All questions are for separate science students only

Q1.

This question is about chemical cells and batteries.

(a) Three different types of battery can be used to power a TV remote control.

The table below gives information about these batteries.

	Zinc-carbon battery	Alkaline battery	Nickel-metal hydride battery
Cost of battery in £ (pounds)	0.17	0.50	1.50
Rechargeable?	No	No	Yes
Time before needing to replace or recharge in months	5	12	8

Give **one** advantage of each type of battery.

Zinc-carbon Cheapest

Alkaline Lasts the longest

Nickel-metal hydride is rechargeable

(3)

(b) **Figure 1** shows a symbol printed on batteries.

Figure 1

This symbol shows that batteries should not be put in household waste.

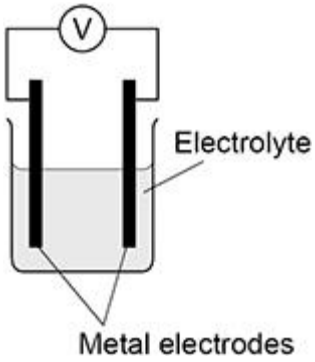
Suggest why batteries should **not** be put in household waste.

metal and alkaline waste can be toxic. recycling saves resources

(1)

Figure 2 shows a chemical cell.

Figure 2



(c) The order of reactivity of three metals is shown below.

Iron	(Most reactive)
Tin	↑
Copper	(Least reactive)

Which combination of metal electrodes would give the highest voltage in the chemical cell in **Figure 2**?

Tick (✓) **one** box.

Copper and iron	✓
Iron and tin	
Tin and copper	

(1)

(d) The voltage produced by the cell in **Figure 2** depends on the type of electrodes and the type of electrolyte.

Suggest **one** other factor that could affect the voltage produced.

Concentration of electrolyte (and temperature)

(1)

(e) Water is produced in a hydrogen fuel cell.

Complete the word equation to show the reaction that produces water in a hydrogen fuel cell.

H_2 + $\frac{1}{2}$ O_2 → water

(2)

(Total 8 marks)

Q2.

This question is about chemical reactions and energy.

Hydrogen reacts with oxygen to produce water.

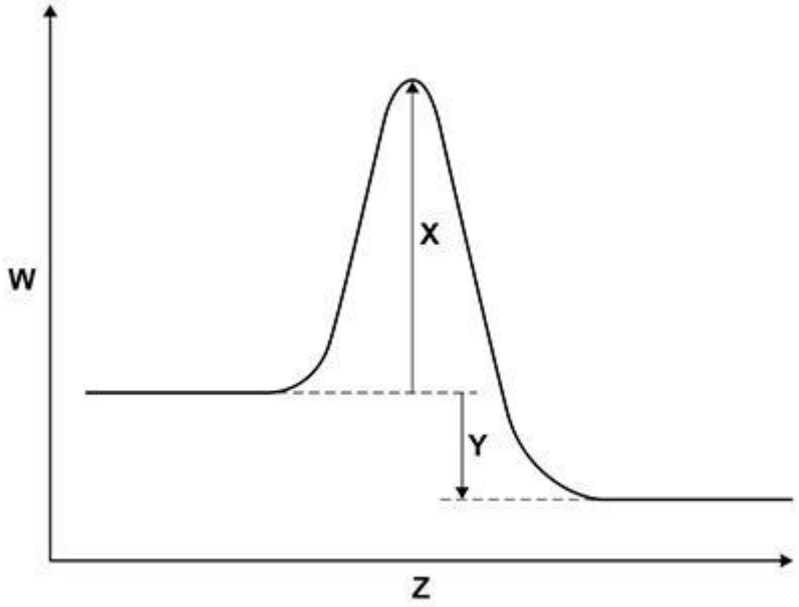
This reaction releases energy.

(a) Complete the word equation for the reaction.

hydrogen + oxygen → water

(1)

(b) The graph below shows a reaction profile for the reaction between hydrogen and oxygen.



What do the labels **W**, **X**, **Y** and **Z** represent?

