Green Sparks: Powering the Future with Redox Reactions

(2-3 days)

Authors

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SUBJECT/GRADE LEVEL

Subject Area: Chemistry/Physical Science

Grade Level: High School

Materials

This activity is for 6 groups (5 students per group)

- 6 - Copper strips (Cu) 1 per group
- 6 - Zinc strips (Zn) 1 per group
- 12 - Beakers (100 mL) 2 per group
- 500 mL - 1M Copper (II) sulfate solution
- 1M Zinc sulfate solution ($ZnSO_4$)
- Salt bridge (filter paper strips)
- filter paper
- 10 g - Potassium nitrate (KNO_3)
- 12 - Alligator clip wires 2 per group
- 6- Multimeters / voltmeters 1 per group
- 30- Safety goggles
- 30- Gloves (nitrile)
- 30- Aprons or lab coats
- Battery Lab Instructions
- Redox Battery Lab Sheet
- Redox Reaction Notes Sheet
- Guided Practice Problems
- Battery Comparison Worksheet
- Choice Board Exit Ticket

STANDARDS

Next Generation Science Standards

- **SEP2 HS3:** Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-PS1-4)
- **PS1.B HS1:** Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy. (HS-PS1-4), (HS-PS1-5)
- **CCC5 HS2:** Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. (HS-PS1-4)

English Language Arts Standards | Common Core State

- CCSS.ELA-LITERACY.SL.11-12.1.A: Come to discussions prepared, having read and researched

material under study; explicitly draw on that preparation by referring to evidence from texts and other research on the topic or issue to stimulate a thoughtful, well-reasoned exchange of ideas.

LESSON OBJECTIVE(S)

By the end of this lesson, students will be able to:

- Define reduction-oxidation (redox) reactions by exploring how electrons are transferred in batteries and voltaic cells.
- Apply the definitions of oxidation and reduction, along with oxidation numbers, to analyze chemical reactions observed during a laboratory investigation.
- Demonstrate understanding of redox principles by evaluating sustainable battery technologies developed in AEOP labs, considering factors such as environmental impact, efficiency, and design.
- Extend their thinking by applying redox concepts to biological combustion, specifically the chemical reaction of burning glucose found in plants that sustain forest fires.
- Work collaboratively to collect data, interpret results, construct scientific explanations using evidence, and communicate their findings through a group infographic or presentation.

CAREER CONNECTION(S)

Mentor and Co-mentor Background: Include the Army S & E mentor's name and bio.

- Dr. Jan Allen is a Chemist and a Senior Scientist of the Battery Science Branch and Energy Sciences Division of the U.S. Army Research Laboratory (ARL) at Adelphi Laboratory Center. Dr. Allen got his PhD in Northwestern University in 1993 in Solid State Chemistry. Afterwards, he completed some post-doctoral and industry positions before joining ARL in 2001. Most of his research work is based on solid state batteries and has been working on battery materials for the past 24 years at ARL. Some of his research interests include, but not limited to the development of materials for low-/high-temperature, lighter, safer, long-lasting, fast-charge batteries. Dr. Allen has authored and co-authored more than 100 publications and patents combined. To read and learn more about some of Dr. Allen's publications, you can look him up through google scholar.

- Dr. Dat Tran is a Chemist and the Deputy Chief of the Battery Science Branch and Energy Science Division at the U.S. Army Research Laboratory (ARL) at Adelphi Laboratory Center. After completing his post-doctoral degree at Cornell University around 2006-2007 school year, Dr. Tran applied to and got accepted at ARL in Adelphi and has been working there for the past 18 years. His interest in battery research was due to the U.S. military need of batteries that can survive battle field conditions as compared to commercial batteries under ambient conditions. Some

other areas of research that peaks Dr. Tran's interest include, but not limited, to development of materials for low-/high-temperature, lighter, safer, long-lasting, fast-charge batteries. Throughout his career, he has also authored and co-authored more than 100 publications and patents combined. To read and learn more about some of Dr. Tran's published research papers, you can look him up through Google Scholar.

