Classroom VIDEO

Teacher's Notes

Wet Cells, Dry Cells, Fuel Cells

How the various electrochemical cells work

Grades: 7-12

Duration: 33 mins

Program Summary

This video is an introductory program outlining the history and development of different types of electrochemical cells with specific emphasis on fuel cells. A detailed explanation of the production of electricity from chemical reactions is provided including the process of oxidation-reduction (REDOX). The program explores various types of fuel cells, describing their chemistry, applications, benefits and drawbacks. The video concludes with a discussion of the Hydrogen Age including the efficiency of fuel cells and their economic and environmental costs.

Introduction

Our lifestyle uses a lot of energy. Electrical energy is a very versatile form of energy for us to use but how do we make electrical energy portable? Electrochemical cells including batteries and fuel cells are one answer.

Oxidation-Reduction (REDOX)

Spontaneous chemical reactions that liberate electrical energy are part of a class of reactions known as oxidation-reduction or REDOX reactions. In this section of the video the chemistry of reactions occurring in electrochemical cells is explained. The transfer of electrons from one atom to another forms the basis of these reactions. Oxidation involves the loss of electrons. Reduction involves the gain of electrons. Electricity is the resulting flow of electrons through an external path or circuit.

Wet Cells

In this section the terms ion and electrolyte are defined. A zinc/copper electrochemical cell is set up and explained. Electrons travel from the negative zinc anode to the positive copper cathode through an external circuit containing a voltmeter. The oxidation reaction taking place at the zinc electrode is

$Zn(s) ? Zn^{+2}(aq) + 2\ e^-$

The reduction reaction taking place at the copper electrode is

$Cu^{+2}(aq) + 2\ e^- ? Cu(s)$

Electrons flow through an external circuit.

Dry Cells

Flashlight batteries are examined in this section. The alkaline cell is depicted and explained. The chemical reaction between the zinc, which is the negative electrode, and hydroxide ions in the electrolyte releases electrons.

$Zn(s) + 2OH^-(aq) ? Zn(OH)_2(s) + 2\ e^-$

The reaction at the positive electrode uses these electrons.

$2MnO_2(s) + 2H_2O(l) + 2\ e^- ? 2MnO(OH)(s) + 2OH^-(aq)$

The flow of electrons in the external circuit light the bulb. Batteries are defined as two or more cells connected together. A cutaway battery is shown with multiple cells exposed.

Secondary Cells

Secondary cells can be recharged. A 12-volt car battery is displayed and explained. Six 2-volt cells connected in series produce 12 volts. At the negative electrode, lead reacts with sulphate ions in the electrolyte releasing electrons.

$Pb(s) + SO_4^{-2}(aq) \rightarrow PbSO_4(s) + 2\,e^-$

At the positive electrode, the lead (IV) oxide reacts with hydrogen and sulphate ions to take up electrons.

$PbO_2(s) + 4H^+(aq) + SO_4^{-2}(aq) + 2\,e^- \rightarrow PbSO_4(s) + 2H_2O(l)$

The reaction is reversed to recharge the battery by connecting the electrodes to a supply of direct current.

Fuel Cells

Fuel cells operate like other electrochemical cells or batteries however, unlike batteries, they do not run down or require recharging. They will continue to produce electricity as long as fuel is supplied to the cell. A fuel cell consists of two electrodes sandwiched around an electrolyte. Oxygen is passed over one electrode and hydrogen or some other fuel is passed over the other, generating electricity and heat. The history of fuel cells over the past 160 years is depicted in the video. Space research, fuel shortages and environmental concerns have prompted further research into fuel cell technology. Ballard Power Systems is one of the leaders in new technological developments today. In the Proton Exchange Membrane Fuel Cell (PEMFC), hydrogen and oxygen are fed into a cell separated by a catalyst coated membrane. Encouraged by the catalyst, hydrogen atoms at the anode of the cell split into protons and electrons.

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

The protons pass through the membrane while the electrons create an electrical current in an external pathway to the cathode. At the cathode the hydrogen atom is recombined and reacts with oxygen to form water.

