Oxidation Number

Elemental Form	zero (0). Only one kind of atom present, no charge.
Atomic Ions	= the charge on the atom (monoatomic ion)
Group 1A Li, Na, K, Rb, Cs	+1 unless elemental form
Group 2A Be, Mg, Ca, Sr, Ba	+2 unless elemental form
Hydrogen (H)	+1 when bonded to a non-metal, -1 when bonded to a metal (rare)
Oxygen (O)	-1 in peroxides O_2^{-} -2 in all other compounds (most common)
Fluorine (F)	-1, always
Neutral Compounds	The sum of all oxidation numbers of atoms or ions in a neutral compound is zero
Ionic Compounds	The sum of all oxidation numbers of atoms in an ionic compound is the charge on the polyatomic ion.

Oxidation-Reduction Reactions

$$Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$$

$$Zn(s) \rightarrow Zn^{2+}(aq) + \cancel{2e^-}$$

$$Cu^{2+}(aq) + \cancel{2e^-} \rightarrow Cu(s)$$

$$Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$$

$$Zn(s) + Cu^{2+}(aq) \longrightarrow Zn^{2+}(aq) + Cu(s)$$

oxidation: loss of e^-; ox.-number ↑

reduction: gain of e^-; ox.-number ↓

reducing agent: species that is oxidized

oxidizing agent: species that is reduced

Activity Series

Metal	Oxidation Reaction
Lithium	$Li(s) \longrightarrow Li^{+}(aq) + e^{-}$
Potassium	$K(s) \longrightarrow K^{+}(aq) + e^{-}$
Barium	$Ba(s) \longrightarrow Ba^{2+}(aq) + 2e^{-}$
Calcium	$Ca(s) \longrightarrow Ca^{2+}(aq) + 2e^{-}$
Sodium	$Na(s) \longrightarrow Na^{+}(aq) + e^{-}$
Magnesium	$Mg(s) \longrightarrow Mg^{2+}(aq) + 2e^{-}$
Aluminum	$Al(s) \longrightarrow Al^{3+}(aq) + 3e^{-}$
Manganese	$Mn(s) \longrightarrow Mn^{2+}(aq) + 2e^{-}$
Zinc	$Zn(s) \longrightarrow Zn^{2+}(aq) + 2e^{-}$
Chromium	$Cr(s) \longrightarrow Cr^{3+}(aq) + 3e^{-}$
Iron	$Fe(s) \longrightarrow Fe^{2+}(aq) + 2e^{-}$
Cobalt	$Co(s) \longrightarrow Co^{2+}(aq) + 2e^{-}$
Nickel	$Ni(s) \longrightarrow Ni^{2+}(aq) + 2e^{-}$
Tin	$Sn(s) \longrightarrow Sn^{2+}(aq) + 2e^{-}$
Lead	$Pb(s) \longrightarrow Pb^{2+}(aq) + 2e^{-}$
Hydrogen	$H_2(g) \longrightarrow 2H^{+}(aq) + 2e^{-}$
Copper	$Cu(s) \longrightarrow Cu^{2+}(aq) + 2e^{-}$
Silver	$Ag(s) \longrightarrow Ag^{+}(aq) + e^{-}$
Mercury	$Hg(l) \longrightarrow Hg^{2+}(aq) + 2e^{-}$
Platinum	$Pt(s) \longrightarrow Pt^{2+}(aq) + 2e^{-}$
Gold	$Au(s) \longrightarrow Au^{3+}(aq) + 3e^{-}$

