

**TRILOGY**

**Lesson Breakdown**

Lesson 1: 4.4.1.1 Metal oxides (practical – pattern seeking enquiry)

Lesson 2: 4.4.1.2 The reactivity series (practical – pattern seeking enquiry)(water and acids)

 4.4.2.1 Reactions of acids with metals

Lesson 3: 4.4.1.2 Displacement reactions

Lesson 4: 4.4.1.3 Extraction of metals and reduction

Lesson 5: 4.4.2.4 The pH scale and neutralisation & 4.4.2.6 Strong and weak acids (HT only)

Lesson 6: 4.4.2.2 Neutralisation of acids and salt production

Lesson 7: 4.4.2.3 Soluble salts & **Required practical:** Preparing a salt (practical – reinforcing theory)

Lesson 8: 4.4.3.1 The process of electrolysis & 4.4.3.2 Electrolysis of molten ionic compounds

Lesson 9: 4.4.3.3 Using electrolysis to extract metals

Lesson 10: 4.4.3.4 Electrolysis of aqueous solutions

Lesson 11: **Required practical 3**: Electrolysis of aqueous solutions

***Embedded in several lessons: 4.4.1.4 Oxidation and reduction in terms of electrons (HT only)***

***Embedded in lesson 8 – 11: 4.4.3.5 Representation of reactions at electrodes as half equations (HT only)***

**Keystone words**

Oxidise

Reduce

Atom

Element

Ion

Neutralisation

Solution

**Lesson 7: Teacher notes**

**AQA Content**

Soluble salts can be made from acids by reacting them with solid insoluble substances, such as metals, metal oxides, hydroxides or carbonates. The solid is added to the acid until no more reacts and the excess solid is filtered off to produce a solution of the salt. Salt solutions can be crystallised to produce solid salts. Students should be able to describe how to make pure, dry samples of named soluble salts from information provided.

**Required practical 1:** preparation of a pure, dry sample of a soluble salt from an insoluble oxide or carbonate using a Bunsen burner to heat dilute acid and a water bath or electric heater to evaporate the solution.

AT skills covered by this practical activity: 2, 3, 4 and 6.

**Chunking**

* Examples of insoluble substances.
* Preparation of crystals of a soluble salt (practical).

**Practical work**

**This lesson involves a required practical.**

**It addresses the following ATs:**



**Explicit and direct explanations:**

In this practical, you will be using a range of skills to crystallise a soluble salt that has been made from an insoluble base.

Insoluble substances do not dissolve. This is useful if you want to make a salt because you can add an excess of the insoluble base to the acid. This means that you can keep adding the base until all of the acid has reacted. The excess base can then be removed by filtration.

If the base was soluble (an alkali), you would need to use an indicator or pH probe to show when all of the acid had reacted. You would then need to remove the indicator before crystallising the salt.

**Teacher notes (e.g. key questions, examples, non-examples, explanations)**

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**Teacher notes (e.g. key questions, examples, non-examples, explanations)**

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**Lesson 7: 4.4.2.3 Soluble salts & required practical: Preparing a salt**

**Objective: You are learning to make crystals of a soluble salt from an insoluble solid.**

**Skills Drill / Retrieval**

|  |  |
| --- | --- |
| Answer | PA / SA |
| 1 |  |  |
| 2 |  |  |
| 3 |  |  |
| 4 |  |  |
| 5 |  |  |

Already balanced

Magnesium sulphate + water

Copper nitrate + water

Potassium nitrate + water

Lithium nitrate

Sodium sulphate

**Catch up (complete this if you were absent last lesson):**

Complete these word equations for neutralisation reactions:

1. Sodium hydroxide + sulphuric acid 🡪 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ + water
2. Lithium hydroxide + nitric acid 🡪 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ + water
3. Potassium hydroxide + nitric acid 🡪 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_ + \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
4. Copper oxide + nitric acid 🡪 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_ + \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
5. Magnesium oxide + sulphuric acid 🡪 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ + \_\_\_\_\_\_\_\_\_\_\_

Balance this symbol equation:

 NaOH (aq) + HCl (aq) 🡪 NaCl (aq) + H2O (l)

Distillation.

