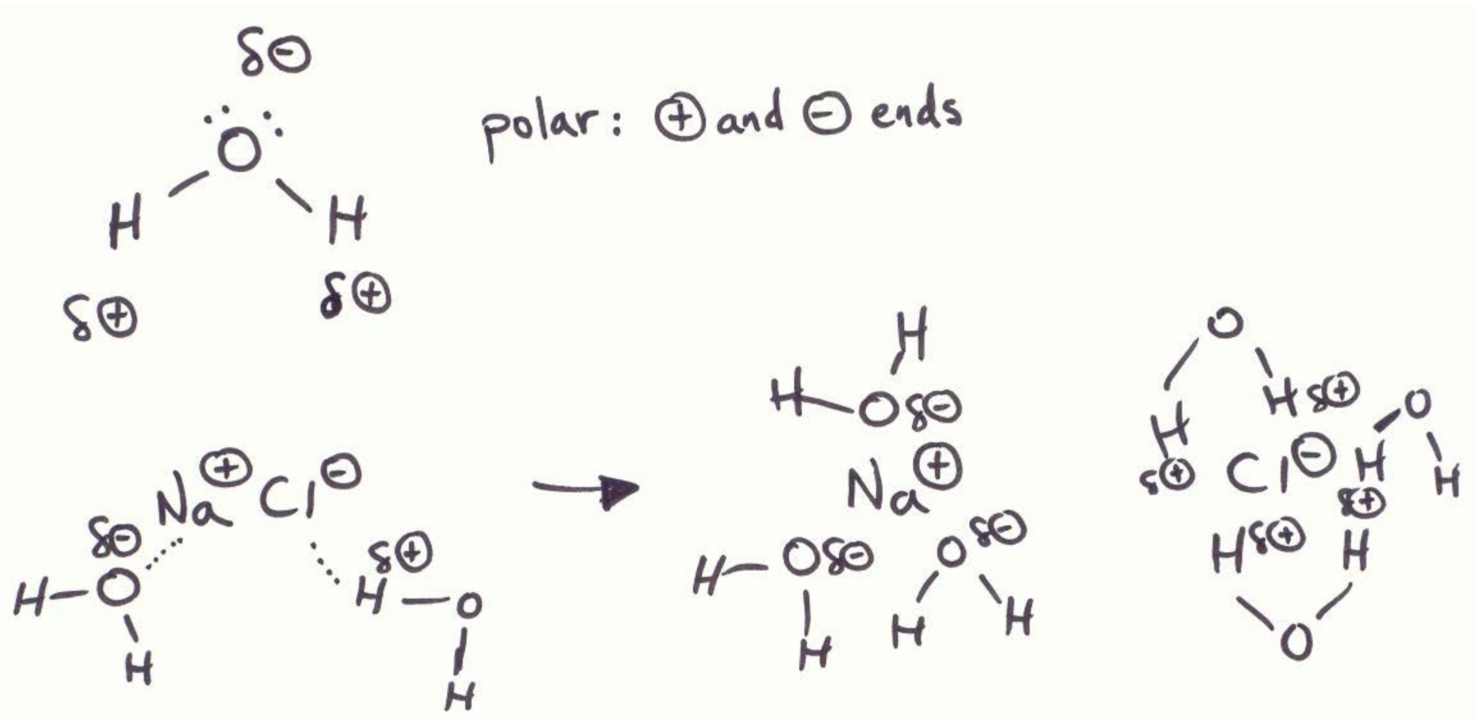
#27 Notes **Unit 4: Reactions in Solutions**

Ch. Reactions in Solutions

I. Solvation

-the act of dissolving (solute (salt) dissolves **in** the solvent (water))

Hydration: dissolving in water, the "universal" solvent.



**The partially (-) oxygen pulls apart and surrounds the (+) cation.
The partially (+) hydrogen pulls apart and surrounds the (-) anion.

