Solutions

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Mixtures – a review

- Mixture: a combination of two or more substances that do not combine chemically, but remain the same individual substances; can be separated by physical means.

- Two types:
  - Heterogeneous
  - Homogeneous

Heterogeneous Mixture

- "Hetero" means "different"
- Consists of visibly different substances or phases (solid, liquid, gas)
- Can be separated by filtering
- Example:

Homogeneous Mixture

- "Homo" means the same
- has the same uniform appearance and composition throughout; maintain one phase (solid, liquid, gas)
- Commonly referred to as **solutions**
- Example:

Salt Water

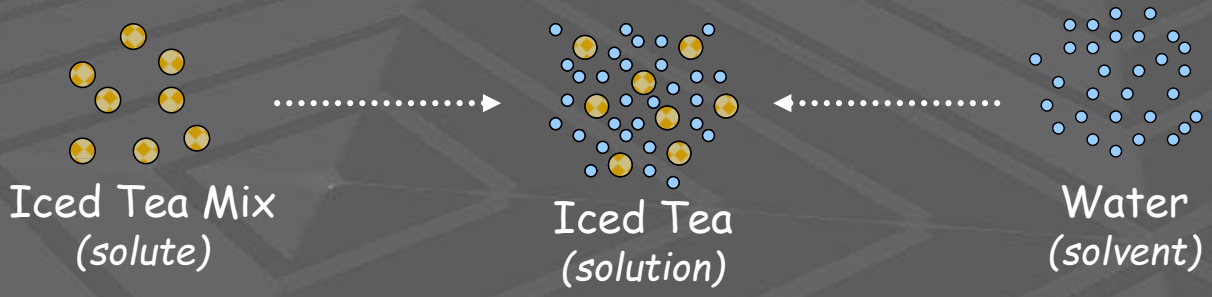
Solution

- Solution: a mixture of two or more substances that is identical throughout (homogeneous)
- can be physically separated
- composed of *solutes* and *solvents*

Salt water is considered a solution. How can it be physically separated?

the substance being dissolved

the substance that dissolves the solute



Solution

- **The <u>solvent</u> is the largest part of the solution and the <u>solute</u> is the smallest part of the solution**

S	**O**	**L**	**V**	**E**	**N**	**T**
S	O	L	U	T	E	

Types of Solutions

- Gaseous solutions – air = **Oxygen + Nitrogen**
- Liquid solutions – drinks = mix + water
- Solid solutions – alloys = steel, brass, etc

Concentration

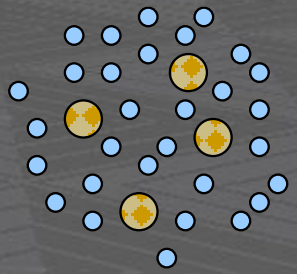
- the amount of solute dissolved in a solvent at a given temperature

  - described as ***dilute*** if it has a low concentration of solute dissolved

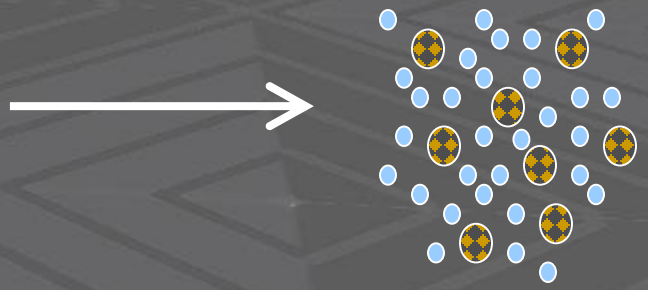
  - described as ***concentrated*** if it has a high concentration of solute dissolved

Concentration

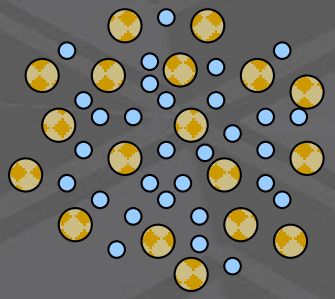
- ***Unsaturated*** - has a less than the maximum concentration of solute dissolved



- ***Saturated*** - has the maximum concentration of solute dissolved (can see solid in bottom of solution)



- ***Supersaturated*** -contains more dissolved solute than normally possible (usually requires an increase in temperature followed by cooling)



Solubility

- the amount of solute that dissolves in a certain amount of a solvent at a given temperature and pressure to produce a saturated solution

