Chemical Batteries

65

2-3

40- to 50-minute sessions

ACTIVITY OVERVIEW

In this activity students investigate energy conversion through the study of simple electrochemical cells. They design an investigation to determine the best combination of metals to use in a wet cell. Students explore different combinations of metals and observe the reaction rates. Metals such as aluminum and zinc react rapidly with copper chloride solution, while iron reacts more slowly. Students apply this knowledge to choosing metals for constructing a battery. Students further investigate the effects of distance between the metals, reversing connections, and reducing surface area of metal on the power of the wet cell.

KEY CONCEPTS AND PROCESS SKILLS

(with correlation to NSE 5–8 Content Standards)

1. Energy is associated with heat, light, electricity, mechanical motion, sound, nuclei, and the nature of a chemical. (PhysSci: 3)
2. In most reactions, energy is transferred into or out of a system. (PhysSci: 3)
3. Students design and conduct a scientific investigation. (Inquiry: 1)
4. Students use appropriate tools and techniques to gather, analyze, and interpret data. (Inquiry: 1)
5. Students use evidence to develop descriptions, explanations, predictions, and models. (Inquiry: 1)

KEY VOCABULARY

battery

electrolyte

electrochemical cell

reactants

MATERIALS AND ADVANCE PREPARATION

For the teacher

- 1 Transparency 65.1, "Metals Activity Chart"
- 1 Scoring Guide: Designing Investigations
- * 1 overhead projector

For the class

Make available to the class extra strips of:

- copper
- magnesium
- zinc
- iron

* multimeter (optional)

For each group of four students

- 1 30-mL dropper bottle of 3% hydrogen peroxide solution
- 1 small piece of sandpaper

For each pair of students

- 1 SEPUP wet cell chamber
- 1 strip of each of the following metals:
  - copper
  - iron
  - magnesium
  - zinc
- 5 packages of table salt
- 1 plastic spoon
- 1 50-mL graduated cylinder
- 2 wire leads—one red and one black
- 1 270-mL (9-oz.) plastic cup
- 1 electric motor
- * masking tape
- * paper towel

For each student

- 1 Scoring Guide: Designing Investigations (DI) (optional)
- 1 Science Skills Student Sheet 5, "Elements of Good Experimental Design" (optional)
- 1 Literacy Student Sheet 4c, "Writing Frame–DI" (optional)
- * 1 pair of safety goggles

**Not supplied in kit*

The magnesium will come in a roll instead of strips. Cut the magnesium into strips the size of the other metal strips.

Masters for scoring guides are in Teacher Resources III: Assessment. Masters for Science Skills Student Sheets are in Teacher Resources II: Diverse Learners.

SAFETY NOTE

Have students wear safety eyewear. Do not allow solutions to touch your skin or clothing. Clean up any spills immediately. Remind students that if accidental contact occurs, they should inform you immediately and rinse exposed areas. Hydrogen peroxide may cause skin reddening in sensitive individuals.

TEACHING SUMMARY

Getting Started

1. Introduce batteries as chemical-to-electrical energy transformers.
2. Introduce students to the equipment for constructing a wet cell.

Doing the Activity

3. (DI Assessment) Students design and conduct an investigation to determine the best combination of metals for a battery.

Follow-Up

4. Students use the data they have collected to recommend the best way to construct a wet-cell battery.

BACKGROUND INFORMATION

A battery is a device that transforms chemical energy into electrical energy through a chemical reaction. For example, when a battery is put in a flashlight and the light is turned on, a path for electron flow has been connected. The manganese dioxide cathode (negative terminal) starts to chemically react with the moist paste, leaving an excess of electrons on this terminal. The electrical current flows through the external circuit, through the flashlight and back to the zinc anode (positive terminal).