II. Electrolytes

A. Strong Electrolytes: completely ionize (fall apart) and will conduct electricity in a solution.

a) soluble salts**:

$$NaCl_{(s)} \xrightarrow{H_2O} Na^{+1}_{(aq)} + Cl^{-1}_{(aq)}$$

$$Fe(NO_3)_{2(s)} \xrightarrow{H_2O} Fe^{2+}_{(aq)} + 2\ NO_3^{-1}{}_{(aq)}$$

$$Cr_2(SO_4)_{3(s)} \xrightarrow{H_2O} 2\ Cr^{3+}_{(aq)} + 3\ SO_4^{2-}{}_{(aq)}$$

b) strong acids or bases:

strong acids start with "H" : HCl, HNO_3, H_2SO_4, $HClO_4$

strong bases end in "OH": NaOH, $Ca(OH)_2$ (hydroxides)

$$HNO_{3(l)} \xrightarrow{H_2O} H^{+1}_{(aq)} + NO_3^{-1}{}_{(aq)}$$ acids produce H^{+1}

$$NaOH_{(s)} \xrightarrow{H_2O} Na^{+1}_{(aq)} + OH^{-1}_{(aq)}$$ bases produce OH^{-1}

B. Weak Electrolytes: only partially ionize (not all of the molecules fall apart) and conduct electricity poorly in solution.

a) Weak or slightly/marginally soluble salts (*see Solubility Table)

$$Ag_2S_{(s)} \overset{H_2O}{\leftrightarrow} 2\ Ag^{+1}_{(aq)} + S^{2-}_{(aq)}$$

↑ equilibrium (There will be a balance, having some reactants and some products present.)

b) Weak acids/bases:

$HC_2H_3O_{2(aq)} \leftrightarrow H^{+1}_{(aq)} + C_2H_3O_2{}^{-1}_{(aq)}$ starts with H

$NH_3 + H_2O_{(l)} \leftrightarrow NH_4{}^{+1}_{(aq)} + OH^{-1}_{(aq)}$ has NH's

C. Nonelectrolytes: may dissolve in water, but produce no ions

sugar: $C_6H_{12}O_{6(s)} \xrightarrow{H_2O} C_6H_{12}O_{6(aq)}$

If time: Write the reactions for:

a) $Ni(ClO_2)_{2(s)} \xrightarrow{H_2O} Ni^{2+}_{(aq)} + 2\ ClO_2{}^{-1}_{(aq)}$

b) $Cu_3(PO_4)_{2(s)} \xrightarrow{H_2O} 3\ Cu^{2+}_{(aq)} + 2\ PO_4{}^{3-}_{(aq)}$

III. Concentration

$$\text{Molarity} = \frac{\text{mol solute}}{\text{L solution}}$$

$1 \text{ ml} = 1 \text{ cm}^3$, $1 \text{ L} = 1 \text{ dm}^3$

Ex. 1) Calculate the molarity of 5.23 g $Fe(NO_3)_2$ in 100.0 cm^3 of solution.

$$\frac{5.23 \text{ g } Fe(NO_3)_2}{} \left| \frac{1 \text{ mol}}{179.855 \text{ g}} \right. = 0.029079 \text{ mol}$$

$$\frac{100.0 \text{ cm}^3}{} \left| \frac{1 \text{ ml}}{1 \text{ cm}^3} \right| \frac{1 \times 10^{-3} \text{ L}}{1 \text{ ml}} = 0.100 \text{ L}$$

$$M = \text{mol} / \text{L} = \frac{0.029079 \text{ mol}}{0.100 \text{ L}} = \mathbf{0.291\ M\ Fe(NO_3)_2}$$

Ex. 2) How do you make 500.0 cm^3 of 4.00 M $Fe(NO_3)_2$ from solid $Fe(NO_3)_2$?

Find mols:

$M = \text{mol} / \text{L}$

$$\frac{500.0 \text{ cm}^3}{} \left| \frac{1 \text{ ml}}{1 \text{ cm}^3} \right| \frac{1 \times 10^{-3} \text{ L}}{1 \text{ ml}} = 0.500 \text{ L}$$

$$4.00 \text{ M} = \frac{\text{mol}}{0.500 \text{ L}}$$

$2.00 = \text{mol}$

Find grams:

$$\frac{2.00 \text{ mol } Fe(NO_3)_2}{} \left| \frac{179.855 \text{ g}}{1\text{mol}} \right. = \mathbf{360\ g\ Fe(NO_3)_2}$$

Add 360. g $Fe(NO_3)_2$ and dilute to 0.500 L with water.

Ex. 3) How would you make 1.5 L of 0.50 M NaOH from a 6.0 M stock solution of NaOH?