Factors affecting solubility of solids

Temperature

increased temperature causes solids to dissolve faster

Shaking

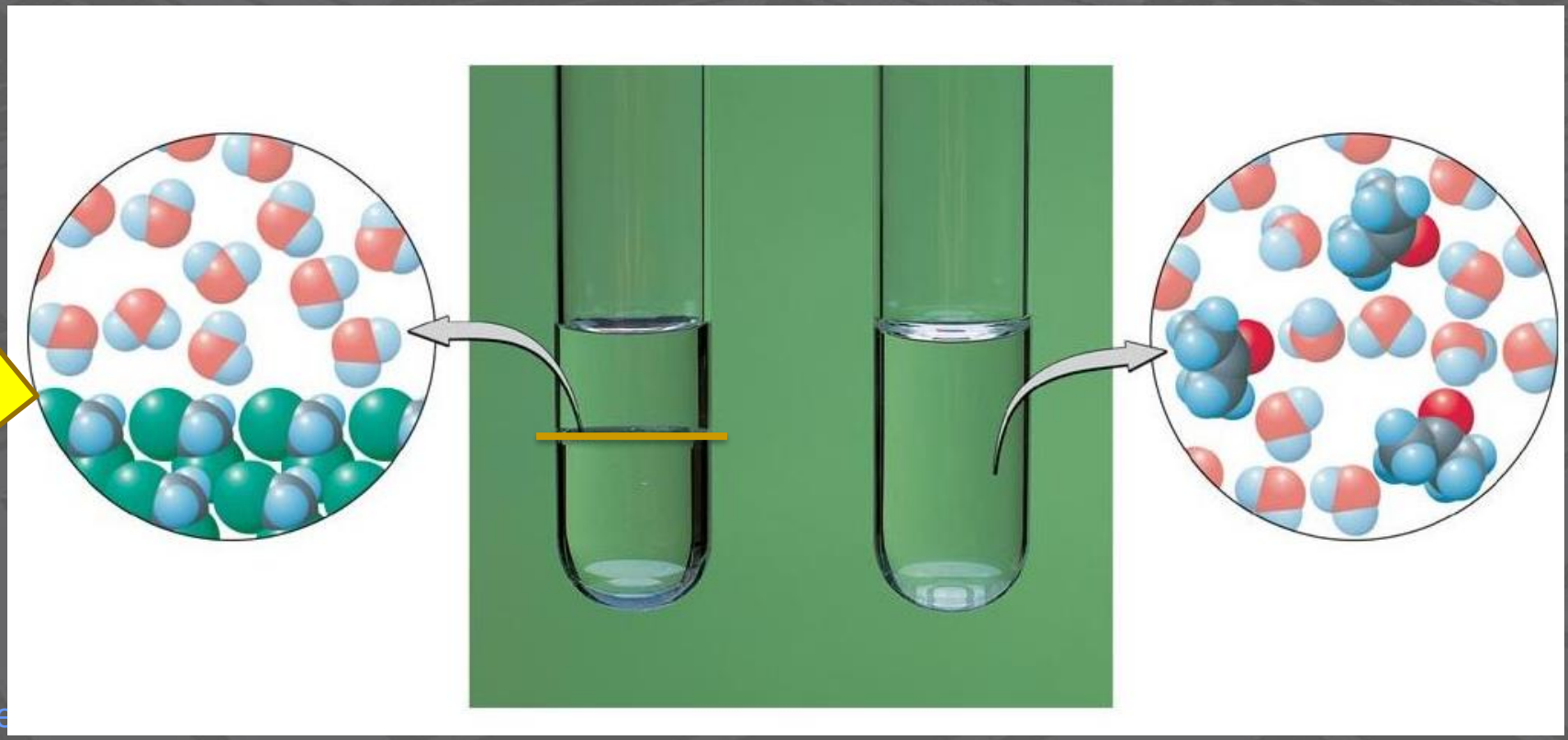
Shaking (agitation) causes solids to dissolve faster

Particle Size

Smaller particles dissolve Faster because they have more surface area

Note: Increasing the amount of solute DOES NOT increase the rate of dissolving

- Miscible liquids can easily dissolve in one another.
- Immiscible liquids are not soluble in each other.

