Teaching Undergraduate Chemistry Students Electrochemistry Fundamentals with Galvanic and Concentration Cells

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Abstract

In this lab, two things were achieved: a galvanic cell was made from different mixed metal components, allowing students to determine the identity of an unknown metal, and the value of the Nernst constant was calculated through experimental data from a concentration cell. A galvanic cell with 1.5M Copper Nitrate solution at the cathode and a 1.5M Zinc Nitrate solution at the anode was made. A copper wire was used for both electrodes. A measured electrochemical cell potential for this system was found to be -0.61V, giving a -19.7% error when compared against the theoretical E_{cell} value of -0.76V. The theoretical E_{cell} value was calculated using the equation $E_{cell} = E_{anode} - E_{cathode}$. Using this technique, a galvanic cell using 1.5M Copper Nitrate aqueous solution and 1.5M Lead Nitrate aqueous was also made, resulting in a -7.69% error when compared against the theoretical. A concentration cell with a Copper Nitrate solution at the anode and cathode yielded a calculated Nernst constant value of 0.0211, generating a -28.96% error when compared against the theoretical Nernst constant value of 0.0297.

Introduction/ Background

$$E_{cell} = E° - (RT/nF)\ln Q$$

Equation 1. The Nernst Equation. RT/F = 0.0592.

$$\Delta G° = nFE° \quad (a)$$
$$\Delta G = \Delta G° + RT\ln Q \quad (b)$$

Equation 2. Gibbs Free Energy Equation for *(a)* standard and *(b)* non- standard conditions

$$E_{cell}° = E°_{cathode} - E°_{anode}$$

Equation 3. $E°_{cell}$ equation. Values typically measured experimentally, or referenced from the Standard Reduction Equations (**Figure 3.**)

°= Denotes system under standard conditions

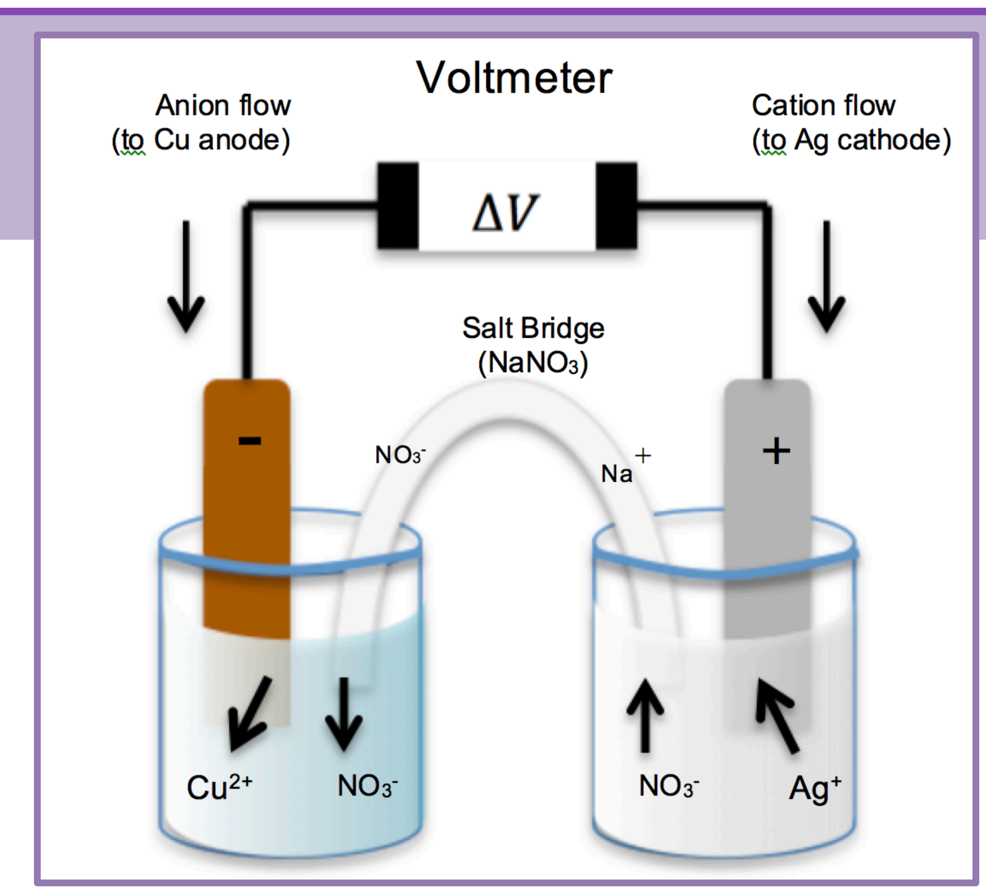


Figure 1. Representation of a typical $Cu(s)|Cu(NO_3)_2||Ag(NO_3)|Ag(s)$ galvanic cell.

