Cambridge Assessment International Education

Skills Pack

Electrolysis of a binary salt

Cambridge IGCSE™

Chemistry 0620

This *Skills Pack* can also be used with the following syllabuses:
- Cambridge IGCSE® Chemistry **0620**
- Cambridge IGCSE® (9–1) Chemistry **0971**
- Cambridge IGCSE® Combined Science **0653**
- Cambridge O Level Chemistry **5070**

Version 0.1

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Debriefing lesson

Introduction

This pack will help you to develop your learners' experimental skills as defined by assessment objective 3 (AO3 Experimental skills and investigations) in the course syllabus.

> **Important note**
> Our *Skills Packs* have been written by **classroom teachers** to help you deliver topics and skills that can be challenging. Use these materials to supplement your teaching and engage your learners. You can also use them to help you create lesson plans for other experiments.
>
> ***This content is designed to give you and your learners the chance to explore practical skills. It is not intended as specific practice for Paper 5 (Practical Test) or Paper 6 (Alternative to the Practical Test).***

There are two options for practising experimental skills. If you have laboratory facilities this pack will support, you with the logistics of running the experiment. If you have limited access to experimental equipment and/or chemicals, this pack will help you to deliver a virtual experiment.

This is one of a range of *Skills Packs*. Each pack is based on one experiment with a focus on specific experimental techniques. The packs can be used in any order to suit your teaching sequence.

The structure is as follows:

Briefing lesson (1 hour*)
This lesson introduces the focus experimental skills to be developed. It also introduces any content needed for your learners to understand the experiment being carried out in the *Lab lesson*.

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Lab lesson (1 hour*)	
Option 1 – run the experiment	**Option 2 – virtual experiment**
This lesson allows the experiment to be run with your learners, providing an opportunity to practise the experimental skills introduced in the *Briefing lesson*.	This lesson allows your learners to complete a virtual experiment, providing an opportunity to practise the experimental skills introduced in the *Briefing lesson*.

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Debriefing lesson (1 hour*)
This lesson consolidates and builds on the progress learners have made. In some cases, it will also provide the opportunity to practise extended writing skills.

** the timings are a guide only; you may need to adapt the lessons to suit your circumstances.*

In this pack will find the lesson plans, worksheets for learners and teacher resource sheets you will need to successfully complete this experiment.

Experiment: Electrolysis of a binary salt

This *Skills Pack* focuses on an electrolysis of a binary salt experiment.

Determining the empirical formula of a substance is a key step in determining the chemical formula of the substance. In this experiment, you will produce experimental data to determine with empirical formula of magnesium oxide.

This experiment has links to the following syllabus content (see syllabus for detail):

3.1 Formulae, 3.3. The mole and the Avogadro constant

The experiment covers the following experimental skills, adapted from **AO3: Experimental skills and investigations** (see syllabus for assessment objectives):

- demonstrate knowledge of how to select and safely use techniques, apparatus, and materials (including following a sequence of instructions where appropriate)
- plan experiments and investigations.
- make and record observations, measurements and estimates.
- interpret and evaluate experimental observations and data.
- evaluate methods and suggest possible improvements.

Prior knowledge

Knowledge from the following syllabus topics is useful for this experiment.

- 2.4 Ions and ionic bonds
- 3.1 Formulae

Going forward

The knowledge and skills gained from this experiment can be used for when you teach learners about ionic bonding.

Briefing lesson: Planning the experiment

Resources	• Worksheets A, B, C
Learning objectives	By the end of the lesson: • ***all*** learners should be able to plan a suitable method for carrying out electrolysis of a binary salt.