Round bottom flask, Liebig condenser, beaker, Bunsen burner or other heat source.

Magnetism.

Magnet.

Evaporation.

Evaporating basin. Tripod, gauze, heat proof mat.

Filtration.

Conical flask. Funnel. Filter paper.

**Connect**

The required practical that you are going to do requires several separation techniques.

You studied separation techniques in **KS3 Separating Mixtures.**

* Name the separation technique that you would use to separate the mixtures below.
* List the apparatus that would be required.
1. Sand and water (insoluble solid and a liquid)

Technique: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Apparatus:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Sodium chloride and water (soluble solid and a liquid)

Technique: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Apparatus:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Iron and sand

Technique: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Apparatus:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Ethanol dissolved in water

Technique: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Apparatus:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_



Describe a method to make pure, dry crystals of magnesium sulfate from a metal oxide

and a dilute acid.

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Describe a safe method for making pure crystals of copper sulfate from copper carbonate and dilute sulfuric acid. Use the information in the figure above to help you.

In your method you should name all of the apparatus you will use.

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 The percentage atom economy for a reaction is calculated using:



The equation for the reaction of copper carbonate and sulfuric acid is:

CuCO3 + H2SO4 → CuSO4 + H2O + CO2

Relative formula masses : CuCO3 = 123.5; H2SO4 = 98.0; CuSO4 = 159.5

Calculate the percentage atom economy for making copper sulfate from copper carbonate.

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Atom economy = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ %

**(3)**

 Give **one** reason why is it important for the percentage atom economy of a reaction to be as high as possible.

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**(1)**

**Lesson 8: Teacher notes**

**AQA Content**

When an ionic compound is melted or dissolved in water, the ions are free to move about within the liquid or solution. These liquids and solutions are able to conduct electricity and are called electrolytes.

Passing an electric current through electrolytes causes the ions to move to the electrodes. Positively charged ions move to the negative electrode (the cathode), and negatively charged ions move to the positive electrode (the anode). Ions are discharged at the electrodes producing elements. This process is called electrolysis.

**(HT only)** Throughout Section 4.4.3 Higher Tier students should be able to write half equations for the reactions occurring at the electrodes during electrolysis, and may be required to complete and balance supplied half equations.

When a simple ionic compound (eg lead bromide) is electrolysed in the molten state using inert electrodes, the metal (lead) is produced at the cathode and the non-metal (bromine) is produced at the anode.

**Students should be able to** predict the products of the electrolysis of binary ionic compounds in the molten state.

**4.4.3.5 (HT only):** During electrolysis, at the cathode (negative electrode), positively charged ions gain electrons and so the reactions are reductions. At the anode (positive electrode), negatively charged ions lose electrons and so the reactions are oxidations.

Reactions at electrodes can be represented by half equations, for example:

2H+ + 2e- → H2 and 4OH- → O2 + 2H2O + 4e or 4OH- – 4e- → O2 + 2H2O

**Chunking**

1. Theory of electrolysis.
2. Electrolysis of molten compounds.
3. Half-equations.

**Key direct and explicit teacher explanations:**

1. In a previous lesson we learnt about how we extract metals from their ores. The method used depended on how reactive the metal was. Unreactive metals are found as pure metals in the ground; physical methods are used to extract the metal.

Metals that are less reactive than carbon can be displaced from their ore by reacting them with carbon.

Reactive metals cannot be extracted by reacting them with carbon; carbon is not reactive enough to displace the metal. Electrolysis is used when a reactive metal is being extracted.

In the next three lessons you will learn about:

1. Electrolysis of single substances.
2. Using electrolysis to extract metals.
3. Electrolysis of aqueous solutions.

The theory is very similar for all of these situations.

Electrolysis uses electricity to separate ions in ionic substances and then oxidise or reduce them so that they become electrically neutral.

