Teaching Pack

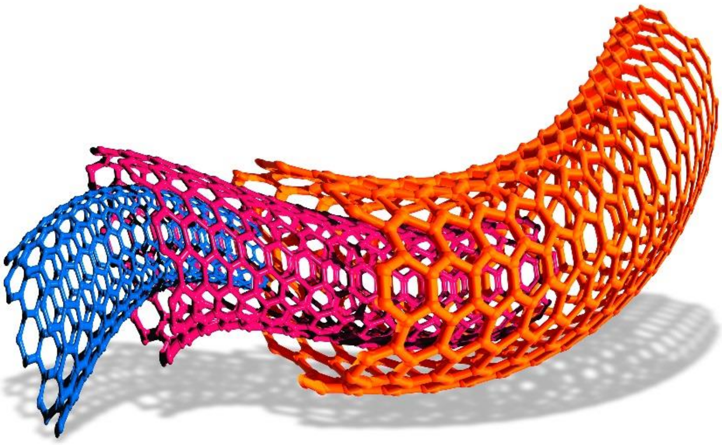
The electrolysis of molten zinc chloride

Cambridge IGCSE™

Chemistry 0620

This *Teaching Pack* can also be used with the following syllabuses:

- Cambridge IGCSE (9–1) Chemistry **0971**
- Cambridge IGCSE Physical Science **0652**
- Cambridge IGCSE Combined Science **0653**
- Cambridge IGCSE Co-ordinated Sciences (Double Award) **0654**
- Cambridge IGCSE (9–1) Co-ordinated Sciences (Double Award) **0973**
- Cambridge O Level Chemistry **5070**
- Cambridge O Level Combined Science **5129**



Version 1

Contents

Icons used in this pack:

Briefing lesson

Lab lesson: Option 1 – run the experiment

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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 *Teaching 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 *Teaching 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*.

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*.

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

Experiment: The Electrolysis of Molten Zinc Chloride

This *Teaching Pack* focuses on electrolysis.

Electrolysis is one of the main methods of obtaining metals from their ores. An electric current is passed into the molten zinc chloride electrolyte causing a non-spontaneous reaction to occur. Reactions at the electrodes produce zinc metal and chlorine gas.

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

- 4.1 Electrolysis
- 6.4 Redox
- 9.4 Reactivity series
- 12.5 Identification of ions and gases

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

- Demonstrate knowledge of how to safely set up an electrolysis of a molten salt.
- Plan an electrolysis experiment.
- Record observations during the experiment and test products
- Interpret and evaluate observational data

Prior knowledge

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

- 2.4 Ions and ionic bonds
- 4.1 Electrolysis
- 9.4 Reactivity series
- 12.5 Identification of ions and gases

Going forward

The knowledge and skills gained from this experiment can be used for when you teach learners about the extraction of metals using redox reactions.

- 6.4 Redox

Briefing lesson: Planning the electrolysis experiment

Resources	• Worksheet A and answer sheet • Worksheet B and answer sheet • A sample of zinc chloride to show learners.
Learning objectives	By the end of the lesson: • ***all*** learners should have been able to draw their lab design with guidance and provide some of the annotations correctly. • ***most*** learners should have been able to draw their lab design and annotated it fully with some assistance. • ***some*** learners will additionally be able to explain how to test the products of the electrolysis.

Timings	**Activity**
10 min	**Starter/Introduction** The objective of this starter activity is to review the reactivity series. Distribute Worksheet A. In pairs, ask learners to annotate the blank reactivity series. Answers are then checked according to the corresponding answer sheet.
45 min	**Main lesson** Show learners some zinc chloride in a dish. Ask learners what its formula is, and what the type of bonding is has. [$ZnCl_2$, ionic bonding] Next, ask learners which elements they might obtain from it. [zinc and chlorine] Explain to the learners that in this lesson they are going to design an experiment to safely obtain zinc and chlorine from zinc chloride. It may be worth pointing out that zinc chloride is being used because it has a particularly low melting point and can therefore be performed in a school laboratory. This is perhaps worth mentioning because in fact zinc sits below carbon in the reactivity series (and could also be obtained by extraction). Divide learners into pairs. Give out Worksheet B. Read through the list of equipment they will have available to them. Explain that their task is to: i. devise a way to use all the equipment/materials to perform an electrolysis experiment ii. test the products. iii. Consider all safety aspects of the experiment.

Timings	Activity
	All the necessary equipment/materials should be on display so that learners can easily access it. [if some or all the equipment is unavailable, supply learners with access to images].
5 min	**Plenary** Handout Worksheet B – answers, so learners can compare their proposed set-up with that of the accepted correct set-up. Discuss any queries and differences with the class.

Lab lesson: Option 1 – run the experiment

Resources	• Worksheets C and D and their corresponding answer sheets
Learning objectives	By the end of the lesson: • ***all*** learners should be able to answer most of the questions on worksheet C and answer the more basic half equation questions on worksheet D • ***most*** learners should be able to answer all questions on worksheet C and be able to construct most of the half-equations/ overall cell reactions on worksheet D with some guidance. • ***some*** learners will be able to answer all questions on worksheet C and be able to correctly construct all the half-equations/ overall cell reactions without assistance.