$1/2O_2(g) + 2H^+(aq) + 2\,e^- \rightarrow H_2O(l)$

These cells operate at low temperatures, start up quickly, have high power density, and can vary their output making them ideal for applications such as in vehicles, buildings and smaller applications where batteries might be used.

Solid Oxide fuel cells are another promising technology. that could be used in large, high power electricity generating stations. Higher operating temperatures (1,000 °C) and longer start up make them more suited to high power electricity generating stations and other industrial applications. Power generating efficiencies could reach 85% with cogeneration.

Alcohol fuel cells are similar to the PEM cells however the anode catalyst draws the hydrogen directly from methanol or ethanol fuel. This eliminates the need for a fuel reformer. Alcohol fuel cells operate at lower temperatures and are ideal for small applications such as powering cellular phones or laptop computers.

Semi fuel cells, such as the zinc air fuel cell, require the replacement of the fuel once it is used up. A watch battery is shown as an example. The main advantage of these cells over other batteries is their high specific energy. They deliver long running duration relative to their weight. The cost of their production is also relatively low in part to the abundance of zinc.

Fuel Cells and Efficiency

Efficiency refers to the ability of a device to transform input energy into another desired form of energy. When referring to fuel cells, efficiency equals the ratio of useful energy obtained from the fuel. Cogeneration combines the utilization of electrical and thermal energy produced, resulting in much higher efficiencies.

The Hydrogen Age

Hydrogen is the most abundant element in the universe however on earth it is found in compounds. All of the fuel cells discussed in this program use hydrogen either directly or from other compounds. Two methods of obtaining hydrogen by decomposing other compounds are explained. The water gas reaction liberates hydrogen from coal.

$C(s) + H_2O(l) \rightarrow CO(g) + H_2(g)$

Hydrogen can also be produced by the electrolysis of water.

$2H_2O(l) \rightarrow 2H_2(g) + O_2(g)$

Both of these processes require high amounts of energy. Storage and safety concerns also exist. Hydrogen must be pumped and stored under high pressure and is extremely flammable. Due to the high costs associated with production, storage and utilization, hydrogen is not currently as viable an energy source as compared to cheaper hydrocarbon fuels.

Suggested Student Activities

- Have students complete the video worksheet/quiz during or following the video presentation.
- Have students complete their own summary review following the viewing of the video.
- Have students construct electrochemical cells in class and investigate factors that affect voltage. (Students can bring in different fruits and vegetables, vinegar, citric juices, etc. A variety of different types of metal electrodes can be used.)
- Have students connect cells together in series and parallel and measure voltage.
- Have students draw labeled diagrams of different types of electrochemical cells.
- Have students research and report on the design and operation of one type of electrochemical cell.
- Have students construct a model of a fuel cell or other electrochemical cell.

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Wet Cells, Dry Cells, Fuel Cells **Name**_____

Video Worksheet/Quiz **/50**

1. Name three sources of energy. _____ _____ _____
2. To what versatile form do we convert much energy? _____
3. How is electrical energy made portable? _____
4. Electrochemical cells produce electricity by _____ reaction or vice versa.
5. **Oxidation-Reduction REDOX** involves the transfer of _____ between atoms.
6. Oxidation involves the _____ of electrons.
7. Reduction involves the _____ of electrons.
8. Electricity is the flow of _____.
9. Who invented the **Wet Cell** or Voltaic cell? _____
10. What is an ion? _____
11. A liquid capable of conducting electricity is called an _____.
12. A common example of a **Dry Cell** is a _____.
13. A chemical reaction in the cell begins and electricity is formed when a _____ is completed.
14. A battery consists of _____.
15. **Secondary Cells** can be _____.
16. A common example of a secondary cell is a _____.
17. Six 2-volt cells connected in _____ produce 12 volts.
18. **Fuel Cells** have _____ and _____ fed in and waste products removed.
19. **PEMFC** stands for _____ Fuel Cell.

