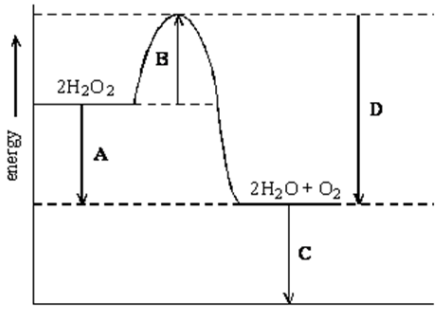
C5: Energy Changes

ANSWER KEY

13.1	**What is an exothermic reaction?**	**Energy is given out or lost to the surroundings (feels warm – temp. of surroundings increases)**
13.2	Give two examples of exothermic reactions	Two from: combustion, respiration, neutralisation
13.3	**State two uses of exothermic reactions**	**Self-heating cans, hand warmers**
13.4	**What is an endothermic reaction?**	**Energy is taken in or gained from surroundings (feels cold – temp. of surroundings decreases)**
13.5	Give an example of an endothermic reaction	Thermal decomposition
13.6	**State a use of endothermic reactions**	**Sports injury packs**
13.7	Looking at the energy level diagram below, which letter represents:  **1. The activation energy, Ea** **2. The overall energy change, ΔH** 3. The energy released making new bonds in the products (HT) 4. The energy taken in breaking bonds in the reactants (HT)	**1. B** **2. A** 3. D 4. B
13.8	**Define activation energy**	**<u>Minimum</u> energy needed to start a reaction**
13.9	In the diagram above, is the reaction endothermic or exothermic?	Exothermic (as products have less energy than reactants)
13.10	**(HT) Which of bond breaking and bond making is endothermic and which is exothermic**	• **Breaking: endothermic (B-endo)** • **Making: exothermic (M-exo)**
13.11	(HT) How do we work out the overall energy change of a reaction, ΔH?	Calculate the difference between energy taken in to break all bonds in reactants and the energy released forming all bonds in products

C5: Chemical Cells and Fuel Cells (Triple Content)

ANSWER KEY

1	What is a chemical cell?	A unit which contains chemicals which produce electricity through a reaction
2	What are the main components of a chemical cell?	An anode, a cathode and an electrolyte
3	What is a battery?	Two or more cells connected in series
4	What happens to the electrodes in a chemical cell?	The more reactive metal gets used up and the less reactive one increases in mass.
5	**Why can some cells not be recharged?**	**Because the reaction is not reversible**
6	How are rechargeable cells and batteries recharged?	By applying an external electric current
7	How does the reactivity of the metal electrodes affect the size of the potential difference (voltage)?	The greater the difference in reactivity, the greater the potential difference (voltage)
8	What is a fuel cell?	A cell which uses a fuel and oxygen (or air) to generate electricity
9	**What are the products in a hydrogen fuel cell?**	**Water**
10	**State three advantages of hydrogen fuel cells**	• **Do not need to be recharged** • **No pollutants are produced (just water)** • **Can be different sizes for different uses**
11	**State three disadvantages of hydrogen fuel cells**	• **Hydrogen is highly flammable** • **Hydrogen is sometimes produced through non-renewable means** • **Hydrogen is difficult to store**
12	Give the overall equation in a hydrogen fuel cell	$2\ H_2 + O_2 \rightarrow 2\ H_2O$
13	**(HT) Write the half equation for H_2 gas reacting to make H^+ ions**	$\mathbf{H_2 \rightarrow 2H^+ + 2e^-}$
14	**(HT) Write the half equation for H^+ ions reacting with O_2 to make H_2O**	$\mathbf{4\ H^+ + 4\ e^- + O_2 \rightarrow 2\ H_2O}$

FOUNDATION TIER

Q1. This question is about energy changes.

(a) Which of these items uses an endothermic reaction? Tick (✓) **one** box.