Timings	Activity
10 min	**Starter/Introduction** • Hand out WS A • In pairs, ask the students to recall/research the formulae of the fourteen ions, and which ions will discharge in aqueous solution.
35 min	**Main lesson** • Ask the students to share their answers with another group, and see if the groups agree. Probe their understanding as to whether they have remembered these by rote, or whether they know the general rules for discharge under electrolysis. Give the rule for positive and negative ions, and relate these back to the ions included in WS A. • Explain that electrolysis can be carried out on an enormous scale, such as extraction of aluminium from bauxite, a lab scale, such as they will see in their text books, and a microscale, where only a few drops of solution are required. Ask the students what benefits there may be for carrying out electrolysis at small scale. *Answers may include quicker, cheaper, safer, easier to see observations.* • Hand out WS B. Their task is to devise a method to carry of out the electrolysis of copper(II) chloride, and account for all the observations. With appropriate guidance, ask learners to work in pairs to draw a fully annotated diagram of their experimental setup. Stress that **all** the equipment/materials must be used.
	Plenary • Show students the expected set up in WS C and discuss any differences they may have. • Ask students to write out a set of control measures beside their equipment, particularly focussed on the toxic chlorine being produced. Remind them about general good laboratory practice including tying back long hair, wearing eye protection, not eating or drinking etc.

Lab lesson: Option 1 – run the experiment

Resources	• Teacher notes • Teacher walk through video • Worksheets B, C, D, E • Equipment as outlines in the notes

Learning objectives	By the end of the lesson: • All learners should be able to carry out the electrolysis of copper(II) chloride solution and make some observations • Most learners should also be able to give chemical explanations for their observations • Some learners should also be able to write balanced ionic equations for the displacement reactions occurring.

Timings	Activity
5 min	**Starter/Introduction** Ask the learners some general questions about the experiment they planned in the previous lesson. For example: 1. What term is used for the positive and negative electrode? *Anode and cathode* 2. Why are graphite/carbon fibre rods used as the electrodes? *These materials conduct electricity and won't react themselves during the electrolysis* 3. Explain how copper is formed in the reaction. *Copper ions are attracted to the cathode, where they gain electrons in a reduction reaction.* 4. Explain why the drops of potassium bromide/iodide change colour. *Chlorine is produced which displaces bromide/iodide from solution, forming the coloured bromine/iodine in solution.*
40 min	• Arrange learners in groups of 2-3. Hand out WS C. Ask the students to talk through the steps they will be carrying out, and who will be responsible for each step. It can be useful for one learner to be scribe, noting down the observations which can be shared afterwards. It can be useful for one student to have special responsibility for checking safety and the setup before proceeding with the reaction. • SAFETY: Circulate the classroom at all times during the experiment so that you can make sure your learners are safe. • Learners perform the experiment following the instructions on WS C carefully. • Issue the students with WS D where the learners write their results and evaluate the experiment. Discuss the answers with the learners using the suggested answers.

	• Ask learners to verbally feedback on their observations and compare & contrast these with the expected observations.
15 min	**Plenary** • Once learners have completed the experiment, ask them to work in pairs and give them WS E. Learners should work through the questions supported by the teacher using model answers as required. • Ask learners to compare their answers to WS E with the model answers and highlight any differences. Make a note of misconceptions that are arising, and focus on these in the Debrief lesson.

Teacher notes

Watch the empirical formula of magnesium oxide video (teacher version) and read these notes.

Each group will require:

- A prepared 5 cm plastic Petri dish (see Notes)
- Two carbon fibre rods – 10 cm x 1.5 mm
- A 9V battery
- A battery clip with wires connected to crocodile clips
- 0.5 M copper chloride solution
- 0.5 M potassium bromide
- 0.5 M potassium iodide
- Blue litmus paper
- Forceps
- Sticky tack

