Rules for Balancing Oxidation/Reduction Reactions
Half Reaction Method

1. **Write the corresponding half reactions.**

2. **Balance all atoms except O and H.**

3. **Balance O; add H_2O as needed.**

4. **Balance H as acidic (H^+).**

5. **Add electrons to both half reactions and balance.**

6. **Add the half reactions; cross out "like" terms.**

7. **If basic or alkaline, add the equivalent number of hydroxides (OH^-) to counterbalance the H^+ (remember to add to both sides of the equation). Recall that $H^+ + OH^- \rightarrow H_2O$.**

BALANCING REDOX

1. **Acidic:** $Cr_2O_7^{2-} + Fe^{2+} \rightarrow Cr^{3+} + Fe^{3+}$

2. **Basic:** $Co^{2+}_{(aq)} + H_2O_{2(aq)} \rightarrow Co(OH)_3\downarrow + H_2O$

3. $MnO_4^{-}(aq) + Cr(OH)_3\,(s) \rightarrow CrO_4^{2-}\,(aq) + Mn^{+2}(aq)$

in basic solution

Balancing Redox Reactions:

acidic: $Cr_2O_7^{2-} + Fe^{2+} \rightarrow Cr^{3+} + Fe^{3+}$

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

$6(\,Fe^{2+} \rightarrow e^- + Fe^{3+}\,)$

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

Balancing Redox Reactions:

Basic: $Co^{2+}_{(aq)} + H_2O_{2(aq)} \rightarrow Co(OH)_3\downarrow + H_2O$

$2e^- + 2H^+ + H_2O_2 \rightarrow 2H_2O$

$3H_2O + Co^{2+} \rightarrow Co(OH)_3 + 3H^+ + 1e^-$

$2H^+ + H_2O_2 + 6H_2O + 2Co^{2+} \rightarrow 2H_2O + 2Co(OH)_3 + 6H^+$

$H_2O_2 + 4H_2O + 2Co^{2+} \rightarrow 2Co(OH)_3 + 4H^+$ Acidic

Add OH- to both sides

$4OH^- + H_2O_2 + 4H_2O + 2Co^{2+} \rightarrow 4H_2O + 2Co(OH)_3$

$4OH^- + H_2O_2 + 2Co^{2+} \rightarrow 2Co(OH)_3$ Basic

ACTIVITY FOR BALANCING REDOX

1. $Br_2\,(aq) + OH^-\,(aq) \rightarrow Br^-\,(aq) + BrO_3^-\,(aq) + H_2O\,(l)$

in acidic solution

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

in basic solution

3. $CrO_4^{2-}\,(aq) + CN^-\,(aq) \rightarrow CNO^-\,(aq) + Cr(OH)_4^-\,(aq)$

in basic solution

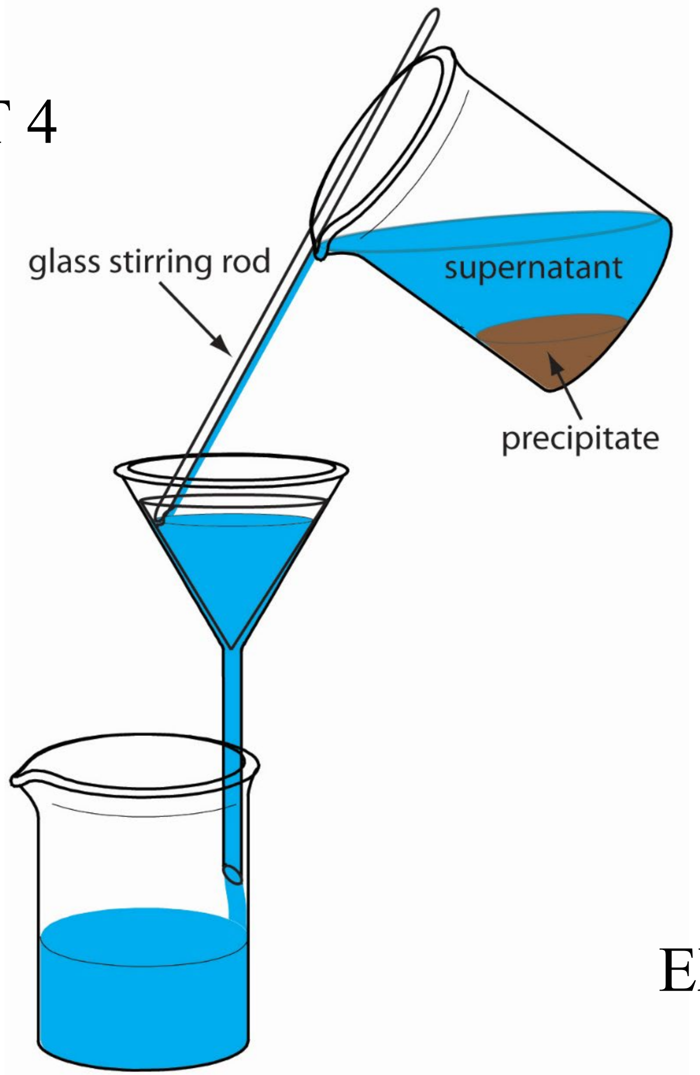
4. $Fe(OH)_2\,(s) + CrO_4^{2-}\,(aq) \rightarrow Fe_2O_3\,(s) + Cr(OH)_4^-\,(aq)$

