper nitrate, magnesium sulfate and zinc chloride.

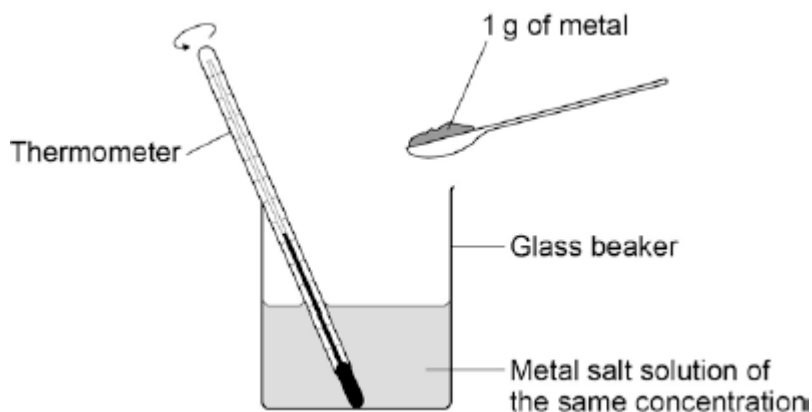
This is the method used.

1. Pour a solution of a metal salt into a glass beaker.
2. Measure the temperature of the solution.
3. Add 1 g of metal to the solution.
4. Measure the temperature of the solution.
5. Calculate the temperature increase.

The students did the experiment using each salt solution with each metal.

**Figure 1** shows the apparatus the students used.

**Figure 1**



The table below shows the students' results.

Solution	Temperature increase in °C			
	Metal W	Metal X	Metal Y	Metal Z
Copper nitrate	46	10	29	No change
Magnesium sulfate	No change	No change	No change	No change
Zinc chloride	15	No change	No change	No change

(a) Which metal is **least** reactive?

Tick **one** box.

Metal W	<input type="checkbox"/>
Metal X	<input type="checkbox"/>
Metal Y	<input type="checkbox"/>
Metal Z	<input type="checkbox"/>

(1)

(b) How do the results show that magnesium is **more** reactive than the metals **W**, **X**, **Y** and **Z**?

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(1)

(c) How do the results show that the reaction between metal **Y** and copper nitrate solution is exothermic?

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(1)

(d) One student said that the investigation was not valid (a fair test).

Write a plan for the investigation that includes improvements to the method and apparatus.

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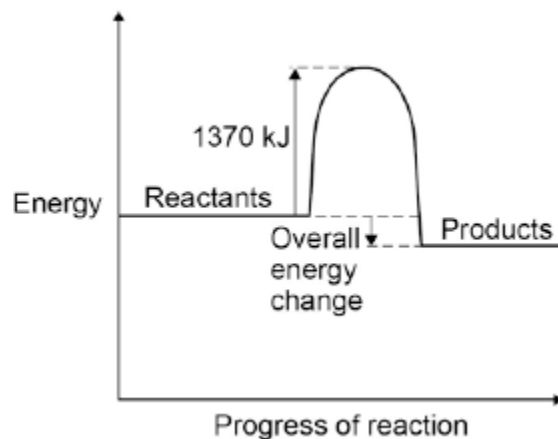
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**(4)**

(e) **Figure 2** shows the reaction profile of an exothermic reaction.

**Figure 2**



What does the energy value of 1370 kJ represent?

Tick **one** box.

Activation energy

Products energy

Reactants energy

Released energy

**(1)**

(f) The overall energy change is 386 kJ.

What percentage of 1370 kJ is this?

Give your answer to two significant figures.

\_\_\_\_\_

Percentage = \_\_\_\_\_ %

**(2)**

**(Total 10 marks)**

6.

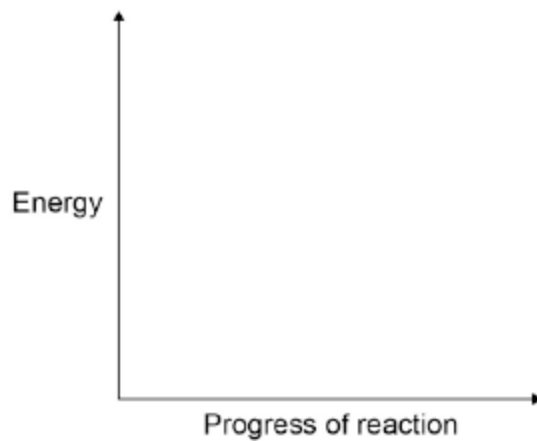
Exothermic reactions transfer energy to the surroundings.