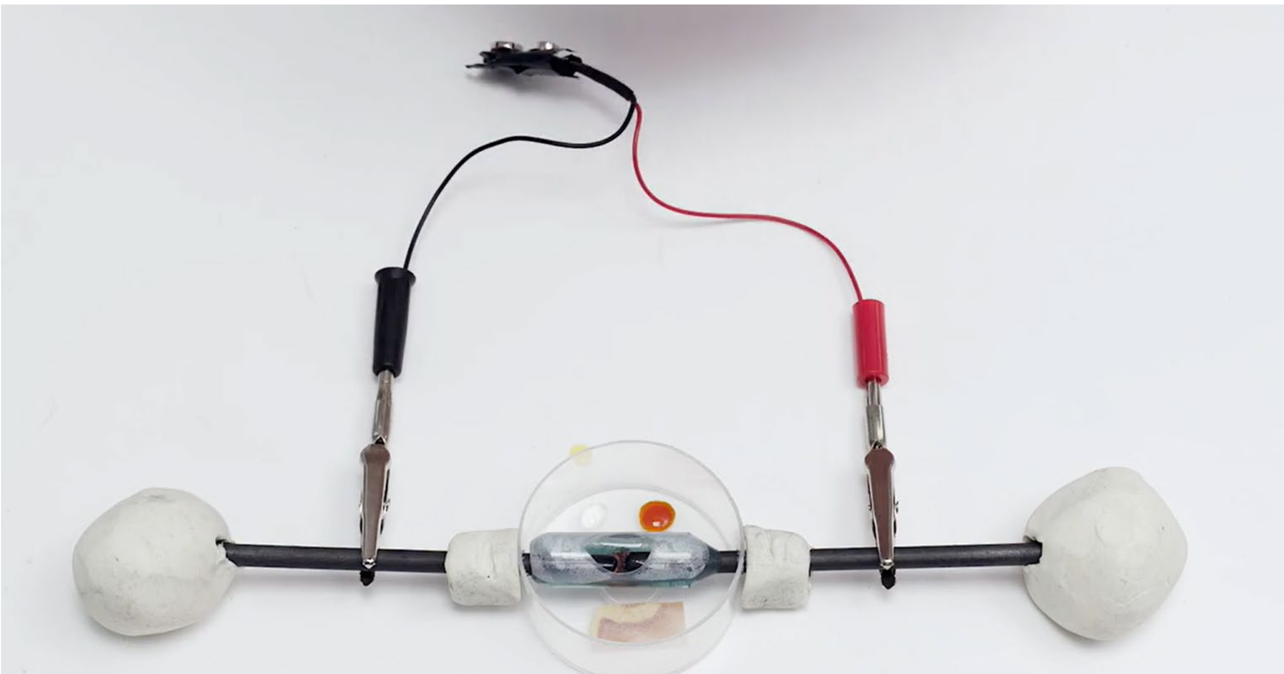
Safety

The information in the table below is a summary of the key points you should consider before undertaking this experiment with your learners.

It is your responsibility to carry out an appropriate risk assessment for this experiment.

- Wear eye protection
- Chlorine (DANGER: Toxic) is produced in small volumes. Work in a well ventilated room. Do not breath in close to the Petri dish.
- Ensure the room/laboratory is well ventilated

Experiment set-up



Teacher method

This is your version of the method for this experiment that accompanies the *Teacher walkthrough* video.

Do not share this method with learners. Give them **Worksheet C**.

Before you begin

Plan how you will group your learners during the experiment session.

Think about:

- the number of groups you will need (group size 2–4 learners)
- the amount of equipment/chemicals required.
- whether you are testing more than one carbonated drink.

Experiment

Walk around the learners during the experiment in case they encounter any difficulties.

Step #	Method	Notes
Before	Check that learners have the materials and apparatus in front of them.	Pre-sorting the equipment into individual group boxes can make distribution and collection of equipment more efficient
Before	Check that the learns have WS C & D.	
Before	(Re)discuss the health and safety aspects of the experiment.	
1	Place the electrodes through the holes in the edge of the Petri dish, with the ends meeting about 5 mm apart in the plastic channel.	Learners may need help with this step – it is important that the electrodes don't move around during the electrolysis
2	Add about 10 drops of copper chloride solution into the plastic channel.	The exact number isn't important, but having both electrodes in the solution is.
3	Add 3-4 drops of potassium bromide and potassium iodide separately into the Petri dish.	Having the same number of drops is useful .
4	Hold the litmus paper with forceps and dampen the paper in water.	Learner can dampen the paper in water from a tap, or a beaker.
5	Place the paper damp litmus paper into the Petri dish.	

6	Place the lid on the Petri dish.	Check that learners have covered their Petri dish before the power is applied. Otherwise, the chlorine will diffuse into the room and the reactions in the potassium halide drops/litmus paper won't be as obvious.
7	Connect the battery to the two electrodes using the crocodile clips.	
8	Observe the reactions at the two electrodes, in the potassium halide solutions, and on the litmus paper.	Encourage the learners to observe consistently over the two minutes – they should be seeing changes over time.
9	Disconnect the battery after 2 minutes.	
10	Record your results and evaluate your experiment using Worksheet D.	

