Reduction Potentials Experiment

PURPOSE
The purpose of this laboratory activity is to establish the reduction potentials of several known metals relative to an arbitrarily chosen metal by measuring the voltage, or potential difference, between various pairs of half-cells.

THEORY

A voltaic cell (also known as a galvanic or electrochemical cell) uses a spontaneous oxidation-reduction reaction to produce electrical energy. Half-cells are normally produced by placing a piece of metal into a solution containing a cation of the metal (e.g., copper (Cu) metal in a solution of copper nitrate ($Cu(NO_3)$or Cu^{2+})). A salt bridge, an aqueous solution of inert ions, normally separates the two half-reactions. The salt bridge completes the circuit, and allows the charge in each solution to remain electrically balanced.

In this web simulation of a voltaic cell, the half-cell will be an electrode made of a piece of metal placed into a beaker of corresponding cation solution. Here, the salt bridge will be a 2.0M solution of aqueous sodium nitrate ($NaNO_3$) placed in a "U-tube" with semipermeable membranes linking the two half cells. Using the computer as a voltmeter, the red (+) wire of the voltage sensor makes contact with one metal and the black (-) wire of the voltage sensor with another.

By comparing the voltage values obtained for several pairs of half-cells, and by recording which metal made contact with the red (+) and black (-) wires, you can establish the reduction potential sequence for the metals in this lab.

PROCEDURE
For this activity, the simulated voltmeter is used to measure the difference in electric potential of multiple voltaic half-cell cells.

Open the following website to access the simulation: http://web.mst.edu/~gbert/Electro/Electrochem.html

Part I - Measuring Cell Voltages

Attached the black wire (left hand half-cell) from the voltmeter to Pt/H_2 electrode and fill the corresponding beaker with 1.00M HNO_3. Use the matching 1.00M solution of the cation for each possible metal electrode in the other half-cell.

Cell pairing with Pt/H_2	**Measured cell voltage (V)**
Cd	
Cu	
Fe	
Pb	
Mg	
Ni	
Ag	
Zn	

By choosing to attach the black wire to the Pt/H_2 electrode with H^+ ions in solution, we are measuring the reduction potential of the metal ion compared to that of the H^+ ions. *A greater reduction potential means a stronger pull on the electrons.*

Circle either **H^+** *or* **M^+** *in each of the following statements to make them true.*

A negative voltage means the **H^+** **M^+** ions are pulling harder on the electrons in that combination.

A positive voltage means the **H^+** **M^+** ions are pulling harder on the electrons in that combination.

Part II - Developing a Reduction Potentials Table

If the reaction $2H^{+}_{(aq)} + 2e^{-} \rightarrow H_{2(g)}$ is assigned a value of 0.00 V, the cell voltages measured in Part I of this procedure can be used to construct a set of reduction potentials for the other electrodes. Because the solution concentrations used were all 1.00M, these are called the "**standard reduction potentials**" or **E^0**.

Complete the following table using the values from part 1:

Half Reactions	Reduction Potential vs. Pt/H+ Electrode (V)
$Ag^{+}_{(aq)} + e^{-} \rightarrow Ag_{(s)}$	
$Cu^{2+}_{(aq)} + 2e^{-} \rightarrow Cu_{(s)}$	
$2H^{+}_{(aq)} + 2e^{-} \rightarrow H_{2(g)}$	0.00
$Pb^{2+}_{(aq)} + 2e^{-} \rightarrow Pb_{(s)}$	
$Ni^{2+}_{(aq)} + 2e^{-} \rightarrow Ni_{(s)}$	
$Cd^{2+}_{(aq)} + 2e^{-} \rightarrow Cd_{(s)}$	
$Fe^{2+}_{(aq)} + 2e^{-} \rightarrow Fe_{(s)}$	
$Zn^{2+}_{(aq)} + 2e^{-} \rightarrow Zn_{(s)}$	
$Mg^{2+}_{(aq)} + 2e^{-} \rightarrow Mg_{(s)}$	

Does a negative reduction potential mean that metal ion does not "pull" on electrons at all?

Which metal ion "pulls the hardest" on electrons?

Which pulls the least?

Using your completed table above and the equation $\mathbf{E^0_{cell} = E^0_{cathode} - E^0_{anode}}$, **calculate** the potentials (voltages) of the following electrochemical cells.

Cu/Zn _____ V Cu/Cd _____ V Cu/Ag _____ V Cu/Mg _____ V Cu/Pb _____ V

Pb/Zn _____ V Pb/Cd _____ V Pb/Ag _____ V Pb/Mg _____ V

Mg/Zn _____ V Mg/Cd _____ V Mg/Ag _____ V

Ag/Zn ______V Ag/Cd _____ V

Cd/Zn ______ V

Part III – Comparison of Predicted Potentials to Measured Potentials.

Construct and measure the cell voltages (potentials) for at least five of the following cells on the website. The red wire (+) goes to the metal with more positive potential (see the above table). Use only 1.00M solutions for the matching cation solutions. *(Note: if the measured voltage for the cell is a negative number, you've constructed it backwards!)*

Cu/Zn _____ V Cu/Cd _____ V Cu/Ag _____ V Cu/Mg _____ V Cu/Pb _____ V

Pb/Zn _____ V Pb/Cd _____ V Pb/Ag _____ V Pb/Mg _____ V

Mg/Zn _____ V Mg/Cd _____ V Mg/Ag _____ V

Ag/Zn ______V Ag/Cd _____ V

Cd/Zn ______ V

How close are the measured and calculated cell reduction potentials?____________________

Part IV – The Effect of Solution Concentration on Cell Potentials.

Write the balanced equation for the spontaneous process taking place in the following cell: $Mg \mid Mg^{2+} \parallel Cu^{2+} \mid Cu$

$\rightarrow$

In this reaction, Mg^{2+} is a ________________ and Cu^{2+} is a __________________ . *(Use reactant or product)*

Construct an electrochemical cell with a copper electrode and a magnesium electrode. Start with 1.00M solutions of the matching cation in each half cell. Then, once solution at a time, change the solution concentration as indicated in the table below and measure the new cell voltage.

[Mg2+]	[Cu2+]	measured cell voltage (V)
0.10	1.00	
0.50	1.00	
1.00	1.00	
2.00	1.00	
1.00	2.00	
1.00	0.50	
1.00	0.10	

Based on your results, in general:

As [reactants] increases, cell voltage __________

As [products] increases, cell voltage __________

So…

When **re**charging a battery, [reactants] ________, [products] ___________, and the cell voltage ____________

When using (***dis****charging*) a battery, [reactants] ___________,[products] ___________, and the cell voltage ____________ .

Part V – The Reduction potential of a mystery metal.

A new metal has been discovered and named "whodatium". Devise a plan to determine its **standard** cell potential. Describe your procedure below. Be detailed enough that next hour could follow your directions and successfully determine the value requested.

Measured standard reduction potential for whodatium: ____________V