8 *Chemical Batteries*

INVESTIGATION

1–2 CLASS SESSIONS

ACTIVITY OVERVIEW

NGSS CONNECTIONS

Students investigate how chemical energy can be transformed via a chemical process into electrical energy. After building a prototype wet cell, students brainstorm improvements and build, test, and evaluate new prototypes to meet a set of predetermined criteria within specified constraints.

NGSS CORRELATIONS

Performance Expectations

Working towards MS-PS1-6: Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes.

Working towards MS-ETS1-3: Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

Working towards MS-ETS1-4: Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

Disciplinary Core Ideas

MS-PS1.B Chemical Reactions: Some chemical reactions release energy, others store energy.

MS-ETS1.B Developing Possible Solutions:

A solution needs to be tested, and then modified on the basis of the test results, in order to improve it.

Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors.

MS-ETS1.C Optimizing the Design Solution: Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of the characteristics may be incorporated into the new design.

Science and Engineering Practices

Constructing Explanations and Designing Solutions: Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints.

Crosscutting Concepts

Energy and Matter: The transfer of energy can be tracked as energy flows through a designed or natural system.

Common Core State Standards—ELA/Literacy

RST.6-8.3: Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.

WHAT STUDENTS DO

Students build a chemical battery that transforms chemical energy into electrical energy, which in turn powers a motor. After building an initial prototype battery, students are given a set of criteria and constraints and asked to design a chemical battery that spins faster than the initial prototype for at least 5 min. Students brainstorm, build, test, and evaluate their prototypes.

MATERIALS AND ADVANCE PREPARATION

- *For each group of four students*
  - 1 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 copper
  - 1 strip of iron
  - 1 strip of magnesium
  - 1 strip of zinc
  - 5 packages of table salt
  - 1 plastic spoon
  - 1 graduated cylinder (50-mL)
  - 2 wire leads: 1 red and 1 black, with clips
  - 1 plastic cup (9-ounce)
  - 1 electric motor
  - * masking tape
  - * paper towels
  - * water

- *For each student*

* 1 pair of chemical splash goggles

1 Student Sheet 8.1, "Chemical Battery Designs"

**not included in kit*

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

SAFETY NOTE

No toxic effects are known to result from handling these chemicals, but students should wear their chemical splash goggles and wash their hands thoroughly after finishing the experiment.

TEACHING SUMMARY

GET STARTED

1. Introduce the idea that chemicals store energy that can be released when chemicals interact.

   Ask students if they are familiar with any uses of chemicals to release energy. List their ideas on the board or chart paper.

2. Introduce chemical batteries as another example of the use of chemicals to release energy.

   Explain that students will investigate a simple battery and will then design and test ways to improve its ability to power a small motor.

3. Introduce the term *prototype*.

DO THE ACTIVITY

4. Have students build and test an initial chemical battery in Part A.
   a. Students are given instructions to build an initial prototype of a chemical battery that is used in a functional circuit.
   b. Ask students to share what they noticed about the battery prototype.
   c. Discuss the role of a prototype in engineering design.

5. Have students complete Part B of the Procedure.
   a. Before students begin Part B, introduce the terms criteria and constraints.
   b. Review the criteria and constraints listed in the Student Book.
   c. Distribute Student Sheet 8.1, "Chemical Battery Designs," for students to use to record their design ideas.
   d. Students build and test their prototypes.

BUILD UNDERSTANDING

6. Students share solutions.
    a. Have groups of students discuss their designs.
    b. Have students share some of their designs with the class.
7. Relate energy and matter to this activity.

TEACHING STEPS

GET STARTED

1. Introduce the idea that chemicals store energy that can be released when chemicals interact.

    Ask students if they are familiar with any uses of chemicals to release energy. List their ideas on the board or chart paper.

    If they are having trouble thinking of examples, remind them of examples in previous activities, such as the use of candles for light. Other possible ideas are the use of fuels in vehicles, fireworks for colorful light displays, or explosives like dynamite for blasting rock to create roads.

    Explain that the rearrangement of matter in some reactions also results in transformation of energy from one form to another. For some reactions, the energy produced is of much greater value than the chemical products. Combustion of a fuel is such an example. The chemical product, carbon dioxide, is a waste, but the energy provided keeps our homes warm and powers factories and vehicles. Another example is the use of food for energy. Both food and fuel store a kind of potential energy called *chemical energy*. As this energy moves through a system it can be tracked.