Clean-up

After the experiment learners should:

- Disconnect the battery and electrodes
- Rinse the Petri dish and electrodes with water down a foul water drain.
- Tidy their work space
- Ensure any spillages have been mopped up
- Return all equipment and unused chemicals to you.

Lab lesson: Option 2 – virtual experiment

Resources	• Virtual experiment video for electrolysis of copper chloride • Worksheets B, D, E
Learning objectives	By the end of the lesson: • All learners should be able to carry out the electrolysis of copper(II) chloride solution and make some observations • Most learners should also be able to give chemical explanations for their observations • Some learners should also be able to write balanced ionic equations for the displacement reactions occurring.

Timings	Activity
5 min	**Starter/Introduction** Ask the learners some general questions about the experiment they planned in the previous lesson. For example: 1. What term is used for the positive and negative electrode? *Anode and cathode* 2. Why are graphite/carbon fibre rods used as the electrodes? *These materials conduct electricity and won't react themselves during the electrolysis* 3. Explain how copper is formed in the reaction. *Copper ions are attracted to the cathode, where they gain electrons in a reduction reaction.* 4. Explain why the drops of potassium bromide/iodide change colour. *Chlorine is produced which displaces bromide/iodide from solution, forming the coloured bromine/iodine in solution.*
30 min	**Main lesson** • Show the *Virtual Experiment video* from start to finish once through without stopping. • In pairs, learners compare and contrast their annotated diagrams from their planning activity (WS B) with what they saw in the video. • Give learners a copy of WS D, allowing them time to look through and understand the questions. They should not write anything at this stage. Show the video again to the learners, stopping the video as necessary. Learners then work in pairs to try to complete the sheet, helping each other when required. Project the answer sheet and go over the answers, allowing them time to correct any mistakes. • Ask learners to verbally feedback on their observations and compare & contrast these with the expected observations.
25 min	**Plenary**

	• Once learners have completed WS D, ask them to work in pairs and give them WS E. Learners should work through the questions supported by the teacher using model answers as required. • Ask learners to compare their answers to WS E with the model answers and highlight any differences. Make a note of misconceptions that are arising, and focus on these in the Debrief lesson.

Debriefing lesson: Consolidating the underlying chemistry.

Resources	• Worksheet F • A sample/image of copper objects (eg coins, pipes, wire) and electroplated objects (eg cutlery, electroplated plastic such as found on mobile phones).
Learning objectives	By the end of the lesson: • **All learners should be able to competently answer questions related to electrolysis of binary compounds.**

Timings	Activity
10 min	**Starter/Introduction** • Ask the learners to consider an aqueous solution of copper bromide, including what ions are present and what products would for if an electrical current was passed through the solution. ○ Cu^{2+}, H^+, Br^- and OH^-. Copper at the cathode and bromine at the anode. • Review the rules of discharge for positive ions (any metal ion for a metal less reactive than hydrogen) and negative ions (halides first producing halogens, then hydroxides producing oxygen).
40 min	**Main lesson** • Give out WS F and ask learners to work in pairs through Q1-5. If they find themselves struggling with any questions, encourage them to consult their textbook, then with another pair of learners before asking the teacher. • Work through the answers to the questions, modelling your thinking to help students understand the mental processes you use when tackling questions. • (Re)introduce the idea of electroplating to the students. Use the electroplated objects as visual hooks. Ask the learners where they have seen electroplated plastic in their lives (eg mobile phones, handles/levers etc in cars). • Ask the learners to complete Q6.
10 min	**Plenary** • Ask for two pairs of volunteers to share their methods with the rest of the group. Ask the other learners to constructively critique the shared methods. • Share the standard method with the learners, and check for understanding with some questioning.