****This problem has 2 molarities!**

If we dilute orange juice, would we still have the same amount of actual orange stuff (just more water)? Yes, same # of orange particles, same # of mols

M = mol / L

$\text{mol}_{\text{undiluted (strong)}} = \text{mol}_{\text{diluted (weak)}}$

M · L = mol
(substitute this in for mols undiluted and diluted)

$$\mathbf{M_{undiluted} \cdot L_{undiluted} = M_{diluted} \cdot L_{diluted}}$$

$(6.0\ \text{M})\ (\text{L}_{\text{undiluted}}) = (0.50\ \text{M})\ (1.5\ \text{L})$

$\mathbf{L_{undiluted} = 0.13}$

1.5 L solution
<u>-0.13 L NaOH</u>

Add 0.13 L of 6.0 M stock solution to 1.37 L H_2O.

<u>Concentration of Ions</u>

Ex. 4) Calculate the molarity of each ion for 76 g $Fe(NO_3)_2$ in 500.0 ml of solution.

$$\frac{76\ \text{g}\ Fe(NO_3)_2}{} \left| \frac{1\ \text{mol}}{179.855\ \text{g}} \right. = 0.423\ \text{mol}$$

$$\frac{500.0\ \text{ml}}{} \left| \frac{1\ \text{X}10^{-3}\ \text{L}}{1\ \text{ml}} \right. = 0.500\ \text{L}$$

$$M = \text{mol} / L = \frac{0.423\ \text{mol}}{0.500\ \text{L}} = \mathbf{0.85\ M\ Fe(NO_3)_2}$$

$$\mathbf{Fe(NO_3)_{2(s)} \rightarrow Fe^{2+}_{(aq)} + 2\ NO_3^{-1}{}_{(aq)}}$$

0.85 M $Fe(NO_3)_2$

<u>X1</u> ↓ ↓ <u>X2</u>

0.85 M Fe^{2+} ↓

1.7 M NO_3^{-1}

#29 Notes IV. Precipitation Reactions:
-are reactions that form solids (precipitate).

Solubility Rules ** soluble = aqueous
marginally/slightly soluble = solid

Solubility Table

1. Nitrate (NO_3^{-1}) salts are soluble.
2. Ammonium (NH_4^{+1}) and Group I Alkali metal (Li^{+1}, Na^{+1}, K^{+1}, Cs^{+1}, Rb^{+1}) salts are soluble.
3. Chloride, Bromide, Iodide (Cl^{-1}, Br^{-1}, I^{-1}) salts are soluble, except for salts with Ag^{+1}, Pb^{2+} and Hg_2^{2+}.
4. Sulfate (SO_4^{2-}) salts are soluble, except Ba^{2+}, Ca^{2+}, Pb^{2+}, and Hg_2^{2+}.
5. Soluble Hydroxides are LiOH, NaOH and KOH. Marginally soluble: $Ba(OH)_2$, $Sr(OH)_2$ and $Ca(OH)_2$. The rest are slightly soluble.
6. Carbonates (CO_3^{2-}), Sulfides (S^{2-}), Chromates (CrO_4^{2-}) and Phosphates (PO_4^{3-}) are slightly soluble. (All with ammonium or Group 1 Alkali metals are soluble.)

Ex. 1) Write the **molecular** equation:

a) $BaCl_{2(aq)} + Na_2SO_{4(aq)} \rightarrow$

Step 1) Break compounds apart to their Single ions:

Ba^{2+} Cl^{-1} & Na^{+1} SO_4^{2-}

2) Mix ions to make new neutral compounds:

Ba^{2+} & SO_4^{2-} Na^{+1} & Cl^{-1} = $BaSO_4$ + $NaCl$

3) Use Solubility Rules from Table:

$BaCl_{2(aq)} + Na_2SO_{4(aq)} \rightarrow \underset{\substack{\uparrow \\ \text{Rule \#4}}}{BaSO_{4(s)}} + \underset{\substack{\uparrow \\ \text{Rule \#2,3}}}{NaCl_{(aq)}}$ **If no rule, then soluble (aq).

