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LEC.3

Useful algebraic relationship in volumetric analysis

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Molality

Molarity is based on the volume of solution containing the solute. Since density is a temperature dependent property on a solution's volume, and thus its molar concentration, changes with temperature. By using the solvent's mass (1 kg) in place of the solution's volume, the resulting concentration becomes independent of temperature.

Molality = no. of moles / weight of solvent (kg)

1.1 Weight, Volume, and Weight-to-Volume Ratios

Weight percent (w/w %), volume percent (% v/v) and weight-to-volume percent

1.(w/w %)= $\frac{Wt\ of\ solute\ g}{Wt\ of\ solution\ g}\ x\ 100$

Example (a):

What is the weight percent of 25 g of sodium sulphate dissolved in 200 g of solution?

(w/w %)= $\frac{25g}{200\ g}\ x\ 100$ = 0.125 x 100 =12.5%

Example:

Calculate v/v% of a solution that was prepared by adding 50 ml of methanol to 200 ml water.

Volume of solution = volume of solute + volume of solvent

Vol. of solution= 50+ 200= 250 ml

(v/v %)= $\frac{50\ ml}{250\ ml}\ x\ 100$ = 20%

2. **(wt/v %)=** $\frac{wt\ of\ solute\ g}{v\ of\ solution\ ml}\ x\ 100$

Example (a):

Calculate wt/v % for 4g of NaOH dissolved in 500 ml solution.

wt/v%= $\frac{4\ g}{500\ ml}\ x\ 100 = 0.8\%$

Example (b)

Calculate the molarity of 4 g of NaOH dissolved in 500 ml solution (NaOH Molecular wt.= 40 g/mole

No. of NaOH moles= 4 g/ 40 g/mol)= 0.1 mol

$$M = \frac{no.\ of\ moles}{litre\ solution}$$

$$M = \frac{0.1\ mol}{\frac{500ml}{1000ml/l}} = \frac{0.1\ mol x\ 1000\ ml\ x\ l}{500\ ml} = 0.2\ M$$

1.2 Parts per Million and Parts per Billion

Part per million (ppm) and ***parts per billion*** (ppb) are ratios giving the grams of solute to, respectively, one million or one billion grams of sample. For example, 450 ppm Mn in steel that is =steel contains 450 µg of Mn for every gram of steel.

If we approximate the density of an aqueous solution as 1.00 g/mL, or 1000 kg/M^3 then solution concentrations can be express in ppm or ppb using the following relationships.

Ppm = mg/ L = mg/1000 ml = mg/1000g = mg/kg or =1mg/1000000mg = ppm

ppb= µg/L = µg/1000ml= µg/1000g = µg/kg= 1 µg /1000000000 µg

For gases a part per million usually is a volume ratio. Thus, a helium concentration of 6.3 ppm means that one liter of air contains 6.3 µL of He.=1µL/L=ppm

2. CONVERTING BETWEEN CONCENTRATION UNITS

The most common ways to express concentration in analytical chemistry are molarity, weight percent, volume percent, weight-to-volume percent, and parts per million and parts per billion.

Example 2.2

A concentrated solution of ammonia is 28.0% w/w NH_3 and has a density of 0.899 g/mL. What is the molar concentration of NH_3 in this solution?

SOLUTION

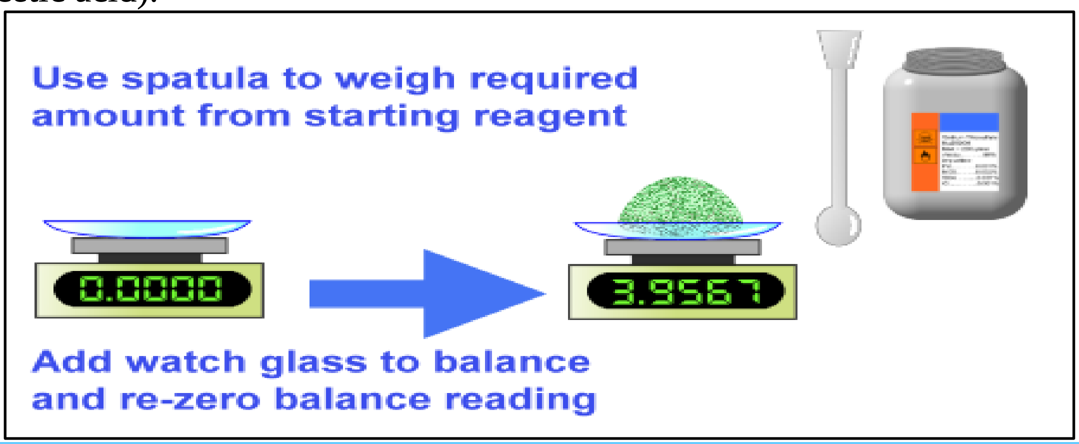
$$\frac{28.0 \text{ g } NH_3}{100 \text{ g solution}} \times \frac{0.899 \text{ g solution}}{\text{mL solution}} \times \frac{1 \text{ mol } NH_3}{17.04 \text{ g } NH_3} \times \frac{1000 \text{ mL}}{\text{L}} = 14.8 \text{ M}$$

