Unit 2

Water and Solutions

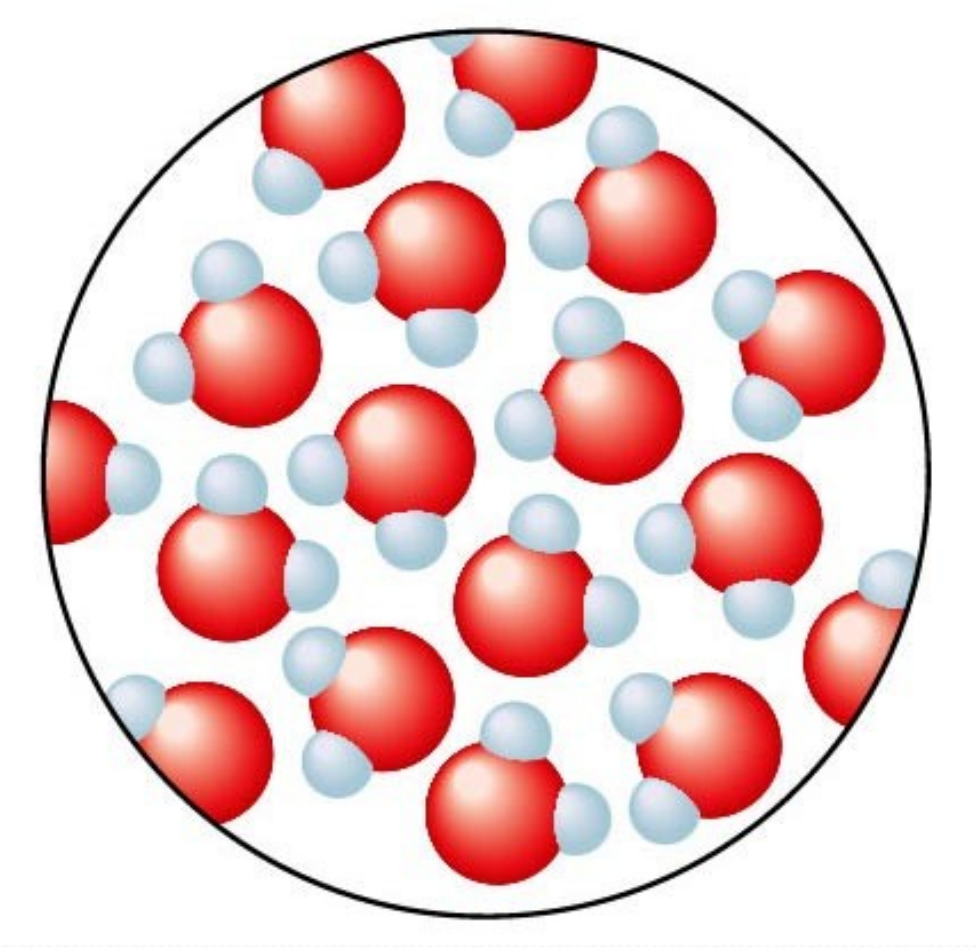
Water and Heterogeneous systems

Objectives:

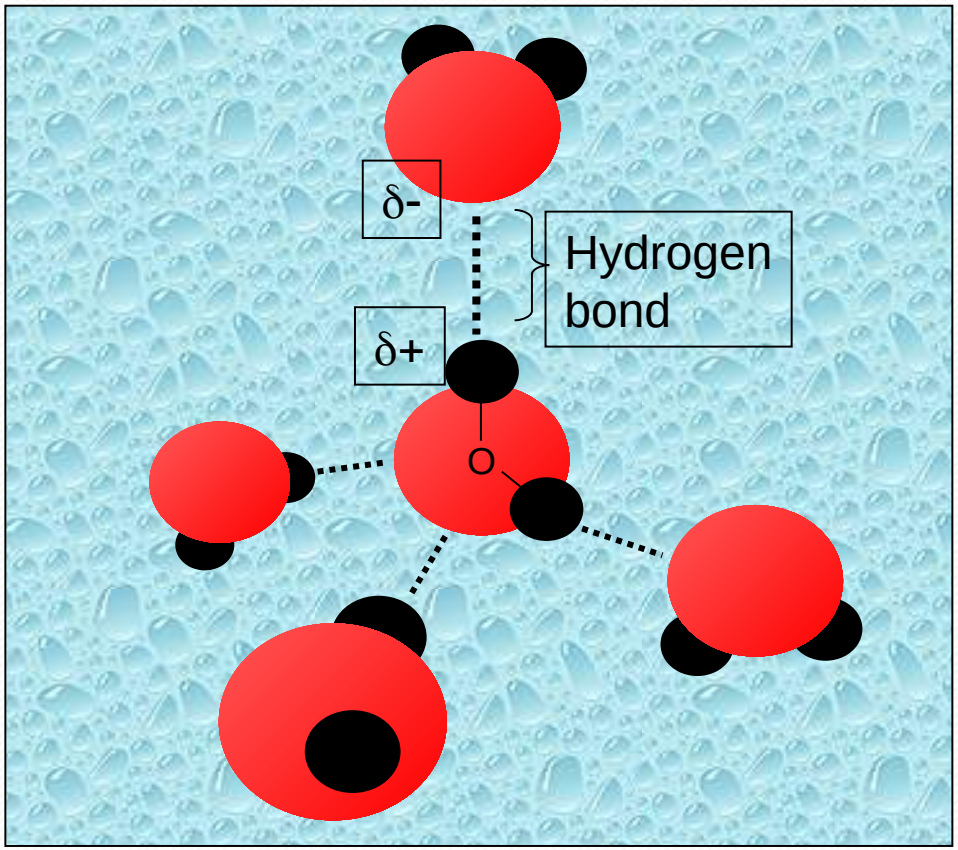
1. Explain surface tension
2. Describe the structure of ice and liquid water.
3. Distinguish between a suspension and a solution
4. Identify the characteristics of a colloid.

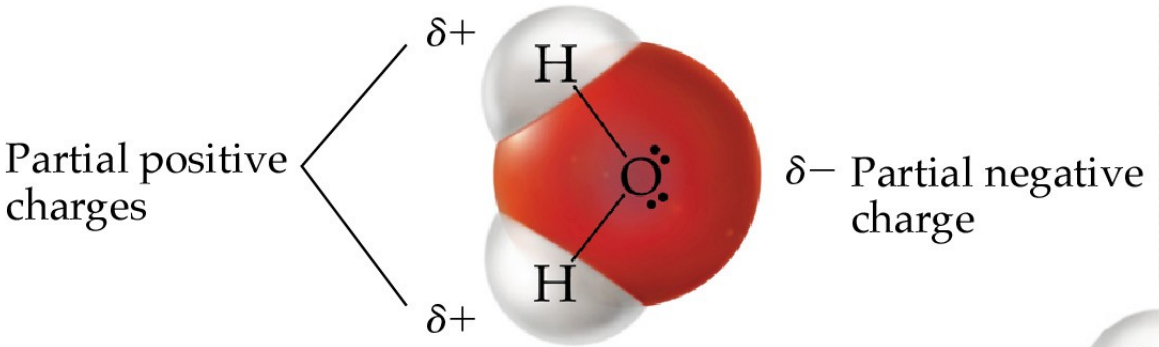
- Water in the liquid state:
  - Water is a polar molecule.

