Conquering Net Ionic Equations

Name_____Per____

AP equations are sprinkled throughout the FR and perhaps some in the MC.

You do *not* need to write down physical state symbols; (aq, s, ppt, L, g ... etc) it's probably best if you leave them off.

The best way to prepare for writing equations is to practice *lots* of equations. Many of the same equation types show up year after year. When you are reading an equation, first try to identify it as a particular type which may help you predict the products.

All AP equations will "work" so you do not need to decide if it is a valid reaction. In each case, a reaction will occur. These equations need to be written in **net ionic** form. All spectator ions must be left out and all ions must be written in ionic form. All molecular substances and non-soluble compounds must be written together (not ionized!). Know your solubility rules!!!

Special considerations concerning solubility rules:

- $Ca(OH)_2$, $Sr(OH)_2$, are moderately soluble and can be written together or as ions. Watch for clues in the question.
  - ✓ $Ba(OH)_2$ is generally considered soluble and $Mg(OH)_2$ and $Be(OH)_2$ are considered insoluble.
- Weak acids, such as acetic acid or hydrofluoric acid, are *not* ionized and must be written as molecules.
- Solids, pure liquids, and gases are written as molecules
- A *saturated* solution is written in ionic form while a *suspension* is written together as a molecule.

Solubility Rules

1. Strong electrolytes (100% ionized) and written as ions, which leads to spectator ions that must be left out of the equation:
2. Know your 7 strong Acids: HCl, HBr, HI, H_2SO_4, HNO_3, $HClO_4$, $HClO_3$
3. Strong Bases: Hydroxides of group IA and IIA (Ba, Sr, Ca are marginally soluble, Be and Mg are insoluble)
4. Soluble Salts: according to the Quickie Table Below (ionic compounds: metal/nonmetal)

ALWAYS SOUBLE IF IN A COMPOUND	EXCEPT WITH
NO_3^-, Alkali ions, NH_4^+, $C_2H_3O_2^-$, ClO_4^-, ClO_3^-	No Exceptions
Cl^- , Br^- , I^-	Pb^{2+}, Ag^+, Hg_2^{2+}
SO_4^{2-}	Pb^{2+}, Ag^+, Hg_2^{2+} Ca^{2+}, Sr^{2+}, Ba^{2+}

5. If it does not fit one of the three rules above, assume it is INSOLUBLE or a WEAK ELECTROLYTE (and written together). (This won't always be correct, but will cover most of the situations.)
6. Also, GASES, PURE LIQUIDS, and SOLIDS are non-electrolytes and written as molecules.
7. Remember the *phantoms* − molecules that decompose into gases when they are a product.
   - as a product, H_2CO_3 decomposes into H_2O and $CO_{2(g)}$
   - as a product, NH_4OH decomposes into H_2O and $NH_{3(g)}$
   - as a product, H_2SO_3 decomposes into H_2O and $SO_{2(g)}$
   - in solution, H^+ with S^{2-} produces a gas, $H_2S_{(g)}$

Polyatomic Ions - If you memorize the shaded ions (and learn their companions), you will be in great shape.

per− (1 more O)	−ate	−ite (1 less O)	hypo− (2 less O)
	nitrate NO_3^-	nitrite NO_2^{1-}	
	sulfate SO_4^{2-}	sulfite SO_3^{2-}	
	phosphate PO_4^{3-}	phosphite PO_3^{3-}	
perchlorate ClO_4^-	chlorate ClO_3^-	chlorite ClO_2^-	hypochlorite ClO^-
perbromate BrO_4^-	bromate BrO_3^-	bromite BrO_2^-	hypobromite BrO^-
periodate IO_4^-	iodate IO_3^-	iodite IO_2^-	hypoiodite IO^-