Choose answers from the box.

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

W Energy

X Activation Energy

Y Overall Energy change

Z Progress of reaction.

(4)

(c) The reaction between hydrogen and oxygen is used in a hydrogen fuel cell.

What is the reason for using this reaction in a fuel cell?

Tick (✓) **one** box.

To produce a change of state	☐
To produce a potential difference	☑
To produce a temperature change	☐

(1)

(d) A student investigated the voltage produced by a chemical cell.

The student used different metals as the electrodes in the cell.

The metals used were:

- copper
- iron
- magnesium.

Which **two** metal electrodes would produce the greatest voltage when used in the chemical cell?

Give **one** reason for your answer.

Metals Mg and Cu

Reason These metals have the largest difference in reactivity.

(2)

(Total 8 marks)

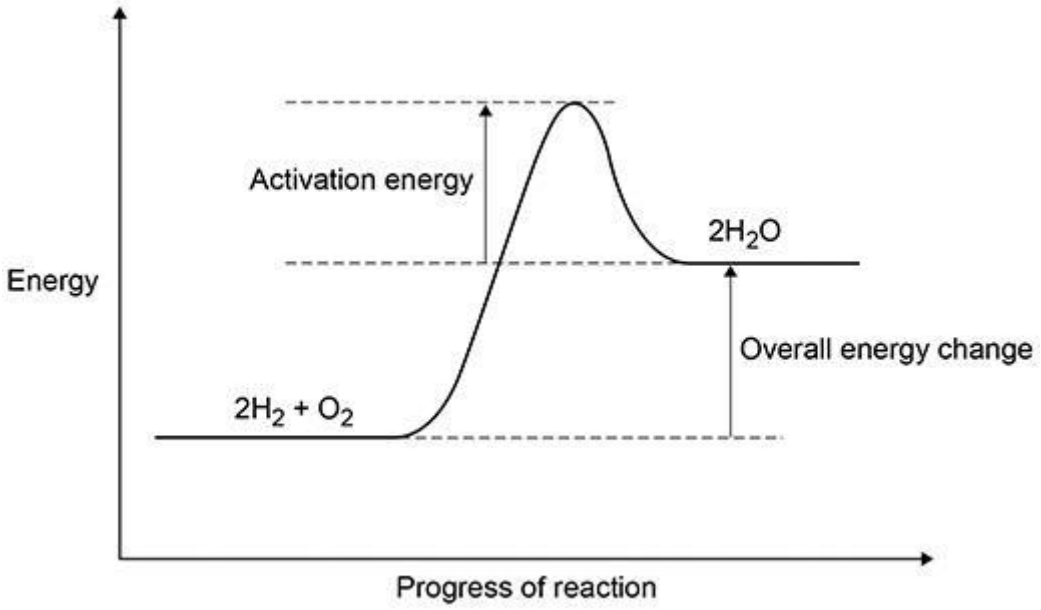
Q3.

The reaction between hydrogen and oxygen releases energy.

(a) A student drew a reaction profile for the reaction between hydrogen and oxygen.

Figure 1 shows the student's reaction profile.

Figure 1



The student made **two** errors when drawing the reaction profile.

Describe the **two** errors.

1 The Activation energy should be from the reactants line to the peak.

2 The products line should be below the reactants line.

(2)

(b) The reaction between hydrogen and oxygen in a hydrogen fuel cell is used to produce electricity.

Hydrogen fuel cells and rechargeable cells are used to power some cars.

Give **two** advantages of using hydrogen fuel cells instead of using rechargeable cells to power cars.

1 Takes less time to refuel than to charge rechargeable cells.

2 No toxic chemicals to dispose of at the end of the cell's life

(2)

(c) Reactions occur at the positive electrode and at the negative electrode in a hydrogen fuel cell.

Write a half equation for **one** of these reactions.