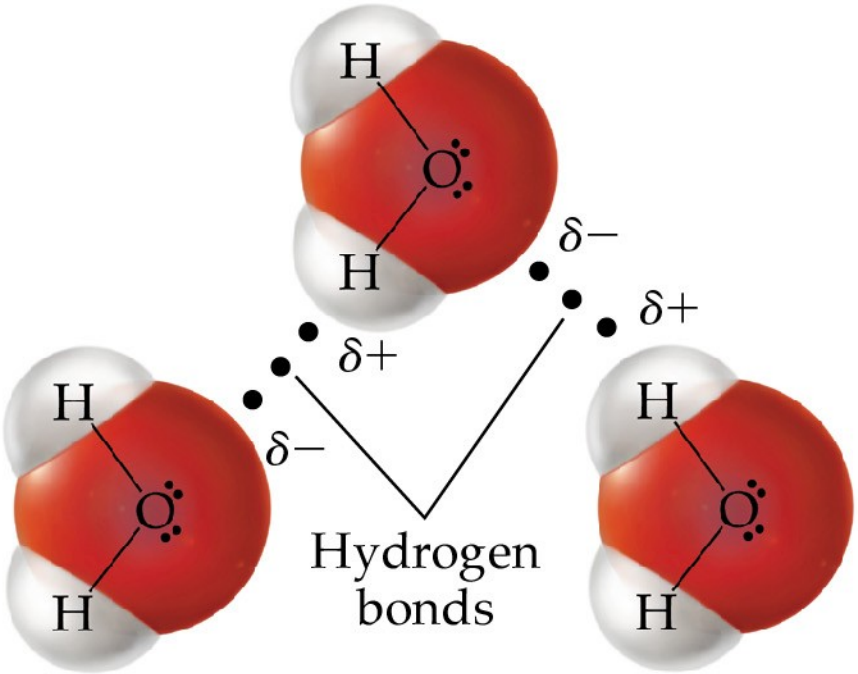
$\delta+$ H_2O $\delta-$



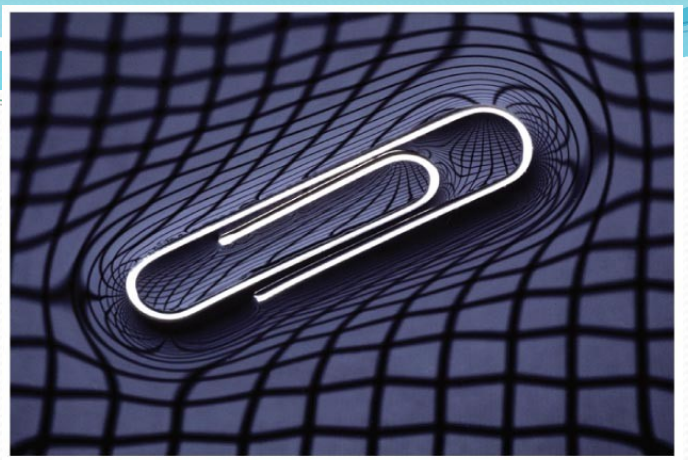
- Hydrogen bonding: the negative end of the water molecule is attracted to the positive ends of other molecules- resulting in hydrogen bonding.

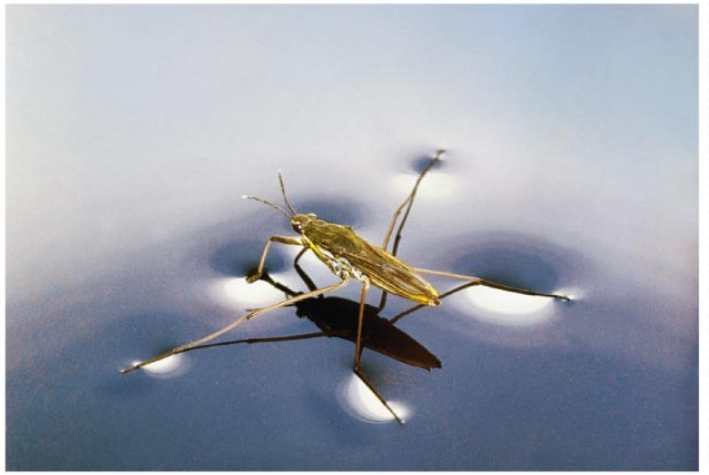



Partial positive charges
δ+
δ+
H
O
H
δ− Partial negative charge


H
O
H
δ−
δ+
δ+
δ−
H
O
H
H
O
H
Hydrogen bonds

Water molecules “stick” together to create **surface tension** to support light weight objects.
It also tends to hold a drop of a liquid in a spherical shape.





Surfactants interfere with hydrogen bonding reducing surface tension.

This attraction between water molecules slows the tendency of water evaporation.

What_s_So_Special_About_Water_.asf

- Suspensions: a mixture from which particles settle out upon standing.
  - Have very large particles
  - Can be filtered
  - Ex. Muddy water

    some medicines (antibiotics)

Suspensions.asf

- Colloids
  - Have medium sized particles
  - Can not be filtered.
  - Many colloids are cloudy or milky in appearance.
  - Show Tyndall effect (the path of light is visible)
  - Colloids.asf

Types of colloids

Colloid type	Dispersion medium	Dispersed substance	Examples
Aerosol	Gas	Liquid	
Aerosol	Gas	Solid	
	Liquid	Gas	
	Liquid	Liquid	
	Liquid	Solid	
	Solid	Gas	
Solid emulsion	Solid	Liquid	
	Solid	Solid	

Types of colloids

Colloid type	Dispersion medium	Dispersed substance	Examples
Aerosol	Gas	Liquid	Clouds, fog,aerosol spray
Aerosol	Gas	Solid	Smoke, dust
Foam	Liquid	Gas	Shaving cream, whipped cream
Emulsion	Liquid	Liquid	Mayonaisse, milk
Sol	Liquid	Solid	Paint, ink
Solid aerosol	Solid	Gas	Marshmallow

Classwork: Complete the table on the last slide, giving examples for the different types of colloids.

