Name:	Target Grade:	Actual Grade:

BRIGHT CULTURE

ELECTROLYSIS
MCQ and STRUCTURED QUESTIONS

READ THESE INSTRUCTIONS FIRST

INSTRUCTIONS TO CANDIDATES

1. Find a quiet, comfortable spot free place from distractions.

2. Spend one minute on each mark.

3. Time yourself for every single question.

4. Every chapter has their own question types. Ensure that you know the different question type for each chapter.

5. Make a conscientious effort to remember your mistakes, especially in terms of answering techniques. E.g Take a picture for the mistakes that you made, keep it in a photo album, and revise it over and over again.

6. Highlight question types that you tend to keep making mistakes and review them nearing exams.

7. Always review the common questions and question type that you tend to make mistakes nearing exams.

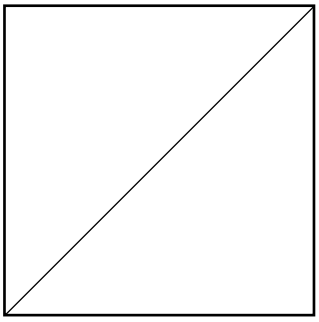
8. During exams, classify the question type and recall what you have learnt, how you need to analyse the questions for the different question type, what you need to take note of and answer with the correct answering techniques!

✨ **Wishing you all the best for this test!**

You've got this!

💡 **With lots of love,**
Bright Culture 💛

MARKS



If you are struggling in this paper, means you need to work harder!

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ELECTROLYSIS MCQ

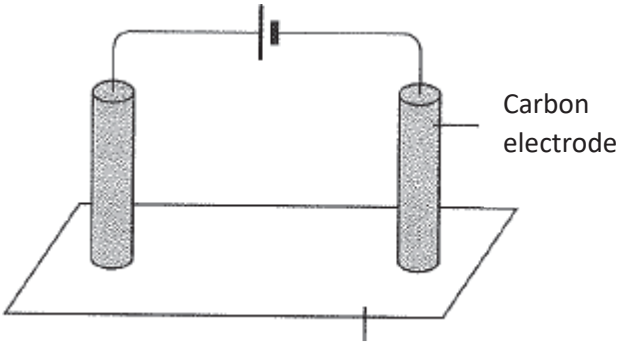
Paper 1

1 Which solution(s) would produce hydrogen gas at the cathode upon electrolysis?

1 dilute nitric acid
2 aqueous potassium hydroxide
3 aqueous sodium chloride

A 1 only
B 1 and 2
C 2 and 3
D all of the above

2 Two carbon electrodes are placed on a piece of red litmus paper soaked in concentrated sodium chloride solution as shown:

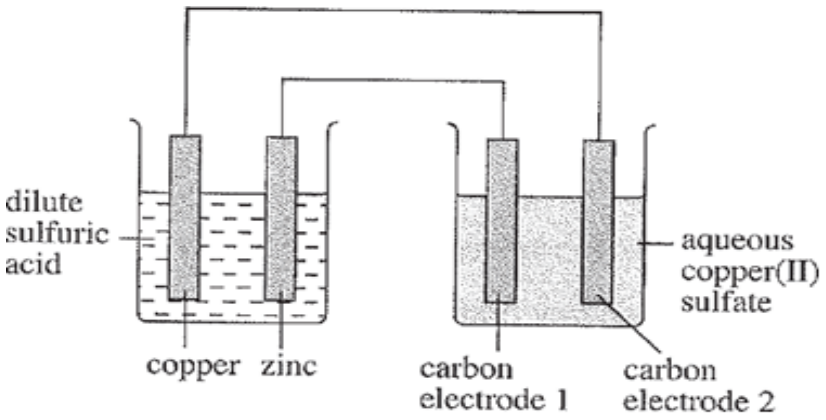


Litmus paper soaked in concentrated sodium chloride solution

What are the observations of the litmus paper at the respective electrodes?

	Cathode	Anode
A	Litmus paper is bleached.	Litmus paper turns blue.
B	Litmus paper turns blue.	Litmus paper is bleached.
C	Litmus paper turns blue.	Litmus paper remains red.
D	Litmus paper remains red.	Litmus paper remains red.

3 Two simple cells were set up as shown:

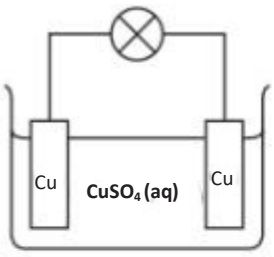


Two substances were discharged at the carbon electrodes. What were these two substances?

	Electrode 1	Electrode 2
A	Copper metal	Hydrogen gas
B	Hydrogen gas	Copper metal
C	Copper metal	Oxygen gas
D	Oxygen gas	Copper metal

4 In which circuit does the bulb light?

A



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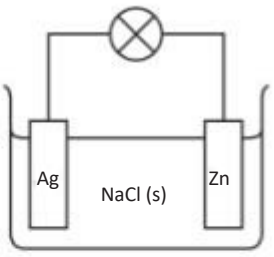

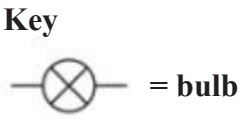

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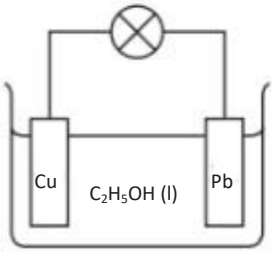
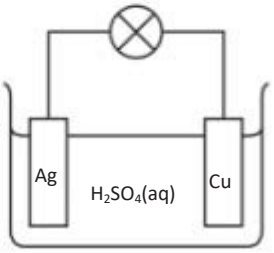


D



5 A molten compound is electrolysed. Two atoms of X are deposited at the negative electrode at the same time as three atoms of Y are deposited at the positive electrode.

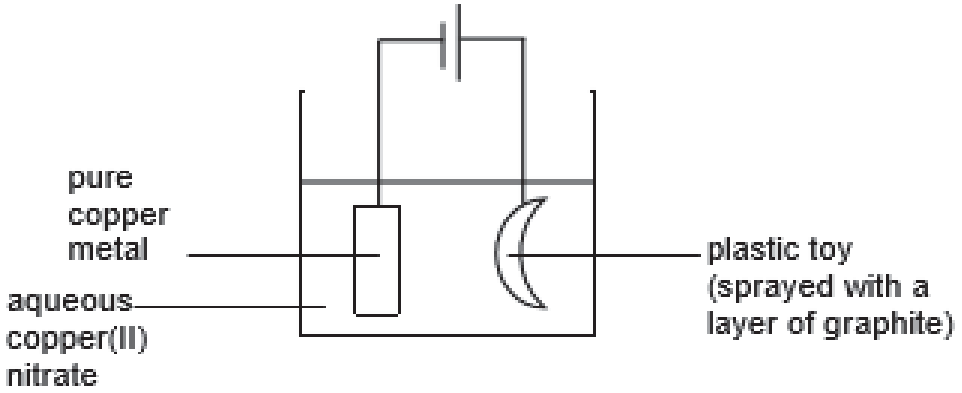
These results show that:

X is a …1…;
Y is a …2…;
the formula of the compound is …3… .

How are gaps **1**, **2** and **3** correctly completed?

	1	2	3
A	Metal	Non-metal	X_3Y_2
B	Metal	Non-metal	X_2Y_3
C	Non-metal	Metal	X_3Y_2
D	Non-metal	metal	X_2Y_3

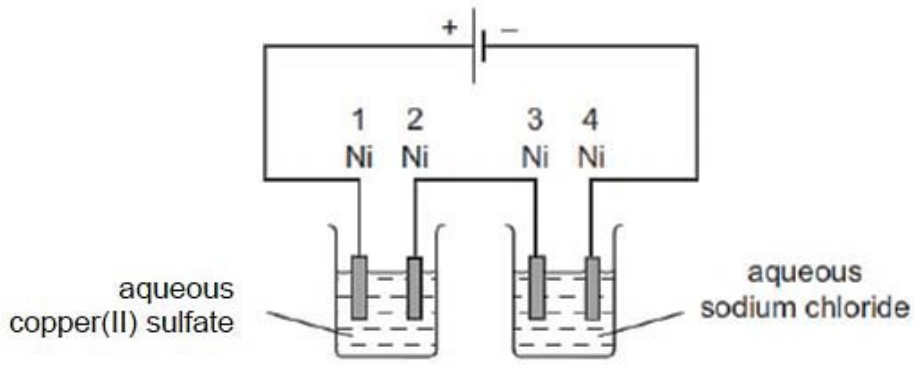
6 A student decides to coat his plastic toy with a layer of copper metal using electrolysis. The diagram shows his set-up.



The experiment failed and no copper was deposited on the plastic toy. Which statement best explains why the experiment failed?

A The electrolyte used should be aqueous silver nitrate.
B The plastic toy should not be submerged in the electrolyte.
C The plastic toy should not be sprayed with a layer of graphite.
D The pure copper strip should be attached to the positive electrode.

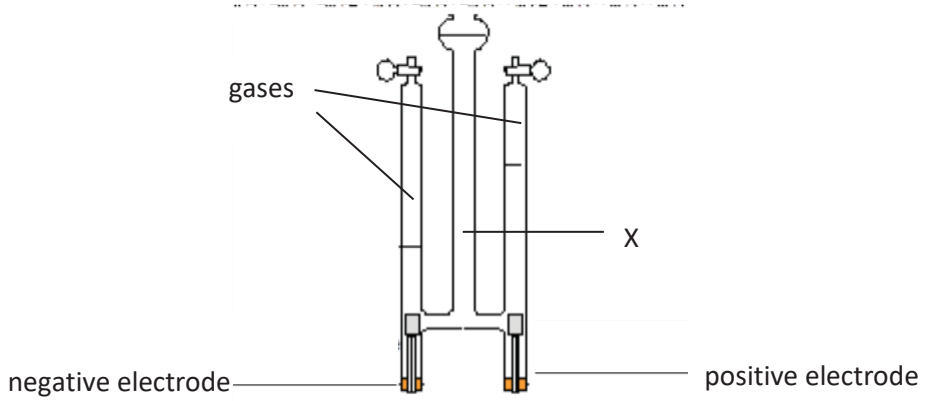
7 The diagram shows an electrolysis experiment to electroplate nickel with a different metal.



Which nickel electrode(s) is/ are plated with a metal?

A 1 only
B 1 and 3 only
C 2 only
C 2 and 4 only

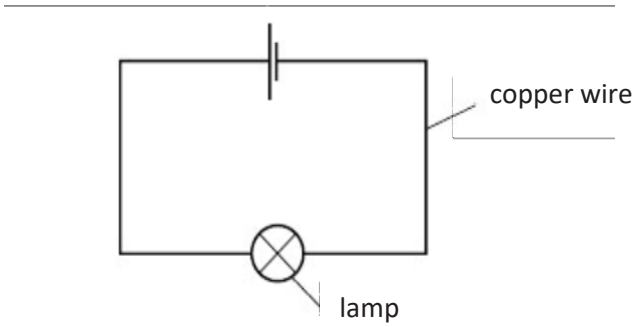
8 The diagram shows the electrolysis of a substance X after a few hours.



What substance could X be?

A copper(II) sulfate solution
B concentrated hydrochloric acid
C silver nitrate solution
D sodium chloride solution

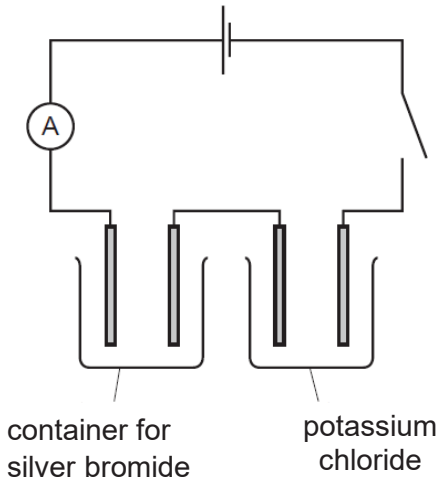
9 Copper wire is used to complete an electrical circuit.



Which statement correctly describes what happens in the copper wire?

A Electrons move along the wire to the negative terminal and positive ions stay in position.
B Electrons move along the wire to the positive terminal and positive ions move to the negative terminal.
C Electrons move along the wire to the positive terminal and positive ions stay in position.
D Negative ions move along the wire to the positive terminal while positive ions move to the negative terminal.

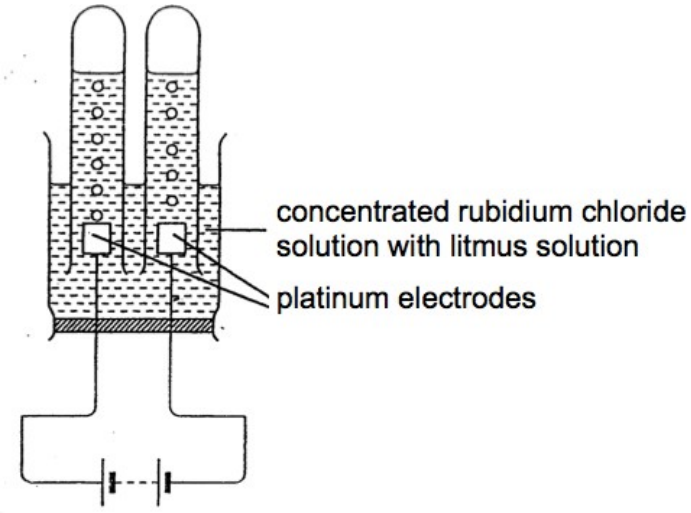
10 The diagram shows the circuit for electrolysing silver bromide and potassium chloride to produce the metal.



To produce a metal, what form must these salts be?

	silver bromide	potassium chloride
A	concentrated solution	molten
B	dilute solution	concentrated solution
C	molten	molten
D	molten	molten

11 A few drops of litmus solution were added to concentrated rubidium chloride solution and the resultant solution was electrolysed using platinum electrodes.

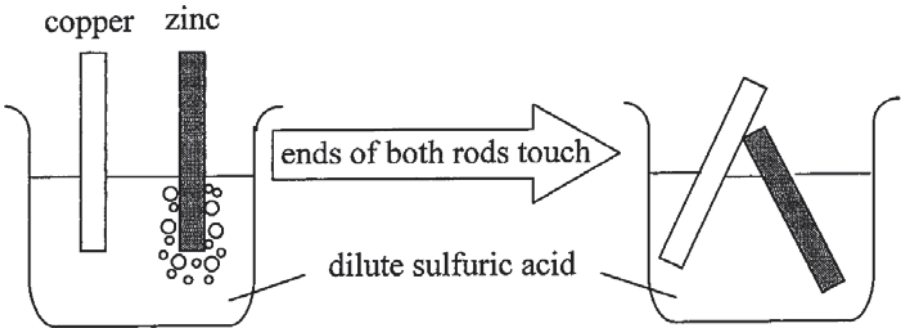


Which statement is true?

A A greenish-yellow gas is formed at the cathode.
B The anode decreases in mass.
C The pH of the electrolyte decreases.
D The solution turns purple around the cathode.

12 In an experiment, a copper rod and a zinc rod are placed into a beaker of sulfuric acid as shown below. Bubbles of gas are produced around the zinc rod only.