in basic solution

Volumetric & Gravimetric Analysis

Volumetric & Gravimetric Analysis

EXPT 4



EXPT 12

VOLUMETRIC & GRAVIMETRIC ANALYSIS
Laboratory problem

In lab, you will analyze a vinegar of your choice for the amount of acetic acid, expt. 12. Vinegar is a mixture of water, acetic acid, flavonoids, coloring, phenolic acids and aldehydes. Since it is a solution you will perform volumetric analysis. We cover that in chapter 4. But do not fret, the steps we learned here are the same for volumetric analysis. In experiment 3, you will be given a metal carbonate or bicarbonate and using these techniques and thought processes you will determine the unknown metal. There are many uses for this process, determining the amount of ascorbic acid (vitamin C) in a vitamin tablet, the acid content in sodas, extracting metals from their ores (similar to expt. 4). Eventually you can extract the fat (or any other compound) out of hot dogs or potato chips.

GRAVIMETRIC ANALYSIS

1. Aluminum can be determined gravimetrically by reaction with a solution of 8-hydroxyquinoline (C_9H_7NO). A mass of 0.1248 g of $Al(C_9H_7NO)_3$ was obtained by precipitating all of the Al^{3+} from a solution prepared by dissolving 1.8571 g of a mineral. What is the mass percent of aluminum in the mineral?

$$\text{mineral} + C_9H_7NO \rightarrow C \rightarrow Al$$

$$0.1248\text{g}\ \cancel{C}^{*}\left(\frac{1\ \text{mol}\ \cancel{C}}{462\ \cancel{\text{g}\ C}}\right)\left(\frac{1\ \text{mol}\ \cancel{Al}}{2\ \cancel{\text{mol}\ C}}\right)\left(\frac{27.0\text{g Al}}{1\cancel{\text{mol}}\ \text{Al}}\right)$$

$$= 7.293 \times 10^{-3}\ \text{g Al}$$

$$\%\ Al = \left(\frac{\text{mass Al}}{\text{mass mineral}}\right)\left(\frac{7.293\text{x}10^{-3}\ \text{g Al}}{1.8571\ \text{g mineral}}\right) = \mathbf{0.3928\%}$$

*To simplify the set up I am going to call $C = Al(C_9H_7NO)_3$

GRAVIMETRIC ANALYSIS – Lecture problems

1) A particular coal contains 2.8% sulfur by weight. When this coal is burned, the sulfur appears as sulfur dioxide gas. This gas then reacts with calcium oxide to form solid calcium sulfite. If the coal is burned in a power plant that used 200 kg/hour of coal, how much calcium sulfite is produced in 2 hours?

Step 1: Since a balanced equation is not possible; in gravimetric analysis the first step is to draw out a plan, draw a picture to represent the physical process in the lab.

