# Electrolysis of aqueous solutions: supporting resources

### This resource supports the practical video Electrolysis of aqueous solutions, available here [rsc.li/3a7LS37](http://rsc.li/3a7LS37)

## Using the follow-up worksheet

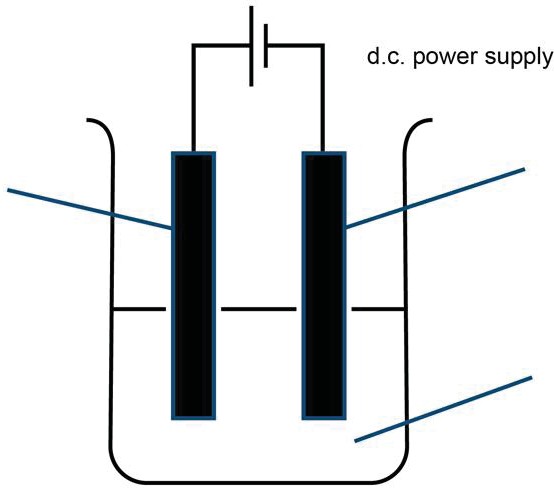
The follow-up worksheet for this video consolidates practical skills and tests understanding of the rules to predict the reaction at each electrode. The questions in this follow-up activity explore electrolysis in an alternative context with hydrochloric acid as the electrolyte.

There is an extension activity included which considers electrolysis of solutions where the solvent is not water. The context used is the extraction of aluminium from aluminium oxide. A video resource showing the industrial processes involved in this real-world application of electrolysis is available at <rsc.li/2N4OENG>.

## **Follow-up worksheet**

This section is about the electrolysis of hydrochloric acid.

Hydrogen chloride is a gas that dissolves readily in water to form hydrochloric acid. Hydrochloric acid is an aqueous solution. Dilute hydrochloric acid (less than 2.7 M) is a mild irritant. Concentrated hydrochloric acid (more than 6.8 M) is corrosive and an irritant.

1. Label the diagram below with the labels a, b, c:
   1. electrolyte
   2. positive electrode
   3. negative electrode
2. Name the electrolyte:
3. Identify the ions present in the electrolyte and identify which electrode they will travel towards:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **compound** | **HCl** | | **H2O** | |
| ions present |  |  |  |  |
| electrode |  |  |  |  |

1. Which ions will travel towards the negative electrode?
2. What will you observe at the negative electrode?

1. Describe the test could you use to identify the product at the negative electrode?

1. Write a half equation to show the reaction of the ion at the negative electrode in the electrolysis of hydrochloric acid, HCl(aq).

+ →

1. Which ions will travel towards the positive electrode?
2. State the rule you have learned for working out which ion reacts at the positive electrode?

1. What will you observe at the positive electrode?

1. What test could you use to identify the product at the positive electrode?
2. Write a half equation to show the reaction of the ion at the positive electrode in the electrolysis of dilute hydrochloric acid, HCl(aq).

→ +

1. What differences would you observe at the positive electrode if the dilute hydrochloric was diluted further and was a very dilute solution?
2. Which test would you use to identify the product at the positive electrode when electrolysing concentrated hydrochloric acid?

### Challenge: Electrolysis of molten solutions

Aluminium is the third most common element in the earth’s crust. Aluminium and aluminium alloys are popular materials due to aluminium being unreactive and having a low density compared to other metals. Aluminium is extracted from its ore, bauxite, using electrolysis.

Bauxite is first purified to form alumina, which is a white powdery substance of aluminium oxide (Al2O3). Aluminium oxide is not water soluble and has a melting point of 2072 °C. However, aluminium oxide does dissolve in a solvent of molten cryolite (Na3AlF6) which has a much lower melting point of 1012 °C.

