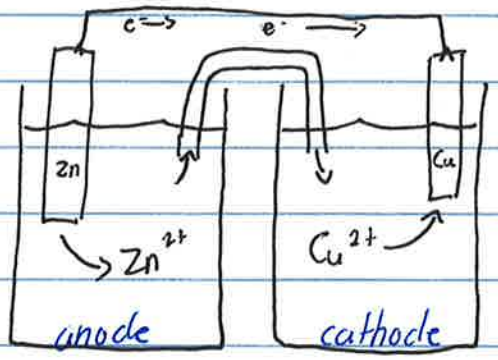
Mon April 8th: Galvanic cells, table of reduction potentials
Tuesday April 9th: expt 12, problem club with Ali
Wednesday April 10th: finish ch 18

Galvanic cells $\Delta G < 0$ $\Delta G = -nFE$
- always spontaneous



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

oxidation reduction

$Zn \mid Zn^{2+}(1M) \parallel Cu^{2+}(1M) \mid Cu$

overall: $Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu$ $E^\circ = +1.10\,V$

$Pb \rightarrow Pb^{2+} + 2e^-$ (anode)

$Cu^{2+} + 2e^- \rightarrow Cu$ (cathode)

$Pb + Cu^{2+} \rightarrow Pb^{2+} + Cu$ $E^\circ = +0.47\,V$

$Zn + Pb^{2+} \rightarrow Zn^{2+} + Pb$ $E^\circ = ?$

$Zn + \cancel{Cu^{2+}} \rightarrow Zn^{2+} + \cancel{Cu}$ $E^\circ = +1.10\,V$ $(n = 2e^-)$

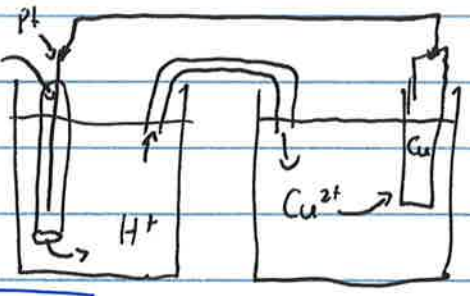
$Pb^{2+} + \cancel{Cu} \rightarrow Pb + \cancel{Cu^{2+}}$ $E^\circ = -0.47\,V$ $(n = 2e^-)$

$Zn + Pb^{2+} \rightarrow Zn^{2+} + Pb$ $E^\circ = +0.63\,V$

$Cu^{2+} + 2e^- \rightarrow Cu \quad E^\circ_{red} = +0.34V$

$H_2 \rightarrow 2H^+ + 2e^- \quad E^\circ_{ox} = 0.00V$

$Cu^{2+} + H_2 \rightarrow Cu + 2H^+ \quad E^\circ = +0.34V$



$2H^+ + 2e^- \rightarrow H_2 \quad E^\circ_{red} = 0.00V$

$Zn \rightarrow Zn^{2+} + 2e^- \quad E^\circ_{ox} = +0.76V$

$Cu^{2+} + 2e^- \rightarrow Cu \quad E^\circ_{red} = +0.34V$

$Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu \quad E^\circ = +1.10V$

Table of reduction potentials

easiest to reduce (cathode)

$Ag^+ + e^- \rightarrow Ag \quad E^\circ = +0.80V$

$Cu^{2+} + 2e^- \rightarrow Cu \quad E^\circ_{red} = +0.34V$

$2H^+ + 2e^- \rightarrow H_2 \quad E^\circ = 0.00V$

$Pb^{2+} + 2e^- \rightarrow Pb \quad E^\circ = -0.13V$

$Zn^{2+} + 2e^- \rightarrow Zn \quad E^\circ = -0.76V$

if $E_{ox} + E_{red}$ add up to $E > 0$, the reaction will be spontaneous

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$2Ag^+ + Pb \rightarrow Pb^{2+} + 2Ag$

$2Ag^+ + 2e^- \rightarrow 2Ag \quad E^\circ_{red} = +0.80V$ ← does not change even though equation is "multiplied by 2"

$Pb \rightarrow Pb^{2+} + 2e^- \quad E^\circ_{ox} = +0.13V$

$Pb + 2Ag^+ \rightarrow Pb^{2+} + 2Ag \quad E^\circ = 0.93V$

$\Delta G^\circ = -nFE^\circ$

$\Delta G^\circ = -(2)(96.5\ kJ/volt)(0.93V)$

$= -179\ kJ$

$\Delta G = -nFE$

$(-) = -(+)(+)(+)$ spontaneous

$(+) = -(+)(+)(-)$ nonspontaneous

What pair would give the smallest $\Delta G < 0$?

$2H^+ + 2e^- \rightarrow H_2 \quad E^\circ_{red} = 0.00V$

$Pb \rightarrow Pb^{2+} + 2e^- \quad E^\circ_{ox} = +0.13V$

$2H^+ + Pb \rightarrow Pb^{2+} + H_2 \quad E^\circ = 0.13V$ spontaneous

$\Delta G^\circ = -nFE^\circ$

$\Delta G^\circ = -(2)(96.5\ kJ/volt)(+0.13V)$

$\Delta G^\circ = -25.09kJ$ spontaneous

$\Delta G^\circ = -RT \ln K_c$

$-25.09kJ = (-8.314 \times 10^{-3}\ kJ/k)(298k) \ln K_c$

$K_c = 2.5 \times 10^4$ spontaneous