Timings	Activity
5 min	**Starter/Introduction** Ask learners what the word 'electrolysis' means to them. [splitting a substance using electricity]. Discuss which kinds of substances can and cannot be split up by electricity. [ionic compounds can, but covalent substances cannot]. Explain that in this lesson only the electrolysis of molten compounds will be treated but in the Debriefing lesson, aqueous electrolyses will be discussed.
	Main lesson This experiment is for demonstration only. **Safety** This experiment must be set-up in a fume cupboard since poisonous chlorine gas is produced during the electrolysis.
5 min	**Set-up** Show the video of the lesson as far as 03:04, urging learners to watch carefully. Most learners will have a good idea what to do already from the Briefing lesson.
40 min	**Run the experiment** Position learners at a safe distance from the fume cupboard so that they can see. Hand out the question Worksheet C which learners will complete during the practical. Ask volunteers to help set the experiment up to the point where the electrodes are ready to be lowered into the crucible. After this point you should take over. Read out loud the questions from Worksheet C at the appropriate time, elaborating on any points you feel necessary.

Timings	Activity
	After the experiment Go through the Worksheet C, answers with the learners. **Half-equations and overall cell reactions** Hand out Worksheet D. This worksheet may be discussed and started during the waiting periods in the above procedure. All the examples on the worksheet concern the electrolysis of molten salts. Aqueous salt electrolyses will be treated in the debriefing lesson. Learners may need reminding that electrons travel around the external circuit (flow of electric current) but only ions move in the electrolyte. You may also need to remind learners about the concept of Lowest Common Multiple, regarding the cancelling of electrons and balancing of equations.
10 min	**Plenary** Handout Worksheet D, answers. Check through the answers carefully with learners.

Teacher notes

Watch the electrolysis of molten zinc chloride video (teacher version) and read these notes.

The electrolysis demonstration will require:

- zinc chloride
- a porcelain crucible
- 2 x carbon electrodes
- a tripod
- a pipe clay triangle
- 2 x crocodile clips
- connecting cables
- a bulb
- a DC power supply set at 12V
- a Bunsen burner
- a heatproof mat
- a clamp stand and boss
- a pair of tongs
- a metal spatula
- an ammeter

Safety

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

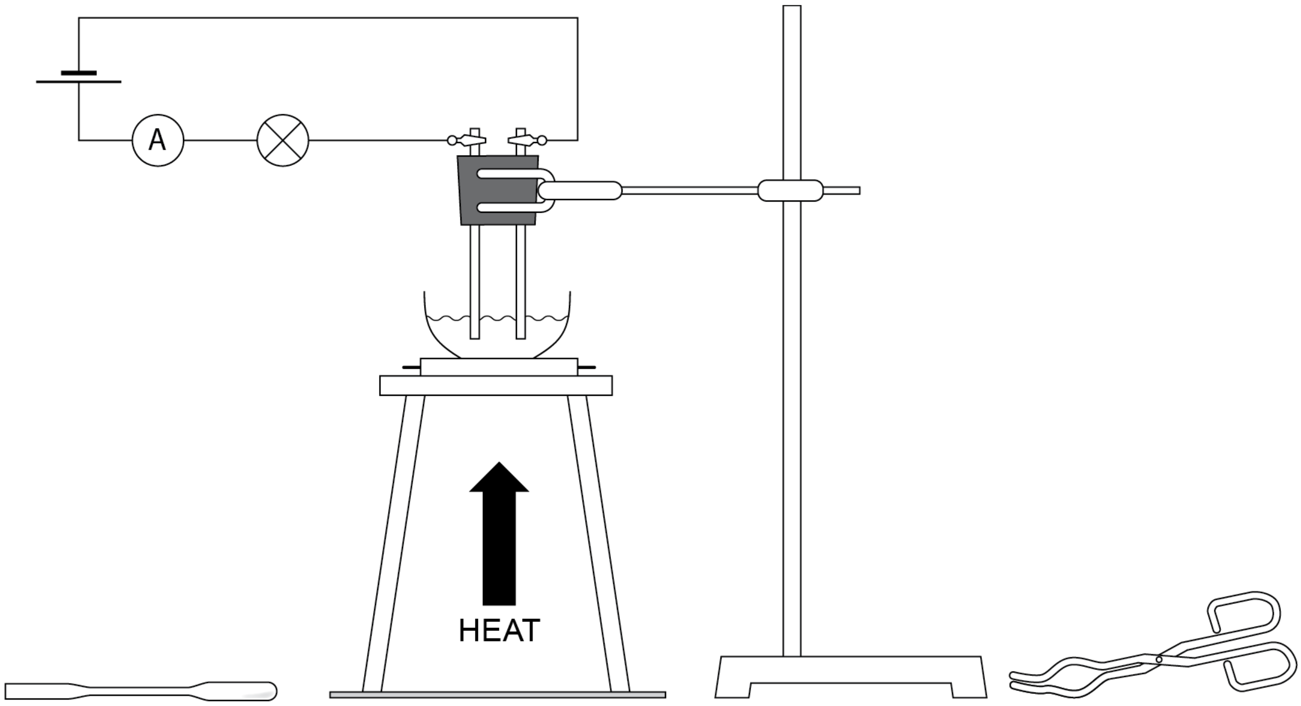
It is your responsibility to carry out an appropriate risk assessment for this experiment.