STEM Careers: This should link to possible careers associated with:

- Chemist[1] - Works with redox reactions in areas like analytical chemistry, electrochemistry, or industrial chemistry.
- Biochemist - Studies cellular respiration and photosynthesis, both of which involve redox processes.
- Environmental Scientist - Investigates redox reactions in natural processes like soil chemistry and pollution remediation.
- Materials Scientist/Engineer[2] - Develops materials like batteries, fuel cells, and corrosion-resistant alloys using redox principles.
- Chemical Engineer - Designs systems like batteries, fuel cells, and electrolyzers that rely on redox reactions.
- Electrical Engineer and Electronic Technologists/Technicians - Focuses on lithium-ion, lead-acid, or other battery technologies driven by redox reactions.
- Medical Scientists and Pharmacologist/Toxicologist - Studies how drugs and toxins affect redox balance in the body.
- Clinical Laboratory Technician - Performs redox-based diagnostic tests, such as those involving blood oxidation levels.
- Biomedical Scientist/Biomedical Engineers-Investigates oxidative stress and redox signaling in diseases like cancer and neurodegeneration.
- Chemical Engineer-Designs chemical plants and processes where redox reactions are used (e.g., refining metals, treating water).
- Metallurgist-Uses redox reactions in extracting and refining metals from ores.
- Water Treatment Specialist-Applies redox reactions to remove contaminants and disinfect water.
- Green Energy Researcher-Works on redox flow batteries, hydrogen fuel cells, or renewable energy storage.

[1] https://www.bls.gov/ooh/life-physical-and-social-science/chemists-and-materials-scientists.htm
[2] https://www.bls.gov/ooh/life-physical-and-social-science/chemists-and-materials-scientists.htm

In this lesson, students will explore redox (reduction-oxidation) reactions through hands-on investigation of voltaic cells and evaluate real-world applications of these reactions in sustainable battery research. Students will investigate electron transfer using metals like copper and zinc, apply oxidation numbers, and analyze battery innovations from AEOP labs. The lesson encourages critical thinking about energy, environmental sustainability, and chemical reactivity.

ENGAGEMENT

Brief Description:

Students will engage in an interactive discussion to activate prior knowledge and curiosity about how batteries work. Using the Think-Talk-Write protocol, students will think individually, discuss their ideas with a partner or small group, and write their responses. This primes them for understanding redox reactions by relating to familiar technology (batteries) and connecting it to real-world applications such as sustainable battery research in AEOP labs..

Procedures (8–10 minutes): Engagement Worksheet

- Set the Stage (2 minutes):
  Display a common AA battery and a smartphone. Ask:
  "What do these two items have in common?"
  Prompt students to observe and make connections.

- Think (2 minutes):
  Ask students to independently reflect on and write down answers to the prompt:
  "How do you think batteries produce electricity?"
  Provide sentence starters if needed (e.g., "I think batteries work by...").

- Talk (3 minutes):
  In pairs or triads, students will share their responses and build on one another's ideas.
  The teacher circulates to listen for misconceptions and interesting thoughts.

- Write (3 minutes):
  Students write a short paragraph synthesizing their ideas and those from their group discussion.
  Prompt:
  "What did you learn from others about how batteries might work?"

- Transition to Lesson (1 minute):
  Briefly explain that understanding batteries involves understanding a type of chemical reaction called redox (short for reduction-oxidation), which they will explore in this lesson.

EXPLORATION

Brief Description: Students will explore how redox reactions occur by constructing a simple electrochemical cell (battery) using common materials such as copper and zinc strips, saltwater, and a voltmeter. Through hands-on experimentation, they will observe electron flow and voltage generation, allowing them to connect the theoretical concepts of oxidation and reduction to a real chemical system.

This activity helps solidify understanding of redox reactions as electron transfer processes and sets the stage for deeper analysis and explanation.

Procedures (50-60 minutes): Exploration Lab Activity Sheet

This part should take approximately 50–60 minutes to complete.