Solutions

- Objectives:
  - Distinguish between a solvent and a solute
  - Describe what happens in the solution process
  - Explain what electrolytes are.
  - Identify the factors that determine the **rate** at which a solute *dissolves*.
  - Identify the factors that determine the mass of solute that *will dissolve* in a given mass of solvent.

Definitions

- **Solution -** homogeneous mixture

  Solute - substance being dissolved

  Solvent - present in greater amount

  Aqueous (*water)*
  Tincture (*alcohol*)
  Amalgam (*mercury*)
  Organic Polar or Non-polar

Dental filling

Solution = Solute + Solvent

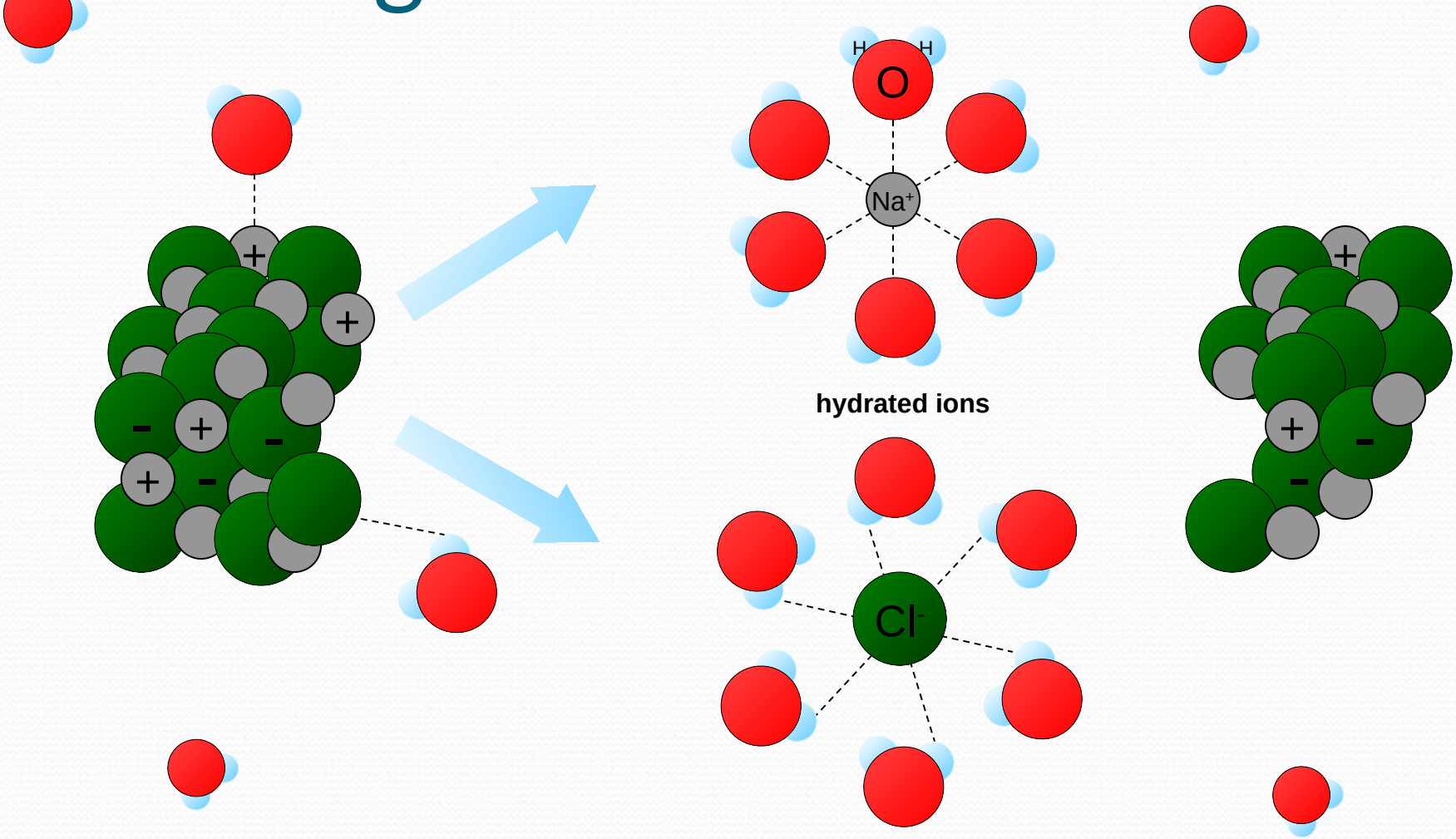
Types of Solutions

Solute	Solvent	Solution
Gaseous Solutions		
gas	gas	air (nitrogen, oxygen, argon gases)
liquid	gas	humid air (water vapor in air)
Liquid Solutions		
gas	liquid	carbonated drinks (CO_2 in water)
liquid	liquid	vinegar (CH_3COOH in water)
solid	liquid	salt water (NaCl in water)
Solid Solutions		
liquid	solid	dental amalgam (Hg in Ag)
solid	solid	sterling silver (Cu in Ag), alloys

Charles H.Corwin, Introductory Chemistry 2005, page 369

- **Solvation –** the process of dissolving:
  - solute particles are surrounded by solvent particles
  - solute particles are separated and pulled into solution
- **Solution formation-** The polarity or composition of the solute and the solvent will determine…Whether a substance *will dissolve and* how *much*

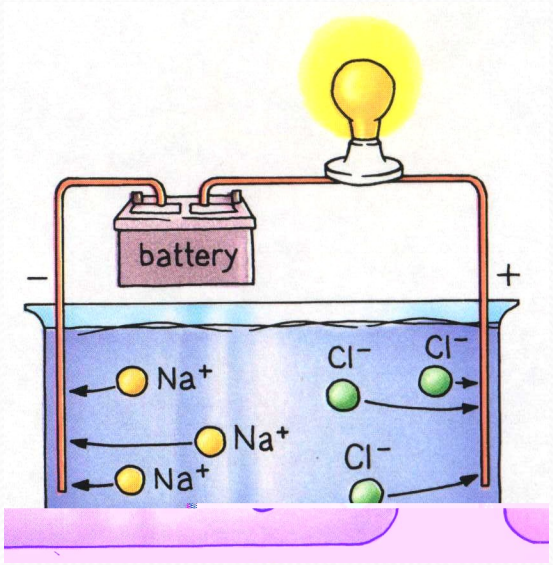
Dissolving of NaCl



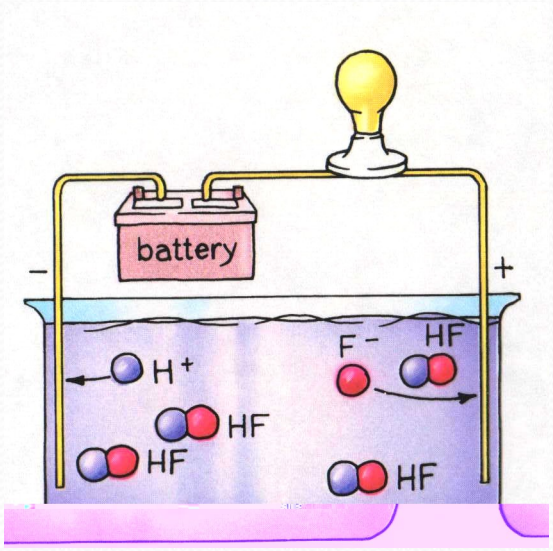
Timberlake, Chemistry 7th Edition, page 287

