GRAYS TUITION CENTRE – Online Tutoring

WEEK: 11

Week Beginning: 01/03/21

Subject: SCIENCE

Year: 10

Lesson Objective:

- To learn about electrolysis
- To learn about electrolysis in aqueous solutions

Keywords/ Concepts

- **Electrolysis**
- **Electrolyte**
- **Cathode**
- **Anode**
- **Half-Equations**

Class Worksheets

- CGP Worksheet: Electrolysis

Homework

- CGP Worksheets: More on Electrolysis

Additional Notes

Electrolysis

Electrolysis uses an electrical current to cause a reaction. It's actually pretty cool. No, really...

Electrolysis Means 'Splitting Up with Electricity'

1) During electrolysis, an electric current is passed through an electrolyte (a molten or dissolved ionic compound). The ions move towards the electrodes, where they react, and the compound decomposes.
2) The positive ions in the electrolyte will move towards the cathode (-ve electrode) and gain electrons (they are reduced).
3) The negative ions in the electrolyte will move towards the anode (+ve electrode) and lose electrons (they are oxidised).
4) This creates a flow of charge through the electrolyte as ions travel to the electrodes.
5) As ions gain or lose electrons, they form the uncharged element and are discharged from the electrolyte.

An electrolyte is just a liquid or solution that can conduct electricity. An electrode is a solid that conducts electricity and is submerged in the electrolyte

Electrolysis of Molten Ionic Solids Forms Elements

1) An ionic solid can't be electrolysed because the ions are in fixed positions and can't move.
2) Molten ionic compounds can be electrolysed because the ions can move freely and conduct electricity.
3) Molten ionic liquids, e.g. lead bromide, are always broken up into their elements.
4) Positive metal ions are reduced to the element at the cathode: $Pb^{2+} + 2e^- \rightarrow Pb$
5) Negative non-metal ions are oxidised to the element at the anode: $2Br^- \rightarrow Br_2 + 2e^-$

The electrodes should be inert so they don't react with the electrolyte.

Metals can be Extracted From Their Ores Using Electrolysis

If a metal is too reactive to be reduced with carbon (page 133) or reacts with carbon, then electrolysis can be used to extract it. Extracting metals via this method is very expensive as lots of energy is required to melt the ore and produce the required current.

1) Aluminium is extracted from the ore bauxite by electrolysis. Bauxite contains aluminium oxide, Al_2O_3.
2) Aluminium oxide has a very high melting temperature so it's mixed with cryolite to lower the melting point.
3) The molten mixture contains free ions — so it'll conduct electricity.
4) The positive Al^{3+} ions are attracted to the negative electrode where they each pick up three electrons and turn into neutral aluminium atoms. These then sink to the bottom of the electrolysis tank.
5) The negative O^{2-} ions are attracted to the positive electrode where they each lose two electrons. The neutral oxygen atoms will then combine to form O_2 molecules.

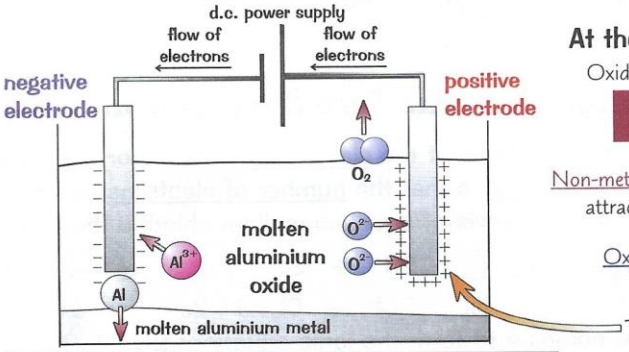
Cryolite is an aluminium based compound with a lower melting point than aluminium oxide.

At the negative electrode:

Reduction — a gain of electrons: $Al^{3+} + 3e^- \rightarrow Al$

Metals form positive ions, so they're attracted to the negative electrode.

Aluminium is produced at the negative electrode.



At the positive electrode:

Oxidation — a loss of electrons: $2O^{2-} \rightarrow O_2 + 4e^-$

Non-metals form negative ions, so they're attracted to the positive electrode.

Oxygen is produced at the positive electrode.

The anode is made of carbon and needs to be replaced regularly as it reacts with oxygen to produce carbon dioxide.

