SOLUTIONS

- Solutions are homogeneous mixture of two or more substances: (solute/s) dispersed throughout another substance (solvent)

SOLUTION (homogeneous mixture)	=	**SOLUTE(S)** substance being dissolved	+	**SOLVENT** substance doing the dissolving

- **AQUEOUS** solutions are solutions in which the **solvent is water**

Examples:

Aqueous Solution	=	**Solute**	+	**Water**
Vinegar	=	Acetic Acid	+	Water
Salt Water	=	Salt	+	Water
Soda Water	=	CO_2	+	Water
Rubbing Alcohol	=	Isopropyl Alcohol	+	Water
Wine	=	Ethyl Alcohol (+ natural flavors from grapes)	+	Water

CONCENTRATION OF SOLUTIONS

- Concentration expresses the relative amount of solute dissolved in a given amount of solution.
- Concentration may be expressed:

I. **Qualitatively** (no precise quantities are given)

- Solutions may be:

Concentrated	**Dilute**
A relatively **large amount of solute** is dissolved in a given amount of solution	A relatively **small amount of solute** is dissolved in a given amount of solution

- Concentrated and Dilute are Relative Terms

II. **Quantitatively**
The ratio between a given amount of solute and a given amount of solution is given.

1. Mass Percent Solution (g solute/g solution)
2. Mass/Volume Percent (grams solute/mL solution)
3. Volume Percent (mL solute/mL solution)
4. Molar Concentration or Molarity (M)
Most common and useful in the Chemistry Laboratory

- Molarity is defined as moles of solute dissolved in one liter of solution

$$\text{Molarity} = \text{M} = \frac{\text{moles of solute}}{\text{L of solution}} = \frac{\text{moles}}{\text{L}}$$

Examples:

1. You work in a lab and your job is to prepare 250.0 mL of **0.2000 M** solution of copper (II) sulfate pentahydrate ($CuSO_4 . 5 H_2O$). How many grams of $CuSO_4 . 5 H_2O$ are needed?

$$? \text{ g } CuSO_4.5\,H_2O = 250.0 \text{ mL solution} \times \frac{\mathbf{0.2000 \text{ moles } CuSO_4.5H_2O}}{\mathbf{1000 \text{ mL solution}}} \times \frac{\mathbf{? \text{ g}}}{1 \text{ mole } CuSO_4.5H_2O}$$

The mass of 1 mole of $CuSO_4.5H_2O$ must be calculated:

1 Cu	=	1	x 63.5	=	63.5
1 S	=	1	x 32.1	=	32.1
4 O	=	4	x 16.0	=	64.0
10 H	=	10	x 1.0	=	10.0
5 O	=	5	x 16.0	=	80.0
Mass of 1 mole				=	**249.6 g/mole**

$$? \text{ g } CuSO_4.5\,H_2O = 250.0 \text{ mL solution} \times \frac{0.2000 \text{ moles } CuSO_4.5H_2O}{1000 \text{ mL solution}} \times \frac{\mathbf{249.6 \text{ g}}}{\mathbf{1 \text{ mole } CuSO_4.5H_2O}}$$

= 12.48 g $CuSO_4 . 5\,H_2O$ needed

250mL
mark

Examples:

2. Calculate the number of moles of NaOH in 27.40 ml of **0.08543 M NaOH** solution.

$$? \text{ moles NaOH} = 27.40 \text{ ml solution} \times \frac{1 \text{ L NaOH solution}}{1000 \text{ mL solution}} \times \frac{\mathbf{0.08543 \text{ moles NaOH}}}{\mathbf{1 \text{ L NaOH solution}}}$$

= 0.002341 moles NaOH

Examples:

