Oxidation and Reduction

Batteries and Fuel Cells
Combustion
Photovoltaic Materials

Oxidation and Reduction

- Oxidation is when something loses electrons
  - An “oxidizing agent” or “oxidizer” is something that strips electrons from something else
  - “oxidizing agents” are reduced
- Reduction is when something gains electrons
  - A “reducing agent” is something that donates electrons to something else
  - “reducing agents” are oxidized
The Periodic Table by electronegativity

- Little tendency to lose or gain electrons
- Tendency to lose electrons
- Tendency to gain electrons

- More likely to behave as oxidizing agent (be reduced)
- More likely to behave as reducing agent (be oxidized)

The Periodic Table by electronegativity

Electronegativity (Pauling)

www.webelements.com
The Periodic Table by electronegativity

<table>
<thead>
<tr>
<th>Group</th>
<th>Elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>H, He</td>
</tr>
<tr>
<td>2</td>
<td>Li, Be</td>
</tr>
<tr>
<td>3</td>
<td>B, C, N, O, F, Ne</td>
</tr>
<tr>
<td>4</td>
<td>Na, Mg, Al, Si, P, S, Cl, Ar</td>
</tr>
<tr>
<td>5</td>
<td>K, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, Ge, As, Se, Br, Kr</td>
</tr>
<tr>
<td>6</td>
<td>Rb, Sr, Y, Zr, Nb, Mo, Tc, Ru, Rh, Pd, Ag, Cd, In, Sn, Sb, Te, I, Xe</td>
</tr>
<tr>
<td>7</td>
<td>Cs, Ba, La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Hf, Ta, W, Re, Os, Ir, Pt, Au, Tl, Pb, Bi, Po, At, Rn</td>
</tr>
</tbody>
</table>

http://staff.jccc.net/pdecell/chemistry/electrons.html
A typical oxidation-reduction couple

Fe + CuCl₂ → FeCl₂ + Cu
Iron is oxidized by copper; copper ions are reduced by iron

Half-reactions for iron-copper system

- Overall reaction:
  - Fe + CuSO₄ → FeSO₄ + Cu
- Oxidation of iron:
  - Fe → Fe²⁺ + 2 e⁻
- Reduction of copper:
  - Cu²⁺ + 2 e⁻ → Cu
- SO₄²⁻ is a “spectator ion”
- Electrons released by iron are taken up by copper: a “redox couple”
Is this all we need for a battery?

- If we separate the iron and copper, why won’t electrons flow through the wire from iron to copper?
  - There is no way to balance the charges!

Is this all we need for a battery?

- If we add a salt bridge, electrons flow through the wire from iron to copper.
  - The salt bridge provides ions that balance the charges!
Inside a flashlight battery

- In the battery, electrons flow from zinc metal to manganese ions
  - \( \text{NH}_4^+ \) ions mediate the process
  - Which of the “boxed” reactions is oxidation-reduction?
  - Ions flow through the membrane to balance charges
  - NOT REVERSIBLE!

Inside a flashlight battery

- The oxidation-reduction reaction is the bottom one
  - \( \text{H}_2 \) is oxidized to \( \text{H}_2\text{O} \)
  - \( \text{Mn}^{4+} \) is reduced to \( \text{Mn}^{3+} \)
  - \( \text{H}_2 \rightarrow 2 \text{H}^+ + 2 \text{e}^- \)
  - \( \text{O}^2- + 2 \text{H}^+ \rightarrow \text{H}_2\text{O} \)
  - \( 2 \text{Mn}^{4+} + 2 \text{e}^- \rightarrow 2 \text{Mn}^{3+} \)
Discharging a lead-acid ("automobile") battery: $\text{Pb} + \text{Pb}^{4+} \rightarrow 2 \text{Pb}^{2+} + \text{energy}$

Charging a lead-acid ("automobile") battery: $2 \text{Pb}^{2+} + \text{energy} \rightarrow \text{Pb} + \text{Pb}^{4+}$