Overall Equation:

aluminium oxide → aluminium + oxygen

$2Al_2O_{3(l)} \rightarrow 4Al_{(l)} + 3O_{2(g)}$

Electrolysis of Aqueous Solutions

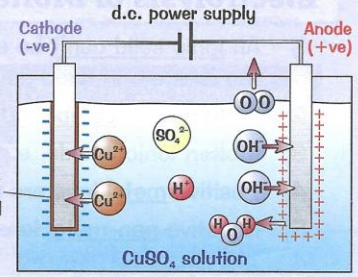
When you electrolyse an aqueous solution, you also have to factor in the ions in the water.

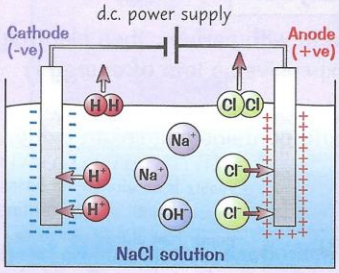
It May be Easier to Discharge Ions from Water than the Solute

1) In aqueous solutions, as well as the ions from the ionic compound, there will be hydrogen ions (H^+) and hydroxide ions (OH^-) from the water: $H_2O_{(l)} \rightleftharpoons H^+_{(aq)} + OH^-_{(aq)}$
2) At the cathode, if H^+ ions and metal ions are present, hydrogen gas will be produced if the metal ions form an elemental metal that is more reactive than hydrogen (e.g. sodium ions). If the metal ions form an elemental metal that is less reactive than hydrogen (e.g. copper ions), a solid layer of the pure metal will be produced instead.
3) At the anode, if OH^- and halide ions (Cl^-, Br^-, I^-) are present, molecules of chlorine, bromine or iodine will be formed. If no halide ions are present, then the OH^- ions are discharged and oxygen will be formed.

A solution of copper(II) sulfate ($CuSO_4$) contains four different ions: Cu^{2+}, SO_4^{2-}, H^+ and OH^-.

- Copper metal is less reactive than hydrogen. So at the cathode, copper metal is produced and coats the electrode.
$$Cu^{2+} + 2e^- \rightarrow Cu$$
- There aren't any halide ions present. So at the anode oxygen and water are produced. The oxygen can be seen as bubbles.
$$4OH^- \rightarrow O_2 + 2H_2O + 4e^-$$





A solution of sodium chloride (NaCl) contains four different ions: Na^+, Cl^-, OH^- and H^+.

- Sodium metal is more reactive than hydrogen. So at the cathode, hydrogen gas is produced.
$$2H^+ + 2e^- \rightarrow H_2$$
- Chloride ions are present in the solution. So at the anode chlorine gas is produced.
$$2Cl^- \rightarrow Cl_2 + 2e^-$$

If you're drawing the apparatus for an electrolysis experiment, remember to include a d.c. power supply, wires and labels for the anode and the cathode. The anode is the electrode on the same side as the longer line of the d.c. power supply symbol.

PRACTICAL

You can set up an electrolysis experiment in the lab like the set-up on page 236. Once the experiment is finished you can test any gaseous products to work out what was produced.

- Chlorine bleaches damp litmus paper, turning it white.
- Hydrogen makes a "squeaky pop" with a lighted splint.
- Oxygen will relight a glowing splint.

For more on tests for gases, turn to page 155.

The Half Equations — Make Sure the Electrons Balance

Half equations show the reactions at the electrodes. The important thing to remember when you're combining half equations is that the number of electrons needs to be the same for each half equation. For the electrolysis of aqueous sodium chloride the half equations are:

Negative Electrode: $2H^+ + 2e^- \rightarrow H_2$

Positive Electrode: $2Cl^- \rightarrow Cl_2 + 2e^-$ or $2Cl^- - 2e^- \rightarrow Cl_2$

These combine to form the ionic equation: $2H^+ + 2Cl^- \rightarrow H_2 + Cl_2$

The electrons on each side of the half equations balance, so they can be cancelled out in the full ionic equation.

When a halide isn't present in the aqueous solution, the half equation for the anode is:

$4OH^- \rightarrow O_2 + 2H_2O + 4e^-$ or $4OH^- - 4e^- \rightarrow O_2 + 2H_2O$

I wrote a poem about my tabby — it was a cat ode...

So it's kinda confusing this electrolysis malarkey — you need to take it slow and make sure you get it.

Q1 An aqueous solution of copper chloride, $CuCl_2$, is electrolysed using inert electrodes. Give the half equations for the anode and the cathode. [2 marks]

Electrolysis

Warm-Up

Place the labels on the correct label lines to identify the parts of an electrochemical cell.