Substance/situation	Hazard	First aid
Use a fume cupboard for this experiment	Chlorine gas evolved over an extended period of time (>15min) See below	
Chlorine gas	 GHS03 (*oxidising* **O**) 	**Vapour breathed in:** Remove the casualty to fresh air. Consult a medic if breathing is even slightly affected. **Gas escape in a laboratory:** Open all windows. If over 1 litre of gas is released, evacuate the laboratory. The potential for the release of 1l of gas is possible given the amounts of solid used, but it is produced over an extended time period so danger should be minimised.

Substance/situation	Hazard	First aid
	GHS09 (*hazardous to the aquatic environment* **N**)  GHS06 (*acutely toxic* **T**)	N.B. Small amounts of Cl_2 [C] [T], which can cause respiratory distress in some people, may be produced. The laboratory must be well ventilated.
Solid zinc chloride	 GHS05 (*corrosive* **C**)  GHS07 (*moderate hazard* **MH**)  GHS09 (*hazardous to the aquatic environment* **N**)	**In the eye:** flood the eye with gently-running tap water for at least 10 minutes. See a doctor. **Swallowed:** Do no more than wash out the mouth with water. Do not induce vomiting. Consult a medic. **Spilt on the skin or clothing:** remove contaminated clothing and rinse it. Wash off the skin with plenty of water. **Dust breathed in:** Remove the casualty to fresh air. Consult a medic if breathing is difficult.
Burns	The crucible will be extremely hot. Only after 15 minutes should the crucible be lifted with tongs and plunged into a large volume of cold water in a beaker.	**Immediately get the person away** from the heat source to stop the burning. **Cool the burn** with cool or lukewarm running water for 20 minutes – don't use ice, iced water, or any creams or greasy substances. **Remove any clothing or jewellery** that's near the burnt area of skin, but don't move anything that's stuck to the skin. **Cover the burn** by placing a layer of cling film over it – a clean plastic bag could also be used for burns on your hand.

Substance/situation	Hazard	First aid
		Use painkillers such as paracetamol or ibuprofen to treat any pain. **If the face or eyes are burnt**, sit up as much as possible, rather than lying down - this helps to reduce swelling. **Where burns are severe**, consult a medic.
Singeing leads	Ensure that the electrical leads do not hang above the Bunsen burner.	

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. They will refer to Worksheet B, answers from the planning lesson.

Before you begin

Plan how you will seat your learners around the fume cupboard during the experiment session.

Think about:

- the amount of equipment/chemicals required.

During this demonstration lesson, make sure that you pause to ask questions and allow learners to answer the questions on Worksheet D.

Experiment

Step	Notes
Follow the initial equipment set up as in the video. Ensure that the fume cupboard is switched on and that the learners are safely seated and can see as well as possible.	With larger groups it can be challenging to allow all learners viewing access. In this case, you might consider inviting small groups at a time to view the experiment more closely with the hood down.
After igniting the Bunsen burner, move it under the crucible. Use a small, focused blue flame.	Ensure that there are no leads dangling into the flame.
As soon as the zinc chloride starts to melt, the bulb should light, and the ammeter should show a reading.	Indicate this to your learners.
Test the gas being evolved at the anode.	You might consider allowing learners to each take a piece of damp litmus paper and test the gas evolved themselves. If you do this, explain that they should not touch the apparatus because it is most likely very hot. They should also not allow the litmus paper to touch the molten salt or electrodes, etc. If you use damp blue litmus paper, it will turn red before bleaching. Explain that this is perfectly normal because as well as a bleaching effect, the chlorine dissolves in the damp environment of the litmus paper to create at least one acid. Smell of chlorine gas: point out the smell to learners. They may be able to notice it and perhaps comment that it smells like ‘a

Step	Notes
	swimming pool'. The smell of chlorine can be detected at very low concentrations, so explain to learners that there is no cause for alarm in being able to detect it.
Continue the electrolysis for at least 15 minutes – longer if possible.	Pull the fume cupboard hood down to ensure efficient extraction. This would be a good time to handout Worksheet D to discuss the half-equation for this reaction together. Afterwards, if there is still time, learners could start answering the rest of the questions on that sheet.
After 15 minutes, using tongs, plunge the crucible into a beaker of pure water.	The contents should quickly dissolve but you can agitate the crucible, to speed up this process. Do not use a huge volume of water, since this will take a long time to filter in the next stage. To keep learners involved, ask for a volunteer to help you with this stage.
After filtration, dry the filter paper and scrape the residue off the paper.	The filtration process can take up a lot of your lesson. It may be a good idea to have a sample prepared earlier to test.
Test the residue to see if it conducts electricity.	Learners can help with this stage also. Sometimes the residue does not conduct electricity probably due to impurities in the starting materials and/or oxidation of the zinc formed. If you are unable to get the conductivity test to work, you can always have a sample of powdered zinc ready on a filter paper to test instead.