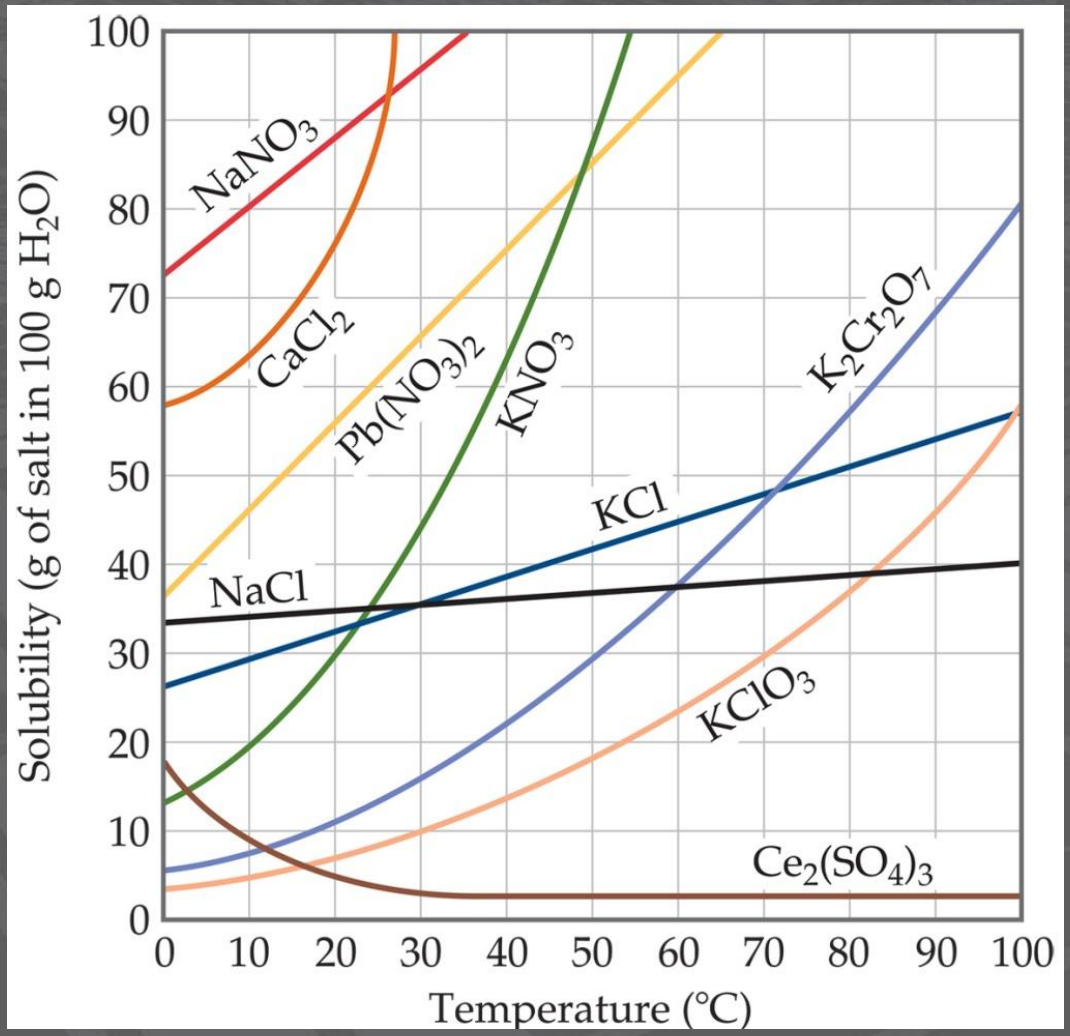


Polarity and Dissolving

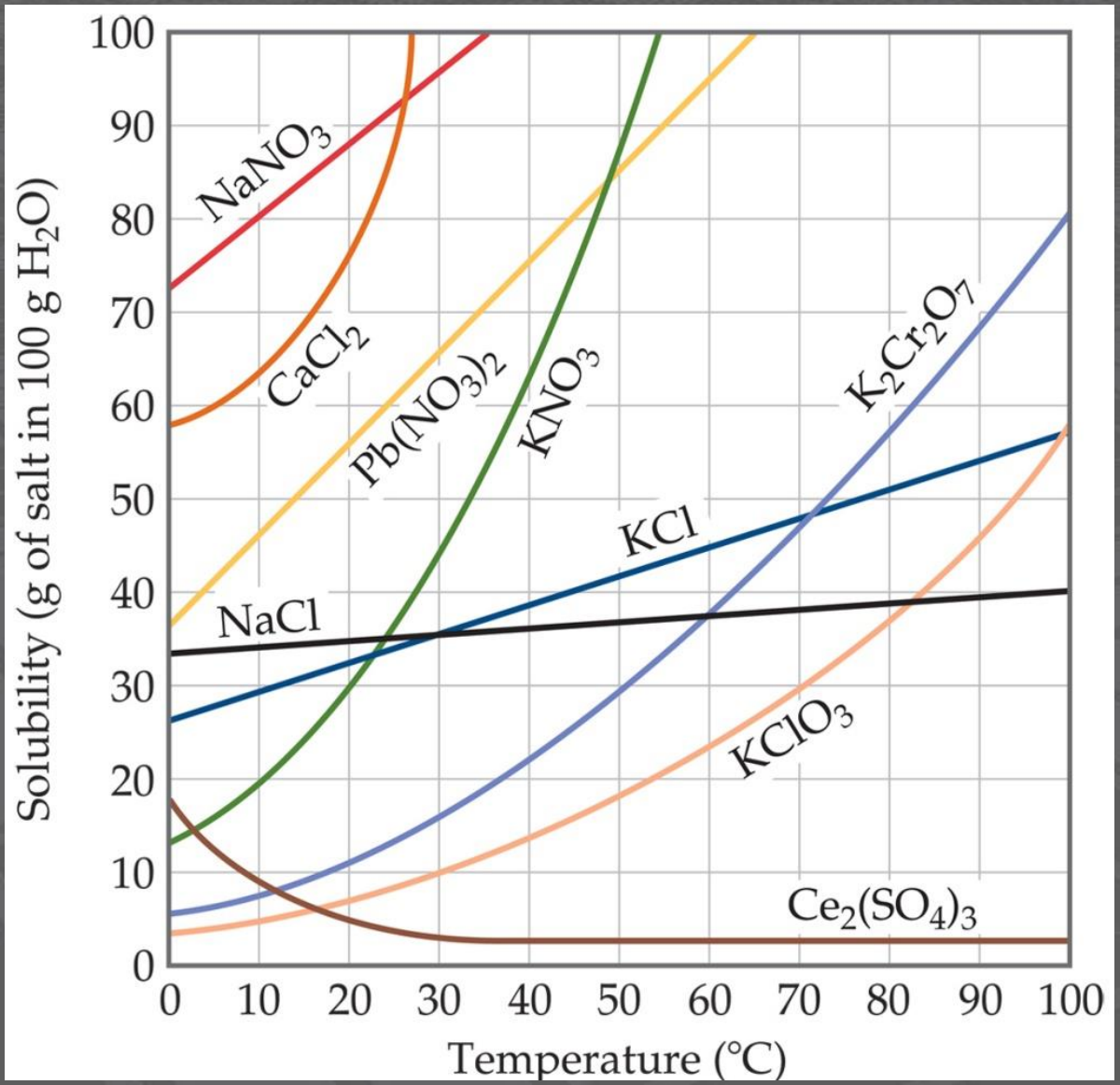
- Chemists use the saying "like dissolves like":
  - Polar solutes tend to dissolve in polar solvents.
  - Nonpolar solutes tend to dissolve in nonpolar solvents.

Oil is nonpolar while water is polar. They are immiscible.

