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Recycling Aluminum

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Recycling Aluminum

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Abstract: Students will investigate and compare the energy cost to produce aluminum products from aluminum ore and recycled aluminum. Students will perform an electrolysis activity to reinforce the idea that recycling metal requires less energy than mining and refining metals from their original source in the earth.

Lesson Description

Grade Level: Grade 6-12

Estimated Time for Completing Activity: One 40-50 minute period.

Learning Outcomes:

- To determine the benefits to the environment of the recycling of Aluminum
- To provide evidence of the conservation of mass during the process of electrolysis
- To show the chemical equation of the change that occurred during this process.

National Standards: NGSS Standards

South Dakota Standards of Learning:

- **MS-ESS3-4** Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems. (SEP: 7; DCI: ESS3.C; CCC:

- **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.(SEP:2; DCI:PS1.B; CCC:Energy/Matter)
- **HS-ESS3-4** Evaluate or refine a technological solution that reduces impacts of human activities on natural systems. * (SEP: 6; DCI: ESS3.C, ETS1.B; CCC: Stability/Change, Technology)
- **HS-PS1-7** Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction. (SEP: 5; DCI: PS1.B; CCC: Energy/Matter, Nature of Science/Consistency)

Prerequisite: None

Materials:

- Two 6-Volt lantern batteries
- Three Alligator clips (1 red(anode) & 1 black (cathode) & 1 alternative color)
- Multimeter w/ leads
- Quarter
- Penny
- Scale
- 250 mL beaker
- 1 M Copper (II) Sulfate solution (1 mole of copper sulfate per 1 Liter of solution; add 159.6 g of copper sulfate per to water to make 1 liter of solution)

Vocabulary:

- Cathode
- Anode
- Electrolysis
- Series Circuit

Lesson Links:

- https://www.novelisrecycling.co.uk/novelis-recycling/why-recycle-aluminium/
- http://www.aluminum.org/sustainability/aluminum-recycling

- https://docs.google.com/presentation/d/1l-nAwSfZRoYpD7IMM-77D5oTKvmlGtlJiFAkMj9xj50/edit#slide=id.p1

Background: This experiment demonstrates the process of electrolysis, which is used in the commercial purification of ores such as aluminum oxide ore. Electrolysis uses an electrical current to move ions in an electrolyte solution between two electrodes.

In copper electrolysis, when a current is applied, positively-charged copper ions (called cations) leave the anode (positive electrode) and move toward the cathode (negative electrode). In this experiment (Figure 1), a U.S. penny (pre-1982) acts as the copper source/anode and a U.S. quarter serves as the cathode (a quarter, versus another penny, makes the movement of copper more obvious). A saturated aqueous solution of copper (II) sulfate is used as the electrolyte. An electric current is provided by a 6-volt (V) battery. When electric current is supplied to the anode (penny) via the positive terminal of the battery, copper atoms are oxidized to form cations with a positive charge (Cu^{2+}). The cations are set free in the electrolyte solution and are attracted to the cathode (quarter), which is connected to the negative terminal of the battery. Additionally, the copper sulfate electrolyte solution contains copper in the form of positively-charged cations(Cu^{2+}), which are also attracted to the negative electrode (the cathode, a quarter). This results in the net loss of copper from the anode (penny) and the gain of a copper coating on the cathode (quarter).

By monitoring the current (amps) of the system during the reaction, students can determine how much energy is needed to produce the mass of a standard aluminum can from aluminum oxide ore using electrolysis.

Procedure:

1. Clean the quarter and penny in a cleaning solution of vinegar and salt (50 mL of vinegar and 5 grams of salt). Stir the solution occasionally to make sure all the surfaces are clean. Remove the penny and quarter from the solution and dry being sure NOT to touch the coins once removed from the cleaning solution.
2. Record the mass of the quarter and the penny (completely dry.

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3. On one 6-V lantern battery, connect one red alligator clip to the positive terminal (anode; penny) and one alternative color alligator clip to the negative terminal (cathode).
4. Connect the alternative colored alligator clip to the second 6-Volt battery at the positive terminal. Connect the black alligator clip to negative terminal of the second 6-Volt battery to the positive lead on the multimeter. Set the multimeter to Amps.
5. Clip the penny into the red alligator clip and clip the quarter into the negative (black) lead from the voltmeter.
6. Pour 150 mL of the copper sulfate electrolyte solution into the beaker.
7. Dip the quarter and the penny into the electrolyte solution.
    a. Make sure to NOT let the coins touch.
    b. Keep the clip portion of the alligator clips out of the solution to ensure the only reactions occurring are between the penny and copper solution and the quarter and copper solution.
8. Measure and record the current on the multimeter. Record the average or median amps shown over the period of time the reaction is in operation (10 minutes).
9. Remove the coins from solution after 10 minutes and allow to dry (must be completely dry).
10. Record the mass of each coin.

Conclusion:

To conclude the lesson, write a paragraph to tell about the difference in energy required to mine and refine aluminum and energy required for recycling. Include 2 different aspects of the environment that are positively impacted by the recycling of aluminum cans.

Extensions: This lesson can be extended to fit high school chemistry.

1. Discuss the mathematics of energy cost using stoichiometry concepts.

    Faraday's Constant = 96485 Coulombs/mole

    Molar mass of Copper = 63.55 g/mole

$$Cu^{+2} + 2e^{-} \rightarrow Cu$$

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or

$$Cu \rightarrow Cu^{+2} + 2e^{-}$$

Because 2 moles of electrons are involved in the copper reaction then the amount of charge (or Coulombs) which are required for these 2 moles is:

(2 mol e^{-})(96485 C/mol) = 192970 C

When 192970 Coulombs pass through the system, one mole of copper will react:

63.55 g Cu/192970 C = 3.293×10^{-4} g/C

In the 10 minutes of operation in this problem, the amount of Coulombs used was assume 1 ampere of current was used in the trial; ALSO 1 ampere = 1 Coulomb per second):

1 A = 1 C/s

(9.321×10^{-5} g/C)(1 C/s)(10 min)(60 s/1 min) = 0.56 g/10 min. This is how many grams of copper will react (and we would produce this many grams of solid copper

2. Have students use stoichiometry to compare the energy cost of making a standard aluminum can from ore vs. making a can from recycled aluminum

   Faraday's Constant = 96485 Coulombs/mole

   Molar mass of Aluminum = 26.98 g/mole

$$Al^{+3} + 3e^{-} \rightarrow Al$$

   (3 mol e^{-})(96485 C/mol) = 289455 C

   26.98 g Al/289455 C = 9.321×10^{-5} g/C

   Using 1 ampere over 24 hours

   (9.321×10^{-5} g/C)(1 C/1 s)(86400 s/day) = 8.053 g/d

Teacher Notes:

- Copper (II) Sulfate is often sold as root melt (Root Kill) in hardware stores.

Assessment:

1. What did you see on the quarter in the solution after 10 minutes?
2. Where did this substance come from? How did this substance get there?
3. Why was there a change in mass of the coins? Was the mass gained by one coin consistent with the loss of mass in the other coin?

In the form of an activity, assessment is not necessarily needed. However, as an addition to the experiment, the students could draw a picture of the experimental design and label all of the necessary parts.

Reference:

- https://www.novelisrecycling.co.uk/novelis-recycling/why-recycle-aluminium/
- http://www.aluminum.org/sustainability/aluminum-recycling

https://docs.google.com/presentation/d/1l-nAwSfZRoYpD7IMM-77D5oTKvmlGtlJiFAkMj9xj50/edit#slide=id.p1

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