Hand warmer ☐

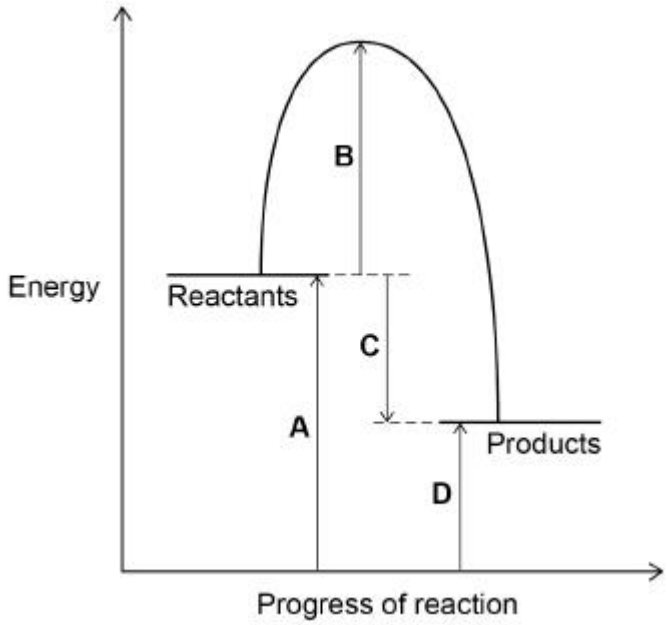
Sports injury pack ☐

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

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.

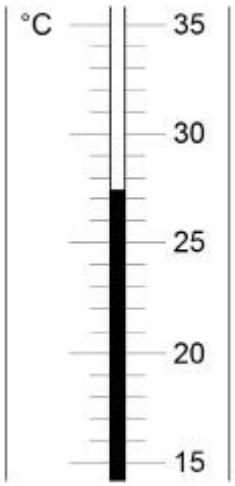
Name the apparatus used to measure the temperature.

_____

(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)

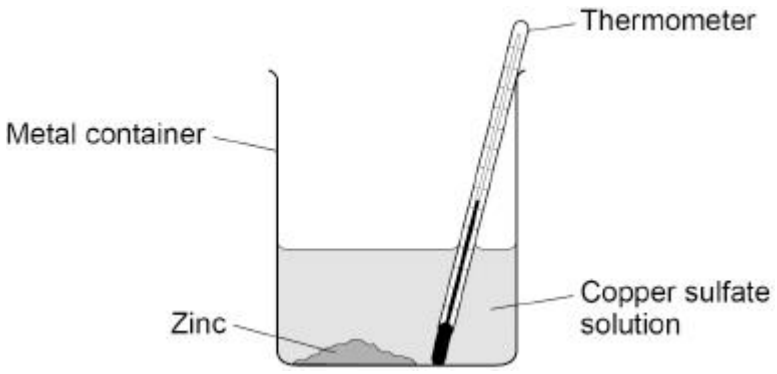
Q2. A student investigated the change in temperature when different masses of zinc were added to copper sulfate solution.

This is the method used.

1. Measure the volume of copper sulfate solution using a measuring cylinder.
2. Pour the copper sulfate solution into a metal container.
3. Add 2 g of zinc.
4. Measure the temperature of the solution.
5. Repeat steps 1 to 4 with different masses of zinc.

Figure 1 shows the apparatus.

Figure 1



(a) Give **three** improvements to the investigation to make the results more accurate.

1 _____

_____

2 _____

_____

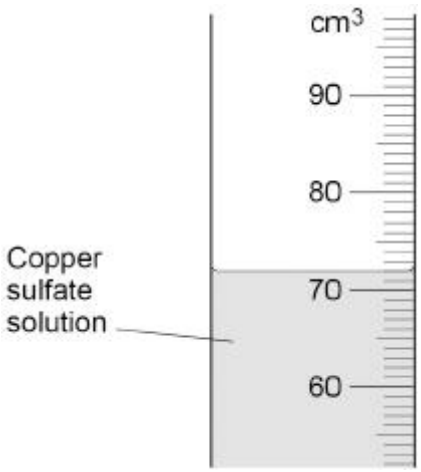
3 _____

_____

(3)

(b) **Figure 2** shows part of the measuring cylinder.

Figure 2



What is the volume of copper sulfate solution in **Figure 2**?