- Students will work in groups of 3–5. Each group will receive lab materials to construct a basic voltaic cell using copper and zinc electrodes, beakers, solutions, salt bridges, and voltmeters.
- Students will follow the step-by-step Battery Lab Instructions to safely set up their voltaic cells.
- Once set up, students will measure the electrical voltage produced, observe the direction of current, and record qualitative and quantitative data in the Redox Battery Lab Sheet.
- Each student will determine which metal undergoes oxidation and which undergoes reduction, and write corresponding half-reactions using oxidation number rules.
- Groups will complete guiding questions on the lab sheet, analyzing which metal is the reducing agent, which is the oxidizing agent, and how this connects to real-world batteries.
- The teacher will circulate to assist with setup, monitor safety, and ask guiding questions (e.g., "What evidence do you see that a redox reaction is happening?").
- After all groups complete the lab, students will participate in a short debrief discussion to share results and connect to the question: "How does this redox process make a battery work?"

EXPLANATION

Brief Description: Students will review and deepen their understanding of redox reactions by connecting their lab results to oxidation numbers, half-reactions, and electron transfer. Through direct instruction, practice, and discussion, students will link their hands-on experiences to scientific concepts and sustainable battery applications..

Procedures (45 - 60 minutes): Redox Reaction Lesson (in PDF) and Guide Notes Sheet

- Students will begin by reviewing their voltaic cell data in small groups and summarizing their findings on whiteboards or chart paper (5–7 min).

- The teacher will lead a brief recap discussion connecting lab observations to oxidation and reduction (5 min), using student responses to prompt thinking.

- Students will receive the **Redox Reaction Notes Sheet** and follow along with direct instruction, where the teacher introduces:

    - Oxidation = loss of electrons
    - Reduction = gain of electrons
    - Identifying oxidizing/reducing agents
    - Assigning oxidation numbers (LEO says GER)

- The teacher will model an example using the Zn–Cu battery to show half-reactions and agents.
- Students will complete guided practice problems identifying oxidation numbers and balancing redox reactions using provided examples (15–20 min).
- The teacher will facilitate a short discussion connecting the reactions observed in the lab to AEOP sustainable battery designs. Example guiding question:
  "Why might researchers be replacing lithium with zinc or organic materials in battery designs?"

ELABORATE

Brief Description: Students will extend their understanding by analyzing real-world battery designs and evaluating them for sustainability, safety, and redox efficiency. Working collaboratively, students will create posters or digital infographics comparing multiple battery types.

Procedures:

Students will work in teams of 3–4 and receive the Battery Comparison Worksheet and a selection of brief battery case studies (print or digital).

Each group will research and compare at least three battery types:

- Traditional lithium-ion battery
- Zinc-air or copper-zinc battery
- Sustainable battery (e.g., AEOP sodium-ion, bio-based, or solid-state)

Students will complete the worksheet by:

- Identifying the redox reaction used
- Describing voltage output and sustainability features
- Rating safety, efficiency, and environmental impact

Using their worksheet data, students will create a poster or infographic (printed or Canva-based) to visually present their evaluation.

Students will participate in a mini-gallery walk or share-out where they display and explain their designs to classmates.

EVALUATION

Brief Description: Students will demonstrate their understanding of redox reactions, oxidation numbers, and sustainable battery design through a Choice Board Exit Ticket. This allows for differentiation based on student interest and learning preference.

Procedures:

Option 1: Problem-Solving Scenario

Students analyze a real-world battery challenge (e.g., powering devices during a blackout using sustainable batteries). They identify the redox pairs and predict how long a device can operate, justifying their reasoning using scientific concepts.

Option 2: Multiple Choice Quiz

Students answer 5–7 questions on oxidation numbers, redox agents, voltaic cell components, and sustainable battery advantages.

Option 3: Reflection Prompt

Students respond to the following in writing:

"Describe two real-world situations where redox reactions are important (besides batteries), and explain why the redox model fits each case."

REFERENCES

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