Understanding Electrolysis

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For Teachers

Introduction

Understanding Electrolysis is aimed at Years 11 and 12 Chemistry and deals with an area that students often find difficult. Electrochemical cells have many uses both in industry and everyday life. They include galvanic cells (batteries) that use chemical reactions to generate electricity and electrolytic cells that use electricity to drive chemical reactions. The concepts of electrochemical cells are dealt with in detail, starting with basic principles, and using a mixture of actual laboratory equipment and animations. The reactivity series is used to help students understand how electrochemical cells work. Teachers are recommended to review the concepts of redox reactions before viewing the program.

Timeline

00:00:00	Introduction
00:00:53	Galvanic Cells
00:07:35	Basic Electrolytic cells & operation
00:13:54	Electrolysis in action 1 – production of chemicals
00:18:41	Electrolysis in action 2 – refining and protecting metals
00:23:49	Law of electrolysis
00:28:24	Conclusion
00:29:01	Credits
00:29:47	End program

Related Titles

All About Chemical Bonding – Ionic
All About Chemical Bonding – Covalent
All About Chemical Bonding – Metallic
DC Electricity – Discovery and Developments

Recommended Resources

http://www.chem.umn.edu/services/lecturedemo/info/cu-zncell.html
http://en.wikipedia.org/wiki/Galvanic_cell
http://www.science.uwaterloo.ca/~cchieh/cact/c123/battery.html
http://www.sparknotes.com/chemistry/electrochemistry/electrolytic/section1.html
http://www.practicalphysics.org/go/Experiment_286.html
http://www.docbrown.info/page01/ExIndChem/ExtraElectrochem.htm#electrolysis
http://www.world-aluminium.org/?pg=78

Student Worksheet

Initiate Prior Learning

1. List five devices that use batteries (cells) to provide electrical energy.

_____

_____

_____

_____

_____

2. What are the major differences between a car battery and a battery used to power a flashlight?

_____

_____

_____

_____

_____

3. What is the charge on an electron?

_____

4. Why are some objects plated with a particular metal (e.g. silver) rather than being made with that metal?

_____

_____

5. Why do metal atoms form ions?

_____

_____

Active Viewing Guide

Complete the following sentences.

1. Chemical reactions can produce _____ and electricity can produce _____ reactions.

2. Electrolysis can be used to coat and protect _____, manufacture industrial _____and refine and purify _____.

3. In cells producing electricity there are two _____. In one half-cell _____ is taking place and in the other _____. _____flow through the external circuit causing a current, and _____ flow through the salt bridge.

4. Standard reduction electrode potentials compare half cells with that of _____. Positive potentials show a metal is more easily _____ and less easily _____ than hydrogen.

5. The reactions in electrolytic cells are non _____ and require _____ energy to proceed.

6. Water is a _____ substance and doesn't conduct electricity well unless e.g. an acid is added to make it an _____. Electricity causes the water to decompose and_____ gas is given off at the anode; and _____ gas at the cathode in the ratios of 1:2. Oxygen _____ a glowing splint and hydrogen _____ when it is ignited with a lit splint.

7. Industry uses electrolysis to produce metals such as _____ as well as the gases _____ and _____ from _____ (Sodium chloride solution).

8. Sodium _____ (NaOH) is a strong _____ and is used in the manufacture of _____, _____, paper and textiles. Chlorine is used in the manufacture of the plastic _____ _____ (PVC) and in the purification of _____.

9. _____ (Al_2O_3) is smelted using vast quantities of _____ to produce aluminum. Cryolite is added to _____ its melting point. In the process the carbon anode is oxidized to form _____Aluminum can be_____, which only uses a fraction of the _____ needed to produce it from its ore.

10. Metals often have a surface coating of an _____ and this can be increased by _____ to protect the metal (e.g. _____) against further corrosion.

11. Silver and _____ are two metals often used to plate other metals. The object to be plated is the _____ and the metal used for plating is the _____. A similar process is used to _____ copper on an industrial scale.

12. Some batteries (cells) can be _____. These include the _____–acid battery used in cars, nickel _____ (NiCad), nickel metal hydride and _____ -ion batteries.