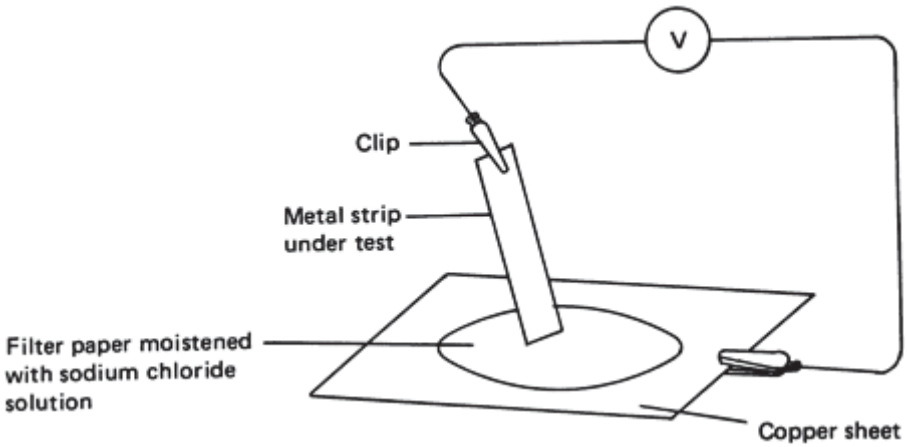
The experiment is repeated with the ends of both rods touching each other.



What happens when the ends of both rods touch each other?

A Bubbles of gas collect around both rods.
B Bubbles of gas collect around copper rod only.
C Bubbles of gas collect around zinc rod only.
D No bubbles of gas collect around both rods.

13 The diagram shows the apparatus used to investigate the relative reactivity of four metals. Strips of these metals were connected in turn with the copper sheet and the voltage was recorded in the table below.



Results table:

metal under test	direction of electron flow	voltage recorded (volts)
W	from W to Cu	+ 0.78
X	from Cu to X	- 2.22
Y	from Y to Cu	+ 1.39
Z	from Z to Cu	+ 0.28

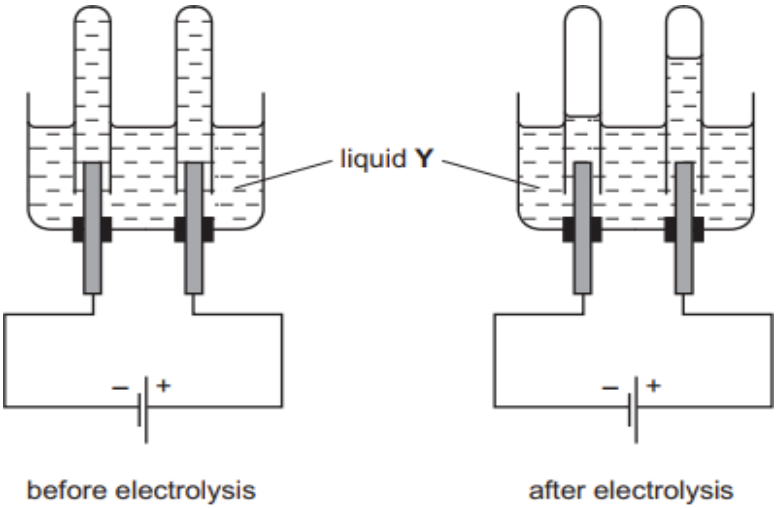
What is the order of decreasing reactivity of the four metals?

	most reactive ⟶			least reactive
A	W	Z	X	Y
B	X	Y	W	Z
C	Y	W	Z	X
D	Z	W	Y	X

14 Which element requires the smallest number of electrons for one mole of atoms to be liberated during electrolysis?

A aluminium
B calcium
C copper
D sodium

15 The diagrams show an electrolysis experiment using inert electrodes.



Which could be liquid Y?

1 aqueous copper(II) sulfate
2 aqueous sodium nitrate
3 concentrated aqueous sodium chloride
4 dilute sulfuric acid

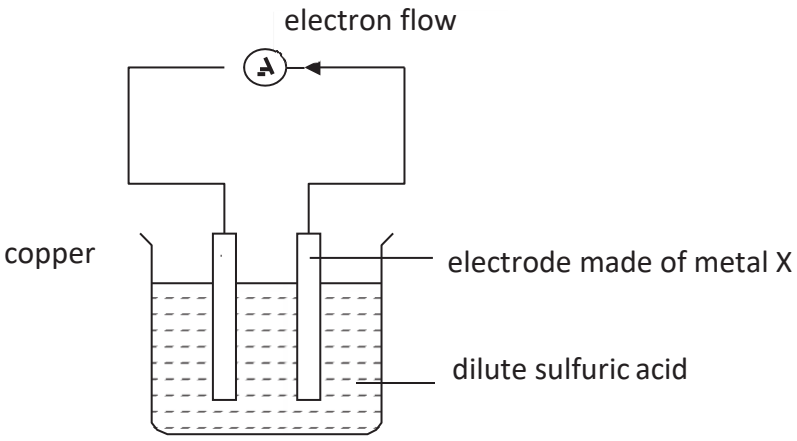
A 4 only
B 1 and 4 only
C 2 and 4 only
D 2, 3 and 4 only

16 In an electrolysis experiment, the same amount of charge deposited 54.0 g of silverand 8.5 g of vanadium.

What is the charge on the vanadium ion?

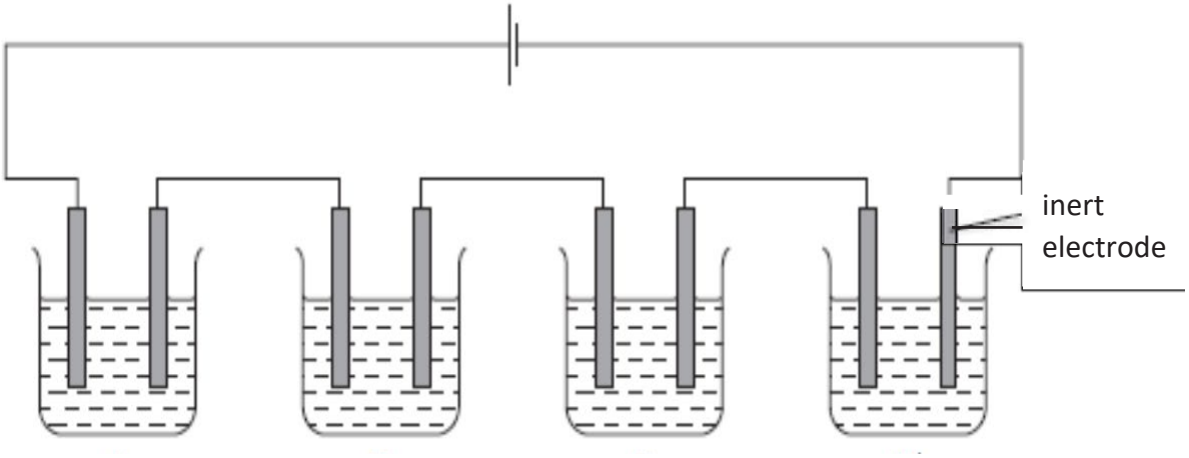
A 1+
B 2+
C 3+
D 4+

17 With reference to the diagram below, which of the following statements is correct?



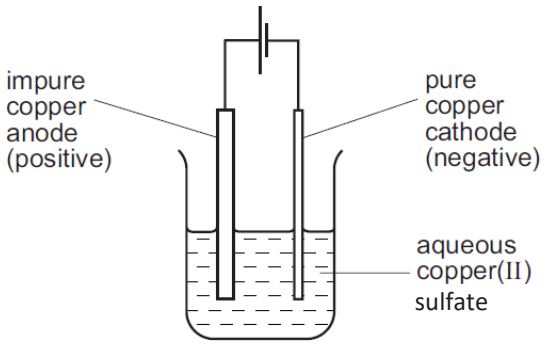
A Copper electrode is the negative electrode.
B Metal X is below copper in the reactivity series.
C The mass of the copper electrode decreases.
D The mass of the metal X electrode decreases.

18 When electrolysed using inert electrodes, which dilute solution would produce the greatest increase in mass of the cathode?



A aluminium sulfate
B copper(II) sulfate
C lead nitrate
D silver nitrate

19 A sample of copper contains a metal impurity which is below copper in the reactivity series. The diagram shows the apparatus used for refining the sample.



The loss in mass of the anode is 50 g and the gain in mass of the cathode is 45 g. What is the percentage purity of this sample of copper?

A 10.0%

B 11.1%

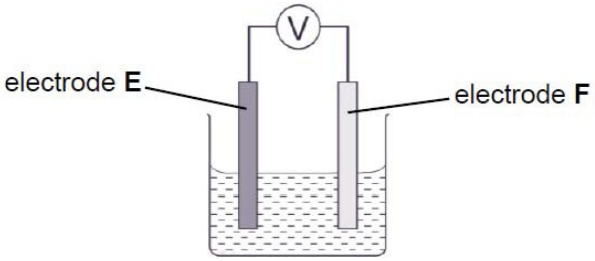
C 90.0%

D 95.0%

20 What products are formed when concentrated aqueous potassium chloride is electrolysed?

	at the anode	at the cathode
A	chlorine	hydrogen
B	chlorine	potassium
C	oxygen	hydrogen
D	oxygen	potassium

21 A galvanic cell is set up as shown below.



Which pair of electrodes would give the largest magnitude on the voltmeter reading?

	electrode E	electrode F
A	copper	zinc
B	magnesium	copper
C	silver	magnesium
D	zinc	Iron

22 The table shows the reactions of metals **A**, **B**, **C** and **D** when placed in aqueous solutions of their nitrates.

metal	nitrate of **A**	nitrate of **B**	nitrate of **C**	nitrate of **D**
A	-	reacts	reacts	reacts
B	no reaction	-	reacts	no reaction
C	no reaction	no reaction	-	no reaction
D	no reaction	reacts	reacts	-

A mixture of aqueous solutions of nitrates of **A**, **B**, **C** and **D** are electrolysed using carbon electrodes.

Which metal ion of metals **A**, **B**, **C** or **D** would most readily be discharged at the negative electrode?

23 Which arrangement is used to electroplate copper onto a steel key?

	electrolyte	anode (positive electrode)	cathode (negative electrode)
A	aqueous copper(II) sulfate	piece of pure copper	steel key
B	aqueous copper(II) sulfate	steel key	piece of pure copper
C	aqueous sulfuric acid	piece of pure copper	steel key
D	aqueous sulfuric acid	steel key	piece of pure copper

24 A simple cell can be made using two different metals as the electrodes and an aqueous solution as the electrolyte.

Which statements about simple cells are correct?

1 A greater voltage is produced using magnesium and silver than using magnesium and copper.

2 The electrolyte is an aqueous solution that contains both positive and negative ions.

3 The more reactive metal will lose electrons more readily than the less reactive metal.

A 1, 2 and 3
B 1 and 3 only
C 1 only
D 2 and 3 only

26 Which statement is **incorrect** about an electrolytic cell?

A Reduction always occurs at the cathode.
B Electrical energy is used to drive chemical reactions.
C At the anode, anions are always the ones being discharged.
D Free-moving ions in the electrolyte act as mobile charge carriers.

27 An unknown fluid was electrolysed with inert electrodes. It was observed that an equal volume of gas was evolved at each electrode.

Which of the following could be the fluid?

A Dilute sulfuric acid
B Aqueous silver nitrate
C Concentrated iron(II) chloride solution
D Concentrated copper(II) iodide solution

28 12.8 g of copper was collected in the electrolysis of concentrated copper(II) chloride solution. What was the volume of the gas collected at the other electrode?

A 2.40 dm^3
B 4.80 dm^3
C 7.20 dm^3
D 9.60 dm^3

29 Which of the following is **true** of the procedure to obtain aluminium metal?

A Silvery solid metal is obtained at the cathode.
B The anode dissolves into the electrolyte during electrolysis.
C A by-product of the electrolysis procedure is carbon dioxide gas.
D The electrolyte used is aqueous aluminium oxide with an added impurity.

30 3.2 g of copper was collected during the electrolysis of copper(II) sulfate solution. In another experiment, the same amount of electricity was passed through aqueous zinc sulfate.

What was the quantity of product obtained at the cathode in the second experiment?

A 3.25 g of Zn metal
B 0.60 dm^3 of O_2 gas
C 1.20 dm^3 of H_2 gas
D 2.40 dm^3 of H_2 gas

31 Which of the following is **true** of a simple cell?

A The less reactive metal electrode is always reduced.
B Electrons in the electrolyte help to conduct electricity.
C A simple cell converts electrical energy into chemical energy.
D Using copper instead of lead in an iron-lead cell would increase its voltage.

ELECTROLYSIS STRUCTURED QUESTIONS

Paper 2 Section A

1 Molten lead (II) bromide was electrolysed using carbon electrodes.

(a) (i) Write the ionic equation for the reaction at the cathode.

……..[1]

(ii) Write the ionic equation for the reaction at the anode.

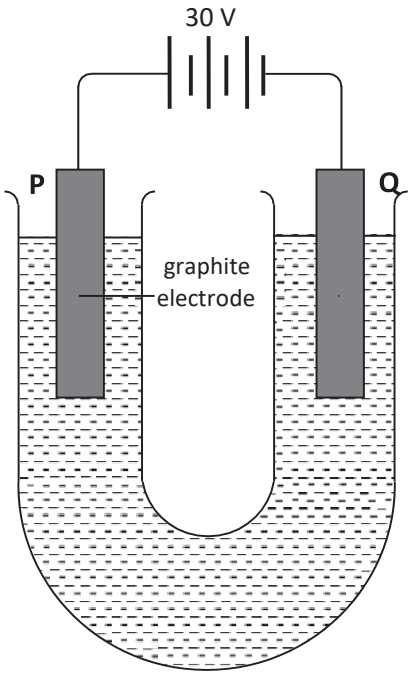
……..[1]

(iii) State the observation at the cathode during the electrolysis.

……...

……..[1]

(b) The setup shows the electrolysis of concentrated sodium chloride solution.



(i) Describe the observations at the electrodes of **P** and **Q**.

Electrode **P**: ……..

……..…

……....

Electrode **Q**: ……..

……..…

……..…[4]

(ii) How does the pH of the electrolyte change as the electrolysis proceeds? Explain your answer.

……

……

…… [2]

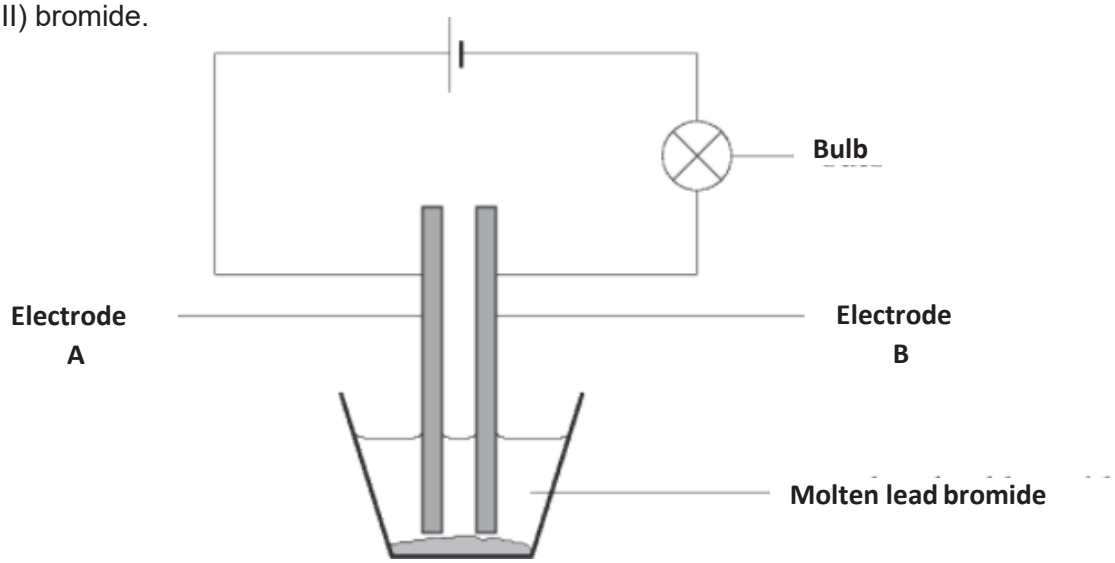
(iii) Suggest why iron is **not** suitable to be used as an electrode for this experiment.

