Energy From Electron Transfer

Chemistry in Context
Energy Types

- Batteries
- Hybrid Cars (Electrical)
- H$_2$ (and Other) Fuel Cells
- Solar
Fuel Cell Car Demo
H₂ Fuel Cell Reactions

• Step 1:
  – H₂(g) → 2H⁺(aq) + 2 e⁻

• Step 2:
  – ½O₂(g) + 2 H⁺(aq) + 2 e⁻ → H₂O (l)

• Overall:
  – H₂(g) + ½O₂(g) → H₂O(l) + energy
Batteries

A battery is a system for the direct conversion of chemical energy to electrical energy.

Batteries are found everywhere in today’s society because they are convenient, transportable sources of stored energy.

The “batteries” shown here are more correctly called galvanic cells.

A series of galvanic cells that are wired together constitutes a true battery – like the one in your car.
A galvanic cell is a device that converts the energy released in a spontaneous chemical reaction into electrical energy.

This is accomplished by the transfer of electrons from one substance to another.

Consider a nickel-cadmium (NiCad) battery:

Electrons are transferred from cadmium to nickel.
Oxidation is loss of electrons: $\text{Cd} \rightarrow \text{Cd}^{2+} + 2 \text{e}^-$

Ni$^{3+}$ gains electrons

Overall cell reaction: $2 \text{Ni}^{3+} + \text{Cd} \rightarrow 2 \text{Ni}^{2+} + \text{Cd}^{2+}$

Oil Rig is a useful mnemonic device

The transfer of electrons through an external circuit produces electricity, the flow of electrons from one region to another that is driven by a difference in potential energy.
To enable this transfer, electrodes (electrical conductors) are placed in the cell as sites for chemical reactions. Oxidation occurs at the anode. Reduction occurs at the cathode. The cathode receives the electrons. The difference in electrochemical potential between the two electrodes is the voltage (units are in volts).
An Alkaline Cell

Cathode (reduction) reaction:
\[ 2 \text{MnO}_2 + \text{H}_2\text{O} + 2e^- \rightarrow \text{Mn}_2\text{O}_3 + 2\text{OH}^- \]

Anode (oxidation) reaction:
\[ \text{Zn} + 2\text{OH}^- \rightarrow \text{Zn(OH)}_2 + 2e^- \]
Rechargeable?

- Ni-Cd: Yes
  \[ \text{Cd(s)} + 2 \text{NiO(OH)(s)} + 2 \text{H}_2\text{O(l)} \rightleftharpoons 2 \text{Ni(OH)}_2\text{(s)} + \text{Cd(OH)}_2\text{(s)} \]
  
  Reversible Reaction

- Alkaline: No
  \[ \text{Zn (s)} + 2\text{MnO}_2\text{(s)} + \text{H}_2\text{O(l)} \rightarrow \text{Zn(OH)}_2\text{(s)} + \text{Mn}_2\text{O}_3\text{(s)} \]
Lead-Acid Storage Batteries
This is a true battery as it consists of a series of six cells.

Anode = Pb
Cathode = PbO₂

\[
\text{Pb}(s) + \text{PbO}_2 (s) + 2 \text{H}_{2}\text{SO}_4 (aq) \rightarrow 2 \text{PbSO}_4 (s) + 2 \text{H}_2\text{O}(l)
\]

Rechargable:
\[
\text{discharging} \quad \rightarrow \quad 2 \text{PbSO}_4 (s) + 2 \text{H}_2\text{O}(l)
\]

8.3
Today, Tuesday May 5

• Newspaper Presentations: Obus and Robert
• Water Lab 'Debrief'
• Finish Chapter 8 Notes
• Fuel Cell and Solar Cell Lab Introduction

For Next Time, Thursday May 7

• Presentation Prep Time
• Exam Review – Bring Questions!
• Chapter 8 Homework Time
• Demos? Ice Cream?
### Table 8.1: Some Common Galvanic Cells

<table>
<thead>
<tr>
<th>Type</th>
<th>Voltage</th>
<th>Rechargeable?</th>
<th>Examples of Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alkaline</td>
<td>1.54</td>
<td>No</td>
<td>Flashlights, small appliances</td>
</tr>
<tr>
<td>Lithium-oxide</td>
<td>2.8</td>
<td>No</td>
<td>Camera batteries, power tools</td>
</tr>
<tr>
<td>Lithium ion</td>
<td>3.7</td>
<td>Yes</td>
<td>Laptop computers, cell phones, digital music players</td>
</tr>
<tr>
<td>Lead-acid (storage battery)</td>
<td>2.0</td>
<td>Yes</td>
<td>Automobiles</td>
</tr>
<tr>
<td>Nickel-cadmium (NiCd)</td>
<td>1.25</td>
<td>Yes</td>
<td>Consumer electronics</td>
</tr>
<tr>
<td>Nickel-metal hydride (NMHL)</td>
<td>1.25</td>
<td>Yes</td>
<td>Replacing NiCd for many uses, hybrid vehicles</td>
</tr>
<tr>
<td>Mercury</td>
<td>1.3</td>
<td>No</td>
<td>Formerly widely used in cameras, other appliances</td>
</tr>
</tbody>
</table>
Lithium Ion Batteries