13. Faraday's First Law of electrolysis states that the quantity of a substance consumed or produced at an electrode is _____ to the _____ used. This is expressed in the formula, Q = I x t, where Q = _____, I = _____ (amps) and t = _____ (seconds)

14. Faraday's _____ relates the quantity of electricity (measured in _____) to the quantity of _____ passing through the circuit.

15. Silver ions have a single positive charge so one _____ of silver ions will need one mole of electrons to be reduced. Reduction takes place at the _____. The mass of metals deposited is the product of the number of _____ multiplied by the _____ _____ _____ (ram)

Extension Activities

1. Explain the difference between oxidation and reduction.

_____

_____

_____

_____

_____

For questions 2 &3 refer to the galvanic cell. (Figure 1)

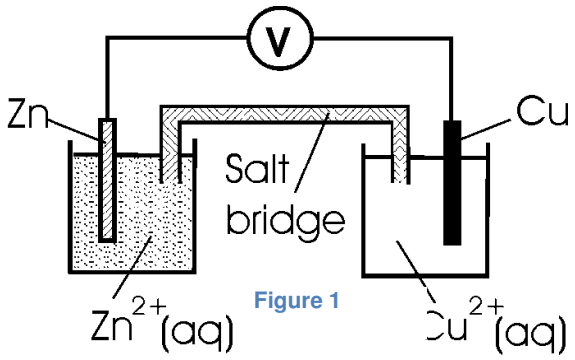

Figure 1

2. On the diagram show polarities (+/-) of the electrodes.

3. On the diagram show the flow of electrons

For questions 4, 5 & 6 refer to the electrolytic cell (Figure 2) which was set up to plate a key with copper.

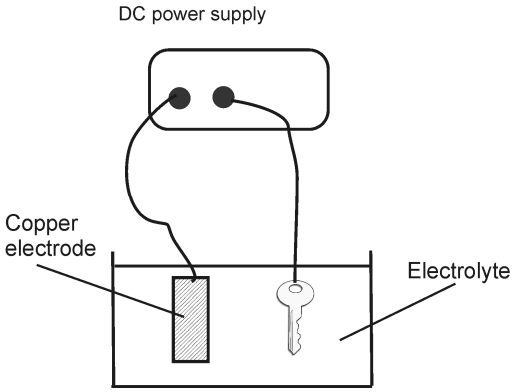

Figure 2

4. On the diagram show polarities (+/-) of the electrodes.

5. Write an equation for the reaction occurring at the copper electrode.

_____

6. Suggest a suitable electrolyte.

_____

7. Figure 3 shows a Hoffman voltameter. Outline how it operates.

_____

_____

_____

_____

_____

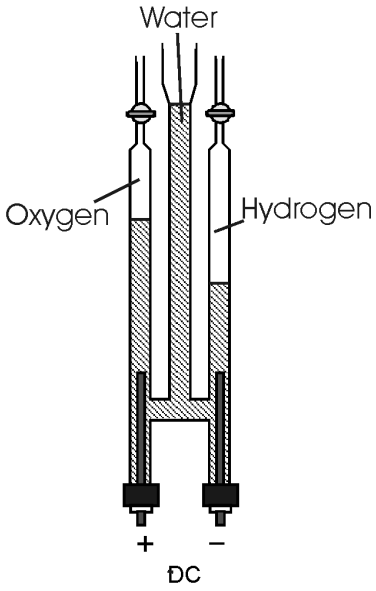

Figure 3

8. Balance the equation showing the electrolysis of brine. Include symbols of state.

   $NaCl + H_2O \rightarrow NaOH + H_2 + Cl_2$

9. Figure 4 shows a cell used to smelt aluminum. Label the figure showing anode, cathode and alumina.

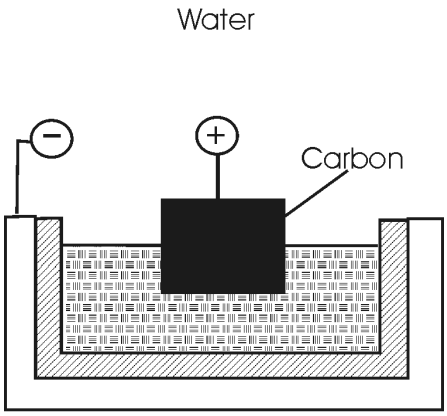

Figure 4

10. Balance the equation. $Al_2O_3 \rightarrow Al + O$. Include symbols of state.

Suggested Student Responses

Initiate Prior Learning

1. List five devices that use batteries (cells) to provide electrical energy.
   Answers will vary but could include:
   Radio
   MP3 player
   Mobile phone
   Flashlight
   Digital camera
   Electric vehicle

