ROYAL SOCIETY OF CHEMISTRY

Electrolysis of aqueous solutions

Practical video

Supporting resources

Registered charity number: 207890

Contents

Teacher notes

These resources support the practical video **Electrolysis of aqueous solutions**, available here: rsc.li/3a7LS37

The value of experiencing live practical work cannot be overstated. Numerous studies provide evidence of its value in terms of learner engagement, understanding, results and the likelihood of continuing to study chemistry or work in a related field. This video can be used to complement live practical work, as well as helping learners to understand the methods, equipment and skills when they cannot access the lab.

How to use this video

The video and additional resources are designed to be used flexibly, but some suggestions follow.

Flipped learning

Learners view the video ahead of the live practical lesson to help it run more smoothly and keep objectives in focus. This may also help build confidence for some learners and improve their outcomes in the lesson. Use questions from the set provided as part of the preparation task.

Consolidation and revision

Learners view the video after the practical – this may be directly after the lesson or learners can return to it as part of revision for examinations.

Revisiting a practical with a different focus

A practical experiment can support many learning outcomes. Focussing on just one or two of those in a lesson will help ensure that the aims are achieved. The video could be used to revisit the experiment with a different focus.

Home learning

Whether it is remote teaching, homework, or individual learner absence, the video provides an opportunity to engage with a practical experiment and the associated skills when learners are not in the lab.

Other tips

- **Provide your own commentary**

  Mute the voice over and provide your own commentary. This will allow you to better engage with learners and adapt to the needs and objectives of your lesson.
- **Use questions**

  A set of pause-and-think questions are provided in two formats, one for teacher-led questions and discussion and a student worksheet which can be used independently by learners. Select from these or create your own questions to help engage learners and target specific aims.

Notes on running the practical experiment

The practical experiment shown in this video is the electrolysis of aqueous copper(II) sulfate.

Technician notes including the equipment list and safety notes are available as a separate document here: rsc.li/3a7LS37. If you are planning to carry out the practical in the classroom, you will need to carry out your own risk assessment.

To avoid confusion, electrolysis should be introduced at the basic level by looking at the electrolysis of molten substances, coupling the theory with a video or teacher demonstration. A video and practical instructions for the electrolysis of molten zinc chloride are available here: rsc.li/2NmdpoB. Once the concept is secure learners can move on to the electrolysis of solutions.

TIP: ***If there is a shortage of individual class equipment it is possible to make a large electrolysis cell by cutting the bottom off a two litre plastic bottle and inserting the carbon electrodes in the neck of the bottle by putting them through two holes in a rubber bung. A standard size rubber bung fits in the neck of the bottle. The electrodes stick up into the electrolyte and down out of the neck of the bottle in order to attach to a power pack. This size of electrolysis cell is also big enough to use normal sized test tubes to collect any gas that is evolved.***

Integrated instructions

Printable integrated instructions are provided for learners. These are available as a separate download at rsc.li/3a7LS37.

Integrated instructions use clear numbering, arrows and simple pictograms, like an eye to show where observations are required. These have been developed using cognitive load theory. Integrated instructions remove unnecessary information, and therefore reduce extraneous load on learners, increasing the capacity of their working memory to think about what they are doing and why. Read more about the use of integrated instructions here: rsc.li/2SdSqkQ.

Extension work based on the electrolysis of copper(II) sulfate solution

To add higher level extension work to this content, you could ask the learners to test the pH of the solution at the end of the experiment. It will show an acid solution. (Note: the solution is slightly acidic to start with, but becomes more acidic so just test acidity at the end.) The blue colour of the copper(II) sulfate solution should have faded. Ask the learners to look at the four ions that were in the solution to start with and cross out the two ions that have reacted at the electrodes. See if they can work out what substance is left. The H^+ ions and SO_4^{2-} ions join together to make colourless sulfuric acid (H_2SO_4), explaining why the blue colour fades and the solution becomes more acidic.

