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| **Lesson Title: Introduction to Electrochemistry** | **Unit #:**  **1** | **Lesson #:**  **2** | **Activity #:**  **3** |
| **Activity Title: How does a battery work?** |

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| **Estimated Lesson Duration:** | **6 class periods (80 minutes each)** |
| **Estimated Activity Duration:** | **1 class period (80 minutes)** |

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| **Setting:** | **Science classroom** |

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| **Activity Objectives:** |

We will… test the effect of household materials, amount of NaCl in the electrolyte solution, electrode surface area and electrode distance

In order to… evaluate the impact of each variable on the current and voltage the electrochemical cell produces

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| **Activity Guiding Questions:** |

* What parts are needed for a Galvanic Cell or battery to operate?
* How is a Galvanic cell or battery assembled?
* What factors contribute to the current or potential produced by a redox reaction?
* Do those factors affect current or potential independently, or do they work cooperatively?

| **Next Generation Science Standards (NGSS)** | |
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| **Science and Engineering Practices (Check all that apply)** | **Crosscutting Concepts (Check all that apply)** |
| ☐ Asking questions (for science) and defining problems (for engineering) | ☐ Patterns |
| ☐ Developing and using models | ☒ Cause and effect |
| ☐ Planning and carrying out investigations | ☒ Scale, proportion, and quantity |
| ☒ Analyzing and interpreting data | ☐ Systems and system models |
| ☒ Using mathematics and computational thinking | ☒ Energy and matter: Flows, cycles, and conservation |
| ☒ Constructing explanations (for science) and designing solutions (for engineering) | ☒ Structure and function. |
| ☒ Engaging in argument from evidence | ☐ Stability and change. |
| ☒ Obtaining, evaluating, and communicating information |  |

| **Ohio’s New Learning Standards for Science (ONLS)** |
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| **Expectations for Learning - Cognitive Demands (Check all that apply)** |
| ☐ Designing Technological/Engineering Solutions Using Science concepts **(T)** |
| ☐ Demonstrating Science Knowledge **(D)** |
| ☐ Interpreting and Communicating Science Concepts **(C)** |
| ☐ Recalling Accurate Science **(R)** |

| **Common Core State Standards -- Mathematics (CCSS)** | |
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| **Standards for Mathematical Practice (Check all that apply)** | |
| ☐ Make sense of problems and persevere in solving them | ☐ Useappropriate tools strategically |
| ☐ Reason abstractly and quantitatively | ☐ Attendto precision |
| ☐ Construct viable arguments and critique the reasoning of others | ☐ Look for and make use of structure |
| ☐ Model with mathematics | ☐ Look for and express regularity in repeated reasoning |

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| **Unit Academic Standards (NGSS, ONLS and/or CCSS):** |

LO = Advanced Placement® Chemistry Learning Objective

SP = Advanced Placement® Science Practice

SEP = NGSS Science and Engineering Practices

LO 3.8 The student is able to identify redox reactions and justify the identification in terms of electron transfer.

SP 6.1 The student can justify claims with evidence.

SEP 7: Engaging in argument from evidence

LO 3.12 The student can make qualitative or quantitative predictions about galvanic or electrolytic reactions based on half-cell reactions and potentials and/or Faraday’s laws.

SP 2.2 The student can apply mathematical routines to quantities that describe natural phenomena.

SP 2.3 The student can estimate numerically quantities that describe natural phenomena.

SP 6.4 The student can make claims and predictions about natural phenomena based on scientific theories and models.

SEP 5: Using mathematics and computational thinking

SEP 6: Constructing explanations and designing solutions

LO 3.13 The student can analyze data regarding galvanic or electrolytic cells to identify properties of the underlying redox reactions.

SP 5.1 The student can analyze data to identify patterns or relationships.

SEP 4: Analyzing and interpreting data

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| **Materials**: (Link Handouts, Power Points, Resources, Websites, Supplies) |

**This activity was inspired by a lesson found published on** pubs.acs.org/jchemeduc

(Furlan, P.Y., Krupa, T., Naqiv, H., and Anderson, K. (2013). “An Open-Ended Project: Building a High Performance, yet Simple, Household Battery” *Journal of Chemical Education*. Vol. 90, 1341-1345.)