Electrolytes

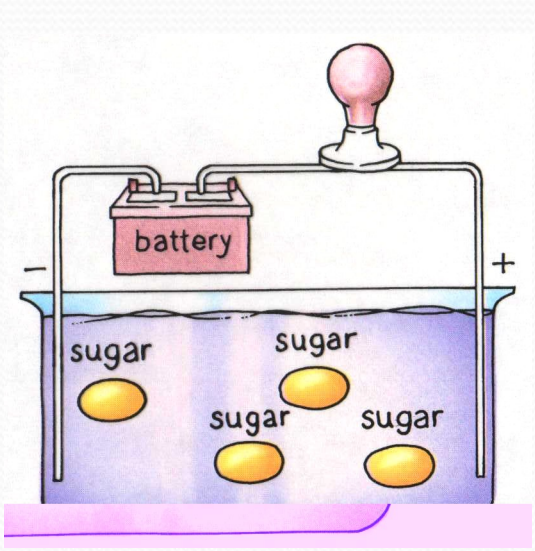
Electrolytes - solutions that carry an electric current



strong electrolyte



weak electrolyte



nonelectrolyte

$NaCl(aq) \rightarrow Na^+ + Cl^-$

$HF(aq) \rightleftharpoons H^+ + F^-$

Timberlake, Chemistry 7th Edition, page 290

Factors determining rate of solution…

1. Stirring (agitation) moves fresh solvent into contact with the solute.
2. Smaller pieces increases the amount of surface area of the solute.
3. Higher temperature increases the rate molecules of the solvent *move faster;* speeds up dissolving.
   - *Higher Temperature* ***ALSO*** *Usually* increases the amount that will dissolve (an exception is gases).

LIQUIDS

- Miscible means that two liquids can dissolve in each other
  - water and antifreeze
  - water and ethanol
- Partially miscible- slightly
  - water and ether
- Immiscible means they can’t
  - oil and vinegar

Solids **tend to dissolve best when:**

- They are heated
- They are stirred
- Crushed into smaller particles

Gases **tend to dissolve best when:**

- The solution is cold
- The pressure is high
- **Thermal pollution** may result from industry using water for cooling

- **Solubility- is the maximum amount of substance that will dissolve at a specific temperature. The units for solubility are: grams of solute/100 grams solvent**

1) **Saturated solution-** Contains the *maximum* amount of solute dissolved. *NaCl = 36.0 g/100 mL water*
2) **Unsaturated solution-** Can still dissolve more solute *(for example 28.0 grams of NaCl/100 mL)*
3) **Supersaturated-** solution that is holding (or dissolving) more than it theoretically can; Very unstable, can crystalize.

Factors Affecting Solubility

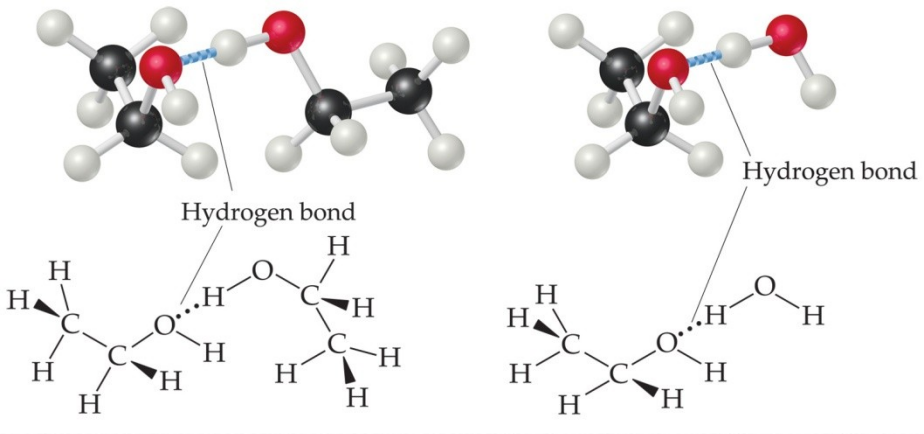
- Chemists use the axiom “like dissolves like”:
  - Polar substances tend to dissolve in polar solvents.
  - Nonpolar substances tend to dissolve in nonpolar solvents.

TABLE 13.3 Solubilities of Some Alcohols in Water and in Hexane*

Alcohol	Solubility in H_2O	Solubility in C_6H_{14}
CH_3OH (methanol)	∞	0.12
CH_3CH_2OH (ethanol)	∞	∞
$CH_3CH_2CH_2OH$ (propanol)	∞	∞
$CH_3CH_2CH_2CH_2OH$ (butanol)	0.11	∞
$CH_3CH_2CH_2CH_2CH_2OH$ (pentanol)	0.030	∞
$CH_3CH_2CH_2CH_2CH_2CH_2OH$ (hexanol)	0.0058	∞
$CH_3CH_2CH_2CH_2CH_2CH_2CH_2OH$ (heptanol)	0.0008	∞

*Expressed in mol alcohol/100 g solvent at 20°C. The infinity symbol indicates that the alcohol is completely miscible with the solvent.