20. _____ pass through the membrane.
21. The waste product is _____.
22. _____ flow through the external circuit.
23. **Solid Oxide Fuel Cells** can use fuels such as _____ or _____.
24. How efficient are Solid Oxide Fuel Cells? _____
25. What is their operating temperature? _____
26. **Alcohol Fuel Cells** use fuels such as _____ or _____.
27. **Semi Fuel Cells** like the common watch battery require replacement when the _____ is used up.
28. **Efficiency** refers to how much of a fuels energy is _____ to electricity.
29. A heat engine is a device that transfers heat energy into _____energy.
30. Name two examples of heat engines. _____ _____
31. Combining the production of electricity and thermal energy is called _____.
32. Heat engines produce pollutants such as _____.
33. Some of the benefits of fuel cells are _____ and _____.
34. **Hydrogen** is separated from compounds such as _____ or _____.
35. Hydrogen can be produced by what two methods? _____ _____
36. Both of these processes require a lot of _____.
37. **Storage and Safety** is a concern because hydrogen is stored under very high _____ and is extremely _____.
38. Why is hydrogen more expensive than fossil fuels to produce? _____
39. Hydrogen will not be a viable energy solution until its _____ and _____ can compete with hydrocarbon fuels.

Wet Cells, Dry Cells, Fuel Cells *Answer Key*

Video Worksheet/Quiz **/50**

1. Name three sources of energy. *Answers may vary,(fossil fuels, nuclear, hydro, etc.)*
2. To what versatile form do we convert much energy? *Electricity*
3. How is electrical energy made portable? *Electrochemical cells or batteries*
4. Electrochemical cells produce electricity by *chemical* reaction or vice versa.
5. **Oxidation-Reduction REDOX** involves the transfer of *electrons* between atoms.
6. Oxidation involves the *loss* of electrons.
7. Reduction involves the *gain* of electrons.
8. Electricity is the flow of *electrons*.
9. Who invented the **Wet Cell** or Voltaic cell? *Alessandro Volta*
10. What is an ion? *A charged atom or group of atoms*
11. A liquid capable of conducting electricity is called an *electrolyte*.
12. A common example of a **Dry Cell** is a *flashlight battery*.
13. A chemical reaction in the cell begins and electricity is formed when a *circuit* is completed.
14. A battery consists of *two or more cells connected together*.
15. **Secondary Cells** can be *recharged*.
16. A common example of a secondary cell is a *car battery*.
17. Six 2-volt cells connected in *series* produce 12 volts.
18. **Fuel Cells** have *fuel (hydrogen)* and *oxygen* fed in and waste products removed.

PEMFC stands for *Proton Exchange Membrane* Fuel Cell.

19. **PEMFC** stands for *Proton Exchange Membrane* Fuel Cell.
20. *Protons* pass through the membrane.
21. The waste product is *water*.
22. *Electrons* flow through the external circuit.
23. **Solid Oxide Fuel Cells** can use fuels such as *natural gas* or *diesel*.
24. How efficient are Solid Oxide Fuel Cells? *60 %*
24. What is their operating temperature? *1,000 °C*
26. **Alcohol Fuel Cells** use fuels such as *methanol* or *ethanol*.
27. **Semi Fuel Cells** like the common watch battery require replacement when the *fuel (zinc)* is used up.
28. **Efficiency refers to how much of a fuel's energy is *converted* to electricity.**
29. A heat engine is a device that transfers heat energy into *mechanical* energy.
30. Name two examples of heat engines. *Internal combustion and steam engines*
31. Combining the production of electricity and thermal energy is called *cogeneration*.
32. Heat engines produce pollutants such as *nitrogen oxides, sulphur dioxide, carbon dioxide*.
33. Some of the benefits of fuel cells are *less pollution, quiet, fewer moving parts*.
34. **Hydrogen** is separated from compounds such as *water* or *hydrocarbons*.
35. Hydrogen can be produced by what two methods? *Water gas reaction or electrolysis of water*
36. Both of these processes require a lot of *energy*.
37. **Storage and Safety** is a concern because hydrogen is stored under very high *pressure* and is extremely *flammable*.
38. Why is hydrogen more expensive than fossil fuels to produce? *High cost to extract and store*
39. Hydrogen will not be a viable energy solution until its *cost* and *efficiency* can compete with hydrocarbon fuels.