For this to happen, the ions need to be able to move. This can be achieved in two ways:

1. Melt the ionic substance
2. Dissolve the ionic substance

Two rods (electrodes) are usually suspended in the liquid. These are made of a conductor. They are attached to a power supply so that one electrode becomes positively charged (anode) and one becomes negatively charged (cathode). The ions will migrate towards the electrode with the opposite charge.

At the positive electrode, the negative ions give electrons to the electrode; the ions are oxidised to form atoms.

At the negative electrode, the positive ions gain electrons; the ions are reduced to form atoms.

1. When a molten compound is used it is easy to predict the products of electrolysis. At the negative electrode the positive ion is reduced to give atoms / molecules of the element; the positive ion gains electrons.

At the positive electrode the negative ions are oxidised; they donate electrons to the electrode.

1. The reactions that occur at the electrodes can be represented using half equations. These equations show ions gaining or losing electrons. These equations need to be balanced just like other symbol equations. However, the charges also need to be balanced.

**Teacher notes (e.g. key questions, examples, non-examples, explanations)**

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**Lesson 8: 4.4.3.1 The process of electrolysis & 4.4.3.2 Electrolysis of molten ionic compounds**

**Objective: You are learning about the process of electrolysis and how it can be represented in equations.**

**Skills Drill / Retrieval**

|  |  |
| --- | --- |
| Answer | PA / SA |
| 1 |  |  |
| 2 |  |  |
| 3 |  |  |
| 4 |  |  |
| 5 |  |  |

Less concentrated. If they had an equal concentration, 12.5ml would be required to neutralise the sulphuric acid. A higher volume is required so the concentration must be lower.

(21 + 20) / 2 = 20.5

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1. Identify the anomaly. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
2. Calculate the mean. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Look carefully at the results.

1. Is the sulphuric acid more concentrated or less concentrated than the sodium hydroxide solution? (Remember, sulphuric acid releases 2 protons per molecule).

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**Catch up (complete this if you were absent last lesson):**

In the last lesson, the class completed a required practical. A sample of the results are below:



Conductors require charged particles to move so they can carry the charge.

The ions in a solid only vibrate. This is insufficient for the charge to be carried through the structure.

The electrostatic forces between ions are very strong.

A lot of energy is required to overcome the forces.

This requires a high temperature.

Giant structures have many ions.

The formula tells you the ratio of the different ions to each other.

Chlorine atoms gain electrons when they react. One electron enters the outer shell.

Electrons are negatively charged so the ion will be negatively charged.

The sodium atom loses one electron from its out er shell when it reacts.

There will be one more proton in the nucleus that the number of electrons. Protons are positively charged so the ion will be positive.

**Connect**

You previously studied ionic compounds in **KS4 Structures and Bonding.**

The structure of sodium chloride, an ionic compound, is shown below:



1. Explain why sodium ions have a positive charge (sodium is in group 1 of the Periodic Table).

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1. Explain why chloride ions have a negative charge (chlorine is in group 7 of the Periodic Table).

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1. Sodium chloride is a giant structure of ions.

Explain what this means.

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1. Explain why ionic compounds have high melting points and boiling points.

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1. Ionic compounds can conduct electricity but only when they aren’t a solid.

Explain why ionic compounds can not conduct electricity when solid.

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Oxidised

Reduced

Positive

Negative

The ions need to be able to move to carry the charge from one point to another.

Fluorine

Oxygen

Chlorine

Chlorine

Lithium

Aluminium

Sodium

Copper

**Which products would be formed at the positive and negative electrodes?**

|  |  |  |
| --- | --- | --- |
| **Solution** | **Positive electrode (anode)** | **Negative electrode (cathode)** |
| Copper (II) chloride |  |  |
| Sodium chloride |  |  |
| Aluminium oxide |  |  |
| Lithium Fluoride |  |  |

Electrolysis is used to separate ions and then produce atoms of the elements.

