

# Investigation 13.A: Measuring Cell Potentials of Voltaic Cells

## Answer Key

### Answers to Prediction Question

1. You can use Appendix G in your text to calculate cell potentials as follows:

(a)

Mg(s) anode, Cu(s) cathode;  $E^\circ_{\text{cell}} = 2.71 \text{ V}$   
 Mg(s) anode, Al(s) cathode;  $E^\circ_{\text{cell}} = 0.71 \text{ V}$   
 Al(s) anode, Cu(s) cathode;  $E^\circ_{\text{cell}} = 2.00 \text{ V}$   
 Mg(s) anode, Ni(s) cathode;  $E^\circ_{\text{cell}} = 2.11 \text{ V}$   
 Ni(s) anode, Cu(s) cathode;  $E^\circ_{\text{cell}} = 0.60 \text{ V}$   
 Al(s) anode, Ni(s) cathode;  $E^\circ_{\text{cell}} = 1.40 \text{ V}$   
 Mg(s) anode, Zn(s) cathode;  $E^\circ_{\text{cell}} = 1.61 \text{ V}$   
 Zn(s) anode, Cu(s) cathode;  $E^\circ_{\text{cell}} = 0.416 \text{ V}$   
 Al(s) anode, Zn(s) cathode;  $E^\circ_{\text{cell}} = 0.90 \text{ V}$   
 Zn(s) anode, Sn(s) cathode;  $E^\circ_{\text{cell}} = 0.62 \text{ V}$   
 Mg(s) anode, Sn(s) cathode;  $E^\circ_{\text{cell}} = 2.23 \text{ V}$   
 Sn(s) anode, Cu(s) cathode;  $E^\circ_{\text{cell}} = 0.48 \text{ V}$   
 Al(s) anode, Sn(s) cathode;  $E^\circ_{\text{cell}} = 1.52 \text{ V}$   
 Ni(s) anode, Sn(s) cathode;  $E^\circ_{\text{cell}} = 0.12 \text{ V}$   
 Mg(s) anode, Fe(s) cathode;  $E^\circ_{\text{cell}} = 1.92 \text{ V}$   
 Fe(s) anode, Cu(s) cathode;  $E^\circ_{\text{cell}} = 0.79 \text{ V}$   
 Al(s) anode, Fe(s) cathode;  $E^\circ_{\text{cell}} = 1.21 \text{ V}$   
 Ni(s) anode, Fe(s) cathode;  $E^\circ_{\text{cell}} = -0.19 \text{ V}$

Zn(s) anode, Fe(s) cathode;  $E^\circ_{\text{cell}} = 0.31 \text{ V}$   
 Sn(s) anode, Fe(s) cathode;  $E^\circ_{\text{cell}} = -0.31 \text{ V}$   
 Mg(s) anode, Ag(s) cathode;  $E^\circ_{\text{cell}} = 3.17 \text{ V}$   
 Cu(s) anode, Ag(s) cathode;  $E^\circ_{\text{cell}} = 0.46 \text{ V}$   
 Al(s) anode, Ag(s) cathode;  $E^\circ_{\text{cell}} = 2.46 \text{ V}$   
 Ni(s) anode, Ag(s) cathode;  $E^\circ_{\text{cell}} = 1.06 \text{ V}$   
 Zn(s) anode, Ag(s) cathode;  $E^\circ_{\text{cell}} = 1.56 \text{ V}$   
 Sn(s) anode, Ag(s) cathode;  $E^\circ_{\text{cell}} = 0.94 \text{ V}$   
 Fe(s) anode, Ag(s) cathode;  $E^\circ_{\text{cell}} = 1.25 \text{ V}$   
 Mg(s) anode,  $\text{H}^+(\text{aq})$  cathode;  $E^\circ_{\text{cell}} = 2.37 \text{ V}$   
 $\text{H}_2(\text{g})$  anode, Cu(s) cathode;  $E^\circ_{\text{cell}} = 0.34 \text{ V}$   
 Al anode,  $\text{H}^+(\text{aq})$  cathode;  $E^\circ_{\text{cell}} = 1.66 \text{ V}$   
 Ni anode,  $\text{H}^+(\text{aq})$  cathode;  $E^\circ_{\text{cell}} = 0.26 \text{ V}$   
 Zn anode,  $\text{H}^+(\text{aq})$  cathode;  $E^\circ_{\text{cell}} = 0.76 \text{ V}$   
 Sn anode,  $\text{H}^+(\text{aq})$  cathode;  $E^\circ_{\text{cell}} = 0.14 \text{ V}$   
 Fe anode,  $\text{H}^+(\text{aq})$  cathode;  $E^\circ_{\text{cell}} = 0.45 \text{ V}$   
 $\text{H}_2(\text{g})$  anode, Ag(s) cathode;  $E^\circ_{\text{cell}} = 0.80 \text{ V}$

Your values will likely be less than predicted, which could be the result of faulty equipment or resistance in the wire. However, you should also consider the conditions under which the standard values listed in Appendix G are calculated.