once you memorize bromate, you'll know the iodate and iodate series

Exceptions
hydroxide OH^-
cyanide CN^-
peroxide O_2^{2-}
ammonium NH_4^+

oxyen, O with an oxidation state = −1

Odd Companions or No Companion	
acetate $C_2H_3O_2^-$	
carbonate CO_3^{2-}	bicarbonate HCO_3^-
chromate CrO_4^{2-} *yellow*	dichromate $Cr_2O_7^{2-}$ *orange*
permanganate MnO_4^- *purple*	manganate MnO_4^{2-}
ferricyanide $Fe(CN)_6^{3-}$	ferrocyanide $Fe(CN)_6^{4-}$

not necessary to memorize, just shown for comparison

not necessary to memorize, as they do not show up on the AP exam but they are ions that we have used in class several times

adapted by Sue Biggs 2014 from Kristen Henry Jones 1/28/99

Single Replacement

- A reaction in which one element displaces another in a compound. One element is oxidized and another is reduced.
- Generic: A + BC → B + AC
  - **Active metals replace less active metals or hydrogen (in acid or water).**

    The more easily oxidized metal replaces the less easily oxidized metal. The metal with the most negative reduction potential will be the most active, because that metal does not "want" to be reduced, it prefers to be oxidized. The question is likely to provide you with half-reactions.

    - *Magnesium turnings are added to a solution of nickel(III) chloride.*

      $3Mg + 2Ni^{3+} \rightarrow 2Ni + 3Mg^{2+}$ (This reaction must be balanced for charge since electrons lost/gained must be equal.)

      (Note that the chloride ions have been removed as they are spectators − unchanged by the reaction)

    - *Nickel is added to hydrochloric acid.*

      $Ni + 2H^{+} \rightarrow Ni^{2+} + H_2$

    - *Sodium is added to water.*

      $2Na + 2H_2O \rightarrow 2Na^{+} + 2OH^{-} + H_2$ (Remember that some metals can replace hydrogen in water. You may find it useful to think of water as HOH)

  - **Active nonmetals replace less active nonmetals from their compounds in aqueous solution.**

    Each halogen will displace less electronegative (heavier) halogens from their binary salts.

    - *Chlorine gas is bubbled into a solution of potassium iodide.*

      $Cl_2 + 2I^{-} \rightarrow I_2 + 2Cl^{-}$

  - **Tricky redox reactions that appear to be ordinary single replacement reactions**: (AP is not likely to test these.)

    Hydrogen reacts with a hot metallic oxide to produce the elemental metal and water.

    - *Hydrogen gas is passed over hot zinc oxide.*

      $H_2 + ZnO \rightarrow Zn + H_2O$

    Metal sulfides react with oxygen to produce the metallic oxide and sulfur dioxide.

    - *Oxygen gas is passed over hot calcium sulfide.*

      $3O_2 + 2CaS \rightarrow 2CaO + 2SO_2$

Double Replacement (metathesis)

Two compounds react to form two new compounds. No changes in oxidation numbers occur. All double replacement reactions must have a "driving force" that removes a pair of ions from solution. These ions may be removed by forming a precipitate, a gas, or molecular compound. If water forms, the double replacement reaction is an acid/base reaction. We can assume that all solutions are aqueous solutions, unless told otherwise.

- **Formation of a precipitate:**
  A precipitate is an insoluble substance formed by the reaction of two aqueous substances. Two ions bond together so strongly that water can not pull them apart. You must know your solubility rules to write these net ionic equations!
  - *Solutions of silver nitrate and sodium sulfide are mixed.*

  $2Ag^+ + S^{2-} \rightarrow Ag_2S$

- **Formation of a gas:**

  Gases may form directly in a double replacement reaction such as H_2S or can form from the decomposition of a product such as H_2CO_3, H_2SO_3, or NH_4OH.
  - *Excess hydrochloric acid solution is added to a solution of sodium sulfite.*

    $2H^+ + SO_3^{2-} \rightarrow (H_2SO_3 \rightarrow) H_2O + SO_2$
  - *A solution of sodium hydroxide is added to a solution of ammonium nitrate.*