2. Introduce chemical batteries as another example of the use of chemicals to release energy.

    Explain that students will investigate a simple battery and will then design and test ways to improve its ability to power a small motor.

3. Introduce the term *prototype*.

    This activity introduces ideas about engineering to students. Students will build an initial prototype of a product, a chemical battery, and then redesign the battery. Students are asked to design improved *prototypes*—early models of a product that provide information about how the device or system works. Inform students that prototypes are often made of materials that are easily accessible or available, not necessarily the final product materials. In this case, students are designing a battery using a transparent, plastic wet cell instead of materials like a metallic cylinder that might be more familiar to them.

Additional terms related to the engineering process are introduced as students perform the Procedure and in future activities.

DO THE ACTIVITY

4. Have students build and test an initial chemical battery in Part A.

   a. Students are given instructions to build an initial prototype of a chemical battery that is used in a functional circuit.

      Circulate as students complete this part of the Procedure.

   b. Ask students to share what they noticed about the battery prototype.

      Students should observe evidence of a chemical reaction, including

      - small bubbles forming on the metal strips.
      - precipitate formation—over time students may see precipitate on the metal strips.

      Students should also see the shaft of their motor spinning, which is evidence that the chemical energy released in the wet cell is being transformed into electrical energy that powers the motor.

   c. Discuss the role of a prototype in engineering design.

      Ask students to share how building the prototype helped them understand how the device works. Encourage students to share any initial ideas they have about how to make the battery better, including what they might change to improve how it works. This discussion continues below in Teaching Step 5c.

5. Have students complete Part B of the Procedure.

   a. Before students begin Part B, introduce the terms *criteria* and *constraints*.

      Engineers design solutions to problems but are limited by a set of *criteria* (minimum requirements for how the design must function; singular *criterion*) and *constraints* (something that limits or restricts the design). When products are developed, they are rarely made perfectly the first time around. Often, developing products requires a lot of brainstorming, building and testing of designs, and redesigning to get a useful product. Before a product is released to the public, it has often gone through many rounds of design and redesign. Many companies continue to improve their designs even after a product is released.

b. Review the criteria and constraints listed in the Student Book.

Sometimes products are redesigned because users want the product to do something new or better. In Part B, students are being asked to redesign the chemical battery so the motor spins faster. As a class, determine if there are additional criteria and constraints that you would like to add to those given.

c. Distribute Student Sheet 8.1, "Chemical Battery Designs," for students to use to record their design ideas.

Introduce the additional materials that students can use—a strip of copper metal and/or a strip of iron metal. Also point out the structure of the wet cell and how the metal strips can be placed in any of the slots. Have the class brainstorm the variables that can be changed. These might include the types of metal, the distance between the metals, and the amount of electrolyte.

Students should then discuss how and why they might modify the original design for the prototype with their partner. On their Student Sheet, students should draw at least four of their ideas, including as many details as possible. Stress to students that these drawings are not meant to be stellar works of art but, rather, a recording of their design ideas before building and testing. These drawings ensure that students working together understand the plan before beginning to build. They can also serve as a record of ideas tried and tested, along with results. See Sample Student Response to Student Sheet 8.1 at the end of this activity. Remind students that they should change only one variable at a time.

d. Students build and test their prototypes.

Circulate to make sure students are recording their observations and results of their different prototypes on their Student Sheet. Depending on how much time you have, students may not get to all four of their prototypes, but they should test at least two. This will allow them to determine which of the two variables has a greater effect on the chemical battery.

Engineers develop different designs to meet criteria and constraints, but modifications are made intentionally. It is not simply a trial-and-error process; instead, it is a process that involves reasoning to identify promising directions for improvement. You may want to ask each pair what modification they are testing and why they chose to make that modification.

BUILD UNDERSTANDING

6. Students share solutions.

   a. Have groups of students discuss their designs.

      In Procedure Step 11, pairs of students are instructed to work with another pair. Students should share the designs, prototypes, and results of their tests. As a group, students should be able to identify similarities and differences in their designs. Have groups discuss a further-improved design based on all of their data.

   b. Have students share some of their designs with the class.