### Answers to Analysis Questions

1. (a)

|                                | Mg/Mg <sup>2+</sup> | Cu/Cu <sup>2+</sup> | Al/Al <sup>3+</sup> | Ni/Ni <sup>2+</sup> | Zn/Zn <sup>2+</sup> | Sn/Sn <sup>2+</sup> | Fe/Fe <sup>3+</sup> | Ag/Ag <sup>+</sup> | H <sup>+</sup> /H <sub>2</sub> |
|--------------------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|--------------------|--------------------------------|
| Mg/Mg <sup>2+</sup>            |                     |                     |                     |                     |                     |                     |                     |                    |                                |
| Cu/Cu <sup>2+</sup>            | (1)                 |                     |                     |                     |                     |                     |                     |                    |                                |
| Al/Al <sup>3+</sup>            | (2)                 | (3)                 |                     |                     |                     |                     |                     |                    |                                |
| Ni/Ni <sup>2+</sup>            | (4)                 | (5)                 | (6)                 |                     |                     |                     |                     |                    |                                |
| Zn/Zn <sup>2+</sup>            | (7)                 | (8)                 | (9)                 | (10)                |                     |                     |                     |                    |                                |
| Sn/Sn <sup>2+</sup>            | (11)                | (12)                | (13)                | (14)                | (15)                |                     |                     |                    |                                |
| Fe/Fe <sup>3+</sup>            | (16)                | (17)                | (18)                | (19)                | (20)                | (21)                |                     |                    |                                |
| Ag/Ag <sup>+</sup>             | (22)                | (23)                | (24)                | (25)                | (26)                | (27)                | (28)                |                    |                                |
| H <sup>+</sup> /H <sub>2</sub> | (29)                | (30)                | (31)                | (32)                | (33)                | (34)                | (35)                | (36)               |                                |

# Investigation 13.A: Measuring Cell Potentials of Voltaic Cells

## Answer Key (continued)

- (1) Mg(s) anode, Cu(s) cathode
- (2) Mg(s) anode, Al(s) cathode
- (3) Al(s) anode, Cu(s) cathode
- (4) Mg(s) anode, Ni(s) cathode
- (5) Ni(s) anode, Cu(s) cathode
- (6) Al(s) anode, Ni(s) cathode
- (7) Mg(s) anode, Zn(s) cathode
- (8) Zn(s) anode, Cu(s) cathode
- (9) Al(s) anode, Zn(s) cathode
- (10) Zn(s) anode, Sn(s) cathode
- (11) Mg(s) anode, Sn(s) cathode
- (12) Sn(s) anode, Cu(s) cathode
- (13) Al(s) anode, Sn(s) cathode
- (14) Ni(s) anode, Sn(s) cathode
- (15) Zn(s) anode, Sn(s) cathode
- (16) Mg(s) anode, Fe(s) cathode
- (17) Fe(s) anode, Cu(s) cathode
- (18) Al(s) anode, Fe(s) cathode

- (19) Ni(s) anode, Fe(s) cathode
- (20) Zn(s) anode, Fe(s) cathode
- (21) Sn(s) anode, Fe(s) cathode
- (22) Mg(s) anode, Ag(s) cathode
- (23) Cu(s) anode, Ag(s) cathode
- (24) Al(s) anode, Ag(s) cathode
- (25) Ni(s) anode, Ag(s) cathode
- (26) Zn(s) anode, Ag(s) cathode
- (27) Sn(s) anode, Ag(s) cathode
- (28) Fe(s) anode, Ag(s) cathode
- (29) Mg(s) anode, H<sup>+</sup>(aq) cathode
- (30) H<sub>2</sub>(g) anode, Cu(s) cathode
- (31) Al(s) anode, H<sup>+</sup>(aq) cathode
- (32) Ni(s) anode, H<sup>+</sup>(aq) cathode
- (33) Zn(s) anode, H<sup>+</sup>(aq) cathode
- (34) Sn(s) anode, H<sup>+</sup>(aq) cathode
- (35) Fe(s) anode, H<sup>+</sup>(aq) cathode
- (36) H<sub>2</sub>(g) anode, Ag(s) cathode

(b) For each of the cells in this investigation, all anodes are negative electrodes and all cathodes are positive electrodes.