$H_2 \longrightarrow 2\,H^+ + 2\,e^-$

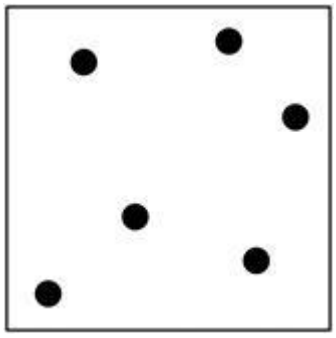
$O_2 + 4\,H^+ + 4\,e^- \longrightarrow 2\,H_2O$

(1)

(d) The three states of matter can be represented by a simple particle model.

Figure 2 shows a simple particle model for hydrogen gas.

Figure 2



Give **two** limitations of this simple particle model for hydrogen gas.

1 Hydrogen (H_2) is not shown as H—H molecules.

2 Does not show the weak forces between particles.

(2)

(e) The hydrogen gas needed to power a car for 400 km would occupy a large volume.

Suggest **one** way that this volume can be reduced.

Cool to condense into a liquid. (Adsorb onto a solid)

(1)

(f) The energy needed for a car powered by a hydrogen fuel cell to travel 100 km is 58 megajoules (MJ). Mega = 1×10^6

The energy released when 1 mole of hydrogen gas reacts with oxygen is 290 kJ kilo = 1×10^3

The volume of 1 mole of a gas at room temperature and pressure is 24 dm^3

Calculate the volume of hydrogen gas at room temperature and pressure needed for the car to travel 100 km

Moles of H_2 needed = $\frac{58 \times 10^6 \text{ J}}{290 \times 10^3 \text{ J}}$ = 200 moles

Volume of H_2 = 24 dm^3 × 200

= 4800 dm^3

Volume of hydrogen gas = 4800 dm^3

(4)

(Total 12 marks)

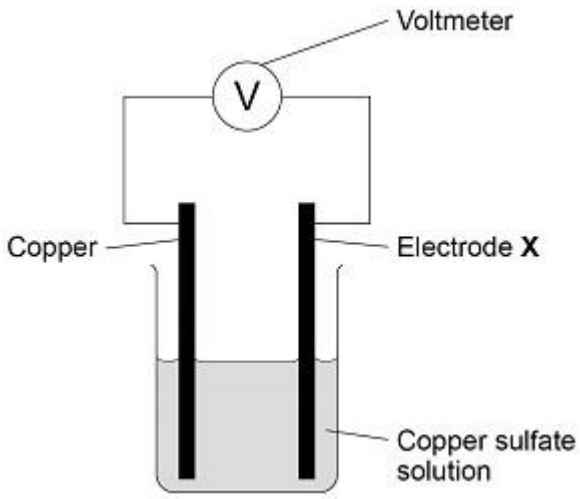
Q4.

This question is about chemical cells and batteries.

A student investigated the voltage produced by different chemical cells.

Figure 1 shows the apparatus.

Figure 1



This is the method used.

1. Use cobalt metal as electrode **X**.

2. Record the cell voltage.

3. Repeat steps 1 and 2 using different metals as electrode **X**.

(a) Suggest **two** variables the student should keep the same to make the investigation valid.

1 Concentration of electrolyte

2 Temperature of solution.

(2)

The following table shows the student's results.

Electrode X	Voltage of the cell in volts
cobalt	0.62
magnesium	2.71
zinc	1.10

3
1
2

(b) Write the three metals used for electrode X in order of reactivity.

Use the table above.

Most reactive Mg

Zn

Least reactive Co

(1)

(c) Copper is used as electrode **X** in **Figure 1**.

Predict the voltage of this cell.

Give **one** reason for your answer.

Voltage = 0 volts

Reason The other electrode is Cu.

2 different metals are needed to produce a voltage.

(2)

(d) Describe how to make a 12 V battery using 1.5 V cells.

Battery voltage = sum of cell voltages.

12 V / 1.5V = 8, Need 8 cells.

(2)

(e) Which is the most suitable use for a non-rechargeable cell?

Tick (✓) **one** box.

Electric toy	✓
Laptop computer	
Mobile phone	

lasts longer - intermittent use.