Worksheets and answers

	Worksheets	Answers
For use in the *Briefing lesson:*		
A: Starter	**x**	**x**
B: Planning the determining the empirical formula of magnesium oxide experiment	**x**	**x**
C: Experimental set-up and method	**x**	**x**
For use in *Lab lesson: Option 1:*		
D: Results and evaluation	**x**	**x**
For use in *Lab lesson: Option 2:*		
D: Results and evaluation	**x**	**x**
For use in the *Debriefing lesson:*		
E: Consolidation questions	**x**	**x**

Worksheet A: Starter

Write the chemical formula for each of the following ions:

Ion	Formula	Ion	Formula
Copper(II)		Nitrate	
Iron(III)		Carbonate	
Sodium		Chloride	
Zinc(II)		Sulfate	
Silver(I)		Bromide	
Magnesium		iodide	

Put the ions into the four boxes:

	Negative ions	Positive ions
Will discharge in aqueous solution		
Won't discharge in aqueous solution		

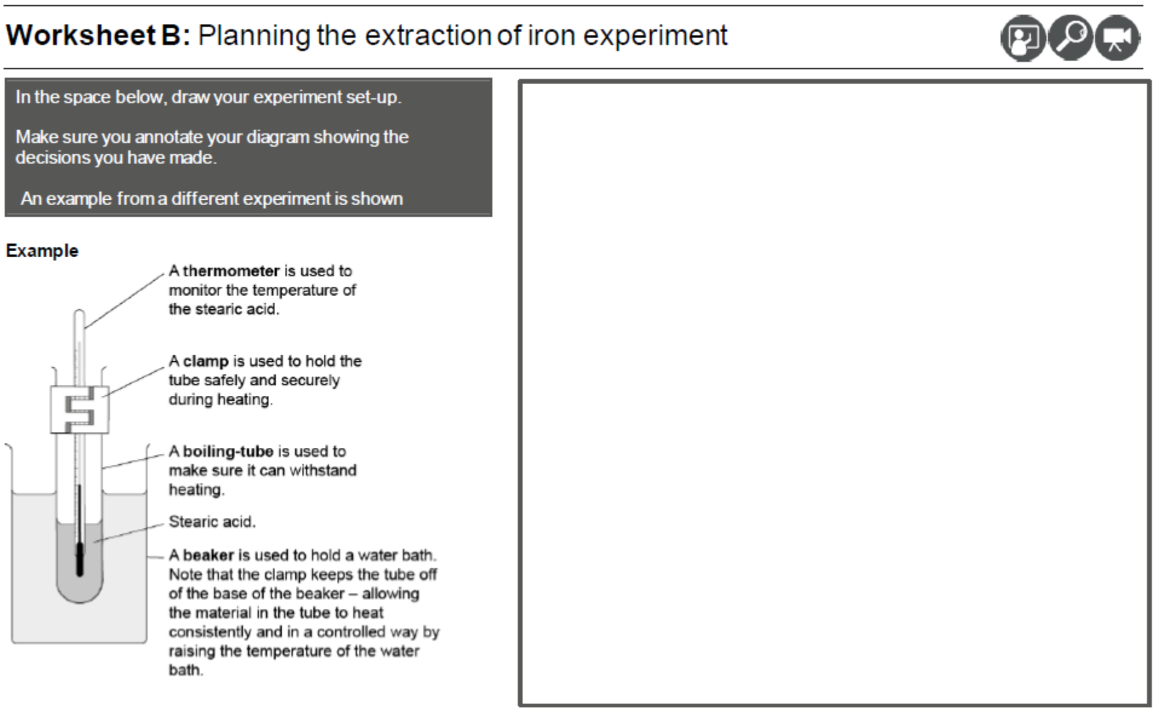
Worksheet B: Planning the electrolysis of copper(II) chloride solution experiment

Instructions

Using all the equipment below, design an experiment for the microscale electrolysis of copper(II) chloride solution