……

…… [1]

[Total:10]

2 The diagram below shows the apparatus used during electrolysis of molten lead (II) bromide.



(a) Suggest a reason why lead (II) bromide must be molten in order for electricity to flow. [1]

……

……

(b) Write the half equation for the reaction taking place at the electrode **A**. [1]

……

(c) **(i)** State, in terms of electrons, what happens to the ions at the electrode **B.** [1]

……

……

(ii) Describe an observation you would expect at the electrode **B**. [2]

……

……

(iii) Electrolysis is allowed to continue for some time before the apparatus is cooled to room temperature. The bulb remains lit.

Explain this observation.

……

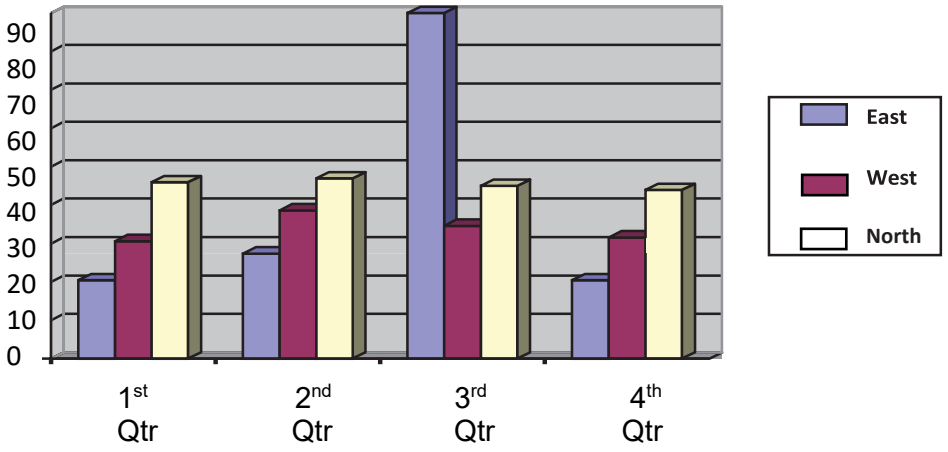
……

……

[Total: 6]

Paper 2 Section B

1 The diagram shows an electrolysis tank used to extract aluminium from aluminium oxide. Pure aluminium oxide melts at 2055 °C.



(a) Cryolite is mixed, as an impurity, with aluminium oxide. State the effect it has on the melting point of the mixture and explain why mixing cryolite is necessary. [2]

……...

……...

(b) Write half equations for the reactions that take place at the anode and cathode. [2]

Anode: ……

Cathode: ……

(c) Draw **two** arrows on the diagram to indicate the flow of electrons. Clearly label on the two electrodes. [1]

(d) What is the volume of oxygen produced, under room temperature and pressure when 540 g of aluminium is produced? [2]

[1]

(e) The carbon electrodes are replaced at regular intervals. Explain the need for this.

……...

……...

(f) Draw a clearly labelled diagram to show how a metal object could be electroplated with copper.

[2]

[Total: 10]

2 Fig 9.1 shows the set-up for the electrolysis of a chloride solution containing two metal ions, copper(II) and iron(II).

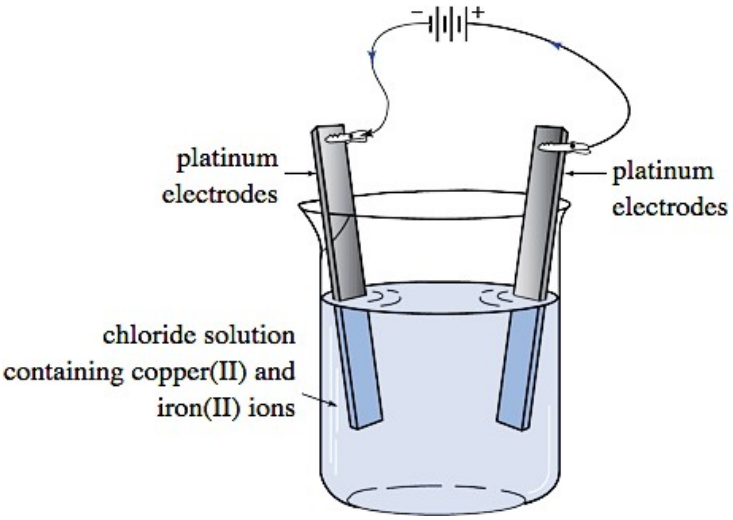


Fig 9.1

An electric current was passed through the cell for a period of time. The observations at different stages were recorded in the table.

Table 9.2

stage	observations
stage 1 – after 10 mins	A yellowish-green gas is observed at one of the electrodes while a brown solid is deposited at the other electrode. There was no visible change to the electrolyte.
stage 2 – after 1 hour	The same observations in stage 1 at the anode and cathode. The electrolyte became pale green.
stage 3 – after 2 hours	Colourless gases are both evolved at the anode and cathode. The pale green of the electrolyte becomes more visible.

(a) **(i)** Write the equations for the reactions taking place at the respective electrodes in stage 1.

……...

……..[2]

(ii) The total mass of the brown solid deposited was 0.584 g.

Calculate the volume of the yellowish-green gas produced at the other electrode.

[2]

(b) Explain why the electrolyte becomes pale green in stage 2 and then darker in stage 3.

……...

……...

……...

……..[2]

(c) A few drops of Universal Indicator were added **at the cathode** in stage 3.

State and explain the result of the test.

……...

……...

……...

……..[2]

(d) A total of three different substances were produced at the cathode throughout the whole electrolysis process.

Identify and list the three substances in order of which they are produced. Explain your answer.

……...

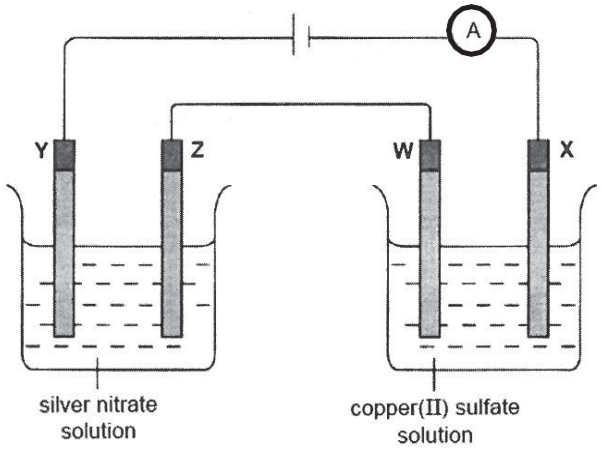
……...

……...

……..[2]

[Total: 10 marks]

3 The diagram below shows the set-up of an electrolysis experiment.



W and X are copper electrodes while Y and Z are silver electrodes.

(a) Electrodes X and Z will increase in mass after some time. Explain why, using half-equations to illustrate your answer.

……

……

……[3]

(b) Electrode Z will increase in mass at a faster rate than electrode X. Explain why this is so.

……

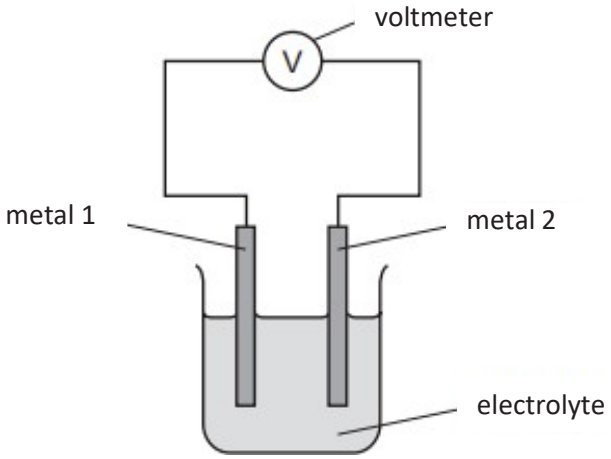
……

…… [2]

[Total: 5]

4 The diagram shows a simple cell, with two different metals as electrodes dipped in dilute nitric acid. A student did an experiment using the simple cell below.
The voltages were recorded in the table.

- If the voltage measured is positive then metal 2 is more reactive than metal 1.
- If the voltage measured is negative then metal 1 is more reactive than metal 2.



		metal 2				
		beryllium	cobalt	nickel	silver	vanadium
metal 1	beryllium	0.0 V	-1.6 V	-1.6 V	not measured	-0.7 V
	cobalt		0.0 V	0.0 V	-1.1 V	0.9 V
	nickel			0.0 V	-1.1 V	0.9 V
	silver				0.0 V	2.0 V
	vanadium					0.0 V

(a) (i) In the simple cell containing nickel and silver, it was observed that the electrolyte slowly turned pale green. Write the ionic equation to explain the colour change.

……..[1]

(ii) What happened to the mass of the nickel electrode?

……...[1]

(b) (i) Using the data given, state the most reactive metal in the table above.
Explain your reasoning.

……

……

…… [2]

(ii) Predict the voltage produced by a simple cell with beryllium as metal 1 and silver as metal 2.

……[1]

(c) (i) The student wanted to rank the metals listed in the table according to their reactivity but he was not able to do so. Why?

……[1]

(ii) Briefly describe one **simple** experiment the student can do which will help him to solve the problem in **c(i).**

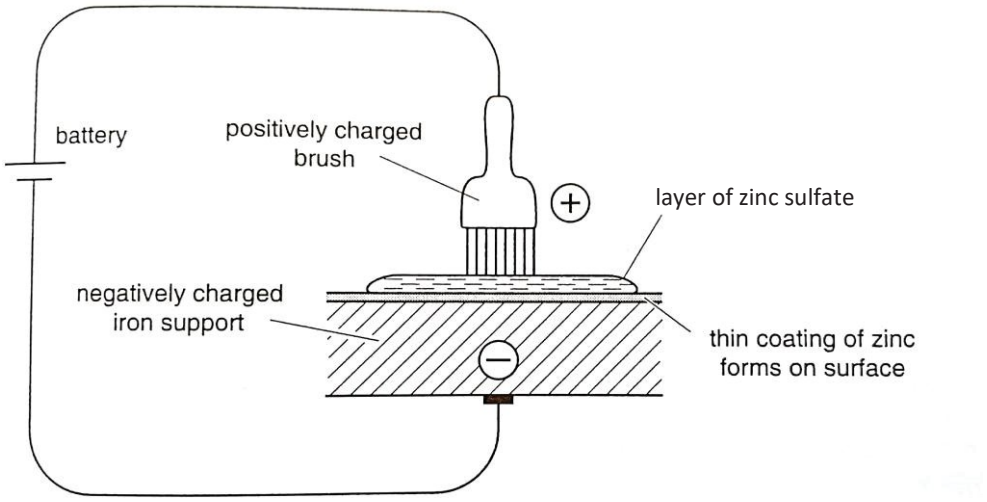
……

……..[1]

[Total: 7]

5 A new type of electroplating is known as 'brush electroplating'.
It is used to electroplate zinc onto very large iron supports to be used in buildings. The iron supports are too big to be plated in a normal electrolysis tank.

During the process, a metal brush spreads a layer of aqueous zinc sulfate over the iron surface.
A battery gives the brush a positive charge and gives the iron support a negative charge.
A layer of zinc forms on the surface of the iron support.



(a) The surface of the iron acts as a cathode.
Zinc ions from the solution form zinc on the surface of the iron.

Write an ionic half-equation, with state symbols, for this reaction.

…… [2]

(b) Two different designs of metal brush are available.
One type of brush is made from zinc, one type is made from platinum.
As the electrolysis takes place, each brush has a different effect on the concentration of zinc ions in the solution.

(i) What will happen to the concentration of the zinc ions during the electrolysis if the brush is made from platinum?

…… [1]

(ii) What will happen to the concentration of the zinc ions during the electrolysis if the brush is made from zinc?

…… [1]

(iii) Platinum brushes are much more expensive than zinc brushes.
However, zinc brushes need replacing regularly but platinum brushes do not.
Explain why.

……

…… [2]

(c) During the process, a worker needs to hold the brush.

Which of the following materials would be a good choice for the handle of the brush? Give a reason for your answer.

chromium copper graphite iron poly(ethene)

material .....[1]

reason .....[1]

(d) Explain why iron supports coated with zinc do not rust, even if the zinc coating is damaged.

……

…… [2]

[Total: 10]

6 Molten zinc chloride can be electrolysed using the apparatus as shown in Fig. 6.1.

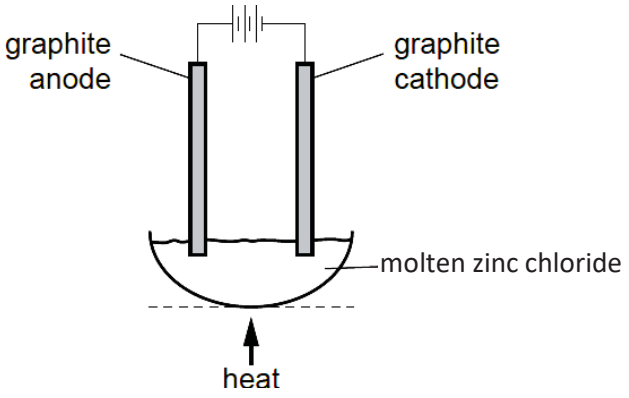


Fig. 6.1

(a) Explain why zinc chloride conducts electricity when molten, but now when solid.

……..

……..

…….[2]

(b) Predict the products of this electrolysis at

the anode ……..[1]

the cathode……[1]

(c) When a dilute aqueous solution of zinc chloride is electrolused hydroxide ions are converted to oxygen at the anode.

Write the ionic equation for the reaction the happens at the anode.

……..[1]

(d) Describe a positive test for zinc ions.

test…….

observations……

……..……[2]

(e) Solid zinc chloride absorbs ammonia to form tetra-ammine zinc chlor=ide, $[Zn(NH_3)4]Cl_2$.

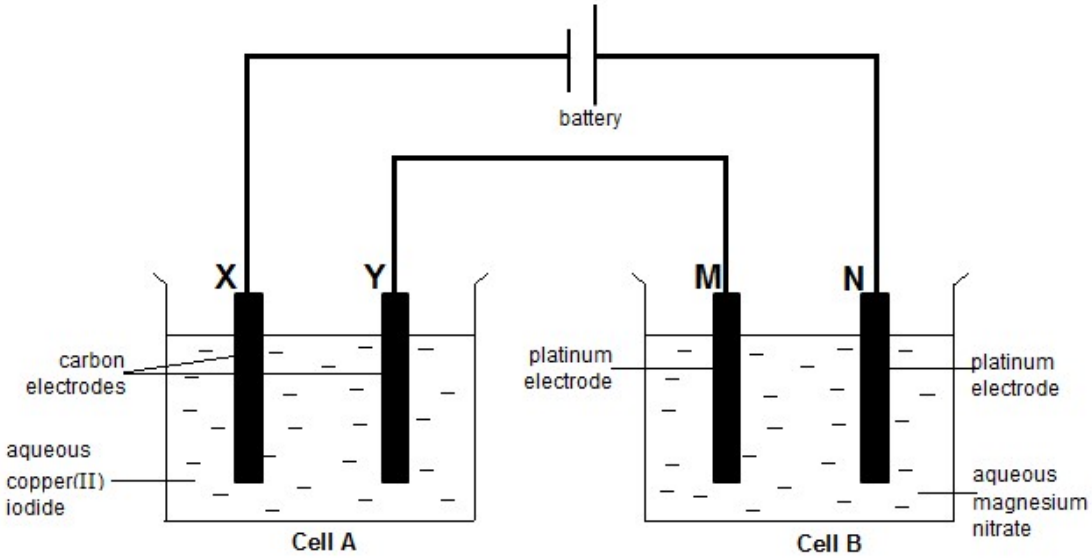
$$ZnCl_2 + 4NH_3 \rightarrow [Zn(NH_3)4]Cl_2$$

Calculate the maximum yield, in grams, of tetra-ammine zinc chloride formed when 3.4g of zinc chloride reacts with excess ammonia.