Clean-up

After the experiment you should:

- clean down and put away equipment
- dispose of any chemical waste into the main chemical waste in a central location
- wash hands with soap and water.

Lab lesson: Option 2 – virtual experiment

Resources	• Virtual experiment video • Worksheets C and D and corresponding answer sheets
Learning objectives	• ***all*** learners should be able to answer most of the questions on Worksheet C and answer the more basic half equation questions on Worksheet D • ***most*** learners should be able to answer all questions on Worksheet C and be able to construct most of the half-equations/ overall cell reactions on Worksheet D with some guidance. • ***some*** learners will be able to answer all questions on Worksheet C and be able to correctly construct all the half-equations/ overall cell reactions without assistance.

Timings	Activity
5 min	**Starter/Introduction** Ask learners what the word 'electrolysis' means to them. [splitting a substance using electricity]. Discuss which kinds of substances can and cannot be split up by electricity. [ionic compounds can but covalent substance cannot]. Explain that in this lesson only the electrolysis of molten compounds will be treated but in the Debriefing lesson, aqueous electrolyses will be discussed.
5 min 40 min	**Main lesson** **Set-up** Show the video of the lesson as far as 03:04, urging learners to watch carefully. **Questions associated with the practical** Handout the question Worksheet C to pairs of learners. They will complete this while watching the remainder of the video. Read out each question at the relevant time whilst stopping and starting the video accordingly. Go through the answer Worksheet C with the learners. **Half-equations and overall cell reactions** Hand out Worksheet D. All the examples on the sheet concern the electrolysis of molten salts. Aqueous salt electrolyses will be treated in the debriefing lesson. Learners may need reminding that electrons travel around the external circuit (flow of electric current) but only ions move in the electrolyte. You may also need to remind learners about the concept of Lowest Common Multiple regarding the cancelling of electrons and balancing of equations.

Timings	Activity
10 min	**Plenary** Handout Worksheet D, answers. Check through answers carefully with learners since some learners may find this topic challenging.

Debriefing lesson: Electrolysis of aqueous solutions

Resources	- Worksheet E and corresponding answer sheet - Worksheet B (reactivity series)

Learning objectives	By the end of the lesson: - ***all*** learners should be able to complete the simpler questions involving the electrolysis of aqueous solutions with some guidance. - ***most*** learners should be able to complete the simpler questions involving the electrolysis of aqueous solutions independently. - ***some*** learners will be able to complete all questions correctly including the correct construction of the half-reactions at the electrodes.

Timings	Activity
5 min	**Starter/Introduction** Ask learners what the products of **molten** potassium bromide are? [potassium and bromine] Then ask them what effect using a concentrated **aqueous** solution of potassium bromide might have on the outcome of the electrolysis. The responses you receive will of course depend on whether you have discussed aqueous electrolysis before or not. [hydrogen and bromine]
20 min	**Main lesson** <u>Some Theory</u> It is a good idea to start from basic principles and explain the rules of electrolysis from the beginning. Learners may find taking notes helpful. Elaborating on the example above, explain to learners that in aqueous electrolyses, water gives rise to hydrogen (H^+) ions and hydroxide (OH^-) ions through its dissociation as follows: $H_2O \rightleftharpoons H^+ + OH^-$ Thus in the aqueous electrolysis of potassium bromide, there are two cations attracted to the cathode and two anions attracted to the anode. Ask for input from learners to find these ions and write their forumlae correctly: Anode (+) — Cathode (-) OH^- — H^+ Br^- — K^+ Only one ion can be discharged at each of the electrodes. Therefore, at the anode either water or bromine will be produced. At the anode, either hydrogen or potassium will be produced.

Timings	Activity
	In order to be able to predict which substance will be produced at each electrode, it is necessary to once again, consider the reactivity series. The following rules apply which learners may wish to write down in their notebooks for future reference: At the Cathode **Hydrogen** is produced if the metal is more reactive than hydrogen (if the metal is above hydrogen in the reactivity series). If it is less reactive, the **metal** forms. At the Anode If the electrolyte contains a halide (chloride, bromide or iodide) and the solution is concentrated, the corresponding **halogen** is produced. If the electrolyte contains a halide (chloride, bromide or iodide), but the solution is dilute, **oxygen** is produced. If there is no halogen present, again, oxygen is produced. Considering the electrolysis of a concentrated aqueous solution of potassium bromide: At the anode, bromine is produced since the solution is concentrated. At the cathode, potassium is more reactive than hydrogen and so hydrogen is produced. Refer to the reactivity series on Worksheet B Anode (+) Cathode (-) OH^- H^+ Br^- K^+ The process can be seen more clearly by writing half-equations for the reactions at the electrodes: $2Br^-_{(aq)} \longrightarrow Br_{2(g)} + 2e^-$ $2H^+_{(aq)} + 2e^- \longrightarrow H_{2(g)}$
25 min	Handout Worksheet E, which asks learners questions about aqueous electrolysis. Learners can work in pairs for this activity. In question 3 and 4, learners may require assistance with the half-equation producing oxygen from hydroxide ions.
10 min	**Plenary** Hand out Worksheet E, answers. Go through the correct answers to the aqueous electrolysis questions.