2. What are the major differences between a car battery and a battery used to power a flashlight?
   Size
   Current
   Length of time it can be used
   Recharge capacity
   Chemicals used in manufacture

3. What is the charge on an electron?
   Negative

4. Why are some objects plated with a particular metal (e.g. silver) rather than being made with that metal?
   Much cheaper and confers same properties

5. Why do metal atoms form ions?
   To achieve full outer shell (octet/noble gas structure)

Active Viewing Guide

Complete the following sentences.

1. Chemical reactions can produce **electricity** and electricity can produce **chemical** reactions.

2. Electrolysis can be used to coat and protect **metals**, manufacture industrial **chemicals** and refine and purify **metals**.

3. In cells producing electricity there are two **half-cells**. In one half-cell **oxidation** is taking place and in the other **reduction**. **Electrons** flow through the external circuit causing a current, and **ions** flow through the salt bridge.

4. Standard reduction electrode potentials compare half cells with that of **hydrogen**. Positive potentials show a metal is more easily **reduced** and less easily **oxidized** than hydrogen.

5. The reactions in electrolytic cells are non **spontaneous** and require **electrical** energy to proceed.

6. Water is a **molecular** substance and doesn't conduct electricity well unless e.g. an acid is added to make it an **electrolyte** Electricity causes the water to decompose and **oxygen** gas is given off at the anode; and **hydrogen** gas at the cathode in the ratios of 1:2. Oxygen **relights** a glowing splint and hydrogen "**pops!**" when it is ignited with a lit splint.

7. Industry uses electrolysis to produce metals such as **aluminum** as well as the gases **chlorine** and **hydrogen** from **brine** (sodium chloride solution).

8. Sodium **hydroxide** (NaOH) is a strong **base** and is used in the manufacture of **soaps**, **detergents**, paper and textiles. Chlorine is used in the manufacture of the plastic **polyvinyl chloride** (PVC) and in the purification of **water.**

9. **Alumina** (Al_2O_3) is smelted using vast quantities of **electricity** to produce aluminum. Cryolite is added to **lower** its melting point. In the process the carbon anode is oxidized to form **carbon** dioxide. Aluminum can be **recycled** which only uses a fraction of the **energy** needed to produce it from its ore.

10. Metals often have a surface coating of an **oxide** and this can be increased by **anodizing** to protect the metal (e.g. **aluminum**) against further corrosion.

11. Silver and **chrome** are two metals often used to plate other metals. The object to be plated is the **cathode** and the metal used for plating is the **anode**. A similar process is used to **refine** copper on an industrial scale.

12. Some batteries (cells) can be **re-charged**. These include the **lead**–acid battery used in cars, nickel **cadmium** (NiCad), nickel metal hydride and **lithium**-ion batteries.

13. Faraday's First Law of electrolysis states that the quantity of a substance consumed or produced at an electrode is **proportional** to the **electricity** used. This is expressed in the formula, Q = I x t, where Q = **coulombs**, I = **current** (amps) and t = **time** (seconds)

14. Faraday's **constant** relates the quantity of electricity (measured in **coulombs**) to the quantity of **electrons** passing through the circuit.

15. Silver ions have a single positive charge so one **mole** of silver ions will need one mole of electrons to be reduced. Reduction takes place at the **cathode**. The mass of metals deposited is the product of the number of **mole** multiplied by the **relative atomic mass** (ram)

Extension Activities

1. Explain the difference between oxidation and reduction.
   Reduction is the gain of electrons and is a decrease in oxidation state/number. Oxidation is the loss of electrons and is a decrease in oxidation state/number.