[2]

[Total: 9]

7 In an experiment, a student connected two cells as shown in the diagram below.



(a) Predict the student's **observations** for the reactions occurring at each electrode in cell **A**. Explain your reasoning.

Electrode **X**: _____

_____

_____

Electrode **Y**: _____

_____

_____

[3]

(b) How would the concentration of the electrolyte in cell **B** differ after a while? Explain.

_____

_____

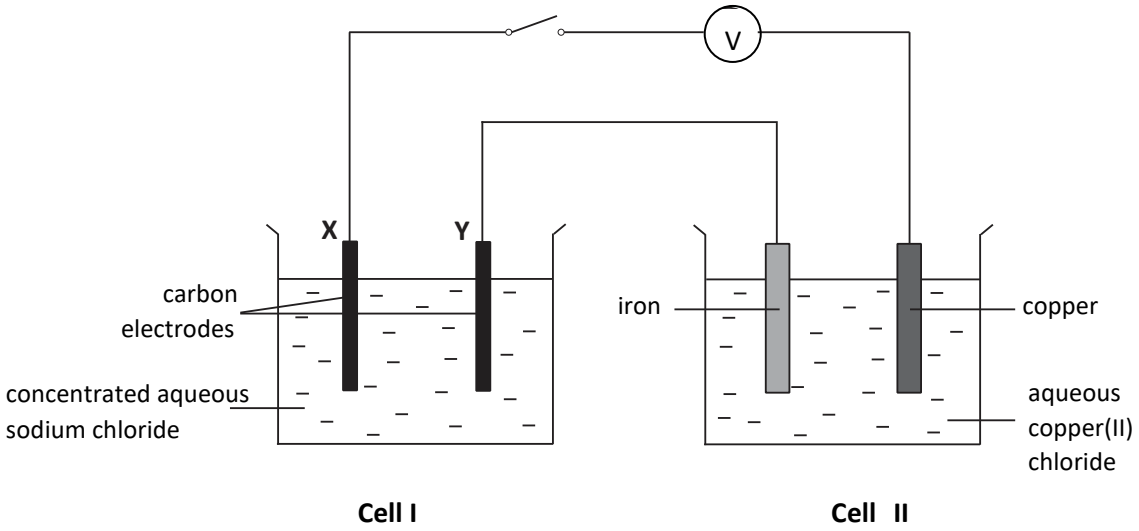
[2]

(c) The battery went flat and could not be used anymore. Suggest a modification to cell **B** in the above set-up, such that electrolysis in cell **A** could still be carried out with the same products at each electrode.

_____

[1]

8 In an experiment, a student connected two cells as shown in the diagram below, and then switched the switch on. Electrolysis was observed to occur at cell **I**.



(a) Write ionic half-equations for the reactions occurring at

(i) the iron electrode in cell **II**

_____ **[1]**

(ii) the copper electrode in cell **II**

_____ **[1]**

(b) Predict and explain the student's **observations** for the reaction occurring at electrode **X**.

_____

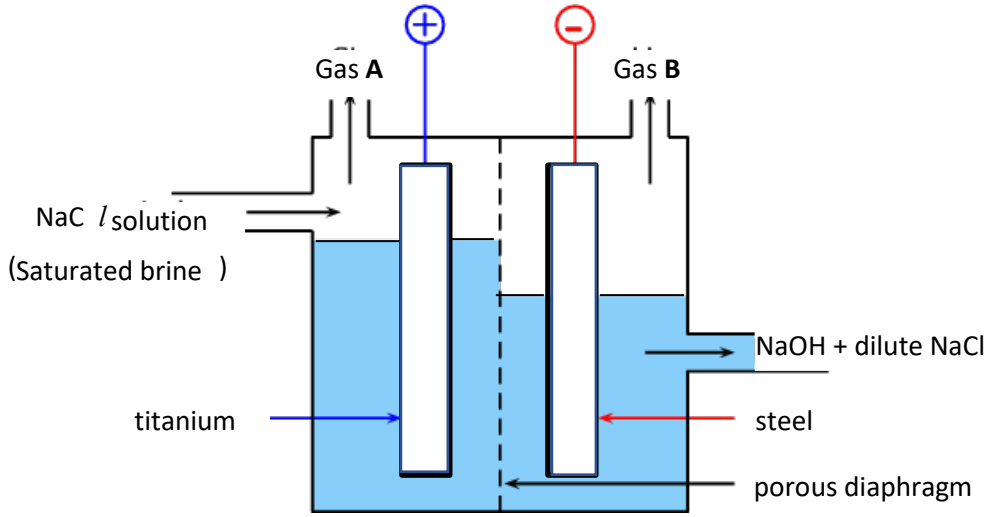
_____

_____

[3]

9 Chlorine can be manufactured by electrolysis of sodium chloride solution (brine). Diaphragm cell and membrane cell electrolysis can be used for the manufacturing of chlorine gas. Two other products, sodium hydroxide and hydrogen gas, are also produced.

In a diaphragm cell, the anode compartment is separated from the cathode compartment by a permeable diaphragm. The diaphragm is made up of a porous mixture of minerals and polymers which allows the solution to move from the anode compartment to the cathode compartment. A simplified diagram of the diaphragm cell is shown.



(a) **(i)** Suggest a reason why one compartment of the cell has a higher level of liquid than the other.

_____ **[1]**

(ii) Write ionic equations for the reactions at the cathode and the anode.

_____

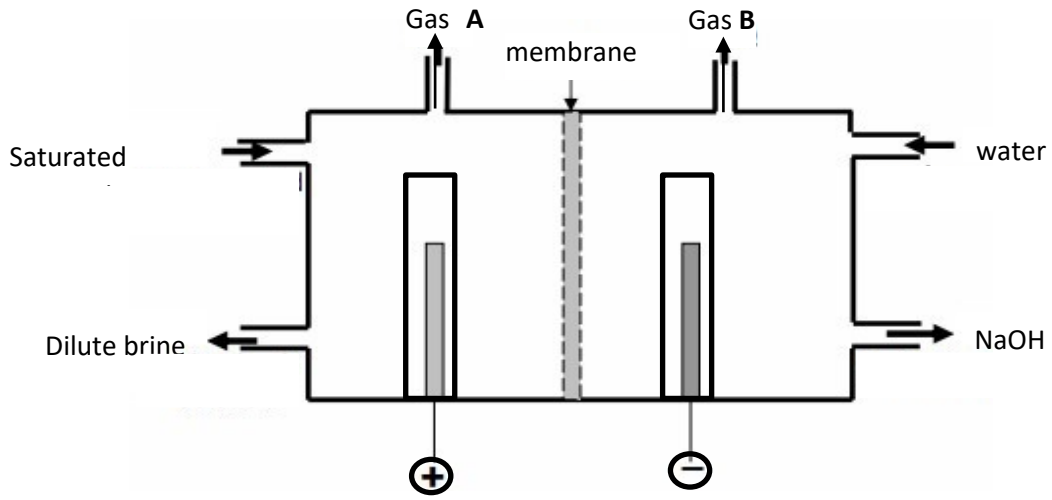
[1]

_____

(iii) Construct the overall equation for this reaction.

_____ **[1]**

(b) In a membrane cell, the anode compartment is separated from the cathode compartment by an ion-exchange membrane. This membrane is made from a polymer which only allows positive ions to pass through it. A simplified diagram of the membrane cell is shown.



(i) Give an advantage of using the membrane cell instead of the diaphragm cell.

_____ [1]

(ii) Suggest a reason why water is added to the compartment containing sodium hydroxide.

_____ [1]

(iii) 278 g of sodium chlorine is dissolved in 1 dm^3 of water to produce saturated brine solution. Given that 30 dm^3 of chlorine gas is produced when 1 dm^3 of brine is electrolysed, calculate the percentage yield of chlorine.

[2]

ANSWER TO ELECTROLYSIS MCQ

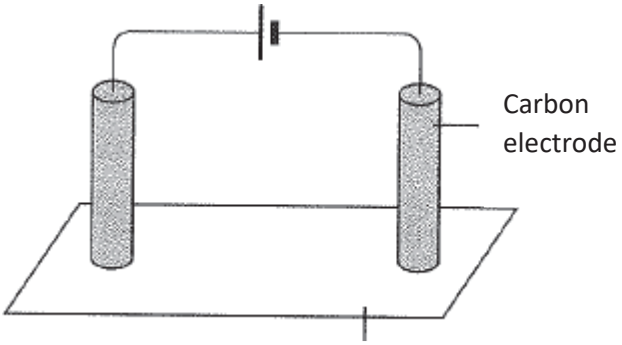
Paper 1

1 Which solution(s) would produce hydrogen gas at the cathode upon electrolysis?

1 dilute nitric acid
2 aqueous potassium hydroxide
3 aqueous sodium chloride

A 1 only
B 1 and 2
C 2 and 3
D all of the above

2 Two carbon electrodes are placed on a piece of red litmus paper soaked in concentrated sodium chloride solution as shown:

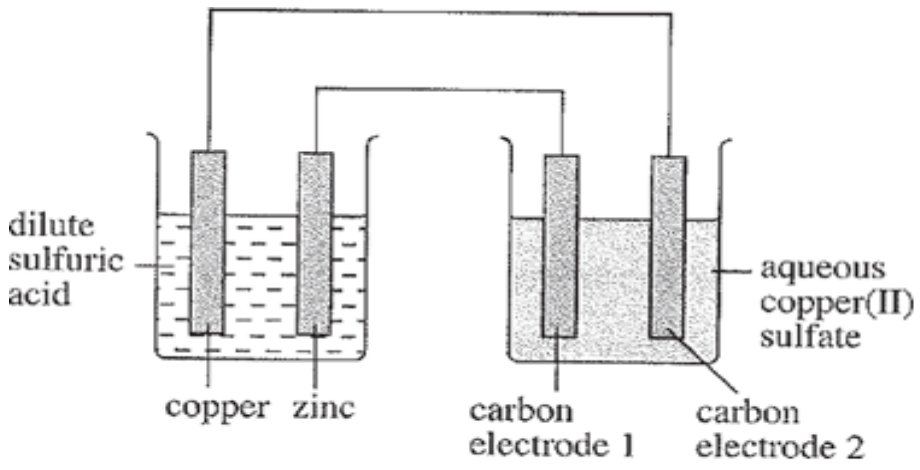


Litmus paper soaked in concentrated sodium chloride solution

What are the observations of the litmus paper at the respective electrodes?

	Cathode	Anode
A	Litmus paper is bleached.	Litmus paper turns blue.
B	Litmus paper turns blue.	Litmus paper is bleached.
C	Litmus paper turns blue.	Litmus paper remains red.
D	Litmus paper remains red.	Litmus paper remains red.

3 Two simple cells were set up as shown:



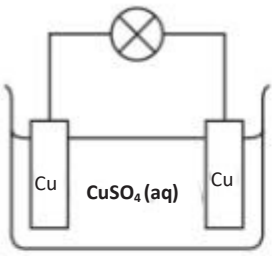
Two substances were discharged at the carbon electrodes. What were

these two substances?

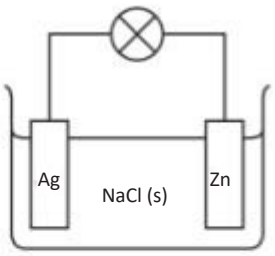
	Electrode 1	Electrode 2
A	Copper metal	Hydrogen gas
B	Hydrogen gas	Copper metal
C	Copper metal	Oxygen gas
D	Oxygen gas	Copper metal

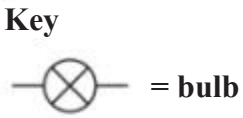
4 In which circuit does the bulb light?

A

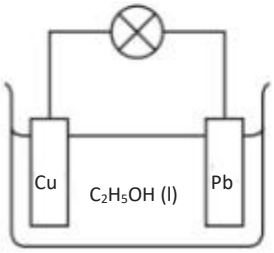


B

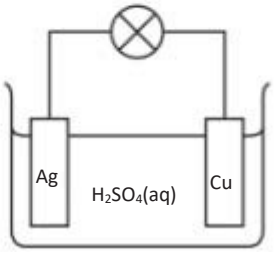




C



D



5 A molten compound is electrolysed. Two atoms of X are deposited at the negative electrode at the same time as three atoms of Y are deposited at the positive electrode.

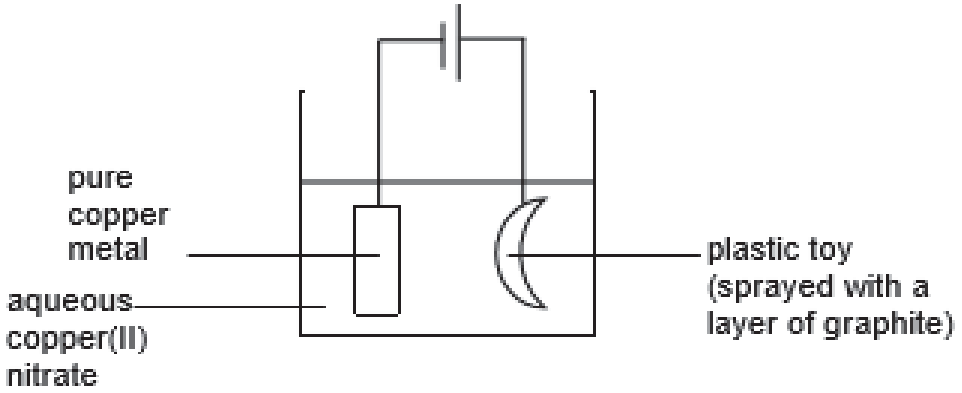
These results show that:

X is a …1…;
Y is a …2…;
the formula of the compound is …3… .

How are gaps **1**, **2** and **3** correctly completed?

	1	2	3
A	Metal	Non-metal	X_3Y_2
B	Metal	Non-metal	X_2Y_3
C	Non-metal	Metal	X_3Y_2
D	Non-metal	metal	X_2Y_3

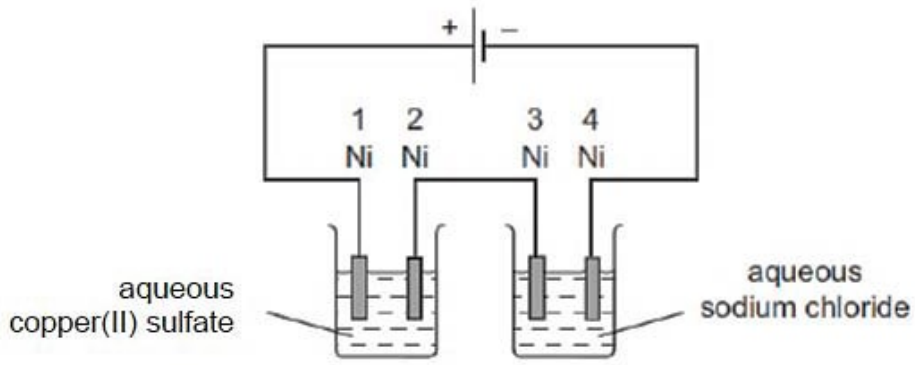
6 A student decides to coat his plastic toy with a layer of copper metal using electrolysis. The diagram shows his set-up.



The experiment failed and no copper was deposited on the plastic toy. Which statement best explains why the experiment failed?

A The electrolyte used should be aqueous silver nitrate.
B The plastic toy should not be submerged in the electrolyte.
C The plastic toy should not be sprayed with a layer of graphite.
D The pure copper strip should be attached to the positive electrode.