Worksheets and answers

	Worksheets	Answers
For use in the *Briefing lesson:*		
A: The reactivity series	**20**	**31**
B: Experiment set-up	**21**	**32**
For use in *Lab lesson: Option 1:*		
C: Questions to ask during the practical	**24**	**34**
D: Half-equations and overall reactions in electrolysis	**26**	**36**
For use in *Lab lesson: Option 2:*		
C: Questions to ask during the practical	**24**	**34**
D: Half- equations and overall reactions in electrolysis	**26**	**36**
For use in the *Debriefing lesson:*		
E: The products of aqueous electrolyses	**28**	**38**

Worksheet A: The reactivity series

On the reactivity series below, annotate the following:

i. Two metals which can be found on Earth uncombined with other substances:

ii. The most reactive metal in the list:

iii. The least reactive metal in the reactivity series:

iv. A non-metal which is solid at room temperature:

v. A non-metal which is gaseous at room temperature:

vi. A metal which is obtained from its ores by metal extraction:

vii. A metal which is usually obtained by electrolysis:

Potassium
Sodium
Calcium
Magnesium
Aluminium
Carbon
Zinc
Iron
Hydrogen
Copper
Silver
Gold

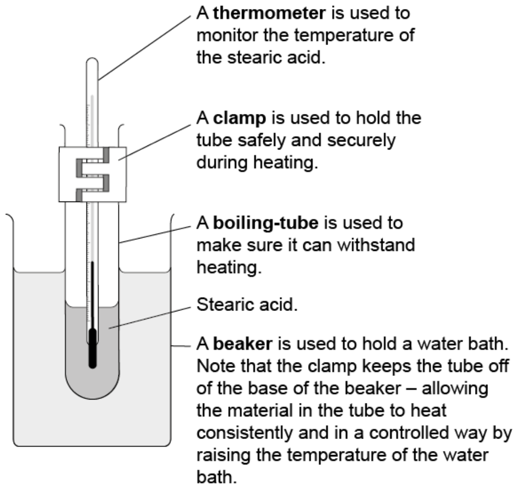
Worksheet B: Experiment set-up

This is a suggested list of the equipment and materials you need to electrolyse molten zinc chloride.

- Powdered zinc chloride
- a porcelain crucible
- 2 x carbon electrodes
- a tripod
- A pipe clay triangle
- 2 x crocodile clips
- connecting cables
- a bulb
- a DC power supply set to 12V
- a Bunsen burner
- a heatproof mat
- a clamp stand
- a pair of tongs
- a spatula
- an ammeter

Tasks

1. Use the example given for reference and draw how you think the experiment should be set-up safely.



A **thermometer** is used to monitor the temperature of the stearic acid.

A **clamp** is used to hold the tube safely and securely during heating.

A **boiling-tube** is used to make sure it can withstand heating.

Stearic acid.

A **beaker** is used to hold a water bath. Note that the clamp keeps the tube off of the base of the beaker – allowing the material in the tube to heat consistently and in a controlled way by raising the temperature of the water bath.

2. Annotate each piece of equipment, explaining the function of each in short, clear sentences.

Worksheet B: Experiment set-up, *continued*

Worksheet B: Experiment set-up, *continued*

Additional questions

1. Explain below how you would test that the product formed at the anode is chlorine.

   Test:

   Result:

2. The substance formed at the cathode is zinc. How could you test this substance to show that it is a metal?

   Test:

   Result:

3. Other than wearing safety goggles and wearing a lab coat what safety recommendations would you make for performing this experiment? Give a reason for your answer.

Worksheet C: Questions to ask during the practical

Watch the electrolysis of molten zinc chloride carefully, and answer the following questions as the experiment progresses:

1. Why does the bulb not light up before the crucible containing zinc chloride is heated? Explain this answer in terms of chemical bonding.

2. What significance does the ammeter showing a reading have?

3. What material are the electrodes made of?

4.
   i. What charge is the anode?

   ii. What can you observe happening at this electrode?

   iii. Which chemical species moves towards the anode?

   iv. What is the special condition for the litmus paper you use in the experiment?

   v. What happens to the damp litmus paper?

   vi. What does your observation confirm?

Worksheet C: Questions to ask during the practical, *continued*

5.
  i. What is the charge at the cathode?

  ii. Which chemical species migrates towards the cathode during electrolysis?

6. Why is it necessary to continue the electrolysis for at least 15min?

7.

i. Why is it necessary to plunge the crucible into cold water?

ii. After filtration, what should the solid residue in the filter paper be?

iii. Draw a simple circuit using circuit symbols, showing how the residue is tested.

iv. What is the result of the test and what does it show?

Worksheet D: Half-equations and overall reactions in electrolysis

The following examples all involve the electrolysis of molten salts only.

Example: Your teacher will help you complete this initial example which is for the electrolysis of molten zinc chloride.