(1)

(f) Hydrogen fuel cells or rechargeable cells can be used to power electric vehicles.

Suggest **one** advantage and **one** disadvantage of using a hydrogen fuel cell compared with a rechargeable cell.

Advantage of hydrogen fuel cell Hydrogen is renewable

Disadvantage of hydrogen fuel cell Difficult to store (flammable)

(2)

(Total 10 marks)

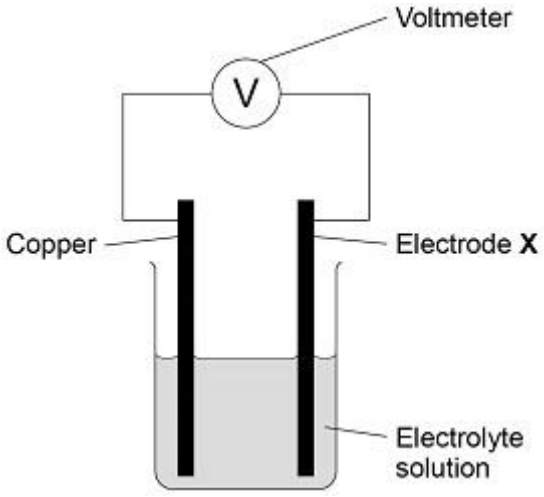
Q5.

This question is about chemical cells.

A student investigated the voltage produced by different chemical cells.

Figure 1 shows the apparatus.

Figure 1



This is the method used.

1. Use cobalt as electrode **X**.

2. Record the cell voltage.

3. Repeat steps 1 and 2 using different metals as electrode **X**.

(a) Suggest **two** control variables used in this investigation.

1 Concentration of electrolyte

2 Temperature of solution.

(2)

The following table shows the student's results.

Electrode X	Voltage of cell in volts	
cobalt	+0.62	2
copper	0.00	5
magnesium	+2.71	1
nickel	+0.59	3
silver	−0.46	6
tin	+0.48	4

(b) Write the six metals used for electrode **X** in order of reactivity.

Use the table above.

Justify your order of reactivity.

Most reactive Mg

Co

Ni

Sn

Cu

Least reactive Ag

Justification The higher the positive voltage,

the more reactive the metal

(4)

(c) Which of the following pairs of metals would produce the greatest voltage when used as the electrodes in the cell?

Use the table above.

Tick (✓) **one** box.

Magnesium and cobalt	☐	+2.71	+0.62
Magnesium and tin	✓	+2.71	+0.48
Nickel and cobalt	☐	+0.59	+0.62
Nickel and tin	☐	+0.59	+0.48

✓ Biggest difference

(1)

(d) Hydrogen fuel cells can be used to power different forms of transport.

Some diesel trains are being converted to run on hydrogen fuel cells.

A newspaper article referred to the converted trains as the new 'steam trains'.

Suggest why.

In a fuel cell, H_2 is oxidised to produce H_2O, water. At these temperatures, water is produced as steam.

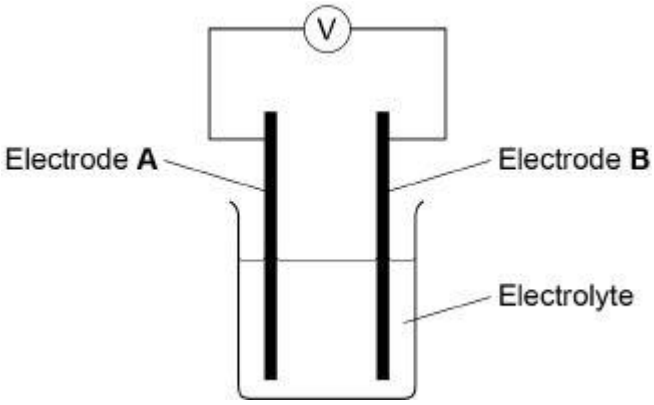
(2)

(Total 9 marks)

Q6.

Chemical reactions can produce electricity.

(a) The diagram below 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?