Ease of oxidation increases

$$Cr(s) \rightarrow Cr^{3+}(aq) + 3e^{-} \quad \times 2$$

$$Ni(s) \rightarrow Ni^{2+}(aq) + 2e^{-} \quad \times 3$$

$$2Cr(s) + 3Ni^{2+}(aq) \rightarrow 2Cr^{3+}(aq) + 3Ni(s)$$

Activity Series

Metal	Oxidation Reaction
Lithium	$Li(s) \longrightarrow Li^{+}(aq) + e^{-}$
Potassium	$K(s) \longrightarrow K^{+}(aq) + e^{-}$
Barium	$Ba(s) \longrightarrow Ba^{2+}(aq) + 2e^{-}$
Calcium	$Ca(s) \longrightarrow Ca^{2+}(aq) + 2e^{-}$
Sodium	$Na(s) \longrightarrow Na^{+}(aq) + e^{-}$
Magnesium	$Mg(s) \longrightarrow Mg^{2+}(aq) + 2e^{-}$
Aluminum	$Al(s) \longrightarrow Al^{3+}(aq) + 3e^{-}$
Manganese	$Mn(s) \longrightarrow Mn^{2+}(aq) + 2e^{-}$
Zinc	$Zn(s) \longrightarrow Zn^{2+}(aq) + 2e^{-}$
Chromium	$Cr(s) \longrightarrow Cr^{3+}(aq) + 3e^{-}$
Iron	$Fe(s) \longrightarrow Fe^{2+}(aq) + 2e^{-}$
Cobalt	$Co(s) \longrightarrow Co^{2+}(aq) + 2e^{-}$
Nickel	$Ni(s) \longrightarrow Ni^{2+}(aq) + 2e^{-}$
Tin	$Sn(s) \longrightarrow Sn^{2+}(aq) + 2e^{-}$
Lead	$Pb(s) \longrightarrow Pb^{2+}(aq) + 2e^{-}$
Hydrogen	$H_2(g) \longrightarrow 2H^{+}(aq) + 2e^{-}$
Copper	$Cu(s) \longrightarrow Cu^{2+}(aq) + 2e^{-}$
Silver	$Ag(s) \longrightarrow Ag^{+}(aq) + e^{-}$
Mercury	$Hg(l) \longrightarrow Hg^{2+}(aq) + 2e^{-}$
Platinum	$Pt(s) \longrightarrow Pt^{2+}(aq) + 2e^{-}$
Gold	$Au(s) \longrightarrow Au^{3+}(aq) + 3e^{-}$

Ease of oxidation increases

tin + hydrochloric acid

$Sn(s) + 2H^{+}(aq) \rightarrow Sn^{2+}(aq) + H_2(g)$

$Sn(s) \rightarrow Sn^{2+}(aq) + 2e^{-}$ ×1

$2H^{+}(aq) + 2e^{-} \rightarrow H_2(g)$ ×1

$$Zn(s) + Pb(NO_3)_2 \xrightarrow{?}$$

$$Zn(s) + Pb^{2+}(aq) \xrightarrow{?} Zn^{2+}(aq) + Pb(s)$$

$$Zn(s) \longrightarrow Zn^{2+}(aq) + 2e^- \qquad \times 1$$

$$Pb^{2+}(aq) + 2e^- \longrightarrow Pb(s) \qquad \times 1$$

$$NiCl_2(aq) + Zn(NO_3)_2 \xrightarrow{?}$$

$$Ni^{2+}(aq) + Zn^{2+}(aq) \xrightarrow{?}$$

$$Ni(s) + Zn^{2+}(aq) \cancel{\xrightarrow{?}} Ni^{2+}(aq) + Zn(s)$$

NR

Balancing Redox Equations in acidic solutions

Unbalanced:

$$MnO_4^-(aq) + C_2O_4^{2-}(aq) \rightarrow Mn^{2+}(aq) + CO_2(g)$$

1. Divide into half reactions

$MnO_4^-(aq) \rightarrow Mn^{2+}(aq)$ $\quad\quad$ $C_2O_4^{2-}(aq) \rightarrow CO_2(g)$

2. Balance half reactions

a). Balance elements other than "O" and "H"