Step 2: Find correlations and relationships (maybe common element)

Step 3: Stoichiometry

GRAVIMETRIC ANALYSIS – Lecture problems

1) A particular coal contains 2.8% sulfur by weight. When this coal is burned, the sulfur appears as sulfur dioxide gas. This gas then reacts with calcium oxide to form solid calcium sulfite. If the coal is burned in a power plant that used 200 kg/hour of coal, how much calcium sulfite is produced in 2 hours?

① Coal 2.8% S $\xrightarrow{\Delta} SO_{2(g)}$

$SO_{2(g)} + CaO_{(s)} \rightarrow CaSO_{3(s)}$

$\boxed{\frac{200\,kg}{hr}(2\,hr) = 400\,kg \text{ of coal}}$

② In the time allotment, 400 kg of Coal is used but only 2.8% of the coal is sulfur. $\% = \left(\frac{S}{Coal}\right)100$

$0.028(400 \times 10^3\,g) = \text{mass } S = 11200\,g\,S$

③ $11200\,g\,S\left(\frac{mol\,S}{32\,g}\right)\left(\frac{1\,mol\,SO_2}{1\,mol\,S}\right)\left(\frac{64\,g\,SO_2}{mol}\right) = 22750\,g\,SO_2$

$22750\,g\,SO_2\left(\frac{1\,mol\,SO_2}{64\,g}\right)\left(\frac{1\,mol\,CaSO_3}{1\,mol\,SO_2}\right)\left(\frac{120\,g\,CaSO_3}{1\,mol}\right) = 42656\,g\,CaSO_3$ produced

OR

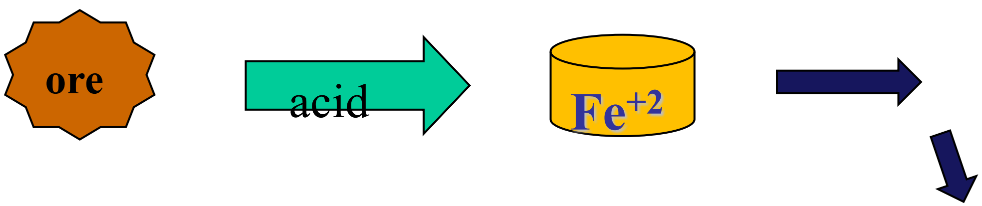
$\boxed{11200\,g\,S\left(\frac{1\,mol\,S}{32\,g}\right)\left(\frac{1\,mol\,SO_2}{1\,mol\,S}\right)\left(\frac{1\,mol\,CaSO_3}{1\,mol\,SO_2}\right)\left(\frac{120\,g\,CaSO_3}{1\,mol}\right)}$

$\boxed{4.3 \times 10^4\,g\,CaSO_3}$ 43 kg

VOLUMETRIC ANALYSIS – Lecture problem

1. A sample of an iron ore is dissolved in acid, and the iron is converted to Fe^{+2}. The sample is then titrated with 47.20 mL of 0.02240 M MnO_4^- solution. If the sample had a mass of 0.8890 g, what is the percentage of iron in the sample?

Step 1: Since a balanced equation is not possible; in gravimetric analysis the first step is to draw out a plan, draw a picture to represent the physical process in the lab.



$$8H^+(aq) + MnO_4^-(aq) + 5Fe^{+2}(aq) \rightarrow Mn^{+2}(aq) + 5Fe^{+3}(aq) + H_2O(l)$$

Step 2: Find correlations and relationships (maybe common element)

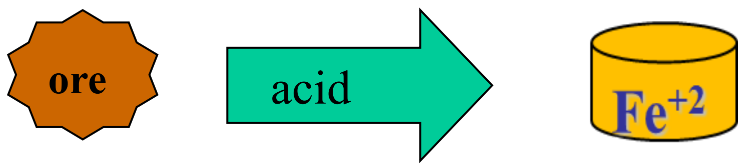
Step 3: Stoichiometry

VOLUMETRIC ANALYSIS – Lecture problem

1. A sample of an iron ore is dissolved in acid, and the iron is converted to Fe^{+2}. The sample is then titrated with 47.20 mL of 0.02240 M MnO_4^- solution. The oxidation-reduction reaction that occurs during titration is:

$$8H^+(aq) + MnO_4^-(aq) + 5Fe^{+2}(aq) \rightarrow Mn^{+2}(aq) + 5Fe^{+3}(aq) + H_2O(l)$$

