Lab Activity 1: Which metals make the best lemon battery?

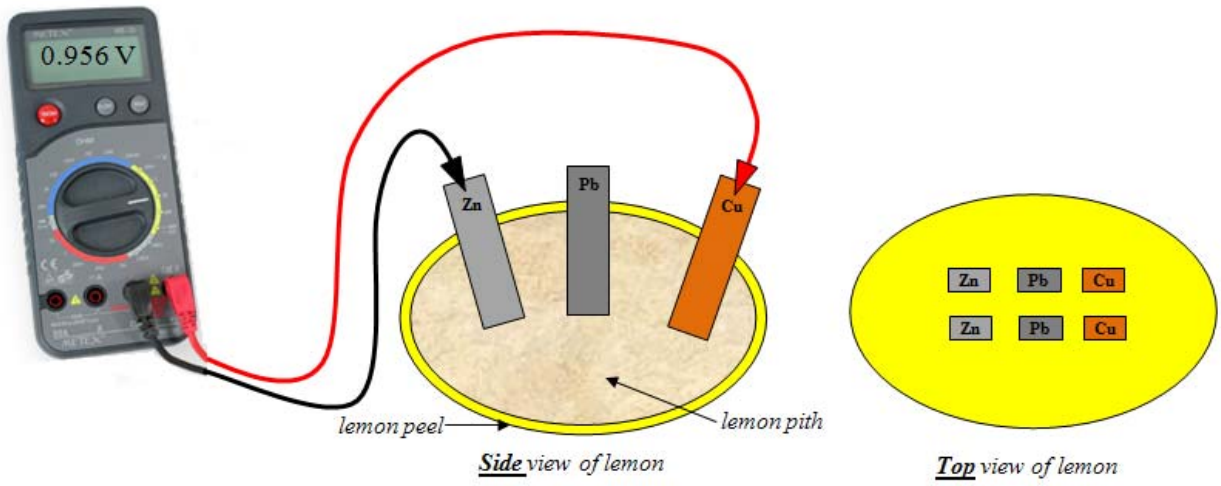
Materials

- digital multimeter (DMM)
- Alligator clip leads
- one fresh lemon
- two zinc plates
- two lead plates
- two copper plates

Procedure

1. Puncture the lemon with each of the metal pieces so that each metal piece contacts the pith of the lemon. Metals should be in a direct line and not contact one another (Figure 1). Make a second row of metal pieces about 1.27 cm (0.5 in.) from the first.

Figure 1: Lemon battery diagram.



2. Take some voltage measurements from the lemon battery:

    a. Connect the black lead from the DMM to the zinc (Zn). Measure the voltage between the zinc and each of the other metals to the nearest 100th of a volt (Figure 1). Fill in the first column of Figure 2, using zinc as the reference or common ground.
    b. Repeat this process using lead (Pb) as the reference metal to complete the second column of Figure 2.
    c. Use copper (Cu) as the reference to complete the third column.

    (**Hint:** Remember to always keep the black lead of the DMM connected to the reference.)

Figure 2: Voltages produced between reference metals and other test metals.

Reference metals	Zinc (Zn)	Lead (Pb)	Copper (Cu)
Test metals	Pb = _____V	Zn = _____V	Pb = _____V
	Cu = _____V	Cu = _____V	Zn = _____V
	Zn = _____V	Pb = _____V	Cu = _____V

3. Many important chemical reactions involve electron transfer from one substance to another. This class of reactions is called *reduction–oxidation* or *redox reactions*. One substance is oxidized (i.e., loses electrons), while the other is reduced (i.e., gains electrons).

    a. In the first column of Figure 3, arrange the voltages produced using zinc as a reference metal. List these in order from the most positive to the least positive.
    b. List the metal associated with each voltage in the second column.
    c. Decide whether this metal gains or loses an electron. Check the appropriate box in columns three, four, and five.
    d. Repeat this process for Figure 4 (using lead as a reference) and in Figure 5 (using copper as a reference).

(**Hint:** A positive voltage indicates that electrons will flow to the reference metal [metal gains electron]. A negative voltage indicates that the reference metal will lose electrons. A zero voltage indicates that there was no electron transfer.)

Figure 3: Hierarchy of voltages with zinc as a reference.

	Voltage (V)	Metal	Gains electrons (metal reduced)	Loses electrons (metal oxidized)	Neither
Most positive voltage					
Least positive voltage					

Figure 4:Hierarchy of voltages with lead as a reference.

	Voltage (V)	Metal	Gains electrons (metal reduced)	Loses electrons (metal oxidized)	Neither
Most positive voltage					

Least positive voltage					

Figure 5: Hierarchy of voltages with copper as a reference.

	Voltage (V)	**Metal**	**Gains electrons (metal reduced)**	**Loses electrons (metal oxidized)**	**Neither**
Most positive voltage					
Least positive voltage					

4. Examine your three hierarchies of voltages tables (Figures 3–5).

    a. Which metal always has the most positive voltage?
    b. Which metal always has the least positive voltage?
    c. Which metal has the greatest tendency to oxidize?
    d. Which metal has the greatest tendency to reduce?
    e. Which metal can either oxidize or reduce?
    f. Which two metals would you select if you were building a battery with a maximum positive voltage?