4) Balance the equation: $\mathbf{BaCl_{2(aq)} + Na_2SO_{4(aq)} \rightarrow BaSO_{4(s)} + 2\ NaCl_{(aq)}}$

Ex. 1b) $NaBr_{(aq)} + Pb(NO_3)_{2(aq)} \rightarrow$

Na^{+1} Br^{-1} & Pb^{2+} NO_3^{-1}

Na^{+1} & NO_3^{-1} Pb^{2+} & Br^{-1} = $NaNO_3$ + $PbBr_2$

$\underline{X2}$

$NaBr_{(aq)} + Pb(NO_3)_{2(aq)} \rightarrow NaNO_{3(aq)} + PbBr_{2(s)}$

↑ ↑

Rule #1,2 Rule #3

$2\ NaBr_{(aq)} + Pb(NO_3)_{2(aq)} \rightarrow 2\ NaNO_{3(aq)} + PbBr_{2(s)}$

Ex. 1c) $Na_2CO_{3(aq)} + AlI_{3(aq)} \rightarrow$

Na^{+1} CO_3^{2-} & Al^{3+} I^{-1}

Na^{+1} & I^{-1} Al^{3+} & CO_3^{2-} = NaI + $Al_2(CO_3)_3$

$\underline{X2}$ $\underline{X3}$

$Na_2CO_{3(aq)} + AlI_{3(aq)} \rightarrow NaI_{(aq)} + Al_2(CO_3)_{3(s)}$

↑ ↑

Rule #2,3 Rule #6

$3\ Na_2CO_{3(aq)} + 2\ AlI_{3(aq)} \rightarrow 6\ NaI_{(aq)} + Al_2(CO_3)_{3(s)}$

Ex. 1d) $KOH_{(aq)} + Sr(NO_3)_{2(aq)} \rightarrow$

K^{+1} OH^{-1} & Sr^{2+} NO_3^{-1}

K^{+1} & NO_3^{-1} Sr^{2+} & OH^{-1} = KNO_3 + $Sr(OH)_2$

$\underline{X2}$

$KOH_{(aq)} + Sr(NO_3)_{2(aq)} \rightarrow KNO_{3(aq)} + Sr(OH)_{2(s)}$

↑ ↑

Rule #1,2 Rule #5

$2\ KOH_{(aq)} + Sr(NO_3)_{2(aq)} \rightarrow 2\ KNO_{3(aq)} + Sr(OH)_{2(s)}$

#30Notes V. Acid/Base Reactions

Acids start with "H", Bases end in "OH".

Weak acids don't matter, since not doing ionic reactions!

Ex. 1) Write the molecular equation.

$HClO_{4(aq)} + KOH_{(aq)} \rightarrow$

H^{+1} ClO_4^{-1} & K^{+1} OH^{-1}

H^{+1} & OH^{-1} K^{+1} & ClO_4^{-1} = $H_2O + KClO_4$

Water is a pure liquid.

$\mathbf{HClO_{4(aq)} + KOH_{(aq)} \rightarrow H_2O_{(l)} + KClO_{4(aq)}}$

↑

No rule, so soluble (aq)

Ex. 2) Write the molecular equation.

$HNO_{3(aq)} + Sr(OH)_{2(s)} \rightarrow$

H^{+1} NO_3^{-1} & Sr^{2+} OH^{-1}

H^{+1} & OH^{-1} Sr^{2+} and NO_3^{-1} = $H_2O + Sr(NO_3)_2$

X2

$2\ \mathbf{HNO_{3(aq)} + Sr(OH)_{2(s)} \rightarrow 2\ H_2O_{(l)} + Sr(NO_3)_{2(aq)}}$

↑

Rule #1

#31 Notes VI. Titration Problems

Titration is a lab procedure in which acids and bases are mixed. If the concentration of one (acid or base) is known, the other (base or acid) can be calculated.

Remember: $HCl_{(aq)} + NaOH_{(aq)} \rightarrow H_2O_{(l)} + NaCl_{(aq)}$
Acid Base Water Salt
NEUTRAL

If there are equal amounts of acid and base, an equivalence point (neutral point) is reached. This can be determined by addition of an indicator, like the cabbage juice.

At the equivalence point: mols H^{+1} = mols OH^{-1}

M = mol/ L

$$M_{H^{+1}} \cdot L_{H^{+1}} = M_{OH^{-1}} \cdot L_{OH^{-1}}$$

Ex. 1) What is the concentration of a HCl solution, if 43.0 ml neutralizes 89.3 ml of 0.0400 M NaOH?