If the sample had a mass of 0.8890 g, what is the percentage of iron in the sample?



$$8H^+(aq) + \underset{\substack{47.20\text{ mL} \\ 0.02240\text{ M}}}{MnO_4^-(aq)} + 5Fe^{+2}(aq) \rightarrow Mn^{+2}(aq) + 5Fe^{+3}(aq) + H_2O(l)$$

$$0.04720\cancel{L}\ MnO_4^-\ \left(\frac{0.0224\text{ mol }\cancel{MnO_4^-}}{\cancel{1L}}\right)\left(\frac{5\text{ mol }\cancel{Fe^{+2}}}{1\text{mol }\cancel{MnO_4^-}}\right)\left(\frac{55.845\text{g }\cancel{Fe^{+2}}}{1\text{mol}}\right)$$

$$= \mathbf{0.29522\ g\ Fe}$$

$$\% = (0.2952\text{ g Fe} / 0.8890\text{ g ore})\ 100 = \mathbf{33.21\%\ Fe}$$

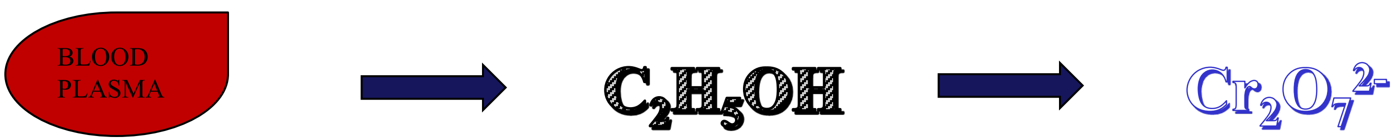
VOLUMETRIC ANALYSIS – Lecture problem

2. A person's blood alcohol level can be determined by titrating a sample of blood plasma with potassium dichromate solution.

$$16H^+ + 2\ Cr_2O_7^{2-} + C_2H_5OH \rightarrow 4\ Cr^{3+} + 2\ CO_2 + 11\ H_2O$$

If 35.46 mL of 0.05961 M $Cr_2O_7^{2-}$ is required to titrate 28.00 g of plasma, what is the mass percent of alcohol in the blood?

Step 1: Since a balanced equation is not possible; in gravimetric analysis the first step is to draw out a plan, draw a picture to represent the physical process in the lab.



Step 2: Find correlations and relationships **(maybe common element)**

Step 3: Stoichiometry

VOLUMETRIC ANALYSIS – Lecture problem

2. A person's blood alcohol level can be determined by titrating a sample of blood plasma with potassium dichromate solution.

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$$16H^+ + 2\,Cr_2O_7^{2-} + C_2H_5OH \rightarrow 4\,Cr^{3+} + 2\,CO_2 + 11\,H_2O$$

35.46 mL

0.05961 M

plasma

$$0.03546\ \text{L}\ Cr_2O_7^{2-}\left(\frac{0.05961\ \text{mol}}{1\ \text{L}}\right)\left(\frac{1\ \text{mol}\ C_2H_5OH}{2\ \text{mol}\ Cr_2O_7^{2-}}\right)\left(\frac{46\text{g}\ C_2H_5OH}{1\text{mol}}\right)$$

$$= 0.048616\ \text{g}\ C_2H_5OH$$

$$\%\ C_2H_5OH = \left(\frac{\text{mass}\ C_2H_5OH}{\text{mass plasma}}\right)\quad\left(\frac{0.048616\ \text{g}\ C_2H_5OH}{28.00\ \text{g plasma}}\right) = 0.17\%$$

GRAVIMETRIC ANALYSIS – Lecture problems

1) **Chloromycetin is an antibiotic composed of 40.88% carbon, 3.74% hydrogen, 24.76% oxygen, 8.67% nitrogen, and 21.94% chlorine. A 1.03-g sample of an ophthalmic ointment containing chloromycetin was chemically treated to convert its chlorine to chloride ions. The chloride ions were precipitated as silver chloride. If the silver chloride weighed 0.0129g, calculate the mass percent of chloromycetin in the ointment.**

