

## Lesson Plan: Electrolysis: Application in Fuel Cell Technology

As a **high school** or **introductory undergraduate Chemistry** or **Environmental Sciences** teacher, you can use this set of computer-based tools to help you in teaching the **basics of electrochemistry, electrolysis** and the **application of electrolysis in fuel cells** as an alternative source of clean energy.

This lesson plan includes resources to teach about **oxidation states, redox reactions, half-cell, cell potentials, electrolysis, and electrolytic cells**. It includes a hands-on laboratory activity to teach your students about the **application of electrolytic cells** for energy generation from **fuel cells**. These fuel cells offer an **alternative to fossil-fuel based energy production** which is the main contributor to global warming and climate change.

Thus, the use of this lesson plan allows you to integrate the teaching of a climate science topic with a core topic in **Chemistry** or **Environmental Sciences**.

Use this lesson plan to help your students find answers to:

- What are redox reactions?
- What is electrolysis? Give examples of electrolytic reactions.
- What are the differences in voltaic/galvanic and electrolytic cells?
- Describe the functioning of a fuel cell.
- What is the importance of fuel cell technology in the context of climate change?

### About the Lesson Plan

**Grade Level:** High School, Introductory Undergraduate

**Discipline:** Chemistry, Environmental Sciences

**Topic(s) in Discipline:** Electrochemistry, Reduction and Oxidation (Redox) Chemical Reactions, Half-cells, Cell Potentials, Electrolysis, Voltaic/Galvanic Cells, Electrolytic Cells, Fuel Cells

**Climate Topic:** Climate and the Atmosphere, Climate and the Anthroposphere, Climate Mitigation and Adaptation

**Location:** Global

**Access:** Online, Offline

**Language(s):** English

**Approximate Time Required:** 2-4 sessions, 40-60 min each

# 1 Contents

## 1. Teaching Module (25 min)

A teaching module to teach the basics of electrochemistry, oxidation states, redox reactions, half-cells, and cell potentials.

This can be accessed at:

<https://www.khanacademy.org/science/chemistry/oxidation-reduction>

## 2. Teaching Module (15 min)

A teaching module to teach about electrolysis, electrolytic cells, and their applications.

This can be accessed at:

[https://chem.libretexts.org/Bookshelves/Analytical\\_Chemistry/Supplemental\\_Modules\\_\(Analytical\\_Chemistry\)/Electrochemistry/Electrolytic\\_Cells/Electrolysis\\_I](https://chem.libretexts.org/Bookshelves/Analytical_Chemistry/Supplemental_Modules_(Analytical_Chemistry)/Electrochemistry/Electrolytic_Cells/Electrolysis_I)

## 3. Reading (10 min)

A case study to introduce fuel cells, how they work, and the types of fuel cells in use currently.

This can be accessed at:

[https://chem.libretexts.org/Bookshelves/Analytical\\_Chemistry/Supplemental\\_Modules\\_\(Analytical\\_Chemistry\)/Electrochemistry/Exemplars/Case\\_Study%3A\\_Fuel\\_Cells](https://chem.libretexts.org/Bookshelves/Analytical_Chemistry/Supplemental_Modules_(Analytical_Chemistry)/Electrochemistry/Exemplars/Case_Study%3A_Fuel_Cells)

#### 4. Classroom/Laboratory Activity (3 sessions, 40-60 min each)

A set of hands on laboratory activities to introduce fuel cells and to demonstrate how they are built and can be used to generate energy efficiently.

These can be accessed at:

<https://www.ccmr.cornell.edu/wp-content/uploads/sites/2/2015/11/RedoxFitzgerald.pdf>

<https://www.ccmr.cornell.edu/wp-content/uploads/sites/2/2015/11/build-a-fuel-cell.pdf>

<https://www.ccmr.cornell.edu/wp-content/uploads/sites/2/2015/11/FuelCellCharacterization.pdf>

#### 5. Suggested questions/assignments for learning evaluation

- What are redox reactions?
- What is electrolysis? Give examples of electrolytic reactions.
- What are the differences in Voltaic/Galvanic and Electrolytic Cells?
- Describe the functioning of a fuel cell.
- What is the importance of fuel cell technology in the context of climate change?