2. An oxidation half-reaction occurs at each anode and a reduction half-reaction occurs at each cathode. For example, for cell (1), the Mg(s)/Mg<sup>2+</sup>(aq) half-cell is the anode and the Cu(s)/Cu<sup>2+</sup>(aq) half-cell is the cathode. Oxidation occurs at the anode. The oxidation half-reaction is:  

$$\text{Mg(s)} \rightarrow \text{Mg}^{2+}(\text{aq}) + 2\text{e}^{-}$$
 Reduction occurs at the cathode. The reduction half-reaction is:  

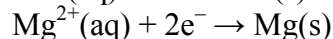
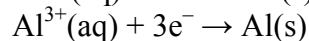
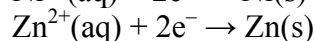
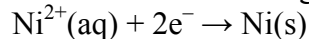
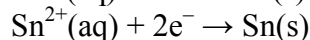
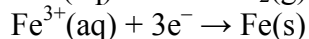
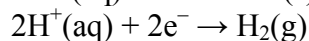
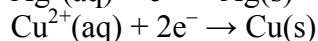
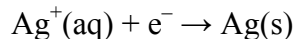
$$\text{Cu}^{2+}(\text{aq}) + 2\text{e}^{-} \rightarrow \text{Cu(s)}$$
 The overall cell reaction is:  

$$\text{Mg(s)} + \text{Cu}^{2+}(\text{aq}) \rightarrow \text{Mg}^{2+}(\text{aq}) + \text{Cu(s)}$$
3. (a) The direction of electron flow for a voltaic cell is always from the anode to the cathode. For example, in cell (1), the electrons flow from the magnesium anode to the copper cathode.  
 (b) Positive ions (cations) move towards the cathode, where reduction occurs, and negatively charged ions (anions) move towards the anode, where oxidation occurs. For example, in cell (1), potassium ions and copper ions move towards the cathode (copper). Nitrate ions move towards the anode (magnesium).
4. Magnesium is the most effective reducing agent since the magnesium half-cell always acted as the anode when coupled with other half-cells.

# Investigation 13.A: Measuring Cell Potentials of Voltaic Cells

## Answer Key (continued)

5. The reduction half-reactions, in order of least to most effective reducing agents, are as follows:



6. The metal ions that are the best oxidizing agents are at the top of the list. The least effective reducing agents tend to be the most effective oxidizing agents.
7. Look for a link between the relative strength of oxidizing agents discussed in Chapter 12 and the higher reductive potentials.
8. Typically, most measured cell potentials ought to be lower than predicted values. In part, this is due to the lower concentration of the solutions, different operating conditions, and resistance in the wiring leading to the voltmeter.
9. Two factors that affect the cell potential of the voltaic cell are the concentration of the electrolyte solution and the identity of the substances used in each half-cell.
10. (a)  $\text{AgNO}_3(\text{aq}) + \text{NaCl}(\text{aq}) \rightarrow \text{AgCl}(\text{s}) + \text{NaNO}_3(\text{aq})$   
Silver nitrate and sodium chloride are both soluble in water. A double displacement reaction takes place when their solutions are mixed, and insoluble silver chloride precipitates.  
(b) and (c) When sodium chloride was added to the  $\text{Ag}(\text{s})/\text{Ag}^+(\text{aq})$  well, you should have observed a change (lowering) in the overall cell voltage. Since the reaction of silver nitrate with silver chloride effectively removes silver ions from solution, it reduces the concentration of the silver ions in solution at the silver electrode. You should conclude, then, that the concentration of the electrolyte solution does affect the cell potential of a voltaic cell.

### Answers to Conclusion Questions

11. Temperature or the electrical resistance of the external circuit would affect the voltage of a voltaic cell. You could suggest a procedure in which you compare the voltage of a voltaic cell at different temperatures. In addition, using leads with different resistances could test if electrical resistance affects cell voltage.
12. The term “standard cell potential” refers to the cell potential using solutions of 1.0 mol/L at SATP conditions, while the term “cell potential” is used for a cell potential measured at any other set of conditions.

### Answer to Application Question

13. You could investigate such items as whether the type or length of the wire changes the measured cell potential.