3. Determine the molarity of a solution prepared by dissolving 32.0 g of NaOH in 185 mL of solution.

4. How many mL of 0.150 M $AgNO_3$ solution contains 3.25 g of solute?

5. How many grams of solute are present in 225 mL of a 3.5% NaCl solution?

Conversion Between Molarity and Mass %

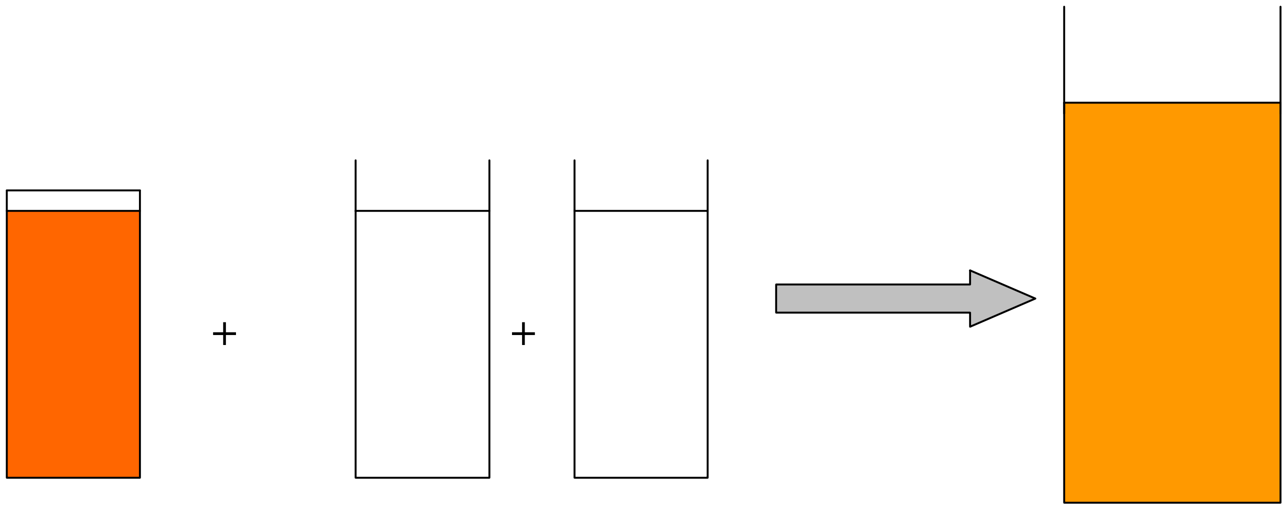
The molarity of a particular brand of vinegar (solution of acetic acid, $HC_2H_3O_2$, in water) is 0.8527 M. The density of vinegar is 1.0052 g/mL. Calculate the mass percent of $HC_2H_3O_2$ in vinegar.

$$? \frac{\text{g } HC_2H_3O_2}{\text{g vinegar}} \times 100 = \frac{0.8527 \text{ ~~moles } HC_2H_3O_2\text{~~}}{1 \text{ ~~L vinegar~~}} \times \frac{60.06 \text{ g } HC_2H_3O_2}{1 \text{ ~~mole } HC_2H_3O_2\text{~~}} \times \frac{1 \text{ ~~L vinegar~~}}{1000 \text{ ~~mL vinegar~~}} \times \frac{1 \text{ ~~mL vinegar~~}}{1.0052 \text{g vinegar}} \times 100$$

= 5.095 % g $HC_2H_3O_2$ / g vinegar

DILUTING SOLUTIONS

- Suppose you are making orange juice from frozen concentrate:



1 can of frozen concentrate

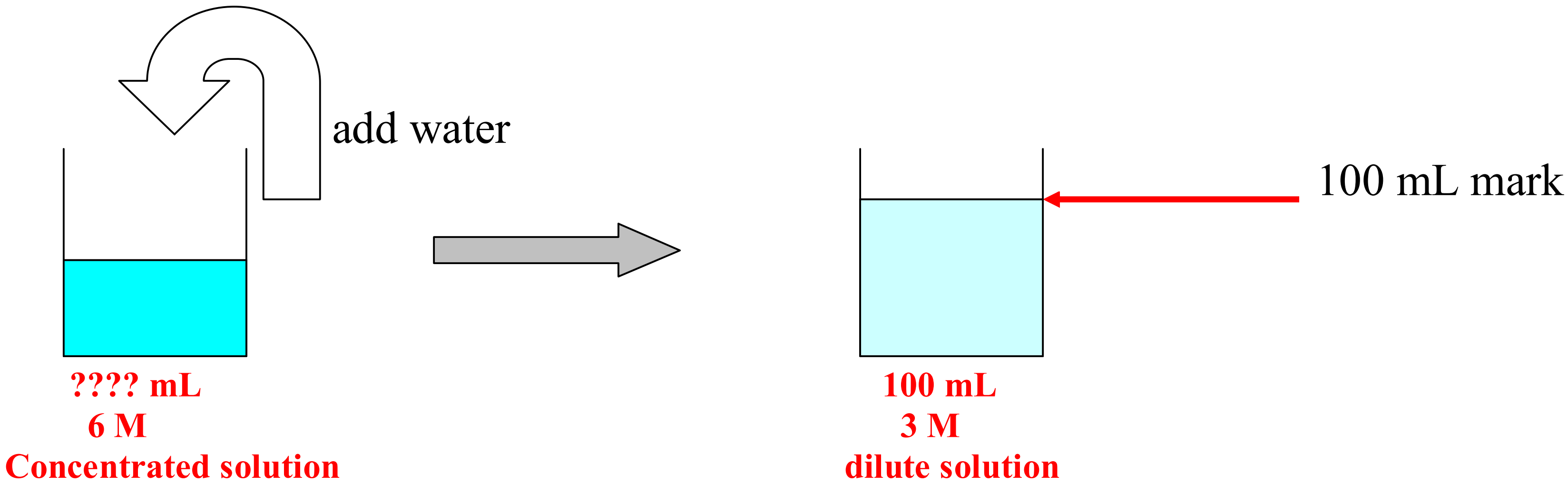
2 cans of water

3 cans of orange juice

NOTE: The diluted Orange Juice:
- has three times the volume of the concentrate (3x)
- one/third the concentration of the concentrate (1/3)

Meaning: Volume and Concentration are inversely proportional

- Suppose you want to prepare 100 mL, 3 M $CuSO_4$ from 6 M $CuSO_4$.



NOTE: **- The concentration is halved (from 6 M to 3 M)**
- The volume must have been doubled

Concentrated Solution	Dilute Solution
Mc = 6 M	Md = 3 M
Vc = ????	Vd = 100 mL

- Recall: Volumes and concentrations (Molarities are inversely proportional)

$$\frac{Mc}{Md} = \frac{Vd}{Vc}$$

or by cross multiplying:

$$Mc \times Vc = Md \times Vd$$

$$Vc = \frac{Md \times Vd}{Mc} = \frac{(3M)\,(100\text{ mL})}{6\text{ M}}$$

Vc = 50 mL

General Dilution Formula

Mc x Vc = Md x Vd (Mc: concentrated; Md: dilute) **OR** **Mf x Vf = Mi x Vi** (Mf: final; Mi: initial) **OR** **M_1 x V_1 = M_2 x V_2** (M_1: Solution 1; M_2: Solution 2)

Examples:

1. 25.00 mL of a vinegar solution was diluted to 250.0 mL. The concentration of the diluted vinegar solution was determined to be 0.08527 M. What was the concentration of the original vinegar ?

Conc'd Solution	Dilute Solution
Vc = 25.00 mL	Vd = 250.0 mL
Mc = ??????	Md = 0.08527 M

Note: - The **volume increased 10 times** (10-fold dilution)
- The **concentration** must have **decreased 10 times** **(Mc = 0.8527 M)**

Mathematically: **Mc x Vc = Md x Vd**

$$\mathbf{Mc} = \frac{\mathbf{Md \times Vd}}{\mathbf{Vc}} = \frac{(0.08527\ \text{M})\ (250.0\ \text{mL})}{25.00\ \text{mL}} = \mathbf{0.8527\ M}$$

2. 1.00 mL of a solution of 6.00×10^{-4} M ferric chloride is diluted to 15.00 mL by addition of water. What is the concentration of the diluted solution ?

Concentrated Solution	Dilute Solution
$V_1 = 1.00$ mL	$V_2 = 15.00$ mL
$M_1 = 6.00 \times 10^{-4}$ M	**M_2 = ???**

$M_1 \times V_1 = M_2 \times V_2$

$$M_2 = \frac{M_1V_1}{V_2} = \frac{(6.00\text{x}10^{-4}\ \text{M})(1.00\ \text{mL})}{15.00\ \text{mL}} = 4.00\text{x}10^{-5}$$

3. What volume of 0.73M solution must be used to prepare 1.36 L of a 0.20M solution?

Concentrated Solution	Dilute Solution
V_1 = ???	$V_2 = 1.36$ L
$M_1 = 0.73$ M	$M_2 = 0.20$ M