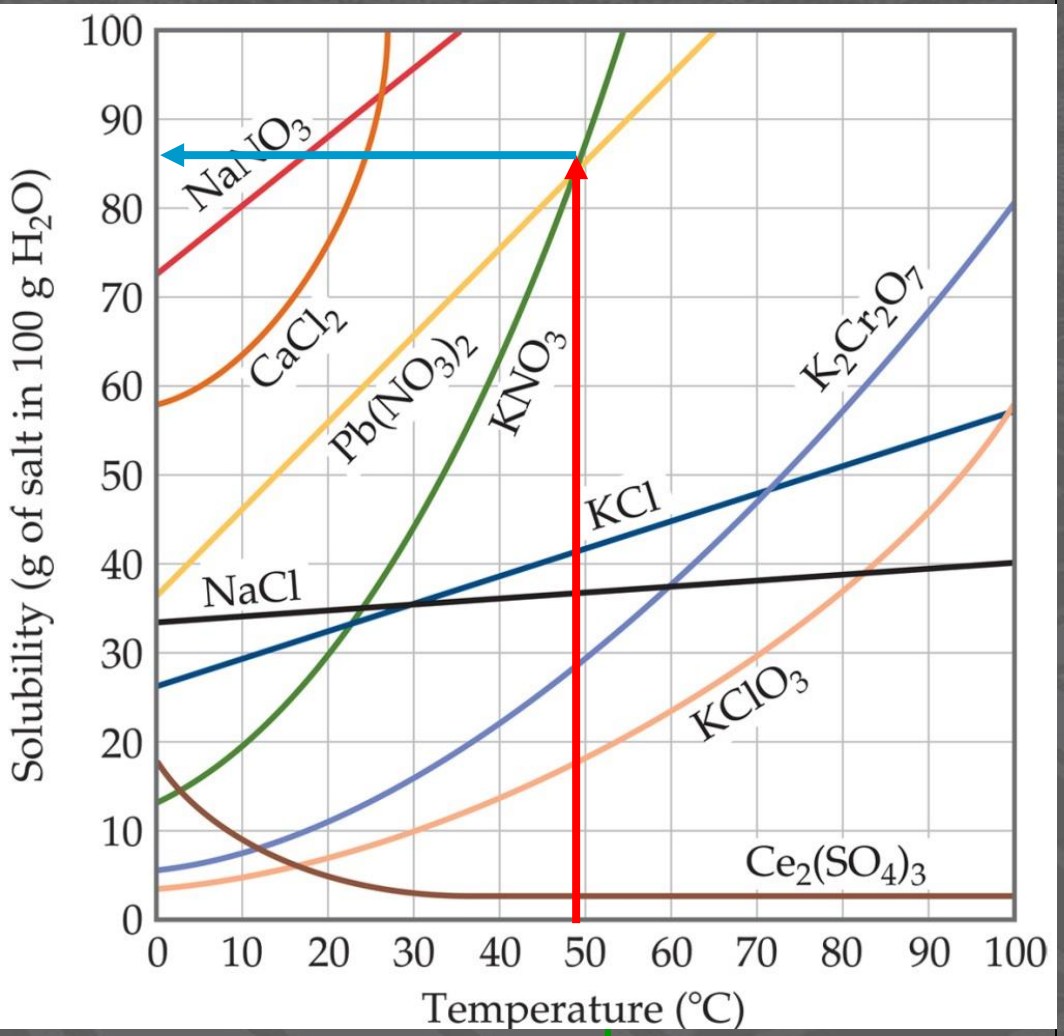
Solubility Curves



Generally, the solubility of **solid** solutes in liquid solvents increases with increasing temperature.



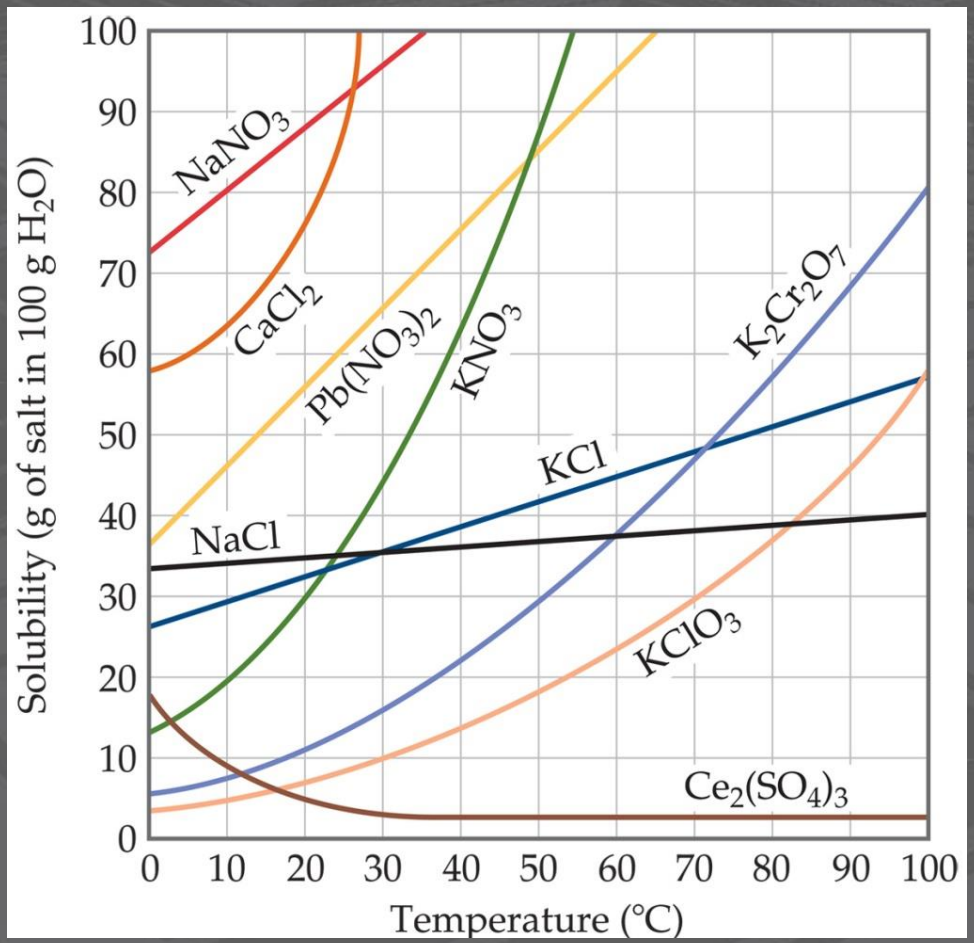
To read the graph, find the line for the substance. The amount that dissolves at a given temperature is on the y- axis.



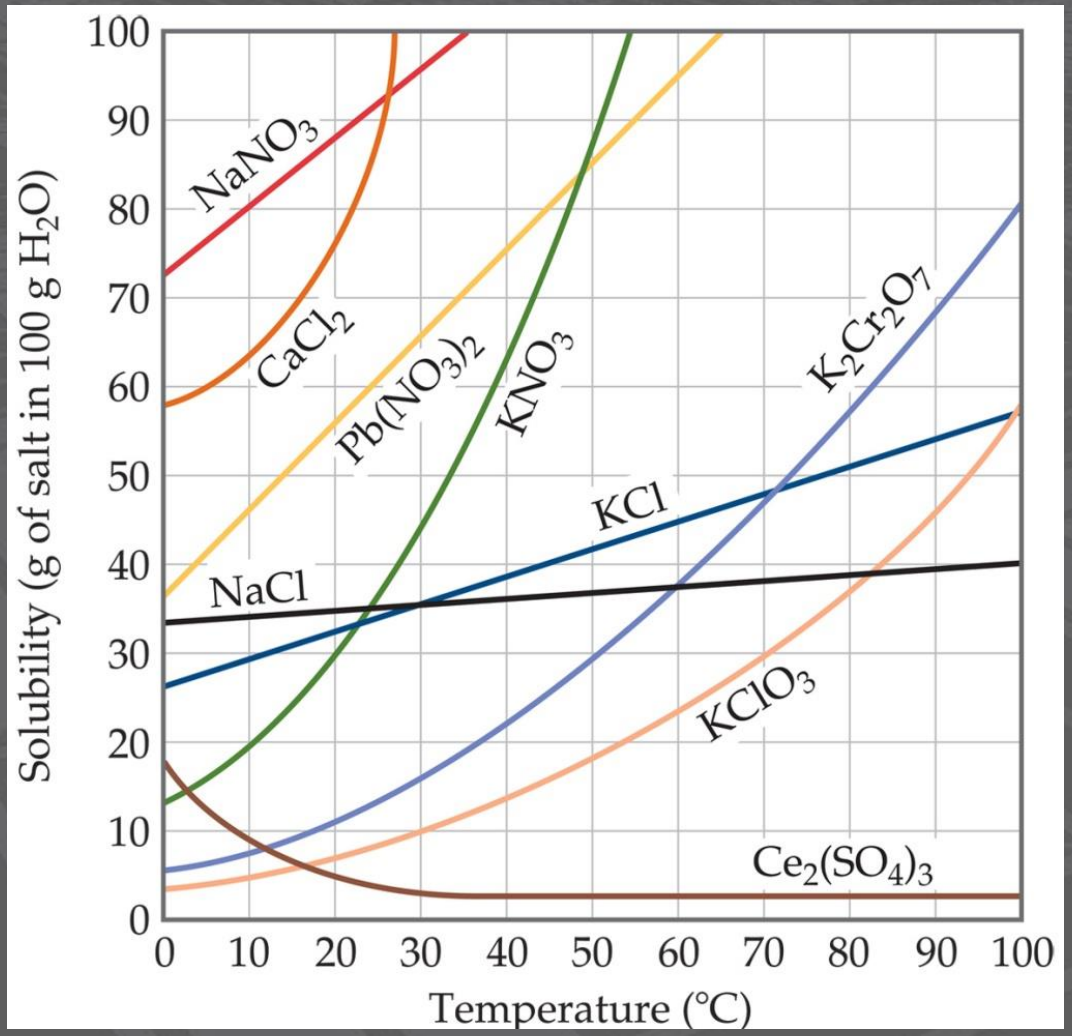
How much KNO_3 dissolves in 100g (or 100mL H_2O at 50°C?