Key terms

Learners will need to have a clear understanding of the following scientific terminology:

- electrolysis
- electrolyte
- inert
- cathode
- anode
- reduction
- oxidation
- half equation
- ions
- electrons
- halogen

Two example Frayer models for the terms 'electrolysis' and 'electrolyte' are included in these resources. You can find more examples, and tips on how to use Frayer models in your teaching here: rsc.li/2WXtuAz.

TIP: ***When eliciting learners' prior knowledge of the term 'electrolysis' some may have come across electrolysis as a beauty treatment. Hair removal by electrolysis is rather different to the electrolysis of aqueous solutions as it uses electricity to kill off the hair follicle and is not easily compared with simple electrolytes and inert electrodes. However, it would be worth noting that if a person has electrolysis as part of a beauty treatment then they can be asked to hold a small metal electrode in one hand in order to complete the circuit!***

Prior knowledge

Learners should already be familiar with structure and bonding from earlier in their 14–16 course. They should be able to identify ionic compounds and describe how positive and negative ions are formed through gain or loss of electrons. It is therefore important that they are familiar with the structure of an atom and, in particular, the arrangement of electrons. Learners should also be able to use the periodic table to help them identify the size of the charge on an ion from the group that element is in.

It is important that learners have been introduced to the reactivity series of metals, including carbon and hydrogen. See our video on the Reactivity series of metals, with supporting resources, rsc.li/3baSTPO.

The mnemonic 'OILRIG', for recalling redox reactions in terms of losing and gaining electrons, is introduced in this video with the expectation that they have covered it before. However, it would be possible to move from this electrolysis experiment into further explanation of redox, and in that case pre-knowledge is not necessarily required as this practical could be used to introduce the concept.

Learners should have a basic understanding of the concept of electrons flowing through wires to make current from their 11–14 studies. It may be pertinent to remind learners that *current is the rate of flow of charge*, and therefore it is the movement of the positive and negative ions which conducts the electricity in solution. However, if this has not been previously taught this knowledge could be acquired as part of this practical. Learners should recognise the concept that a complete circuit is required for current to flow.

Common misconceptions

Learners may get confused by the difference between this process and electroplating, especially as copper(II) sulfate solution can be common to both. In electroplating the electrodes used are active because they take part in the electrolysis. One electrode will gain a covering of the metal that is being plated whilst the other metal will disintegrate. The half equations for electroplating reflect this and are not the same as the half equations for electrolysis with inert electrodes. In this experiment the electrodes are inert so they are not taking part in the reaction, but the negative electrode is still being covered with a metal, as in electroplating, and that can cause confusion. Teaching electrolysis first and gaining a good understanding of the concept will help learners realise the difference when electroplating is introduced.

There also may be confusion with the direction of flow of electrons for the current. The conventional direction of current is opposite to the flow of the electrons. Scientists didn't know about electrons at the time that electricity was discovered so the direction of current was assigned arbitrarily. Learners will need to recognise that electrons are gained at the negative electrode and lost at the positive electrode, despite conventional current flowing from positive to negative. Learners may also be unaware that electrical current can be carried by any charged particle, including positive and negative ions, rather than just negative electrons. Check and refine learners' definitions of current before proceeding.

More ideas for teaching electrolysis can be found here: rsc.li/3qlhic0.

Intended outcomes

It is important that the purpose of each practical is clear from the outset, defining the intended learning outcomes helps to consolidate this. Outcomes can be categorised as hands on, what learners are going to do with objects, and minds on, what learners are going to do with ideas to show their understanding. We have offered some differentiated suggestions for this practical. You may wish to focus on just one or two, or make amendments based your learners' own needs. (Read more at rsc.li/2JMvKa5.)

Consider how you can share outcomes and evaluation with learners, empowering them to direct their own learning.