(a) Draw a reaction profile for an exothermic reaction using the axes in **Figure 1**.

Show the:

- relative energies of the reactants and products
- activation energy and overall energy change.

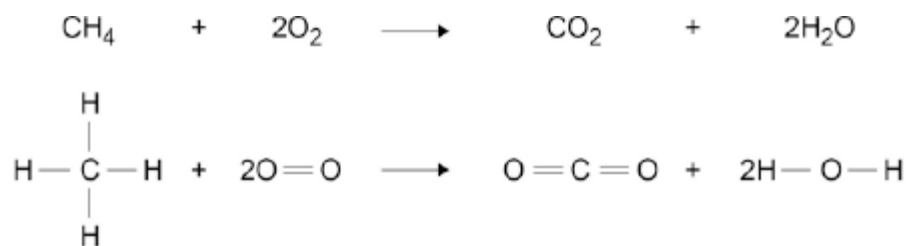
**Figure 1**



(2)

(b) Combustion is an exothermic reaction.

Calculate the overall energy change for the complete combustion of one mole of methane in oxygen.



Bond	Bond energy in kJ / mol
C—H	413
O=O	498
C=O	805
O—H	464

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Overall energy change = \_\_\_\_\_ kJ / mol

(3)



- (d) Another student used displacement reactions to investigate the relative reactivity of the four metals, **W**, **X**, **Y** and **Z**.

The table below shows the student's results.

Solution	Observations			
	Metal W	Metal X	Metal Y	Metal Z
Copper nitrate	Brown layer formed on metal	Brown layer formed on metal	Brown layer formed on metal	No change
Magnesium sulfate	No change	No change	No change	No change
Sulfuric acid	Gas bubbles produced	Few gas bubbles produced	Gas bubbles produced	No change
Zinc chloride	Grey layer formed on metal	No change	No change	No change

Give the order of reactivity of metals, **W**, **X**, **Y** and **Z**.

Use the results in the table above to justify your answer.

> > >

\_\_\_\_\_

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(3)



(b) Oxygen difluoride ( $\text{OF}_2$ ) has a melting point of  $-224\text{ }^\circ\text{C}$  and a boiling point of  $-145\text{ }^\circ\text{C}$

What is the state of oxygen difluoride at room temperature?

Explain your answer in terms of structure and bonding.

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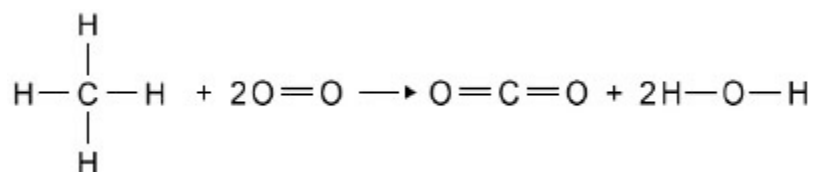
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**(4)**

(c) The equation shows the reaction of methane with oxygen.



The table shows the bond energies.

Bond	C-H	O=O	C=O	O-H
Bond dissociation energy in kJ per mole	412	496	803	463

Calculate the overall energy change for the combustion of one mole of methane.

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Energy change = \_\_\_\_\_ kJ mol<sup>-1</sup>

(3)

(Total 9 marks)

## Mark schemes

1.

(a) temperature (change)

