$$\left(\frac{\text{wt}}{\text{wt}}\%\right) = \frac{\text{wt solute (g)}}{\text{wt solution or sample (g)}} \times 100\%$$

And to convert the wt/wt% to the molar concentration we use the following relationship:

$$\%\frac{Wt}{\text{Wt.}} \times \frac{1000 * density\ of\ solution}{molar\ mass\ (mm)} = \frac{mole}{\text{L}}$$

III- Volume per volume percentage:

$$\left(\frac{\text{V}}{\text{V}}\%\right) = \frac{\text{V solute (mL)}}{\text{V solution or sample (mL)}} \times 100\%$$

$$\%\frac{vol.}{\text{vol.}} \times \frac{1000 * density\ of\ solute}{molar\ mass} = \frac{mole}{\text{L}}$$

2- ppm or part per million: which can be defined by the weight in mgr per liter solution, or the weight in mgr per kg of solution. To simplify the dealing with the ppm we can use the following relationship:

$$\text{ppm} \times \frac{1}{1000 * molar\ mass} = \frac{mole}{\text{L}} \text{ with no density}$$

$$\text{Or ppm} * \frac{1 * density\ of\ solution}{1000 * molar\ mass} = \frac{mole}{\text{L}}$$

4- P-function: another type of concentration expression which is used mainly for the very low concentrations and can be calculated from the following: $px = -\log[x]$

Preparation of chemical Solutions:

The chemical solutions can be prepared from two types of materials:

1- Solids: then the main goal for the chemist is to find the ***mass of solid*** material that needed to prepare the wanted solution. To simplify the problem, we can always convert the many types of concentrations expression to the molar concentration, which is very easy to solve when it concerned with the mass and its relationship with the number of moles.
2- Liquids: which give us the main purpose, which is finding the volume of standard solution that is needed to prepare the solution in question

*** taking in considerations the Stoichiometric relationships that involved in the preparation of the solutions.

Stoichiometric Calculations

A balanced chemical equation gives the combining ratios, or Stoichiometry-in units of mole of reacting substances and their products. Thus, the equation:

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

indicates that 2 mol of aqueous sodium iodide combine with 1 mol of aqueous lead nitrate to produce 1 mol of solid lead iodide and 2 mol of aqueous sodium nitrate.

** Often the physical state of substances appearing in equations indicated by the letters *(g). (l), (s),* and *(aq),* which refer to gaseous, liquid, solid, and aqueous solution states, respectively.

Example 4-12 demonstrates how the weight in grams of reactants and products;

in a chemical reaction are related. As shown in Figure 4-2, a calculation of this type is a three-step process involving:

1- transformation of the known mass of a substance in grams to a Corresponding number of moles
2- multiplication by a factor that accounts for the Stoichiometry
3- reconversion of the data in moles back to the metric units called for in the answer.

(a) What mass of $AgNO_3$ (169.9 g/mol) is needed to convert 2.33 g of $Na_2CO_3$ (106.0 g/mol) to $Ag_2CO_3$? (b) What mass of $Ag_2CO_3$ (275.7 g/mol) will be formed?

(a) $Na_2CO_3(aq) + 2AgNO_3(aq) \rightarrow Ag_2CO_3(s) + 2NaNO_3(aq)$

**Step 1.** $\text{no. mol } Na_2CO_3 = n_{Na_2CO_3} = 2.33\ \cancel{\text{g } Na_2CO_3} \times \frac{1 \text{ mol } Na_2CO_3}{106.0\ \cancel{\text{g } Na_2CO_3}}$

$= 0.02198 \text{ mol } Na_2CO_3$

**Step 2.** The balanced equation reveals that

$$\text{no. mol AgNO}_3 = n_{\text{AgNO}_3} = 0.02198 \text{ mol } \cancel{\text{Na}_2\text{CO}_3} \times \frac{2 \text{ mol AgNO}_3}{1 \text{ mol } \cancel{\text{Na}_2\text{CO}_3}}$$
$$= 0.04396 \text{ mol AgNO}_3$$

Here the stoichiometric factor is (2 mol $AgNO_3$)/(1 mol $Na_2CO_3$).