1. Explain why ionic substances only conduct electricity when molten or dissolved.

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1. Metal ions are positively charged. Do they migrate towards the positive or negative electrode?

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1. Non-metal ions are negatively charged. Do they migrate towards the positive or negative electrode?

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1. Are the metal ions oxidised or reduced when they reach the electrode?

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1. Are the non-metal ions oxidised or reduced when they reach the electrode?

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2O2- 🡪 O2 + 4e-

2Cl- 🡪 Cl2 + 2e-

 Co2+ + 2e- 🡪 Co

Zn2+ + 2e- 🡪 Zn

Reduction

2I-‑  🡪 I2 + 2e-

Li+ + e-‑ 🡪 Li

+ 2e-

+ 2e-

+ 2e-

+ 2e-

4

2

3

2

**Writing Half-Equations**

Complete these half-equations by adding the correct number of electrons:

1. Mg2+ + \_\_\_e- 🡪 Mg
2. Al3+ + \_\_\_e- 🡪 Al
3. 2Cl- 🡪 Cl2 + \_\_\_e-
4. 2O2- 🡪 O2 + \_\_\_e-

Complete by adding electrons to the correct side of the equation:

1. Ca2+ 🡪 Ca
2. 2H+ 🡪 H2
3. 2Br- 🡪 Br2
4. Pb2+ 🡪 Pb

Write balanced half equations for the following reactions:

1. Reduction of lithium (Li+) ions to lithium atoms
2. Oxidation of iodide (I-) ions to iodine atoms
3. \_\_\_\_\_\_\_\_\_ of zinc (Zn2+) ions to zinc atoms

Correct the mistakes in the following:

1. Co2+ - 2e- 🡪 Co
2. Cl- 🡪 Cl + e-
3. 2O2- + 4e- 🡪 O2





This question is about zinc and magnesium.

Zinc is produced by electrolysis of molten zinc chloride, as shown in the figure below.



(a)    (i)      Why must the zinc chloride be molten for electrolysis?

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(ii)     Describe what happens at the negative electrode.

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**(3)**

(iii)    Complete the half equation for the reaction at the positive electrode.

\_\_\_\_\_\_\_\_        Cl2    +    \_\_\_\_\_\_\_\_    e–

**(1)**

(b)     Magnesium can be produced from magnesium oxide.

The equation for the reaction is:

Si(s)    +    2 MgO(s)        SiO2(s)    +    2 Mg(g)

(i)      How can you tell from the equation that the reaction is done at a high temperature?

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**(1)**

**Lesson 9: Teacher notes**



Some students investigated the electrolysis of copper nitrate solution using inert electrodes.

**Figure 1** shows the apparatus.

**Figure 1**

****

The students investigated how the mass of copper produced at the negative electrode varied with time and current.

This is the method used.

1.   Weigh the negative electrode.

2.   Set up the apparatus shown in **Figure 1**.

3.   Adjust the power supply until the ammeter shows a current of 0.3 A

4.   Switch off the power supply after 5 minutes.

5.   Rinse the negative electrode with water and allow to dry.

6.   Reweigh the negative electrode.

7.   Repeat steps 1 to 6 for different times.

8.   Repeat steps 1 to 7 at different currents.

(d)  Some of the copper produced did not stick to the negative electrode but fell to the bottom of the beaker.

Suggest how the students could find the total mass of copper produced.

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**AQA Content**

Metals can be extracted from molten compounds using electrolysis. Electrolysis is used if the metal is too reactive to be extracted by reduction with carbon or if the metal reacts with carbon. Large amounts of energy are used in the extraction process to melt the compounds and to produce the electrical current.

Aluminium is manufactured by the electrolysis of a molten mixture of aluminium oxide and cryolite using carbon as the positive electrode (anode).

**Students should be able to:** • explain why a mixture is used as the electrolyte • explain why the positive electrode must be continually replaced.

**(HT only)** Throughout Section 4.4.3 Higher Tier students should be able to write half equations for the reactions occurring at the electrodes during electrolysis, and may be required to complete and balance supplied half equations.