Factors Affecting Solubility



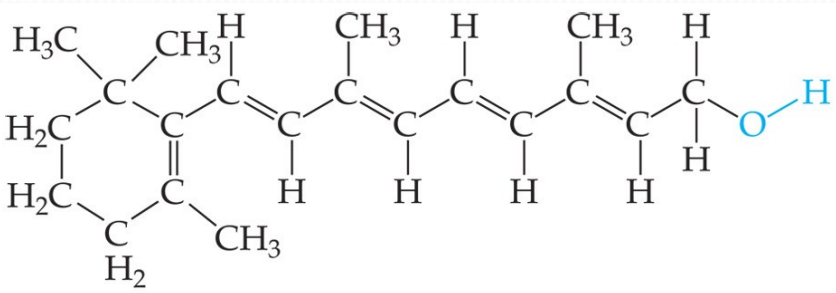
Example: ethanol in water

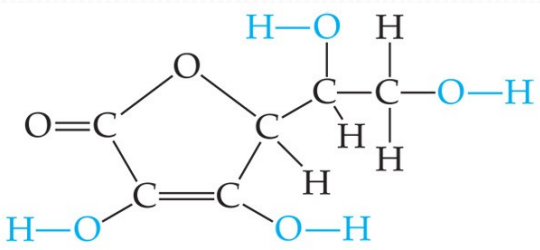
Ethanol = CH_3CH_2OH

The stronger the intermolecular attractions between solute and solvent, the more likely the solute will dissolve.

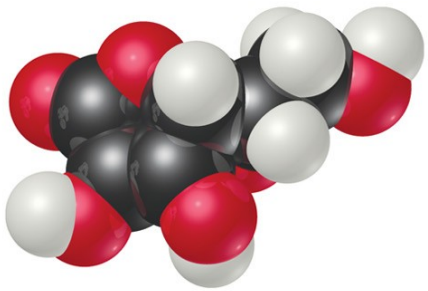
Factors Affecting Solubility

- Vitamin A is soluble in nonpolar compounds (like fats).
- Vitamin C is soluble in water.



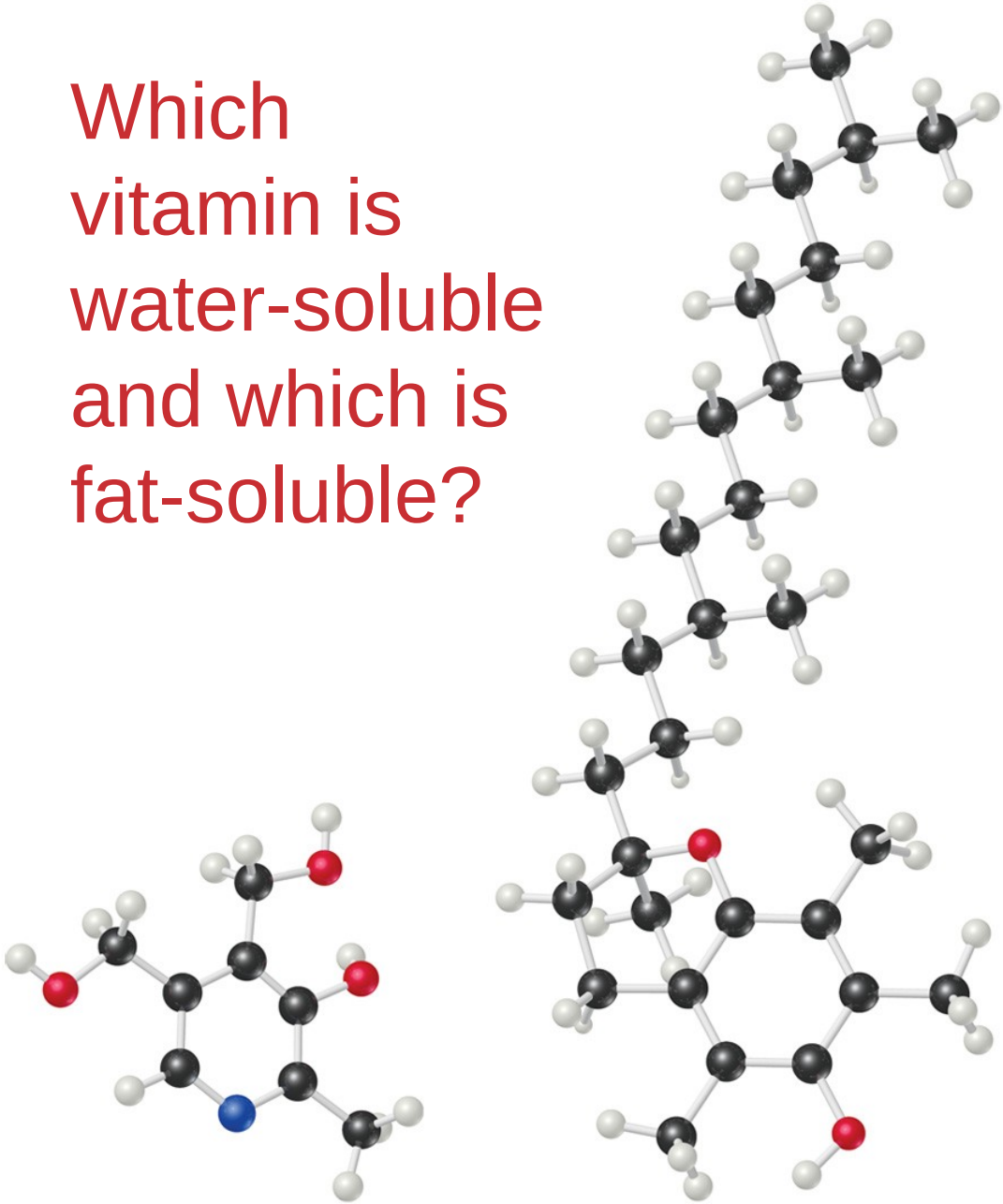


Vitamin A



Vitamin C

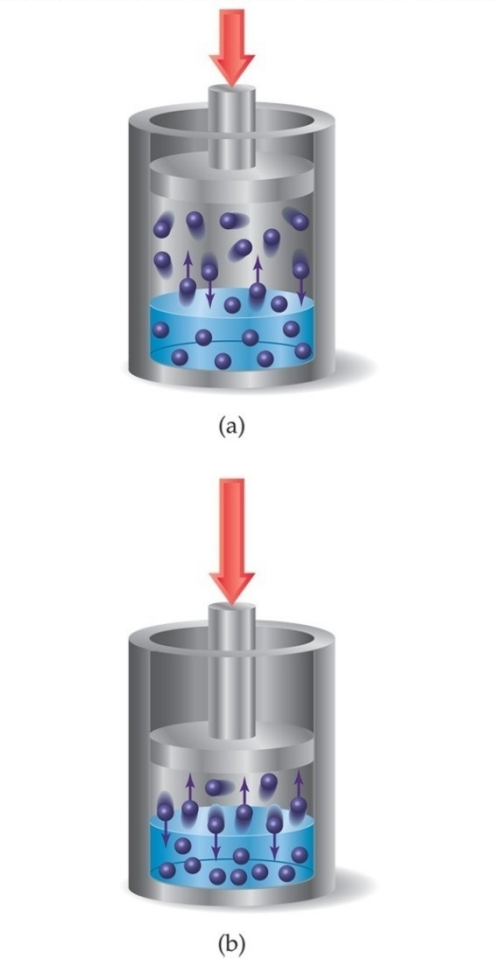
Which vitamin is water-soluble and which is fat-soluble?



