Teaching Chemistry with Hydrogen and Fuel Cells

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Curriculum Website: sepuplhs.org/hydrogen
Issue-Oriented Science

- Engages students in learning science and applying it to make evidence-based decisions.

- In most cases, does not advocate a particular decision, but does advocate the use of scientific evidence and concepts in the decision-making process.

- Encourages students to look at various sides of an issue and evaluate the trade-offs involved in a complex decision.

How can we transport ourselves in a sustainable fashion?

- Price volatility
- Climate change
- Dependence on foreign resources
- Depletion of nonrenewable resources
- Air and water pollution
Part of our future energy picture?

Activity #1: Hydrogen for Transportation?
Hydrogen

- Hydrogen is the most common element in the universe.
- The sun is composed mostly of hydrogen gas.
- Where is hydrogen found on Earth?
- Hydrogen occurs naturally as a component of water and hydrocarbon fuels like coal, oil and natural gas.

How do we get Hydrogen?

Hydrocarbon + Heat → **Reformer** → Hydrogen + CO₂

Water + Electricity → **Electrolyzer** → Hydrogen + Oxygen
What do we do with Hydrogen?

- A way to store energy (like a battery)
- A way to move energy (like electricity)
- NOT an energy source and NOT free

Fuel Cell Electrochemistry – Redox Reactions

- What happens on H₂ side? O₂ side?
- Where does oxidation occur? Reduction?
- Which side is anode? Cathode?

PEM membrane

H₂ (g) → H⁺ → H₂O

e⁻ → O₂ (g)
Six activities take approximately two weeks of instructional time.

1. **Energy for Transportation** - Students examine trade-offs of various fuel/vehicle combinations.

2. **Obtaining Hydrogen through Electrolysis** - In this hands-on lab, students generate hydrogen and examine the required energy input, stoichiometry, and electrochemistry involved in the process.

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**Bench-top Kit**

- Electrolyzer
- Fuel cell
- Fan motor
The HyTEC Curriculum

3. Putting a Hydrogen Fuel Cell to Work - Students generate H₂ and O₂, and use a single cell fuel cell to perform work.

4. Modeling a Fuel Cell Redox Reaction - Students use model pieces and a fuel cell simulation to explore the fuel cell reaction.

Activity #4: Modeling the Fuel Cell Reaction
Modeling the Fuel Cell Reaction

Now use the puzzle pieces to model what happens in the fuel cell.
Student Activity
The Fuel Cell Half Reactions

- The half-reactions:
  - Oxidation: $\text{H}_2 \rightarrow 2\text{H}^+ + 2e^-$
  - Reduction: $4\text{H}^+ + \text{O}_2 + 4e^- \rightarrow 2\text{H}_2\text{O}$
- Adding the half-reactions:
  - Oxidation: $2\text{H}_2 \rightarrow 4\text{H}^+ + 4e^-$
  - Reduction: $4\text{H}^+ + \text{O}_2 + 4e^- \rightarrow 2\text{H}_2\text{O}$

$2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O} + \text{energy (electricity)}$

The HyTEC Curriculum

5. Fuel Cell Efficiency –
   In a hands-on lab, students measure fuel cell efficiency.

6. Hydrogen for Transportation - Students conduct research and engage in a simulated City Council Meeting to present the advantages and challenges of using hydrogen and fuel cells for a city bus program.
NSES Addressed

Structure of Atoms:
• Matter is made of minute particles called atoms.

Structure and Properties of Matter:
• Atoms interact with one another by sharing or transferring electrons

Chemical Reactions:
• Chemical reactions occur all around us
• Chemical reactions may release or consume energy
• A large number of reactions involve transfer of electrons
• Catalysts lower activation energy necessary for reactions

Website and Videos

Hydrogen Fuel Cell website:
sepuplhs.org/hydrogen

• Simulation of fuel cell
• Clips from video field trip
• Web Resources
• Info on fuel cells
Applications of Fuel Cells

- Video highlights
- Fuel cell bus in Oakland, CA
- Portable applications: video camera, computer
- Production from hydrogen using renewable sources
- Production of hydrogen from landfill gas
What’s really happening with hydrogen fueled transportation?

Fuel Cell Vehicles
Pre-commercial, 100’s on the road, most mfg’s represented
Fuel Cell Bus Programs

• National research and demonstration program

• FC bus projects in CA, CT, DE, NY, MA, SC, TX

• AC Transit – largest program, 12 buses

• Buses throughout Europe
Hydrogen Fueling Stations

- Stations throughout US, some retail
- Networks in SoCal, northeast US

Fuel Cell Parts – Form and Function
The Proton Exchange Membrane (PEM)

- Modified polyethylene hydrocarbon chains
- Fluorine substitutions create polytetrafluorethylene (PTFE: teflon®)
- To make it electrolytic: side chains with hydrophilic sulphonate (-SO₃H) groups are added

Challenges to Hydrogen Economy

- Developing infrastructure and improving technology
- Reducing cost
- Addressing public concerns about safety
- Production of hydrogen from water using renewable energy sources
Hydrogen Technology and Energy Curriculum

• Funded by U.S. Dept of Energy
• “Introduction to Alternative Energy: Hydrogen & Fuel Cells”
• Developed by a team of scientists, engineers, curriculum developers, teachers, and other educational leaders
• Development process includes extensive classroom testing and feedback
• High School Chemistry (or Physics & Envi. Sci.)

Partners

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