**Step 3.** $$\text{mass AgNO}_3 = 0.04396 \cancel{\text{ mol AgNO}_3} \times \frac{169.9 \text{ g AgNO}_3}{\cancel{\text{mol AgNO}_3}}$$
$$= 7.47 \text{ g AgNO}_3$$

(b) no. mol $Ag_2CO_3$ = no. mol $Na_2CO_3$ = 0.02198 mol

$$\text{mass Ag}_2\text{CO}_3 = 0.02198 \cancel{\text{ mol Ag}_2\text{CO}_3} \times \frac{275.7 \text{ g Ag}_2\text{CO}_3}{\cancel{\text{mol Ag}_2\text{CO}_3}}$$
$$= 6.06 \text{ g Ag}_2\text{CO}_3$$

What mass of $Ag_2CO_3$ (275.7 g/mol) is formed when 25.0 mL of 0.200 M $AgNO_3$ are mixed with 50.0 mL of 0.0800 M $Na_2CO_3$?

Mixing these two solutions will result in one (and only one) of three possible outcomes, specifically:

(a) An excess of $AgNO_3$ will remain after reaction is complete.
(b) An excess of $Na_2CO_3$ will remain after reaction is complete.
(c) An excess of neither reagent will exist (that is, the number of moles of $Na_2CO_3$ is exactly equal to twice the number of moles of $AgNO_3$).

As a first step, we must establish which of these situations applies by calculating the amounts of reactants (in chemical units) available at the outset.

Initial amounts are

$$\text{amount AgNO}_3 = n_{\text{AgNO}_3} = 25.0 \cancel{\text{ mL AgNO}_3} \times \frac{1 \cancel{\text{ L AgNO}_3}}{1000 \cancel{\text{ mL AgNO}_3}}$$
$$\times \frac{0.200 \text{ mol AgNO}_3}{\cancel{\text{L AgNO}_3}} = 5.00 \times 10^{-3} \text{ mol AgNO}_3$$

$$\text{no. mol Na}_2\text{CO}_3 = n_{\text{Na}_2\text{CO}_3} = 50.0 \cancel{\text{ mL Na}_2\text{CO}_3} \times \frac{1 \cancel{\text{ L Na}_2\text{CO}_3}}{1000 \cancel{\text{ mL Na}_2\text{CO}_3}}$$
$$\times \frac{0.0800 \text{ mol Na}_2\text{CO}_3}{\cancel{\text{L Na}_2\text{CO}_3}} = 4.00 \times 10^{-3} \text{ mol Na}_2\text{CO}_3$$

Because each $CO_3^{2-}$ ion reacts with two $Ag^+$ ions, $2 \times 4.00 \times 10^{-3} = 8.00 \times 10^{-3}$ mol $AgNO_3$ is required to react with the $Na_2CO_3$. Since we have insufficient $AgNO_3$, situation (b) prevails and the amount of $Ag_2CO_3$ produced will be limited by the amount of $AgNO_3$ available. Thus,

$$\frac{1 \cancel{\text{ mol Ag}_2\text{CO}_3}}{} \quad \frac{275.7 \text{ g Ag}_2\text{CO}_3}{}$$

What will be the analytical molar $Na_2CO_3$ concentration in the solution produced when 25.0 mL of 0.200 M $AgNO_3$ are mixed with 50.0 mL of 0.0800 M $Na_2CO_3$?

We have seen in the previous example that formation of $5.00 \times 10^{-3}$ mol of $AgNO_3$ will require $2.50 \times 10^{-3}$ mol of $Na_2CO_3$. The number of moles of unreacted $Na_2CO_3$ is then given by

$$n_{\text{Na}_2\text{CO}_3} = 4.00 \times 10^{-3} \text{ mol Na}_2\text{CO}_3 -$$
$$5.00 \times 10^{-3} \cancel{\text{ mol AgNO}_3} \times \frac{1 \text{ mol Na}_2\text{CO}_3}{2 \cancel{\text{ mol AgNO}_3}}$$
$$= 1.50 \times 10^{-3} \text{ mol Na}_2\text{CO}_3$$

By definition the molarity is the number of moles of $Na_2CO_3$/L. Thus,

$$c_{\text{Na}_2\text{CO}_3} = \frac{1.50 \times 10^{-3} \text{ mol Na}_2\text{CO}_3}{(50.0 + 25.0) \cancel{\text{ mL}}} \times \frac{1000 \cancel{\text{ mL}}}{1 \text{ L}} = 0.0200 \text{ M Na}_2\text{CO}_3$$

***4-5.** How many $Na^+$ ions are contained in 5.43 g of $Na_3PO_4$?

**4-6.** How many $K^+$ ions are contained in 6.76 mol of $K_3PO_4$?

***4-7.** Find the number of moles of the indicated species in
(a) 4.96 g of $B_2O_3$.
(b) 333 mg of $Na_2B_4O_7 \cdot 10H_2O$.
(c) 8.75 g of $Mn_3O_4$.
(d) 167.2 mg of $CaC_2O_4$.