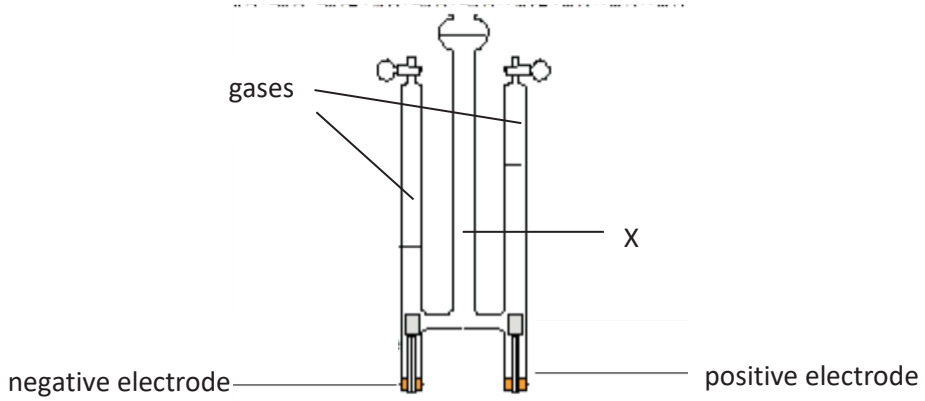
7 The diagram shows an electrolysis experiment to electroplate nickel with a different metal.



Which nickel electrode(s) is/ are plated with a metal?

A 1 only
B 1 and 3 only
C 2 only
D 2 and 4 only

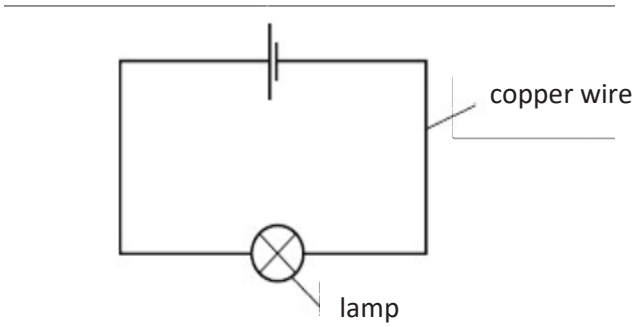
8 The diagram shows the electrolysis of a substance X after a few hours.



What substance could X be?

A copper(II) sulfate solution
B concentrated hydrochloric acid
C silver nitrate solution
D sodium chloride solution

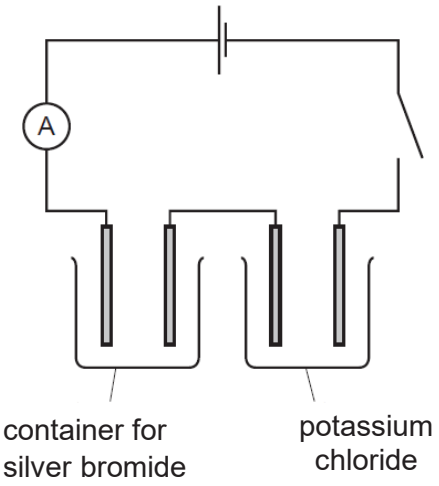
9 Copper wire is used to complete an electrical circuit.



Which statement correctly describes what happens in the copper wire?

A Electrons move along the wire to the negative terminal and positive ions stay in position.
B Electrons move along the wire to the positive terminal and positive ions move to the negative terminal.
C Electrons move along the wire to the positive terminal and positive ions stay in position.
D Negative ions move along the wire to the positive terminal while positive ions move to the negative terminal.

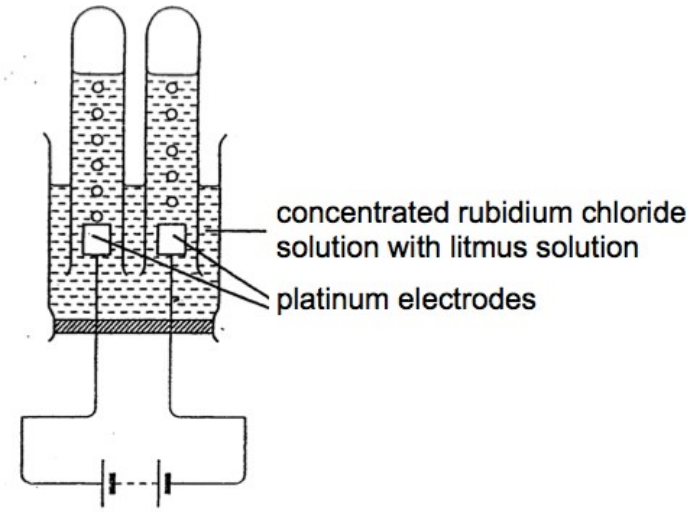
10 The diagram shows the circuit for electrolysing silver bromide and potassium chloride to produce the metal.



To produce a metal, what form must these salts be?

	silver bromide	potassium chloride
A	concentrated solution	molten
B	dilute solution	concentrated solution
C	molten	molten
D	molten	molten

11 A few drops of litmus solution were added to concentrated rubidium chloride solution and the resultant solution was electrolysed using platinum electrodes.

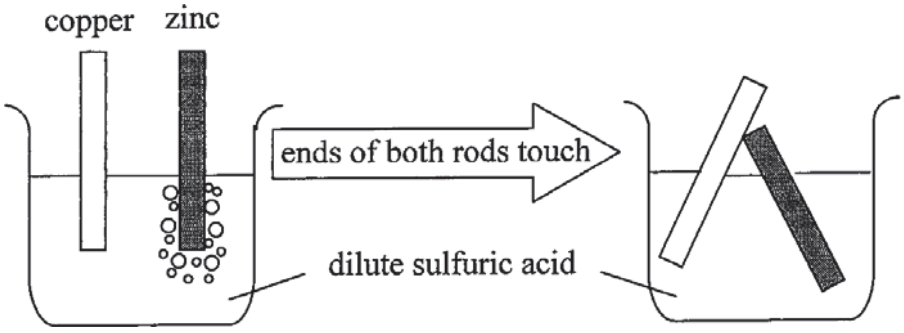


Which statement is true?

A A greenish-yellow gas is formed at the cathode.
B The anode decreases in mass.
C The pH of the electrolyte decreases.
D The solution turns purple around the cathode.

12 In an experiment, a copper rod and a zinc rod are placed into a beaker of sulfuric acid as shown below. Bubbles of gas are produced around the zinc rod only.

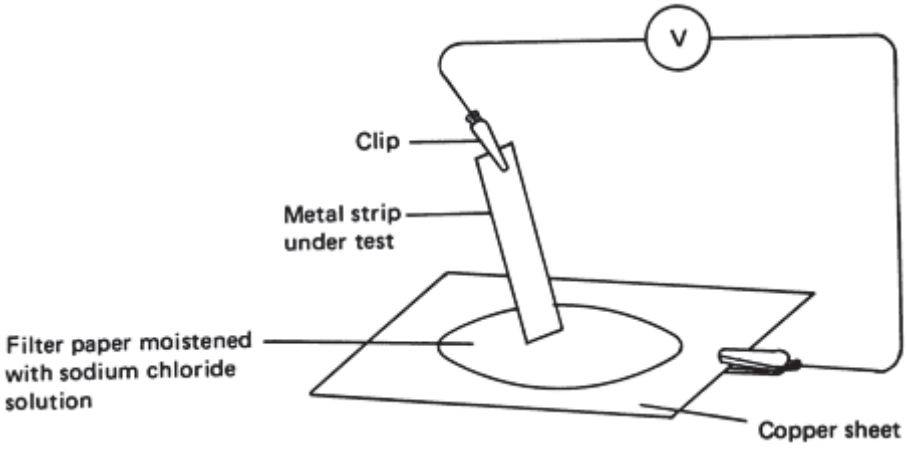
The experiment is repeated with the ends of both rods touching each other.



What happens when the ends of both rods touch each other?

A Bubbles of gas collect around both rods.
B Bubbles of gas collect around copper rod only.
C Bubbles of gas collect around zinc rod only.
D No bubbles of gas collect around both rods.

13 The diagram shows the apparatus used to investigate the relative reactivity of four metals. Strips of these metals were connected in turn with the copper sheet and the voltage was recorded in the table below.



Results table:

metal under test	direction of electron flow	voltage recorded (volts)
W	from W to Cu	+ 0.78
X	from Cu to X	- 2.22
Y	from Y to Cu	+ 1.39
Z	from Z to Cu	+ 0.28

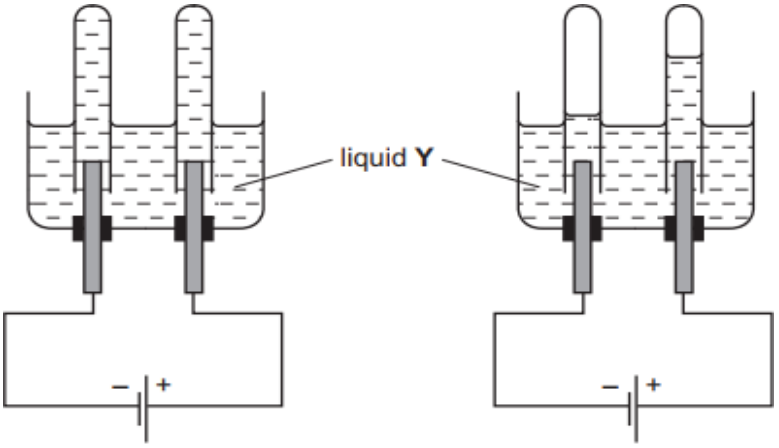
What is the order of decreasing reactivity of the four metals?

	most reactive →			least reactive
A	W	Z	X	Y
B	X	Y	W	Z
C	Y	W	Z	X
D	Z	W	Y	X

14 Which element requires the smallest number of electrons for one mole of atoms to be liberated during electrolysis?

A aluminium
B calcium
C copper
D sodium

15 The diagrams show an electrolysis experiment using inert electrodes.



Which could be liquid Y?

1 aqueous copper(II) sulfate
2 aqueous sodium nitrate
3 concentrated aqueous sodium chloride
4 dilute sulfuric acid

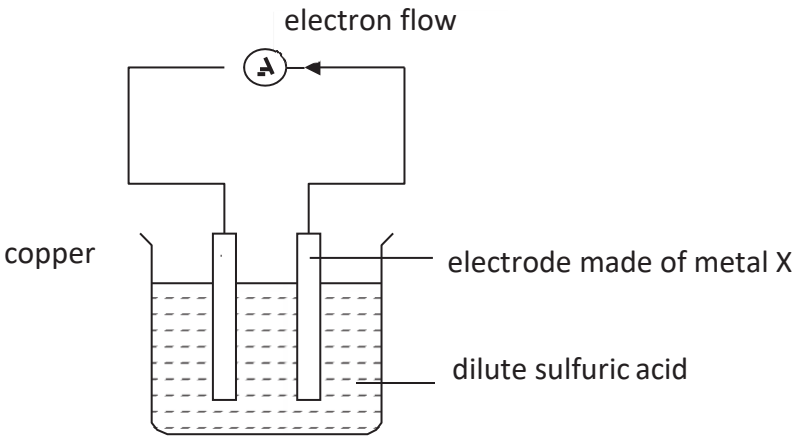
A 4 only
B 1 and 4 only
C 2 and 4 only
D 2, 3 and 4 only

16 In an electrolysis experiment, the same amount of charge deposited 54.0 g of silverand 8.5 g of vanadium.

What is the charge on the vanadium ion?

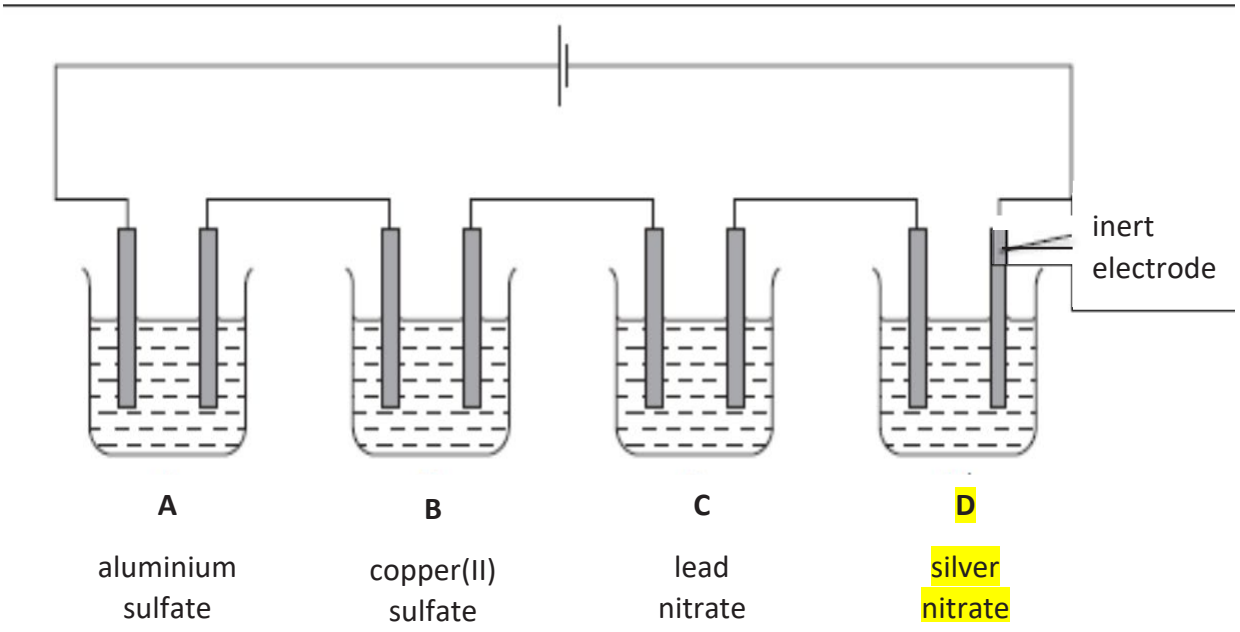
A 1+
B 2+
C 3+
D 4+

17 With reference to the diagram below, which of the following statements is correct?

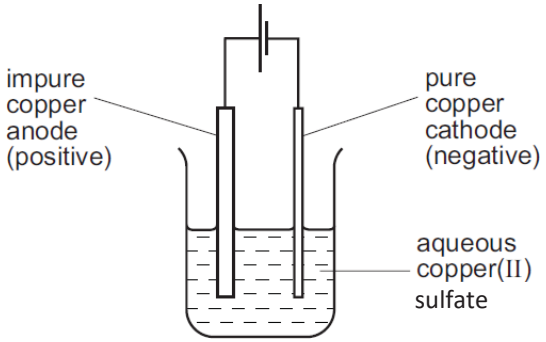


A Copper electrode is the negative electrode.
B Metal X is below copper in the reactivity series.
C The mass of the copper electrode decreases.
D The mass of the metal X electrode decreases.

18 When electrolysed using inert electrodes, which dilute solution would produce the greatest increase in mass of the cathode?



19 A sample of copper contains a metal impurity which is below copper in the reactivity series. The diagram shows the apparatus used for refining the sample.



The loss in mass of the anode is 50 g and the gain in mass of the cathode is 45 g. What is the percentage purity of this sample of copper?

A 10.0%

B 11.1%

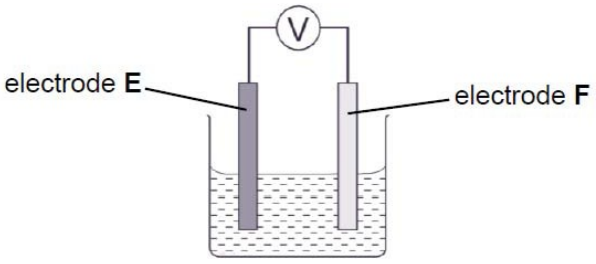
C 90.0%

D 95.0%

20 What products are formed when concentrated aqueous potassium chloride is electrolysed?

	at the anode	at the cathode
A	chlorine	hydrogen
B	chlorine	potassium
C	oxygen	hydrogen
D	oxygen	potassium

21 A galvanic cell is set up as shown below.



Which pair of electrodes would give the largest magnitude on the voltmeter reading?

	electrode E	electrode F
A	copper	zinc
B	magnesium	copper
C	silver	magnesium
D	zinc	Iron

22 The table shows the reactions of metals **A**, **B**, **C** and **D** when placed in aqueous solutions of their nitrates.

metal	nitrate of **A**	nitrate of **B**	nitrate of **C**	nitrate of **D**
A	-	reacts	reacts	reacts
B	no reaction	-	reacts	no reaction
C	no reaction	no reaction	-	no reaction
D	no reaction	reacts	reacts	-

A mixture of aqueous solutions of nitrates of **A**, **B**, **C** and **D** are electrolysed using carbon electrodes.