Free electrons are produced during the reaction in a battery, and kinds of metals react differently. Unit B, "The Chemistry of Materials," of Issues and Physical Science helped provide students with the experimental background for understanding that different metals have different chemical properties. The reactivity of some common metals with copper chloride is as follows:

Reactivity of Metals

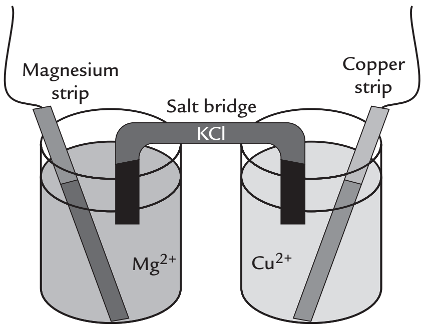
Metal	With copper chloride
Magnesium	Reacts rapidly
Aluminum	Reacts rapidly
Zinc	Reacts slowly
Iron	Reacts slowly
Copper	No reaction

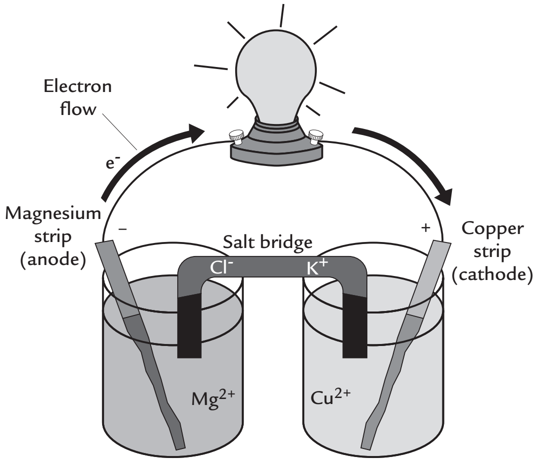
The reason some metals react more readily (dissolve in acid, oxidize in air, react with copper chloride solution) than others is because the electrons in these metals are only loosely held and are readily lost to other materials. When a neutral element loses electrons, it forms positive ions. This tendency to lose electrons is summarized in the table below. The values are given in volts for standard chemical cells. The higher the voltage listed, the greater the potential to lose electrons. The voltage values reflect the potential energy available in a chemical reaction when one metal loses electrons to a less reactive substance (another metal, for example).

Metal	Ion formed	Electrons lost	Voltage (V)
Magnesium (Mg)	Mg^{2+}	2e–	+2.37
Aluminum (Al)	Al^{3+}	3e–	+1.66
Zinc (Zn)	Zn^{2+}	2e–	+0.76
Iron (Fe)	Fe^{2+}	2e–	+0.44
Copper	Cu^{2+}	2e–	–0.34

Notice that magnesium loses two electrons to form a positive magnesium ion. This chemical change releases 2.37 volts of potential energy. On the other hand, copper is least likely to lose electrons—it has a negative voltage of –0.34 volts. This helps to explain why we find no pure, elemental magnesium in nature, but native copper is quite common. Magnesium readily loses electrons to form ionic compounds, i.e., the magnesium salts found in seawater. Copper, being less reactive, slowly forms a patina or coating with oxygen, water, and carbon dioxide that helps protect it from further corrosion.

In an electrochemical cell, two different metals are placed in a salt solution (the electrolyte) and connected by a salt bridge and wire, as shown below. Electrons (current) flow from the more reactive to the less reactive metal. This current passes through a circuit. If a lightbulb is in contact, and the current is sufficiently strong, the bulb will glow. In a copper-and-magnesium battery the magnesium gives up electrons to form positive magnesium ions, and positive copper ions gain these electrons to form a coating of copper on the copper bar. The metals are called electrodes.





The following equation reflects this electrochemical cell. The overall reaction can be written as the sum of two simple half-cell reactions, which gives the net voltage the cell can produce:

$$\begin{array}{rcll} Mg(s) & \rightarrow & Mg^{2+}(aq) + 2e^- & +2.37\ V \\ Cu^{2+}(aq) + 2e^- & \rightarrow & Cu(s) & +0.34\ V \\ \hline Cu^{2+}(aq) + Mg & \rightarrow & Cu(s) + Mg^{2+}(aq) & +2.71\ V \end{array}$$

The bottom line equation shows that by adding the two half-cell equations the electrons have canceled out. Notice that we have reversed the copper reaction to show that the copper ions are the receivers of electrons from the magnesium metal. If two or more of these cells are connected in series, a battery (literally, two or more cells joined together) is formed with an increasingly higher voltage. Three of these cells connected in series would produce a total of 3 x 2.71 volts, or 8.13 volts.