      Have students share both successful and not-so-successful designs. Discuss how students may have approached the problem similarly or differently based on the designs shared. This is also an opportunity to discuss how designs that do not meet the criteria and constraints often inform future design ideas. This is also an opportunity to highlight the importance of collaboration. Designers often do not work in isolation but in teams. They also learn from the work of other designers.

7. Relate energy and matter to this activity.

   In previous activities, students investigated how chemical reactions lead to the rearrangement of matter to produce new chemicals. They also observed that these rearrangements of matter sometimes release energy. In this activity, students investigated the use of chemical reactions to release electrical energy. The electrical energy produced flowed through their circuit to power their motor. In the motor, electrical energy was transformed into mechanical energy.

   Emphasize that just as scientists can track and account for matter throughout a reaction, students can track and account for energy changes.

SAMPLE RESPONSES TO ANALYSIS

1. Did a chemical change take place in your wet cell? Use evidence from your investigation to support your answer.

   Yes, a chemical change took place. I know this because lots of little bubbles formed on the metal strips. When bubbles did not appear, the motor also didn't spin, which means the reaction wasn't happening and energy wasn't being released.

2. Which of your design ideas

   a. made the motor spin the fastest?

      Student responses may vary based on the prototypes they designed. One sample response is shown here:

      When I moved the metal strips closer together, the motor spun faster.

   b. made the motor spin the slowest?

      Student responses may vary based on the prototypes they designed. One sample response is shown here:

      When I used copper and iron, the motor didn't spin at all.

3. Why do you think the motor spun the fastest in the design you described in Analysis item 2a?

   Student responses may vary based on the prototypes they designed and built. One sample response is shown here:

   I think the metals were reacting together to create the electricity. When I moved them closer together, they could react faster and release more energy to power the motor.

4. When designing your prototypes, you made one modification at a time. Based on the designs from all of your classmates, which types of modifications most improved the chemical battery's performance?

   Changing the types of metals made a big difference since some metal combinations worked better than others. For example, copper and magnesium worked really well, but copper and iron didn't work at all. Moving the metals closer together also helped in some of the designs.

REVISIT THE GUIDING QUESTION

How can we improve the design of a chemical battery?

Chemicals store energy. When chemicals are rearranged during a chemical reaction, this stored energy may be released. The chemical energy can be transformed into electrical energy, or electricity. By modifying the reaction inside the battery, we can improve its performance. As engineers, new ideas can be designed, built, and tested. Testing of multiple ideas leads to the identification of which variables should be modified for improved performance.

ACTIVITY RESOURCES

KEY VOCABULARY

constraint

criterion; criteria

prototype

BACKGROUND INFORMATION

BATTERIES

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 zinc anode (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 manganese dioxide cathode (positive terminal).

Free electrons are produced during the reaction in a battery. Different metals react differently, as seen through the pairings of metals in this activity. 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 metals. When a neutral element loses electrons, it forms positive ions. Increased voltage in a battery is related to the increased 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 (e.g., another metal). Since we do not go into atomic structure and electrons in middle school NGSS, this is not explained to students in the Student Book.

The choice of metals used in a battery depends on both the voltage desired and how quickly the current will drain from the battery. Another consideration is how the voltage drops off with use. The amount of energy a battery can supply also depends on the number of electrons produced per second in the reaction.

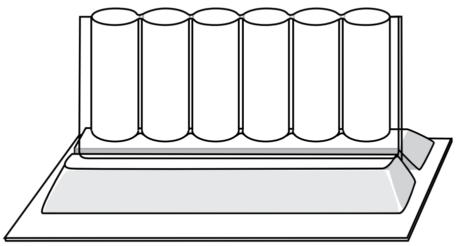
Name____________________________ Date__________

STUDENT SHEET 8.1

CHEMICAL BATTERY DESIGNS

Draw and label your preliminary designs.