A reactant is used up, then the reaction stops.

(1)

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

The reaction is not reversible

(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.

$$\underline{2}\ H_2 + \underline{O_2}\ \rightarrow \underline{2}\ H_2O$$

(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.

Reasons why fuel cells could be better:
- Refuelling time faster than recharging
- Fuel cell has greater range.
- Produces only H_2O
- H_2 can be produced by renewable means.
- No pollutants on disposal
- Li-ion batteries have finite life.

Reasons why Li-ion batteries could be better:
- More efficient use of energy
- cost of Li-ion car is much less
- charging points are more available than H_2 filling stations.

- H_2 is difficult to store
- H_2 can be explosive.

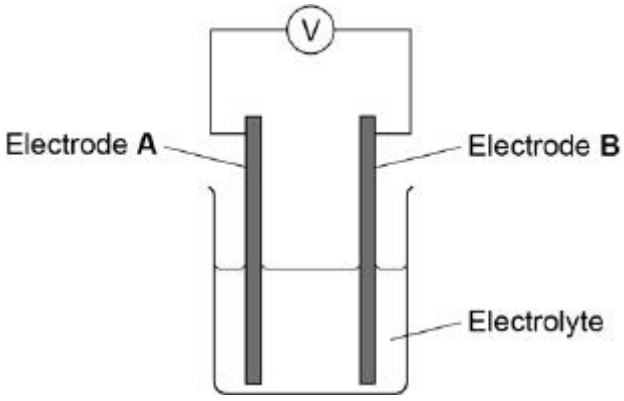
(6)

(Total 11 marks)

Q7.

A student investigated the voltage produced by simple cells.

The diagram shows the apparatus used.



The table shows the voltage produced with different metal electrodes.

Electrode A	Electrode B	Voltage in V	
Copper	Copper	0.00	5
Copper	Iron	0.78	3
Copper	Magnesium	2.71	1
Copper	Tin	0.48	4
Copper	Zinc	1.10	2

(a) List the metals in the table in order of reactivity.

Most reactive Mg

Zn

Fe

Sn

Least reactive Copper

(2)

(b) Batteries consist of cells.

Describe how a 6.0 V battery can be made from cells of voltage 1.5 V

$\frac{6.0V}{1.5V} = 4$

Use 4 (1.5 V) cells connected in series.

(2)

(c) Why do non-rechargeable cells stop producing electricity?

The reaction stops because one of the reactants is used up.

(2)

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

hydrogen + oxygen → water

(1)

(e) Give **two** reasons why using a hydrogen fuel cell is seen as non-polluting.

Use the equation in part (d).

1. Only produces H_2O

2. Does not produce CO_2

(2)

(Total 9 marks)

Q8.

Cells contain chemicals which react to produce electricity.

(a) Why can a rechargeable cell be recharged?

The chemical reaction is reversible

(1)

(b) Give **two** factors that affect the voltage produced by a cell.

1. Type of electrode
2. Concentration of electrolyte

(2)

(c) Balance the half-equation for the reaction occurring at an electrode in one type of hydrogen fuel cell.

$$H_2 + 2\,OH^- \rightarrow 2\,H_2O + 2\,e^-$$

(1)

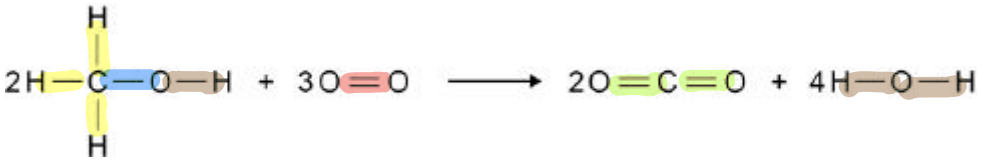
(d) Why is the fuel cell in Question (c) described as an alkaline fuel cell?

Because it contains OH^- ions.

(1)

(e) Another type of fuel cell uses methanol instead of hydrogen.

The diagram represents the reaction in this fuel cell.