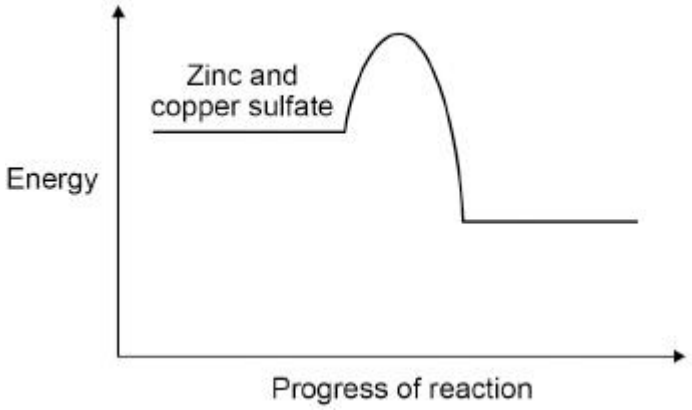
Volume = _____ cm^3

(1)

(c) When zinc was added to copper sulfate solution the temperature increased.

Figure 3 shows the reaction profile.

Figure 3



What type of reaction is shown in **Figure 3**?

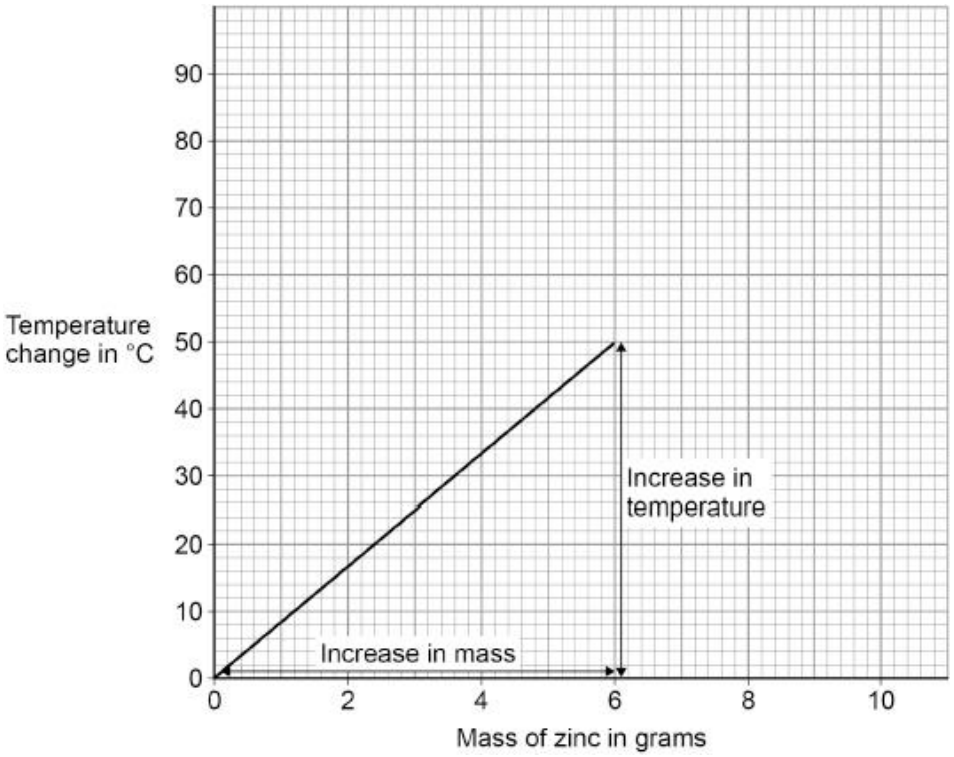
Tick (✓) **one** box.

Endothermic ☐ Exothermic ☐ Neutralisation ☐

(1)

Figure 4 shows the results.

Figure 4



(d) Determine the gradient of the line in **Figure 4**.

Use the equation:

$$\text{gradient} = \frac{\text{increase in temperature in °C}}{\text{increase in mass in grams}}$$

Gradient = _____ °C per g

(4)

(e) Suggest why the student should **not** use more than 10 g of zinc.