1. Why is it necessary for the aluminium oxide to be either molten or dissolved in a solution for electrolysis to occur?
2. Why is it preferable to electrolyse aluminium oxide dissolved in molten cyrolite, rather than molten aluminium oxide on its own?
3. Complete the table by identifying the ions in an aluminium oxide solution with cryolite:

|  |  |  |  |
| --- | --- | --- | --- |
| **Al2O3** | | **Na3AlF6** | |
|  |  |  | AlF63- |

1. During electrolysis, aluminium oxide is decomposed into aluminium and oxygen. Balance the following symbol equation for the decomposition of aluminium oxide:

aluminium oxide → aluminium + oxygen

Al2O3 → Al + O2

1. Which ions will travel towards the negative electrode?
2. Which ion will react at the negative electrode? Why?
3. Write a half equation to show the reaction of the ion at the negative electrode.

+ →

1. Which ions will travel towards the positive electrode?
2. It is the oxide ion rather than the AlF 3- which reacts at the positive electrode. Write a half equation to show the reaction of the ion at the positive electrode.

→ +

6

There are no hydrogen or hydroxide ions involved in the electrolysis of aluminium oxide solution. Why?

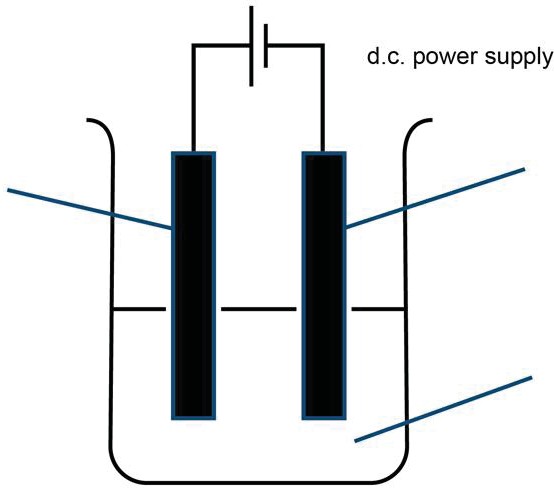
1. An aluminium extraction plant runs 24 hours a day, 365 days a year. What would happen to the electrolyte if the plant was to lose power for more than a couple of hours?
2. The positive carbon electrode has to be regularly replaced. Suggest a reason for this. (Hint: think about the reaction that happens at the anode and the temperature of the anode.)

## **Follow-up worksheet: answers**

This section is about the electrolysis of dilute hydrochloric acid.

Hydrogen chloride is a gas that dissolves readily in water to form hydrochloric acid. Hydrochloric acid is an aqueous solution. Dilute hydrochloric acid (less than 2.7 M) is a mild irritant. Concentrated hydrochloric acid (more than 6.8 M) is corrosive and an irritant.

1. Label the diagram below with the labels a, b, c:
   1. electrolyte
   2. positive electrode
   3. negative electrode



**a. electrolyte**

**b. positive electrode**

**c. negative electrode**

1. Name the electrolyte:

##### Hydrochloric acid

1. Identify the ions present in the electrolyte and identify which electrode they will travel towards:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **compound** | **HCl** | | **H2O** | |
| ions present | **H+** | **Cl-** | **H+** | **OH-** |
| electrode | **negative** | **positive** | **negative** | **positive** |

1. Which ions will travel towards the negative electrode?

##### Hydrogen ions (H+)

1. What will you observe at the negative electrode?

##### Bubbles of colourless gas.

##### (Or bubbles of hydrogen gas).

1. Describe the test could you use to identify the product at the negative electrode?

##### If you collect the gas in a test tube and bring a lit splint to the mouth of the test tube it will produce a squeaky pop. This would be a positive test for hydrogen.

1. Write a half equation to show the reaction of the ion at the negative electrode in the electrolysis of hydrochloric acid, HCl(aq).

##### 2H+(aq) + 2e- → H2(g)

1. Which ions will travel towards the positive electrode?

##### Hydroxide (OH-) and chorine (Cl-) ions.

1. State the rule you have learned and use it to work out which ion reacts at the positive electrode.

##### If there is a halide ion from a halogen present then it will react at the positive electrode to produce a halogen gas. If there is no halogen present, or only a very dilute concentration, then you will get oxygen. We are using dilute hydrochloric acid so there is a halide (chlorine) present. Chlorine will be produced at the positive electrode unless the solution is very weak.