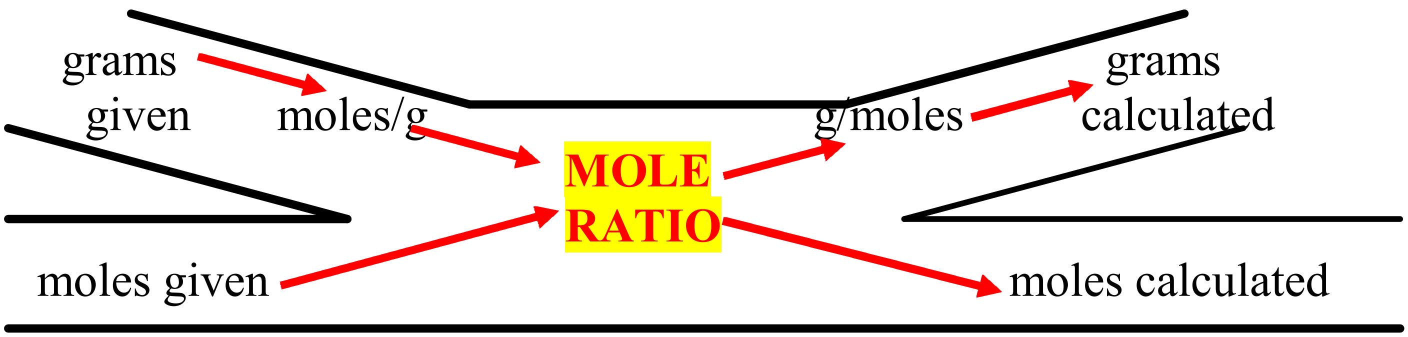
$M_1 \times V_1 = M_2 \times V_2$

$$V_1 = \frac{M_2V_2}{M_1} = \frac{(0.20\ \text{M})(1.36\ \text{L})}{0.73\ \text{M}} = 0.37\ \text{L}$$

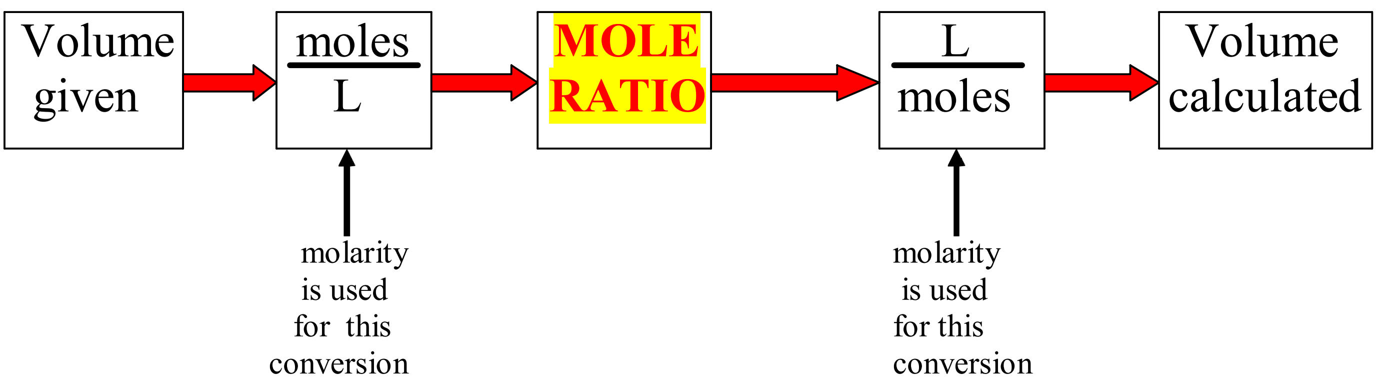
4. How much water must be added to 60.0 mL of 0.150M solution of HCl to prepare a 0.100 M solution?

STOICHIOMETRY OF AQUEOUS SOLUTIONS (VOLUMETRIC ANALYSIS)

- Stoichiometry is the calculation of quantities of reactants and products in a chemical reaction.
- Stoichiometry is based on mole ratio between amounts of substances in a balanced chemical reaction.



- In aqueous solutions, the amounts of substances are commonly given based on volume and molarity.
- As a result, mass measurements are replaced with volume measurements.



Examples:

1. When aqueous solutions of Na_2SO_4 and $Pb(NO_3)_2$ are mixed, $PbSO_4$ precipitates. What mass of $PbSO_4$ is formed when 1.25 L of 0.0500 M $Pb(NO_3)_2$ and 2.00 L of 0.0250 M Na_2SO_4 are mixed?

Solution Plan:

- Write a balanced equation.
- Calculate moles of each reactant from volume and concentration.
- Calculate moles and mass of product using molar ratios and molar mass.