	Hands on	Minds on
Effective at a lower level	**Students correctly:** • Follow instructions • Use of safety goggles and awareness of hazards of chemicals and the need to wash hands after • Have a go at setting up the electrolysis circuit after watching a simple demonstration and with a diagram • Make simple observations at electrodes	**Students can:** • Record simple observations • Link observations to positive or negative electrode • Identify ions in solutions • Work out which ion has reacted at each electrode based on observations
Effective at a higher level	**Students correctly:** • Correctly set up the electrolysis circuit with minimal intervention • Collect and test for hydrogen and oxygen gas	**Students can:** • Predict which ion will react at each electrode • Use the reactivity series to explain which ion will react at each electrode • Write half equations • Identify whether oxidation or reduction has taken place in a half equation

How to use the additional resources

Using the pause-and-think questions

Pause-and-think questions are supplied in two formats: a teacher version for 'live' questioning and a student version which can be used during independent study. The time stamps allow you to pause the video when presenting to a class, or learners to use for active revision.

The questions could also be used to support delivery of the experiment as a demonstration or class practical. Responses will help you to assess understanding and address misconceptions.

Teacher version

The questions are presented in a table and you can choose to use as many as appropriate for your class and the learning objectives.

Some questions have two timestamps to allow you to adapt the questions for different classes or scenarios. Pause the videos at the earlier timestamp to ask a question before the answer is given, useful for revision or to challenge learners. Pause at the later timestamp to ask a question reflectively and assess whether learners have understood what they have just heard or seen. This would be useful when introducing a topic, in a flipped learning scenario or when additional support and encouragement is needed.

Think about how you will ask for responses. Variation may help to increase engagement – learners could write and hold up short answers; more complex questions could be discussed in groups.

Not all answers to questions are included in the video. Some of the questions will draw on prior learning or extend learners' thinking beyond the video content.

Student version

The same questions are offered as a printable worksheet for learners. Use in situations where there is not a teacher present to guide discussion during the video, for example homework, revision or remote learning.

Using the structure strips

Writing about chemistry encourages learners to reflect on their understanding, formulate new ideas and make links between ideas in new ways. Learners also need to practice for longer-answer questions in examinations. Structure strips provide scaffolded prompts and help overcome ‘fear of the blank page’. The learner sticks the strip into the margin of their exercise book or onto an A4 sheet of paper and writes alongside it. Use this long-answer question to consolidate learning after the practical or for revision. (Read more at rsc.li/2P0JDlW.)

Long-answer question:

A student has a beaker containing 50 cm^3 sodium chloride solution. They are going to apply a direct electrical current to the solution using inert carbon electrodes.

Using your knowledge of reactivity, predict what substance will be produced at the positive and negative electrodes. Write a half equation for each reaction, identifying whether oxidation or reduction has occurred.

What tests could you carry out to show that your prediction is correct?

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.

Additional resources

Frayer model: electrolysis

1. **What does the word electrolysis mean to you?**

   Where have you come across this word before?

2. **Explore electrolysis.**

   Electro- and -lysis

   Can you think of any other words containing electro- or –lysis?

Electrolysis

3. **Definition of electrolysis.**

4. **Complete the sentences:**

At the _________________ electrode the negative ions ________ electrons and become _________________.

The electrode where oxidation occurs is called the ____________.

At the _________________ electrode the positive ions _________ electrons to become _________________.

The electrode where reduction occurs is called the ____________.

Available in landscape format as editable slide at rsc.li/3a7LS37.

Additional resources

Frayer model: electrolyte

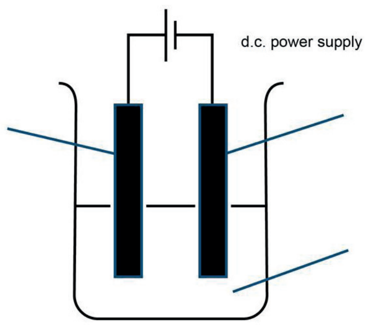
1. **What does the word electrolyte mean to you?**

   Where have you come across this word or similar words before?

2. **Definition of electrolyte.**

Electrolyte

3. **Label the diagram:**



Labels:

positive electrode

negative electrode

electrolyte

4. **From the list below, circle/highlight the substances that could be used as electrolytes.**

   graphite

   copper(II) sulphate solution

   brine

   water

   copper metal

   molten lead(II) bromide

   aluminium oxide

Available in landscape format as editable slide at rsc.li/3a7LS37.