When the concentration of copper ions falls below a certain value, the electrons no longer flow and the cell is said to be "dead." In certain types of cells—the lead–acid and nickel–cadmium batteries, for example—recharging makes the cell regenerate by reversing the chemical reaction and adding electrons to the system.

The choice of metals used in a battery depends both on the voltage desired and how quickly the current will drain from the battery. Another consideration is how the voltage drops off with use. Mercury and nickel–cadmium batteries can supply a constant voltage until their reactants are exhausted. Alkaline and carbon-cell batteries slowly decrease in voltage and, even though still useful for lower voltage applications, will stop working in appliances that have minimum voltage requirements. This is referred to as the cut-off voltage.

The amount of energy a battery can supply also depends on the number of electrons produced per second in the reaction. (The number of electrons per second is commonly referred to as the current, which is measured in amperes.) Even though a 9-volt battery has a greater potential voltage, it supplies far fewer electrons per second than the 1.5-volt battery. The 1.5-volt battery can supply more total energy than the 9-volt. For example, a standard flashlight bulb glows much more brightly when it is connected to a 1.5-volt battery than to a 9-volt battery.

As another example, a Van de Graaff generator may produce thousands of volts, but since there are few electrons being produced per unit time, it cannot harm a person who makes contact with its brilliant sparks. In contrast, a 60-volt battery rated at 50 amperes could produce a lethal current.

TEACHING SUGGESTIONS

■ GETTING STARTED

1. **Introduce batteries as chemical-to-electrical energy transformers.**

Ask students, ***What do a battery and a peanut have in common when we consider them as sources of energy?*** Students should respond that each is made up of chemicals, and each has the potential to release its energy through chemical change. In Activity 63, "Measuring Calories," students observed how during combustion the peanut released some of its stored energy as heat.

Ask, ***Does anyone know what goes on inside a battery?*** Some students may suggest that batteries are full of chemicals. Some may have observed how a leaky battery corrodes its casing and connectors if it is left too long without changing it, or they may know that a car battery has acid in it. Suggest that a battery is actually an energy transformer. A chemical reaction releases electrical energy. Batteries use two different materials, usually two metals that serve as positive and negative terminals. Introduce the term **electrolyte**. An electrolyte is a material capable of conducting electricity that allows the current to flow as it released from the reaction. The electrolyte material in an alkaline battery, for example, is potassium hydroxide or manganese dioxide paste. The nature and the amount of materials inside the battery determine how much potential chemical energy is available.

■ **Teacher's Note:** Technically a battery is the combination of more than one cell. However, we are following the popular usage of the term battery, which includes single cells (such as the 1.5 V) that operate independently.

2. **Introduce students to the equipment for constructing a wet cell.**

Tell students that they will now have the opportunity to construct simple chemical batteries from different types of materials and explore how much potential chemical energy each one can convert to electrical energy. They will test and compare each kind of battery they produce by trying to run a motor with each one. How fast the motor runs is an indicator of the rate at which energy is transmitted (the voltage and electric current) from the battery to the motor.

Distribute the materials to each team of four students, and identify each of the components. The alligator clips on the wire leads connect the small motor to the metal strips. Stress that it is important to handle the motor very carefully when attaching these clips; the small pins on the motor will break off with constant bending. Warn students to avoid getting the motor wet and to handle it gently. Demonstrate how to stick a small piece of masking tape to the drive shaft of the motor so that it resembles a flag.

Tell students that they will use the motor to measure how much energy their batteries produce by observing how quickly the shaft turns. Have students connect one end of the red jumper cable to the pin on the motor marked with a red dot. Connect the black cable to the other pin. Explain to each group that one person should hold the motor during each battery test and count how many times the shaft turns in 10 seconds, or observe the relative speed of the shaft. Or, you may want to have one pair in each group perform three copper–metal combinations and the other pair perform the remaining combinations. The entire group should observe as each type of battery is tested with the motor.

