TOPIC 6: ELECTROCHEMISTRY

APPENDICES

Appendix 6.1: Activity Series: Lab Activity

Purpose

In this qualitative lab activity, you will place drops of solutions onto strips of different metals and observe any reactions that occur. Each solution will have an aqueous ion that matches one of the metal strips.

Caution:

- The chemicals used in this lab activity are oxidizers and should be handled carefully.
- All lab participants must wear personal safety equipment for protection of eyes, hands, and clothes.
- Refer to the MSDS sheets for more information on each chemical you choose to use.

Materials

- 19 mm × 125 mm strips of aluminum (Al), copper (Cu), iron (Fe), zinc (Zn), and/or other metals
- 0.2 mol/L solutions of $Al(NO_3)_3$, $Cu(NO_3)_2$, $Fe(NO_3)_3$, $Zn(NO_3)_2$, and/or other nitrates with cation species matching any other metals you may be using (e.g., Pb(s) and $Pb(NO_3)_2$)—Students will be using 15 to 20 drops of each solution, so 50 to 100 mL should be enough for several groups.
- eyedroppers, dropper bottles, or dropper pipettes
- steel wool or sandpaper
- pencils
- water bottle
- paper towels

Procedures

1. Prepare 0.2 mol/L solutions of $Al(NO_3)_3$, $Cu(NO_3)_2$, $Fe(NO_3)_3$, and $Zn(NO_3)_2$.
2. Using steel wool or sandpaper, gently scrub approximately two-thirds of one side of the metal strips to remove oxidation, dirt, and so on. Wipe the dust into a garbage receptacle.
3. Using a pencil, draw ~7 mm circles in a row on the newly cleaned surfaces of the metal strips.
4. Place the strips on a paper towel, circles facing upward.
5. Place 2 drops of one solution on one of the circles. Wait a few seconds, and then record any observations.
6. Rinse off and dry the metal strips.
7. On a separate circle for each solution, perform the same drop test, and record observations.

Appendix 6.1: Activity Series: Lab Activity *(continued)*

Observations

On a data table similar to the following, record observations, noting whether there was a reaction or no reaction.

Reducing Agent	**Oxidizing Agent**			
	$Al^{3+}_{(aq)}$	$Cu^{2+}_{(aq)}$	$Fe^{3+}_{(aq)}$	$Zn^{2+}_{(aq)}$
$Al_{(s)}$				
$Cu_{(s)}$				
$Fe_{(s)}$				
$Zn_{(s)}$				

Using the observations, complete the following:

- Write net ionic equations for each reaction that occurred. Identify the oxidizing agent, the reducing agent, what is being oxidized, and what is being reduced.
- Create a list of reduction half-reactions for each of the oxidizing agents, putting them in order from strongest to weakest oxidizer. Explain why you chose to order them in this way.

Possible Follow-up Questions

1. Which metal would be most likely to corrode? What leads you to believe this?
2. Zinc is used to coat objects such as nails made of iron in a process called *galvanization*. What would this accomplish?
3. Look up the electronegativities for the metals that were used. How do these electronegativities correlate to the observations? Discuss whether or not they should correlate.
4. Devise a way in which you could determine, experimentally, the oxidation numbers for the substances given to you.

Appendix 6.2: Table of Standard Reduction Potentials

↑ Greatest Affinity for Electrons / Most Easily Reduced / Strongest Oxidizing Agent