    $OH^- + NH_4^+ \rightarrow (NH_4OH \rightarrow) NH_3 + H_2O$
  - *Dilute sulfuric acid is added to a solution of sodium bicarbonate.*

    $H^+ + HCO_3^- \rightarrow (H_2CO_3 \rightarrow) H_2O + CO_2$
  - *Concentrated hydroiodic acid is added to solid copper(II) sulfide.*

    $2H^+ + CuS \rightarrow H_2S + Cu^{2+}$

- **Formation of a molecular substance (often an acid base neutralization):**

  When a molecular substance such as water or a weak acid is formed, ions are removed from solution and the reaction "works".
  - *Dilute solutions of lithium hydroxide and hydrobromic acid are mixed.*

    $OH^- + H^+ \rightarrow H_2O$ (Remember your strong acids - HBr, HCl, and HI are three of them, HF is not.)
  - *Dilute solutions of sodium fluoride and hydrobromic acid are mixed.*

    $F^- + H^+ \rightarrow HF$ (Remember HF is a weak acid, thus a molecule is formed.)
  - *Dilute solutions of potassium acetate and sulfuric acid are mixed.*

    $C_2H_3O_2^- + H^+ \rightarrow HC_2H_3O_2$ (Remember $HC_2H_3O_2$ is a weak acid, thus a molecule is formed.)
  - *Gaseous hydrofluoric acid reacts with solid silicon dioxide.* (A rare situation that is not likely to be tested on the AP exam)

    $4HF + SiO_2 \rightarrow SiF_4 + 2H_2O$

Acid/Base Neutralization *(a particular "flavor" of double replacement reaction)*

Acids react with bases to produce salts and water.

One mole of hydrogen ions react with one mole of hydroxide ions to produce one mole of water. Remember which acids are strong (and thus ionize completely) and those acids which are weak (should be written as a molecule). We can assume that all solutions are aqueous solutions, unless told otherwise.

Sulfuric acid (a strong acid) can be written as H^+ and SO_4^{2-} or as H^+ and HSO_4^- (AP will accept either as a correct response)

- *A solution of dilute sulfuric acid is added to a solution of barium hydroxide until the same number of moles of each compound as been added.*

  $H^+ + SO_4^{2-} + Ba^{2+} + OH^- \rightarrow BaSO_4 + H_2O$ (It's true that in the "overall reaction, 2's would show up, but they all drop out of the net ionic equation:

- **Watch out for acids or bases that should be written as a molecule, such as weak acids or weak bases and gases.**
  - *A dilute solution of ammonia is added to a dilute solution of hydrochloric acid*

    $NH_3 + H^+ \rightarrow H_2O + NH_4^+$

  - *Acetic acid solution is added to an aqueous solution of sodium hydroxide.*

    $HC_2H_3O_2 + OH^- \rightarrow H_2O + C_2H_3O_2^-$

  - *Hydrogen sulfide gas is bubbled through excess sodium hydroxide solution.*

    $H_2S + 2OH^- \rightarrow 2\ H_2O + S^{2-}$

  - *A suspension of magnesium hydroxide is added to a dilute solution of hydrochloric acid.*

    $Mg(OH)_2 + 2H^+ \rightarrow 2H_2O + Mg^{2+}$

- **Watch out for substances that can react with water before reacting with an acid or a base. (See the anyhdride section on next page) These are easier if though of as two step reactions, making the acid first, then neutralizing, though it is written all as one.**
  - *Sulfur dioxide gas is bubbled into an excess of a saturated solution of calcium hydroxide.*

    $SO_2 + Ca^{2+} + OH^- \rightarrow CaSO_3 + H_2O$ ($SO_2 + H_2O$ in the solution ➙ H_2SO_3 which reacts with $Ca^{2+} + OH^-$ ➙ $CaSO_3 + H_2O$)