Which metal ion of metals **A**, **B**, **C** or **D** would most readily be discharged at the negative electrode?

23 Which arrangement is used to electroplate copper onto a steel key?

	electrolyte	anode (positive electrode)	cathode (negative electrode)
A	aqueous copper(II) sulfate	piece of pure copper	steel key
B	aqueous copper(II) sulfate	steel key	piece of pure copper
C	aqueous sulfuric acid	piece of pure copper	steel key
D	aqueous sulfuric acid	steel key	piece of pure copper

24 A simple cell can be made using two different metals as the electrodes and an aqueous solution as the electrolyte.

Which statements about simple cells are correct?

1 A greater voltage is produced using magnesium and silver than using magnesium and copper.

2 The electrolyte is an aqueous solution that contains both positive and negative ions.

3 The more reactive metal will lose electrons more readily than the less reactive metal.

A 1, 2 and 3
B 1 and 3 only
C 1 only
D 2 and 3 only

25 Which statement is **incorrect** about an electrolytic cell?

A Reduction always occurs at the cathode.
B Electrical energy is used to drive chemical reactions.
C At the anode, anions are always the ones being discharged.
D Free-moving ions in the electrolyte act as mobile charge carriers.

Explanation:
B:Electrical energy provided by the battery is used to pump electrons from + to -, which hence allows chemical reactions to occur at the electrodes.
C: When reactive electrodes are used, the metal electrode is oxidised to form metal ions

26 An unknown fluid was electrolysed with inert electrodes. It was observed that an equal volume of gas was evolved at each electrode.

Which of the following could be the fluid?

A Dilute sulfuric acid
B Aqueous silver nitrate
C Concentrated iron(II) chloride solution
D Concentrated copper(II) iodide solution

Explanation:
A: At the cathode, hydrogen ion is discharged. $2H^+(aq) + 2e \rightarrow H_2(g)$ and at the anode, hydroxide is discharged $4OH^-(aq) \rightarrow 2H_2O(l) + O_2(g) + 4e$. With equal number of electrons, twice the volume of hydrogen gas is formed compared to oxygen.
B: At the cathode, silver ion is discharged to form silver metal. No gas is formed.
C: At the cathode, hydrogen ion is discharged. $2H^+(aq) + 2e \rightarrow H_2(g)$ and at the anode, chloride ions are discharged $2Cl^-(aq) + 2e \rightarrow Cl_2(g)$. With equal number of electrons same volume of hydrogen gas is formed compared to chlorine.
D: At the cathode, copper ion is discharged to form copper metal. No gas is formed.

27 12.8 g of copper was collected in the electrolysis of concentrated copper(II) chloride solution. What was the volume of the gas collected at the other electrode?

A 2.40 dm^3
B 4.80 dm^3
C 7.20 dm^3
D 9.60 dm^3

Explanation:
No. of mols of Cu deposited = 12.8 / 63.5 = 0.20157
$Cu^{2+}(aq) + 2e \rightarrow Cu(s)$
Cu^{2+}: e = 1: 2 hence no. of mol of e = 0.20157 x 2 = 0.40314
Anode: $2Cl^-(aq) + 2e \rightarrow Cl_2(g)$
Cl_2: e = 1:2 hence no. of mol of Cl_2 = 0.20157 Therefore, Vol of gas = 0.20157x24 = 4.80dm^3

28 Which of the following is **true** of the procedure to obtain aluminium metal?

A Silvery solid metal is obtained at the cathode.
B The anode dissolves into the electrolyte during electrolysis.
C A by-product of the electrolysis procedure is carbon dioxide gas.
D The electrolyte used is aqueous aluminium oxide with an added impurity.

Explanation:

A: During the electrolysis of aluminium oxide to formed aluminium, aluminium metal is formed at the cathode but not at solid state. It is formed at liquid state as aluminium would have melted due to high temperature that molten aluminium oxide is at.

B: Electrodes are made of graphite which are inert hence will not participate in the electrolysis. C: Oxygen gas is produced at the anode which will react with carbon electrode at high temperature to form carbon dioxide gas.

D: Impurity is added to lower the melting point of aluminium oxide so that it can be melted at a lower temperature and reduce cost.

29 3.2 g of copper was collected during the electrolysis of copper(II) sulfate solution. In another experiment, the same amount of electricity was passed through aqueous zinc sulfate.

What was the quantity of product obtained at the cathode in the second experiment?

A 3.25 g of Zn metal
B 0.60 dm^3 of O_2 gas
C 1.20 dm^3 of H_2 gas
D 2.40 dm^3 of H_2 gas

Explanation:
No. of mols of Cu deposited = 3.2 / 63.5 = 0.050394
$Cu^{2+}(aq) + 2e \rightarrow Cu(s)$ Cu: e = 1: 2
Cathode of another experiment: $2H^+(aq) + 2e \rightarrow H_2(g)$
H_2: Cu = 1:1 hence no. of mol of H_2 = 0.050394 Therefore, Vol of gas = 0.050394x24 =1.20dm^3

30 Which of the following is **true** of a simple cell?

A The less reactive metal electrode is always reduced.
B Electrons in the electrolyte help to conduct electricity.
C A simple cell converts electrical energy into chemical energy.
D Using copper instead of lead in an iron-lead cell would increase its voltage.

Explanation:
A: less reactive metal is always the cathode and electrode is not involved in electrolysis.
B: It is mobile ions that are charge carriers in electrolyte. Electrons are charge carriers in wires. C: Chemical energy to electrical as chemical reactions(ie. Oxidation and reduction) occurs to create the flow of electrons.
D: Copper- lead has a greater difference in reactivity as compared to iron-lead hence a greater voltage.

ANSWER FOR ELECTROLYSIS STRUCTURED QUESTIONS

Paper 2 Section A

1 Molten lead (II) bromide was electrolysed using carbon electrodes.

(a) (i) Write the ionic equation for the reaction at the cathode.

$Pb^{2+}(l) + 2e^- \rightarrow Pb(l)$ [1]

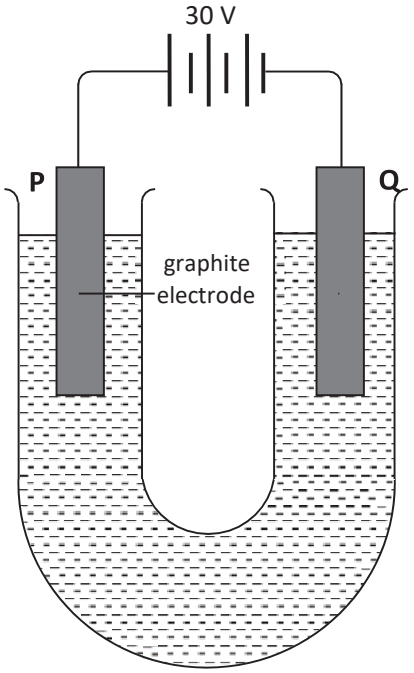
(ii) Write the ionic equation for the reaction at the anode.

$2Br^-(l) \rightarrow Br_2(g) + 2e^-$ [1]

(iii) State the observation at the cathode during the electrolysis.

Shiny, silvery globule was found at the bottom of the beaker. [1]

(b) The setup shows the electrolysis of concentrated sodium chloride solution.



concentrated sodium chloride solution with universal indicator

(i) Describe the observations at the electrodes of **P** and **Q**.

Electrode **P**:

Green Universal indicator turned blue/violet. [1] /**bubbling / effervescence** of pale green gas [1] [max 2]

Electrode **Q**:

Green Universal indicator turned red. [1] / **bubbling / effervescence** of colourless gas

[4]

(ii) How does the pH of the electrolyte change as the electrolysis proceeds? Explain your answer.

pH will increase. [1] Hydrogen ions preferentially discharged at cathode results in decreasing concentration of hydrogen ions / concentration of hydroxide ions higher than that of hydrogen ions. [1]

NB: reject if students write gas instead of ions are discharged. [2]

(iii) Suggest why iron is **not** suitable to be used as an electrode for this experiment.

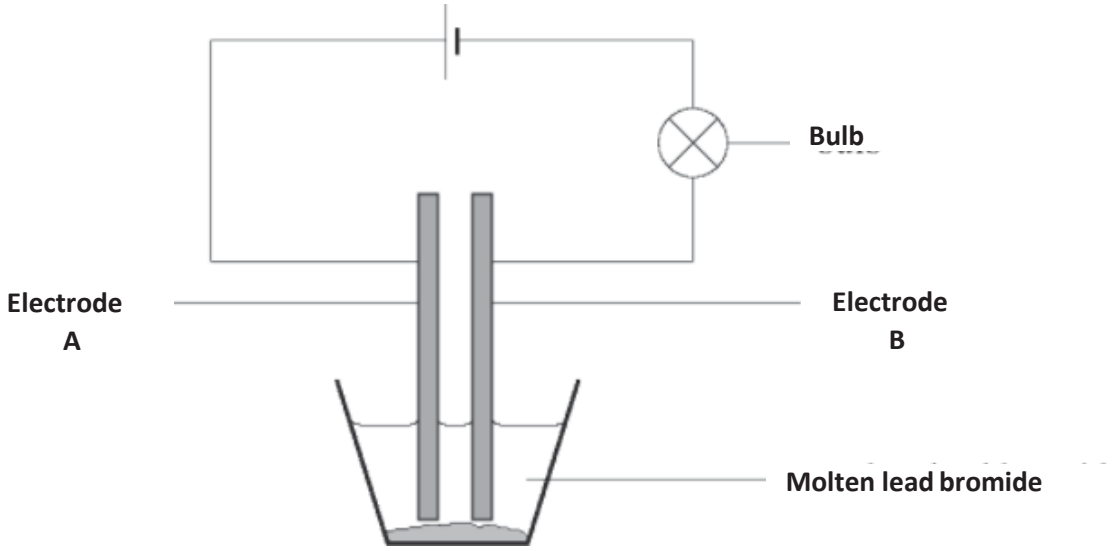
Chlorine gas formed at anode will oxidise iron anode away/ hydrogen ions at cathode will react iron cathode away

Reject: chloride ions will react with iron. [Reaction of chloride ions with iron is slow]

NB: reject if students write gas instead of ions are discharged. [1]

[Total:10]

2 The diagram below shows the apparatus used during electrolysis of molten lead (II) bromide.



(a) Suggest a reason why lead (II) bromide must be molten in order for electricity to flow. [1]

It allows the **ions** to be mobile / move / act as mobile charge carriers

(b) Write the half equation for the reaction taking place at the electrode **A**. [1]

$2Br^-(l) \rightarrow 2e^- + Br_2(g)$
(Happens at anode, hence oxidation happens)

[1]

(c) (i) State, in terms of electrons, what happens to the ions at the electrode **B.**

Lead (II) ions / Ions would gain electrons

(ii) Describe an observation you would expect at the electrode **B**. [2]

Increase [1] in mass / size / layer formed [1]
OR
Silvery [1] substance [1]
R: Solid. Be it is molten state

(iii) Electrolysis is allowed to continue for some time before the apparatus is cooled to room temperature. The bulb remains lit.

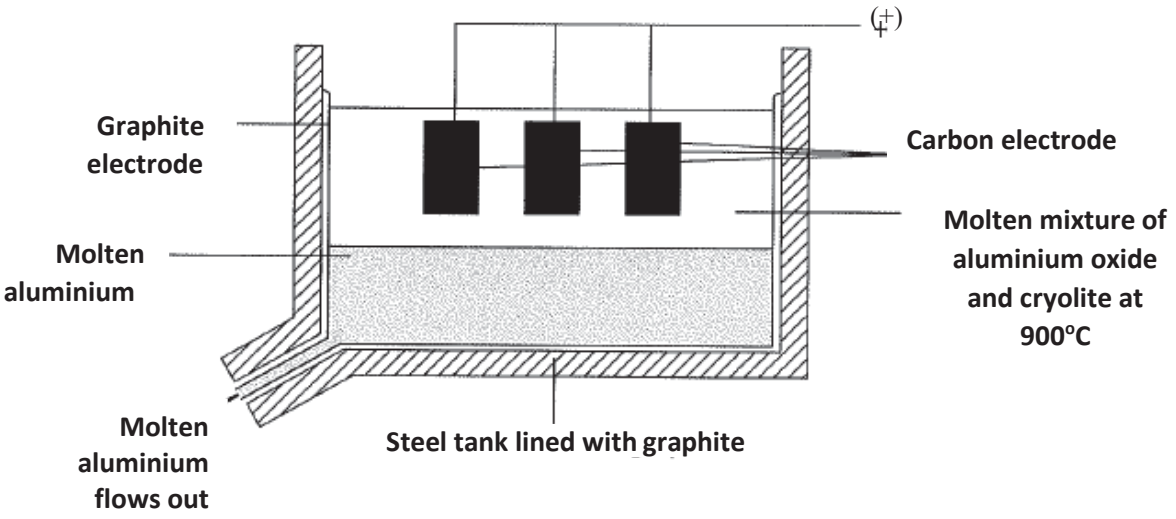
Explain this observation.

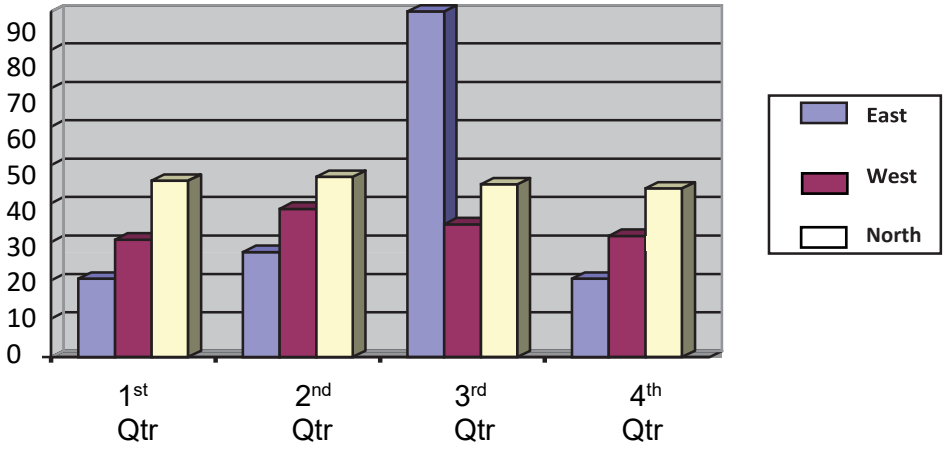
Lead metal conduct electricity [1]

[Total: 6]

Paper 2 Section B

1 The diagram shows an electrolysis tank used to extract aluminium from aluminium oxide. Pure aluminium oxide melts at 2055 °C.





(a) Cryolite is mixed, as an impurity, with aluminium oxide. State the effect it has on the melting point of the mixture and explain why mixing cryolite is necessary.