**Chunking**

1. Electrolysis and extracting metal.

**Key direct and explicit teacher explanations:**

The best example of using electrolysis to extract a metal is extraction of aluminium from aluminium oxide.

The melting point of aluminium oxide is extremely high. A substance called cryolite is added to the aluminium oxide; this reduces the melting point of aluminium so that a lower temperature can be used to melt aluminium oxide.

The aluminium ions are positively charged so they migrate towards the cathode. Electrons are then donated to the ions so they are reduced and form aluminium metal.

The oxygen ions migrate towards the positive electrode (anode). The oxygen ions are oxidised and form oxygen gas.

The electrodes have to be replaced regularly. This is because the electrodes are made of carbon (graphite). This is because the carbon in the electrodes reacts with the oxygen to form carbon dioxide.

**Examples and non-examples: A range of examples and non-examples are given to enable interpolation and limit**

**extrapolation:**

Examples of viruses: They show a range of morphology. However, they all have a protein coat and contain genetic material).

Some viruses have a lipid envelope derived from the host cells (e.g., HIV). This makes it harder for the immune system to recognise.

Ebola: RNA Smallpox: DNA Tobacco rattle virus: RNA SARS-CoV-2: RNA

**Teacher notes (e.g. key questions, examples, non-examples, explanations)**

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**Lesson 9: 4.4.3.3 Using electrolysis to extract metals**

**Objective: You are learning how electrolysis is used to extract metals from metal compounds.**

**Skills Drill / Retrieval**

|  |  |
| --- | --- |
| Answer | PA / SA |
| 1 |  |  |
| 2 |  |  |
| 3 |  |  |
| 4 |  |  |
| 5 |  |  |

**Catch up (complete this if you were absent last lesson):**

In the last lesson the class learnt about the process of electrolysis. This process can be used to extract pure metals from metal compounds.

Diagrams of the apparatus used can be fond in the Knowledge Booklet.

1. Electrolysis only works for ionic compounds. Are metal ions positively or negatively charged?

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1. Will the metal ions migrate towards the positive or negative electrode?

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1. When the metal ions reach the electrode, will they be oxidised or reduced?

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1. Electrolysis only works for ionic compounds. Are non-metal ions positively or negatively charged?

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1. Will the non-metal ions move towards the positive or negative electrode?

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1. When the metal ions reach the electrode, will they be oxidised or reduced?

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Oxidised / lose electrons

Positive / anode

Negative

Reduced / gain electrons

Negative / cathode

Positive

Magnesium is more reactive than carbon / above carbon in the reactivity series.

So carbon cannot displace the magnesium.

Carbon is more reactive that iron / above iron in the reactivity series.

Carbon is reactive enough to displace the iron.

Gold is unreactive / at the bottom of the Reactivity Series.. It doesn’t react with oxygen, water or other substances that it is exposed to.

At KS3, and earlier in this topic, you learnt about how metals can be put in order of reactivity. This is called the Reactivity Series.

In **KS4 Atomic Structure and Periodic Table** you learnt why potassium (group 1) is more reactive that lithium (also in group 1).

You have also learnt about what the Reactivity Series tells us about how metals can be extracted.

1. Explain, in terms of reactivity, why gold is found as a pure metal in the ground.

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1. Explain, in terms of reactivity, why iron can be extracted from iron oxide by displacing it with carbon.

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1. Explain, in terms of reactivity, why magnesium can not be extracted from its ore by displacing it with carbon.

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**Connect**











Aluminium is extracted by electrolysis using the ionic compound aluminium oxide.

 
              Molten aluminium

(i)      Aluminium **cannot** be extracted by heating aluminium oxide with carbon.

Suggest why.

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**(1)**

(ii)     Why is aluminium oxide dissolved in molten cryolite?

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**(1)**

(iii)    Aluminium metal is produced at the negative electrode (cathode).

Complete the half equation for the process.