Review the following with the class before they begin:

1. One person is to hold the motor.
2. The masking tape "flag" should be small and not touch the motor. After the connections are made, students may gently push the flag to help the motor begin turning.
3. Before lowering the metal strips into the wet cell solutions, attach each lead to the motor and to one end of a metal strip. Some of the reactions last only a few seconds, so students should not lower the metal strips into the solutions until they are prepared to make their observations.

4. At the beginning of each test, students should use the piece of sandpaper to clean the surface of the metals.

Have students complete "Part A: Testing the Motor" to make sure the equipment is working properly and that they understand the general idea of the activity.

■ **Teacher's Note:** Because of chemical changes on the surface of the iron, you may need to use a new iron strip to obtain consistent readings after one or two uses.

■ DOING THE ACTIVITY

3. (DI ASSESSMENT) Students design and conduct an investigation to determine the best combination of metals for a battery.

If students are having difficulty designing the experiment, you may want to review Science Skills Student Sheet 5, "Elements of Good Experimental Design," with them. Remind them of the following requirements for a well designed investigation:

- The procedure should change only one variable at a time.
- Measurements should be taken consistently.
- Minimize human error.

As students begin to design their experiments, circulate among the groups, and encourage group members to demonstrate to each other their suggestions for how the experiment could be run. Look at their notes, and ask them if they think another student could run the experiment after just reading their procedure steps. If a group's procedure doesn't look clear, ask them to follow the procedure as you read it. This will help them identify problems in their design.

The DESIGNING INVESTIGATIONS (DI) Scoring Guide can be used to evaluate students' work in Procedure Step 3. If appropriate, give each student a copy of the DI Scoring Guide. For more information about the DI Scoring Guide and the SEPUP Assessment System, see Teacher Resources III: Assessment. If you chose not to assess students using the DI Scoring Guide, you might instead have the class discuss together what would be a Level 3 complete and correct design. A sample design is shown below.

Level-3 Response:

"Chemical Batteries: Metal Combinations " Procedure

1. Pour the electrolyte into the SEPUP wet cell.
2. Lower two strips of different metals into the outside slots of the SEPUP wet cell. There should be a small amount of metal sticking out of the cells.
3. Connect the wire leads to the motor and the metal strips.
4. Observe the motor spinning.
5. Record observations in a data table.
6. Disconnect the wire leads. Remove the two metal pieces. Dry them, and then clean both sides with a piece of sandpaper.
7. Repeat Steps 1–6 for all the metal combinations that cause the motor to spin.

See the sample response on the next page for an appropriate data table. If students are assessed on "Part C: Other Effects," the procedures should be similar but vary the distance, orientation, or surface area of the strips.

As you go over groups' plans, decide which groups can complete the investigation effectively on their own and which will need your assistance in carrying out the work. Alternatively, if you have time, have students critique each other's plans. Collect the groups' original plans, and copy them for scoring purposes. Then allow groups to trade plans and respond to them before carrying out the investigation.

Students will use different combinations of four metals to construct the poles of a chemical battery. You may want them to construct their own table after thinking about what combinations are possible. Instead, you may want to provide guidance for a table similar to the one on the next page, which shows typical results of the six possible combinations. Students may try using two strips of the same reactive metal (i.e. copper) and discover it doesn't work.

Sample Student Data: Chemical Batteries

Metal combinations		Observations	Motor speed
Copper	Magnesium	Magnesium bubbles	Very fast
Copper	Zinc	Copper discolors	Moderate
Copper	Iron	No change	None
Zinc	Magnesium	Magnesium bubbles	Slow
Zinc	Iron	No change	None, or slight turn when flag is pushed
Magnesium	Iron	Magnesium bubbles	Fast

To measure the voltage and current generated by each cell, you can use a multimeter. The class can record voltage and current and compare those numbers to the number of turns and speed of the motor for each combination of metals. Some sample results are shown in the table below. These are average values; you may see other results based on the experimental setup.

