Answers to Review #9: Redox Reactions and Electrochemistry

1. Define: oxidation, reduction, oxidizing agent, reducing agent, half reaction, anode, cathode, reduction potential and E°

2. Find the oxidation numbers of the elements in **bold** print.

a) K**Cl**O_2 Ox'n # Cl = +3

b) K**Mn**O_4 Ox'n # Mn = +7

c) **U**F_6 Ox'n # U = +6

d) H_2**O_2** Ox'n # O = –1 (peroxide)

e) **Pb**SO_4 Ox'n # Pb = +2

f) Li**Br**O_4 Ox'n # Br = +7

g) **Cl**O_3^{1-} Ox'n # Cl = +5

h) Mg**Si**F_6 Ox'n # Si = +4

i) H**C**OOH Ox'n # C = +2

j) H_2**S**O_3 Ox'n # S = +4

k) **Fe_2**O_3 Ox'n # Fe = +3

l) H_2**Se**O_3 Ox'n # Se = +4

3. State whether each of the following changes is an oxidation or a reduction:

a) $NO_3^- \rightarrow NO_2$ reduction

b) $I_2 \rightarrow IO_3^-$ oxidation

c) $NO_3^- \rightarrow NO$ reduction

d) $PCl_3 \rightarrow P_4$ reduction

e) $O_2 \rightarrow Na_2O_2$ reduction

f) $Fe \rightarrow FeN$ oxidation

g) $Xe \rightarrow XeF_6$ oxidation

h) $SO_4^{2-} \rightarrow SO_2$ reduction

i) $Cr_2O_7^{2-} \rightarrow CrO_3^{2-}$ reduction

j) $I^- \rightarrow I_2$ oxidation

k) $BrO_2^{1-} \rightarrow BrO_3^{1-}$ oxidation

l) $C_2H_2 \rightarrow C_2H_6$ reduction

4. Balance these oxidation-reduction equations in both acidic and basic conditions. In each equation, underline the oxidizing agent. (I have highlighted them. Remember, the oxidizing agent is the species that is reduced and gains electrons.)

a) $Cr_2O_7^{2-} + C_2H_5OH \rightarrow Cr^{3+} + CO_2$

Acidic conditions: $16\,H^+ + 2\,Cr_2O_7^{2-} + C_2H_5OH \rightarrow 4\,Cr^{3+} + 2\,CO_2 + 11\,H_2O$

Basic conditions: $5\,H_2O + 2\,Cr_2O_7^{2-} + C_2H_5OH \rightarrow 4\,Cr^{3+} + 2\,CO_2 + 16\,OH^-$

b) $HNO_3 + P \rightarrow NO + H_3PO_4$

Acidic conditions: $5\,HNO_3 + 3\,P + 2\,H_2O \rightarrow 5\,NO + 3\,H_3PO_4$

Basic conditions: $5\,HNO_3 + 3\,P + 2\,H_2O \rightarrow 5\,NO + 3\,H_3PO_4$

same for both, there are no H^+ or OH^- ions present

c) $As_2O_3 + NO_3^- \rightarrow H_3AsO_4 + NO$

Acidic conditions: $3\,As_2O_3 + 4\,NO_3^- + 7\,H_2O + 4\,H^+ \rightarrow 6\,H_3AsO_4 + 4\,NO$

Basic conditions: $3\,As_2O_3 + 4\,NO_3^- + 11\,H_2O \rightarrow 6\,H_3AsO_4 + 4\,NO + 4\,OH^-$

d) $H_2SeO_3 + Br^- \rightarrow Se + Br_2$

Acidic conditions: $H_2SeO_3 + 4\,Br^- + 4\,H^+ \rightarrow Se + 2\,Br_2 + 3\,H_2O$

Basic conditions: $H_2SeO_3 + 4\,Br^- + H_2O \rightarrow Se + 2\,Br_2 + 4\,OH^-$

e) $CrO_4^{2-} + I^- \rightarrow Cr^{3+} + I_2$

Acidic conditions: $2\,CrO_4^{2-} + 6\,I^- + 16\,H^+ \rightarrow 2\,Cr^{3+} + 3\,I_2 + 8\,H_2O$