PowerPoint Lesson

Chart Paper

Rubric for Experimental Design

Rubric for Presenting Data

Rubric for Supporting Claims with Evidence

Supplies for each team:

* an aluminum soda can (0.3 mm thick) or sheet (1.0 mm thick),
* a copper sheet (0.8 mm thick),
* other metals (zinc, 0.8 mm thick; iron, 0.8 mm thick; Ni, 0.7 mm thick),
* vinegar (5% HC2H3O2),
* table salt (NaCl),
* bleach (5− 6% NaClO, <1% NaOH),
* Drano Liquid Drain Cleaner (1− 5% NaOH, 3− 7% NaClO, 1− 5% Na2SiO3).
* beakers (150 or 250 mL),
* small butter containers (3cm Å~ 12 cm Å~ 3 cm),
* copper wire,
* alligator clip leads,
* clear silicone sealant,
* coffee stirring sticks,
* steel wool, metal cutter,
* pliers,
* a digital multimeter,
* a ruler, and
* a laboratory balance.

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| **Teacher Advance Preparation:** |

Purchase student materials and develop model electrochemical cell

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| **Activity Procedures:** |

1. Warm-up: Students will be prompted with the following questions:

What would happen to an electrochemical cell if you the electrodes were smaller?

How could you test this prediction?

This will prompt students to consider that a smaller electrode will have less surface area, which will decrease the amount of electrons to transfer. This decrease in electron transfer should lead the students predict that the cell will provide less current and, thus, have a smaller voltage.

The “how to test it…” question gets at ensuring how students could create a systematic approach to collecting data in a way that will tell them if their prediction is correct or not (experimental design).

1. Notebook Setup: Students set up the day/unit in their interactive notebook, including table of contents, unit title page, and Day 1 content (Topic, Objective, Essential Question – print-out to maximize time)
2. Design: Student lab groups will be assigned a variable to test and provided 10 minutes to plan out their experiment on a large dry-erase board that will include procedural steps, as well as what they plan to manipulate (variables), measure (outcome), and maintain consistent (constants).
3. Gallery Walk: Students will be provided post-it notes to complete a gallery walk of the experimental designs for each group. Each group will provide feedback on the post-it note according to a rubric for assessing “Experimental Design.”
4. Revision: Each student group will utilize their Gallery Walk feedback to ensure their design is proficient to begin.
5. Testing: Once proficient through design revision, student groups will be permitted into the lab to test their assigned variable as planned.
6. Pitch: Upon collecting data, student groups will publish their findings on Chart Paper and present their findings in a group Elevator Pitch. During presentations, other groups will assess the group’s ability to present data and support claims with evidence using the rubric guidelines for each.
7. Exit Ticket: Students will be asked to write at least one paragraph that answers our essential questions:
   1. What factors contribute to the current or potential produced by a redox reaction?
   2. Do those factors affect current or potential independently, or do they work cooperatively?

**Formative Assessments:** Link the items in the Activities that will be used as formative assessments.

1. Warm-up: These two questions will determine the depth and breadth of students’ prior knowledge for the activity.
2. Dry erase board design: This will allow the teacher to see if students are on track as well as help refine their thinking through follow-up/probing questions.
3. Gallery Walk: This will be assess student understanding of the design rubric as well as allow them to re-think their ideas and obtain ideas from other groups.
4. Revision: the revision process will be illustrate enhancements to student understanding as shown on their dry-erase board.
5. Pitch: Student understanding of the variable they tested as well as the meaning of the data will assessed through the poster and presentation.
6. Exit Ticket: This will demonstrate the level of synthesizing of information students were able to formulate from the activity and student presentations.

**Summative Assessments:** These are optional; there may be summative assessments at the end of a set of Activities or only at the end of the entire Unit.

Students will have a unit assessment that will include 30 released multiple-choice items and 4 released free response items (2 long form and 2 short form questions). This will serve as a post-test to matching test items in the diagnostic for the course offered at the beginning of the school year.

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| **Differentiation:** Describe how you modified parts of the Lesson to support the needs of different learners.  Refer to Activity Template for details. |

Kinestic/tactile learners will benefit from the hands-on nature of the activity.

Auditory and visual learners will benefit from creating the dry-erase board experimental design, the gallery walk, and the poster/pitch.

Students will special needs will be working in cooperative learning groups designed based on learning styles assessment from the beginning of the year.

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| **Reflection:** Reflect upon the successes and shortcomings of the lesson. |

This lesson’s biggest challenge hinged on the amount of time it took students to figure out how to use a digital multi-meter to measure current and voltage across a home-made cell or battery. In the future, student efficacy could be greatly improved with a tutorial, chunked instruction, and modeling of how to use a digital multi-meter in the “field.” Students are greatly familiar with electronics, but collecting data real-time with an unfamiliar tool and without prior-knowledge of upper-level physics proved challenging. Unfortunately, the publication that first illustrated the ability to create batteries with this design did not provide any material or instructor directions on how to address student misconceptions. In the future, the teacher will spend more time testing conditions, reaching out to the author of the publication, and designing a more fail-proof effort so students do not lose time by discovering how to make measurements with a multi-meter and trial-and-error.