1. Find the line (green)
2. Find the temperature and follow up to the line.(red arrow)
3. Read across to the y-axis and this is the answer. (blue arrow)
4. Since it is more than $\frac{1}{2}$-way between 80 and 90, it is 87.

- A point on the line is a ***saturated*** solution.
- Above the line is ***supersaturated***.
- Below the line is ***unsaturated***.



Using Solubility Curves



What is the solubility of $NaNO_3$ in 100 g of H_2O at 0°C?

73g $NaNO_3$

How many grams of KNO_3 will dissolve in 200g of H_2O at 45°C?

$$\frac{75\text{g}}{100\text{g } H_2O} = \frac{?}{200\text{g } H_2O}$$

= 150 g KNO_3

How much water is needed to dissolve 190g of $NaNO_3$ at 30°C?

$$\frac{95\text{g}}{100\text{g } H_2O} = \frac{190\text{g}}{?\text{ g } H_2O}$$

= 200 g H_2O

Molarity (M)

Molarity

- Molarity is the concentration of a solution expressed in moles of solute per Liter of solution.
- Molarity is a conversion factor for calculations

$$\text{Molarity (M)} = \frac{\text{moles of solute}}{\text{Liters of solution}}$$

Molarity

$$M = \frac{\text{mol (solute)}}{\text{L (solution)}}$$

- Example 1: What is the molarity of a solution that has 2.3 moles of sodium chloride in 0.45 liters of solution?

$$\frac{2.3 \text{ moles NaCl}}{0.45 \text{ L}} = 5.1M \text{ NaCl}$$

Molarity

$$M = \frac{\text{mol (solute)}}{\text{L (solution)}}$$

- Example 2: How many moles of Na_2CO_3 are there in 10.0 L of 2.0 M solution?

$$\frac{10.0\ \text{L}}{1} \left| \frac{2.0\ \text{mol } Na_2CO_3}{1\ \text{L}} \right. = 20.0\ \text{moles } Na_2CO_3$$

Molarity

$$M = \frac{\text{mol (solute)}}{\text{L (solution)}}$$

- Example 3: How many moles of KNO_3 are needed to make 450. mL of 1.5 molar solution?

$$\frac{450.\text{ mL}}{1} \left| \frac{1\text{L}}{1000\text{mL}} \right| \frac{1.5\text{ mol } KNO_3}{1\text{L}}$$

$$= .675 \text{ moles } KNO_3$$

Molarity

$$M = \frac{\text{mol (solute)}}{\text{L (solution)}}$$

- Example 4: How many grams of NaCl are needed to make 3.0 L of 1.5 M solution?

$$\frac{3.0\ \text{L}}{1} \left| \frac{1.5\ \text{mol NaCl}}{1\ \text{L}} \right| \frac{58.44\ g\ \text{NaCl}}{1\ \text{mol NaCl}}$$

$$= 260\ g\ \text{NaCl}$$

Molarity

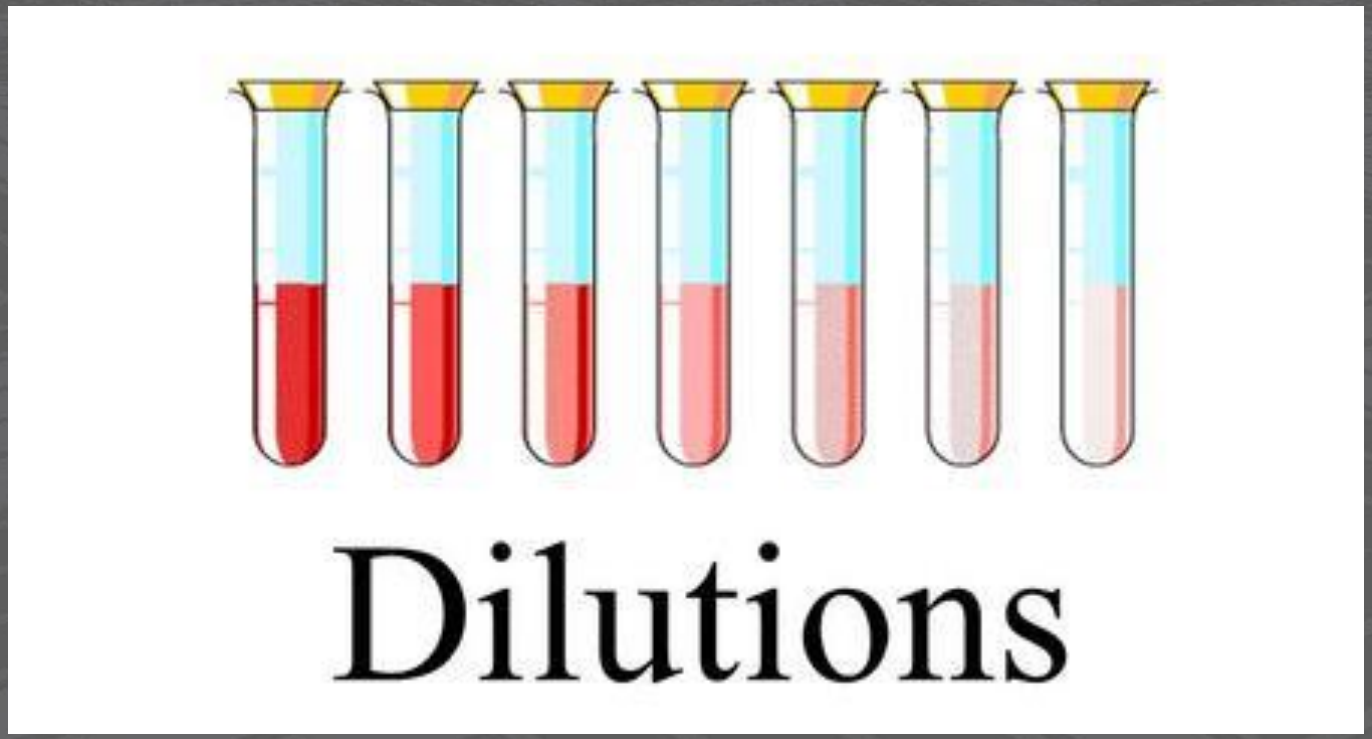
$$M = \frac{\text{mol (solute)}}{\text{L (solution)}}$$