Vitamin B_6 Vitamin E

Gases in Solution

Increasing pressure above solution forces more gas to dissolve.



- The solubility of **liquids** and **solids** does not change appreciably with pressure.
- But, the solubility of a **gas** in a liquid is directly proportional to its pressure.

Temperature and Solubility of Solids

Temperature	Solubility (g/100 g H_2O)	
	KCl(s)	
$NaNO_3$(s)		
0°	27.6	74
20°C	34.0	88
50°C	42.6	114
100°C	57.6	182

The solubility of most solids (decreases or in creases)with an increase in the temperature.

Temperature and Solubility of Gases

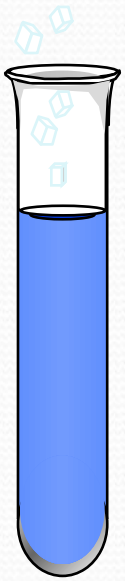
Temperature	Solubility (g/100 g H_2O)	
	$CO_2(g)$	$O_2(g)$
0°C	0.34	0.0070
20°C	0.17	0.0043
50°C	0.076	0.0026

The solubility of gases (decreases or increases) with an increase in temperature.

Solubility

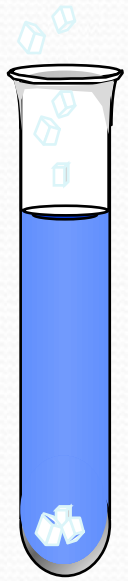
UNSATURATED SOLUTION

more solute dissolves



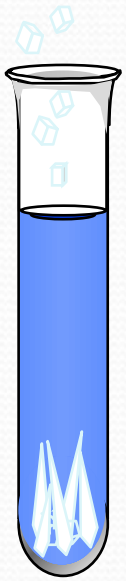
SATURATED SOLUTION

no more solute dissolves



SUPERSATURATED SOLUTION

becomes unstable, crystals form



increasing concentration

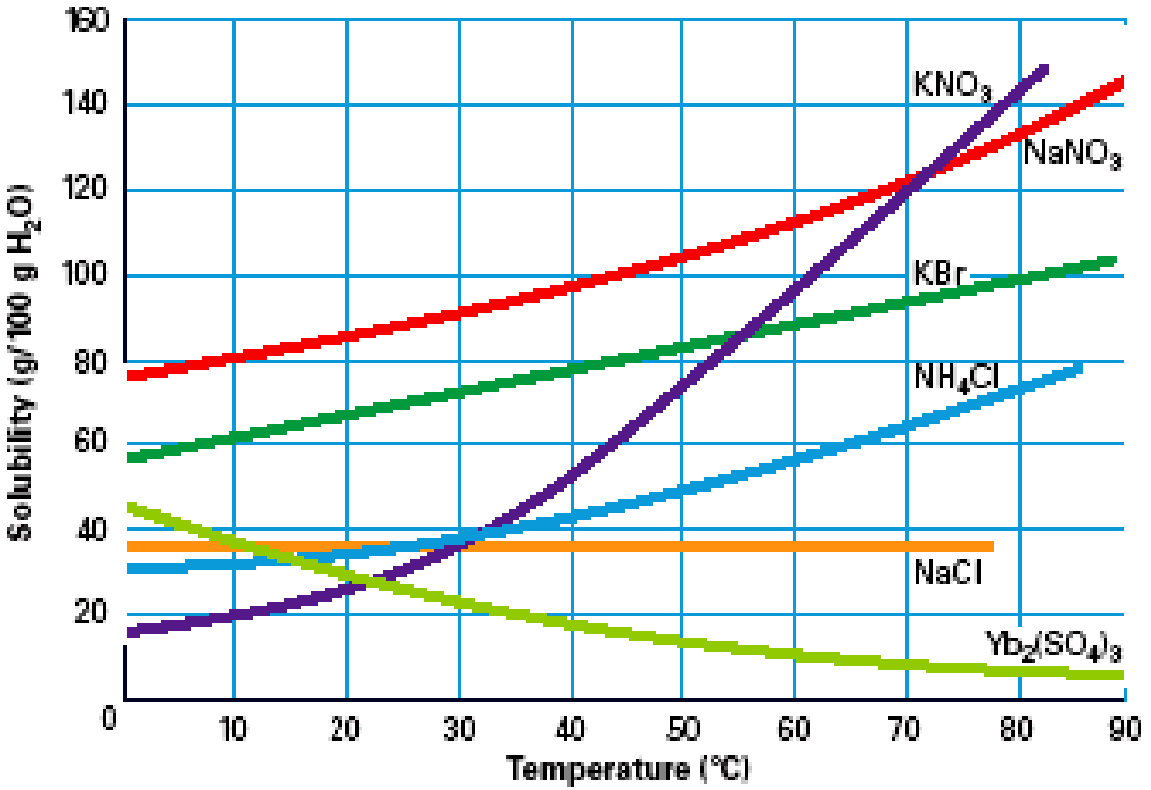
Figure 16.4 Interpreting Graphs

INTERPRETING GRAPHS

a. Describe What happens to the solubility of KNO_3 as the temperature increases?

b. Identify Which substance shows a decrease in solubility as temperature increases? Which substance exhibits the least change in solubility?

c. Apply Concepts Suppose you added some solid sodium chloride (NaCl) to a saturated solution of sodium chloride at 20°C and warmed the mixture to 40°C. What would happen to the added sodium chloride?



a) 80g $NaNO_3$ at 45˚C. The solution is ? unsaturated

b) 100g $NaNO_3$ at 45˚C. The solution is ?

saturated

c) 120g $NaNO_3$ at 45˚C. The solution is ?