In this problem:

Step 1: Resolve empirical formula (in other problems could be any topic we have previously covered) density, isotopes, combustion analysis, etc

Step 2: gravimetric analysis
- draw picture & set up relationships
- stoichiometry

GRAVIMETRIC ANALYSIS – Lecture problems

1) Chloromycetin is an antibiotic composed of 40.88% carbon, 3.74% hydrogen, 24.76% oxygen, 8.67% nitrogen, and 21.94% chlorine. A 1.03-g sample of an ophthalmic ointment containing chloromycetin was chemically treated to convert its chlorine to chloride ions. The chloride ions were precipitated as silver chloride. If the silver chloride weighed 0.0129g, calculate the mass percent of chloromycetin in the ointment.

step 1 E.F.

$C_xH_yO_zN_wCl_v \rightarrow xC + yH + zO + wN + vCl$

40.88% 3.74% 24.76% 8.67% 21.94%

$40.88\%\,C \rightarrow 40.88g\,C\left(\frac{1\,mol}{12g}\right) = 3.40667\,mol\,C$

$3.74\%\,H \rightarrow 3.74g\,H\left(\frac{1\,mol}{1g}\right) = 3.74\,mol\,H$

$24.76\%\,O \rightarrow 24.76g\,O\left(\frac{1\,mol}{16g}\right) = 1.5475\,mol\,O$

$8.67\%\,N \rightarrow 8.67g\,N\left(\frac{1\,mol}{14g}\right) = 0.61928\,mol\,N$ *

$21.9\%\,Cl \rightarrow 21.9g\,Cl\left(\frac{1\,mol}{35.45g}\right) = 0.61777\,mol\,Cl$ *

/.619

5.5 C		11 C
6 H		12 H
2.50 O	x2	5 O
N 1		2 N
Cl 1		2 Cl

$\boxed{C_{11}H_{12}O_5N_2Cl_2}$ E.F.

322.9 g/mol

Step 2

Ointment 1.03g → Cl^- → AgCl 0.0129g

%

$0.0129g\,AgCl\left(\frac{1\,mol}{143.32g\,AgCl}\right)\left(\frac{1\,mol\,Cl^-}{1\,mol\,AgCl}\right)\left(\frac{1\,mol\,C_{11}H_{12}O_5N_2Cl_2}{2\,mol\,Cl^-}\right) = 4.50\times10^{-5}\,mol\left(\frac{322.9\,g}{1\,mol}\right)$

$= 0.01453g$ chloromycetin

Step 3

$\% = \left(\frac{0.01453g}{1.03g}\right)100 = \boxed{1.41\%}$

Application Discussion # 1

If you needed to analyze the difference between Pepsi and Coke, describe how you would design your experiment.

ACTIVITY on REDOX &Gravimetric Analysis

1. Impure nickel can be purified by first forming the compound $Ni(CO)_4$, which is then decomposed by heating to yield very pure nickel. Metallic nickel reacts with gaseous carbon monoxide as follows:

$$Ni\,(s) + 4\,CO\,(g) \rightarrow Ni(CO)_4\,(g)$$

Other metals present do not react. If 94.2 g of a metal mixture produces 98.4 g of $Ni(CO)_4$, what is the mass percent of nickel in the original sample?

2. A 1.0000g sample of XI_2 is dissolved in water, and excess silver nitrate is added to precipitate all if the iodide as silver iodide. The mass of the dry AgI, is found to be 1.375g. Calculate the molar mass of X.

3. The active agent in many hair bleaches is hydrogen peroxide. The amount of hydrogen peroxide in 13.8 g of hair bleach was determined by titration with a standard potassium permanganate solution.
Unbalanced equation:

$$MnO_4^- + H_2O_2 \rightarrow O_2 + Mn^{2+}$$

a) Balance the above redox reaction in an acidic solution.

b) How many grams of hydrogen peroxide were present in the 13.8 g sample of hair bleach if 43.2 mL of 0.105 M $KMnO_4$ was needed to reach the endpoint?