Use **Figure 4**.

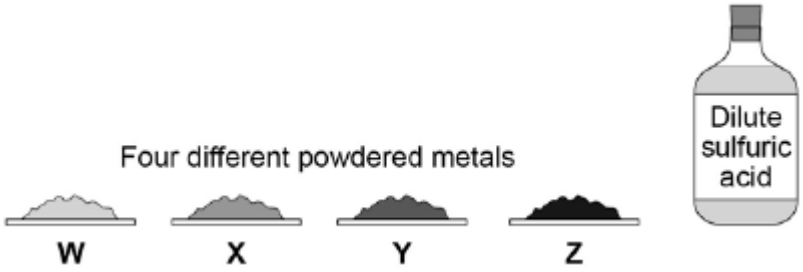
You should extend the graph line.

(2)

(Total 11 marks)

Q3. **Figure 2** shows the chemicals given to a student.

Figure 2



The student wants to investigate the reactivity of the four metals.

Outline a plan the student could use to investigate the relative reactivity of the four metals, **W**, **X**, **Y** and **Z**.

The plan should use the fact that all four metals react exothermically with dilute sulfuric acid.

You should name the apparatus used and comment on the safe use of the chemicals.

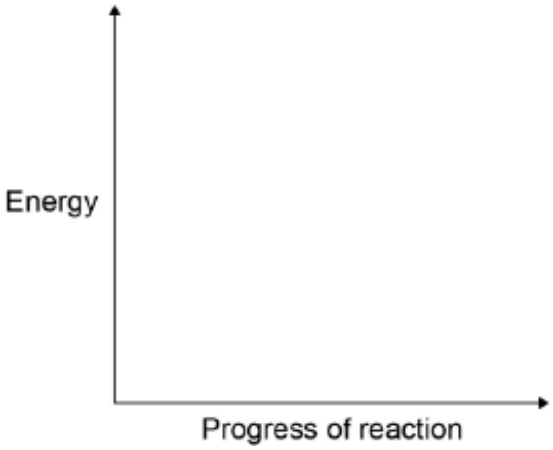
(6)

HIGHER TIER

Q4. Exothermic reactions transfer energy to the surroundings.

(a) Draw a reaction profile for an exothermic reaction using the axes below. Show the:

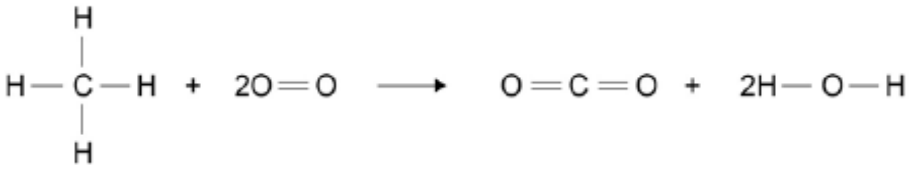
- relative energies of the reactants and products
- activation energy and overall energy change.



(2)

(b) Combustion is an exothermic reaction. Calculate the overall energy change for the complete combustion of one mole of methane in oxygen.

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$$



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

Overall energy change = _____ kJ / mol

(3)

(Total 5 marks)

Q5. Methane, ethane and propane all react with oxygen to produce carbon dioxide and water.

(a) Suggest why a mixture of methane and oxygen does **not** react at room temperature.

Answer in terms of particles.

_____

_____

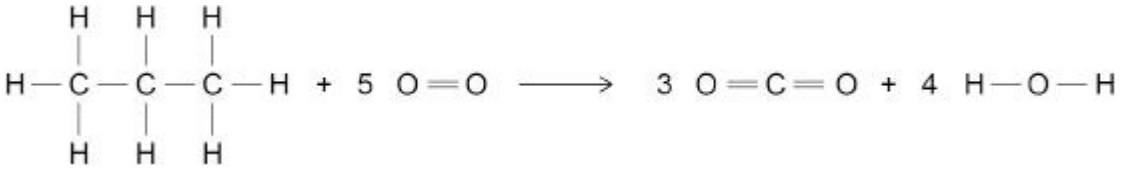
_____

_____

(2)

(b) Propane reacts with oxygen to produce carbon dioxide and water.