Anhydrides

- Anhydride means "without water, " and thus these anhydrides are reacted with water.
  - **Nonmetallic oxides (aka: acidic anhydrides) plus water yield acids.**
    - *Carbon dioxide is bubbled into water.*

      $CO_2 + H_2O \rightarrow H_2CO_3$

    (The acid that forms is the one in which the nonmetal will maintain the *same* oxidation number.)
    - *Sulfur trioxide is bubbled into water.*

      $SO_3 + H_2O \rightarrow H_2SO_4$ (not H_2SO_3 the oxidation number of the sulfur remains +6)

  - **Metallic oxides (aka: basic anhydrides) plus water yield bases.**
    - *Solid sodium oxide is added to water.*

      $Na_2O + H_2O \rightarrow 2Na^+ + 2OH^-$ (Think of water as HOH and the reaction looks like a single replacement reaction.)

  - **Metallic hydrides plus water yield metallic hydroxides and hydrogen gas. (This is a redox disproportionation reaction.)**
    - *Solid sodium hydride is added to water.*

      $NaH + H_2O \rightarrow Na^+ + OH^- + H_2$

Below you will find three interesting examples, but certainly nothing you would ever be responsible for remembering

- **Phosphorus halides react with water to produce an acid of phosphorus (phosphorous acid or phosphoric acid - the oxidation numbers will remain the same) and a hydrohalic acid.**
  - *Phosphorus tribromide is added to water.*

    $PBr_3 + 3H_2O \rightarrow H_3PO_3 + 3H^+ + 3Br^-$
- **Group I&II nitrides react with water to produce the metallic hydroxide and ammonia.**
  - *Solid calcium nitride is added to water.*

    $Ca_3N_2 + 6H_2O \rightarrow 3Ca^{2+} + 6OH^- + 2NH_3$ (Since calcium hydroxide is only *slightly* soluble, you could write it as a compound as well. $Ca_3N_2 + 6H_2O \rightarrow 3Ca(OH)_2 + 2NH_3$
- **Amines (weak base) react with water to produce alkyl-ammonium ions and hydroxide ions.**
  - *Methylamine gas is bubbled into distilled water.*

    $CH_3NH_2 + H_2O \rightarrow CH_3NH_3^+ + OH^-$

Complex Ion Reactions

Vocabulary

- **Ligand** - any particle with an unshared pair of electrons that can bond to a metal ion
- **Complex ion (coordination complex)** - the combination of a central metal ion and its ligands
- **Coordination compound** - a neutral compound containing complex ions

  $[Co(NH_3)_6]Cl_3$ is a coordination compound

  $[Co(NH_3)_6]^{3+}$ is the complex ion

  NH_3 is the ligand

- **When the reaction adds excess of some reactant, a complex is often formed**
  - An excess of sodium hydroxide solution is added to a solution of aluminum chloride

    $4OH^- + Al^{3+} \rightarrow [Al(OH)_4]^-$

- **Excess acid will remove the complexed ammonia (amine) because the acid reacts with the weak base ammonia**
  - Excess dilute nitric acid is added to a solution containing the tetraamine nickel(II) ion

    $4H^+ + [Ni(NH_3)_4]^{2+} \rightarrow 4NH_4^+ + Ni^{2+}$

- **Excess ammonia will produce a complex ion**
  - Silver chloride is dissolved in excess ammonia solution

    $AgCl + 2NH_3 \rightarrow [Ag(NH_3)_2]^+ + Cl^-$

- **Water complexes around cations in solution**
  - Hydrated iron(III) hydrolyzes to produce acidic solutions

