Worksheet 9

Some things to note that are often misunderstood:

- Anions flow through the salt bridge into the anode compartment while cations flow into the cathode compartment to maintain electroneutrality.
- The anode of a voltaic cell is negative (like an anion), and the cathode is positive (like a cation). Electrons move from the negative anode through an external circuit to the positive cathode.
- When a chemical equation is balanced by the half-reaction method, the number of electrons that occur on both sides of the balanced equation (before canceling) is equal to the value of n.
- For a spontaneous reaction ΔG is negative but E is positive.
- Standard conditions for $E°$, the standard cell potential, are identical with standard conditions for the $\Delta G°$, $\Delta H°$, and $\Delta S°$.
- Every reduction half-cell reaction has a corresponding standard reduction potential, $E°_{red}$. If the reaction is reversed, it becomes an oxidation half-cell reaction with a corresponding standard oxidation half-cell potential, $E°_{ox}$. For any given half-cell reaction, $E°_{ox} = - E°_{red}$.
- Half-cell potentials are *never* multiplied by a coefficient when used in the equation $E°_{cell} = E°_{ox} + E°_{red}$.
- The general form of the Nernst equation is used to correct the standard cell potential for concentrations other than 1 M, partial pressures other than 1 atm, or a temperature other than 25°C. This form of the Nernst equation applies only to reactions occurring at 25°C.
- The Nernst equation relates the concentrations of any chemical species, including H^+, to cell potential.

1. Describe voltaic cells that use the following reactions. In each case, write the anode and cathode half-reactions, and sketch the experiment setup. Label the anode and cathode, identify the sign of each electrode, and indicate the direction of electron and ion flow.

(a) $Cd(s) + Sn^{2+}(aq) \longrightarrow Cd^{2+}(aq) + Sn(s)$

(b) $2\ Al(s) + 3\ Cd^{2+}(aq) \longrightarrow 2\ Al^{3+}(aq) + 3\ Cd(s)$

(c) $Cr_2O_7^{2-}(aq) + 6\ Fe^{2+}(aq) + 14\ H^+(aq) \longrightarrow 2\ Cr^{3+}(aq) + 6\ Fe^{3+}(aq) + 7\ H_2O(l)$

2. Write the shorthand notation for each cell in Problem 1.

3. Write balanced equations for the electrode and overall cell reactions in the following voltaic cells.

(a) $Co(s)\ |\ Co^{2+}(aq)\ ||\ Cu^{2+}(aq)\ |\ Cu(s)$

(b) $Fe(s)\ |\ Fe^{2+}(aq)\ ||\ O_2(g)\ |\ H^+(aq), H_2O(l)\ |\ Pt(s)$

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4. The silver oxide-zinc battery used in hearing aids delivers a voltage of 1.60 V. Calculate the free-energy change (in kilojoules) for the cell reaction:

$$Zn(s) + Ag_2O(s) \longrightarrow ZnO(s) + 2\ Ag(s)$$

5. Calculate E° for each of the following reactions, and tell which are spontaneous under standard-state conditions.

(a) $2\ Fe^{2+}(aq) + Pb^{2+}(aq) \longrightarrow 2\ Fe^{3+}(aq) + Pb(s)$

(b) $Mg(s) + Ni^{2+}(aq) \longrightarrow Mg^{2+}(aq) + Ni(s)$

6. The Nernst equation applies to both cell reactions and half-reactions. For the conditions specified, calculate the potential for the following half-reactions at 25°**.**

(a) $I_2(s) + 2\ e^- \longrightarrow 2\ I^-(aq)$; $[I^-] = 0.020$ M

(b) $Fe^{3+}(aq) + e^- \longrightarrow Fe^{2+}(aq)$; $[Fe^{3+}] = [Fe^{2+}] = 0.10$ M

(c) $Sn^{2+}(aq) \longrightarrow Sn^{4+}(aq) + 2\ e^-$; $[Sn^{2+}] = 1.0 \times 10^{-3}$ M, $[Sn^{4+}] = 0.40$ M

(d) $2\ Cr^{3+}(aq) + 7\ H_2O(l) \longrightarrow Cr_2O_7^{2-}(aq) + 14\ H^+(aq) + 6\ e^-$; $[Cr^{3+}] = [Cr_2O_7^{2-}] = 1.0$ M, $[H^+] = 0.010$ M

7. The following cell has a potential of 0.27 V at 25°C:

$$Pt(s)\ |\ H_2(1\ atm)\ |\ H^+(\ ?\ M)\ ||\ Ni^{2+}(1\ M)\ |\ Ni(s)$$

What is the pH of the solution in the anode compartment?

8. Calculate the equilibrium constant at 25°C for the disproportionation of Hg_2^{2+}:

$$Hg_2^{2+}(aq) \longrightarrow Hg(l) + Hg^{2+}(aq)$$