1

(b) to reach a constant temperature

*allow to reach room temperature*

1

(c) line of best fit after 7 minutes

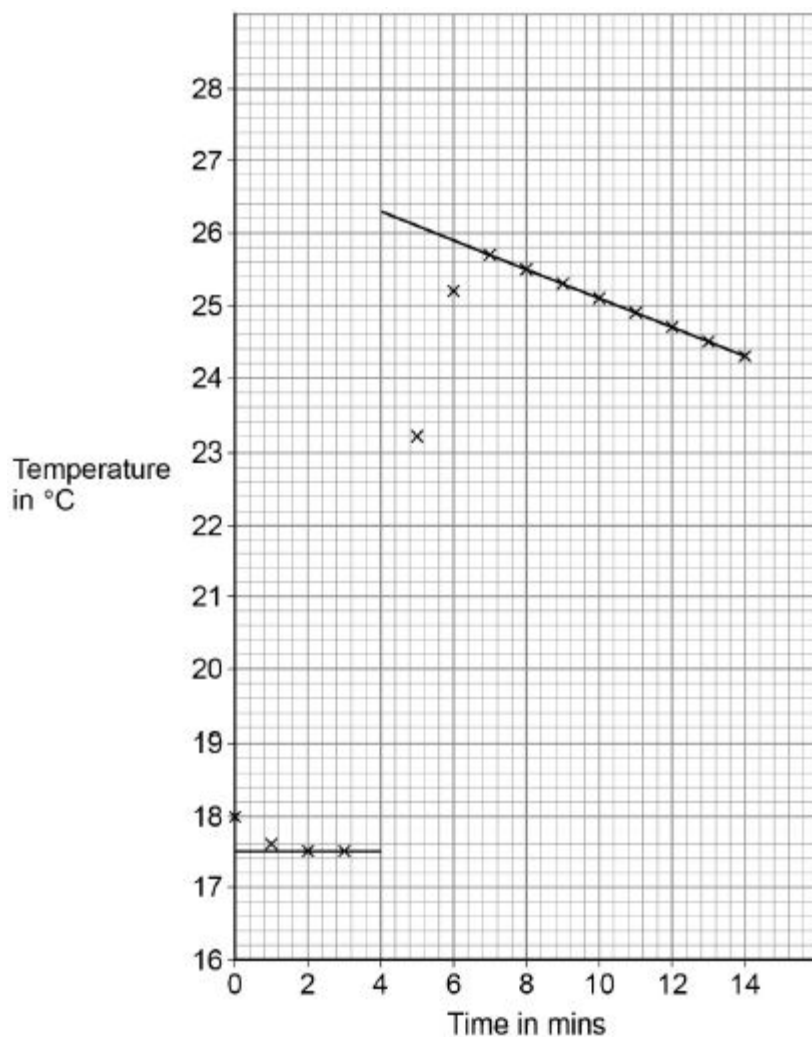
1

extends line back to 4 minutes

*ignore extension of line beyond 4 minutes*

1

the diagram below scores **2** marks



- (d) (maximum **and** minimum values at 4 minutes)  
26.3 (°C) **and** 17.5 (°C)

*allow ecf from (c)*

1

(temperature change at 4 minutes)  
= 8.8 (°C)

1

- (e) the reaction finished / stopped

*allow maximum temperature has been reached*

1

(so) energy is lost to surroundings / atmosphere

**or**

(so the) solution cools (back to room temperature)

*allow heat for energy*

1

- (f) aluminium / zinc / iron / beryllium

*allow Al / Zn / Fe / Be*

*do **not** accept copper, silver*

*MP2 dependent on a correct answer to MP1*

1

metal **Q** is less reactive (than magnesium)

**or**

metal **Q** is lower in reactivity series

*allow converse*

1

- (g) (unit conversion)  
 $30.0 \text{ cm}^3 = 0.030 \text{ dm}^3$   
**or**  
 $0.500 \text{ dm}^3 = 500 \text{ cm}^3$

1

$$\text{(moles} = \frac{30}{500} \times 0.1 \text{ =) } 0.006$$

*allow correct use of incorrect / no unit conversion*

**or**

$$\text{(moles} = \frac{0.030}{0.50} \times 0.1 \text{ =) } 0.006$$

1

$$\text{mass} = 0.006 \times 159.5$$

*allow correct use of incorrect value for number of moles*

1

$$= 0.957 \text{ (g)}$$

*allow 0.96 (g)*

1

[14]

2.

- (a) sports injury pack

1

- (b) B

1

- (c) C

1

- (d) lower than

1

- (e) thermometer

1

- (f) 27.4 (°C)

*allow values in the range 27.2–27.5 (°C)*

1

$$(27.4 - 14.3 \text{ =) } 13.1 \text{ (°C)}$$

*allow correct subtraction of incorrect temperature reading*

1

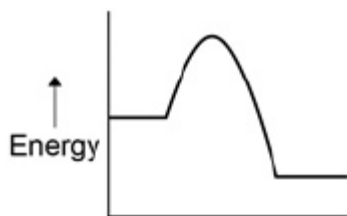
[7]

3.