Anode

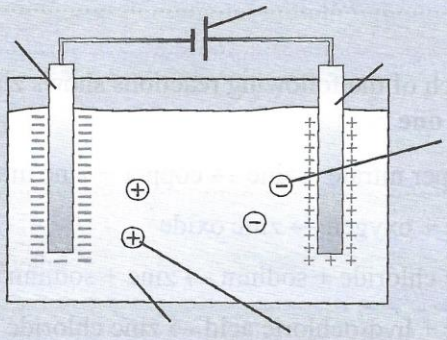
Electrolyte

D.C. power supply

Cathode

Anions

Cations



1 Lead bromide can be electrolysed, using molten lead bromide as the electrolyte.

Grade 4-6

1.1 What is an electrolyte?

.....

[1]

1.2 Write the word equation for the electrolysis of lead bromide.

.....

[1]

1.3 Explain why lead ions move towards the cathode and not the anode.

.....

.....

[2]

1.4 What ions move towards the anode? Give the chemical formula and charge of the ion.

.....

[1]

1.5 Is the reaction at the anode oxidation or reduction?

.....

[1]

1.6 Why does the lead bromide need to be molten? Tick **one** box.

So the ions can move to the electrodes ☐

So the electrons can be conducted through the substance ☐

So the electrodes don't corrode ☐

So there is enough heat for the reaction to occur ☐

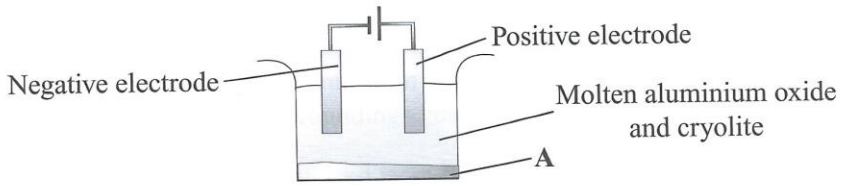
[1]

[Total 7 marks]

2 **Figure 1** shows the extraction of aluminium. Aluminium oxide is mixed with cryolite. This mixture is then melted and electrolysed. Metallic aluminium is made at the cathode.

Grade 4–6

Figure 1



2.1 What is the liquid labelled **A**?

.....

[1]

2.2 What is the purpose of mixing the aluminium oxide with cryolite?

.....

[1]

2.3 Why do the graphite electrodes need to be replaced regularly?

.....

.....

[2]

[Total 4 marks]

3 Aqueous iron chloride solution can be electrolysed using inert electrodes.

Grade 6–7

3.1 Write the names of the ions present in iron chloride solution.

.....

[2]

3.2 Draw **one** line to connect the correct products at each electrode when iron chloride is electrolysed.

At the cathode	At the anode
Iron is discharged	Iron is discharged
Hydrogen is discharged	Oxygen is discharged
Chlorine is discharged	Chlorine is discharged

[1]

3.3 What is discharged at the anode when iron sulfate solution is electrolysed with inert electrodes?

.....

[1]

3.4 Iron can be extracted from iron solutions by electrolysis but this is not the usual method. Why is electrolysis not the usual method of extracting iron?

.....

.....

[2]

[Total 6 marks]

4 A student investigated the products of electrolysis of a variety of aqueous solutions using inert electrodes.

Grade 7-9 PRACTICAL

4.1 Draw a labelled diagram of suitable apparatus that could be used for these experiments.

[4]

4.2 Complete **Table 1** by predicting the products at the anode and cathode for each of the solutions.

Table 1

Solution	Product at cathode	Product at anode
$CuCl_2$		
KBr		
H_2SO_4		

[6]

4.3 When potassium nitrate solution is electrolysed neither potassium nor nitrogen are discharged. Explain why and state what is produced instead.

.....

.....

.....

[4]

4.4 Write two half equations for the reaction that occurs when water is electrolysed.

Cathode: .....

Anode: .....

[2]

[Total 16 marks]

Exam Practice Tip

Electrolysis can be a hard subject to get your head around, and adding the electrolysis of aqueous solutions in to the mix doesn't make it any easier. But remember, in aqueous solution, different ions can be discharged depending on their reactivity. Make sure you know the different ions that can be removed from solution, and in what situations that will happen — it really isn't too complicated once you know what you are doing, but you do need to learn the rules.