Pause-and-think questions

Teacher version

Timestamp(s)		Question	Answer/discussion points
00:00	00:13	What do you understand by the word electrolysis?	Electro = electricity. Lysis = split, dissolve, break down. Electrolysis = Using electricity to break down an ionic substance. A Frayer model framework for this term is provided.
00:13–00:40		Write down some applications of electrolysis in industry.	Production of aluminium, chlorine and sodium hydroxide. Chlorine and sodium hydroxide are produced from the electrolysis of brine (concentrated sodium chloride solution). Electroplating uses electrolysis to create a thin layer of metal on another metal. This is used for plating jewellery and in electronic devices - inside your phone will be circuitry that has been electroplated in order to make electrical contacts. NB. Electroplating is slightly different process as it uses active electrodes one of which is the metal that you want to plate.
01:04		What is meant by 'aqueous solution'?	An aqueous solution is where the solute is dissolved in a solvent of water. Answer is discussed at 02:10.
01:07	01:10	What is an electrolyte? Give a definition. What is the electrolyte in this experiment?	A liquid or solution that conducts electricity and breaks down during electrolysis. Copper(II) sulfate solution.
01:14		What does inert mean? What are the electrodes that are used in this experiment made from?	Inert means unreactive. The inert electrodes in this experiment are made from carbon (in the form of graphite). Sometimes platinum, an inert metal, is used.
01:17	01:22	Why do the electrodes need to be inert?	The electrodes in this experiment need to be inert so that they do not react with the electrolyte.
01:27		Why must the electrodes not be allowed to touch?	This would create a 'short circuit' which can be hazardous. The current will flow directly from one electrode to the other and will not pass through the liquid. Electrolysis would not occur.
01:31		Why does the current need to flow in one direction only?	If an alternating current was used then the anode and cathode would constantly swap. The positive and negative ions would be attracted to both electrodes alternately. Deposition would occur unevenly at both electrodes.
01:49	01:58	What do you see at: a) the negative electrode b) the positive electrode	 brown solid bubbles

02:10		What is an ion?	A positively or negatively charged particle.
02:17	02:28	List the four ions present in copper(II) sulfate solution.	Cu^{2+} H^{+} SO_4^{2-} OH^{-}
02:54		**The NEGATIVE electrode**	
02:54		Which two ions are attracted towards the negative electrode?	Cu^{2+} and H^{+}
02:57	03:02	Which ion reacted at the negative electrode?	Cu^{2+}
03:10	03:30	What is the rule for working out which positive ion reacts at the negative electrode?	If a metal is less reactive than hydrogen then that metal will appear at the negative electrode. If the metal is more reactive than hydrogen then H_2 hydrogen gas will form at the electrode.
03:30	03:38	Which ion reacts at the negative electrode and why? How do we know?	Cu^{2+} reacts because copper is less reactive than hydrogen. We observe a brown solid of copper.
03:37	03:45	Write a half equation for the reaction of Cu^{2+} at the negative electrode.	$Cu^{2+} + 2e^{-} \rightarrow Cu$
03:48		**The POSITIVE electrode**	
03:48	03:56	Which two ions are attracted towards the positive electrode?	SO_4^{2-} and OH^{-}
04:00	04:02	When you test the gas given off at the positive electrode, a glowing splint relights. What is this gas?	Oxygen
04:01	04:04	Which negative ion is reacting at the positive electrode?	OH^{-}
04:11	04:33	State the rule for working out which negative ion reacts at the positive electrode.	If a halide ion (Cl^{-}, Br^{-} or I^{-}) is present then you will get the halogen (Cl_2, Br_2 or I_2) given off at the positive electrode. If there is no halide or it is in a very low concentration, then oxygen gas will be given off at the positive electrode.
04:33	04:43	Write a half equation for the reaction of OH^{-} at the positive electrode.	$4OH^{-} \rightarrow 2H_2O + O_2 + 4e^{-}$
04:44		**Oxidation and reduction**	
04:55	05:01	What does the mnemonic OILRIG stand for?	Oxidation Is Loss of electrons Reduction Is Gain of Electrons
05:08		What do the white dots represent?	Electrons travelling in the electrodes.
05:08	05:19	Is this oxidation or reduction? Explain why.	Reduction The Cu^{2+} has gained electrons.