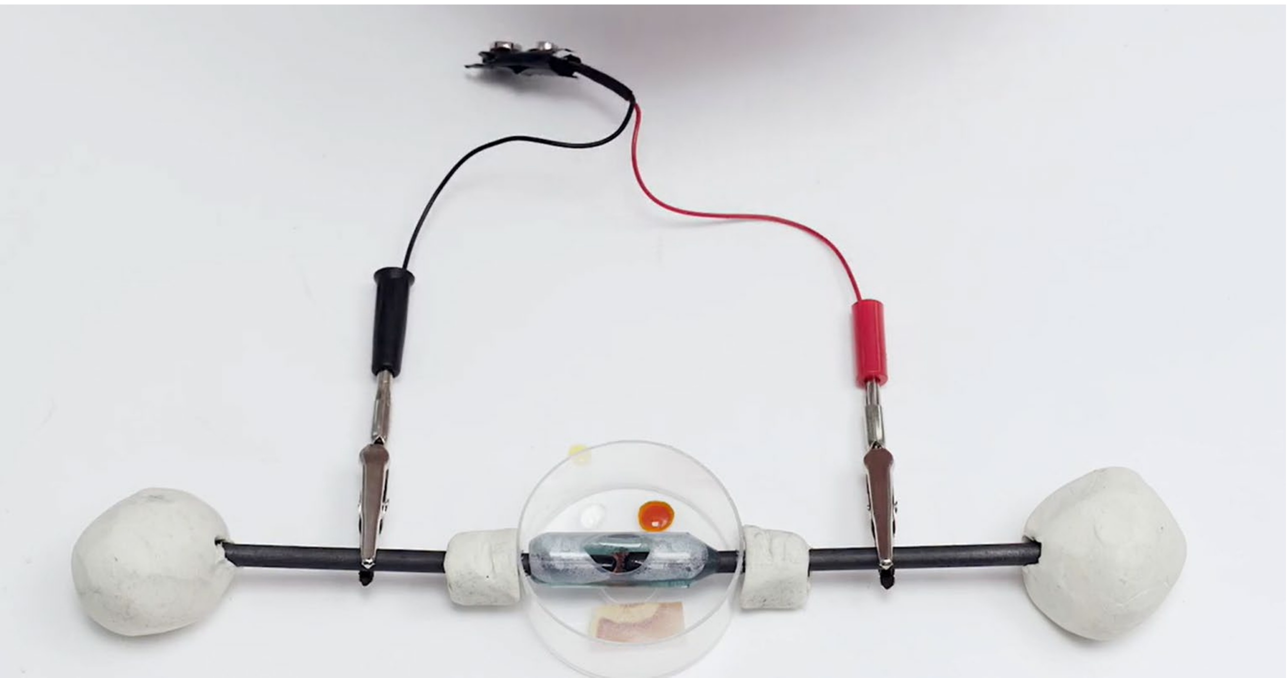
- A prepared 5 cm plastic Petri dish (see Notes)
- Two carbon fibre rods - 10 cm x 1.5 mm
- A 9V battery
- A battery clip with wires connected to crocodile clips
- 0.5 M copper chloride solution
- 0.5 M potassium bromide
- 0.5 M potassium iodide
- Blue litmus paper
- Forceps
- Sticky tack

Worksheet B: *continued*



Worksheet C: Experimental set-up and method

Instructions to user



Method

1. Place the electrodes through the holes in the edge of the Petri dish, with the ends meeting about 5 mm apart in the plastic channel. **Use sticky tack to hold the electrodes in place if necessary**
2. Add about 10 drops of copper chloride solution into the plastic channel. **Ensure the ends of the electrodes are completely immersed in the solution**.
3. Add 3-4 drops of potassium bromide and potassium iodide separately into the Petri dish.
4. Hold the litmus paper with forceps and dampen the paper in water.
5. Place the paper damp litmus paper into the Petri dish.
6. Place the lid on the Petri dish. **The lid contains the chlorine in the dish, ensuring the different reactions can occur.**
7. Connect the battery to the two electrodes using the crocodile clips. **If no reaction appears to occur after 10-15 seconds, check that the electrodes are immersed in the copper chloride, and that the battery is producing current.**
8. Observe the reactions at the two electrodes, in the potassium halide solutions, and on the litmus paper.
9. Disconnect the battery after 2 minutes.
10. Record your results and evaluate your experiment using Worksheet D.