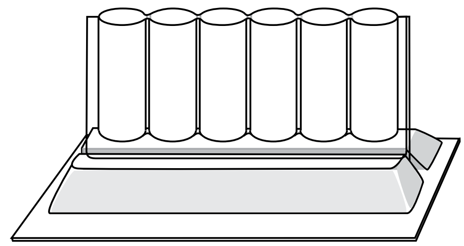
Design 1



Variable changed from the original design:

Testing result(s):

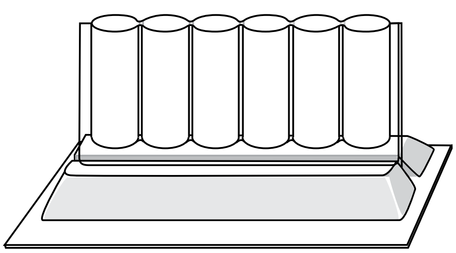
Design 2



Variable changed from the original design:

Testing result(s):

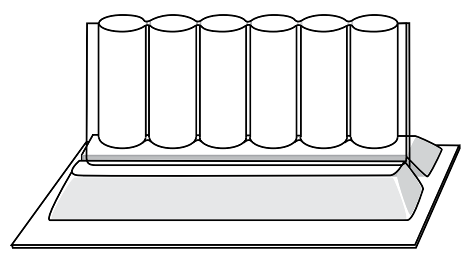
Design 3



Variable changed from the original design:

Testing result(s):

Design 4



Variable changed from the original design:

Testing result(s):

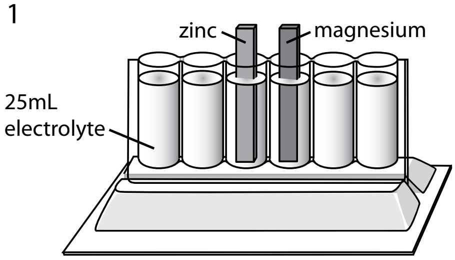
Name Sample student response Date

STUDENT SHEET 8.1

CHEMICAL BATTERY DESIGNS

Draw and label your preliminary designs.

Design 1



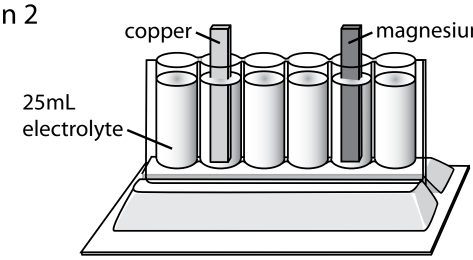
Variable changed from the original design:

Distance between metals—moved metal strips together

Testing result(s):

The motor spun for 5 min but not much faster than the original design.

Design 2



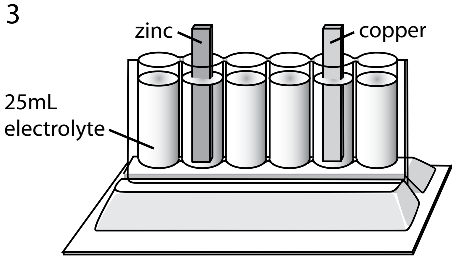
Variable changed from the original design:

Type of metals – replaced zinc with copper

Testing result(s):

The motor spun for 5 min and much faster than the original design.

Design 3



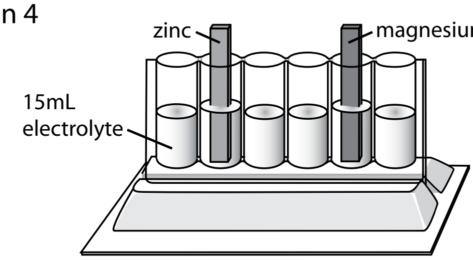
Variable changed from the original design:

Types of metals – replaced magnesium with copper

Testing result(s):

The motor spun for 5 min and a little faster than the original design.

Design 4



Variable changed from the original design:

Amount of electrolyte—decreased from 25mL to 15 mL

Testing result(s):

The motor spun for 5 min. Not much change from the original design.

NGSS UNIT OVERVIEW

CHEMICAL REACTIONS

Performance Expectation MS-PS1-2: Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.

Performance Expectation MS-PS1-5: Develop and use a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved.

Performance Expectation MS-PS1-6: Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes.