## 2 Step-by-step User Guide

Here is a step-by-step guide to using this lesson plan in the classroom/laboratory. We have suggested these steps as a possible plan of action. You may customize the lesson plan according to your preferences and requirements.

### 1. Topic introduction and discussion

Use the teaching module, '[Redox reactions and electrochemistry](#)' by Khan Academy to teach your students the basics of electrochemistry, oxidation states, oxidation-reduction (redox) reactions, half-cells, cell potentials, galvanic/voltaic cells, and electrolysis. Use the in-built examples and exercises to extend your students' understanding of various electrochemistry concepts. Emphasize on the process of electrolysis and electrolytic cells.

This can be accessed at:

<https://www.khanacademy.org/science/chemistry/oxidation-reduction>

### 2. Extend understanding

Use the teaching module, '[Electrolysis I](#)' by LibreTexts™, UC Davis, to teach about electrolysis and to describe it quantitatively. Use the tool to teach how electrolytic cells are constructed and to describe several electrolytic reactions. Elaborate upon the differences between Voltaic/Galvanic and Electrolytic Cells. Use the in-built examples and exercises to assess students' understanding of electrolytic reactions. Explain how an electrolysis reaction could be evaluated quantitatively. Finally, discuss how electrolytic reactions could be used for commercial purposes such as electroplating and in fuel cell technology.

This can be accessed at:

[https://chem.libretexts.org/Bookshelves/Analytical\\_Chemistry/Supplemental\\_Modules\\_\(Analytical\\_Chemistry\)/Electrochemistry/Electrolytic\\_Cells/Electrolysis\\_I](https://chem.libretexts.org/Bookshelves/Analytical_Chemistry/Supplemental_Modules_(Analytical_Chemistry)/Electrochemistry/Electrolytic_Cells/Electrolysis_I)

### 3. Discuss further

Use the case study, '[Fuel Cells](#)' by LibreTexts™, UC Davis, to introduce fuel cells, describe how they work, and discuss the different types of fuel cells. Use the tool to describe the hydrogen fuel cell that is used to generate electricity, water, and heat and is used to power vehicles and even spacecraft. With no byproduct of carbon emissions, discuss how this is a cleaner alternative to fossil fuel-based energy production. Describe the other fuel cell types and discuss the benefits and limitations of fuel cells.

This can be accessed at:

[https://chem.libretexts.org/Bookshelves/Analytical\\_Chemistry/Supplemental\\_Modules\\_\(Analytical\\_Chemistry\)/Electrochemistry/Exemplars/Case\\_Study%3A\\_Fuel\\_Cells](https://chem.libretexts.org/Bookshelves/Analytical_Chemistry/Supplemental_Modules_(Analytical_Chemistry)/Electrochemistry/Exemplars/Case_Study%3A_Fuel_Cells)

### 4. Apply understanding with a set of hands on laboratory exercises

Use a set of 3 hands on laboratory exercises- '[Intro to Fuel Cells](#)', '[Build a Fuel Cell](#)', and '[Fuel Cell Characterization](#)' by Michael Fitzgerald, Cornell Center for Materials Research, to enable your students to apply their understanding of the various electrochemistry concepts discussed in this lesson plan. You may choose to conduct all or few of these activities.

Note: All the laboratory exercises are structured as complete teaching modules- with learning objectives, background information, step-by-step instructions for conducting the activity, evaluation exercises, and discussion points- and are available for downloading.