Voltage and Current for Metal Combinations

Metal combinations		Voltage (V)	Milliamperes (mA)
Copper	Magnesium	1.53	1.50
Copper	Zinc	0.84	0.60
Copper	Iron	0.38	0.25
Zinc	Magnesium	0.68	0.55
Zinc	Iron	0.46	0.30
Magnesium	Iron	1.20	1.00

When students are finished, they should rinse and dry all materials. The equipment, such as the alligator clips, will corrode easily if left in contact with the salt solution.

■ FOLLOW-UP

4. **Students use the data they have collected to recommend the best the best way to construct a wet-cell battery.**

Call on different groups to review the student's data and explain how they arrived at their conclusions. Stress the importance of basing their conclusions on the evidence from their observations. Students should note that any combination with magnesium made the motor turn, and in the case of copper and zinc the motor turns slowly for a considerable time. On the other hand, all but one combination with iron produced no motion. Therefore, combinations with magnesium work best, and iron works poorly in most combinations.

Have students refer to their data tables. Ask, ***Do you have any ideas why some combinations worked better than others in providing energy for the motor?*** For example, why did the combination of copper and magnesium work so well? The more the metals differ in their reactivity, the more there is a tendency for electrons to flow from one metal to the other, as discussed in Analysis Question 3. Therefore, more energy is available to power the motor.

Tell the class that by analyzing the results of many experiments involving metals reacting with each other, scientists have produced a table of metal activities that help us predict what will happen in any pairing of two metals. Display Transparency 65.1, "Metals Activity Chart." Based on this information, scientists and engineers have selected certain metals to produce stronger and longer-lasting batteries. Some of these in use today are mercury, nickel–cadmium, lead–acid, silver oxide, zinc–air, and lithium batteries.

Review the important concepts that were developed in the activity. Emphasize that a battery transforms potential chemical energy into electrical energy. When the circuit is completed, electrical current is allowed to flow from the negative pole of a battery to the positive pole. This electricity can do work, such as light a lamp or run a CD player. Students saw evidence for this reaction in how quickly the motor shaft turned and in the discoloration of the metals and the slight bubbling of the magnesium strip.

SUGGESTED ANSWERS TO QUESTIONS

1. *Was there a chemical change when you inserted the strips into the electrolyte? Describe any evidence that supports your answer.*

   Students should be aware of signs of a chemical change such as a color change, temperature increase, or the formation of a precipitate or gas. In this activity, the magnesium in combination with any of the other three metals formed a gas, as indicated by small bubbles. The zinc and copper combination resulted in a discolored copper strip. The other two combinations involving iron showed no signs of chemical change and did not drive the motor.

2. *Use your results from Part B to rank the metal combinations from 1 to 6 with 1 as the highest-releasing electrical energy rate, and 6 as the least. Describe any evidence that determined the ranking.*

   Magnesium–copper

   Magnesium–iron

   Zinc–copper

   Zinc–magnesium

   Zinc–iron

   Copper–iron

3. *Look at the table below that describes the reactivity of the metals used in this activity. Compare the table to your response in Analysis Question 2.*

Metal	Reactivity	Tendency to give up electrons
Magnesium	Most ↓ Least	Most ↓ Least
Zinc		
Iron		
Copper		

Based on the comparison:

a. *Does reactivity alone indicate what combinations of metals will release the most energy?*

   The table shows that metal reactivity alone is not enough to predict the general productivity of the battery. Otherwise, all the combinations with magnesium would rate the highest, and all the combinations with copper would rate the lowest.

b. *What patterns do you see that could indicate why the most and least energy combinations occurred?*

   The farther apart in reactivity the two metals in the combination are, the more energy was released. For example, the magnesium–copper combination released the highest energy rate because magnesium and copper are the farthest apart in their tendency to give up electrons. When comparing that to combinations where metals are close in rank, the combination that includes a higher and a lower reactive metal releases more energy. For example, the magnesium–iron combination released more energy than the zinc–copper. The most productive combinations includes a metal that is reactive and a combination of metals where one tends to give up electrons and the other one that tends not to give up electrons.

c. *Gold is the least reactive metal known and tends not to give up electrons. Which metal from the table would you pair it with to make a strong battery? Explain your choice.*

   Gold should be paired with magnesium to produce the most energy releasing battery. This is because gold is less reactive than copper, making the two metals the farthest apart on the table in terms of reactivity and tendency to give up electrons.