Performance Expectation MS-ETS1-3: Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

Performance Expectation MS-ETS1-4: Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

Activity Description	Disciplinary Core Ideas	Science and Engineering Practices	Crosscutting Concepts	Common Core State Standards
1. **Investigation: Producing Circuit Boards** Students analyze and interpret data to compare the initial and final substances when a copper-coated circuit board is etched. This begins a series of activities that reveal patterns of changes indicating that chemical reactions have taken place.	MS-PS1.A MS-PS1.B	Analyzing and Interpreting Data Connections to Nature of Science: Scientific Knowledge Is Based on Empirical Evidence	Patterns	ELA/Literacy: RST.6-8.1 RST.6-8.9
2. **Laboratory: Evidence of Chemical Change** Students carry out an investigation and analyze the results to identify evidence that may indicate that a chemical change has taken place. In later activities, the patterns they observe at the macroscopic level will be explained in terms of changes at the atomic/molecular level.	MS-PS1.A MS-PS1.B	Planning and Carrying Out Investigations Analyzing and Interpreting Data Connections to Nature of Science: Scientific Knowledge Is Based on Empirical Evidence	Patterns	ELA/Literacy: RST.6-8.3
3. **Reading: Physical Changes and Chemical Reactions** Students read about observable (macroscopic) and atomic/molecular-level patterns of changes in physical and chemical properties and how they can be signs of chemical reactions. They also read about how to use logical reasoning to avoid mistaking physical changes for chemical changes. They integrate ideas in the reading with their observations of chemical changes in the previous investigation, and analyze and interpret several examples to determine whether a change is physical or chemical.	MS-PS1.A MS-PS1.B	Analyzing and Interpreting Data Obtaining, Evaluating, and Communicating Information Connections to Nature of Science: Scientific Knowledge Is Based on Empirical Evidence	Patterns	ELA/Literacy: RST.6-8.1 RST.6-8.4 RST.6-8.7 WH.6-8.9

CHEMICAL REACTIONS (continued)

Activity Description	Disciplinary Core Ideas	Science and Engineering Practices	Crosscutting Concepts	Common Core State Standards
4. **Modeling: Chemical Reactions at the Molecular Scale** Students use molecular models to explore the kinds and numbers of each kind of atom, as well as the arrangements of atoms, in the reactants and products of several chemical reactions. The patterns they observe demonstrate the concept of conservation of atoms in chemical reactions, as well as the relationship between changes at the atomic/molecular scale and changes in the observable properties of substances.	MS-PS1.B	Developing and Using Models Connections to Nature of Science: Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena	Energy and Matter Scale, Proportion, and Quantity Structure and Function	ELA/Literacy: RST.6-8.3
5. **Talking it Over: Physical or Chemical Change?** Students analyze and interpret information on the observable properties of substances before and after a change to determine whether the change is a physical change or a chemical reaction. This activity provides an assessment opportunity for Performance Expectation MS-PS1-2.	MS-PS1.A MS-PS1.B	Analyzing and Interpreting Data Systems and System Models Connections to Nature of Science: Scientific Knowledge Is Based on Empirical Evidence	Patterns	ELA/Literacy: RST.6-8.1 SL.8.1
6. **Laboratory: Comparing the Masses of Reactants and Products** Students investigate conservation of mass on a macroscopic scale. Students analyze and interpret data from two reactions to determine how the total mass of the products of a chemical reaction compares to the total mass of the reactants.	MS-PS1.B	Analyzing and Interpreting Data Connections to Nature of Science: Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena	Energy and Matter Systems and System Models Scale, Proportion, and Quantity	ELA/Literacy: RST.6-8.3
7. **Modeling: Explaining Conservation of Mass** Students use a combination of molecular modeling and mathematical computation to describe the atomic/molecular basis for mass conservation in chemical reactions. They are introduced to the law of conservation of mass and the relevance of this law to various natural phenomena. This activity provides an assessment opportunity for Performance Expectation MS-PS1-5.	MS-PS1.B	Developing and Using Models Systems and System Models Connections to the Nature of Science: Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena	Energy and Matter Systems and System Models Scale, Proportion, and Quantity	

CHEMICAL REACTIONS (continued)