Al3+    +    \_\_\_\_\_  e–         Al

**(1)**

(iv)      Use the half equation to state why Al3+ ions are reduced.

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**(1)**



(v)      Explain why the positive electrodes (anodes) burn away.

Use your knowledge of the products of electrolysis to help you.

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**(4)**

China is currently going through an industrial revolution. Other heavily industrialised countries have tried to discourage this because of the harm that is caused to the environment; they are concerned about global warming because carbon dioxide is a greenhouse gas.

Other countries disagree with large scale production of aluminium using electrolysis. They also disagree with building more fossil fuel power stations to generate electricity.

**Question: Explain how using electrolysis to extract aluminium contributes to global warming.**

 **Suggest what the Chinese government could do to reduce the contribution to global**

 **warming.**

**You should include:**

* An explanation of what global warming is and how it affects the environment.
* Two ways that using electrolysis to extract aluminium produces carbon dioxide.
* Suggestions of how to reduce the volume of carbon dioxide produced when the electricity is generated (how else could they generate electricity?).
* Suggestions of how to reduce the amount of carbon dioxide produced by the electrolysis process itself (which other conductor cold be used to make the electrodes?).

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**Lesson 10: Teacher notes**

**AQA Content**

The ions discharged when an aqueous solution is electrolysed using inert electrodes depend on the relative reactivity of the elements involved.

At the negative electrode (cathode), hydrogen is produced if the metal is more reactive than hydrogen.

At the positive electrode (anode), oxygen is produced unless the solution contains halide ions when the halogen is produced.

This happens because in the aqueous solution water molecules break down producing hydrogen ions and hydroxide ions that are discharged.

**Students should be able to** predict the products of the electrolysis of aqueous solutions containing a single ionic compound.

**Chunking**

1. Why use aqueous solutions instead of molten substances?
2. Ions in aqueous solution
3. Predicting products in aqueous solutions
4. Half equations

**Key direct and explicit teacher explanations:**

1. Electrolysis of molten substances is very predictable because only two ions are present in the electrolyte. It can also be use with every ionic substance; it can be used to extract even the most reactive metals.

The disadvantage is that it is very expensive. This is because it the salt needs to be melted; there are heating costs. The electricity used in electrolysis is a second cost (an inevitable one).

The alternative is to use electrolysis of aqueous solutions; the ions can move because they are dissolved in water. An advantage of this is that you don’t have to pay the costs associated with melting the substance.

A disadvantage is that there are four ions in the solution (two from water and two from the salt). This makes the chemistry more complex because two positive ions compete for electrons and two negative ions compete to lose electrons.

Fortunately, three are simple rules for predicting the outcome of electrolysis of aqueous solutions.

1. There are usually four ions in aqueous solutions.
2. Hydrogen ions from water (positively charged).
3. Hydroxide ions from water (negatively charged).
4. Positive ions from the salt.
5. Negative ions from the salt.
6. The products made at each electrode can be predicted if you follow some simple rules:

Cathode (negative electrode): Hydrogen will be produced unless the metal ion is for metal less reactive than hydrogen.

Anode (positive electrode): If a group 7 ion is present, a group 7 element will be produced. If a group 7 ion is not present, oxygen is produced.

1. The half equations follow the same format as for electrolysis of molten substances. The half equation that produces oxygen from hydroxide ions iss more complex:



**Teacher notes (e.g. key questions, examples, non-examples, explanations)**

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**Lesson 10: 4.4.3.4 Electrolysis of aqueous solutions**

**Objective: You are learning to predict the products made during electrolysis of aqueous solutions.**

**Skills Drill / Retrieval**

|  |  |
| --- | --- |
| Answer | PA / SA |
| 1 |  |  |
| 2 |  |  |
| 3 |  |  |
| 4 |  |  |
| 5 |  |  |

Graphite reacts with oxygen produced at the anode to produce carbon dioxide.

Graphite

Reduces the temperature that is used.

Reduces expenditure on energy.

