Problem Set I: REVIEW OF SOME BASIC CONCEPTS

I. Calculation of Solution Concentrations

A. **Molarity** (moles/liter) or (millimoles/milliliter) mol/L or mmol/mL

Thus how would one define Molarity?

$$\text{Molarity} = \frac{\#\text{moles}}{\#\text{Liters}} = \frac{(\#g / \text{molar mass})}{\#\text{Liters}}$$

What analytic problems are often associated with determining high concentrations?

Solubility of solute and some times reactivity of solution

Why is Molarity the most common measure used in chemistry?

Molarity is indicator of # molecules in fixed volume.

Equilibriums require Molarity because Equil. is special case of Kinetics.

Equilibrium Molarity describes the molar concentration of a particular chemical species at equilibrium, i.e., after acid/base dissociation or complexation reactions.

B. Weight Percent = $100 \times \frac{\#g\ \text{solute}}{\#g\ \text{total solution}}$

C. Volume Percent = $100 \times \frac{\text{volume (ml) of solute}}{\text{Volume (ml) of solution (total)}}$

D. Weight/Volume Percent = $100 \times \frac{\#g\ \text{of solute}}{\#ml\ \text{of solution (total)}}$

Important: <u>B and D may be considered the same for dilute Aqueous solutions</u>

Why is this possible? 1 ml = 1 gram when density = 1.00 (Very Dilute.

E. Parts per million = $10^6 \times \frac{\#g\ \text{solute}}{\#g\ \text{of solution}} \approx 10^6\ \frac{\#g\ \text{solute}}{\#ml\ \text{of solution}}$

$\rho = 1.00$ $\#g_{solute} \ll g_{solution}$

mg/kg = ppm, concentrations in *mg/liter* may be expressed as ppm for dilute solutions.

($ppm \cong mg/L$) Very close if < 100 ppm

How would you define parts per billion (ppb) or parts per trillion (ppt)?

$$\text{Ratio} = \frac{\#g\ \text{solute}}{\#g\ \text{solution}}$$

$\text{Ratio} \times 10^2 = \%$

$\text{Ratio} \times 10^6 = ppm$

$\text{Ratio} \times 10^9 = ppb$

$\text{Ratio} \times 10^{12} = ppt$

II. Density and Specific Gravity

A. Density is defined as mass per unit volume. Solution densities are expressed as $\boxed{\text{grams/ml.}}$ Gas densities are expressed as $\boxed{\text{grams/liter.}}$ $\sim$

Because solid/liquid molecules 10^3 closer than in gas

B. Specific Gravity (*Dimensionless quantity*) is the ratio of the mass of a substance to the mass of an equal volume of water at 4° C.

Consider the following example:
A bottle of concentrated sulfuric acid that you would get from the stockroom has a concentration ***of 18.3 M and is 98% by weight H_2SO_4.***

How many mL of concentrated reagent should be diluted to 1.00 L to give a concentration of 1.00 M?

$$M_{desired} V_{desired} = M_{stock} V_{stock}$$

$$(1.0\ M)(1.0\ L) = (18.3 M)(?)$$

$V = 54.64$ ml of stock and dilute to 1.0 L.

What is the density of the concentrated reagent?

$$\frac{10 \times \rho \times \%}{MM} = \text{Molarity} \qquad \rho = \frac{M \cdot MM}{10 \times \%} = \frac{(18.3M)(98.08)}{(10)(98)}$$

$$\boxed{\rho = 1.83\ g/ml}$$

Consider the following problem:
Exactly 75.00 ml of a 0.3333 M solution of Na_2SO_3 were mixed with 150.00 ml of a 0.3912 M $HClO_4$ solution. (126.043)

(100.4585

When you approach a problem of this sort you must realize only one of ***THREE POSSIBLE*** *outcomes can occur.*

- *There will be excess Na_2SO_3 when the reaction is complete.*
- *There will be excess $HCLO_4$ when the reaction is complete.* ✓
- *Both species will have reacted totally.*

a.) How many grams of SO_2 gas were evolved?

$$Na_2SO_3^{*}{}_{(aq)} + 2HClO_{4(aq)} \longrightarrow 2NaClO_{4(aq)} + H_2SO_3$$

$$H_2SO_3 \downarrow H_2O + \underline{\underline{SO_2}}$$

25.00 mmoles   58.68 mmoles

25.0 mmole

b.) What is the concentration of the unreacted reagent?

- *In solving this problem you must first* ***BALANCE*** *the equation. ($NaClO_4$ and H_2O are the other species produced in this reaction.)*
- *Then you must* ***identify the limiting reagent****. In doing this you must calculate the number of moles or millimoles of each reactant you have at the beginning.*

The number of millimoles of $HCLO_4$ you have is given by: $\boxed{\text{ml} \times M = \text{mmoles}}$

$(150\ \text{ml})(.3912) = 58.68$ mmoles (Excess)

The number of millimoles of Na_2SO_3 you have is given by:

$(75\ \text{ml})(.3333M) = 25.00$ mmoles (Limiting)

In order to react all the Na_2SO_3 that is present how many millimoles of $HClO_4$ are necessary?

$$25.00\ \cancel{\text{mmoles}\ Na_2SO_3}\ \frac{2\ \text{mmoles of}\ HClO_4}{1\ \cancel{\text{mmole}\ Na_2SO_3}} = 50.00\ \text{mmoles}\ HClO_4$$

In order to react all the $HClO_4$ that is present in solution how many millimoles of Na_2SO_3 are needed?

$$58.68\ \cancel{\text{mmoles}\ HClO_4}\ \frac{1\ \text{mmole}\ Na_2SO_3}{2\ \cancel{\text{mmoles}\ HClO_4}} = 29.34\ \text{mmoles}\ Na_2SO_3$$

In order to determine the limiting reagent you must compare the amounts of reagents available to amounts necessary to consume each reagent totally. The limiting reagent is:

Na_2SO_3

(64.07)

How many grams of SO_2 gas were evolved? (Amount of gas or precipitate formed is defined by the limiting reagent.)

1 mole of Na_2SO_3 $\longrightarrow$ 1 moles SO_2

25.0 mmoles Na_2SO_3 $\longrightarrow$ 25.00 mmoles SO_2

25.00 mmoles SO_2 $\longrightarrow \times \frac{64.07\ mg}{mmol} = \boxed{\begin{array}{l}1601.7\ mg \\ 1.602\ g\end{array}}$

What is the concentration of the $HClO_4$ remaining?

58.68 start mmoles
− 50.00 used mmoles

$\boxed{8.68\ mM}$

$$mM = \frac{8.68\ mM}{(.075L + .150L)} = \frac{8.68\ mmoles}{.225L} = \boxed{38.6\ mM}$$

What is the pH of this solution? Why is this calculation fairly simple?

If SO_2 stayed in solution as H_2SO_3

then $[H_2SO_3] = [SO_2]$ $pK_{a1} = 1.92$

Weak Acid $pK_{a2} = 7.18$ (Ignore) (for now)

$$[H_3O^+] = \sqrt{(10^{-1.92})(.0386)}$$
$$= 0.0215 \Rightarrow \boxed{pH = 1.67}$$

If it had been strong $pH = -\log(.0386) = 1.41$ (close)