- Example 5: How many L of 4.0 M solution can be made with 132g of NaCl ?

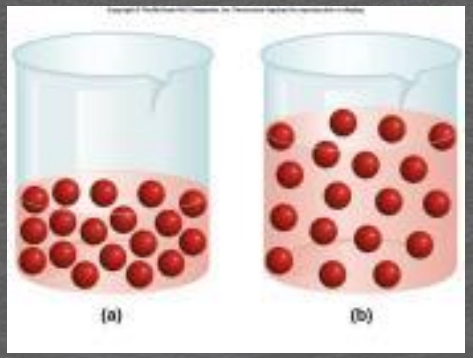
$$\frac{132\text{ g NaCl}}{1} \left| \frac{1\text{ mol NaCl}}{58.44\text{ g NaCl}} \right| \frac{1\text{ L}}{4.0\text{ mol NaCl}}$$

$$= .565\text{ L}$$

Dilutions



Dilutions and Molarity



- Use this formula to make a more dilute solution from a concentrated solution

$Molarity_1 \times Volume_1 = Molarity_2 \times Volume_2$

(Concentrated) (Dilute)

(before) = (after)

$$M_1V_1 = M_2V_2$$

Example 1

How many liters of 2.5 M HCl are required to make 1.5 L of 1.0 M HCl?

$$M_1V_1 = M_2V_2$$

$M_1 = 2.5\ M$

$V_1 = ?$

$M_2 = 1.0\ M$

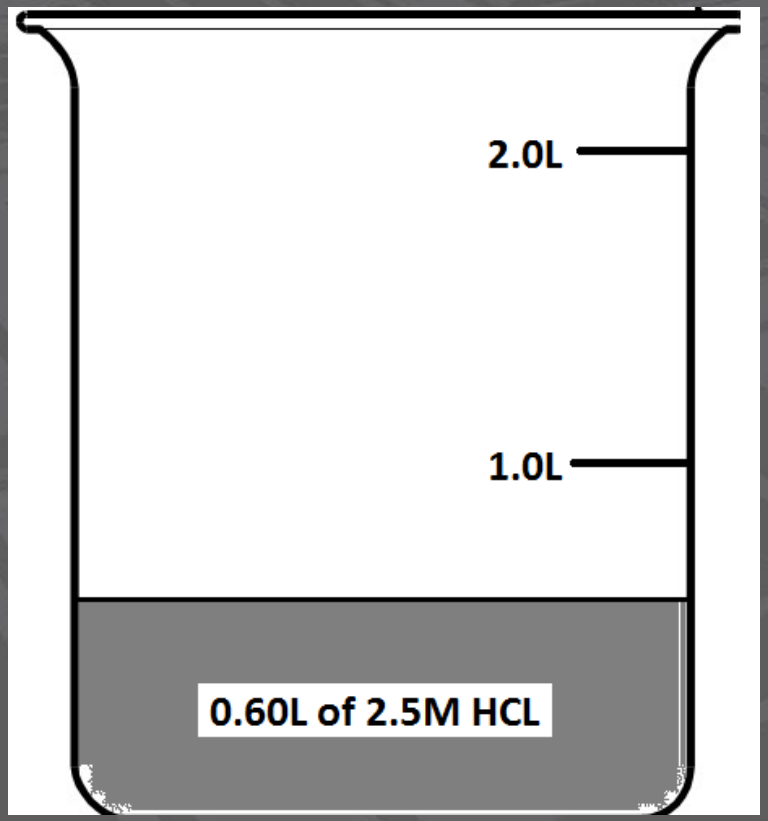
$V_2 = 1.5\ L$

$$\frac{(2.5M)\ V_1}{2.5M} = \frac{(1.0M)\ (1.5\ L)}{2.5M} = 0.60L$$

Example 1

M_1 = 2.5M V_1 = 0.60L M_2 = 1.0 M V_2= 1.5 L

How much water should you add to the volume of 2.5M HCl you calculated above to make the solution? (draw this in your notes)