Activity Description	Disciplinary Core Ideas	Science and Engineering Practices	Crosscutting Concepts	Common Core State Standards
8. **Investigation: Chemical Batteries** Students investigate how chemical energy can be transformed via a chemical process into electrical energy. After building a prototype wet cell, students brainstorm improvements and build, test, and evaluate new prototypes to meet a set of predetermined criteria within specified constraints.	MS-PS1.B MS-ETS1.B MS-ETS1.C	Constructing Explanations and Designing Solutions	Energy and Matter	ELA/Literacy: RST.6-8.3
9. **Laboratory: Thermal Energy and Reactions** Students explore chemical reactions that absorb or release thermal energy. Through classroom discussion, students are introduced to the crosscutting concept that energy and matter are conserved but can transfer within a system between reactants, products, and the environment. They are also introduced to the idea that the absorption or release of energy is caused by the rearrangement of atoms during a reaction. Some rearrangements require energy; others release it.	MS-PS1.B MS-PS3.A	Analyzing and Interpreting Data	Energy and Matter	ELA/Literacy: RST.6-8.3
10. **Design: Developing a Prototype** Students undertake a design challenge to construct and test a hand warmer device that uses the thermal energy released from an iron exothermic reaction. When testing their designs, students analyze their results and brainstorm ideas for further modification.	MS-PS1.B MS-ETS1.B MS-ETS1.C MS-PS3.A	Analyzing and Interpreting Data Constructing Explanations and Designing Solutions	Energy and Matter	
11. **Design: Refining the Design** Students use the thermal energy release from combining iron, calcium chloride, and water to design a hand warmer. Students redesign, construct, test, and evaluate their hand warmer designs from the “Developing a Prototype” activity. A new criterion is introduced— students must consider how to control the start of the chemical reaction in their design modifications. This activity provides an assessment opportunity for Performance Expectation MS-PS1-6.	MS-PS1.B MS-ETS1.B MS-ETS1.C MS-PS3.A	Analyzing and Interpreting Data Constructing Explanations and Designing Solutions	Energy and Matter	

CHEMICAL REACTIONS (continued)

Activity Description	Disciplinary Core Ideas	Science and Engineering Practices	Crosscutting Concepts	Common Core State Standards
12. **Laboratory: Recovering Copper** Students investigate the use of reactions with three metals for reducing copper waste and reclaiming copper from the used copper etching solution produced in the first activity of the unit. Students use data from their investigation and text sources to develop an evidence- based argument for which metal is the best choice for recovering copper from the waste solution.	MS-PS1.A MS-PS1.B	Analyzing and Interpreting Data Planning and Carrying Out Investigations Engaging in Argument from Evidence	Patterns Energy and Matter	ELA/Literacy: WHST.6-8.1
13. **Laboratory: Another Approach to Recovering Copper** Students close the unit by applying what they have learned in previous activities to conduct a final investigation to figure out which precipitation reaction works best to remove copper from wastewater. Students analyze and interpret their data from this activity and previous activities to develop their evidence-based argument for the best choice of reactions.	MS-PS1.A MS-PS1.B	Analyzing and Interpreting Data Planning and Carrying Out Investigations Engaging in Argument from Evidence	Patterns Energy and Matter	ELA/Literacy: WHST.6-8.1

PHENOMENA, DRIVING QUESTIONS AND STORYLINE

CHEMICAL REACTIONS

This is a work in progress. Please check the Tools and Resources opening page in the online Teacher Portal for future updates.

This unit explores the anchoring phenomenon: Chemical reactions can be used to solve problems but can also create problems. Examples explored include that combining certain substances releases a gas, combining certain substances releases energy (such as thermal energy, light, electricity), combining certain liquids results in a color change or formation of a solid. Students generate and answer questions such as: What happens when new materials are formed? How do particles combine into new substances? How can chemical reactions solve and create problems?

Phenomenon	Driving Questions	Guiding Questions	Activities	PE	Storyline/Flow (How an activity leads to subsequent activities)
Sometimes when we make a product, we get side products that we don't want.	What are the desired products and wastes from a chemical reaction?	How are chemical processes used to produce circuit boards? (Activity 1)	1 (12, 13)	MS-PS1-2 MS-PS1-5	Chemical reactions are used to produce desirable products (circuit boards), but they also lead to production of wastes (by-products) from chemical processes. (Substances can be identified by their properties and can't be made to just "go away.")
When you mix some substances, they do things like fizz, change color, or change temperature.	What is happening when something fizzes, changes color, or changes temperature when you mix substances?	How can you tell if a chemical change has occurred? (Activity 2)	2, 3, 5	MS-PS1-2 MS-PS1-5 MS-PS1-6	Four common signs frequently indicate that chemical reactions have taken place.
		What is the difference between a physical and a chemical change? (Activity 3)			Careful observation of properties is needed to distinguish physical and chemical changes.
		Is the change observed a physical change or a chemical change (reaction)? (Activity 5)			In this activity, students apply what they have learned about physical and chemical changes to several scenarios.