The displayed formula equation for the reaction is:



The reaction is exothermic.

In the reaction, the energy released when forming new bonds is 1640 kJ/mol greater than the energy needed when breaking bonds.

Table 2 shows bond energies.

Bond	**H–C**	**C–C**	**O=O**	**C=O**	**O–H**
Bond energy in kJ/mol	410	**X**	500	740	460

Calculate the C—C bond energy (**X**).

_____

_____

_____

_____

_____

_____

_____

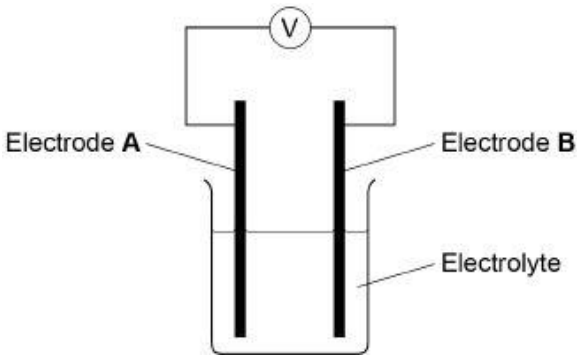
X = _____ kJ/mol

(5)

(Total 7 marks)

SEPARATE SCIENCE

Q6. Chemical reactions can produce electricity.



(a) The diagram shows a simple cell.

Which of these combinations would not give a zero reading on the voltmeter in the diagram above?

Tick **one** box.

Electrode A	Electrode B	Electrolyte	
Copper	Copper	Sodium chloride solution	☐
Zinc	Zinc	Water	☐
Copper	Zinc	Sodium chloride solution	☐
Copper	Zinc	Water	☐

(1)

Alkaline batteries are non-rechargeable.

(b) Why do alkaline batteries eventually stop working?

_____

_____

(1)

(c) Why can alkaline batteries **not** be recharged?

_____

_____

(1)

Hydrogen fuel cells and rechargeable lithium-ion batteries can be used to power electric cars.

(d) Complete the balanced equation for the overall reaction in a hydrogen fuel cell.

$$\_\_\_\_\_\ H_2 + \_\_\_\_\_ \longrightarrow \_\_\_\_\_\ H_2O$$

(2)

(e) The table below shows data about different ways to power electric cars.

	Hydrogen fuel cell	**Rechargeable lithium-ion battery**
Time taken to refuel or recharge in minutes	5	30
Distance travelled before refuelling or recharging in miles	Up to 415	Up to 240
Distance travelled per unit of energy in km	22	66
Cost of refuelling or recharging in £	50	3
Minimum cost of car in £	60 000	18 000

Evaluate the use of hydrogen fuel cells compared with rechargeable lithium-ion batteries to power electric cars.

Use the table above and your own knowledge.

(6)

(Total 11 marks)

Q1.

(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 =) 13.1 (°C)

allow correct subtraction of incorrect temperature reading

1

[7]

Q2.

(a) any **three** from:

- use a (glass) beaker
  or
  use a polystyrene cup
- insulate the metal container
- add a lid
- measure copper sulfate solution with a pipette
- use same volume (of copper sulfate solution)
- use a more accurate balance
- stir (the mixture)
- record the initial **and** the highest temperature
- use a digital thermometer
  or
  use a more accurate thermometer
- repeat the experiment **and** calculate the mean (ignoring anomalous results)

3

(b) 72 (cm^3)

1

(c) exothermic

1

(d) (increase in temperature =) 50 (°C)

1

increase in mass = 6 (g)

allow a value in the range 5.8 – 6 (g)

1

(gradient =) $\frac{50}{6}$

allow correct use of incorrectly determined value(s) for temperature and/or mass

1

= 8.33 (°C per g)

1

(e) extends line on graph to 10 g of zinc

1

any **one** from:

- temperature (change) of 84 (°C)

  allow a temperature (change) over 80 (°C)

- (so the solution will be) too hot

- (so the solution will be) over 100 (°C)

- (so the solution will) boil

1

[11]

Q3.

