Redox Stoichiometry

- **Stoichiometry** uses calculations to compare the quantities of a reactant or product to another chemical involved in a chemical reaction.
- In order to perform stoichiometric calculations, it is mandatory to have a balanced chemical reaction. Creating a balanced reaction (redox reactions for chemistry 30) is ultimately the first step for a stoichiometric calculation
    - Once a balanced reaction is obtained, follow the next steps to calculate a quantity of a chemical based off the information of another chemical involved in the reaction

      Step 1: Calculate the of moles of the chemical you know the most information about

      Step 2: Multiply the moles of the chemical in step 1 by the "*want over have*" ratio to find the moles of the chemical you are trying to find the quantity of.

      Step 3: Solve for the unknown (ie. mass, concentration, etc.)
    - Remember that when working with solids, use the formula $m = Mn$ and when working with solutions, use the formula $C = \frac{n}{V}$

EXAMPLES:

1. In a reaction between copper metal and aqueous iron(III) chloride, $Fe^{3+}_{(aq)}$ is reduced to $Fe^{2+}_{(aq)}$, while $Cu_{(s)}$ is oxidized to $Cu^{2+}_{(aq)}$. Determine the mass of $Cu_{(s)}$ required to react with 50 mL of 1.3 mol/L $FeCl_{3(aq)}$.

$$\cancel{2e^-} + 2Fe^{3+}_{(aq)} \rightarrow 2Fe^{2+}_{(aq)} \quad (\times 2)$$

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

$$2Fe^{3+}_{(aq)} + Cu_{(s)} \rightarrow 2Fe^{2+}_{(aq)} + Cu^{2+}_{(aq)}$$

same info for $FeCl_{3(aq)}$

$m = ?$

$V = 50 mL = 0.050 L$

$C = 1.3 mol/L$

① $n = CV$

$n = (1.3 mol/L)(0.050 L)$

$n = 0.065 mol$

② $n_{Cu(s)} = 0.065 mol \times \left(\frac{1}{2}\right) = 0.0325 mol$

③ $m = Mn = (63.55 g/mol)(0.0325 mol)$

$m = 2.0653 \ldots g$

$\boxed{m = 2.1 g}$

2. The un-balance equation for the reaction between bromine, $Br_{2(aq)}$, and aqueous iodate ion, $IO_3^-{}_{(aq)}$, in acidic solution is $Br_{2(aq)} + IO_3^-{}_{(aq)} \rightarrow Br^-{}_{(aq)} + IO_4^-{}_{(aq)}$. What volume of 0.788 mol/L $KIO_{3(aq)}$ will react with 4.00 g $Br_{2(aq)}$?

oxidized

$$\underset{0}{Br_{2(aq)}} + \underset{+5\quad -2}{IO_3^-{}_{(aq)}} \longrightarrow \underset{-1}{Br^-_{(aq)}} + \underset{+7\quad -2}{IO_4^-{}_{(aq)}}$$

reduced

$$H_2O_{(l)} + IO_3^-{}_{(aq)} \longrightarrow IO_4^-{}_{(aq)} + 2H^+_{(aq)} + \cancel{2e^-}$$

$$\cancel{2e^-} + Br_{2(aq)} \longrightarrow 2Br^-_{(aq)}$$

$$H_2O_{(l)} + IO_3^-{}_{(aq)} + Br_{2(aq)} \longrightarrow 2Br^-_{(aq)} + IO_4^-{}_{(aq)} + 2H^+_{(aq)}$$

Same info, for KIO_3

$C = 0.788$ mol/L

$V = ?$

$m = 4.00$g

$M = 159.80$ g/mol

① $n = \frac{m}{M} = \frac{4.00\text{g}}{159.80\text{g/mol}}$

$n = 0.02503$ mol

② $n_{IO_3^-} = (0.02503\text{mol})\left(\frac{1}{1}\right) = 0.02503$ mol

③ $C = \frac{n}{V} = V = \frac{n}{C}$

$V = \frac{0.02503\text{mol}}{0.788\text{mol/L}}$

$V = 0.0317639\ldots$ L

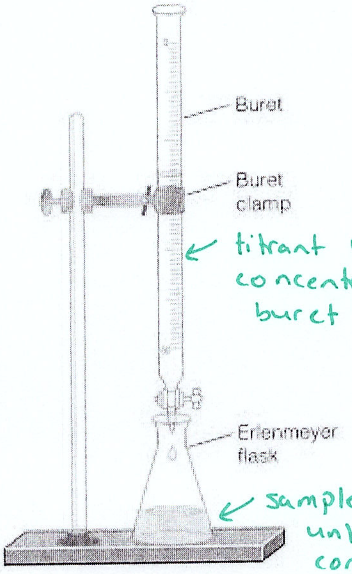
$\boxed{V = 0.0318\text{L or } 31.8\text{mL}}$

*****Now try Practice Problems #1, 2 & pg. 469 #20-21 *****

For #20, mass% = mass of alcohol/mass of plasma x 100%

- Titration is a laboratory process that is used in combination with stoichiometry to determine the quantity of an unknown sample.