$M_{H^{+1}} \cdot L_{H^{+1}} = M_{OH^{-1}} \cdot L_{OH^{-1}}$
$(M_{H^{+1}})$ (43.0 ml) = (0.0400 M NaOH) (89.3 ml)
$(M_{H^{+1}})$ (43.0 ml) = 3.572
(M_{H+1}) = 0.0831 M HCl

Ex. 2) What volume of 0.250 M HNO_3 is needed to react completely with 29.4 ml of 0.311M $Ca(OH)_2$?

$M_{H^{+1}} \cdot L_{H^{+1}} = M_{OH^{-1}} \cdot L_{OH^{-1}}$
(0.250 M HNO_3) $(L_{H^{+1}})$ = (2 OH^{-1}) (0.311 M $Ca(OH)_2$) (29.4 ml)
$(L_{H^{+1}})$ = **73.1 ml HNO_3**

H_2SO_4 ….. X2 H^{+1}
$Al(OH)_3$ ….X3 OH^{-1}

#32 Notes VII. Oxidation Numbers (for individual atoms):

Oxidation Rules:

1) Any free element (without a charge) is zero. Ex.) $Zn_{(s)}$, $N_{2(g)}$

2) Monoatomic ions have their charge. Ex.) $Zn^{2+}{}_{(aq)}$, $F^{-1}{}_{(aq)}$

3) Hydrogen is always +1, unless it is alone with a positive metal, then the H is -1.
Ex.) NaH = Na^{+1} H^{-1}

4) Oxygen is always -2, unless it is in a peroxide, then O is -1.
Ex.) H_2O_2 = $H^{+1}{}_2O^{-1}{}_2$

5) Fluorine is always -1.

6) The sum of oxidation numbers in a group of elements equals the charge of the group.
Ex.) NaCl so $NaCl^{=0}$, $SO_4{}^{2-}$ so $SO_4{}^{=-2}$

** Remember charges on Periodic Table Columns, for **single** element ions.
(1st column = +1, 2nd column = +2 etc.)

Ex.1) Find the charge on each element:

a) Na_2SO_4 $Na^{+1}{}_2$ $S^{?}$ $O^{-2}{}_4$
↑ ↑
1st column rule #4 **Next, add up charges and solve for S.

+2 ?S -8 = 0 (since a neutral compound)
S must equal +6

$\mathbf{Na^{+1}{}_2S^{+6}O^{-2}{}_4}$

b) $MgCO_3$ Mg^{+2} $C^{?}$ $O^{-2}{}_3$
↑ ↑
2nd column rule #4
+2 ?C -6 = 0 C must equal 4

$\mathbf{Mg^{+2}C^{+4}O^{-2}{}_3}$

c) HSO_4^{-1} $(H^{+1}$ $S^{?}$ $O^{-2}{}_4)^{-1}$

+1 ?S -8 = -1 S must equal +6

$H^{+1}S^{+6}O^{-2}{}_4{}^{-1}$

d) $Ca(NO_2)_2$ Ca^{2+} $(N^{?}$ $O^{-2}{}_2)_2$

+2 ?N(X2) -2(4) = 0
+2 2N -8 = 0
2N = 6
N must equal +3

$Ca^{2+}(N^{+3}O^{-2}{}_2)_2$

VIII. Oxidation-Reduction Reactions (Redox)

Oxidation- element gets more (+), it loses electrons
Reduction- element gets more (-), it gains electrons

Ex. 1) $Mg + Cu(NO_3)_2 \rightarrow Mg(NO_3)_2 + Cu$

↓ **Mg oxidized** ↓
$Mg^{0} + Cu^{2+}(NO_3)_2 \rightarrow Mg^{2+}(NO_3)_2 + Cu^{0}$
↑ **Cu reduced** ↑

Mg oxidized, reducing agent
Cu reduced, oxidizing agent

Ex. 2) $SnCl_4 + Fe \rightarrow SnCl_2 + FeCl_2$

↓ **Sn reduced** ↓
$Sn^{4+}Cl_4 + Fe^{0} \rightarrow Sn^{2+}Cl_2 + Fe^{2+}Cl_2$
↑ **Fe oxidized** ↑

Sn reduced, oxidizing agent
Fe oxidized, reducing agent

Ex. 3) $2\ Na + S \rightarrow Na_2S$

$$\overset{\downarrow\ \textbf{Na oxid}\ \downarrow}{2\ Na^{\mathbf{0}} + S^{\mathbf{0}} \rightarrow Na^{\mathbf{+1}}{}_2S^{\mathbf{-2}}}$$
$$\uparrow\ \textbf{S red}\ \uparrow$$

