AQA Chemistry Unit 6

Electrolysis

Crompton House Chemistry

		Learned it	Revised it
1	I can label a simple process of electrolysis and describe each of the labelled processes		
2	I can predict the products of electrolysis for molten compounds and aqueous solutions		
3	I can explain using the reactivity series why electrolysis is used for extraction		
4	I can describe and explain the process of aluminium extraction		
5	HT I can describe the reactions at the electrodes during electrolysis as oxidation and reduction reactions and write balanced half equations for these reactions		

DODDLE QUIZZES

AQA Electrolysis: _____%

AQA Electrolysis of Solutions: _____%

AQA Electrolysis Practical Quiz: _____%

Kerboodle Extension Quizzes

Positive Points/postcards for completion

C6 Homework: Electrolysis _____%

C6 Progress Quiz: Electrolysis 1 _____%

C6 Progress Quiz: Electrolysis 2 _____%

C6 Checkpoint quiz: Electrolysis _____%

Self Reflection

WWW:

EBI:

Checked by Teacher:

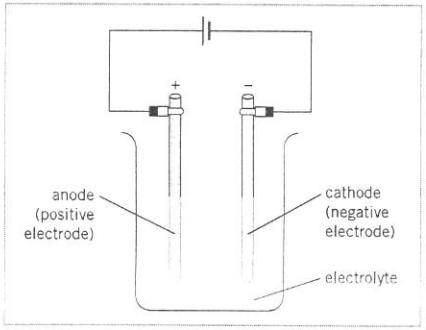
Date:

Chapter 6: Electrolysis

Knowledge organiser

Electrolysis

In the process of **electrolysis**, an electric current is passed through an **electrolyte**. An electrolyte is a liquid or solution that contains ions and so can conduct electricity. This causes the ions to move to the **electrodes**, where they form pure elements.



Electrolysis of molten compounds

Solid ionic compounds do not conduct electricity as the ions cannot move. To undergo electrolysis they must be molten or dissolved, so the ions are free to move.

When an ionic compound is molten:

- The positive metal ions are *attracted* to the **cathode**, where they will *gain* electrons to form the pure metal
- The negative non-metal ions are *attracted* to the **anode**, where they will *lose* electrons and become the pure non-metal.

For example, molten sodium chloride, NaCl, can undergo electrolysis to form sodium at the cathode and chlorine at the anode.

Half equations (HT only)

sodium chloride → sodium + chlorine

$2NaCl(l) \rightarrow 2Na(s) + Cl_2(g)$

- at the cathode:

  $2Na^+(l) + 2e^- \rightarrow 2Na(s)$

- at the anode:

  $2Cl^-(l) \rightarrow Cl_2(g) + 2e^-$

Electrolysis of aqueous solutions

Solid ionic compounds can also undergo electrolysis when dissolved in water.

- It requires less energy to dissolve ionic compounds in water than it does to melt them.
- However, in the electrolysis of solutions, the pure elements are not always produced. This is because the water can also undergo ionisation:

$H_2O(l) \rightarrow H^+(aq) + OH^-(aq)$

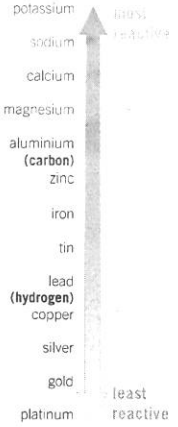
Products at the anode

In In the electrolysis of a solution, if the non-metal contains oxygen then oxygen gas is formed at the anode:

- The $OH^-(aq)$ ions formed from the ionisation of water are attracted to the anode.
- The $OH^-(aq)$ ions lose electrons to the anode and form oxygen gas.
- $4OH^-(aq) \rightarrow O_2(g) + 2H_2O(l) + 4e^-$

If the non-metal ion is a halogen, then the halogen gas is formed at the anode.