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
- balance

Method

- weigh the same mass of each metal in each same state of division eg powder
- measure same 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

6

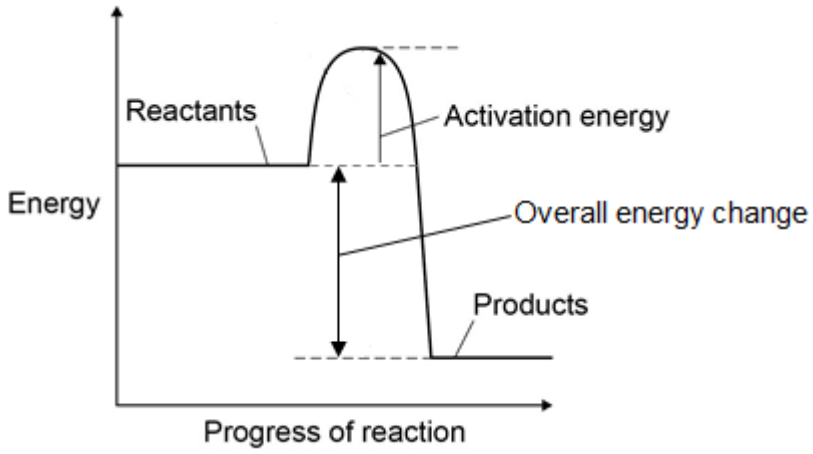
Q4.

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

1

the activation energy

1



(b) (4 × 413) + (2 × 498) = 2 648

1

(2 × 805) + (4 × 464) = 3 466

1

(3466 − 2648 =) 818 (kJ / mol)

1

*allow max **2** marks for one ecf*

[5]

Q5.

(a) particles collide

1

(but at room temperature) particles have insufficient energy
or
(but) have energy less than the activation energy (so collisions are not successful)

1

(b) (bonds broken =

(8 × 410) + 2 **X** + (5 × 500) = 5780 + 2 **X**

*allow C–C for **X***

allow (bonds broken = (8 × 410) + (5 × 500) = 5780

1

(bonds formed =
(6 × 740) + (8 × 460) = 8120

1

(bonds broken – bonds formed = energy released)
(5780 + 2 **X**) – 8120 = – 1640

allow correct use of incorrect values from step 1 and/or step 2

1

(2 **X** =) 700

allow correct use of incorrect value from step 3

1

(**X** =) 350 (kJ/mol)

1

[7]

Q6.

(a) copper, zinc, sodium chloride solution

1

(b) a reactant is used up

allow the reaction stops

allow electrolyte / electrode / ions / metal / metal hydroxide / alkali for reactant

1

(c) the reaction is not reversible

1

(d) $2H_2 + O_2 \longrightarrow 2H_2O$

allow fractions / multiples
*allow **1** mark for O_2*

2

(e) **Level 3:** A judgement, strongly linked and logically supported by a sufficient range of correct reasons, is given.

5–6

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

3–4

Level 1: Relevant points are made. This is not logically linked.

1–2

No relevant content

0

Indicative content

reasons why fuel cells could be judged as better

from the table	from other knowledge
• time for refuelling a fuel cell is faster than recharging **or** a fuel cell does not need to be recharged • a fuel cell has a greater range	• hydrogen can be renewable if made by electrolysis using renewable energy • lithium-ion batteries can catch fire • produces only water **or** no pollutants produced • lithium-ion batteries may release toxic chemicals on disposal • lithium-ion batteries (eventually cannot be recharged so) have a finite life

reasons why the lithium-ion battery could be judged as better

from the table	from other knowledge
• lithium-ion uses energy more efficiently • cost of lithium-ion car much less • cost of recharging much less than refuelling with hydrogen	• hydrogen is often made from fossil fuels so is not renewable • charging points are more widely available than hydrogen filling stations • hydrogen takes up a lot of space **or** is difficult to store • hydrogen can be highly flammable / explosive

	• no emissions produced • (catalyst in the hydrogen fuel-cell eventually becomes poisoned so) have a finite life

[11]