05:24		What is the name of the electrode where reduction occurs?	Cathode
05:26	05:35	Is this oxidation or reduction? Explain why.	Oxidation The OH^- has lost electrons.
05:39		What is the name of the electrode where oxidation occurs?	Anode
06:00		What carries the electricity in the wires? What carries electricity in the electrolyte solution?	Flow of electrons. Movement of ions.
06:20		Write a summary to explain what happens at the positive and negative electrodes.	At the positive electrode the negative ions lose electrons and become oxidised. The electrode where oxidation occurs is called the anode. At the negative electrode positive ions gain electrons to become reduced. The electrode where reduction occurs is called the cathode.
06:44		Please see the separate resource for a structure strip and suggested response to the long-answer question: *A student has a beaker containing 50 cm³ sodium chloride solution. They are going to apply a direct electrical current to the solution using inert carbon electrodes.* *Using your knowledge of reactivity, predict what substance will be produced at the positive and negative electrodes. Write a half equation for each reaction, identifying whether oxidation or reduction has occurred.* *What tests could you carry out to show that your prediction is correct?*	

Pause-and-think questions

Student version

Pause the video at the time stated to test or revise your knowledge of these practical experiments.

Time	Question
00:33	What does the word ‘electrolysis’ mean?
00:40	Write down some applications of electrolysis in industry.
00:44	What is meant by the term ‘aqueous solution’?
01:07	What is an electrolyte? Give a definition.
	What is the electrolyte in this experiment?
01:14	What does inert mean?
	What are the electrodes that are used in this experiment made from?
01:22	Why do the electrodes need to be inert?
01:27	*Challenge: Why must the electrodes not be allowed to touch?*
01:31	*Challenge: Why does the current need to flow in one direction only?*
01:49	What do you see at the negative electrode?
	What do you see at the positive electrode?

02:10 What is an ion?

____

____

02:28 List the four ions present in copper (II) sulfate solution.

$CuSO_4$		H_2O	

02:54 Which two ions are attracted towards the negative electrode?

_______________ and _______________

03:30 Complete the sentences:

If a metal is __________ reactive than ______________ then that metal will appear at the negative electrode.

If the metal is __________ reactive than ______________then ____________ gas will form at the electrode.

03:38 Which ion reacts at the negative electrode and why?

____

____

____

How do we know?

____

03:37 Write a half equation for the reaction the reaction of Cu^{2+} at the negative electrode.

_______________ + _______________ → _______________

03:56 Which two ions are attracted towards the positive electrode?

_______________ and _______________

04:00 When you test the gas given off at the positive electrode, a glowing splint relights. What is this gas?

____

04:33 Complete the sentences:

If a _____________ ion (eg _____________) is present then you will get a halogen (eg ________________) given off at the positive electrode

If there is no _____________ ion, or it is in a very low concentration, then ______________ gas will be given off at the positive electrode

04:33 Write a half equation for the reaction the reaction of OH^- at the negative electrode.

_______________ + _______________ → _______________

04:55 Fill in the expression below to describe what happens to electrons during oxidation and reduction

O ____________________________

I ____________________________

L ____________________________

R ____________________________

I ____________________________

G ____________________________

05:08 What do the white dots represent?

____

05:19 Is this oxidation or reduction? Explain why.

____

____

05:24 What is the name of the electrode where reduction occurs?

____

05:35 Is this oxidation or reduction? Explain why.

____

____

05:24 What is the name of the electrode where oxidation occurs?

____

05:50 What carries the electricity in the wires?

____

What carries the electricity in the electrolyte solution?