4. *Make a table that summarizes your investigation in Part C. It should identify each effect, summarize the results, and include a brief explanation of why you think each result happened.*

Effect	Result summary	Explanation
Distance	Motor turned more rapidly.	Ions in solution have less distance to travel so there is less energy loss.
Reverse	Motor turned the opposite direction.	Energy changes direction.
Surface area	Less surface produced slower turning	Surface area is needed to react in the battery, so less surface area slows the reaction.

5. *From the materials in this activity, draw and label a battery that would produce the most energy.*

   Students' diagrams should include the metals magnesium and copper, a small distance between the metals and a large surface area.

Metals Activity Chart

Most Active

Lithium
Magnesium
Aluminum
Zinc
Iron
Cadmium
Nickel
Lead
Copper
Mercury
Silver
Gold

Least Active

SEPUP SCORING GUIDES AND ASSESSMENT COMPONENTS

1. Designing Investigations	*(DI)*
2. Organizing Data	*(OD)*
3. Analyzing Data	*(AD)*
4. Understanding Concepts	*(UC)*
5. Recognizing Evidence	*(RE)*
6. Evidence and Trade-offs	*(ET)*
7. Communication Skills	*(CS)*
8. Organizing Scientific Ideas	*(SI)*
9. Group Interaction	*(GI)*

1. DESIGNING INVESTIGATIONS (DI)

What to look for:

- *Response states a design and specifies data to be collected for the investigation.*
- *Procedures are described completely and accurately.*

Assessment Components

COMPONENT	INDICATOR
1. Reason for investigation	a. States goals and objectives of the investigation clearly.
	b. The question (in those circumstances where the student chooses the question to investigate) that the student seeks to answer is one that can be investigated scientifically in a typical classroom situation.
2. Design of investigation	a. States hypothesis or prediction clearly.
	b. Design is appropriate for the investigation.
	c. Procedures are clear, reproducible, and list specific data to be collected.
	d. Variables are identified and controlled as necessary.
3. Conducting an investigation	a. Data are accurate and precise.
	b. Data set is complete with no unnecessary gaps.
	c. Data are consistent and reproducible.

Scoring Guide

LEVEL	DESCRIPTION
Level 4 Above and beyond	Student accomplishes Level 3 and goes beyond in some significant way, such as: • identifying alternate procedures. • suggesting improved materials. • relating clearly to scientific principles and approaches.
Level 3 Complete and correct	Student's design is appropriate and has a reproducible procedure, if required.
Level 2 Almost there	Student's design or procedure is incomplete and/or has significant errors.
Level 1 On your way	Student's design or procedure is incorrect or demonstrates a lack of understanding of the goals of the investigation.
Level 0	Student's design or procedure is missing, illegible, or irrelevant.
X	Student had no opportunity to respond.

2. ORGANIZING DATA (OD)

What to look for:

- *Response accurately records and logically displays data.*

Assessment Components

COMPONENT	INDICATOR
1. Table of results	a. Data table has appropriate columns in correct sequence (e.g. independent variable in first column).
	b. Columns have appropriate headings that include measurement units.
	c. Data are in ascending or descending order.
2. Graph of results	a. Type of graph is appropriate for representing the data.
	b. Data are arranged on appropriate axes (e.g. independent variable is on x-axis).
	c. Scales used are the most appropriate for the data.
	d. Axes are labeled with names of variables and units.
	e. Data points are plotted correctly.

Scoring Guide

LEVEL	DESCRIPTION
Level 4 Above and beyond	Student accomplishes Level 3 and goes beyond in some significant way, such as: • using innovation in the organization or display of data.
Level 3 Complete and correct	Student logically presents complete and accurate data.
Level 2 Almost there	Student reports data logically BUT records are incomplete.
Level 1 On your way	Student reports data BUT records are illogical OR records contain major errors in the data.
Level 0	Student's data is missing, illegible, or irrelevant.
X	Student had no opportunity to respond.