supersaturated

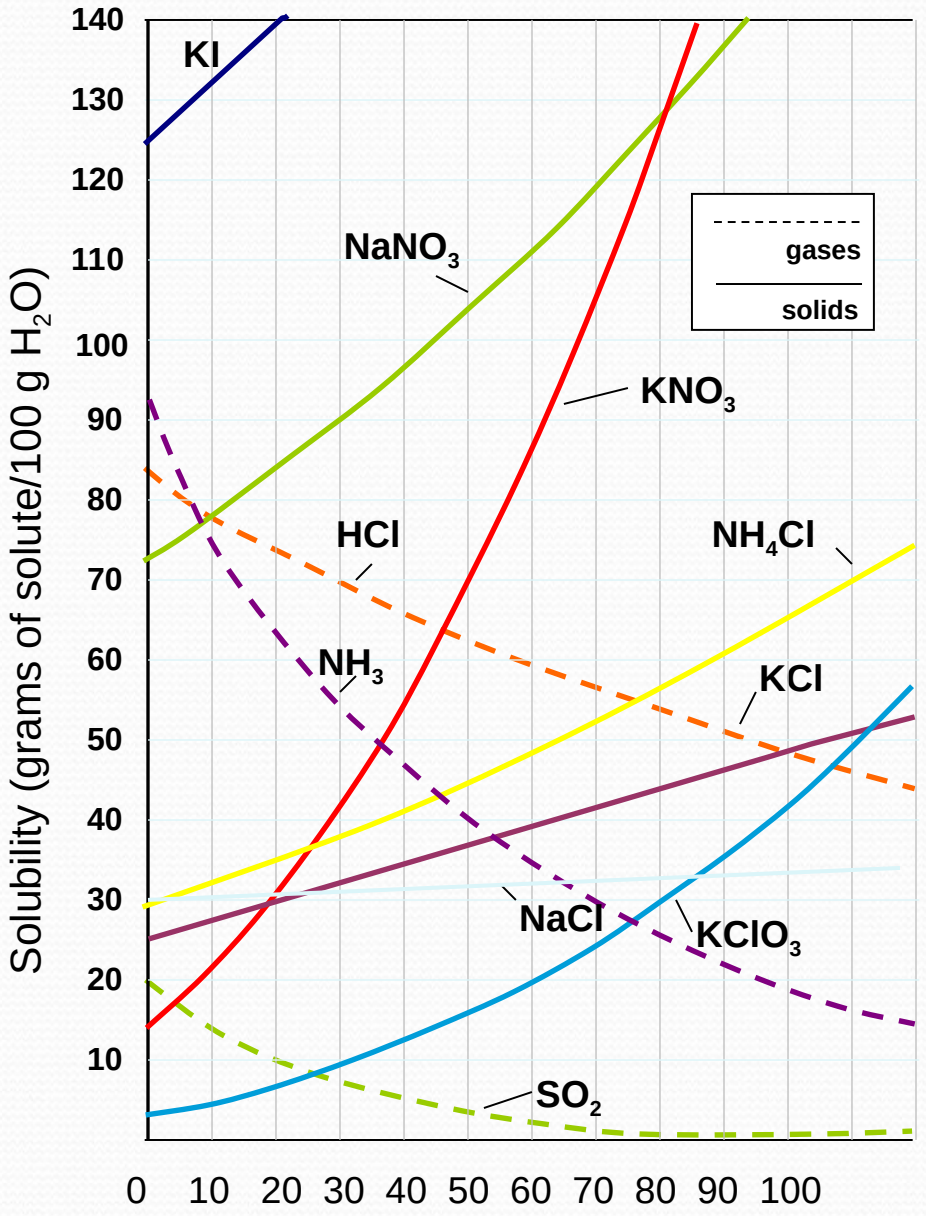
d) How much more $NaNO_3$ can you add to a solution with 40g of $NaNO_3$ at 45˚C until it becomes saturated?

60 g

e) What is the solubility of NH_3 at 25˚C?

58 g

e) 100 g of water are saturated with $NaNO_3$ at 30˚C. If the solution is heated to 60˚C, how much more can be dissolved? 20 g

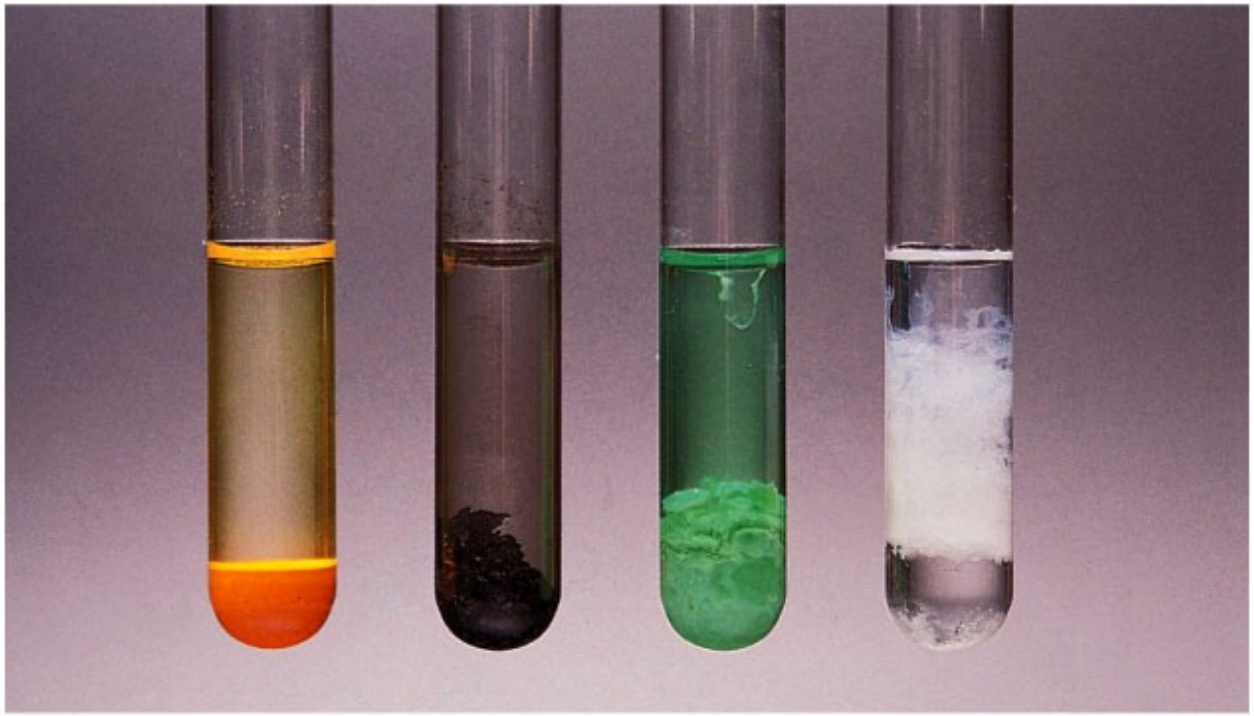


LeMay Jr, Beall, Robblee, Brower, Chemistry Connections to Our Changing World , 1996, page 517

Precipitation Reactions

- ***Precipitation Reaction-*** a reaction that results in the formation of an insoluble product.
- These reactions usually involve ionic compounds.
- Formation of PbI_2:
  - $Pb(NO_3)_{2(aq)} + 2KI_{(aq)} \rightarrow PbI_{2(s)} + 2KNO_{3(aq)}$

Precipitate



Precipitation Reactions

- How do you know whether or not a precipitate will form when a compound is added to a solution?
- By knowing the solubility of the solute!
- ***Solubility-*** The maximum amount of solute that will dissolve in a given quantity of solvent at a specific temperature.
- Three levels of solubility: Soluble, slightly soluble or insoluble.