Basic conditions: $2\,CrO_4^{2-} + 6\,I^- + 8\,H_2O \rightarrow 2\,Cr^{3+} + 3\,I_2 + 16\,OH^-$

f) $MnO_4^- + H_2O_2 \rightarrow Mn^{2+} + O_2$

Acidic conditions: $2\,MnO_4^- + 5\,H_2O_2 + 6\,H^+ \rightarrow 2\,Mn^{2+} + 5\,O_2 + 8\,H_2O$

Basic conditions: $2\,MnO_4^- + 5\,H_2O_2 \rightarrow 2\,Mn^{2+} + 5\,O_2 + 2\,H_2O + 6\,OH^-$

g) BrO_3^- + MnO_2 → Br^- + MnO_4^-

Acidic conditions: $BrO_3^- + 2\ MnO_2 + H_2O \rightarrow Br^- + 2\ MnO_4^{1-} + 2\ H^+$

Basic conditions: $BrO_3^- + 2\ MnO_2 + 2\ OH^- \rightarrow Br^- + 2\ MnO_4^{1-} + H_2O$

h) S^{2-} + ClO_3^{1-} → Cl^{1-} + S

Acidic conditions: $3\ S^{2-} + ClO_3^{1-} + 6\ H^+ \rightarrow Cl^{1-} + 3\ S + 3\ H_2O$

Basic conditions: $3\ S^{2-} + ClO_3^{1-} + 3\ H_2O \rightarrow Cl^{1-} + 3\ S + 6\ OH^-$

i) $Cr_2O_7^{2-}$ + I^- → Cr^{3+} + I_2

Acidic conditions: $Cr_2O_7^{2-} + 6\ I^- + 14\ H^+ \rightarrow 2\ Cr^{3+} + 3\ I_2 + 7\ H_2O$

Basic conditions: $Cr_2O_7^{2-} + 6\ I^- + 7\ H_2O \rightarrow 2\ Cr^{3+} + 3\ I_2 + 14\ OH^-$

j) CuS + NO_3^- → Cu^{2+} + NO_2 + S

Acidic conditions: $CuS + 2\ NO_3^- + 4\ H^+ \rightarrow Cu^{2+} + 2\ NO_2 + S + 2\ H_2O$

Basic conditions: $CuS + 2\ NO_3^- + 2\ H_2O \rightarrow Cu^{2+} + 2\ NO_2 + S + 4\ OH^-$

k) HS^- + IO_3^- → I^- + S

Acidic conditions: $3\ HS^- + IO_3^- + 3\ H^+ \rightarrow I^- + 3\ S + 3\ H_2O$

Basic conditions: $3\ HS^- + IO_3^- \rightarrow I^- + 3\ S + 3\ OH^-$

l) IO_4^- + I^- → I_2

Acidic conditions: $2\ IO_4^- + 14\ I^- + 16\ H^+ \rightarrow 8\ I_2 + 8\ H_2O$

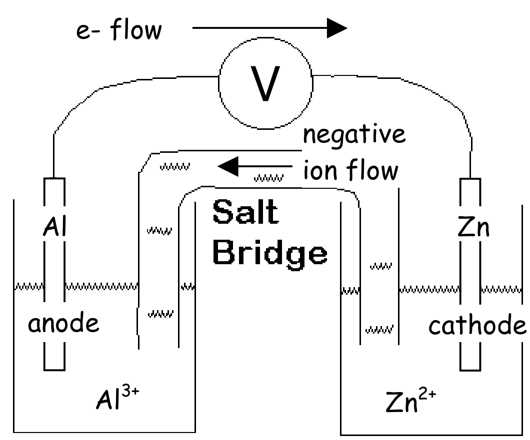
Basic conditions: $2\ IO_4^- + 14\ I^- + 8\ H_2O \rightarrow 8\ I_2 + 16\ OH^-$

m) Cr + NO_2^- → CrO_2^- + $N_2O_2^{2-}$

Acidic conditions: $4\ Cr + 6\ NO_2^- + 2\ H_2O \rightarrow 4\ CrO_2^- + 3\ N_2O_2^{2-} + 4\ H^+$

Basic conditions: $4\ Cr + 6\ NO_2^- + 4\ OH^- \rightarrow 4\ CrO_2^- + 3\ N_2O_2^{2-} + 2\ H_2O$

5. Consider a simple electrochemical cell using the metals zinc and aluminum:



a) Which metal is easier to oxidize, zinc or aluminum?