The mixture would have lower melt ng point. [1] this allow the xide to melt at a lower temperature and make the process more economical. [1] / Save money from electrical energy that is reduced. [1]

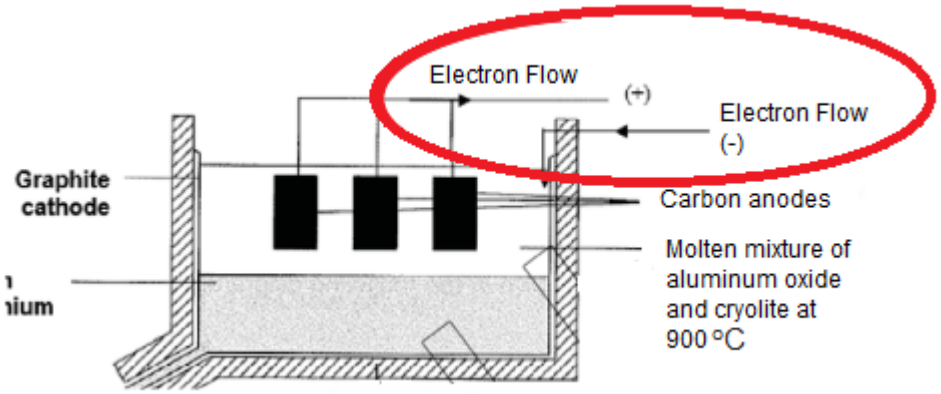
[2]

(b) Write half equations for the reactions that take place at the anode and cathode. [2]

Anode: $2O^{2-}(l) \rightarrow O_2(g) + 4e^-$

Cathode: $Al^{3+}(l) + 3e \rightarrow Al(l)$

(c) Draw **two** arrows on the diagram to indicate the flow of electrons. Clearly label on the two electrodes. [1]



(d) What is the volume of oxygen produced, under room temperature and pressure when 540 g of aluminium is produced? [2]

The overall equation is

$2Al_2O_3 \rightarrow 4Al + 3O_2$

No. of moles of Al = 540 / 27

= 20 mol

No. of moles of oxygen produced

= 20 / 4 x 3 = **15 mol [1]**

Volume of oxygen produced = 15 x 24 dm^3

= 360 dm3 [1]

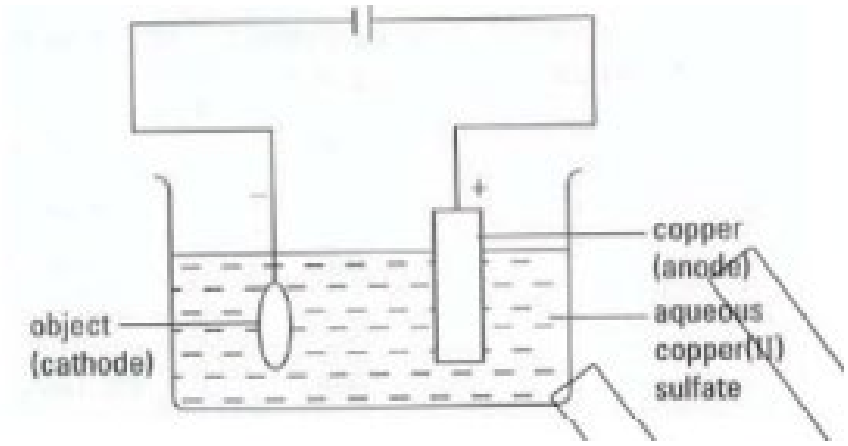
(e) The carbon electrodes are replaced at regular intervals. Explain the need for this.

The presence of oxygen gas reacts with carbon anode to form oxides of carbon [1] . Or Oxidises the carbon electrode and reduce the mass.

[1]

(f) Draw a clearly labelled diagram to show how a metal object could be electroplated with copper.

[2]



1m – correct terminals and label of anode and cathode

1m – correct label of materials

(Copper and copper sulfate solution)

[Total: 10]

2 Fig 9.1 shows the set-up for the electrolysis of a chloride solution containing two metal ions, copper(II) and iron(II).

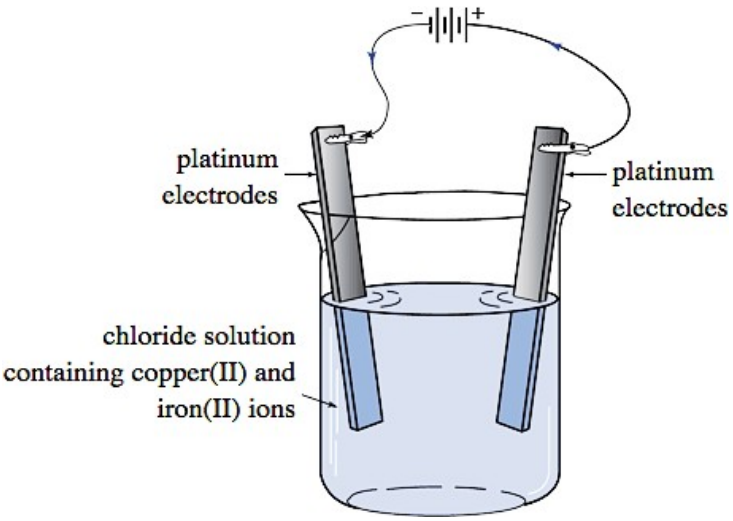


Fig 9.1

An electric current was passed through the cell for a period of time. The observations at different stages were recorded in the table.

Table 9.2

stage	observations
stage 1 – after 10 mins	A yellowish-green gas is observed at one of the electrodes while a brown solid is deposited at the other electrode. There was no visible change to the electrolyte.
stage 2 – after 1 hour	The same observations in stage 1 at the anode and cathode. The electrolyte became pale green.
stage 3 – after 2 hours	Colourless gases are both evolved at the anode and cathode. The pale green of the electrolyte becomes more visible.

(a) (i) Write the equations for the reactions taking place at the respective electrodes in stage 1.

$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$
$2Cl^-(aq) \rightarrow Cl_2(g) + 2e^-$. [2]

(ii) The total mass of the brown solid deposited was 0.584 g.

Calculate the volume of the yellowish-green gas produced at the other electrode.

Number of moles of Cu = 0.584 / 64 = 0.009125 mol
For the same amount of electricity (2 mol of e-), 1 mol of Cu and 1 mol of Cl2 are produced. Hence, number of moles, of Cl2 produced is also 0.009125 mol.
Volume of Cl2 produced = 0.009125 x 24 = 0.219 dm3

[2]

(b) Explain why the electrolyte becomes pale green in stage 2 and then darker in stage 3.

At stage 2, **Cu^{2+} ions were preferentially discharged** leaving behind Fe^{2+}ions in the electrolyte which are pale green in colour.
At stage 3, **$H^{\pm}$ and OH = ions· from water are discharged**.
Hence the concentration of the electrolyte increases and the solution becomes darker due to the· Fe^{2+}. .[2]

(c) A few drops of Universal Indicator were added **at the cathode** in stage 3.

State and explain the result of the test.

The Universal Indicator will change colour **from green to violet/ blue. H± ions are preferentially discharged** at the cathode
leaving behind OH=-ions in solution / concentration of H± decreases which thus increases the concentration of OH= in electrolyte which makes the solution around the cathode alkaline...[2]

(d) A total of three different substances were produced at the cathode throughout the whole electrolysis process.

Identify and list the three substances in order of which they are produced. Explain your answer.

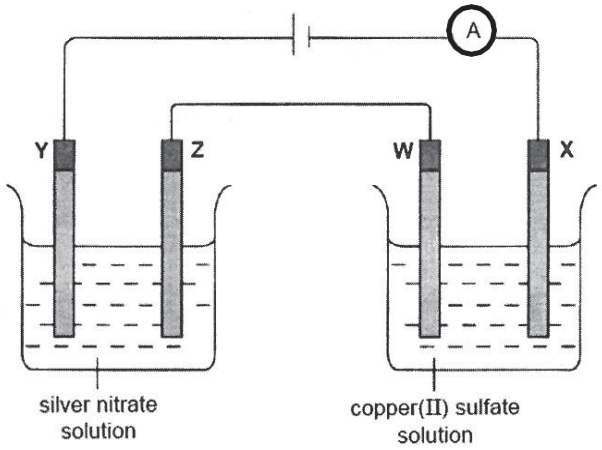
The three substances are **copper, hydrogen gas and iron.**
Any one of the following explanations :

- Copper atoms are the least reactive, followed by hydrogen atoms, then iron atoms. Hence,
- Copper(!I) ions are preferentially discharged followed by hydrogen ions, then iron(II) ions

Copper(II) ions accept electrons most readily followed by hydrogen ions then iron(II) ions….. [2]

[Total: 10 marks]

3 The diagram below shows the set-up of an electrolysis experiment.



W and X are copper electrodes while Y and Z are silver electrodes.

(a) Electrodes X and Z will increase in mass after some time. Explain why, using half-equations to illustrate your answer.

……

……

……[3]

(b) Electrode Z will increase in mass at a faster rate than electrode X. Explain why this is so.

……..

……..

…… [2]

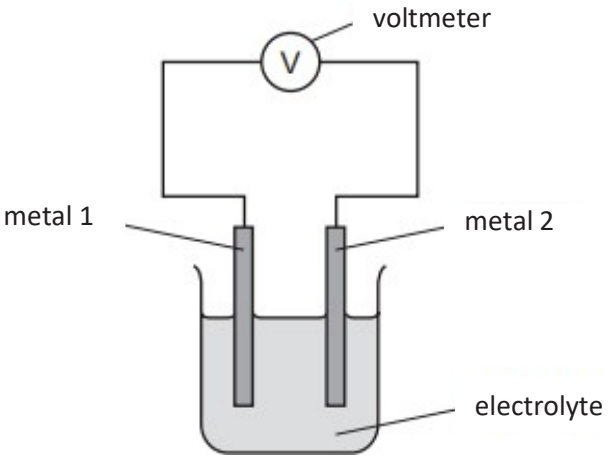
[Total: 5]

Answer:

3	**(a)**	X: Cu^{2+} (aq) + 2e → Cu (s) Z: Ag^{+} + (aq) + e → Ag (s) Copper metal deposited on X and silver metal deposited on Z increases the mass of X and Z	1 1 1	Generally well- answered
	(b)	Silver requires 1 mole of electrons to be discharged whereas copper requires 2 moles of electrons to be discharged. Hence Z will increase at a rate double that of X	1 1	Generally well-answered. Students who got it wrong mentioned that silver is less reactive than copper hence it will be discharged faster. This concept is wrong.

4 The diagram shows a simple cell, with two different metals as electrodes dipped in dilute nitric acid. A student did an experiment using the simple cell below.
The voltages were recorded in the table.

- If the voltage measured is positive then metal 2 is more reactive than metal 1.
- If the voltage measured is negative then metal 1 is more reactive than metal 2.



		metal 2				
		beryllium	cobalt	nickel	silver	vanadium
metal 1	beryllium	0.0 V	-1.6 V	-1.6 V	not measured	-0.7 V
	cobalt		0.0 V	0.0 V	-1.1 V	0.9 V
	nickel			0.0 V	-1.1 V	0.9 V
	silver				0.0 V	2.0 V
	vanadium					0.0 V

(a) (i) In the simple cell containing nickel and silver, it was observed that the electrolyte slowly turned pale green. Write the ionic equation to explain the colour change.

……..[1]

(ii) What happened to the mass of the nickel electrode?

……..[1]

(b) (i) Using the data given, state the most reactive metal in the table above.
Explain your reasoning.

……

……..

…… [2]

(ii) Predict the voltage produced by a simple cell with beryllium as metal 1 and silver as metal 2.

……[1]

(c) (i) The student wanted to rank the metals listed in the table according to their reactivity but he was not able to do so. Why?

……[1]

(ii) Briefly describe one **simple** experiment the student can do which will help him to solve the problem in **c(i).**

……

……...[1]

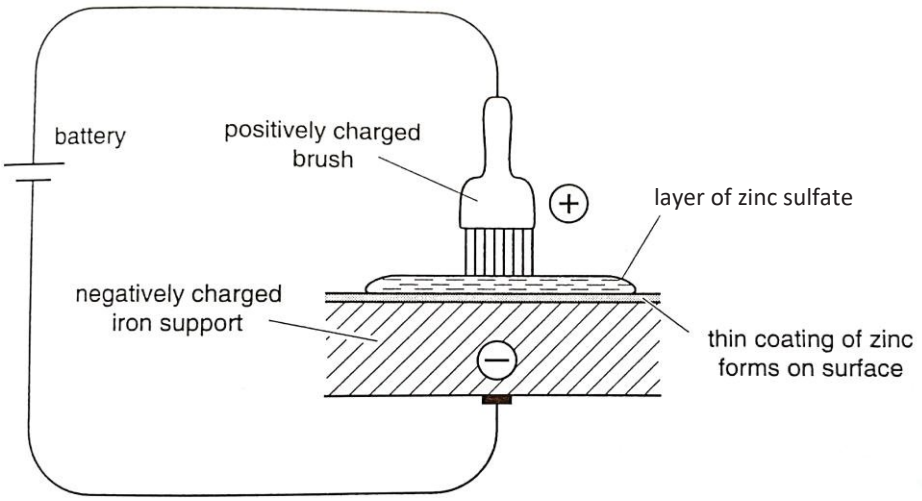
[Total: 7]

Answer:

4	**(ai)**	$Ni(s) \rightarrow Ni^{2+}(aq) + 2e$	[1]
	(ii)	mass decrease	[1]
	(bi)	Beryllium It has the largest voltage with cobalt/nickel	[1] [1]
	(ii)	-2.7 V (V + Ag) + (V + Be)	[1]
	(ci)	both nickel and cobalt has the same reactivity	[1]
	(ii)	Place a piece of nickel in cobalt nitrate solution. If nickel displaces cobalt, nickel is more reactive than cobalt.	[1]

5 A new type of electroplating is known as 'brush electroplating'.
It is used to electroplate zinc onto very large iron supports to be used in buildings. The iron supports are too big to be plated in a normal electrolysis tank.

During the process, a metal brush spreads a layer of aqueous zinc sulfate over the iron surface.
A battery gives the brush a positive charge and gives the iron support a negative charge.
A layer of zinc forms on the surface of the iron support.



(a) The surface of the iron acts as a cathode.
Zinc ions from the solution form zinc on the surface

of the iron.

Write an ionic half-equation, with state symbols, for this reaction.

……
[2]

(b) Two different designs of metal brush are available.
One type of brush is made from zinc, one type is made from platinum.
As the electrolysis takes place, each brush has a different effect on the concentration of zinc ions in the solution.

(i) What will happen to the concentration of the zinc ions during the electrolysis if the brush is made from platinum?

…… [1]

(ii) What will happen to the concentration of the zinc ions during the electrolysis if the brush is made from zinc?

…… [1]

(iii) Platinum brushes are much more expensive than zinc brushes.
However, zinc brushes need replacing regularly but platinum brushes do not.
Explain why.

……

…… [2]

(c) During the process, a worker needs to hold the brush.

Which of the following materials would be a good choice for the handle of the brush? Give a reason for your answer.

chromium copper graphite iron poly(ethene)

material
……[1]

Reason
……[1]

(d) Explain why iron supports coated with zinc do not rust, even if the zinc coating is damaged.

.....