____

06:20 Fill in the gaps to complete the summary:

At the ________________ electrode the negative ions ________ electrons and become ________________. The electrode where oxidation occurs is called the ____________.

At the ________________ electrode the positive ions _________ electrons to become ________________. The electrode where reduction occurs is called the ____________.

06:44 Now try writing a longer answer to this question using the structure strips:

A student has a beaker containing 50 cm^3 sodium chloride solution. They are going to apply a direct electrical current to the solution using inert carbon electrodes.

Using your knowledge of reactivity, predict what substance will be produced at the positive electrode and the negative electrode. Write a half equation for each reaction, identifying whether oxidation or reduction has occurred.

Which tests could you carry out to show that your prediction is correct?

This question has a structure strip. Find more resources to support you here rsc.li/3a7LS37.

Electrolysis Structure strip	Electrolysis Structure strip	Electrolysis Structure strip	Electrolysis Structure strip	Electrolysis Structure strip
Identify the ions present in NaCl(aq) solution.	Identify the ions present in NaCl(aq) solution.	Identify the ions present in NaCl(aq) solution.	Identify the ions present in NaCl(aq) solution.	Identify the ions present in NaCl(aq) solution.
Which electrode would the ions travel towards?	Which electrode would the ions travel towards?	Which electrode would the ions travel towards?	Which electrode would the ions travel towards?	Which electrode would the ions travel towards?
State the rule used to work out which ion reacts at the positive electrode. Identify the ion.	State the rule used to work out which ion reacts at the positive electrode. Identify the ion.	State the rule used to work out which ion reacts at the positive electrode. Identify the ion.	State the rule used to work out which ion reacts at the positive electrode. Identify the ion.	State the rule used to work out which ion reacts at the positive electrode. Identify the ion.
Write a half equation for the positive electrode. Is this oxidation or reduction?	Write a half equation for the positive electrode. Is this oxidation or reduction?	Write a half equation for the positive electrode. Is this oxidation or reduction?	Write a half equation for the positive electrode. Is this oxidation or reduction?	Write a half equation for the positive electrode. Is this oxidation or reduction?
What will you observe at the positive electrode? How could you test to confirm?	What will you observe at the positive electrode? How could you test to confirm?	What will you observe at the positive electrode? How could you test to confirm?	What will you observe at the positive electrode? How could you test to confirm?	What will you observe at the positive electrode? How could you test to confirm?
State the rule used to work out which ion reacts at the negative electrode. Identify the ion.	State the rule used to work out which ion reacts at the negative electrode. Identify the ion.	State the rule used to work out which ion reacts at the negative electrode. Identify the ion.	State the rule used to work out which ion reacts at the negative electrode. Identify the ion.	State the rule used to work out which ion reacts at the negative electrode. Identify the ion.
Write a half equation for the negative electrode. Is this oxidation or reduction?	Write a half equation for the negative electrode. Is this oxidation or reduction?	Write a half equation for the negative electrode. Is this oxidation or reduction?	Write a half equation for the negative electrode. Is this oxidation or reduction?	Write a half equation for the negative electrode. Is this oxidation or reduction?
What will you observe at the negative electrode? How could you test to confirm?	What will you observe at the negative electrode? How could you test to confirm?	What will you observe at the negative electrode? How could you test to confirm?	What will you observe at the negative electrode? How could you test to confirm?	What will you observe at the negative electrode? How could you test to confirm?