Na oxidized, reducing agent
S reduced, oxidizing agent

Ex. 4) $HCl + NaOH \rightarrow NaCl + H_2O$

$H^{+1}Cl^{-1} + Na^{+1}O^{-2}H^{+1} \rightarrow Na^{+1}Cl^{-1} + H^{+1}{}_2O^{-2}$ **not redox**, nothing oxidizes or reduces

#33 Notes IX. Balancing Redox Reactions:

1) Write the half reactions. (one for oxidation, one for reduction)

2) For each half reaction:
   a) Balance the electrons, by looking at the oxidation number of the elements that are oxidizing or reducing. (Make sure these elements are first balanced!)
   b) Balance all other atoms except H and O. (If necessary, put in other compounds from the original reaction.)
   c) Balance O by adding H_2O.
   d) Balance H by adding H^+.
   e) Make sure all elements and charges balance.

3) Multiply the half reactions by numbers so that each has the same number of electrons.
4) Add half reactions and cancel what you can.
5) **If in basic solution**:
   a) Notice how many H^+ are left. Add the same amount of OH^- as H^+, to both sides of the reaction.
   b) The OH^- and H^+ that are on the same side make H_2O.
   c) Cancel any H_2O that will cancel.
6) Make sure all charges and atoms balance.

Ex. 1) $MnO_4^{-1} + H_2SO_3 \rightarrow Mn^{2+} + HSO_4^{-1}$ (acidic)

$(Mn^{+7}O^{-2}{}_4)^{-1} + H^{+1}{}_2S^{+4}O^{-2}{}_3 \rightarrow Mn^{2+} + (H^{+1}S^{+6}O^{-2}{}_4)^{-1}$

Step 1:

S Oxidizes

$H_2S^{\mathbf{+4}}O_3 \rightarrow HS^{\mathbf{+6}}O_4^{-1}$

Mn reduces

$Mn^{+7}O_4^{-1} \rightarrow Mn^{\mathbf{2+}}$

Step 2a): Add negative electrons to balance changing oxidation #'s.

$\mathbf{+4} \rightarrow \mathbf{+6} + 2e^-$

$H_2S^{\mathbf{+4}}O_3 \rightarrow HS^{\mathbf{+6}}O_4^{-1} \mathbf{+ 2e^-}$

$\mathbf{+7} + 5e^- \rightarrow \mathbf{2+}$

$Mn^{+7}O_4^{-1} \mathbf{+ 5\,e^-} \rightarrow Mn^{\mathbf{2+}}$

Step 2b): all balanced except H, O

Step 2c): Add H_2O to balance O.

$\mathbf{H_2O} + H_2SO_3 \rightarrow HSO_4^{-1} + 2e^-$

$MnO_4^{-1} + 5\,e^- \rightarrow Mn^{2+} + \mathbf{4\,H_2O}$

Step 2d): Add H^+ to balance H.

$H_2O + H_2SO_3 \rightarrow HSO_4^{-1} + 2e^- + \mathbf{3\,H^+}$

$\mathbf{8\,H^+} + MnO_4^{-1} + 5\,e^- \rightarrow Mn^{2+} + 4\,H_2O$

Step 3: Multiply to get common # of electrons.

$5\,(H_2O + H_2SO_3 \rightarrow HSO_4^{-1} + 2e^- + 3\,H^+)$

$2\,(8\,H^+ + MnO_4^{-1} + 5\,e^- \rightarrow Mn^{2+} + 4\,H_2O)$

Step 4: Add ½ reactions.

$5\ H_2O + 5\ H_2SO_3 \rightarrow 5\ HSO_4^{-1} + 10e^- + 15\ H^+)$

$\underline{16\ H^+ + 2\ MnO_4^{-1} + 10\ e^- \rightarrow 2\ Mn^{2+} + 8\ H_2O}$ cancel e^-, reduce H^+ & H_2O

$\mathbf{5\ H_2SO_3 + H^+ + 2\ MnO_4^{-1} \rightarrow 5\ HSO_4^{-1} + 2\ Mn^{2+} + 3\ H_2O}$

Ex. 2) $As_2O_3 + NO_3^{-1} \rightarrow H_3AsO_4 + NO$ (acidic)

$As^{+3}{}_2O^{-2}{}_3 + (N^{+5}O^{-2}{}_3)^{-1} \rightarrow H^{+1}{}_3As^{+5}O^{-2}{}_4 + N^{+2}O^{-2}$