$MnO_4^-(aq) \rightarrow Mn^{2+}(aq)$ $\quad\quad$ $C_2O_4^{2-}(aq) \rightarrow 2CO_2(g)$

b). Balance "O" atoms by adding H_2O as needed

$MnO_4^-(aq) \rightarrow Mn^{2+}(aq) + 4H_2O(l)$ $\quad C_2O_4^{2-}(aq) \rightarrow 2CO_2(g)$

c). Balance "H" atoms by adding H^+ as needed

$$\underbrace{MnO_4^-(aq) + 8H^+(aq)}_{7+} \rightarrow \underbrace{Mn^{2+}(aq) + 4H_2O(l)}_{2+}$$

$$\underbrace{C_2O_4^{2-}(aq)}_{2-} \rightarrow \underbrace{2CO_2(g)}_{0}$$

d). Balance charges by adding "e^-"

$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(l) \; | \times 2$

$C_2O_4^{2-}(aq) \rightarrow 2CO_2(g) + 2e^- \; | \times 5$

3. Equalize e^- for the two half reactions

$2MnO_4^-(aq) + 16H^+(aq) + \cancel{10e^-} \rightarrow 2Mn^{2+}(aq) + 8H_2O(l)$

$5C_2O_4^{2-}(aq) \rightarrow 10CO_2(g) + \cancel{10e^-}$

$2MnO_4^-(aq) + 16H^+(aq) + 5C_2O_4^{2-}(aq) \rightarrow 2Mn^{2+}(aq) + 8H_2O + 10CO_2(g)$

Balancing Redox Reactions in Basic Solution

$$CN^-(aq) + MnO_4^-(aq) \rightarrow CNO^-(aq) + MnO_2(s)$$

Initially the same as for acidic solution

1. Half-Reactions

$CN^-(aq) \rightarrow CNO^-(aq)$ $\quad$ $MnO_4^-(aq) \rightarrow MnO_2(s)$

2. Balance Half Reactions

a). Balance elements other than "O" and "H"

$CN^-(aq) \rightarrow CNO^-(aq)$ $\quad$ $MnO_4^-(aq) \rightarrow MnO_2(s)$

b) balance "O" by adding H_2O

$CN^-(aq) + H_2O(l) \rightarrow CNO^-(aq)$ $\quad$ $MnO_4^-(aq) \rightarrow MnO_2(s) + 2H_2O(l)$

c). Balance "H" by adding H^+

$$CN^-(aq) + H_2O(l) \rightarrow CNO^-(aq) + 2H^+(aq)$$

$$4H^+(aq) + MnO_4^-(aq) \rightarrow MnO_2(s) + 2H_2O(l)$$

d). Balance charges:

$$CN^-(aq) + H_2O(l) \rightarrow CNO^-(aq) + 2H^+(aq) + 2e^-$$

$$4H^+(aq) + MnO_4^-(aq) + 3e^- \rightarrow MnO_2(s) + 2H_2O(l)$$

3. Neutralize H^+ by adding OH^- to both sides

$$\times 3 \mid CN^-(aq) + H_2O(l) + 2OH^-(aq) \rightarrow CNO^-(aq) + \underbrace{2H^+ + 2OH^-}_{2H_2O} + 2e^-$$

$$\times 2 \mid \underbrace{4H^+ + 4OH^-}_{4H_2O}(aq) + MnO_4^-(aq) + 3e^- \rightarrow MnO_2(s) + 2H_2O(l) + 4OH^-$$

$$3CN^- + \cancel{3H_2O} + 6OH^- \rightarrow 3CNO^- + \overset{3}{6}H_2O + 6e^-$$

$$\overset{4}{8}H_2O(l) + 2MnO_4^- + 6e^- \rightarrow 2MnO_2(s) + \cancel{4H_2O}(l) + 8OH^-(aq)$$

$$\cancel{6e^-} + \cancel{6OH^-} + 3CN^- + \cancel{4}\,{}^{1}H_2O + 2MnO_4^- \rightarrow 3CNO^- + \cancel{3H_2O} + \cancel{6e^-} + 2MnO_2 + \cancel{8}\,{}_{2}OH^-$$

$$3CN^-(aq) + H_2O(l) + 2MnO_4^-(aq) \rightarrow 3CNO^-(aq) + 2MnO_2(s) + 2OH^-$$