UNIT 8

REDOX REACTIONS

ANSWERS

Rules for Assigning Oxidation Numbers

Exercise: Assign oxidation numbers to the atoms in the following species:

HCl H → +1 Cl → -1	LiH Li → +1 H → -1	$HClO_3$ H → +1 Cl → +5 O → -2	H_3PO_4 H → +1 P → +7 O → -2	H_2O H → +1 O → -2
H_2O_2 H → +1 O → -1	CaO Ca → +2 O → -2	CaF_2 Ca → +2 F → -1	NO_3- N → +5 O → -2	$S_2O_3^{-2}$ S → +2 O → -2
Cl- Cl → -1	ClO- Cl → +1 O → -2	ClO_2- Cl → +3 O → -2	ClO_3- Cl → +5 O → -2	ClO_4- Cl → +7 O → -2

Redox Half-Reactions

Assignment

(1) Al+3 + 3e- → Al reduction
O-2 → 2e- + O_2 oxidation
Al+3

(2) 2HBr → H_2 + Br_2
2H+ + 2e- → H_2 reduction
2Br- → 2e- + Br_2 oxidation
2H+ 2Br- → H_2 + Br_2

(3) $NaBr_2$ + H_2O → NaOH + 2HBr
Na+2 +e- → Na+ reduction
2Br- → e- + 2Br oxidation

Balancing Redox Equations

1. $3CuO + 2NH_3 \rightarrow 3Cu + N_2 + 3H_2O$
2. $10HNO_3 + I_2 \rightarrow 2HIO_3 + 10NO_2 + 4H_2O$
3. $3H_2S + 2HNO_3 \rightarrow 3S + 2NO + 4H_2O$
4. $2KMnO_4 + 10FeSO_4 + 8H_2SO_4 \rightarrow K_2SO_4 + 2MnSO_4 + 8H_2O + 5Fe_2(SO_4)_3$
5. $K_2Cr_2O_7 + 6HI + 8HCl \rightarrow 2KCl + 2CrCl_3 + 3I_2 + 7H_2O$
6. $8Al + 3NaNO_3 + 5NaOH + 18H_2O \rightarrow 3NH_3 + 8NaAl(OH)_4$
7. $3CuS + 8HNO_3 \rightarrow 3Cu(NO_3)_2 + 3S + 2NO + 4H_2O$
8. $2MnSO_4 + 5PbO_2 + 3H_2SO_4 \rightarrow 2HMnO_4 + 5PbSO_4\ 2H_2O$
9. $3P_4 + 20HNO_3 + 8H_2O \rightarrow 12H_3PO_4 + 20NO$
10. $2KMnO_4 + 5H_2O_2 + 6HCl \rightarrow 2MnCl_2 + 2KCl + 5O_2 + 8H_2O$

Extra Balancing Equations: Redox

1. $5Co + 2MnO_4^- + 16H^+ \rightarrow 5Co^{+2} + 2Mn^{+2} + 8H_2O$
2. $Cl_2 + 2OH^- \rightarrow ClO^- + Cl^- + H_2O$
3. $5I^- + IO_3^- + 6H^+ \rightarrow 3I_2 + 3H_2O$
4. $CrO_7^{-2} + 3SO_3^{-2} + 8H^+ \rightarrow 2Cr^{+3} + 3SO_4^{-2} + 4H_2O$
5. $I_2 + 5Cl_2 + 6H_2O \rightarrow 2IO_3^- + 10Cl^- + 12H^+$
6. $14H^+ + 3S^{-2} + Cr_2O7^{-2} \rightarrow 3S + 2Cr^{+3} + 7H_2O$
7. $S^{-2} + 6NO_3^- + 8H^+ \rightarrow SO_2 + 6NO_2 + 4H_2O$
8. $2H_2O_2 \rightarrow O_2 + 2H_2O$
9. $3Fe_3O_4 + 8Al \rightarrow 9Fe + 4Al_2O_3$
10. $Cu + 2NO_3^- + 4H^+ \rightarrow Cu^{+2} + 2NO_2^- + 2H_2O$
11. $5Fe^{+2} + MnO_4^- + 8H^+ \rightarrow 5Fe^{+3} + Mn^{+2} + 4H_2O$
12. $H_2S + 2NO_3^- + 2H^+ \rightarrow S + 2NO_2 + 2H_2O$