- $2Cl^-(aq) \rightarrow Cl_2(g) + 2e^-$



Products at the cathode

In the electrolysis of a solution, if the metal is *more* **reactive** than hydrogen then hydrogen gas is formed at the cathode:

- The $H^+(aq)$ ions from the ionisation of water are attracted to the cathode and react with it.
- The $H^+(aq)$ ions gain electrons from the cathode and form hydrogen gas.
- $2H^+(aq) + 2e^- \rightarrow H_2(g)$
- The metal ions remain in solution.

Electrolysis of aluminium oxide

Electrolysis can be used to extract metals from their ionic compounds.

Electrolysis is used if the metal is more reactive than carbon.

Aluminium is extracted from aluminium oxide by electrolysis.

1. The aluminium oxide is mixed with a substance called **cryolite**, which lowers the melting point.
2. The mixture is then heated until it is molten.
3. The resulting molten mixture undergoes electrolysis.

aluminium oxide → aluminium + oxygen

$2Al_2O_3(l) \rightarrow 4Al(l) + 3O_2(g)$

cathode: pure aluminium is formed

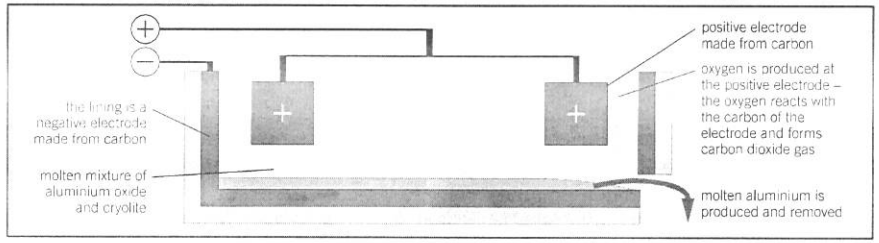
$Al^{3+}(l) + 3e^- \rightarrow Al(l)$

anode: oxygen is formed

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

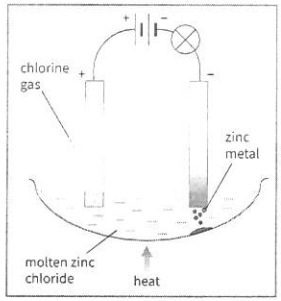
In the electrolysis of aluminium, the anode is made of graphite.

The graphite reacts with the oxygen to form carbon dioxide and so slowly wears away. It therefore needs to be replaced frequently.



Electrolysis of zinc chloride

Molten zinc chloride is broken down by electrolysis. This means zinc metal is collected at the cathode and a pale green chlorine gas is collected at the anode. Free ions from the molten zinc chloride are able to move around and carry electric currents, hence why the bulb lights up.



Key terms

Make sure you can write a definition for these key terms.

anode, cathode, cryolite, electrode, electrolysis, electrolyte, reactivity

ELECTROLYSIS OF SOLUTIONS

- About 0.00001% of water molecules break down into H^+ and OH^- ions: $H_2O \rightarrow \underset{\text{hydrogen ions}}{H^+} + \underset{\text{hydroxide ions}}{OH^-}$
- These H^+ and OH^- ions are present in solutions of ionic compounds in water and so could also be discharged.
- For example, in a solution of sodium chloride in water, there are Na^+, Cl^-, H^+ and OH^- ions present. The H^+ and Cl^- ions are discharged to form hydrogen and chlorine. The other ions, the Na^+ and OH^- are left in the solution.
- However, at each electrode only **the ions that are the easiest to discharge** are discharged.

+ ions

Which ions are discharged:

the + ion from the compound or the H^+ ions from the water?

Ions of the elements lower in the reactivity series are easier to discharge.

- Solutions containing ions of low reactivity metals (e.g. copper ions, silver ions, gold ions and platinum ions)
  - Ions of the low reactivity metal are discharged instead of H^+ ions (because the low reactivity ions are easier to discharge then H^+ ions)
- Solutions containing ions of higher reactivity metals (e.g. sodium ions, calcium aluminium ions, zinc ions, etc)
  - H^+ ions are discharged instead of the metal (because the H^+ ions are easier to discharge than the metal ions)
  - When H^+ ions are discharged, H_2 is formed: $2\,H^+ + 2\,e^- \rightarrow H_2$

Which of these pairs of + ions is easiest to discharge? Circle the correct answer

Na^+ or H^+	Ag^+ or H^+	Cu^{2+} or H^+	Al^{3+} or H^+	Mg^{2+} or H^+

– ions

Which ions are discharged:

the – ion from the compound or the OH^- ions from the water?