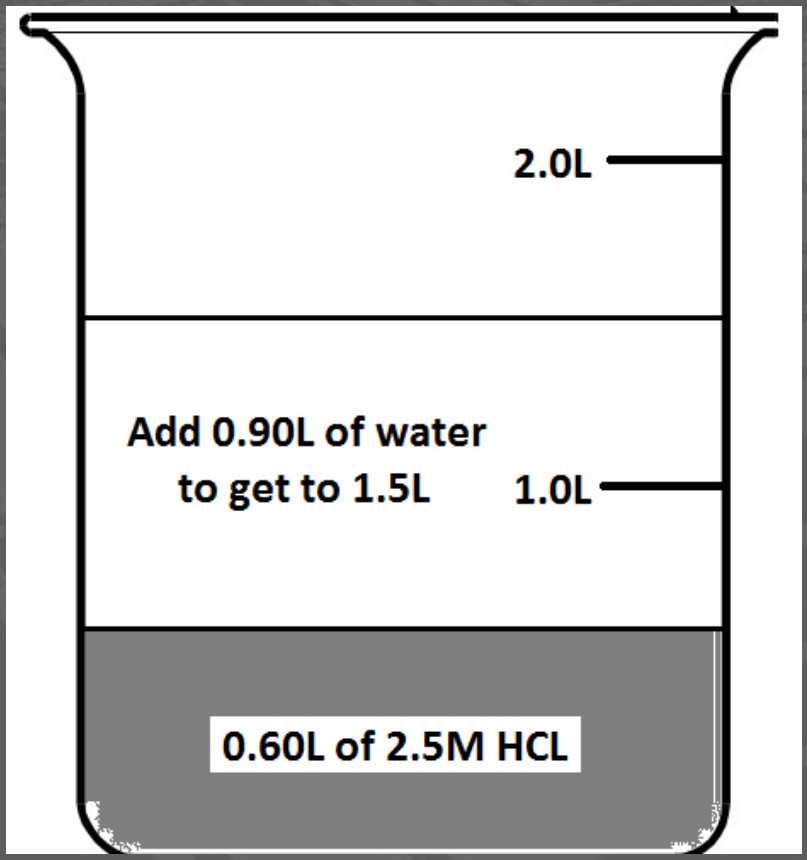


1st add .60L of HCl to measuring device.

Example 1

M_1 = 2.5M V_1 = 0.60L M_2 = 1.0 M V_2= 1.5 L

How much water should you add to the volume of 2.5M HCl you calculated above to make the solution?



Then add enough water to get to 1.5L of solution

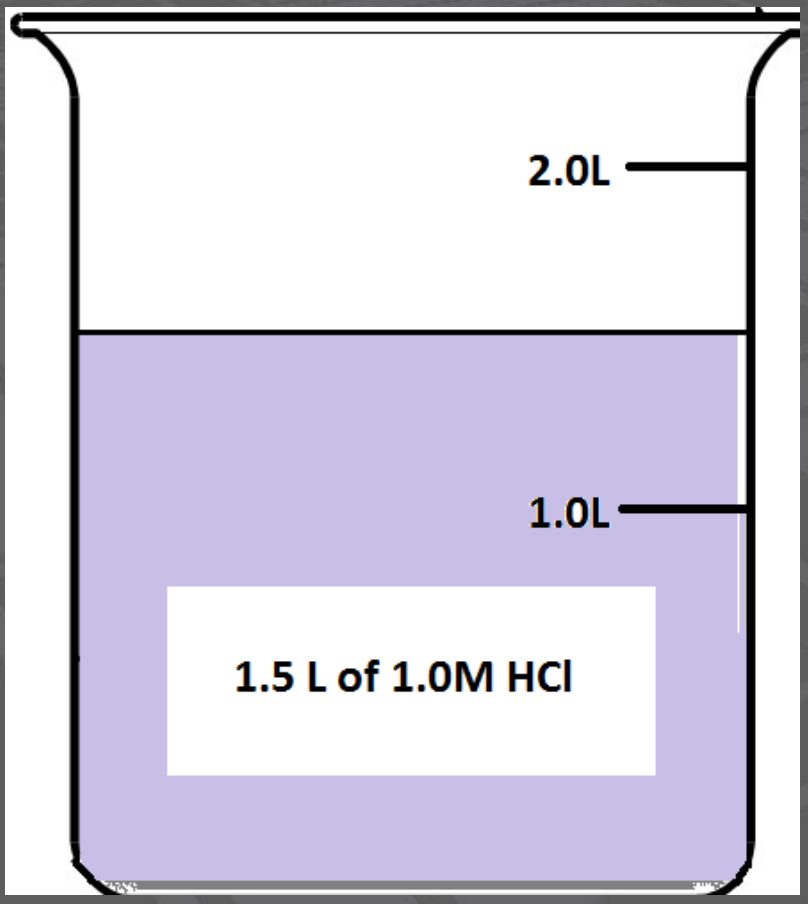
$V_2 - V_1$ = Amount of water

1.5L – 0.60L = 0.90L water

Example 1

M_1 = 2.5M V_1 = 0.60L M_2 = 1.0 M V_2= 1.5 L

How much water should you add to the volume of 2.5M HCl you calculated above to make the solution?



Final solution is 1.5L of 1.0M HCl

Example 2

- 250.0 mL of a 0.500 M HCl solution needs to be made from concentrated HCl. What volume of the concentrated solution is needed if its molarity is 12.0 M?

$$M_1V_1 = M_2V_2$$

M_1 =

V_1 =

M_2 =

V_2 =

Example 2

- 250.0 mL of a 0.500 M HCl solution needs to be made from concentrated HCl. What volume of the concentrated solution is needed if its molarity is 12.0 M?

$$M_1V_1 = M_2V_2$$

M_1 = 12.0M
V_1 = 10.4mL
M_2 = 0.500M
V_2 = 250.0mL

How much water would you add to make the final solution?

250.0mL - 10.4mL = 239.6mL

Mass Percent

Mass Percent

- Solutions can also be represented as percent of solute in a specific mass of solution.
- For a solid dissolved in water, you use percent by mass which is Mass Percent.
- $$\% \text{ by mass} = \frac{\text{mass solute}}{\text{mass of solution}} \times 100$$

**Mass of solution = solute mass + solvent mass

Example 1

- If a **solution** that has a mass of 800.0 grams contains 20.0 grams of NaCl, what is the concentration using **Percent by Mass**?

$$\% \text{ by mass} = \frac{\text{mass solute}}{\text{mass of solution}} \times 100$$

$$\% \text{ by mass} = \frac{20.0\text{g NaCl}}{800.0\text{g solution}} \times 100$$

$$= 2.50\% \text{ NaCl}$$

Example 2

- If 10.0 grams of NaCl is dissolved in 90.0 grams of **water**, what is the concentration using **Percent by Mass**?

$$\% \text{ by mass} = \frac{\text{mass solute}}{\text{mass of solution}} \times 100$$

$$\% \text{ by mass} = \frac{10.0\text{g NaCl}}{100.0\text{g solution}} \times 100 = 10.0\%\text{NaCl}$$