13. $Cl_2 + SO_2 + 2H_2O \rightarrow SO_4^{-2} + 2Cl^- + 4H^+$

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

15. $2H^+ + H_2O_2 + 2Cl^- \rightarrow Cl_2 + 2H_2O$

16. $4H^+ + MnO_2 + 2Fe^{+2} \rightarrow Mn^{+2} + 2Fe^{+3} + 2H_2O$

17. $2NO_3^- + 3Sn^{+2} + 8H^+ \rightarrow 2NO + 3Sn^{+4} + 4H_2O$

Others:

1. $5U^{+4} + 2MnO_4^- + 2H_2O \rightarrow 2Mn^{+2} + 5UO_2^{+2} + 4H^+$
2. $SeO_3^{-2} + 4I^- + 6H^+ \rightarrow Se + 2I_2 + 3H_2O$
3. $4Zn + NO_3^- + 5H_2O \rightarrow 4ZnO_2^{-2} + NH_3 + 7H^+$
4. $Pt + 6NO_3^- + 6Cl^- + 12H^+ \rightarrow PtCl_6 + 6NO_2 + 6H_2O$

Predict whether the following are likely to react.
Write equations only where you predict a reaction will be likely
Part A

1. metal + acid → hydrogen

$Zn + 2H^+ \leftrightarrow Zn^{+2} + H_{2(g)}$

2. Cu, Na^+, I^-

$Cu \rightarrow Cu^+ + e^-$ $E° = -0.52$
$Cu \rightarrow Cu^{+2} + 2e^-$ $E° = -0.34$
$2I \rightarrow I_2 + 2e^-$ $E° = -0.54$
$Na^+ + e^- \rightarrow Na$ $E° = -2.71$

All –ve therefore no reaction

3. Ni, Cl

$Ni \rightarrow Ni^{+3} + 3e^-$ rare! (not listed)
ox $Ni \rightarrow Ni^{+2} + 2e^-$ $E° = +0.24$
red $Cl_2 + 2e^- \rightarrow 2Cl^-$ $E° = +1.36$

+ve E°

$Ni + Cl_2 \rightarrow Ni^{+2} + 2Cl^-$ $E° = 1.60$

4. $Mg^{+2}, NO_3^-, Na^+, OH^-$

K_{sp} of $Mg(NO_3)_2$ is $5.6*10^{-12}$ so this ppt will form

$Mg(NO_3)_2 + NaOH \leftrightarrow Mg(OH)_{2(s)} + Na^+ + 2NO_3^-$

5. $Ba^{+2}, NO_3^-, K^+, SO_4^{-2}$

K_{sp} of $BaSO_4$ is $1.1*10^{-10}$ so this ppt will form

$Ba(NO_3)_2 + K_2SO_4 \rightarrow BaSO_{4(s)} + 2K^+ + 2NO_3^-$

6. Cl_2, NO_3^-, Ag^+

red $Cl_2 + 2e^- \rightarrow 2Cl^-$ $E° = +1.36$
Acid red $NO_3^- + 3e^- \rightarrow NO$ $E° = +0.96$
Acid red $NO_3^- + 2e^- \rightarrow HNO_2$ $E° = +0.94$
red $Ag^+ + e^- \rightarrow Ag$ $E° =$

All Red reactions therefore no reaction occurs

Part B

1. Fe^{+2}, Cl^-, Cu^{+1}

1) ox $Fe^{+2} \rightarrow Fe^{+3} + e^-$ $E° = -0.77$
2) red $Fe^{+2} + 2e^- \rightarrow Fe_{(s)}$ $E° = -0.44$
3) ox $2Cl^- \rightarrow Cl_2 + 2e^-$ $E° = -1.36$
4) red $Cu^{+1} + e^- \rightarrow Cu$ $E° = +0.52$
5) ox $Cu^{+1} \rightarrow Cu^{+2} + e^-$ $E° = -0.15$

1,2 (2 irons → NR)
2,3 → E° is neg. → NR
2,5 → E° is neg. → NR
Therefore no reaction occurs

4,1 → E° is neg. →NR
4,3 → E° is neg. →NR
4,5 → 2 coppers → NR

2. K^+, $Cr_2O_7^{-2}$, Na^+, SO_3^{-2}

1) red $K^+ + e^- \rightarrow K$ $E° = -2.92$
2) red $Cr_2O_7^{-2} + 14H^+ + 6e^- \rightarrow 7H_2O + 2Cr^{+3}$ $E° = +1.33$
3) red $Na^+ + e^- \rightarrow Na$ $E° = -2.71$
4) ox $H_2SO_3^{-2} \rightarrow SO_4^{-2} + 2e^- + 4H^+$ $E° = -0.17$ acid