- If the compound contains halide ions (i.e. Cl^-, Br^- or I^-), then the halide ion is discharged instead of the OH^- ion
  - Halide ions are discharged instead of OH^- ions (because halide ions are easier to discharge than OH^- ions)
- Solutions containing other negative ions (e.g. nitrate ions NO_3^-, sulfate ions SO_4^{2-}, carbonate ions CO_3^{2-})
  - OH^- ions are discharged (because the OH^- ions are easier to discharge than the nitrate / sulfate / carbonate ions)
  - When OH^- ions are discharged, O_2 is formed: $4\,OH^- - 4\,e^- \rightarrow O_2 + 2\,H_2O$

Which of these pairs of - ions is easiest to discharge? Circle the correct answer

SO_4^{2-} or OH^-	Br^- or OH^-	Cl^- or OH^-	NO_3^- or OH^-	I^- or OH^-

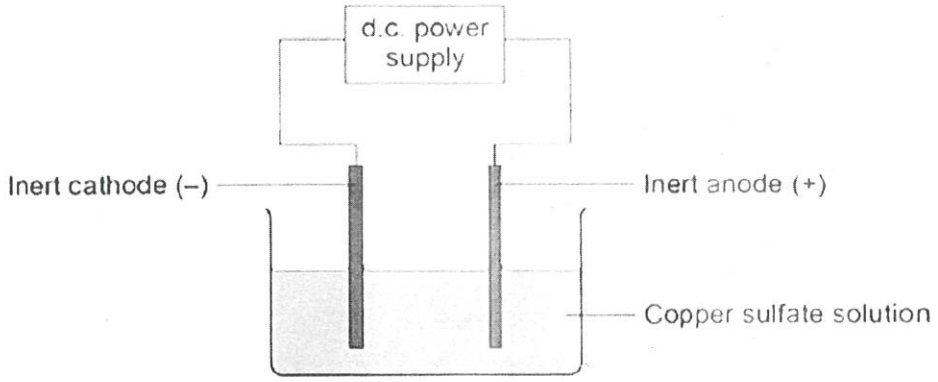
+ IONS		– IONS	
Ions of low reactivity metals	**Ions of higher reactivity metals**	**Halide ions**	**Other – ions**
e.g. Ag^+, Cu^{2+}	e.g. Na^+, Mg^{2+}, Zn^{2+}	e.g. Cl^-, Br^-, I^-	e.g. SO_4^{2-}, NO_3^-
Metal ions discharged (forms metal)	Hydrogen ions discharged (forms H_2)	Halide ions discharged (forms Cl_2, Br_2, I_2)	Hydroxide ions discharged (forms O_2)

Complete the table below. The first one has been done for you.

Compound dissolved in water	+ ions in the solution	- ions in the solution	Product at the + electrode	Product at the – electrode
NaCl	Na^+ (circle) H^+	(circle) Cl^- OH^-	chlorine Cl_2	hydrogen H_2
$CuSO_4$				
$CaBr_2$				
$AgNO_3$				
H_2SO_4				
$Pb(NO_3)_2$				
$CuCl_2$				
$PtSO_4$				
HNO_3				
NaOH				
KNO_3				
$FeCl_3$				
$Ca(NO_3)_2$				
$Al_2(SO_4)_3$				

EXAM QUESTIONS

Q1. The figure below shows an apparatus to produce elements from a solution of an ionic compound.



(a) What is the name of the process in the figure?

Tick **one** box.

Combustion	☐	Distillation	☐
Crystallisation	☐	Electrolysis	☐

(1)

(b) The table below shows the products formed from three experiments using different compounds and the apparatus shown in the figure above.