**4-8.** Find the number of millimoles of the indicated species in
(a) 57 mg of $P_2O_5$.
(b) 12.92 g of $CO_2$.
(c) 40.0 g of $NaHCO_3$.
(d) 850 mg of $MgNH_4PO_4$.

***4-9.** Find the number of millimoles of solute in
(a) 2.00 L of $3.25 \times 10^{-3}$ M $KMnO_4$.
(b) 750 mL of 0.0555 M KSCN.
(c) 250 mL of a solution that contains 5.41 ppm of $CuSO_4$.
(d) 3.50 L of 0.333 M KCl.

**4-10.** Find the number of millimoles of solute in
(a) 175 mL of 0.320 M $HClO_4$.
(b) 15.0 L of $8.05 \times 10^{-3}$ M $K_2CrO_4$.
(c) 5.00 L of an aqueous solution that contains 6.75 ppm of $AgNO_3$.
(d) 851 mL of 0.0200 M KOH.

***4-11.** What is the mass in milligrams of
(a) 0.777 mol of $HNO_3$?
(b) 500 mmol of MgO?
(c) 22.5 mol of $NH_4NO_3$?
(d) 4.32 mol of $(NH_4)_2Ce(NO_3)_6$ (548.23 g/mol)?

**4-12.** What is the mass in grams of
(a) 7.1 mol of KBr?
(b) 20.1 mmol of PbO?
(c) 3.76 mol of $MgSO_4$?
(d) 9.6 mmol of $Fe(NH_4)_2(SO_4)_2 \cdot 6H_2O$?

**4-13.** What is the mass in milligrams of solute in
*(a) 26.0 mL of 0.250 M sucrose (342 g/mol)?
*(b) 2.92 L of $4.76 \times 10^{-3}$ M $H_2O_2$?
(c) 656 mL of a solution that contains 4.96 ppm of $Pb(NO_3)_2$?
(d) 6.75 mL of 0.0619 M $KNO_3$?

**4-14.** What is the mass in grams of solute in
*(a) 450 mL of 0.164 M $H_2O_2$?
*(b) 27.0 mL of $8.75 \times 10^{-4}$ M benzoic acid (122 g/mol)?
(c) 3.50 L of a solution that contains 21.7 ppm of $SnCl_2$?
(d) 21.7 mL of 0.0125 M $KBrO_3$?

**4-15.** Calculate the p-value for each of the indicated ions in the following:
*(a) $Na^+$, $Cl^-$, and $OH^-$ in a solution that is 0.0335 M in NaCl and 0.0503 M in NaOH.
(b) $Ba^{2+}$, $Mn^{2+}$, and $Cl^-$ in a solution that is $7.65 \times 10^{-3}$ M in $BaCl_2$ and 1.54 M in $MnCl_2$.
*(c) $H^+$, $Cl^-$, and $Zn^{2+}$ in a solution that is 0.600 M in HCl and 0.101 M in $ZnCl_2$.
(d) $Cu^{2+}$, $Zn^{2+}$, and $NO_3^-$ in a solution that is $4.78 \times 10^{-2}$ M in $Cu(NO_3)_2$ and 0.104 M in $Zn(NO_3)_2$.
*(e) $K^+$, $OH^-$, and $Fe(CN)_6^{4-}$ in a solution that is $2.62 \times 10^{-7}$ M in $K_4Fe(CN)_6$ and $4.12 \times 10^{-7}$ M in KOH.
(f) $H^+$, $Ba^{2+}$, and $ClO_4^-$ in a solution that is $3.35 \times 10^{-4}$ M in $Ba(ClO_4)_2$ and $6.75 \times 10^{-4}$ M in $HClO_4$.

**4-16.** Calculate the molar $H_3O^+$ ion concentration of a solution that has a pH of
*(a) 4.76. *(c) 0.52. *(e) 7.32. *(g) −0.31.
(b) 4.58. (d) 13.62. (f) 5.76. (h) −0.52.