Half-equation occurring at the Cathode (-) →

Half-equation occurring at the Anode (+) →

Overall reaction: →

<u>Questions</u>

Following similar ideas, write half-equations and overall equations for the following molten electrolyses:

1. Sodium chloride

Half-equation occurring at the Cathode (-) →

Half-equation occurring at the Anode (+) →

Overall reaction: →

Worksheet D: Half-equations and overall reactions in electrolysis, *continued*

2. Lead bromide ($PbBr_2$)

Half-equation occurring at the Cathode (-) →

Half-equation occurring at the Anode (+) →

Overall reaction: →

3. Aluminium oxide (Al_2O_3)

Half-equation occurring at the Cathode (-) →

Half-equation occurring at the Anode (+) →

Overall reaction: →

Worksheet E: The products of aqueous electrolyses

For each of the following aqueous solutions:

a) Write the chemical formulae of the ions which are attracted to each electrode.
b) Then, according to the rules governing the products of electrolyses, name the product formed.
c) Explain the reason for your choice.
d) Finally, write down the half-equations occurring at each electrode.

Use a copy of the reactivity series on the worksheet to help you answer this question.

1. Concentrated aqueous sodium chloride solution.

At the cathode:

Ions attracted:

Product:

Explanation:

Half-reaction:

At the anode:

Ions attracted:

Product:

Explanation:

Half-reaction:

2. Concentrated aqueous calcium iodide solution.

At the cathode:

Ions attracted:

Product:

Explanation:

Half-reaction:

Worksheet E: The products of aqueous electrolyses, *continued*

At the anode:

Ions attracted:

Product:

Explanation:

Half-reaction:

3. Copper (II) sulfate solution.

At the cathode:

Ions attracted:

Product:

Explanation:

Half-reaction:

At the anode:

Ions attracted:

Product:

Explanation:

Half-reaction:

4. A dilute aqueous sodium chloride solution.

At the cathode:

Ions attracted:

Product:

Explanation:

Half-reaction:

Worksheet E: The products of aqueous electrolyses, *continued*

At the anode:

Ions attracted:

Product:

Explanation:

Half-reaction:

Worksheet A: Answers

On the reactivity series below, annotate the following:

i. Two metals which can be found on Earth uncombined with other substances:

ii. The most reactive metal in the list:

iii. The least reactive metal in the reactivity series:

iv. A non-metal which is solid at room temperature:

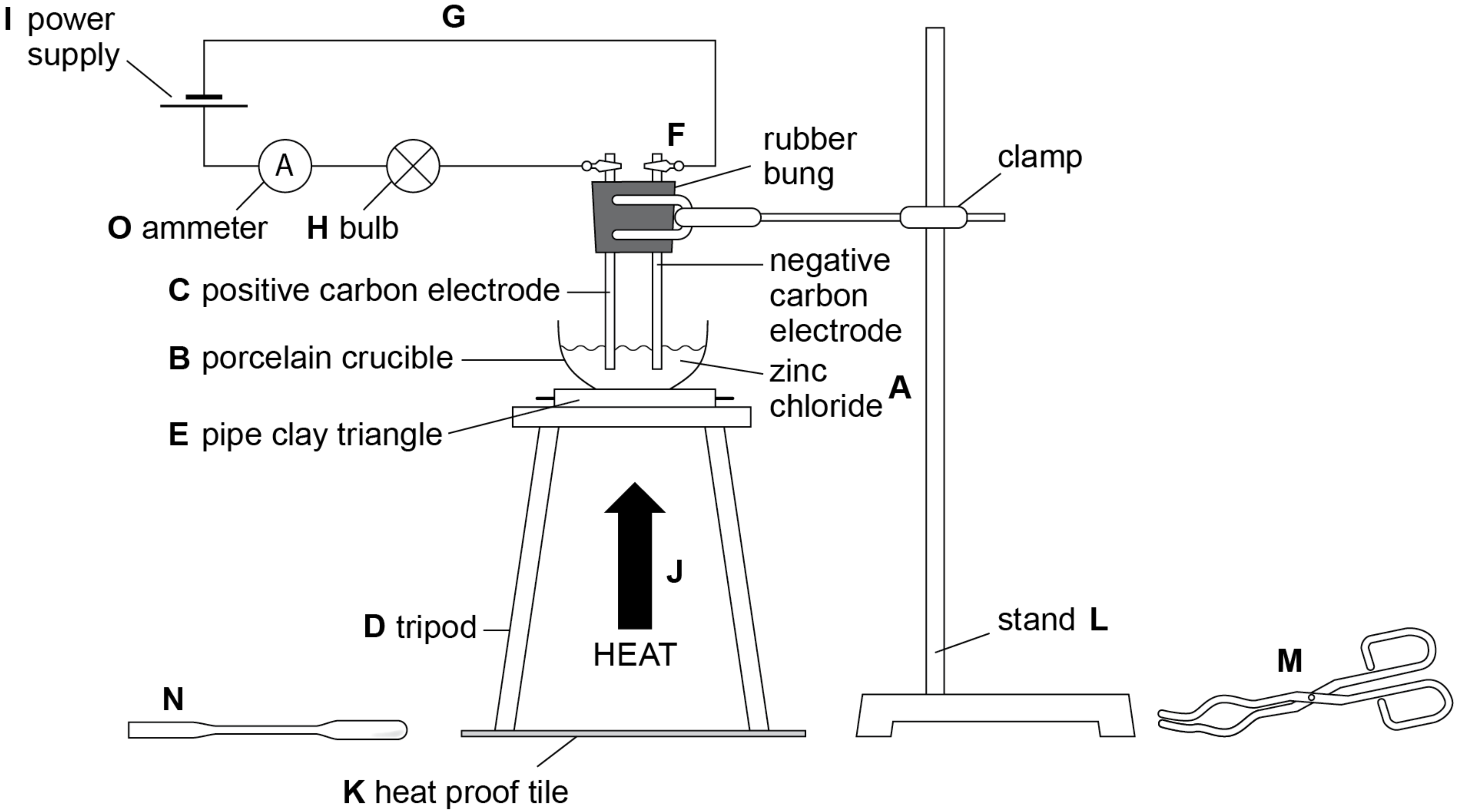
v. A non-metal which is gaseous at room temperature:

vi. A metal which is obtained from its ores by metal extraction:

vii. A metal which is usually obtained by electrolysis:

Potassium	The most reactive metal in the reactivity series
Sodium	
Calcium	
Magnesium	
Aluminium	A metal which is obtained from its ores by electrolysis
Carbon	A non-metal which is solid at room temperature
Zinc	
Iron	A metal which is obtained from its ores by metal extraction
Hydrogen	A gaseous non-metal
Copper	
Silver	May be found uncombined
Gold	May be found uncombined. The least reactive metal in this list

Worksheet B: Answers



Worksheet B: Answers, *continued*

- Powdered zinc chloride
- A porcelain crucible is a vessel which can withstand high temperatures
- Carbon electrodes conduct electricity and form part of the external circuit during electrolysis. They are also inert meaning that they do not take part chemically in the electrolysis.
- A tripod is used to support the apparatus above it
- A pipe clay triangle supports the crucible and is able to withstand high temperatures
- Connecting cables form the external circuit together with the electrodes
- A bulb is used to show when the external circuit is complete meaning that ions can move in the molten electrolyte
- The DC power supply provides the electric current necessary to cause the reaction
- A Bunsen burner is used to melt the zinc chloride
- A heatproof mat is necessary to protect the surface below it
- A clamp stand is needed to move the electrode assembly into and out of the crucible
- A pair of tongs is required to pick up the hot crucible
- A spatula is needed to transfer and compact zinc chloride into the crucible
- A positive reading on the ammeter shows that the electrolysis is in progress.

Answers to additional questions

1. Explain below how you would test that the product formed at the anode is chlorine.

Test: *Hold a piece of damp indicator paper close to the anode.*

Result: *If the paper bleaches, this confirms the presence of chlorine gas.*

2. The substance formed at the cathode is zinc. How could you test this substance to show that it is a metal?

Test: *Make a conductivity testing circuit using a bulb, a DC power supply and some leads. Touch the leads to the metal produced from the reaction to complete a circuit.*

Result: *If the bulb lights then the product is a metal (sensibly the metal should be zinc since the starting material was zinc chloride).*

3. Other than wearing safety goggles and wearing a lab coat what safety recommendations would you make for performing this experiment? Give a reason for your answer.

Ensure that this experiment is performed in a fume cupboard. This is because the chlorine produced is a toxic gas.

Worksheet C: Answers

Watch the electrolysis of molten zinc chloride carefully, and answer the following questions as the experiment progresses:

1. Why does the bulb not light up before the crucible containing zinc chloride is heated? Explain this answer in terms of chemical bonding.

This is because the zinc chloride is solid and ionic solids cannot conduct electricity because their ions are bound tightly in a lattice.

2. What significance does the ammeter showing a reading have?

A reading on the ammeter indicates that an electric current is now flowing in the external circuit – electrolysis has begun

3. What material are the electrodes made of?

The electrodes are made of graphite

4.
   i. What charge is the anode?

   It is positively charged

   ii. What can you observe happening at this electrode?

   bubbles of gas are observed coming from the anode

   iii. Which chemical species moves towards the anode?

   chloride ions (Cl^-)

   iv. What is the special condition for the litmus paper you use in the experiment?

   it must be damp

   v. What happens to the damp litmus paper?

   the damp litmus paper becomes bleached

   vi. What does your observation confirm?

   this confirms the presence of chlorine gas

Worksheet C: Answers, *continued*

5.

i. What is the charge at the cathode?

The cathode is negatively charged

ii. Which chemical species migrates towards the cathode during electrolysis?

The positively charged zinc ions migrate towards the cathode. (Zn^{2+})

6. Why is it necessary to continue the electrolysis for at least 15min?

The crucible has been filled with zinc chloride. It takes time to break down all the ionic solid using electricity. A current must therefore be passed for at least 15min

7.

i. Why is it necessary to plunge the crucible into cold water?

The purpose of doing this is to dissolve any unreacted zinc chloride

ii. After filtration, what should the solid residue in the filter paper be?

The remaining solid should be zinc

iii. Draw a simple circuit using circuit symbols, showing how the residue is tested.

Your circuit should contain a bulb, a power pack and connecting leads

iv. What is the result of the test and what does it show?

The bulb should light up. This shows that the substance is likely to be metallic. [in this case, zinc since the starting material was zinc chloride]

Worksheet D: Answers

The following examples all involve the electrolysis of molten salts only.