    $Fe(H_2O)_6^{3+} \rightarrow [Fe(H_2O)_5(OH)]^{2+} + H^+$

Common complex ions formed in AP equations		
Ligand	**Complex Ion**	**Name**
NH_3, ammonia	$[Ag(NH_3)_2]^+$	diamine silver ion
	$[Cu(NH_3)_4]^{2+}$	tetramine copper(II) ion
OH^-, hydroxide ion	$[Al(OH)_4]^-$	tetrahydroxo aluminate ion
	$[Zn(OH)_4]^{2-}$	tetrahydroxo zincate ion
Cl^-, chloride ion	$[AuCl_4]^-$	tetrachloro gold(III) ion
SCN^-, thiocyanate ion	$[FeSCN]^{2+}$	(mono) thiocyano iron(III) ion
CN^-, cyanide ion	$[Ag(CN)_2]^-$	dicyano silver ion

Decomposition Reactions

Reaction in which a compound breaks down into two or more elements or compounds. Heat, electrolysis, or a catalyst is usually necessary.

- **A compound may break down to produce two elements (always a redox reaction).**
    - *Molten sodium chloride is electrolyzed.*

      $2NaCl \rightarrow 2Na + Cl_2$

- **A compound may break down to produce an element and a compound (also a redox reaction).**
    - *A solution of hydrogen peroxide is decomposed catalytically.*

      $2H_2O_2 \rightarrow 2H_2O + O_2$

- **A compound may break down to produce two compounds (not usually a redox reaction).**
    - *Solid magnesium carbonate is heated. Reactions involving carbonates often show up.*

      $MgCO_3 \rightarrow MgO + CO_2$

Rules worth memorizing

- *Metallic carbonates* break down to yield metallic oxide and carbon dioxide. (Reverse is a synthesis.)
- *Metallic hydroxides* break down to yield metallic oxide and water.
- *Metallic chlorates* break down to yield metallic chloride and oxygen.
- *Hydrogen peroxide* decomposes into water and oxygen.
- Don't forget the phantoms:
    - ✓ *Ammonium carbonate* decomposes into ammonia, water and carbon dioxide.
    - ✓ *Sulfurous acid* decomposes into water and sulfur dioxide.
    - ✓ *Carbonic acid* decomposes into water and carbon dioxide.

Addition (aka Synthesis) Reactions

Two or more elements or compounds combine to form a single product.

- **A Group IA or IIA metal may combine with a nonmetal to make a salt.**
    - *A piece of lithium metal is dropped into a container of nitrogen gas.*

      $6Li + N_2 \rightarrow 2Li_3N$
- **When an element combines with a compound, you can usually sum up all of the elements on the product side.**
    - *Phosphorus trichloride is reacted with chlorine gas.*

      $PCl_3 + Cl_2 \rightarrow PCl_5$
- **Two compounds combine to form a single product.**
    - *Sulfur dioxide gas is passed over solid calcium oxide.*

      $SO_2 + CaO \rightarrow CaSO_3$
    - *The gases boron trifluoride and ammonia are mixed. (The classic Lewis acid/base reaction supposedly no longer tested.)*

      $BF_3 + NH_3 \rightarrow H_3NBF_3$

Combustion

Reaction of some chemical with oxygen to produce oxide compounds.

- **Hydrocarbons, carbohydrates, or alcohols combine with oxygen to form carbon dioxide and water.**
  - *Ethanol is burned completely in air.*

    $C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$
- **Metals react with oxygen to form their metallic oxide**
  - *Sodium metal react with oxygen*

    $2Na + O_2 \rightarrow 2Na_2O$

The following three combustion reactions are shown, but certainly need not be memorized. AP is not likely to test this without plenty of information embedded in the question.

- **Nonmetallic sulfides combine with oxygen to form oxides and sulfur dioxide.**
  - *Carbon disulfide vapor is burned in excess oxygen.*

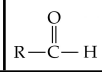
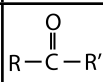
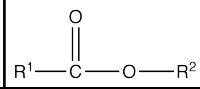
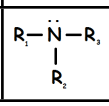
    $CS_2 + 2O_2 \rightarrow CO_2 + 2SO_2$
- **Nonmetallic hydrides combine with oxygen to form oxides and water.**
  - *Dinitrogen tetrahydride is burned completely in air.*