PHENOMENA, DRIVING QUESTIONS AND STORYLINE

CHEMICAL REACTIONS (continued)

Phenomenon	Driving Questions	Guiding Questions	Activities	PE	Storyline/Flow (How an activity leads to subsequent activities)
In chemical reactions, the total amount of matter after the reaction is the same as the total amount of matter before the reaction.	How is mass conserved during a chemical reaction?	What happens to atoms and molecules during a chemical reaction? (Activity 4)	4, 6, 7	MS-PS1-2 MS-PS1-5	Atoms are reorganized and conserved in chemical reactions. Changes in the organization of particles at the atomic/ molecular scale helps to explain physical and chemical changes and to distinguish one from the other.
		What happens to the mass of the reactants during a chemical reaction? (Activity 6)			The total mass of the products of a reaction equals the total mass of the reactants.
		Why is mass always conserved in chemical reactions? (Activity 7)			The conservation of atoms during reactions explains the conservation of mass.
When you mix some chemicals, they get hot or cold or give off electricity or light.	How can chemical reactions be used to provide energy?	How can we improve the design of a chemical battery? (Activity 8)	8, 9, 10, 11	MS-PS1-2 MS-PS1-6 MS-ETS1-3 MS-ETS1-4	Changing certain variables can affect how much energy is produced from a reaction.
		What does thermal energy have to do with chemical reactions? (Activity 9)			Chemical reactions can be used to release or absorb thermal energy.
		How do engineers design and test a prototype hand warmer? (Activity 10)			Variables can be modified as a device, such as a cold pack, is designed and refined through testing.
		How can the hand warmer design prototypes be redesigned and improved? (Activity 11)			

PHENOMENA, DRIVING QUESTIONS AND STORYLINE

CHEMICAL REACTIONS (continued)

Phenomenon	Driving Questions	Guiding Questions	Activities	PE	Storyline/Flow (How an activity leads to subsequent activities)
Sometimes when we make a product, we get side products that we don't want— but we can do something about it.	How can chemical reactions be used to clean up waste?	Which metal is best at reclaiming copper from the used copper chloride solution? (Activity 12) Which compound in solution is best for reclaiming copper from the used copper chloride solution? (Activity 13)	12, 13	MS-PS1-2 MS-PS1-5	Several chemical reactions can be used to reclaim copper, and the best reaction to use can be evaluated based on several criteria.

UNIT OVERVIEW

CHEMICAL REACTIONS

This unit explores issues related to the use and disposal of chemicals. Listed below is a summary of the activities in this unit. Note that the total teaching time is listed as 19–25 periods of approximately 45–50 minutes (approximately 4–5 weeks).

Activity Description	Topics	Advance Preparation	Assessment	Teaching Periods
1. **Investigation: Producing Circuit Boards** After a brief introduction to the function of a circuit board in a computer and other electronic devices, students mask a circuit board and etch it with an acidic copper-etching solution. They then read about the etching process and consider the copper-containing waste it produces.	Properties of substances, circuit boards, evidence, trade-offs LITERACY	Obtain circuit board sample (optional); fill a beaker with water; prepare Student Sheet.		2–3
2. **Laboratory: Evidence of Chemical Change** The class reviews the safety guidelines for working with chemicals in the science classroom. They investigate five chemical changes. For each one, they identify the signs of chemical change and the elements present before and after the reactions. Students discover that in a chemical change, new substances form that have different properties from the starting substances. They are introduced to the idea that the elements in the substances at the beginning and end of the reaction are the same, but they have rearranged into new chemical combinations.	Properties of substances, chemical change, chemical reactions, evidence of reactions LITERACY	Prepare materials for the demonstrations; prepare Student Sheets.	AID A3	2
3. **Reading: Physical Changes and Chemical Reactions** Students read about both physical and chemical changes. They learn how to distinguish these two phenomena at the observable level and begin to describe how they are different at the atomic/molecular scale.	Physical vs. chemical changes at macroscopic and atomic/molecular levels, evidence of reactions, dissolving, precipitate formation LITERACY	Prepare Student Sheet.	AID A4	2
4. **Modeling: Chemical Reactions at the Molecular Scale** Students use molecular models to investigate the reactants and products of chemical reactions. They apply their experiences with the models to develop the idea that kinds of atoms and the number of each kind of atom in the reactants and products are identical.	Chemical equations, conservation of atoms, reactants, products	Prepare modeling sets.	MOD A1	1–2