..... [2]

[Total: 10]

Answer:

5	**(a)**	Zn^{2+} (aq) + 2e → Zn (s)	[2]
	(bi)	Concentration of zinc ions will decrease over time.	[1]
	(bii)	Concentration of zinc ions will remain constant throughout electrolysis.	[1]
	(biii)	Zinc brush will form zinc ions during electrolysis and will be up whereas platinum is an inert electrode therefore no change in mass	[1] [1]
	(c)	Material – poly(ethene) Reason – It does not conduct electricity	[1] [1]
	(d)	Zinc is more reactive than iron and therefore provides sacrificial protection by corroding in place of iron.	[1] [1]

6 Molten zinc chloride can be electrolysed using the apparatus as shown in Fig. 6.1.

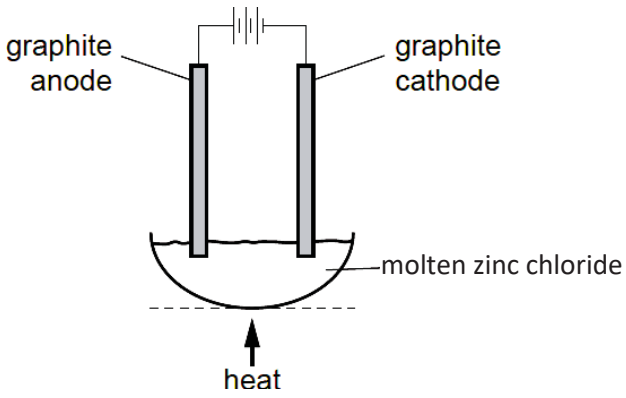


Fig. 6.1

(a) Explain why zinc chloride conducts electricity when molten, but now when solid.

……

……

……[2]

(b) Predict the products of this electrolysis at

the anode
……..[1]

the cathode
……..……[1]

(c) When a dilute aqueous solution of zinc chloride is electrolused hydroxide ions are converted to oxygen at the anode.

Write the ionic equation for the reaction the happens at the anode.

……[1]

(d) Describe a positive test for zinc ions.

test……

observations……

……..……[2]

(e) Solid zinc chloride absorbs ammonia to form tetra-ammine zinc chlor=ide, $[Zn(NH_3)4]Cl_2$.

$$\mathbf{ZnCl_2 + 4NH_3 \rightarrow [Zn(NH_3)4]Cl_2}$$

Calculate the maximum yield, in grams, of tetra-ammine zinc chloride formed when 3.4g of zinc chloride reacts with excess ammonia.

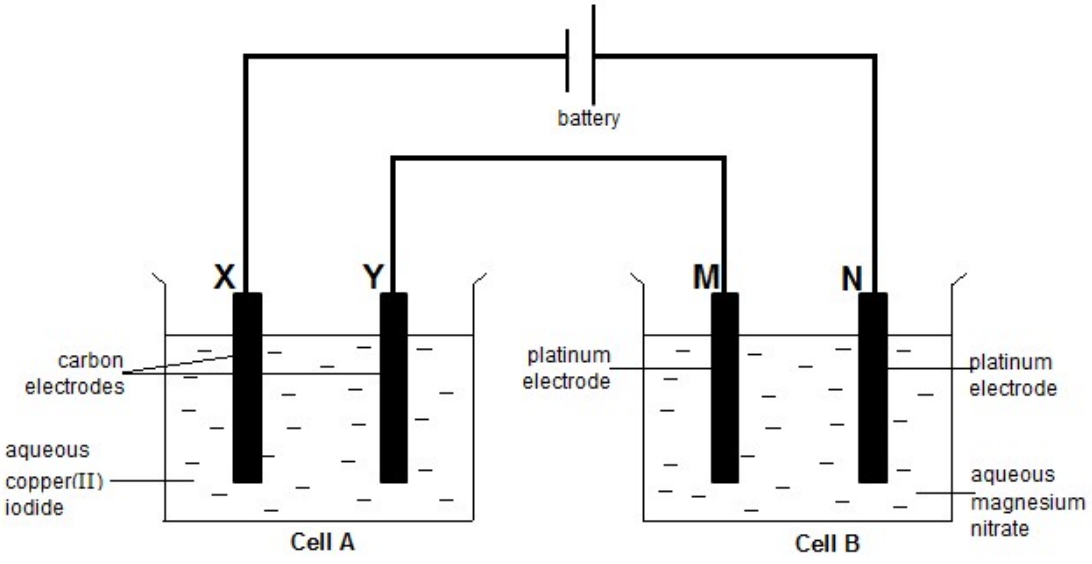
[2]

Answer:

6	**(a)**	When molten, the strong electrostatic forces of attraction between the oppositely charged ions, Zn^{2+} and Cl^-, are overcome. or In solid state, the oppositely-charged ions are held together by the strong electrostatic forces of attraction and can only vibrate about in fixed position In molten state, the ions can slide around / move / are mobile to carry the charges across to conduct electricity. [1] or There are free moving (mobile) ions in molten state (Reject: any phrase on 'electrons' / 'sea of delocalised ions)	[1]
	(b)	at anode: Chlorine gas evolved. ($2Cl^-(l) \rightarrow Cl_2(g) + 2e^-$) at cathode: Zinc metal deposited on the cathode. ($Zn^{2+}(l) + 2e\acute{i} \rightarrow Zn(s)$)	[1] [1]
	(c)	$4OH^-(aq) \rightarrow 2H_2O(l) + O_2(g) + 4e^-$	[1]
	(d)	Test: add aqeuous sodium hydroxide (aqueous ammonia) dropwise, followed by in excess Observations: White precipitate, soluble in excess giving a colourless solution	[1] [1]
	(e)	M_r of $ZnCl_2$ = 65 + 35.5 + 35.5 =136 No. of moles of $ZnCl_2 = \frac{3.4}{136}$ = 0.025 mol. No. of moles of $[Zn(NH_3)_4]Cl_2$ = 0.025 mol. M_r of $[Zn(NH_3)_4]Cl_2$ = 65 + 4(14 + 3) + (35.5 × 2) = 204 Mass of $[Zn(NH_3)_4]Cl_2$ = 0.025 × 204 = 5.10 g (3 sig. fig.)	[1] [1]

[Total: 9]

7 In an experiment, a student connected two cells as shown in the diagram below.



(a) Predict the student's **observations** for the reactions occurring at each electrode in cell **A**. Explain your reasoning.

Electrode **X**:

A pink solid is deposited [1] on electrode X. Cu^{2+} ions are selectively discharged over H^+ ions as Cu is lower in the reactivity series [1] than H. Hence, the ions gain electrons to form copper metal.

Explanation: X is the cathode as it is connected to negative terminal of battery

Electrode **Y**:

A colourless, odourless gas [1] that relights a glowing splint [1] is is observed. OH^- is lower than I^- in the electrochemical series [1] and hence OH^- loses electrons to form oxygen gas.

Explanation: Y is the anode as it is connected to positive terminal of battery

[3]

(b) How would the concentration of the electrolyte in cell **B** differ after a while? Explain.

It would increase [1] because the hydrogen and hydroxide ions are discharged [1], leaving less water in the electrolyte.

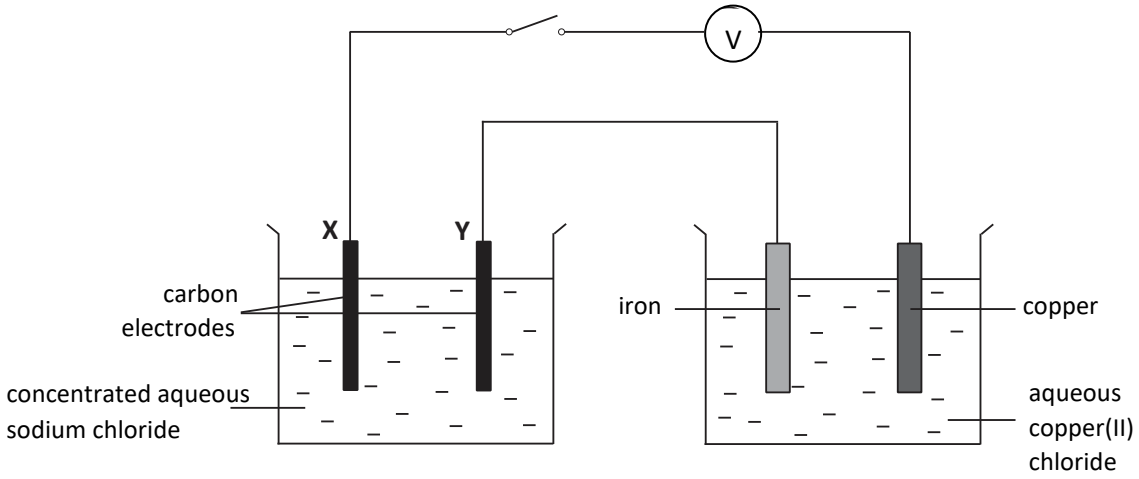
[2]

(c) The battery went flat and could not be used anymore. Suggest a modification to cell **B** in the above set-up, such that electrolysis in cell **A** could still be carried out with the same products at each electrode.

Switch electrode N to a metal that is more reactive than platinum.
Explanation: Switching electrode N to a metal more reactive than platinum will create a simple cell. Has to be electrode N as we need electrons to flow in the same direction as the battery
which is from electrode N to electrode X.

[1]

8 In an experiment, a student connected two cells as shown in the diagram below, and then switched the switch on. Electrolysis was observed to occur at cell **I**.



(a) Write ionic half-equations for the reactions occurring at

(i) the iron electrode in cell **II**

$Fe(s) \rightarrow Fe^{2}+(aq) + 2e^{-}$
Explanation: Iron is more reactive than Cu hence oxidised **[1]**

(ii) the copper electrode in cell **II**

$Cu^{2+}(aq) + 2e^{-} \rightarrow Cu(s)$
Explanation: Copper electrode is the cathode hence Cu2+ is discharged as it is lower in electrochemical series as compared to H+ ions in the electrolyte**.** **[1]**

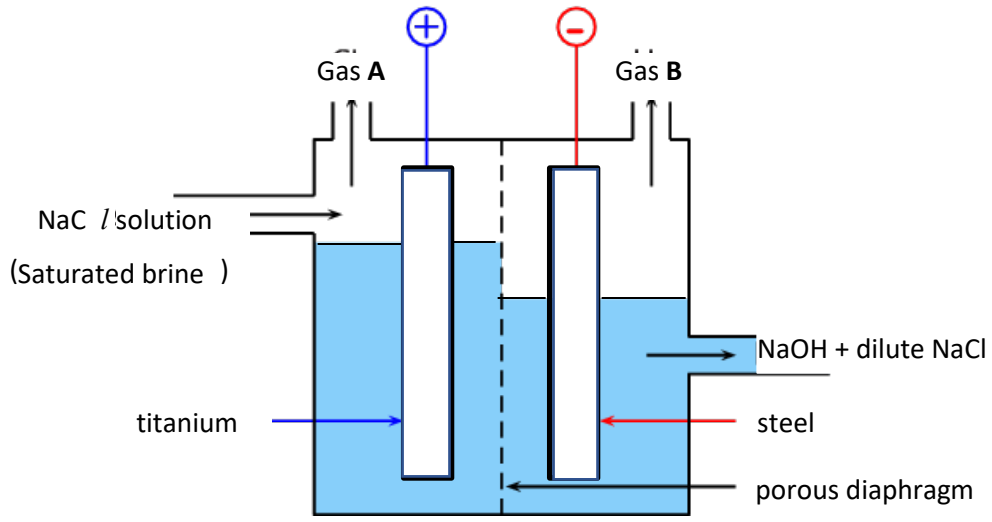
(b) Predict and explain the student's **observations** for the reaction occurring at electrode **X**.

A pungent, yellowish-green gas [1] that bleaches moist red litmus paper [1] forms. Chlorine gas is produced as chloride ions are in higher concentration [1] than hydroxide ions, thus it will be selectively discharged.

[3]

9 Chlorine can be manufactured by electrolysis of sodium chloride solution (brine). Diaphragm cell and membrane cell electrolysis can be used for the manufacturing of chlorine gas. Two other products, sodium hydroxide and hydrogen gas, are also produced.

In a diaphragm cell, the anode compartment is separated from the cathode compartment by a permeable diaphragm. The diaphragm is made up of a porous mixture of minerals and polymers which allows the solution to move from the anode compartment to the cathode compartment. A simplified diagram of the diaphragm cell is shown.



(a) (i) Suggest a reason why one compartment of the cell has a higher level of liquid than the other.

To prevent the NaOH from flowing back to the anode compartment; to ensure the flow in one direction;
Explanation: If NaOH flows back, the concentration of hydroxide ions may increased and diluting the concentration of chloride ions in the saturated brine. Hydroxide will then be discharged instead of chloride which is not preferred as the set-up aims to discharge chloride ions to get chlorine gas.

[1]

(ii) Write ionic equations for the reactions at the cathode and the anode.

Cathode:
$2H^+ (aq) + 2e \rightarrow H_2 (g)$;
Anode:
$2Cl^- (aq) \rightarrow Cl_2 (g) + 2e$; **[1]**

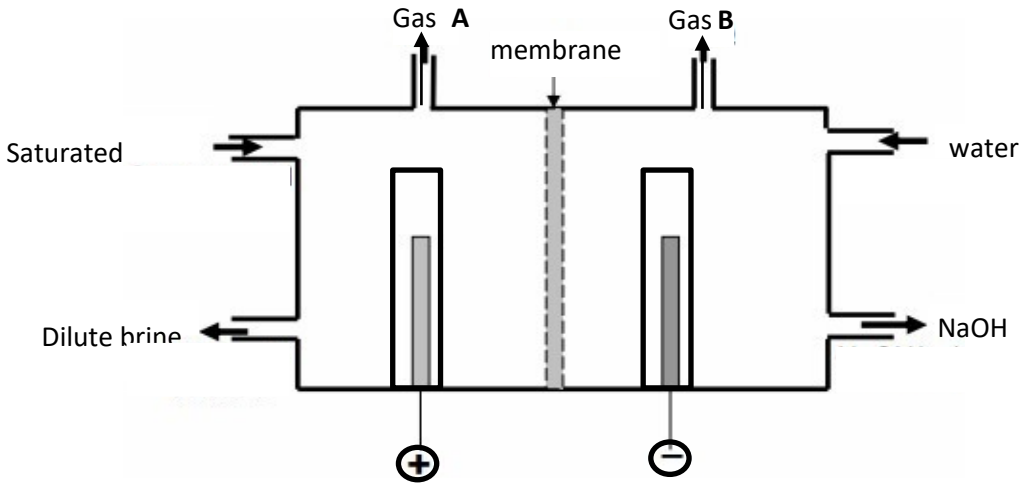
(iii) Construct the overall equation for this reaction.

$2\ NaCl\ (aq) + 2\ H_2O\ (l) \rightarrow 2\ NaOH\ (aq) + H_2\ (g) + Cl_2\ (g)$ **[1]**

Explanation: Based on the information provided, saturated brine is used to produced sodium hydroxide, hydrogen gas and chlorine gas. Water is added to the equation to balance the equation and water is present as saturated brine is an aqueous solution.

[1]

(b) In a membrane cell, the anode compartment is separated from the cathode compartment by an ion-exchange membrane. This membrane is made from a polymer which only allows positive ions to pass through it. A simplified diagram of the membrane cell is shown.



(i) Give an advantage of using the membrane cell instead of the diaphragm cell.

NaOH formed does not contain sodium chloride as the membrane prevents chloride
ions (negative ion) from flowing over to the cathode compartment
Explanation: Infer from information given. [1]

(ii) Suggest a reason why water is added to the compartment containing sodium hydroxide.

NaOH is corrosive if concentrated, so water is added to dilute the NaOH formed to prevent corrosion of the reactor; **[1]**

Explanation: Inference question. In industrial applications questions, usually cost and safety are important issues to consider. [1]

(iii) 278 g of sodium chlorine is dissolved in 1 dm^3 of water to produce saturated brine solution. Given that 30 dm^3 of chlorine gas is produced when 1 dm^3 of brine is electrolysed, calculate the percentage yield of chlorine.

[2]

Mol Cl_2 $\frac{30}{24}$ = 1.25 mol [0.5m]

Mol NaCl = $\frac{278}{23+35.5}$ = 4.75213675 mol [0.5m]

Mol ratio NaCl: Cl_2 = 2: 1

Mol Cl_2 (theoretical) = 4.75213675 × 0.5 = 2.376068376

% yield = $\frac{1.25}{2.376068376}$ ×100= 52.6 % (3.s.f)