Bauxite

**Catch up (complete this if you were absent last lesson):**

In the last lesson the class learnt how we extract metals using electrolysis. We specifically looked at extracting aluminium.

1. Which substance is mixed with bauxite (mainly aluminium oxide) to reduce its melting point?

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1. Why is it important to reduce the melting point?

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1. What are the electrodes made of?

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1. Why do the electrodes have to be replaced regularly?

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Cl-

OH-

Na+

H+

Na+

Cl-

H+

OH-

**Connect**

When ionic substances are dissolved in water to make an aqueous solution, more types of ions are present. This makes it more difficult to predict the products made by electrolysis.

When we learnt about neutralisation, we learnt that water is composed of two ions:

1. Hydrogen ion, H+.
2. Hydroxide ion, OH-.

A solution will also contain the ions from the ionic substance.

Questions:

1. Which ions are present in a solution of sodium chloride (NaCl)?
2. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
3. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
4. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
5. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
6. Which ions will migrate towards the negative electrode (cathode)?

1. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

2. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Which ions will migrate towards the positive electrode (anode)?

1. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

2. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_



|  |  |  |  |
| --- | --- | --- | --- |
| **Electrolyte** | **Ions present** | **Product at the cathode** | **Product at the anode** |
| Sodium chloride  | Na+, Cl- | Sodium, Na | Chlorine, Cl2 |
| Molten lead bromide | Pb2+, Br- | Lead, Pb | Bromine, Br2 |
| Liquid aluminium oxide | Al3+, O2- | Aluminium, Al | Oxygen, O2 |
| Liquid Copper(II) Fluoride | Cu2+, F- | Copper, Cu | Fluorine, F2 |
| Molten potassium bromide | K+, Br- | Potassium, K | Bromine, Br2 |

What products would be made at the anode and cathode?

Aqueous solutions:

|  |  |  |  |
| --- | --- | --- | --- |
| **Electrolyte** | **Ions present** | **Product at the cathode** | **Product at the anode** |
| Sodium chloride solution | Na+, Cl-, H+, OH‑ | Hydrogen, H2 | Chlorine, Cl2 |
| Lead bromide solution |  |  |  |
| Aluminium oxide solution |  |  |  |
| Copper(II) nitrate solution |  |  |  |
| Aqueous potassium bromide |  |  |  |
| Sulfuric acid (H2SO4)  |  |  |  |

Molten electrolytes:

|  |  |  |  |
| --- | --- | --- | --- |
| **Electrolyte** | **Ions present** | **Product at the cathode** | **Product at the anode** |
| Sodium chloride  | Na+, Cl- | Sodium, Na | Chlorine, Cl2 |
| Molten lead bromide | Pb2+, Br- | Lead, Pb | Bromine, Br2 |
| Liquid aluminium oxide | Al3+, O2- | Aluminium, Al | Oxygen, O2 |
| Copper(II) Fluoride  | Cu2+, F- | Copper, Cu | Fluorine, F2 |
| Molten potassium bromide | K+, Br- | Potassium, K | Bromine, Br2 |

**\*Modified from task authored by Ellenderr (Tes resources)**



**Products of Electrolysis**

If it’s molten, you don’t need the rules (there’s only 1 option for each electrode).
E.g. molten zinc chloride makes zinc and chlorine – it doesn’t contain anything else.

But if it’s aqueous (a solution) you need to follow the rules:

Rule at the cathode: **‘Hydrogen or metal is produced – whichever is less reactive.’**

Rule at the anode: **‘Group 7 – if not, oxygen.’**

 What would be produced if we electrolysed:

1. Molten sodium chloride 1. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ 2. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
2. Aqueous sodium chloride 1. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ 2. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
3. Molten magnesium oxide 1. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ 2. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
4. Aqueous magnesium oxide 1. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ 2. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
5. Molten copper fluoride 1. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ 2. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
6. Aqueous copper fluoride 1. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ 2. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
7. Molten lead bromide 1. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ 2. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
8. Aqueous lead bromide 1. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ 2. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
9. Molten potassium chloride 1. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ 2. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
10. Aqueous potassium chloride 1. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ 2. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
11. Molten silver oxide 1. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ 2. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
12. Aqueous silver oxide 1. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ 2. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
13. Molten aluminium iodide 1. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ 2. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
14. Aqueous aluminium iodide 1. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ 2. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
15. Molten copper chloride 1. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ 2. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
16. Aqueous copper chloride 1. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ 2. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**\*Purchased from Miss Wetton Science (TES resources)**

Predict the products at each electrode and write half equations for all the ionic compounds in the table.

|  |  |  |
| --- | --- | --- |
| Electrolyte | Negative Cathode | Positive Anode |
| NaBr(l) |  |  |
| PbCl2(l) |  |  |
| SnO(l) |  |  |
| Na2SO4(aq) |  |  |
| CuCl2(aq) |  |  |
| KBr(aq) |  |  |
| AgNO3(aq) |  |  |
| MnCl2(l) |  |  |
| NiBr2(l) |  |  |
| AuCl3(aq) |  |  |
| Al2O3(l) |  |  |
| H2SO4(aq) |  |  |
| NaOH(aq) |  |  |
| CuSO4(aq) |  |  |
| CsF(l) |  |  |
| CsI(aq) |  |  |
| ZnCl2(aq) |  |  |
| Li2CO3(aq) |  |  |
| CoBr2(l) |  |  |
| FeBr3(l) |  |  |
| Mg(NO3)2(aq) |  |  |
| HCl(aq) |  |  |

**\*Purchased from gerwynb (TES resources)**



**Lesson 11: Teacher notes**

**AQA Content**

Required practical 3: investigate what happens when aqueous solutions are electrolysed using inert electrodes. This should be an investigation involving developing a hypothesis.

AT skills covered by this practical activity: 3, 7 and 8.

**Chunking**

This lesson is for a required practical.

Exposition should focus on setting the experiment up correctly (including safety).

Students do need to predict the outcomes of electrolysis.

**Practical work**

**This lesson involves a required practical.**

**It addresses the following ATs:**



**Teacher notes (e.g. key questions, examples, non-examples, explanations)**

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**Lesson 11: Required practical 3: Electrolysis**

**Objective:**

**Skills Drill / Retrieval**

|  |  |
| --- | --- |
| Answer | PA / SA |
| 1 |  |  |
| 2 |  |  |
| 3 |  |  |
| 4 |  |  |
| 5 |  |  |

**Catch up (complete this if you were absent last lesson):**

|  |  |  |  |
| --- | --- | --- | --- |
| **Electrolyte** | **Ions present** | **Product at the cathode** | **Product at the anode** |
| Sodium chloride solution | Na+, Cl-, H+, OH‑ | Hydrogen, H2 | Chlorine, Cl2 |
| Lead bromide solution |  |  |  |
| Aluminium oxide solution |  |  |  |
| Copper(II) nitrate solution |  |  |  |
| Aqueous potassium bromide |  |  |  |
| Sulfuric acid(H2SO4) |  |  |  |



They should specify that it needs to be close to an electrode.

Need to use direct current terminals on the power supply.

Potential difference needs to be specified.

Volume should be specified.

Size of beaker should be specified.

**Connect**

You will be performing a required practical today.

A plan for the practical is shown below. However, it isn’t a very good plan.

Improve the plan where required.

1. Pour copper (II) chloride solution into a beaker.

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1. Connect crocodile clips to the electrodes and connect these to the power supply.

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1. Turn the power supply on.

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1. Look at both electrodes and record your observations.

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1. Hold the blue litmus in the solution.

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**Draw a fully labelled diagram of your apparatus:**

**Required practical: Electrolysis.**

Predict what substances will be made at the electrodes if the following solutions are used:

|  |  |  |
| --- | --- | --- |
| **Solution** | **Positive electrode (anode)** | **Negative electrode (cathode)** |
| Copper (II) chloride |  |  |
| Sodium chloride |  |  |

**Results**