Example 3

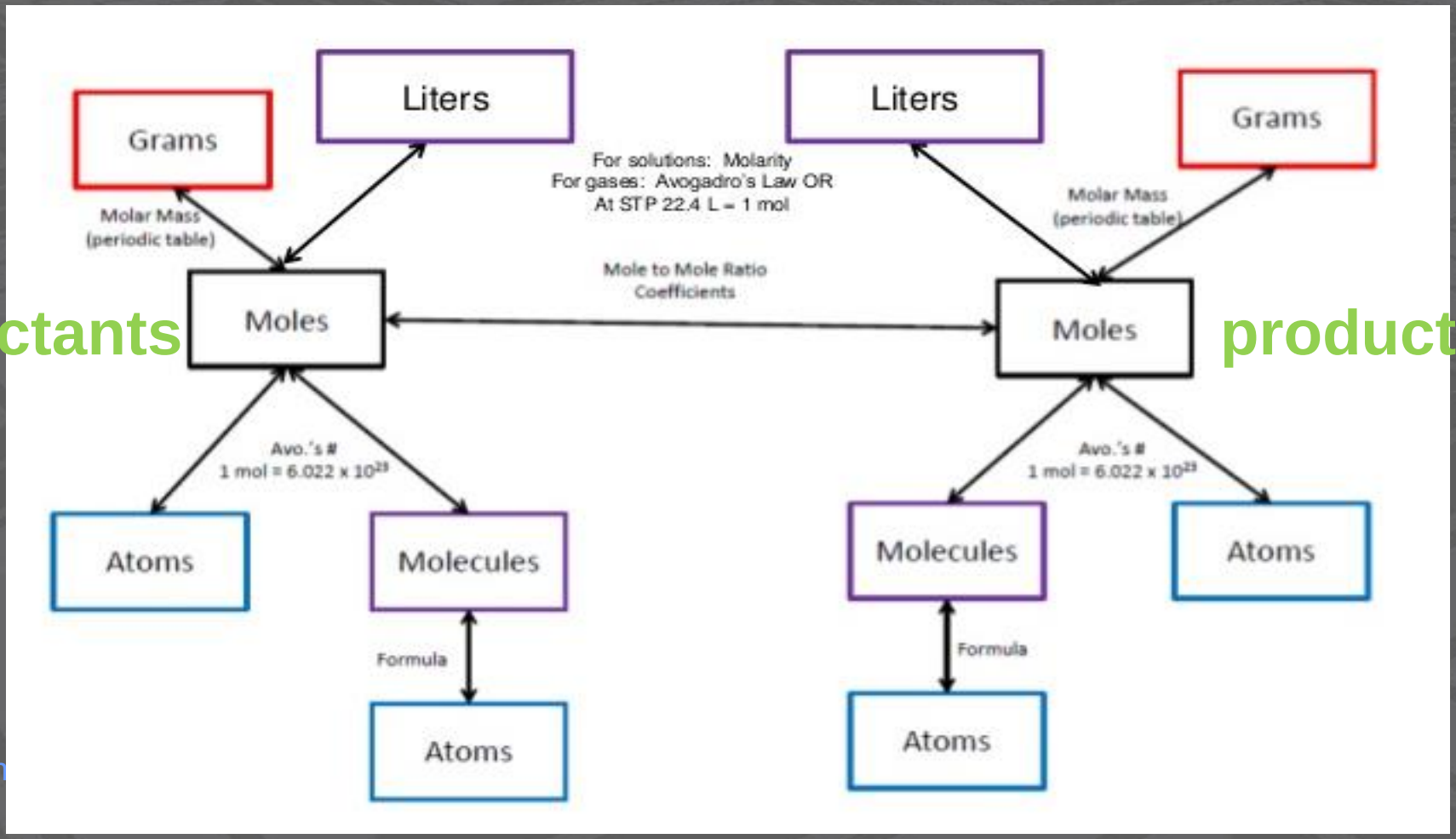
- How many grams of sodium bromide are in 200.0g of solution that is 15.0% sodium bromide by mass?

$$\% \text{ by mass} = \frac{\text{mass solute}}{\text{mass of solution}} \times 100$$

$$\% \text{ by mass} = \frac{?\ g\ NaBr}{200.0g\ \text{solution}} \times 100 = 15.0\%NaBr$$

$$g\ NaBr = \frac{200.0 \times 15.0}{100} = 30\ g\ NaBr$$

Solution Stoichiometry



Solution Stoichiometry

- When we previously did stoichiometry for a reaction to determine theoretical yield, we only worked with GRAMS and MOLES
- Ex/ How many MOLES of HCl are required to react with 13 GRAMS of zinc?

$$Zn + 2\,HCl \rightarrow ZnCl_2 + H_2$$

Solution Stoichiometry

- But we may be given something OTHER than grams and moles

- We can use stoichiometry to solve for ANY unit. We just need to make sure units cancel out and we end up with the unit we are trying to solve for!

- The mole ratio using coefficients from the balanced chemical equation is the key to switching between compounds

Solution Stoichiometry

Ex/ How many LITERS of 12 M HCl are required to react with 13.0 GRAMS of zinc?

$$Zn + 2\,HCl \rightarrow ZnCl_2 + H_2$$

$$\frac{13.0\text{g Zn}}{1} \left| \frac{1\text{ mole Zn}}{65.38\text{g Zn}} \right| \frac{2\text{ mol HCl}}{1\text{ mol Zn}} \left| \frac{1\text{L HCl}}{12\text{ mol HCl}} \right.$$

Remember – Molarity (M) is a conversion Factor

= 0.0331 L HCl

Solution Stoichiometry

- Ex/ How many grams of NaOH would be required to react with 1.50 L of 3.75M sulfuric acid?

$H_2SO_4 + NaOH \rightarrow Na_2SO_4 + H_2O$

$$\frac{1.50\text{L } 1\ H_2SO_4}{1} \left| \frac{3.75\text{ mole } H_2SO_4}{1\text{ L } H_2SO_4} \right| \frac{2\text{ mol NaOH}}{1\text{ mole } H_2SO_4} \left| \frac{40.00\text{g NaOH}}{1\text{ mol NaOH}} \right.$$

$= 450.\ g\ NaOH$