- Used in laptops and cell phones
- 3.7 Volts
Combining the use of gasoline and battery (Ni-MH) technology

Many hybrids, unlike conventional gasoline-powered cars, deliver better mileage in city driving than at highway speeds.
Fuel Cells

• Fuel is not burned but instead it is converted directly to electricity.
• Example Hydrogen and oxygen fuel cell.
  – Power and water are only products.
• Still needs a source of fuel.
  – Where does the hydrogen come from?

http://www.fuelcellstore.com/education.asp
Producing Hydrogen

• Presently much is produced from CH₄ in a process called reforming (could be from coal or other hydrocarbon as well)
  – CH₄ + 2H₂O → CO₂ + 4H₂
  – Easier to capture CO₂ during reforming
• Could also be produced by electrolysis of water
  – 2H₂O → 2H₂ + O₂
  – More expensive, could be done with renewables
• Algae
Issues with moving towards a hydrogen economy

- Infrastructure
- Cost
- Safety
- Storage
  - Tanks of compressed H₂
  - Liquid
  - Solid –metal hydride
  - Nanofiber
H₂ Vehicles

Skateboard design
For more info on H₂ Fuel

http://www.hydrogencarsnow.com/
H₂ Fuel Cell Reactions

- $\text{H}_2(\text{g}) \rightarrow 2\text{H}^+(\text{aq}) + 2 \text{e}^-$
- $\frac{1}{2}\text{O}_2(\text{g}) + 2 \text{H}^+(\text{aq}) + 2 \text{e}^- \rightarrow \text{H}_2\text{O (l)}$
- $\text{H}_2(\text{g}) + \frac{1}{2}\text{O}_2(\text{g}) \rightarrow \text{H}_2\text{O(l)}$
Other Fuel Cell Types

- Solid Oxide Fuel Cells
- Direct Methanol Fuel Cell
  - Methanol-water solution as fuel
  - Increased portability and decreased size
  - \( \text{CH}_3\text{OH} + \frac{3}{2}\text{O}_2 \rightarrow \text{CO}_2 + 2 \text{H}_2\text{O} \)

<table>
<thead>
<tr>
<th>Fuel Cell Type</th>
<th>Common Electrolyte</th>
<th>Operating Temp.</th>
<th>Output Power</th>
<th>Efficiency</th>
<th>Application</th>
<th>Advantages</th>
<th>Drawbacks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phosphoric Acid</td>
<td>H3PO4 saturated in a solid electrolyte</td>
<td>100-200 °C</td>
<td>50-100 kW</td>
<td>60-70%</td>
<td>Distributed generation</td>
<td>High efficiency</td>
<td>Low efficiency at high temperatures</td>
</tr>
<tr>
<td>PEM</td>
<td>Perfluorinated ionomer</td>
<td>50-100 °C</td>
<td>&lt;1-10 kW</td>
<td>55-60%</td>
<td>Backup power</td>
<td>Quick start-up</td>
<td>High cost</td>
</tr>
<tr>
<td>DMFC</td>
<td>Solid polymer membrane</td>
<td>40-60 °C</td>
<td>&lt;1 kW</td>
<td>30-40%</td>
<td>High portability</td>
<td>High portability</td>
<td>Relatively low efficiency</td>
</tr>
<tr>
<td>MCFC</td>
<td>Ceramic</td>
<td>650-1000 °C</td>
<td>5-50 MW</td>
<td>60-65%</td>
<td>Distributed generation</td>
<td>High efficiency</td>
<td>High cost</td>
</tr>
</tbody>
</table>
### Comparing Combustion with Fuel Cell Technology

<table>
<thead>
<tr>
<th>Process</th>
<th>Reactants</th>
<th>Products</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional Combustion</td>
<td>Fuel: gasoline, hydrocarbons, ethanol, wood, etc. Oxidant: O₂ (from air)</td>
<td>H₂O, heat, light, sound, CO₂ and CO (greenhouse gases)</td>
<td>Rapid process, flame present, lower efficiency, best process for producing heat</td>
</tr>
<tr>
<td>Fuel Cell Technology</td>
<td>Fuel: H₂ Oxidant: O₂ (from air)</td>
<td>H₂O, electricity, some heat</td>
<td>Slower process, no flame, quiet and more efficient, best for generating electricity</td>
</tr>
</tbody>
</table>

8.5
Photovoltaic Cells (solar cells)


Our society has been using photovoltaic cells (solar cells) at a minimum level, but will we all begin picking up on this natural form of energy as a way to conserve our natural coal and petroleum supply?

Thin wafers of ultra pure Si used for voltaic cells.
Silicon Semiconductors
Doped Semiconductors

- Increase conductivity of silicon and lower energy sunlight can be used

n-type doped: Freely moving electrons
p-type doped: Freely moving positive charges, holes
Challenges with PV Cells

- Silicon is most commonly found as SiO2 – otherwise known as sand
- Conversion of sunlight is not very efficient – a typical commercial solar cell has efficiency of 15%!
- Expensive
Other countries making use of solar energy

Solar Park Gut Erlauze in Bavaria. At peak capacity, it can generate 12 MW.

Harnessing the energy of the sun for pumping water

It’s time to make important decisions and advances in alternative energy technology and new sources of renewable energy.