    $N_2H_4 + O_2 \rightarrow 2NO_2 + 2H_2O$
- **Ammonia combines with *limited* oxygen to produce NO and water (and with *excess* oxygen to produce NO_2 and water).**
  - *Ammonia is reacted with excess oxygen in the presence of a catalyst*

    $4NH_3 + 7O_2 \rightarrow 4NO_2 + 6H_2O$

Simple Organic

Organic compounds worth learning about.

group name	situation	generic formula	examples
alkanes, -ane	saturated with hydrogens, all single bonds	C_nH_{2n+2}	propane, C_3H_8
alkenes, -ene	double bond	C_nH_{2n}	ethene, C_2H_4
alkynes, -yne	triple bond	C_nH_{2n-2}	pentyne, C_5H_8
aromatic	contains a benzene ring	C_6H_6	
alcohol, -ol (aka ...-yl alcohol)	an −H replaced with an −OH	$C_nH_{2n+1}OH$	hexanol, $C_6H_{13}OH$
carboxylic acid, ...-oic acid	an −H replaced with a −COOH	$C_nH_{2n-1}COOH$	acetic acid (aka ethanoic acid), C_2H_5COOH
ethers	an O between two carbons	R−O−R′	dimethyl ether, H_3COCH_3
aldehydes	a double bonded oxygen at end of chain		formaldehyde, CH_2O
ketones	a double bonded oxygen not at end (some are sweet smelling)		acetone,$(CH_3)_3CO$ (nail polish remover)
esters	a double bonded oxygen and another oxygen (nearly all sweet smelling)		methylbutanoate, $C_4H_7OOCH_3$ (causes smell & taste of apples)
amine	nitrogen with three groups attached (nearly all smell very bad)		trimethylamine, $N(CH_3)_3$ (rotten fish odor)

Prefixes that indicate the number of carbons:

1. meth-
2. eth-
3. prop-
4. but-
5. pent-
6. hex-
7. hept-
8. oct-
9. non-
10. dec−

adapted by Sue Biggs 2014 from Kristen Henry Jones 1/28/99

Redox *in solution*

Oxidation # method

1. using oxidation #'s identify which elements are oxidized and reduced
2. balance the redox atoms by inspection
3. multiply redox atoms by integers so that total electrons transferred will be equal
4. balance any other elements, other than H and O
5. balance O by adding H_2O as necessary
6. balance H by adding H^+ as necessary
7. if the reaction occurs in *basic solution*, convert to basic by adding an equal number of OH^- ions to both sides to cancel out the H^+ ions
   a. convert H^+ & OH^- into H_2O
   b. simplify by gathering H_2O all to one side of reaction
8. recheck by confirming that charge is balanced

Half-Reaction Method

1. divide the reaction into two unbalanced half reactions
2. balance each half reaction:
   a. balance each element other than H and O
   b. balance O by adding H_2O as necessary
   c. balance H by adding H^+ as necessary
   d. balance the charge by adding electrons
3. multiply each half reaction by an integer so the total number of electrons is the same in each half reaction
4. add the half reaction and simplify by gathering terms
5. if the reaction occurs in *basic solution*, convert to basic by adding an equal number of OH^- ions to both sides to cancel out the H^+ ions
   a. convert H^+ & OH^- into H_2O
   b. simplify by gathering H_2O all to one side of reaction
6. recheck by confirming that charge is balanced

- **These solution redox reactions will likely occur in acid or basic solutions − you would be told which (or be given the hint of having H^+ or OH^- already written in the reaction.**
  - *In acidic solution, potassium permanganate reacts with oxalate ions to produce manganese(II) ions and carbon dioxide gas.*

$$MnO_4^- + C_2O_4^{2-} \rightarrow Mn^{2+} + CO_2$$

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

- *In basic solution, sulfite ions react with elemental chlorine to produce sulfate ions and chloride ions. (Don't forget the potassium and sodium are spectator ions.)*

$$SO_4^{2-} + Cl_2 \rightarrow SO_4^{2-} + Cl^-$$

(ANSWER: $2OH^- + SO_3^{2-} + Cl_2 \rightarrow SO_4^{2-} + 2Cl^- + H_2O$)

adapted by Sue Biggs 2014 from Kristen Henry Jones 1/28/99

more on Redox *in solution*

Redox reactions involve the transfer of electrons. The oxidation numbers of at least two elements must change.