- (a) (a reaction that) transfers energy to the surroundings

1

(b)



1

(c)  $2 \times 16 (= 32)$

1

$(M_r =) 44$

1

72.7 (%)

1

(d) 2 2

*allow multiples*

1

(e) 3.2 g of  $O_2$  produced from 6.8 g of  $H_2O_2$

1

32 (g)

1

**[8]**

**4.**

(a) (difference)

sodium has one and chlorine has seven electrons in outer level / shell

**or**

number of electrons

*number of electrons must be correct if quoted*

1

(similarity)

both have three / same number of levels / shells

**or**

have electrons in third level / shell

**or**

both have incomplete (outer) levels / shells

*allow both have 2 electrons in inner shell*

**or**

*both have 8 electrons in second shell*

**or**

*both are one electron away from full outer level / shell*

1

(b) sodium (atom) loses  
*allow moves / transfers for loses*  
*do **not** accept sodium ion loses*

1

one (outer shell electron)

1

chlorine (atom) gains  
*do **not** accept chloride*

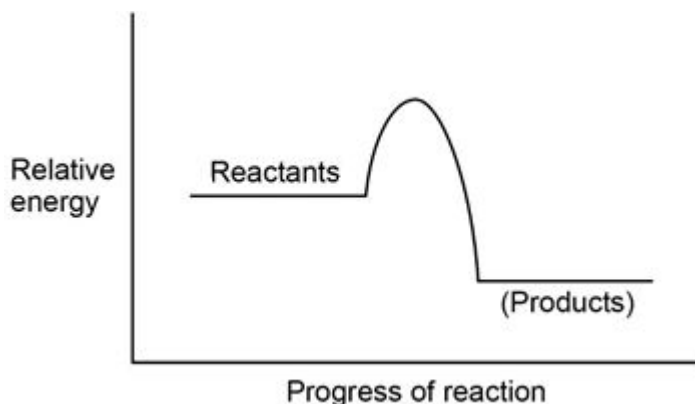
1

one (electron)

1

*transfer of 1 electron from chlorine to sodium **max 2** marks*  
*reference to sharing or covalent bonding **max 3** marks*  
*allow marks from suitable diagram(s)*

(c)



*ignore labels*  
*any curve / line going up and then down*  
*products line below reactants*  
*allow curve to start / finish anywhere along reactant / product lines*

1

1

[8]

5.

(a) Z

1

(b) magnesium sulfate does not react with any of the metals  
*allow there is no change / increase in temperature with any of the metals*

1

(c) temperature increase

1

(d) **Level 2 (3–4 marks):**

A detailed and coherent plan covering all the steps. The steps include the improvements and are set out in a logical manner.

**Level 1 (1–2 marks):**

Simple statements of improvements to the apparatus or steps are made but they may not be set out in a logical manner.

**0 marks:**

No relevant content

**Indicative content**

Simple statements

- stir the solution
- use the same amount of each solution
- use the same concentration of solution
- put insulation or a lid on the beaker
- measure how high temperature goes

Coherent statements in a logical order

- pour a fixed, measured volume of the metal salt solution into a plastic / polystyrene cup
- measure and record the temperature of the solution
- stir and add 1 g of metal to the solution
- (put a lid on the cup)
- measure and record the temperature after a set time or measure and record the greatest / highest temperature
- calculate and record the temperature increase
- (repeat each individual experiment at least two more times and calculate the mean temperature increase)

4

(e) Activation energy

1

(f)  $386 \text{ (kJ)} / 1370 \times 100$

1

28 %

1

[10]