3. PREPARING STOCK SOLUTIONS

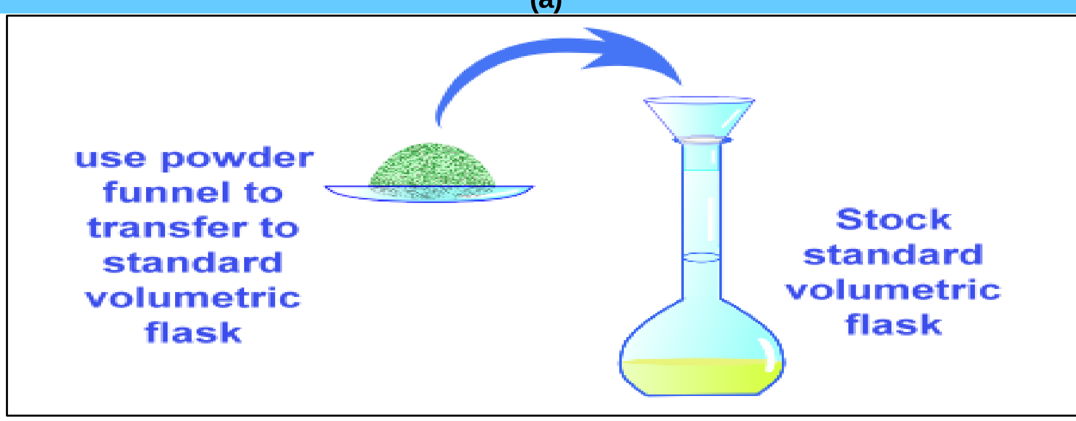
A stock solution is prepared by weighing out an appropriate portion of a pure solid or by measuring out an appropriate volume of a pure liquid and diluting to a known volume. Exactly how this is done depends on the required concentration unit. For example, to prepare a solution with a desired molarity you weigh out an appropriate mass of the reagent, dissolve it in a portion of solvent, and bring to the desired volume. To prepare a solution where the solute's concentration is a volume percent, you measure out an appropriate volume of solute and add sufficient solvent to obtain the desired total volume.

Example 4

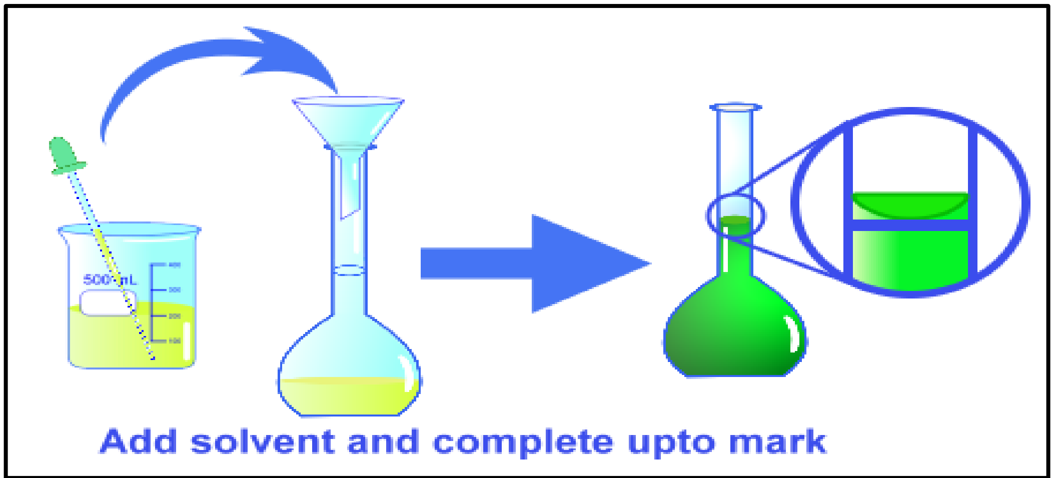
Describe how to prepare the following three solutions: (a) 500 mL of approximately 0.20 M NaOH using solid NaOH; (b) 1 L of 150.0 ppm Cu^{2+} using Cu metal; and (c) 2 L of 4% v/v acetic acid using concentrated glacial acetic acid (99.8% w/w acetic acid).