<u>As oxidizes</u>

$As^{+3}{}_2O_3 \rightarrow H_3As^{+5}O_4$

**** Balance As before doing electrons,**
so then multiply charges by 2, since there are 2 Arsenics!!

$\mathbf{+6} \rightarrow \mathbf{+10}$ +4e-

$As^{+3}{}_2O_3 \rightarrow \mathbf{2}\ H_3As^{+5}O_4 + \mathbf{4e^-}$

<u>N reduces</u>

$N^{+5}O_3^{-1} \rightarrow N^{+2}O$

3e- $\mathbf{+5} \rightarrow \mathbf{+2}$

$\mathbf{3e^-} + N^{+5}O_3^{-1} \rightarrow N^{+2}O$

$\mathbf{5\ H_2O} + As_2O_3 \rightarrow 2\ H_3AsO_4 + 4e^-$

$3e^- + NO_3^{-1} \rightarrow NO + \mathbf{2\ H_2O}$

$5\ H_2O + As_2O_3 \rightarrow 2\ H_3AsO_4 + 4e^- + \mathbf{4\ H^+}$

$\mathbf{4\ H^+} + 3e^- + NO_3^{-1} \rightarrow NO + 2\ H_2O$

$3\ (5\ H_2O + As_2O_3 \rightarrow 2\ H_3AsO_4 + 4e^- + 4\ H^+)$

$4\ (4\ H^+ + 3e^- + NO_3^{-1} \rightarrow NO + 2\ H_2O)$

$15\ H_2O + 3\ As_2O_3 \rightarrow 6\ H_3AsO_4 + 12e^- + 12\ H^+$

$\underline{16\ H^+ + 12e^- + 4\ NO_3^{-1} \rightarrow 4\ NO + 8\ H_2O}$ cancel e^-, reduce H_2O & H^+

$\mathbf{7\ H_2O + 3\ As_2O_3 + 4\ H^+ + 4\ NO_3^{-1} \rightarrow 6\ H_3AsO_4 + 4\ NO}$

 IX. Balancing continued

Ex.3) $MnO_4^{2-} \rightarrow MnO_4^{-1} + MnO_2$ (acidic)

$(Mn^{+6}O^{-2}{}_4)^{2-} \rightarrow (Mn^{+7}O^{-2}{}_4)^{-1} + Mn^{+4}O^{-2}{}_2$

Mn oxidizes

$Mn^{+6}O_4^{2-} \rightarrow Mn^{+7}O_4^{-1}$

$\mathbf{+6} \rightarrow \mathbf{+7}$ $+1e^-$

$Mn^{\mathbf{+6}}O_4^{2-} \rightarrow Mn^{\mathbf{+7}}O_4^{-1} + \mathbf{1e^-}$

Mn reduces

$Mn^{+6}O_4^{2-} \rightarrow Mn^{+4}O_2$

$2e^-$ $\mathbf{+6} \rightarrow \mathbf{+4}$

$\mathbf{2e^-} + Mn^{\mathbf{+6}}O_4^{2-} \rightarrow Mn^{\mathbf{+4}}O_2$

$MnO_4^{2-} \rightarrow MnO_4^{-1} + 1e^-$

$2e^- + MnO_4^{2-} \rightarrow MnO_2 + \mathbf{2\ H_2O}$

$MnO_4^{2-} \rightarrow MnO_4^{-1} + 1e^-$

$\mathbf{4\ H^+} + 2e^- + MnO_4^{2-} \rightarrow MnO_2 + 2\ H_2O$

$2(\ MnO_4^{2-} \rightarrow MnO_4^{-1} + 1e^-)$

$1\ (4\ H^+ + 2e^- + MnO_4^{2-} \rightarrow MnO_2 + 2\ H_2O)$

$2\ MnO_4^{2-} \rightarrow 2\ MnO_4^{-1} + 2e^-$

$\underline{4\ H^+ + 2e^- + MnO_4^{2-} \rightarrow MnO_2 + 2\ H_2O}$

$\mathbf{3\ MnO_4^{2-} + 4\ H^+ \rightarrow 2\ MnO_4^{-1} + MnO_2 + 2\ H_2O}$

Ex. 4) $NO_2^{-1} + Al \rightarrow NH_3 + AlO_2^{-1}$ (basic)