Example: Your teacher will help you complete this initial example which is for the electrolysis of molten zinc chloride.

Half-equation occurring at the Cathode (-) $Zn^{2+} + \cancel{2e^-} \longrightarrow Zn$

Half-equation occurring at the Anode (+) $2Cl^- \longrightarrow Cl_2 + \cancel{2e^-}$

Overall reaction: $Zn^{2+} + 2Cl^- \equiv ZnCl_{2(l)} \longrightarrow Zn_{(l)} + Cl_{2(g)}$

<u>Questions</u>

Following similar ideas, write half equations and overall equations for the following molten electrolyses:

1. Sodium chloride

Half-equation occurring at the Cathode (-) $Na^+ + e^- \longrightarrow Na$

Doubled to balance electrons: $2Na^+ + \cancel{2e^-} \longrightarrow 2Na$

Half-equation occurring at the Anode (+) $2Cl^- \longrightarrow Cl_2 + \cancel{2e^-}$

Overall reaction: $2Na^+ + 2Cl^- \equiv 2NaCl_{(l)} \longrightarrow 2Na_{(l)} + Cl_{2(g)}$

Worksheet D: Answers, *continued*

2. Lead bromide ($PbBr_2$)

Half-equation occurring at the Cathode (-) $Pb^{2+} + \cancel{2e^-} \longrightarrow Pb$

Half-equation occurring at the Anode (+) $2Br^- \longrightarrow Br_2 + \cancel{2e^-}$

Overall reaction: $Pb^{2+} + 2Br^- \equiv PbBr_{2)l)} \longrightarrow Pb_{(l)} + Br_{2(g)}$

3. Aluminium oxide (Al_2O_3)

Half-equation occurring at the Cathode (-) **x4** $Al^{3+} + 3e^- \longrightarrow Al$

Half-equation occurring at the Anode (+) **x3** $2O^{2-} \longrightarrow O_2 + 4e^-$

Electrons do not balance on the left and right above and cannot be cancelled. Therefore, the half equations must be multiplied in accordance with their lowest common multiple (12):

Half-equation occurring at the Cathode (-) $4Al^{3+} + \cancel{12e^-} \longrightarrow 4Al$

Half-equation occurring at the Anode (+) $6O^{2-} \longrightarrow 3O_2 + \cancel{12e^-}$

Overall reaction: $4Al^{3+} + 6O^{2-} \equiv 2Al_2O_3 \longrightarrow 4Al_{(l)} + 3O_{2(g)}$

Worksheet E: Answers

1. Concentrated aqueous sodium chloride solution

At the cathode:

Ions attracted: H^+ and Na^+

Product: hydrogen

Explanation: sodium is a very reactive metal which lies above hydrogen in the reactivity series, therefore H^+ ions are discharged.

Half-reaction: $2H^+_{(aq)} + 2e^- \longrightarrow H_{2(g)}$

At the anode:

Ions attracted: Cl^- and OH^-

Product: chlorine

Explanation: the solution is concentrated solution of halide ions. Therefore, chloride ions are discharged.

Half-reaction: $2Cl^-_{(aq)} \longrightarrow Cl_{2(g)} + 2e^-$

2. Concentrated aqueous calcium iodide solution

At the cathode:

Ions attracted: Ca^{2+} and H^+

Product: hydrogen

Explanation: calcium is a reactive metal which lies above hydrogen in the reactivity series, therefore H^+ ions are discharged.

Half-reaction: $2H^+_{(aq)} + 2e^- \longrightarrow H_{2(g)}$

At the anode:

Ions attracted: I^- and OH^-

Product: iodine

Explanation: the solution is concentrated solution of halide ions. Therefore, iodide ions are discharged.

Half-reaction: $2I^-_{(aq)} \longrightarrow I_{2(g)} + 2e^-$

Worksheet E: Answers, *continued*

3. Copper (II) sulfate solution

At the cathode:

Ions attracted: Cu^{2+} and H^{+}

Product: copper

Explanation: copper is an unreactive metal below hydrogen in the reactivity series. Therefore, copper is discharged.

Half-reaction: $Cu^{2+}_{(aq)} + 2e^{-} \longrightarrow Cu_{(s)}$

At the anode:

Ions attracted: SO_4^{2-} and OH^{-}

Product: oxygen

Explanation: the solution does not contain a halogen so oxygen is produced.

Half-reaction: $4OH^{-}_{(aq)} \longrightarrow O_{2(g)} + 2H_2O_{(l)} + 4e^{-}$

4. A dilute aqueous sodium chloride solution

At the cathode:

Ions attracted: H^{+} and Na^{+}

Product: hydrogen

Explanation: sodium is a very reactive metal which lies above hydrogen in the reactivity series, therefore H^{+} ions are discharged.

Half-reaction: $2H^{+}_{(aq)} + 2e^{-} \longrightarrow H_{2(g)}$

At the anode:

Ions attracted: Cl^{-} and OH^{-}

Product: oxygen

Explanation: the solution is dilute so OH^{-} are discharged in preference to Cl^{-} ions

Half-reaction: $4OH^{-}_{(aq)} \longrightarrow O_{2(g)} + 2H_2O_{(l)} + 4e^{-}$

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