(a)



(b)



(c)

Figure 1.1: Preparing a stock solution of known molarity. (a) A measured number of moles of solute is weighed using analytical balance. (b) Solute is transferred in a volumetric flask. (c) Enough solvent is added to dissolve the solute by swirling and further solvent is carefully added until the calibration mark on the neck of the flask is reached, and the solution is then shaken until uniform.

$$\frac{0.20 \text{ mol NaOH}}{\text{L}} \times \frac{40.0 \text{ g NaOH}}{\text{mol NaOH}} \times 0.50 \text{ L} = 4.0 \text{ g}$$

To prepare the solution, place 4.0 grams of NaOH, weighed to the nearest tenth of a gram, in a bottle or beaker and add approximately 500 mL of water.

$$\frac{150.0 \text{ mg Cu}}{\text{L}} \times 1.000 \text{ L} = 150.0 \text{ mg Cu} = 0.1500 \text{ g Cu}$$

To prepare the solution we measure out exactly 0.1500 g of Cu into a small beaker and dissolve using small portion of concentrated HNO_3. The resulting solution is transferred into a 1-L volumetric flask. Rinse the beaker several times with small portions of water, adding each rinse to the volumetric flask. This process, which is called a quantitative transfer, ensures that the complete transfer of Cu^{2+} to the volumetric flask. Finally, additional water is added to the volumetric flask's calibration mark.

c.

$$\frac{4 \text{ mL } CH_3COOH}{100 \text{ mL}} \times 2000 \text{ mL } = 80 \text{ mL } CH_3COOH$$

To prepare the solution, use a graduated cylinder to transfer 80 mL of glacial acetic acid to a container that holds approximately 2 L and add sufficient water to bring the solution to the desired volume.

NOTE: What is the difference between acetic acid and glacial acetic acid?

There is technically no difference between the two but the acetic acid you buy in shops (vinegar) is usually 5-6% acetic acid in water and glacial acetic acid is basically 100% and gets its name from its tendency to freeze when it's cold. Glacial acetic acid can be purchased from chemical suppliers such as Sigma Aldrich.

Practice Exercise 2.5

Provide instructions for preparing 500 mL of 0.1250 M $KBrO_3$.

$KBrO_3$=167.0 g/mol. Ans. =10.44 g $KBrO_3$

4. PREPARING SOLUTIONS BY DILUTION

Solutions are often prepared by diluting a more concentrated stock solution. A known volume of the stock solution is transferred to a new container and brought to a new volume. The resulting new concentration can be calculated using:

C1 V1 = C2V2

Example (dilution)

If 25.0 mL of a 2.19 M solution are diluted to 72.8 mL, what is the final concentration?

Solution

Using the dilution equation, we have

(2.19 M) (25.0 mL) = M_2 (72.8 mL)   M =mol/L= mmol/ml L

Solving for the second concentration (noting that the milliliter units cancel),

M_2 = 0.752 M

Example (dilution)

If the stock solution is 10.0% KCl and the final volume and concentration need to be 100 mL and 0.50%, respectively, determine how much stock solution to use

(10%) $V1$ = (0.50%)(100 mL)   0.5= .5

$V1$ = 5 mL

How to Convert between Percent & Parts per Million (ppm) Concentrations

Suppose we are given a parts per million measurement (ppm of X in Y) and we want to convert that to a percent concentration of X in Y.

% Concentration = ppm / 10,000

= ppm concentration divided by 10,000

The number 10000 is always used in these conversion.

Example 1

The air we breathe is 0.9% argon. Convert this value to ppm=1/1000000

$0.9\% = \frac{0.9}{100} \times \frac{10000}{10000} = 9{,}000$ ppm

Example 2

The air we breathe is about 0.036% carbon dioxide CO2. Convert this value to ppm.

$0.036\% = \frac{0.036}{100} \; x \frac{10000}{10000}$ =360 ppm

To change ppm values to percentages $\frac{1}{10000}$

Example 3

Whole milk is around 48000 ppm convert this value to %

$$48000\ ppm = \frac{48000}{100\,00\,00} \times \frac{\frac{1}{10000}}{\frac{1}{10000}} = 4.8\%$$

Example 4

A solution of Salt (NaCl) in water contains 520 ppm Sodium ions Na^{+}. **Convert** this value to percentage.%

$$520\ ppm = \frac{520}{100\,00\,00} \times \frac{\frac{1}{10000}}{\frac{1}{1000}} = 0.052\%$$