Weakest Reducing Agent / Least Easily Oxidized

Half-Reaction	E (volts)
$F_{2(g)} + 2e^- \rightarrow 2F^-_{(aq)}$	+2.87
$H_2O_{2(aq)} + 2H^+_{(aq)} + 2e^- \rightarrow 2H_2O_{(l)}$	+1.77
$MnO_{4(aq)} + 8H^+_{(aq)} + 5e^- \rightarrow Mn^{2+}_{(aq)} + 4H_2O_{(l)}$	+1.52
$Au^{3+}_{(aq)} + 3e^- \rightarrow Au_{(s)}$	+1.50
$Cl_{2(g)} + 2e^- \rightarrow 2Cl^-_{(aq)}$	+1.36
$Cr_2O^{2-}_{7(aq)} + 14H^+_{(aq)} + 6e^- \rightarrow 2Cr^{3+}_{(aq)} + 7H_2O_{(l)}$	+1.33
$MnO_{2(s)} + 4H^+_{(aq)} + 2e^- \rightarrow Mn^{2+}_{(aq)} + 2H_2O_{(l)}$	+1.28
$1/2O_{2(g)} + 2H^+_{(aq)} + 2e^- \rightarrow H_2O_{(l)}$	+1.23
$Br_{2(l)} + 2e^- \rightarrow 2Br^-_{(aq)}$	+1.06
$AuCl^-_{4(aq)} + 3e^- \rightarrow Au_{(s)} + 4Cl^-_{(aq)}$	+1.00
$NO^-_{3(aq)} + 4H^+_{(aq)} + 3e^- \rightarrow NO_{(g)} + 2H_2O_{(l)}$	+0.96
$Ag^+_{(aq)} + e^- \rightarrow Ag_{(s)}$	+0.80
$1/2Hg^{2+}_{2(aq)} + e^- \rightarrow Hg_{(l)}$	+0.79
$Hg^{2+}_{(aq)} + 2e^- \rightarrow Hg_{(l)}$	+0.78
$NO^-_{3(aq)} + 2H^+_{(aq)} + e^- \rightarrow NO_{2(g)} + H_2O_{(l)}$	+0.78
$Fe^{3+}_{(aq)} + e^- \rightarrow Fe^{2+}_{(aq)}$	+0.77
$O_{2(g)} + 2H^+_{(aq)} + 2e^- \rightarrow H_2O_{2(aq)}$	+0.68
$I_{2(s)} + 2e^- \rightarrow 2I^-_{(aq)}$	+0.53
$Cu^+_{(aq)} + e^- \rightarrow Cu_{(s)}$	+0.52
$Cu^{2+}_{(aq)} + 2e^- \rightarrow Cu_{(s)}$	+0.34
$SO^{2-}_{4(aq)} + 4H^+_{(aq)} + 2e^- \rightarrow SO_{2(g)} + 2H_2O_{(l)}$	+0.17
$Cu^{2+}_{(aq)} + e^- \rightarrow Cu^+_{(aq)}$	+0.15
$Sn^{4+}_{(aq)} + 2e^- \rightarrow Sn^{2+}_{(aq)}$	+0.15
$S_{(s)} + 2H^+_{(aq)} + 2e^- \rightarrow H_2S_{(g)}$	+0.14
$2H^+_{(aq)} + 2e^- \rightarrow H_{2(g)}$	0.00
$Pb^{2+}_{(aq)} + 2e^- \rightarrow Pb_{(s)}$	–0.13
$Sn^{2+}_{(aq)} + 2e^- \rightarrow Sn_{(s)}$	–0.14
$Ni^{2+}_{(aq)} + 2e^- \rightarrow Ni_{(s)}$	–0.25
$Co^{2+}_{(aq)} + 2e^- \rightarrow Co_{(s)}$	–0.28
$Se_{(s)} + 2H^+_{(aq)} + 2e^- \rightarrow H_2Se_{(g)}$	–0.40
$Cr^{3+}_{(aq)} + e^- \rightarrow Cr^{2+}_{(aq)}$	–0.41
$Fe^{2+}_{(aq)} + 2e^- \rightarrow Fe_{(s)}$	–0.44
$Ag_2S_{(s)} + 2e^- \rightarrow 2Ag_{(s)} + S^{2-}_{(aq)}$	–0.69
$Te_{(s)} + 2H^+_{(aq)} + 2e^- \rightarrow H_2Te_{(g)}$	–0.72
$Cr^{3+}_{(aq)} + 3e^- \rightarrow Cr_{(s)}$	–0.74
$Zn^{2+}_{(aq)} + 2e^- \rightarrow Zn_{(s)}$	–0.76
$2H_2O_{(l)} + 2e^- \rightarrow 2OH^-_{(aq)} + H_{2(g)}$	–0.83
$Mn^{2+}_{(aq)} + 2e^- \rightarrow Mn_{(s)}$	–1.18
$Al^{3+}_{(aq)} + 3e^- \rightarrow Al_{(s)}$	–1.66
$Mg^{2+}_{(aq)} + 2e^- \rightarrow Mg_{(s)}$	–2.37
$Na^+_{(aq)} + e^- \rightarrow Na_{(s)}$	–2.71
$Ca^{2+}_{(aq)} + 2e^- \rightarrow Ca_{(s)}$	–2.87
$Sr^{2+}_{(aq)} + 2e^- \rightarrow Sr_{(s)}$	–2.89
$Ba^{2+}_{(aq)} + 2e^- \rightarrow Ba_{(s)}$	–2.90
$Cs^+_{(aq)} + e^- \rightarrow Cs_{(s)}$	–2.92
$K^+_{(aq)} + e^- \rightarrow K_{(s)}$	–2.92
$Rb^+_{(aq)} + e^- \rightarrow Rb_{(s)}$	–2.92
$Li^+_{(aq)} + e^- \rightarrow Li_{(s)}$	–3.00

Least Affinity for Electrons / Least Easily Reduced / Weakest Oxidizing Agent

↓ Most Easily Oxidized / Strongest Reducing Agent