CHEMICAL REACTIONS (continued)

Activity Description	Topics	Advance Preparation	Assessment	Teaching Periods
5. **Talking it Over: Physical or Chemical Change?** Student groups consider six scenarios that describe changes in matter. They apply evidence and logical reasoning to develop arguments about whether each scenario describes a a physical change or a chemical reaction.	Properties of substances, chemical and physical changes, chemical reactions	Prepare Student Sheets.	AID A3 (Assessment of PE MS-PS1-2)	1–2
6. **Laboratory: Comparing the Masses of Reactants and Products** Students explore the law of conservation of mass. They conduct a precipitation reaction and measure the total mass before and after the reaction. Future activities will build on this concept as students are asked to think about the implications of conservation of atoms and mass in their investigations of chemical methods of waste treatment.	Chemical reactions, mass, reactants, products	Set up electronic balances.		1
7. **Modeling: Explaining Conservation of Mass** Students are given evidence about the masses of atoms. They use this to model mass conservation as an outcome of conservation of atoms. This is tied to the concept that the copper from the "Producing Circuit Boards" activity has not gone away; it is just in a different form.	Conservation of atoms, conservation of mass	Prepare modeling sets.	MOD A1 (Assessment of PE MS-PS1-5)	1
8. **Investigation: Chemical Batteries** Students build a chemical battery that transforms chemical energy into electrical energy, which in turn powers a motor. After building an initial prototype battery, students are given a set of criteria and constraints and asked to design a chemical battery that spins faster than the initial prototype for at least 5 min. Students brainstorm, build, test, and evaluate their prototypes.	Energy transformation, batteries, design criteria and constraints	Prepare Student Sheet.		1–2
9. **Laboratory: Thermal Energy and Reactions** Students set up two chemical reactions, measuring the temperature of the reactants and products. They use their measurements to identify which reaction releases and which absorbs energy.	Thermal energy, energy change as evidence of reactions, endothermic and exothermic reactions		AID A1	1–2

CHEMICAL REACTIONS (continued)

Activity Description	Topics	Advance Preparation	Assessment	Teaching Periods
10. **Design: Developing a Prototype** Students design a hand warmer and then construct, test, and evaluate a prototype.	Engineering design, criteria, constraints, prototypes, thermal energy, energy transfer, exothermic reactions	Prepare the demonstration hand warmer; prepare the pre-swelled beads 24 hours in advance; prepare Student Sheet.		1–2
11. **Design: Refining the Design** Students brainstorm new designs that will allow users to start the chemical reaction when they want to use the hand warmer. These designs may be redesigns of those developed in the previous activity or may be totally new. Students discuss designs and choose one to build as a prototype. Pairs of students exchange prototypes, and test and evaluate them. Students then think about how to further modify their designs.	Engineering design, criteria, constraints, prototypes, thermal energy, energy transfer, exothermic reactions	Prepare the demonstration hand warmer; prepare more pre-swelled beads 24 hours in advance, if needed; prepare Student Sheet.	ENG A3 (Assessment of PE MS-PS1-6)	2–3
12. **Laboratory: Recovering Copper** Students compare the effectiveness of three different metals in extracting copper from the used copper chloride solution from the activity "Producing Circuit Boards." After determining which of the metals removes copper ions from the solution, they examine cost- and health- related information to inform their decisions of which metal to use.	Metal replacement, chemical waste, reclaiming metal waste	Fill empty labeled dropper bottles with used etching solution; set up the copper dilutions series; prepare Student Sheet.	E&T A3	2
13. **Laboratory: Another Approach to Recovering Copper** Students compare two double-replacement reactions for recovering the copper waste. They apply what they have learned in this activity and the previous activity to decide which reaction works best to reclaim the copper.	Metal replacement, chemical waste, reclaiming metal waste LITERACY	Refill dropper bottles with used etching solution; set up the control filtration; prepare Student Sheet.	E&T A2	1