WATER (Continued from previous page)

	ACTIVITY DESCRIPTION	KEY CONCEPTS AND PROCESSES	ADVANCE PREPARATION	ASSESSMENT	TEACHING PERIODS
49	**MODELING: A Model for Acid-Base Neutralization** Students explore a particle model to explain neutralization.	Further evidence for particle theory of matter, elements vs compounds. MATHEMATICS	Collect index cards, red and blue marker		1–2
50	**READING: The Chemistry of Acids and Bases** Students read about the difference between ionic and covalent bonds, the dissolving of ionic and covalent compounds, and the reaction between an acid and a base.	Properties of substances, acids and bases as categories of substances, neutralization reactions.	Collect distilled water Copy student sheet	Q5: UC	1–2
51	**LABORATORY: Testing and Treating Wastewater** Students test and design a treatment for wastewater before it is discharged to the environment.	Water treatment approaches use chemical (and physical) properties of substances to remove or inactivate contaminants.		Q4: DI Q4: SI Q5: ET	2–3
52	**TALKING IT OVER: Decisions about Willow Grove's Water** Students decide whether the three water sources they have tested are suitable for proposed uses. They make recommendations about whether Carla's neighborhood should join the Willow Grove Water District or continue to use well water, drink bottled or tap water, and any ways to improve water safety in Willow Grove.	Chemical and physical properties of water and water contaminants. Risk assessment		Proc: CS Q1: ET	2

UNIT D: ENERGY

Listed below is a summary of the activities in this unit. Note that the total teaching time as listed is 34-51 periods (approximately 7–10 weeks if you teach the activities as recommended every day). If you find that you cannot finish in this timeframe, consider skipping Activities 55, 59, 60, 66.

	ACTIVITY DESCRIPTION	KEY CONCEPTS AND PROCESSES	ADVANCE PREPARATION	ASSESSMENT	TEACHING PERIODS
53	**INVESTIGATION: Home Energy Use** Students collect data on six human characteristics and discuss causes of human variation.	Energy, energy use, trade-off LITERACY	Copy student sheets		1–2
54	**LABORATORY: Drive a Nail** Students explore energy transfer as they drive a nail into a block. The concepts of kinetic and gravitational potential energy are introduced.	kinetic energy, gravitational potential energy, energy transfer and transformation, variables		Proc: DI	2–3
55	**ROLE PLAY: Roller Coaster Energy** Students further examine energy transfer and the transformation between gravitational potential energy and kinetic energy in the context of roller coasters.	kinetic energy, gravitational potential energy, energy transfer and transformation LITERACY	Copy student sheet	Q1: UC Quick Check	1–2
56	**INVESTIGATION: Shake the Shot** Students add mechanical energy to a system and measure the temperature change that results from the energy transformation.	Energy transformation, heat, temperature, thermal energy	Fill shakers		1–2

ENERGY (Continued from previous page)

	ACTIVITY DESCRIPTION	KEY CONCEPTS AND PROCESSES	ADVANCE PREPARATION	ASSESSMENT	TEACHING PERIODS
56A	**LABORATORY: Motors and Generators** Students construct a simple motor from a wire coil, magnets, and batteries. They investigate ways of making the motor spin faster and observe that a magnetic field is produced around a current-carrying wire. Students then use a motor as a generator to light a light-emitting diode (LED).	Kinetic energy, potential energy, motors, generators, electromagnetism	Check that coil arms are scraped on one side only	Q5: UC	1–2
57	**READING: Conservation of Energy** Students read about the Law of the Conservation of Energy, the process of heat transfer during transformations and the principle of energy efficiency.	Absorption and release of energy, Law of the Conservation of Energy, efficiency, conserving energy LITERACY		Q3: UC Quick Check	1–2
58	**INVESTIGATION: Follow the Energy** Students identify different energy types as they follow energy movement in every day events.	energy types, following energy ransfer and transformation LITERACY	Copy student sheets	Q2: UC Quick Check	2–3
59	**LABORATORY: Ice Melting Contest** Students explore heat transfer by conduction as they design a method for melting an ice cube as quickly as possible.	Heat conduction, conductors, heat transfer	Provide ice, set up control		2
60	**MODELING: Ice-Preserving Contest** Students design a container to preserve an ice-cube. They follow this up by reading about ice boxes and refrigeration.	Insulation, insulators, heat transfer, refrigeration and refrigeration cycle LITERACY	Provide ice, set up control		2
61	**LABORATORY: Mixing Hot and Cool Water** Students mix different temperatures and volumes of water in order to analyze the heat transfer that occurs.	Heat conduction, thermal energy movement from hot to cold	Provide hot water		2
62	**INVESTIGATION: Quantifying Energy** Students measure temperature differences with a calorimeter and calculate the energy transferred from ice to water during melting.	calculating energy, calorie, heat and temperature MATHEMATICS	Provide ice		1–2
63	**LABORATORY: Measuring Calories** Students use a calorimeter to measure the stored energy in a nut. They use the data to calculate the Calories in the nut.	Measuring energy, calorie, heat transfer, chemical reactions give off heat, light, etc. MATHEMATICS LITERACY	Assemble coat-hanger device and shield, gather calorimetry items	Q6: AD Quick Check	2–3
64	**READING: Electricity Generation** Students investigate the sources of electricity in the United States. They read about renewable and non-renewable sources and discuss the trade-offs of different electricity generation methods.	Renewable and non-renewable energy source, electricity generation, power plant, energy types, energy transformation LITERACY	Get local power portfolio	Q3: ET Q4: AD	2–3