Compound	State	Product at cathode	Product at anode
Copper chloride	Molten	Copper	Chlorine
Copper chloride	Aqueous solution	Copper	Chlorine
Potassium bromide	Molten	Potassium	Bromine

Use the table above to name the products formed at each electrode if using an aqueous solution of potassium bromide.

At cathode _____ At anode _____

_____

(2)

(c) Explain why copper is formed at the cathode during the electrolysis of its salts.

_____

_____

_____

_____

(2)

(Total 5 marks)

Q2. This question is about the extraction of aluminium.

(a) An aluminium atom is represented as:

$$^{27}_{13}Al$$

Give the number of electrons and neutrons in the aluminium atom.

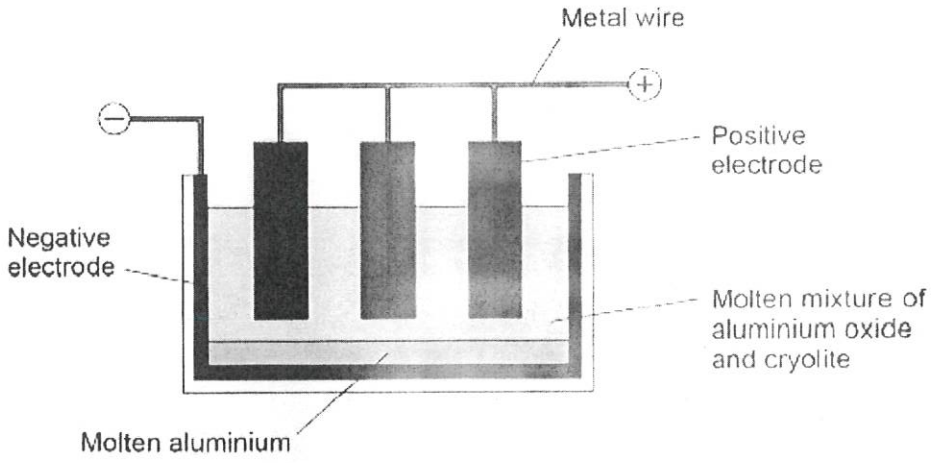
Number of electrons _____

Number of neutrons _____

(2)

Aluminium is extracted by the electrolysis of a molten mixture of aluminium oxide and cryolite.

The diagram below shows the cell used for the electrolysis.



(b) Aluminium is produced by the reduction of aluminium oxide (Al_2O_3).

What is meant by the term reduction?

_____

_____

(1)

(c) Oxygen is formed at the positive carbon electrodes.

Explain why the positive carbon electrodes must be continually replaced.

_____

_____

_____

_____

_____

_____

(3)

(d) A substance conducts electricity because of free moving, charged particles.

What are the free moving, charged particles in a:

- carbon electrode (made from graphite)
- molten mixture of aluminium oxide and cryolite
- metal wire?

Carbon electrode (made from graphite) _____

Molten mixture of aluminium oxide and cryolite _____

Metal wire _____

(3)

(Total 9 marks)

HIGHER TIER ONLY LEVEL 3 QUESTION

Q3. This question is about the electrolysis of aqueous solutions.

Hydrogen gas and chlorine gas are produced when sodium chloride solution is electrolysed.

(a) Hydrogen ions (H^+) are attracted to the negative electrode.

The half equation for the reaction at the negative electrode is:

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

What type of reaction happens at the negative electrode?

Give the reason for your answer.

Type of reaction _____

Reason _____

_____

(2)

(b) Chloride ions are attracted to the positive electrode.

Complete the half equation for the production of chlorine gas (Cl_2).

$$\_\_\_\ Cl^- \rightarrow \_\_\_\_\_ + \_\_\_\_\_$$

(2)

(c) Hydrogen gas and oxygen gas are produced when sodium sulfate solution is electrolysed.

Explain how oxygen gas is produced in the electrolysis of sodium sulfate solution.

_____

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_____

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_____

(4)

(Total 8 marks)