- from the chart of standard reduction potentials, Al is below zinc. Zinc has a stronger attraction for electrons so it will be reduced. Al has a weaker attraction for electrons so it loses electrons more easily and is oxidized

b) Label the Galvanic cell to the right, including the anode, which metal is the anode, the cathode, which metal is the cathode, the direction of electron flow and the direction of negative ion flow.

c) Write the half-reaction that occurs at each electrode.

oxidation half reaction: $Al \rightarrow Al^{3+} + 3e^-$ E° = + 1.662 V

reduction half reaction: $Zn + 2e^- \rightarrow Zn^{2+}$ E° = - 0.762 V

d) Calculate the theoretical voltage (E°) for this cell: E° = + 0.900 V

6. For the following combinations of elements in electrochemical cells
   i) write the net ionic equation for the reaction that will occur
   ii) represent the cell using Galvanic Cell Notation
   iii) calculate the theoretical voltage (E°) for each combination:

a) Cr/Cr^{3+} and Fe/Fe^{3+}

i) Fe/Fe^{3+} is above Cr/Cr^{3+} on the standard reduction potentials chart, so it will be reduced (gain e^-)

Fe^{3+} (aq) + Cr (s) → Cr^{3+} (aq) + Fe (s)

ii) Cr | Cr^{3+} || Fe^{3+} | Fe

iii) Fe^{3+} (aq) + 3e- → Fe (s)   E° = - 0.037 V

Cr (s) → Cr^{3+} (aq) + 3e-   E° = + 0.744 V

overall E° = + 0.707 V

b) Al/Al^{3+} and Sn/Sn^{2+}

i) Sn/Sn^{2+} is above Al/Al^{3+} on the standard reduction potentials chart, so it will be reduced (gain e^-)

3 Sn^{2+} (aq) + 2 Al (s) → 2 Al^{3+} (aq) + 3 Sn (s)

ii) Al | Al^{3+} || Sn^{2+} | Sn

iii) Sn^{2+} (aq) + 2e- → Sn (s)   E° = - 0.138 V

Al (s) → Al^{3+} (aq) + 3e-   E° = + 1.662 V

overall E° = + 1.524 V

c) Cd/Cd^{2+} and Mg/Mg^{2+}

i) Cd/Cd^{2+} is above Mg/Mg^{2+} on the standard reduction potentials chart, so it will be reduced (gain e^-)

Cd^{2+} (aq) + Mg (s) → Mg^{2+} (aq) + Cd (s)

ii) Mg | Mg^{2+} || Cd^{2+} | Cd

iii) Cd^{2+} (aq) + 2e- → Cd (s)   E° = - 0.403 V

Mg (s) → Mg^{2+} (aq) + 2e-   E° = + 2.372 V

overall E° = + 1.969 V

d) Cl_2/Cl^{1-} and Ag/Ag^{1+}

i) Cl_2/Cl^{1-} is above Ag/Ag^{1+} on the standard reduction potentials chart, so it will be reduced (gain e^-)

Cl_2 (g) + 2 Ag (s) → 2 Cl^{1-} (aq) + 2 Ag^{1+} (aq)

ii) Ag | Ag^{1+} || Cl_2 | Cl^{1-} | Pt (inert electrode)

iii) Cl_2 (g) + 2e- → 2 Cl^{1-} (aq)   E° = + 1.358 V

Ag (s) → Ag^{1+} (aq) + e-   E° = - 0.800 V

overall E° = + 0.558 V