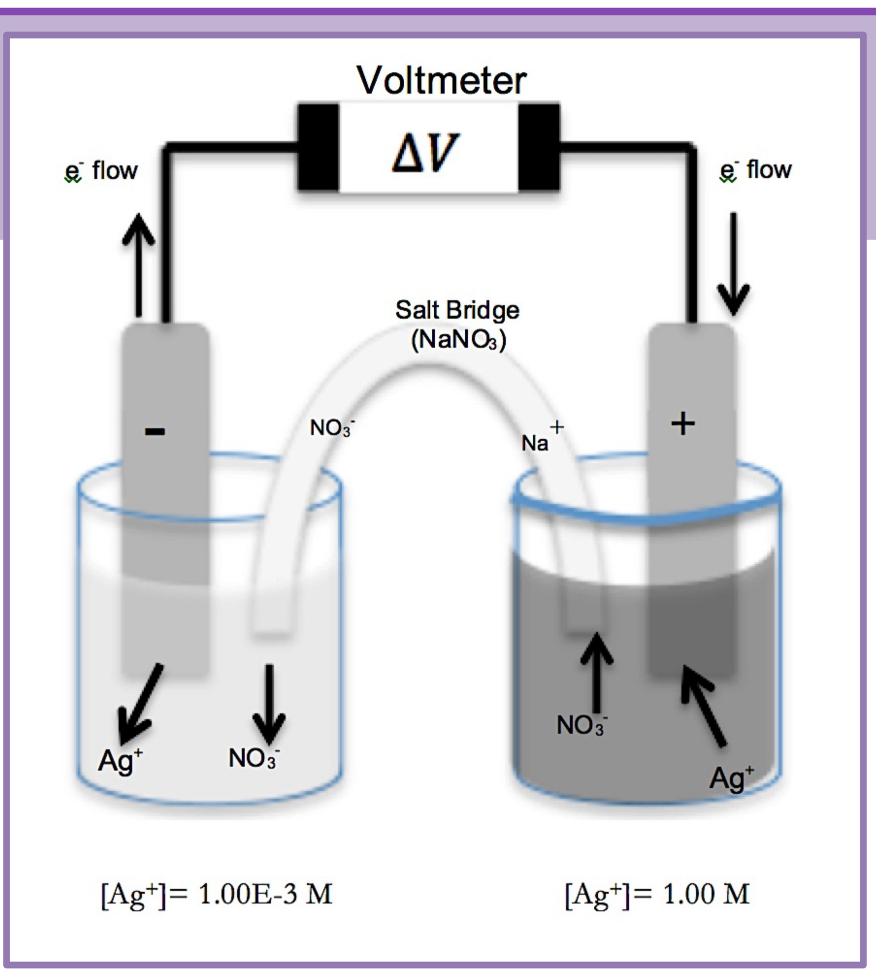


Figure 2. Representation of a Silver concentration cell.

Results & Discussion

Galvanic Cell

Galvanic Cell Type (with a copper cathode)	Measured E_{cell} (V)	Accepted $E_{cathode}$ (V) from standard Cu reduction potential	Calculated E_{anode} (V)	Accepted E_{anode} (V) from standard reduction potentials	% Error for E_{anode} (V)
Zn[a]	0.95	0.34	-0.61	-0.76	-19.7
Pb[b]	0.46	0.34	-0.12	-0.13	-7.69
Fe[c]	-0.47	0.34	0.81	0.77	5.19
Mg[d]	1.58	0.34	-1.24	-2.37	-47.7
Sn[e]	0.53	0.34	-0.19	-0.14	35.7

Table 1. Galvanic Cell data with measured E_{cell} values, Accepted $E_{cathode}$ values, Calculated E_{anode} values, Accepted E_{anode} values, and % error between the accepted and calculated E_{anode} values