- Write a balanced equation:

  Na_2SO_4 (aq) + $Pb(NO_3)_2$ (aq) $\rightarrow$

- Calculate moles of each reactant from volume and concentration:

  Moles Na_2SO_4 =

  Moles $Pb(NO_3)_2$ =

- Calculate moles and mass of product formed using molar rations and molar mass:

Examples:

2. A beaker contains 35.0 mL of 0.175 M H_2SO_4. How many milliliters of 0.250 M NaOH must be added to completely neutralize the sulfuric acid?

Solution Plan:

- Write a balanced equation.
- Calculate moles of acid from volume and concentration.
- Calculate moles of base using molar ratios.
- Calculate volume of base using moles and concentration.

- Write a balanced equation:

$$H_2SO_4(aq) \quad + \quad 2\ NaOH(aq) \quad \rightarrow \quad Na_2SO_4(aq) \quad + \quad 2\ H_2O(l)$$

- Calculate moles of acid from volume and concentration:

Moles H_2SO_4 =

- Calculate moles of base using molar ratios:

Moles NaOH =

- Calculate volume of base using moles and concentration

- Alternate solution:

TITRATION

- Titration is a laboratory procedure that uses the reaction between two substances to determine the concentration of one substance.

- Titration is based on the balanced chemical equation that represents the reaction.

$$aA + bB \longrightarrow$$

aA	bB
V_A (known volume)	V_B (known volume)
M_A (known molarity)	**M_B (unknown molarity)**

The MOLE RATIO: $\frac{a}{b}$ must be known

ACID – BASE TITRATION

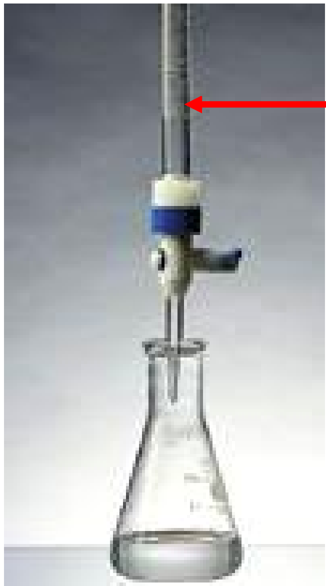
- Uses the neutralization reaction between an acid and a base to determine the concentration of the acid or the base in a solution.

Example: Find the concentration of an aqueous solution of $HC_2H_3O_2$(aq), acetic acid.

Available: An aqueous solution of NaOH(aq) of known molarity (0.07776 M) (this solution is referred to as the TITRANT)

Procedure:
1. An exact volume of acetic acid, $HC_2H_3O_2$(aq) (for example 20.00 mL) is measured into an Erlenmeyer flask.
2. Phenolphtalein (indicator) is added. There is no color change (colorless)
3. NaOH(aq) is added drop-wise from a buret until the solution in the Erlenmeyer flask just turns faint pink (experimental end point).
4. The volume of the NaOH needed to reach the end point is accurately recorded.

buret reading
28.35 mL



NaOH(aq)
0.07776 M

20.00 mL $HC_2H_3O_2$(aq)
+
2-3 drops phenolphtalein

buret reading
46.44 mL

NaOH was added to the solution in the flask until a faint pink color was reached, marking the experimental end point of the titration.
(NaOH is in very slight excess)

46.50 mL

Common error:
The addition of several drops of NaOH solution beyond the end point gives a deep pink color
(NaOH is in great excess)

Volume of NaOH added = 46.44 mL – 28.35 ml = **18.09 mL** (Buret is read in reverse)

<u>Calculations</u>:

$$\mathbf{1}\ HC_2H_3O_2(aq) + \mathbf{1}\ NaOH(aq) \longrightarrow NaC_2H_3O_2(aq) + H_2O(l)$$

20.00 mL 18.09 mL

?????? M 0.07776 M

$$0.01809\text{ L} \times \frac{0.07776\text{ moles}}{1\text{ L}}$$

$$\downarrow$$

1.407×10^{-3} moles NaOH

1.407×10^{-3} moles NaOH reacts exactly with 1.407×10^{-3} moles $HC_2H_3O_2$ (1:1 Mole Ratio)

$$\textbf{Molarity of } HC_2H_3O_2 = \frac{\textbf{moles of } HC_2H_3O_2}{\textbf{L of } HC_2H_3O_2} = \frac{1.407 \times 10^{-3}\textbf{ moles}}{0.02000\textbf{ L}} = \mathbf{0.07035\ M}$$