- In a titration, the **titrant** is the chemical in the buret with a known concentration. The sample with the unknown concentration is placed in the Erlenmeyer flask.
    - The titrant is slowly added to the sample until the *endpoint* is reached. The *endpoint* is indicated by a sudden color change of the solution in the Erlenmeyer flask.
    - The endpoint is usually an indication that the *equivalence point* has been reached; this occurs when the moles of the titrant added is equal to the moles of chemical in the sample.



← titrant with known concentration in buret

← sample with unknown concentration

- The color change that occurs at the endpoint is either due to the addition of an indicator or the actual reactants themselves having a different color than the products

$$Cr_2O_7{}^{2-}{}_{(aq)} + 14H^+{}_{(aq)} + 6e^- \longrightarrow 2Cr^{3+} + 7H_2O$$

orange

green

↗

Strong OA, which would be a titrant.

Half-rxn just copied from pg. 7 of data book,

3. A 25.00 mL sample of solution containing iron (II) ions was titrated with a 0.02043mol/L potassium dichromate solution to determine the concentration of iron (II) in the sample. The table below shows the data collected from the titration lab.

Titration of 25.00mL of acidic $Fe^{2+}_{(aq)}$ with 0.02043 mol/L $K_2Cr_2O_{7(aq)}$

Trail	**1**	**2**	~~**3**~~	**4**
Initial burette reading (mL)	62.1	76.8	~~53.7~~	64.0
Final burette reading (mL)	26.5	41.5	~~16.9~~	28.3
Volume of $K_2Cr_2O_{7(aq)}$ (mL)	35.6	35.3	~~36.8~~	35.7

- trial #3 was omitted b/c too far off!
- Average volume of $K_2Cr_2O_7$ added is 35.5$\bar{3}$ mL!

What is the concentration of iron (II) ions in the original, acidic sample?

- first need a balanced rxn, so make a list of all chemicals & identify the SOA & SRA; the strongest agents will determine the overall redox rxn!

$Fe^{2+}_{(aq)}$, $K_2Cr_2O_{7(aq)}$, $H^+_{(aq)}$, $H_2O_{(l)}$

SRA

$2K^+_{(aq)}$ $Cr_2O_{7(aq)}^{2-}$

SOA

(x6) $6Fe^{2+}_{(aq)} \rightarrow 6Fe^{3+}_{(aq)} + \cancel{6e^-}$

$Cr_2O_{7(aq)} + 14H^+_{(aq)} + \cancel{6e^-} \rightarrow 2Cr^{3+}_{(aq)} + 7H_2O_{(l)}$

} copied from data book pg. 7

$Cr_2O_{7(aq)}^{-} + 14H^+_{(aq)} + 6Fe^{2+}_{(aq)} \rightarrow 6Fe^{3+}_{(aq)} + 2Cr^{3+}_{(aq)} + 7H_2O_{(l)}$

$V = 35.5\bar{3}mL$

$v = 0.0355\bar{3}mL$

$C = 0.02043mol/L$

① $n = Cv$

$n = (0.02043mol/L)(0.0355\bar{3}mL)$

$n = 7.25946\times10^{-3} mol$

$V = 25.00mL = 0.002500L$

$C = ?$

③ $C = \frac{n}{V} = \frac{0.04355676 mol}{0.002500 L} = 0.174227... mol/L$

$\boxed{C = 0.1742 mol/L}$

② $n_{Fe^{2+}} = 7.25946\times10^{-3} mol \times \left(\frac{6}{1}\right) = 0.04355676 mol$

Now try pg. 469 #19 & Practice Problems #3, 4

Practice Problems

1. Silver reacts in a single replacement reaction with 75 mL of 0.25 mol/L $AuCl_{3(aq)}$. What mass of reducing agent is used? **[6.07g]**

2. The reaction shown below occurs in acid solution. Balance the equation and calculate the mass of methanol (CH_3OH) that will react completely with 3.33L of 0.150mol/L $MnO_4^-{}_{(aq)}$. **[20.0g]**

$$CH_3OH_{(aq)} + MnO_4^-{}_{(aq)} \rightarrow HCOOH_{(aq)} + Mn^{2+}{}_{(aq)}$$

3. An acidified solution of permanganate ion, $MnO_4^-{}_{(aq)}$, reacts with aqueous chloride ion, $Cl^-{}_{(aq)}$.
   a. In the reaction, $MnO_4^-{}_{(aq)}$ oxidizes the chloride ions, while the manganese is reduced to $Mn^{2+}{}_{(aq)}$. Write the two balanced half-reactions that are involved in the reaction.
   b. Balance the overall redox reaction.
   c. A 100.0 mL sample of $NaCl_{(aq)}$ is reacted with 21.0 mL of 1.30 mol/L $KMnO_{4(aq)}$. What is the concentration of $NaCl_{(aq)}$? **[1.37 mol/L]**

4. Use the following titration data collected in a lab to determine the concentration of tin (II) ions in a solution prepared for research on toothpaste. **[0.337mol/L]**

Titration of 10.00mL of acidic $Sn^{2+}{}_{(aq)}$ with 0.0832 mol/L $KMnO_{4(aq)}$

Trail	**1**	**2**	**3**
Initial burette reading (mL)	50.2	33.9	17.8
Final burette reading (mL)	33.9	17.8	1.6
Volume of $KMnO_4$ (mL)			