The table shows the bond energies for the reaction.

	C–H	C–O	O–H	O=O	C=O
Bond energy in kJ / mol	412	360	464	498	805

Calculate the overall energy change for the reaction.

Use the diagram and the table above.

Energy Change = Bonds Broken − Bonds Formed

$[2(3\times C-H)+2C-O+2O-H+3\times O=O] - [(4\times C=O)+8\times O-H]$

$2(3\times 412)+2\times 360+2\times 464+(3\times 498) - (4\times 805)+(8\times 464)$

$[2472+720+928+1494] - [3220+3712]$

5614 − 6932

= −1318

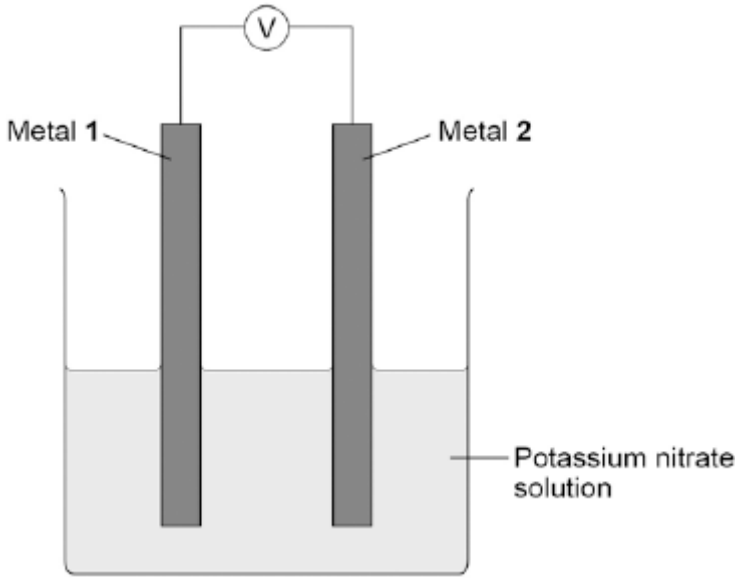
Overall energy change = 1318 kJ / mol

(3)

(Total 8 marks)

Q9.

A student investigated simple cells using the apparatus shown in the figure below.



- If metal **2** is more reactive than metal **1** then the voltage measured is positive.
- If metal **1** is more reactive than metal **2** then the voltage measured is negative.
- The bigger the difference in reactivity of the two metals, the larger the voltage produced.

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

Metal 1 \ Metal 2	Chromium	Copper	Iron	Tin	Zinc
Chromium	0.0 V				
Copper	1.2 V	0.0 V			
Iron	0.5 V	not measured	0.0 V		
Tin	0.8 V	-0.4 V	0.3 V	0.0 V	
Zinc	0.2 V	-1.0 V	-0.3 V	-0.6 V	0.0 V

(a) The ionic equation for the reaction occuring at the zinc electrode in the simple cell made using copper and zinc electrodes is:

$$Zn \rightarrow Zn^{2+} + 2e^-$$

OIL RIG

Zinc is oxidised in this reaction.

Give a reason why this is oxidation.

Zn has lost electrons

(1)

(b) Look at the table above.

Which **one** of the metals used was the least reactive?

Give a reason for your answer.

Metal Cu

Reason It gave the most negative voltage when used as metal 2

(2)

(c) Predict the voltage that would be obtained for a simple cell that has iron as metal **1** and copper as metal **2**. Fe Cu

Explain your answer.

Voltage with Cr + Cu = 1.7

" " Cr + Fe = 0.5

Cu less reactive than Fe

∴ Fe - Cu = −0.7

(3)

(d) Hydrogen fuel cells have been developed for cars.

Write a word equation for the overall reaction that takes place in a hydrogen fuel cell.

hydrogen + oxygen → water

(1)

(e) Write the **two** half equations for the reactions that occur at the electrodes in a hydrogen fuel cell.

$H_2 \longrightarrow 2H^+ + 2e^-$

$O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$

(2)

(Total 9 marks)