1. What will you observe at the positive electrode?

##### Bubbles of a green gas.

1. What test could you use to identify the product at the positive electrode?

##### The test for chlorine gas would be to hold damp litmus paper near to the electrode. A positive test would be if the litmus paper was bleached white.

1. Write a half equation to show the reaction of the ion at the positive electrode in the electrolysis of dilute hydrochloric acid, HCl(aq).

##### 2Cl-(aq) → Cl2(g) + 2e-

1. What differences would you observe at the positive electrode if the dilute hydrochloric acid was diluted further so it was a very dilute solution?

##### If the hydrochloric acid was diluted sufficiently then there would not be enough chloride ions present in the solution and the hydroxide would be oxidised instead. Bubbles of a colourless gas would be observed rather than green gas.

1. Which test would you use to identify the product at the positive electrode when electrolysing weakened hydrochloric acid?

##### If you collect the gas in a test tube and bring a glowing splint to the mouth of the test tube it will relight. This would be a positive test for oxygen.

### Challenge: Electrolysis of molten solutions

Aluminium is the third most common element in the earth’s crust. Aluminium and aluminium alloys are popular materials due to aluminium being unreactive and having a low density compared to other metals. Aluminium is extracted from its ore, bauxite, using electrolysis.

Bauxite is first purified to form alumina, which is a white powdery substance of aluminium oxide (Al2O3). Aluminium oxide is not water soluble and has a melting point of 2072 °C. However, aluminium oxide does dissolve in a solvent of molten cryolite (Na3AlF6) which has a much lower melting point of 1012 °C.

1. Why is it necessary for the aluminium oxide to be either molten or dissolved in a solution for electrolysis to occur?

##### The charged particles need to be free to move in order to be able to carry the electrical current.

1. Why is it preferable to electrolyse aluminium oxide dissolved in molten cyrolite, rather than molten aluminium oxide on its own?

##### It would take a lot more energy to raise the temperature to 2072 °C to melt aluminium.

1. Complete the table by identifying the ions in an aluminium oxide solution with cryolite:

|  |  |  |  |
| --- | --- | --- | --- |
| **Al2O3** | | **Na3AlF6** | |
| **Al3+** | **O2-** | **Na+** | **AlF63-** |

1. During electrolysis, aluminium oxide is decomposed into aluminium and oxygen. Balance the following symbol equation for the decomposition of aluminium oxide:

aluminium oxide → aluminium + oxygen

**2** Al2O3 → **4**Al + **3**O2

1. Which ions will travel towards the negative electrode?

##### Aluminium (Al3+) and sodium (Na+).

1. Which ion will react at the negative electrode? Why?

##### Aluminium is less reactive than sodium in the reactivity series. Sodium will stay in solution and pure aluminium will be formed at the negative electrode.

1. Write a half equation to show the reaction of the ion at the negative electrode.

**4Al3+ + 12e- → 4Al**

**or, Al3+ + 3e- → Al**

1. Which ions will travel towards the positive electrode?

##### Oxygen (O2-) and AlF63-

1. It is the oxide ion rather than the AlF63- which reacts at the positive electrode. Write a half equation to show the reaction of the ion at the positive electrode.

**6O2- → 3O2 + 12e- or, 2O2- → O2 + 4e-**

1. There are no hydrogen or hydroxide ions involved in the electrolysis of aluminium oxide solution. Why?

##### Aluminium oxide is not water soluble. The solution is not an aqueous solution. The aluminium is dissolved in a molten cryolite which does not contain hydrogen or hydroxide.

1. An aluminium extraction plant runs 24 hours a day, 365 days a year. What would happen to the electrolyte if the plant was to lose power for more than a couple of hours?

##### The molten cryolite and aluminium oxide solution would cool down and solidify.

1. The positive carbon electrode has to be regularly replaced. Suggest a reason for this. (Hint: think about the reaction that happens at the anode and the temperature of the anode.)

##### At high temperatures the oxygen gas that is produced at the positive electrode reacts with the carbon that it is made from to produce carbon dioxide gas. This gas escapes to the atmosphere and the carbon electrode is gradually eroded.