   For questions 2 &3 refer to the galvanic cell. (Figure 1)

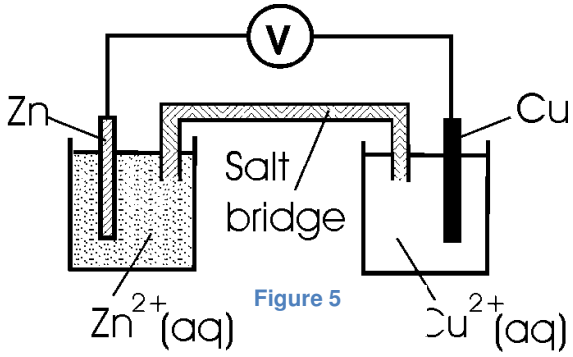

Figure 5

2. On the diagram show polarities (+/-) of the electrodes.
   The zinc electrode is negative and the copper is positive.

3. On the diagram show the flow of electrons
   Electrons are flowing from zinc to copper through the external circuit (i.e. through the voltmeter)

   For questions 4, 5 & 6 refer to the electrolytic cell (Figure 2) which was set up to plate a key with copper.

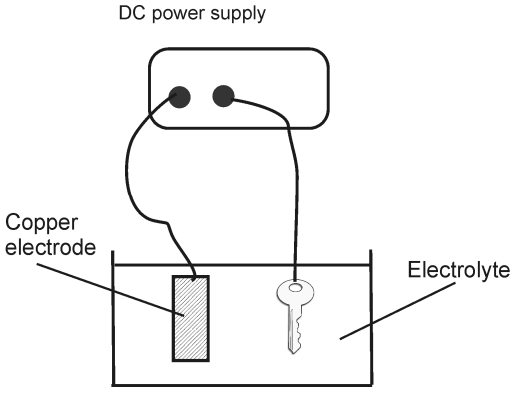

Figure 6

4. On the diagram show polarities (+/-) of the electrodes.
   The copper electrode is positive and the key is negative.

5. Write an equation for the reaction occurring at the copper electrode.
   $Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$

6. Suggest a suitable electrolyte.
   Copper sulphate

7. Figure 3 shows a Hoffman voltameter. Outline how it operates.

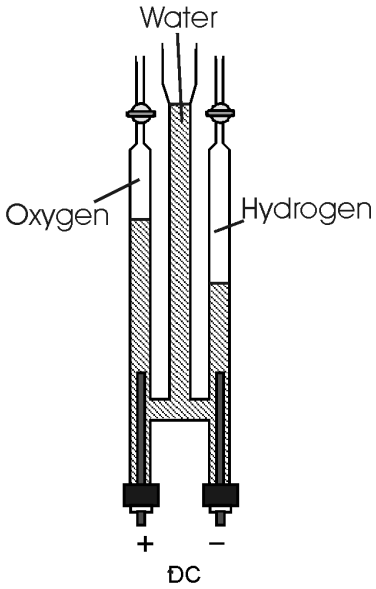

Figure 7

DC current is supplied to the (unreactive) electrodes. Hydrogen is given off at the negative cathode and oxygen is given off at the positive anode in the ratio of 2:1.

8. Balance the equation showing the electrolysis of brine. Include symbols of state.

   $NaCl + H_2O \rightarrow NaOH + H_2 + Cl_2$

   $2NaCl(aq) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g) + Cl_2(g)$

9. Figure 4 shows a cell used to smelt aluminum. Label the figure showing anode, cathode and alumina.

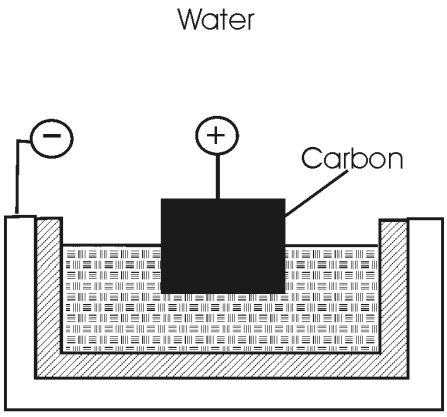

Figure 8

The anode is the positive terminal (carbon), the cathode is the negative terminal (casing) and the alumina is the contents of the cell

10. Balance the equation. $Al_2O_3 \rightarrow Al + O$. Include symbols of state.
    $Al_2O_3(l) \rightarrow 2Al(l) + 1½O_2(g)$ or $2Al_2O_3(l) \rightarrow 4Al(l) + 3O_2(g)$