**4-17.** Calculate the p-functions for each ion in a solution that is
*(a) 0.0200 M in NaBr.
(b) 0.0100 M in $BaBr_2$.
*(c) $3.5 \times 10^{-3}$ M in $Ba(OH)_2$.
(d) 0.040 M in HCl and 0.020 M in NaCl.
*(e) $6.7 \times 10^{-3}$ M in $CaCl_2$ and $7.6 \times 10^{-3}$ M in $BaCl_2$.
(f) $4.8 \times 10^{-8}$ M in $Zn(NO_3)_2$ and $5.6 \times 10^{-7}$ M $Cd(NO_3)_2$.

**4-18.** Convert the following p-functions to molar concentrations:
*(a) pH = 9.67. *(e) pLi = −0.221.
(b) pOH = 0.135. (f) $pNO_3$ = 7.77.
*(c) pBr = 0.034. *(g) pMn = 0.0025.
(d) pCa = 12.35. (h) pCl = 1.020.

***4-19.** Sea water contains an average of $1.08 \times 10^3$ ppm of $Na^+$ and 270 ppm of $SO_4^{2-}$. Calculate
(a) the molar concentrations of $Na^+$ and $SO_4^{2-}$ given that the average density of sea water is 1.02 g/mL.
(b) the pNa and $pSO_4$ for sea water.

**4-20.** Average human blood serum contains 18 mg of $K^+$ and 365 mg of $Cl^-$ per 100 mL. Calculate
(a) the molar concentration for each of these species; use 1.00 g/mL for the density of serum.
(b) pK and pCl for human serum.

***4-21.** A solution was prepared by dissolving 5.76 g of $KCl \cdot MgCl_2 \cdot 6H_2O$ (277.85 g/mol) in sufficient water to give 2.000 L. Calculate

# Gravimetric Analysis

Introduction

## 1.) Gravimetric Analysis:

(i) A technique in which the amount of an analyte in a sample is determined by converting the analyte to some product.

(ii) A type of quantitative analysis in which the amount of a species in a material is determined by converting the species to a product that can be isolated completely and weighed

Mass of product can be easily measured

(iii) Overall, gravimetry sounds simple.

Advantages - when done correctly is highly accurate (most accurate of all time); requires minimal equipment

Disadvantage - requires skilled operator, slow.

Convert analyte into a solid, filter, weigh, calculate via a mole map

Determination of lead ($Pb^{+2}$) in water

$$Pb^{+2} + 2Cl^- \rightarrow PbCl_2(s)$$

| Analyte | Reagent | Solid Product |
|---|---|---|

By adding excess $Cl^-$ to the sample, essentially all of the $Pb^{+2}$ will precipitate as $PbCl_2$.

Mass of $PbCl_2$ is then determined.

***used to calculate the amount of $Pb^{+2}$ in original solution***

**Example:**

What is the %KCl in a solid if 5.1367 g of solid gives rise to 0.8246 g AgCl?

$$Cl^- + Ag^+ \rightarrow AgCl(s)$$

- Zinc sulfide reacts with hydrochloric acid to produce hydrogen sulfide gas:
  - $ZnS(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2S(g)$
- How many milliliters of 0.0512 M HCl are required to react with 0.392 g ZnS?
  - Molar mass of ZnS = 97.47 g

$$0.392\text{ g ZnS} \times \frac{1\text{ mol ZnS}}{97.47\text{ g ZnS}} \times \frac{2\text{ mol HCl}}{1\text{ mol ZnS}} \times \frac{1\text{L solution}}{0.0512\text{ mol HCl}}$$

$= 0.157\ L = 157\ mL\ HCl$ solution

**Another examples:** A soluble silver compound was analyzed for the percentage of silver by adding sodium chloride solution to precipitate the silver ion as silver chloride. If 1.583 g of silver compound gave 1.788 g of silver chloride, what is the mass percent of silver in the compound?

- Molar mass of silver chloride ($AgCl$) = 143.32 g

$$1.788\ g\ AgCl \times \frac{1\ mol\ AgCl}{143.32\ g\ AgCl} \times \frac{1\ mol\ Ag}{1\ mol\ AgCl} \times \frac{107.9\ g\ Ag}{1\ mol\ Ag}$$

$$= 1.346\ g\ Ag \text{ in the compound}$$

$$\frac{1.346\ g\ Ag}{1.583\ g\ \text{silver compound}} 100\%$$

$$= 85.03\%\ Ag$$