Chemistry 12

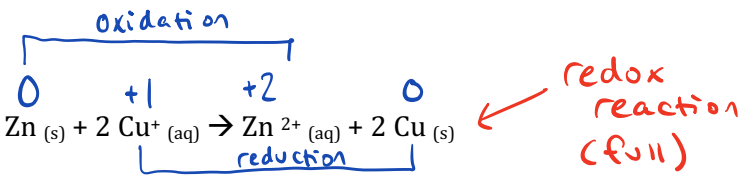
Electrochemistry II

Name: Notes
Date:
Block:

1. **Half-Reactions**
2. **Balancing Redox Reactions**

Half-Reactions

Consider the following reaction:

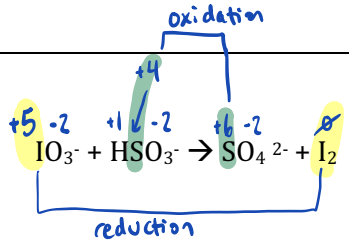


- Notice that 2 Cu^+ ions are reduced for every 1 Zn atom oxidized.
- It is possible to separate out the reduction and oxidation portions of a redox reaction.
- **Half-reactions: an equation representing either an oxidation or a reduction including the number of electrons lost or gained.**

Oxidation: $Zn \rightarrow Zn^{2+} + 2\ e^-$ ← half reaction

Reduction: $Cu^+ + e^- \rightarrow Cu$

Consider the following reaction:



Oxidation: $HSO_3^- \rightarrow SO_4^{2-} + 2e^-$

Reduction: $IO_3^- + 5e^- \rightarrow I_2$

Balancing Half-Reactions Steps:

M 1. Balance the major atoms

O 2. Balance the oxygen atoms by adding H_2O

H 3. Balance the hydrogen atoms by adding H^+

e⁻ 4. Balance the charge by adding e^-

5. Check by calculating ox #

- Most reactions occur in acidic conditions. However, if it is stated that the reaction takes place in basic conditions…

6. Add OH^- to both sides to neutralize H^+

Practice:

Balance the following half-reactions. Also state whether this is an oxidation or a reduction:

e⁻ as product ↩ ↪ e⁻ as reactant

1. $14e^- + 16H^+ + 2ClO_4^- \rightarrow Cl_2 + 8H_2O$

14+ 0

reduction

☑ Balance major atoms. ☑ Balance O's. ☑ Balance H's. ☑ Balance charge. (check!)

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2. $Sm \rightarrow Sm^{3+} + 3e^-$

Oxidation

N/A ☐ Balance major atoms. N/A ☐ Balance O's. N/A ☐ Balance H's. ☑ Balance charge. (check!)

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3. $8e^- + 10H^+ + NO_3^- \rightarrow NH_4^+ + 3H_2O$

9+ 1+

reduction

☑ Balance major atoms. ☑ Balance O's. ☑ Balance H's. ☑ Balance charge. (check!)

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4. $10OH^- + 5H_2O + S_2O_3^{2-} \rightarrow 2SO_4^{2-} + 10H^+ + 8e^-$

(basic)

-2 +6 +10 OH⁻ → 10 H₂O

5

☐ Balance major atoms. ☐ Balance O's. ☐ Balance H's. ☐ Balance charge. (check!)

$10OH^- + S_2O_3^{2-} \rightarrow 2SO_4^{2-} + 5H_2O + 8e^-$

Oxidation

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Balancing Redox Reactions:

Rules: /Steps

1. Separate the redox rxn into half rxns
2. Balance each half reaction (MOHHe⁻)
3. Multiply each half rxn to balance the transfer of e⁻
4. Add half rxns together, cancelling where appropriate
5. If basic, add OH⁻ to both sides

Practice:

$IO_3^- + HSO_3^- \rightarrow SO_4^{2-} + I_2$

- Separate into two half reactions. (Look for common atoms to help you.)

$IO_3^- \rightarrow I_2$ $\qquad$ $HSO_3^- \rightarrow SO_4^{2-}$

- Balance each half reaction. (There must be an electron gain in one side and loss on the other!)

$10e^- + 12H^+ + 2IO_3^- \rightarrow I_2 + 6H_2O$

$5 \times (H_2O + HSO_3^- \rightarrow SO_4^{2-} + 3H^+ + 2e^-)$

- Balance the electron loss and gain. (check oxidation numbers!)

$5H_2O + 5HSO_3^- \rightarrow 5SO_4^{2-} + 15H^+ + 10e^-$ (3)

- Add the balanced half-reactions together, cancelling where appropriate.

$2IO_3^- + 5HSO_3^- \longrightarrow I_2 + H_2O + 5SO_4^{2-} + 3H^+$

$H_3AsO_4 + Zn \rightarrow AsH_3 + Zn^{2+}$

$8e^- + 8H^+ + H_3AsO_4 \rightarrow AsH_3 + 4H_2O$

$4 \times (Zn \rightarrow Zn^{2+} + 2e^-)$

$4Zn \rightarrow 4Zn^{2+} + 8e^-$

$$8H^+ + H_3AsO_4 + 4Zn \rightarrow AsH_3 + 4H_2O + 4Zn^{2+}$$

$FeHPO_3 + Cr_2O_7^{2-} \rightarrow Cr^{3+} + H_3PO_4 + Fe^{3+}$

(under basic conditions)

5

$6e^- + 14H^+ + Cr_2O_7^{2-} \rightarrow 2Cr^{3+} + 7H_2O$

$2 \times (2H_2O + 2FeHPO_3 \rightarrow 2H_3PO_4 + 2Fe^{3+} + 3e^-)$

6

$14H^+ + Cr_2O_7^{2-} + 2FeHPO_3 \rightarrow 2Cr^{3+} + 5H_2O + 2H_3PO_4 + 2Fe^{3+}$

$+ 14OH^-$ $\quad + 14OH^-$

$14 H_2O$

9

$$9H_2O + Cr_2O_7^{2-} + 2FeHPO_3 \rightarrow 2Cr^{3+} + 2H_3PO_4 + 2Fe^{3+} + 14OH^-$$

A disproportionation reaction is a redox reaction in which the same species is both reduced and oxidized. Since there is only one reactant, the reactant must be involved in both the reduction reaction and the oxidation reaction.