Figure 3. Standard Reduction Equations[a,b,c,d,e]:

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

$Pb^{2+} + 2e^- \rightarrow Pb$

$Fe^{2+} + 2e^- \rightarrow Fe$

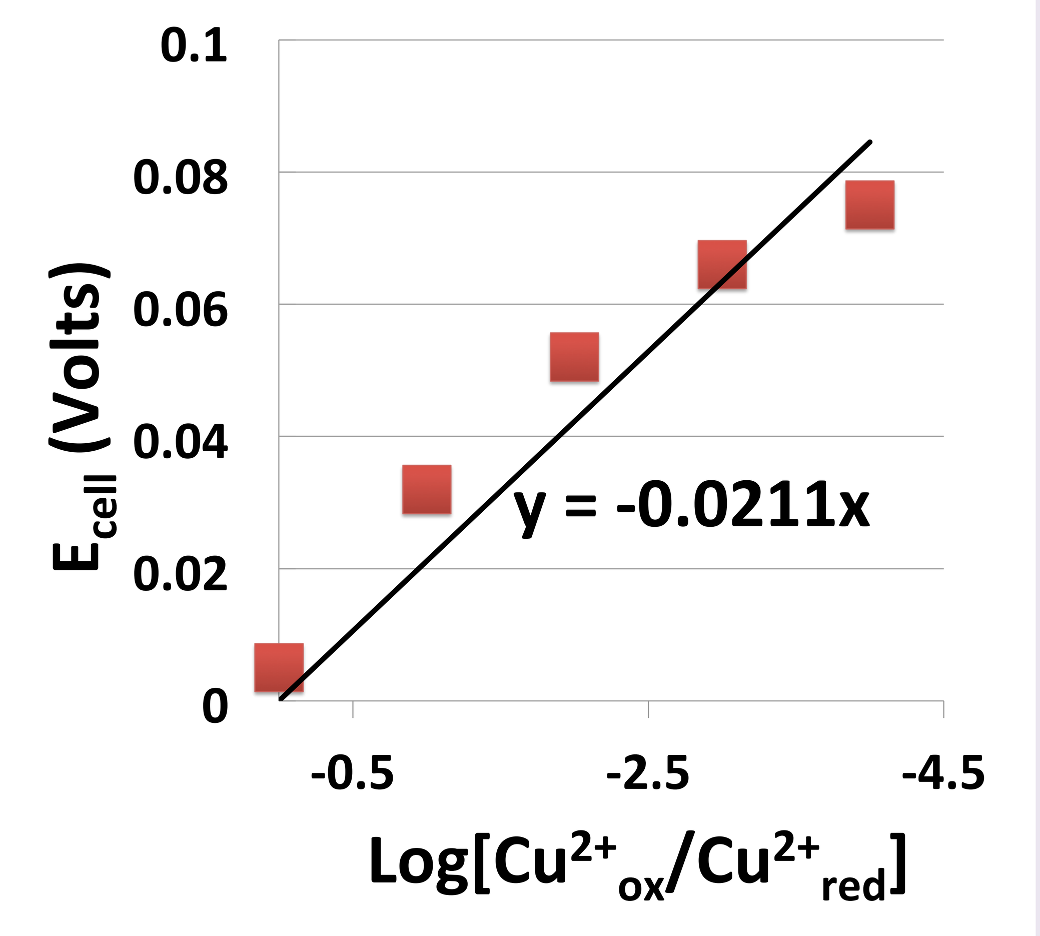
$Mg^{2+} + 2e^- \rightarrow Mg$

$Sn^{2+} + 2e^- \rightarrow Sn$

Concentration Cell

Experimental:

Figure 4. Concentration cell data of $\log[Cu^{2+}_{ox}/Cu^{2+}_{red}]$ vs measured E_{cell} for a copper concentration cell



Theoretical (n= 2) : See Equation 1.

$$E_{cell} = 0 - (0.0296)\ln Q$$

Percent Error: -28.96%

Conclusions

Through this lab, students should leave with a more thorough understanding of galvanic and concentrations cells and strengthen their foundation in electrochemistry.

Potential lab questions for undergraduate students:

1. *What do you notice about the Voltage reading as you change …?*
2. *How else could you have confirmed the identity of the unknown metal?*
3. *Metal oxides form readily at the surface of electrodes. How would this affect the voltage reading you see?*

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