Worksheet D: Results and evaluation

1. What colour is the copper(II) chloride solution at the start and the end of the reaction?

2. What observation did you make at the negative electrode showing formation of elemental copper?

3. What observation did you make at the positive electrode showing the formation of elemental chlorine?

4. What observations did you make in the potassium bromide and potassium iodide drops?

5. What observations did you make on the damp blue litmus paper?

6. Discuss any challenges involved in scaling up this method to produce useful amounts of copper or chlorine.

Worksheet E: Chemical equations for the reactions

1. What positive ions are present in the copper(II) chloride solution?

2. Why do copper ions preferentially discharge in this solution?

3. Write a half equation for the discharge of copper(II) ions.

4. State whether this is an oxidation or reduction reaction.

5. What negative ions are present in the copper(II) chloride solution?

6. Write a half equation for the discharge of chloride ions.

7. State whether this is an oxidation or reduction reaction.

8. Chlorine is a more reactive halogen than bromine and iodine. Explain how the observations in the drops of potassium halide support this statement.

9. Chlorine forms acidic and oxidising substances when dissolved in water. Explain how the observations in the damp blue litmus paper support this statement.

Worksheet F: Chemical equations for the reactions

1. Draw a labelled diagram showing the electrolysis of copper(II) sulfate solution.

2. Describe how the movement of particles in the apparatus you drew in Q1 allows for the production of copper and oxygen.

3. Complete the table below identifying the products of electrolysis of the substances.

Substance	Positive electrode (anode)	Negative electrode (cathode)
Molten lead(II) bromide		
Concentrated aqueous sodium chloride		
Dilute sulfuric acid		

4. Write ionic half equations for the reactions at both electrodes for the electrolysis of concentrated aqueous sodium chloride.

5. What substance is left over when the electrolysis in Q2 is complete. Explain your answer.

6. A student wants to silver plate some steel cutlery to make them more attractive. Outline a method the student could use.

Worksheet A: Answers

Ion	Formula	Ion	Formula
Copper(II)	Cu^{2+}	Nitrate	NO_3^-
Iron(III)	Fe^{3+}	Carbonate	CO_3^{2-}
Sodium	Na^+	Chloride	Cl^-
Zinc(II)	Zn^{2+}	Sulfate	SO_4^{2-}
Silver(I)	Ag^+	Bromide	Br^-
Magnesium	Mg^{2+}	iodide	I^-
Hydrogen	H^+	Hydroxide	OH^-

	Negative ions	Positive ions
Will discharge in aqueous solution	Chloride, bromide, iodide, hydroxide	Copper(II), silver(I), hydrogen
Won't discharge in aqueous solution	Carbonate, nitrate, sulfate	Iron(III), sodium, zinc(II), magnesium