- All single replacement (often in solution) are redox reactions.
- All combustion reactions are redox reactions.
- Some combination (synthesis) are redox reactions.
- Some decomposition reactions are redox reactions.

Who are these other solution redox reactions? Reactions that don't neatly fit in the categories above.

- **When a problem mentions an acidic or basic solution, it is probably a redox in solution.**
  - *A solution of tin(II) chloride is added to an acidified solution of potassium permanganate.*

    $5Sn^{2+} + 16H^+ + 2MnO_4^- \rightarrow 5Sn^{4+} + 2Mn^{2+} + 8H_2O$
  - *A solution of potassium iodide is added to an acidified solution of potassium dichromate.*

    $6I^- + 14H^+ + Cr_2O_7^{2-} \rightarrow 2Cr^{3+} + 3I_2 + 7H_2O$
- **If hydrogen peroxide is a reactant, it will be a redox reaction.**
  - *Hydrogen peroxide solution is added to an acidified solution of iron(II) sulfate.*

    $H_2O_2 + 2Fe^{2+} + 2H^+ \rightarrow 2Fe^{3+} + 2H_2O$
- **Some reactions are disproportionation reactions (the same element is both oxidized and reduced).**
  - *A piece of iron is added to a solution of iron(III) sulfate.*

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

Information about "Redox agents" that you would NOT be expected to have memorized.

Oxidizing Agents (are reduced)	Δ in oxid #		Products formed
MnO_4^- in acidic	+7	+2	Mn^{2+}
MnO_4^- in basic or neutral	+7	+4	$MnO_{2(s)}$
MnO_2 in acidic	+4	+2	Mn^{2+}
$Cr_2O_7^{2-}$ in acidic	+6	+3	Cr^{3+}
metal-ic ions, X^+	+	less+	metal-ous ions, $X^{less\ +}$
HNO_3, dilute	+5	+2	NO
HNO_3, concentrated	+5	+4	NO_2
H_2SO_4, hot, conc	+6	+4	SO_2
H_2O_2	-1	-1	H_2O
diatomic halogens, X_2	0	-1	halide ions, X^-
$HClO_4$	+7	-1	Cl^-
alkali peroxide X_2O_2	-1	-2	XOH

Reducing Agents (are oxidized)	Δ in oxid #		Products formed
metal-ous ions, X^+	+	more+	metal-ic ions, $X^{more\ +}$
free metals, X	0	+	metal ions, X^+
NO_2^-	+3	+5	NO_3^-
SO_3^{-2} or SO_2	+4	+6	SO_4^{-2}
H_2O_2	-1	0	O_2
halide ions, X^-	-1	0	diatomic halogens, X_2
diatomic halogens, X_2 dilute basic	0	+1	hypohal-ite ions, XO^-
diatomic halogens, X_2 conc basic	0	+5	hal-ate ions, XO_3^-
$C_2O_4^{-2}$	+3	+4	CO_2

- Chlorine gas reacts with dilute sodium hydroxide to produce sodium hypochlorite, sodium chloride and water.
- Copper reacts with concentrated sulfuric acid to produce copper(II) sulfate, sulfur dioxide, and water.
- Copper reacts with <u>dilute</u> nitric acid to produce copper(II) nitrate, nitrogen monoxide and water.
- Copper reacts with <u>concentrated</u> nitric acid to produce copper(II) nitrate, nitrogen dioxide and water.

adapted by Sue Biggs 2014 from Kristen Henry Jones 1/28/99