Structure strip: suggested answer content

Electrolysis Structure strip	
Identify the ions present in NaCl(aq) solution.	Sodium chloride is an ionic substance containing sodium (Na^+) and chloride (Cl^-) ions. Since the sodium chloride is in aqueous solution the solution will also contain hydrogen H^+ and hydroxide (OH^-) ions.
Which electrode would the ions travel towards?	The positive Na^+ and H^+ ions will be attracted to the negative electrode. The negative Cl^- and OH^- ions will be attracted to the positive electrode.
State the rule used to work out which ion reacts at the positive electrode. Identify the ion.	At the positive electrode, if a halide is present, it will react to form a halogen gas. The halide chloride is present so the Cl^- ions will react at the positive electrode to form chlorine gas.
Write a half equation for the positive electrode. Is this oxidation or reduction?	The half equation for the reaction at the positive electrode is: $2Cl^-(aq) \rightarrow Cl_2(g) + 2e^-$ The chloride ion has lost electrons therefore oxidation has occurred at the positive electrode. (The electrode where oxidation occurs is called the anode.)
What will you observe at the positive electrode? How could you test to confirm?	If chlorine gas is produced you will observe bubbles of a green gas forming at the positive electrode. (Chlorine gas is hazardous therefore the reaction should take place in a fume cupboard.) You can test for chlorine gas using damp litmus paper (usually blue litmus paper but red will work also). A positive test for chlorine will see the litmus paper bleached to white.
State the rule used to work out which ion reacts at the negative electrode. Identify the ion.	At the negative electrode, if the metal in the aqueous solution is less reactive than hydrogen it will react and the metal solid will appear. If the metal is more reactive than hydrogen, it will stay in solution and hydrogen gas will be produced. Sodium is more reactive than hydrogen, so the hydrogen ion will react to produce hydrogen gas.
Write a half equation for the negative electrode. Is this oxidation or reduction?	The half equation for the reaction at the negative electrode is: $2H^+(aq) + 2e^- \rightarrow H_2(g)$ The hydrogen ion has gained electrons therefore reduction has occurred at the negative electrode. (The electrode where reduction occurs is called the cathode.)
What will you observe at the negative electrode? How could you test to confirm?	If hydrogen gas is produced you will observe bubbles of a colourless gas forming at the negative electrode. You can test for hydrogen gas using a lighted splint. A positive test for hydrogen will produce a squeaky pop sound.

Follow-up worksheet

This section is about the electrolysis of hydrochloric acid.

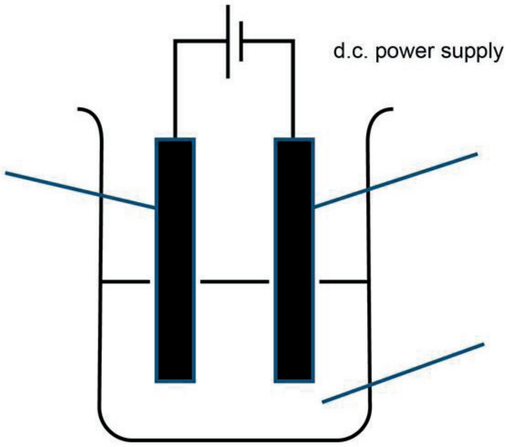
Hydrogen chloride is a gas that dissolves readily in water to form hydrochloric acid. Hydrochloric acid is an aqueous solution. Dilute hydrochloric acid (less than 2.7 M) is a mild irritant. Concentrated hydrochloric acid (more than 6.8 M) is corrosive and an irritant.

1. Label the diagram below with the labels a, b, c:

   a. electrolyte

   b. positive electrode

   c. negative electrode



2. Name the electrolyte:

   ____

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

compound	HCl		H_2O	
ions present				
electrode				

4. Which ions will travel towards the negative electrode?

   ____

5. What will you observe at the negative electrode?

   ____

   ____

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

   ____

   ____

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

   _______________ +_______________ → ____________

8. Which ions will travel towards the positive electrode?

   ____

9. State the rule you have learned for working out which ion reacts at the positive electrode?

____

____

____

____

____

10. What will you observe at the positive electrode?

____

____

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

____

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

_______________ → _______________ + ____________

13. What differences would you observe at the positive electrode if the dilute hydrochloric was diluted further and was a very dilute solution?

____

____

____

14. 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 (Al_2O_3). 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 (Na_3AlF_6) which has a much lower melting point of 1012 °C.