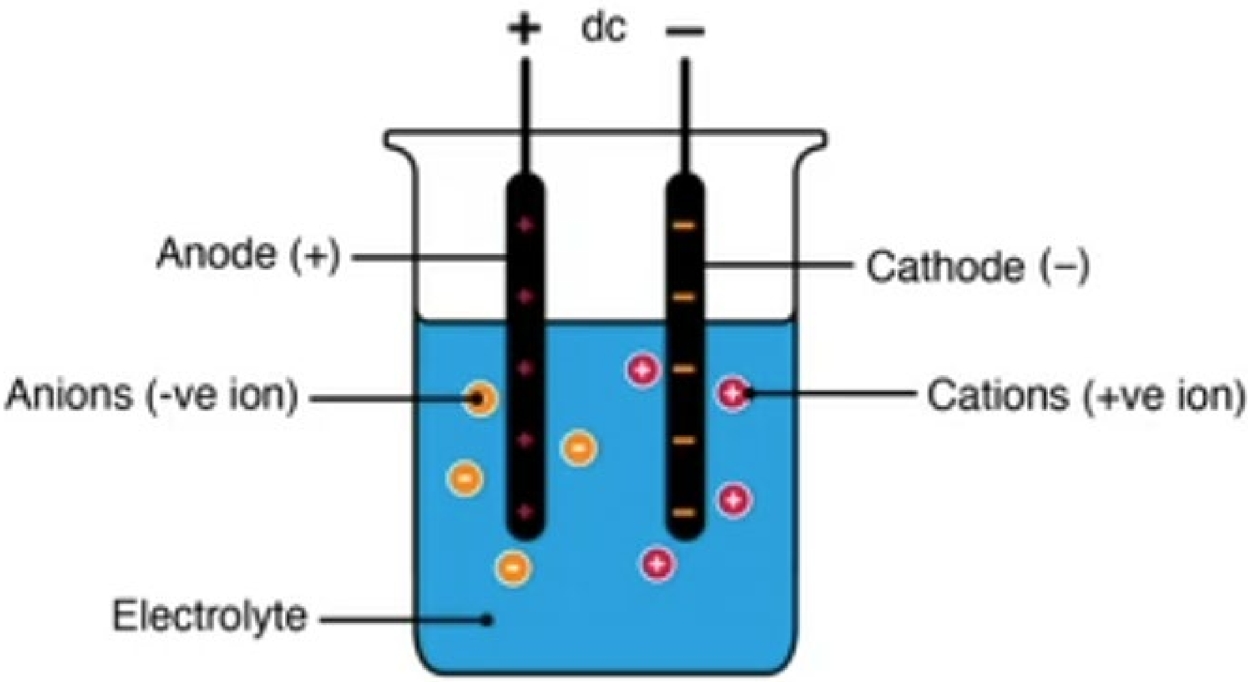
Worksheet D: Answers

1. Start – blue, end - colourless
2. A brown solid forming.
3. Bubbles of colourless gas forming.
4. The potassium iodide drop turned brown quickly, the potassium bromide drop turned brown more slowly.
5. The paper decolourised over time, turning from blue to white. The edges of the paper turned briefly red.
6. Very large quantities of copper(II) chloride solution would be needed, which would be very expensive. Much larger power sources would be required, which would prove dangerous. Large quantities of chlorine would be produced and need to be safely captured, as chlorine is a toxic gas. The copper formed would need to be purified from the electrolyte.
   The students may make other suggestions, including cheaper sources of chloride ions, such as sea water. They may identify reaction of copper(II) oxide with carbon powder as a better method for producing copper.

Worksheet E: Answers

1. Cu^{2+}, H^+
2. Copper is less reactive than hydrogen, so will preferentially discharge under electrolysis.
3. $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$
4. Reduction, as the copper ion is gaining electrons.
5. Cl^-, OH^-
6. $2Cl^-(aq) \rightarrow Cl_2(g) + 2e^-$
7. Oxidation, as the chloride ions are losing electrons.
8. Chlorine reacts with potassium iodide in solution, producing potassium chloride and iodine. Iodine in solution is a brown, which is observed. A similar reaction occurs in the potassium bromide drop, with potassium chloride and bromine (orange/brown in solution) forming.
9. Chlorine reacts with water, forming hydrochloric acid and hydrogen chlorate(I). The hydrochloric acid is acidic, turning litmus from blue to red. The hydrogen chlorate(I) is an oxidising agent, and bleaches the litmus, turning litmus from blue to white.

Worksheet F: Answers



1.
2. The Cu^{2+} ions are attracted to and flow towards the negative electrode, as they have opposite charges. At the negative electrode, the copper ions gain electrons, forming copper atoms.
   The hydroxide ions are attracted to and flow towards the positive electrode, as they have opposite charges. At the positive electrode, the hydroxide ions lose electrons, forming oxygen and water.
   The electrons flow through the electrodes and external circuit from the positive electrode to the negative electrode.
3. Complete the table below identifying the products of electrolysis of the substances.

Substance	Positive electrode (anode)	Negative electrode (cathode)
Molten lead(II) bromide	Bromine (Br_2)	Lead (Pb)
Concentrated aqueous sodium chloride	Chlorine (Cl_2)	Hydrogen (H_2)
Dilute sulfuric acid	Oxygen (O_2)	Hydrogen (H_2)

4. Positive: $2Cl^{-}(aq) \rightarrow Cl_2(g) + 2e^{-}$; Negative: $2H^{+}(aq) + 2e^{-} \rightarrow H_2(g)$
5. Sodium hydroxide. The sodium ions come from the sodium chloride. As the hydrogen ions discharge, more hydroxide ions are formed by water self-ionising.

6)

- Place a solution of silver nitrate in a beaker.
- Connect a piece of pure silver to the positive terminal of a power pack, and place the silver in the beaker.
- Connect the piece of cutlery to the negative terminal of the power pack, and place the cutlery in the beaker.
- Turn on the power and observe the plating reaction.

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