ENERGY (Continued from previous page)

	ACTIVITY DESCRIPTION	KEY CONCEPTS AND PROCESSES	ADVANCE PREPARATION	ASSESSMENT	TEACHING PERIODS
65	**LABORATORY: Electrochemical Batteries** Students build a wet cell to explore how different metals react to produce electrical energy. A small motor is used to detect the amount of energy the different reactions produce.	Chemical reactions can create electricity, batteries, exothermic reactions	Cut magnesium into strips	Proc: DI	2–3
65A	**LABORATORY: Energy and Magnetic Fields** Students investigate magnetic fields using a plotting compass. They also read about some of the properties of fields and electromagnets.	Energy, characteristics of fields, electromagnetism			1–2
66	**INVESTIGATION: Connecting Circuits** Students build simple circuits that transform electrical energy into light, sound, and mechanical energy. They test various materials for conductivity and explore series and parallel circuits.	Transforming electricity into sound, light and heat, conductors, electric circuits, series and parallel circuits	Obtain batteries	Proc: DI	2–3
67	**LABORATORY: Hot Bulbs** Students calculate the efficiency of a flashlight bulb in producing light by measuring how much energy is “wasted” as thermal energy.	efficiency, calorie, cost analysis, watt MATHEMATICS LITERACY	Obtain lightbulbs, batteries for demonstration	Q5: AD Quick check	2–3
68	**LABORATORY: Photovoltaic Cells** Students experiment with photovoltaic cells as they explore the sunlight– electricity energy transformation	Photovoltaic cells, parallel, series circuits		Proc: DI	1–2
69	**LABORATORY: Solar Heating** Students continue their exploration of solar energy by investigating a model solar heat collector and calculating its efficiency.	Absorption of sunlight, efficiency MATHEMATICS LITERACY	Obtain batteries, provide room temperature water		1–2
70	**MODELING: Collecting Solar Energy** Students build and compare two boxes; one to absorb as much sunlight as possible and the other one to absorb as little sunlight as possible.	Absorption, reflection and transmission of sunlight, house design Sunlight, efficiency	Assemble boxes, gather building supplies.	Proc: GI	2
71	**READING: Household Energy Efficiency** Students read about home energy use, ways to improve energy efficiency and methods of conserving energy.	efficiency, energy conservation, passive energy design, engineering, trade-offs LITERACY		Q1: UC Quick Check	1
72	**INVESTIGATION: Improving Household Efficiency** Students are presented with fictional scenarios of families who want to reduce their home energy cost. Using their knowledge of energy concepts, they conduct an economic analysis and make energy-saving recommendations that meet the needs of the family.	Efficiency, energy conservation, cost analysis, trade-offs LITERACY MATHEMATICS	Energy efficiency in the home	Q1: ET	2–3