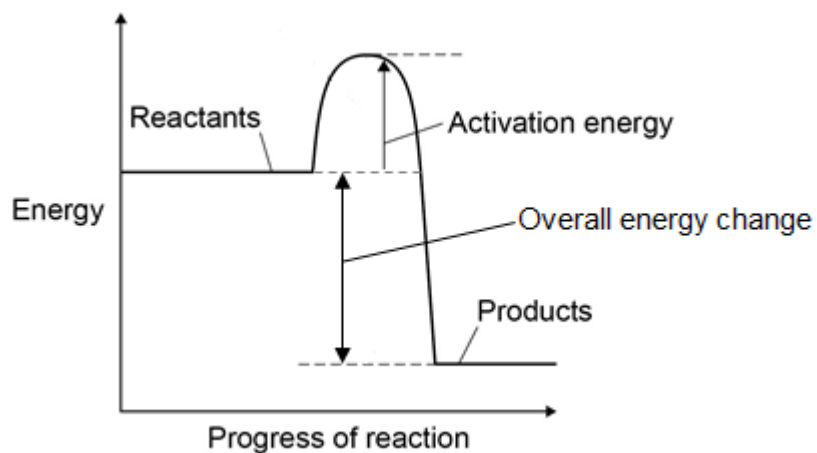
6.

(a) the relative energies of the reactants, products and the overall energy change

1

the activation energy

1



(b)  $(4 \times 413) + (2 \times 498) = 2\,648$

1

$(2 \times 805) + (4 \times 464) = 3\,466$

1

$(3466 - 2648 =) 818 \text{ (kJ / mol)}$

1

*allow max 2 marks for one ecf*

(c) **Level 3 (5–6 marks):**

A coherent method is described with relevant detail, which demonstrates a broad understanding of the relevant scientific techniques and procedures. The steps in the method are logically ordered with the dependent and control variables correctly identified. The method would lead to the production of valid results.

**Level 2 (3–4 marks):**

The bulk of a method is described with mostly relevant detail, which demonstrates a reasonable understanding of the relevant scientific techniques and procedures. The method may not be in a completely logical sequence and may be missing some detail.

**Level 1 (1–2 marks):**

Simple statements are made which demonstrate some understanding of some of the relevant scientific techniques and procedures. The response may lack a logical structure and would not lead to the production of valid results.

**0 marks:**

No relevant content

**Indicative content**

Named apparatus

- thermometer
- measuring cylinder
- stirring rod
- spatula
- plastic cup (with lid) or beaker
- stopwatch
- filter paper or watch glass
- balance

Method

- weigh the same mass of each metal in each same state of division eg powder
- measure a set volume of sulfuric acid into a plastic cup or beaker
- measure and record the temperature of the sulfuric acid
- add metal W into the plastic cup or beaker
- stir and record the highest temperature or record the temperature after a set time
- calculate the increase in temperature
- repeat the method for metals X, Y and Z
- repeat for each metal at least three times to calculate a mean

Safe use

- comment on safe use should include wearing safety glasses

(d) **W>Y>X>Z**

1

reason for position of **W** and **Z**

*W reacts with most solutions whereas Z reacts with none of the solutions*

1

reason for position of **X** and **Y**

*Y is more reactive than X because Y reacts more with sulfuric acid*

1

(e) magnesium is most reactive because not displaced by any metal

1

zinc is second most reactive because displaced by only one metal

1

copper and hydrogen cannot be placed in order of reactivity or are least reactive because

1

they both are displaced by the most / three metals

1

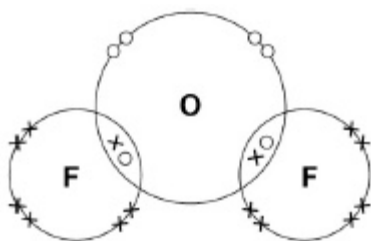
experiment – add sulfuric acid to copper because copper is less reactive than hydrogen then copper would not react with sulfuric acid to displace hydrogen

1

[19]

7.

(a)



*two shared pair of electrons  
all outer shells complete*

1

1

(b) gas

1

small molecules

1

(with) intermolecular forces

1

(so require) little energy to overcome

1

(c) calculates sum of all bonds broken:

$$4 \times (\text{C-H}) + 2 \times (\text{O=O}) = (4 \times 412) + (2 \times 496) = 2640$$

1

calculates sum of all bonds made:

$$4 \times (\text{O-H}) + 2(\text{C=O}) = (4 \times 463) + (2 \times 803) = 3458$$

1

overall energy change =

bonds broken – bonds made =

$$2640 - 3458 = (-)818$$

1

**[9]**