Electrochemistry

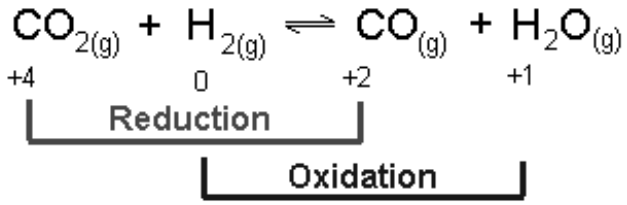
- Topics covered
  - Oxidation-reduction reactions
  - Balancing oxidation-reduction equations
- Homework
  - Read 20.1-20.4
  - Exercises 20.1-20.9 odd

Oxidation-Reduction Review

- **Oxidation** refers to the loss of electrons (LEO)
- **Reduction** refers to the gain of electrons (GER)
- Thus oxidation-reduction occurs when electrons are transferred from the atom that is oxidized to the atom that is reduced

Oxidation-Reduction Reactions

- Oxidation-reduction reactions are often called **redox** reactions
- By writing the oxidation number of each element above or below the equation we can see the oxidation state changes that occur



Oxidation-Reduction Reactions

- In any redox reaction both oxidation and reduction *must* occur
- The substance that is being reduced is called the **oxidizing agent** or **oxidant** and is gaining electrons in the reaction
- The substance being oxidized is called the **reducing agent** or **reductant** and is losing electrons to the oxidant

Sample Problem

- The nickel-cadmium (nicad) battery uses the following redox reaction to generate electricity:
  - $Cd(s) + NiO_2(s) + 2H_2O(l) \rightarrow Cd(OH)_2(s) + Ni(OH)_2(s)$
- Identify the substances that are oxidized and reduced, and indicate which are oxidizing agents and which are reducing agents.
  - Answer: Cd is oxidized (Cd the is reducing agent) and Ni is reduced (NiO_2 is the oxidizing agent)
- Identify the oxidant and reductant in the following equation:
  - $2H_2O + Al + MnO_4 \rightarrow Al(OH)_4^- + MnO_2(s)$
  - Answer: Al is the reductant and MnO_4 is the oxidant

Balancing Redox Reactions

- When balancing reactions we must obey the law of conservation of mass
- As we balance redox reactions we must also balance the loss and gain of electrons
- It is often easiest to do this by separating a reaction into oxidation and reduction **half-reactions**
  - $Sn^{2+} + 2Fe^{3+} \rightarrow Sn^{4+} + 2Fe^{2+}$
  - Oxidation: $Sn^{2+} \rightarrow Sn^{4+} + 2e^-$
  - Reduction: $2Fe^{3+} + 2e^- \rightarrow 2Fe^{2+}$

Balancing by Half-Reaction

- We can use half-reactions to balance complicated redox reactions in acidic solution by using the following procedure:
  - Divide the equation into two incomplete half reactions, one for oxidation and one for reduction
  - Balance each half reaction
    - First balance the elements other than H and O
    - Next, balance the O atoms by adding H_2O
    - Then balance the H atoms by adding H^+
    - Finally, balance the charge by adding e^-

Balancing by Half-Reaction

- Multiply each half-reaction by an integer so that the number of electrons lost in one reaction equals the number of electrons gained in the other
- Add the two half-reactions and simplify by cancelling species that occur on both sides
- Check the equation to make sure that there are the same number of atoms of each kind and the same total charge on each side

Sample Problems

- Balance the following reactions in acidic solution:
  - $MnO_4^- + C_2O_4^{2-} \rightarrow Mn^{2+} + CO_2$
    - Answer: $16H^+ + 2MnO_4^- + 5C_2O_4^{2-} \rightarrow 2Mn^{2+} + 8H_2O + 10CO_2$
  - $Cr_2O_7^{2-} + Cl^- \rightarrow Cr^{3+} + Cl_2$
    - Answer: $14H^+ + Cr_2O_7^{2-} + 6Cl^- \rightarrow 2Cr^{3+} + 7H_2O + 3Cl_2$
  - $Cu + NO_3^- \rightarrow Cu^{2+} + NO_2$
    - Answer: $4H^+ + Cu + 2NO_3^- \rightarrow Cu^{2+} + 2NO_2 + 2H_2O$

Balancing Redox Reactions in Basic Solution

- If a redox reaction occurs in basic solution, the equation must me balanced using OH^- and H_2O instead of H^+ and H_2O
- The half-reactions can be balanced initially as if they occurred in acidic solution
- The H^+ ions can then be “neutralized” by adding an equal number OH^- ions to each side and canceling the resulting water molecules

Sample Problems

- Complete and balance the following reactions in basic solution:
  - $CN^- + MnO_4^- \rightarrow CNO^- + MnO_2$
    - Answer: $H_2O + 3CN^- + 2MnO_4^- \rightarrow 3CNO^- + 2MnO_2 + 2OH^-$
  - $NO_2^- + Al \rightarrow NH_3 + Al(OH)_4^-$
    - Answer: $NO_2^- + 2Al + 5H_2O + OH^- \rightarrow NH_3 + 2Al(OH)_4^-$
  - $Cr(OH)_3 + ClO^- \rightarrow CrO_4^{2-} + Cl_2$
    - Answer: $2Cr(OH)_3 + 6ClO^- \rightarrow 2CrO_4^{2-} + 3Cl_2 + 2OH^- + 2H_2O$