$(N^{+3}O^{-2}{}_2)^{-1} + Al^0 \rightarrow N^{-3}H^{+1}{}_3 + (Al^{+3}O^{-2}{}_2)^{-1}$

<u>Al oxidizes</u>
$Al^0 \rightarrow Al^{+3}O_2^{-1}$

<u>N reduces</u>
$N^{+3}O_2^{-1} \rightarrow N^{-3}H_3$

$\mathbf{0} \rightarrow \mathbf{+3}$ $+3e^-$
$Al^{\mathbf{0}} \rightarrow Al^{\mathbf{+3}}O_2^{-1} + \mathbf{3e^-}$

$6e^-$ $\mathbf{+3} \rightarrow \mathbf{-3}$
$\mathbf{6e^-} + N^{\mathbf{+3}}O_2^{-1} \rightarrow N^{\mathbf{-3}}H_3$

$\mathbf{2\ H_2O} + Al \rightarrow AlO_2^{-1} + 3e^-$

$6e^- + NO_2^{-1} \rightarrow NH_3 + \mathbf{2\ H_2O}$

$2\ H_2O + Al \rightarrow AlO_2^{-1} + 3e^- + \mathbf{4\ H^+}$

$\mathbf{7\ H^+} + 6e^- + NO_2^{-1} \rightarrow NH_3 + 2\ H_2O$

$2\ (2\ H_2O + Al \rightarrow AlO_2^{-1} + 3e^- + 4\ H^+)$
$1\ (7\ H^+ + 6e^- + NO_2^{-1} \rightarrow NH_3 + 2\ H_2O)$

$4\ H_2O + 2\ Al \rightarrow 2\ AlO_2^{-1} + 6e^- + 8\ H^+$
$\underline{7\ H^+ + 6e^- + NO_2^{-1} \rightarrow NH_3 + 2\ H_2O}$
$2\ H_2O + 2\ Al + NO_2^{-1} \rightarrow 2\ AlO_2^{-1} + H^+ + NH_3$
$\uparrow \mathbf{1\ H^+}$

Step 5: Note how many H^+.
Add this amount of OH^- to both sides, canceling the H^+.

$2\ H_2O + 2\ Al + NO_2^{-1} \rightarrow 2\ AlO_2^{-1} + \mathbf{H^+} + NH_3$
$\underline{\mathbf{+\ 1\ OH^-} \qquad\qquad \mathbf{+1\ OH^-}}$
$OH^{-1} + 2\ H_2O + 2\ Al + NO_2^{-1} \rightarrow 2\ AlO_2^{-1} + H_2O + NH_3$

***** $H^+ + OH^- \rightarrow H_2O$***

Cancel H_2O, if necessary.

$\mathbf{OH^{-1} + 1\ H_2O + 2\ Al + NO_2^{-1} \rightarrow 2\ AlO_2^{-1} + NH_3}$

Ex. 5) Do Ex. 3) as if it were BASIC.

$3\ MnO_4^{2-} + 4\ H^+ \rightarrow 2\ MnO_4^{-1} + MnO_2 + 2\ H_2O$

Note the number of H^+, and add this amount of OH^- to both sides.

$$\begin{array}{l} 3\ MnO_4^{2-}\ \mathbf{+\ 4\ H^+} \rightarrow 2\ MnO_4^{-1} + MnO_2 + 2\ H_2O \\ \underline{\quad \mathbf{+\ 4\ OH^-} \qquad\qquad\qquad\qquad\qquad\qquad \mathbf{+\ 4\ OH^-}} \\ 3\ MnO_4^{2-}\ +\mathbf{4\ H_2O} \rightarrow 2\ MnO_4^{-1} + MnO_2 + 2\ H_2O + \mathbf{4\ OH^-} \end{array}$$

***** $H^+ + OH^- \rightarrow H_2O$***

(so $4\ H^+ + 4\ OH^- \rightarrow \underline{\mathbf{4}}\ H_2O$)

Cancel/Reduce H_2O:

$\mathbf{3\ MnO_4^{2-} + 2\ H_2O \rightarrow 2\ MnO_4^{-1} + MnO_2 + 4\ OH^-}$

***Pull down ions or compounds from the original reaction as needed to balance.

<u>*End of Notes*</u> (Assignments #35-37 are Review Assignments. There are no notes for these assignments.)