$ClO_2^- \rightarrow ClO_3^- + Cl^-$

$2H_2O + 2ClO_2^- \rightarrow 2ClO_3^- + 4H^+ + 4e^-$

$4e^- + 4H^+ + ClO_2^- \rightarrow Cl^- + 2H_2O$

$$3\,ClO_2^- \rightarrow 2\,ClO_3^- + Cl^-$$

$P_4 \rightarrow HPO_4^{2-} + PH_3$

$\times 3\,(16H_2O + 3P_4 \rightarrow 12HPO_4^{2-} + 24H^+ + 20e^-)$

$\times 5\,(20e^- + 20H^+ + 5P_4 \rightarrow 20PH_3)$

$48H_2O + 8P_4 \rightarrow 12HPO_4^{2-} + 24H^+ + 20PH_3$

$\div 4$

$$12\,H_2O + 2\,P_4 \rightarrow 3\,HPO_4^{2-} + 6\,H^+ + 5\,PH_3$$

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Worksheet

EXERCISE:

19. Balance the following half–reactions.

a) $Ce^{4+} \rightleftharpoons Ce^{2+}$

b) $I_2 \rightleftharpoons I^-$

c) $Mn^{2+} \rightleftharpoons MnO_2$ (acidic solution)

d) $O_2 \rightleftharpoons H_2O_2$ (acidic solution)

e) $S_2O_8^{2-} \rightleftharpoons HSO_4^-$ (acidic solution)

f) $H_3AsO_4 \rightleftharpoons HAsO_2$ (acidic solution)

g) $H_2SeO_3 \rightleftharpoons Se$ (acidic solution)

h) $N_2H_4 \rightleftharpoons N_2$ (basic solution)

i) $HO_2^- \rightleftharpoons O_2$ (basic solution)

j) $HXeO_4^- \rightleftharpoons HXeO_6^{3-}$ (basic solution)

k) $HC_2H_3O_2 \rightleftharpoons C_2H_5OH$ (acidic solution)

l) $Cr(OH)_3 \rightleftharpoons CrO_4^{2-}$ (basic solution)

m) $CH_3CHO \rightleftharpoons CH_2CH_2$ (acidic solution)

EXERCISE:

24. Balance the following redox equations.

a) $U^{4+} + MnO_4^- \longrightarrow Mn^{2+} + UO_2^{2+}$ (acidic)

b) $Zn + As_2O_3 \longrightarrow AsH_3 + Zn^{2+}$ (acidic)

c) $Fe^{2+} + Cr_2O_7^{2-} \longrightarrow Cr^{3+} + Fe^{3+}$ (acidic)

d) $Cl_2 + SO_2 \longrightarrow Cl^- + SO_4^{2-}$ (acidic)

e) $Cu + NO_3^- \longrightarrow Cu^{2+} + NO$ (acidic)

f) $S^{2-} + ClO_3^- \longrightarrow Cl^- + S$ (basic)

g) $OCl^- \longrightarrow Cl^- + ClO_3^-$ (basic)

h) $CN^- + IO_3^- \longrightarrow I^- + CNO^-$ (basic)

i) $Sn^{2+} + H_2O_2 \longrightarrow Sn^{4+}$ (basic)

j) $Br_2 \longrightarrow Br^- + BrO_3^-$ (basic)

k) $HSO_3^- + IO_3^- \longrightarrow I_2 + SO_4^{2-}$ (acidic)

l) $HNO_2 \longrightarrow HNO_3 + NO$

m) $Mn^{2+} + HBiO_3 \longrightarrow Bi^{3+} + MnO_4^-$ (acidic)

n) $H_2O_2 + Cr(OH)_4^- \longrightarrow CrO_4^{2-}$ (basic)

o) $Sb_2S_3 + NO_3^- \longrightarrow NO_2 + SO_4^{2-} + Sb_2O_5$ (acidic)

p) $As_2S_3 + NO_3^- \longrightarrow NO + SO_4^{2-} + H_3AsO_4$ (acidic)

q) $FeS + NO_3^- \longrightarrow NO + SO_4^{2-} + Fe^{3+}$ (acidic)

r) $FeHPO_3 + Cr_2O_7^{2-} \longrightarrow Cr^{3+} + H_3PO_4 + Fe^{3+}$ (acidic)

s) $SnS_2O_3 + MnO_4^- \longrightarrow Mn^{2+} + SO_4^{2-} + Sn^{4+}$ (acidic)

t) $CuS + HNO_3 \longrightarrow Cu(NO_3)_2 + NO_2 + SO_2$

u) $Ca_3(PO_4)_2 + SiO_2 + C \longrightarrow P_4 + CaSiO_3 + CO$

v) $KMnO_4 + H_2S + H_2SO_4 \longrightarrow K_2SO_4 + MnSO_4 + S$

w) $CuF_2 + NH_3 \longrightarrow Cu_3N + NH_4F + N_2$