These can be accessed at:

- 1) Introduction to Fuel Cells: <https://www.ccmr.cornell.edu/wp-content/uploads/sites/2/2015/11/RedoxFitzgerald.pdf>
- 2) Build a Fuel Cell: <https://www.ccmr.cornell.edu/wp-content/uploads/sites/2/2015/11/build-a-fuel-cell.pdf>
- 3) Fuel Cell Characterization: <https://www.ccmr.cornell.edu/wp-content/uploads/sites/2/2015/11/FuelCellCharacterization.pdf>

## 5. Questions/Assignments

Use the tools and the concepts learned so far to discuss and determine answers to the following questions:

- What are redox reactions?
- What is electrolysis? Give examples of electrolytic reactions.
- What are the differences in voltaic/galvanic and electrolytic cells?
- Describe the functioning of a fuel cell.
- What is the importance of fuel cell technology in the context of climate change?

## 3 Learning Outcomes

The tools in this lesson plan will enable students to:

- learn about the basics of electrochemistry, oxidation states, redox reactions, half-cells, and cell potentials
- describe electrolysis, electrolytic cells, and their applications
- explain what fuel cells are, describe their types, and how they work
- discuss the importance of fuel cells as an alternative source of energy in the context of climate change

## 4 Additional Resources

If you or your students would like to explore the topic further, these additional resources will be useful.

### 1. A set of teaching resources: a reading, a video micro-lecture, and a classroom/laboratory activity

A set of tools to teach about galvanic cells and the use of their spontaneous electrical energy generation in batteries.

These can be accessed at:

[https://chem.libretexts.org/Bookshelves/Analytical\\_Chemistry/Supplemental\\_Modules\\_\(Analytical\\_Chemistry\)/Electrochemistry/Basics\\_of Electrochemistry/Electrochemistry/Galvanic\\_Cells](https://chem.libretexts.org/Bookshelves/Analytical_Chemistry/Supplemental_Modules_(Analytical_Chemistry)/Electrochemistry/Basics_of_Electrochemistry/Electrochemistry/Galvanic_Cells)

<http://www.bozemanscience.com/ap-chem-034-electrochemistry>

<https://www.ccmr.cornell.edu/wp-content/uploads/sites/2/2015/11/GalvanicCellGame.pdf>

### 2. Reading;

A chapter by M. Cassir et al from the Handbook of Membrane Reactors to describe various electrochemical devices like fuel cells for energy generation.

This can be accessed at:

[https://www.researchgate.net/publication/288498018\\_Electrochemical\\_devices\\_for\\_energy\\_Fuel\\_cells\\_and\\_electrolytic\\_cells](https://www.researchgate.net/publication/288498018_Electrochemical_devices_for_energy_Fuel_cells_and_electrolytic_cells)

## 5 Credits/Copyrights

All the teaching tools in our collated list are owned by the corresponding creators/authors/organizations as listed on their websites. Please view the individual copyright and ownership details for each tool by following the individual links provided. We have selected and analyzed the tools that align with the overall objective of our project and have provided the corresponding links. We do not claim ownership of or responsibility/liability for any of the listed tools.

### 1. Teaching Module; 'Redox reactions and electrochemistry'

By [Khan Academy](#)

### 2. Teaching Module; 'Electrolysis I'

By [LibreTexts™](#), UC Davis

### 3. Reading; 'Fuel Cells'

By [LibreTexts™](#), UC Davis

### 4. Classroom/Laboratory Activities; 'Intro to Fuel Cells', 'Build a Fuel Cell', and 'Fuel Cell Characterization'

By Michael Fitzgerald, Modules Library, [Cornell Center for Materials Research](#)

## 5. Additional Resources

[LibreTexts™](#)

[BozemanScience](#)

[Cornell Center for Materials Research](#)

[Cassir, Michel & Jones, D. & Ringuédé, Armelle & Lair, Virginie. \(2013\). Electrochemical devices for energy: Fuel cells and electrolytic cells. 10.1533/9780857097347.3.553.](#)