1,4 → E° is neg. → NR
2,4 → E° is pos. → r*n
3,4→ E° is neg. → NR

$8H^+ Cr_2O_7^{-2} + 3SO_3^{-2} \rightarrow 3SO_4^{-2} + 2Cr^{+3} + 4H_2O$

3. Zn^{+2}, SO_4^{-2}, NH_4^+, CO_3^{-2}

$ZnCO_3$ has $K_{sp} = 1.2*10^{-10}$ so a ppt will form

4. Again AgCl ($k_{sp}=1.86*10^{-10}$) will form

5. K^+, MnO_4^-, H^+, Cl^-

1) red $K^+ + e^- \rightarrow K$ $E°=-2.92$
2) red $2H^+ + 2e^- \rightarrow H_2$ $E°= 0$
3) ox $2Cl^- \rightarrow Cl_2 + 2e^-$ $E°=-1.36$
4) red $MnO_4^- + 5e^- \rightarrow Mn^{+2}$ $E°=+1.52$

3,1→E° is neg. → NR
3,2→ E° is neg. → NR
3,4→ E° is pos. → r*n

$MnO_4^- + Cl^- \rightarrow Mn^{+2} + Cl_2$

Balance
$5e^- + 8H^+ + MnO_4^- \rightarrow Mn^{+2} + 4H_2O$
$2Cl^- \rightarrow Cl_2 + 2e^-$
$16H^+ + 2MnO_4^- + 10Cl^- \rightarrow 5Cl_2 + 2Mn^{+2} + 8H_2O$

6. Cu, Fe^{+3}, Cl^-

1) ox $Cu \rightarrow Cu^+ + e^-$ $E°= -0.52$
2) ox $Cu \rightarrow Cu^{+2} + 2e^-$ $E°= -0.34$
3) red $Fe^{+3} + e^- \rightarrow Fe^{+2}$ $E°= +0.77$
4) red $Fe^{+3} + 3e^- \rightarrow Fe$ $E°=$ successive steps $E°=+0.33$
5) ox $2Cl^- \rightarrow Cl_2 + 2e^-$ $E°= -1.36$

3,1 → is pos. → r*n $E°=0.25$
3,2 → is pos. → r*n $E°=0.43$
3,5 → is neg. → NR

The $E°$ is like a K_{eq} and determines how far a reaction proceeds thus $E°=0.43$ is the dominant reaction.

$2Fe^{+3} + Cu \rightarrow Cu^{+2} + 2Fe^{+2}$

7. $K+, Br^-, Fe^{+3}, Cl^-$

1) red $K^+ + e^- \rightarrow K$ $E°=-2.92$
2) ox $2Br^- \rightarrow Br_2 + 2e^-$ $E°= -1.06$
3) ox $2Cl^- \rightarrow Cl_2 + 2e^-$ $E°= -1.36$
4) red $Fe^{+3} + e^- \rightarrow Fe^{+2}$ $E°= +0.77$
5) red $Fe^{+3} + 3e^- \rightarrow Fe$ $E°=+0.33$

2,1 → is neg. → NR
2,4 → is neg. → NR
2,5 → is neg. → NR
3,1 → is neg. → NR
3,4 → is neg. → NR
3,5 → is neg. → NR

No reaction

8. $Fe^{+2}, SO_4^{-2}, K^+, MnO_4^-$

1) red $K^+ + e^- \rightarrow K$ $E°=-2.92$
2) red $MnO_4^- + 5e^- \rightarrow Mn^{+2}$ $E°=+1.52$
3) ox $SO_4^{-2} \rightarrow S_2O_8^{-2} + 2e^-$ $E°=-2.05$
4) red $SO_4^{-2} + 2e^- \rightarrow H_2SO_3$ $E°=+0.17$
5) red $Fe^{+2} + 2e^- \rightarrow Fe_{(s)}$ $E° =-0.44$
6) ox $Fe^{+2} \rightarrow Fe^{+3} + e^-$ $E°= -0.77$

3,1 → is neg → NR
3,2 → is neg → NR
3,4 → is neg → NR
3,5 → is neg → NR
6,1 → is neg → NR
6,2 → is pos→ r*n $E°=+0.75$
6,3 → is neg → NR
6,5 → is neg → NR

$Fe^{+2} + MnO_4^- \rightarrow Mn^{+2} + Fe^{+3}$
$5e^- + 8H^+ + MnO_4^- \rightarrow Mn^{+2} + 4H_2O$
$Fe^{+2} \rightarrow Fe^{+3} + e^-$
$8H^+ + MnO_4^- + 5Fe^{+2} \rightarrow Mn^{+2} + 5Fe^{+3} + 4H_2O$