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

____

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

____

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

Al_2O_3		Na_3AlF_6	
			AlF_6^{3-}

18. 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

______ Al_2O_3 → _______ Al + _______ O_2

19. Which ions will travel towards the negative electrode?

____

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

____

____

____

____

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

_______________ + _______________ → _______________

22. Which ions will travel towards the positive electrode?

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23. It is the oxide ion rather than the AlF_6^{3-} which reacts at the positive electrode. Write a half equation to show the reaction of the ion at the positive electrode.

_______________ → _______________ + ____________

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

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25. 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?

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26. 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.)

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Follow-up worksheet: answers

This section is about the electrolysis of dilute hydrochloric acid.

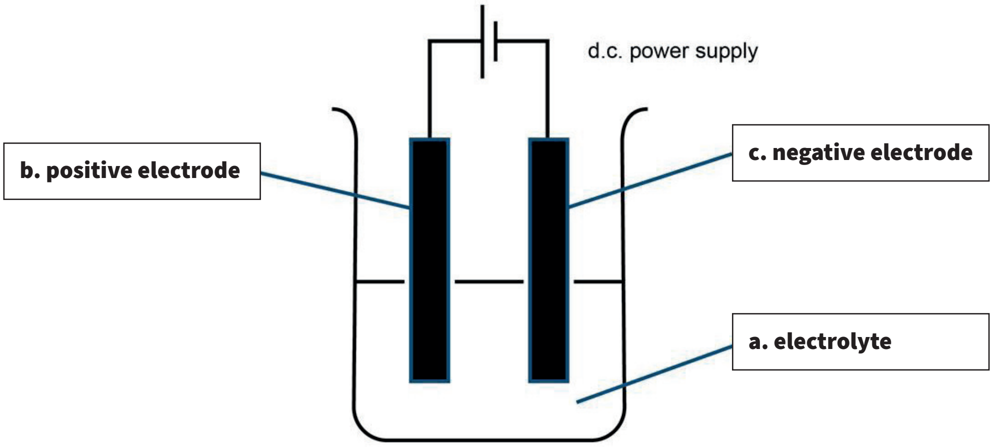
Hydrogen chloride is a gas that dissolves readily in water to form hydrochloric acid. Hydrochloric acid is an aqueous solution. Dilute hydrochloric acid (less than 2.7 M) is a mild irritant. Concentrated hydrochloric acid (more than 6.8 M) is corrosive and an irritant.

1. Label the diagram below with the labels a, b, c:

   a. electrolyte

   b. positive electrode

   c. negative electrode



2. Name the electrolyte:

   Hydrochloric acid

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

compound	HCl		H_2O	
ions present	**H^+**	**Cl^-**	**H^+**	**OH^-**
electrode	**negative**	**positive**	**negative**	**positive**

4. Which ions will travel towards the negative electrode?

   Hydrogen ions (H^+)

5. What will you observe at the negative electrode?

   Bubbles of colourless gas.

   (Or bubbles of hydrogen gas).

6. 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.

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

   $2H^+(aq) + 2e^- \rightarrow H_2(g)$

8. Which ions will travel towards the positive electrode?

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

9. 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.

10. What will you observe at the positive electrode?

Bubbles of a green gas.

11. 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.

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

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

13. 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.

14. 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 (Al_2O_3). 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 (Na_3AlF_6) which has a much lower melting point of 1012 °C.

15. 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.

16. 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.

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

Al_2O_3		Na_3AlF_6	
Al^{3+}	**O^{2-}**	**Na^+**	AlF_6^{3-}

18. 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 $Al_2O_3 \rightarrow$ **4**Al + **3**O_2

19. Which ions will travel towards the negative electrode?

Aluminium (Al^{3+}) and sodium (Na^+).

20. 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.

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

$4Al^{3+} + 12e^- \rightarrow 4Al$

or, $Al^{3+} + 3e^- \rightarrow Al$

22. Which ions will travel towards the positive electrode?

Oxygen (O^{2-}) and AlF_6^{3-}

23. 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.

$6O^{2-} \rightarrow 3O_2 + 12e^-$

or, $2O^{2-} \rightarrow O_2 + 4e^-$

24. 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.

25. 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.

26. 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.