Precipitation Reactions

Ions That Form *Soluble* Compounds	Exceptions
Group 1 ions (Li^+, Na^+, etc.)	
ammonium (NH_4^+)	
nitrate (NO_3^-)	
acetate ($C_2H_3O_2^-$ or CH_3COO^-)	
hydrogen carbonate (HCO_3^-)	
chlorate (ClO_3^-)	
perchlorate (ClO_4^-)	
halides (Cl^-, Br^-, I^-)	when combined with Ag^+, Pb^{2+}, and Hg_2^{2+}
sulfates (SO_4^{2-})	when combined with Ag^+, Ca^{2+}, Sr^{2+}, Ba^{2+}, and Pb^{2+}

Ions That Form *Insoluble* Compounds	Exceptions
carbonate (CO_3^{2-})	when combined with Group 1 ions or ammonium (NH_4^+)
chromate (CrO_4^{2-})	when combined with Group 1 ions or ammonium (NH_4^+)
phosphate (PO_4^{3-})	when combined with Group 1 ions or ammonium (NH_4^+)
sulfide (S^{2-})	when combined with Group 1 ions or ammonium (NH_4^+)
hydroxide (OH^-)	when combined with Group 1 ions, Ca^{2+}, Ba^{2+}, or Sr^{2+}

Determining Solubility

- Determine the level of solubility for the following:

  (1) Ag_2SO_4

  (2) $CaCO_3$

  (3) Na_3PO_4

- Classwork: solubility graph handout

Concentration of Solutions

Objectives:

1. Solve problems involving the molarity of a solution.
2. Describe the effect of dilution on the total moles of solute in solution.
3. Define percent by volume and percent by mass solutions.

Mass/Mass

$$Mass\% = \frac{mass\ A}{total\ mass\ of\ solution} \times 100$$

$$ppm = \frac{mass\ A}{total\ mass\ of\ solution} \times 10^6$$

$$ppb = \frac{mass\ A}{total\ mass\ of\ solution} \times 10^9$$

Moles/Moles

$$X_A = \frac{moles\ of\ solute}{total\ moles}$$

Moles/L

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

Moles/Mass

$$m = \frac{moles\ of\ solute}{kg\ of\ solvent}$$

Concentration is…

- a measure of the amount of solute dissolved in a given quantity of solvent
- A ***concentrated*** solution has a *large* amount of solute
- A ***dilute*** solution has a *small* amount of solute
  - These are *qualitative* descriptions
- But, there are ways to express solution concentration *quantitatively (NUMBERS!)*

CONCENTRATED

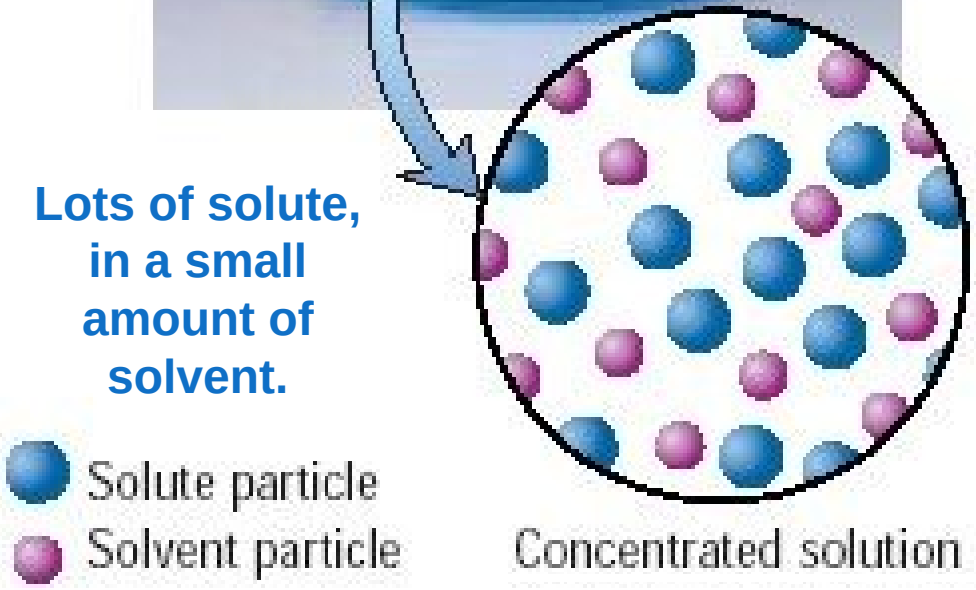
DILUTE

Notice how dark the solutions appears.

Notice how light the solution appears.

Lots of solute, in a small amount of solvent.

Small amount of solute in a large amount of solvent.

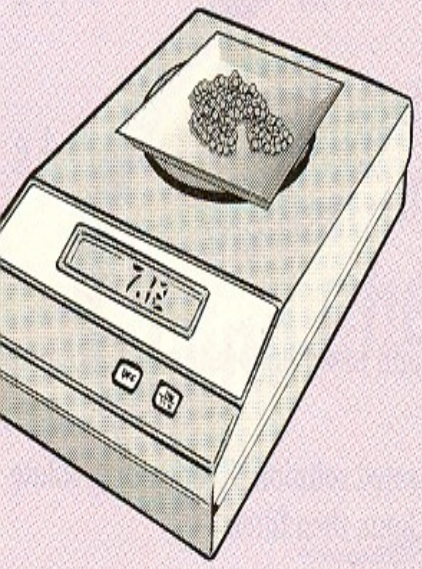


Making solutions

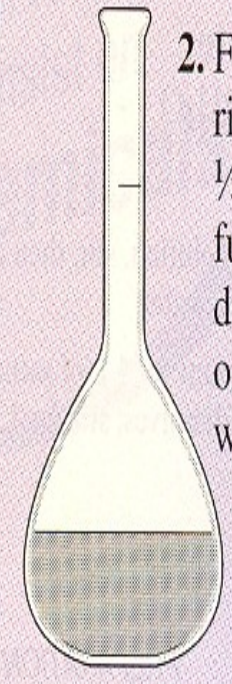
1) Pour in a *small amount* of the solvent, maybe about one-half
2) Then add the pre-massed solute (and mix by swirling to dissolve it)
3) Carefully fill to final volume.

How To

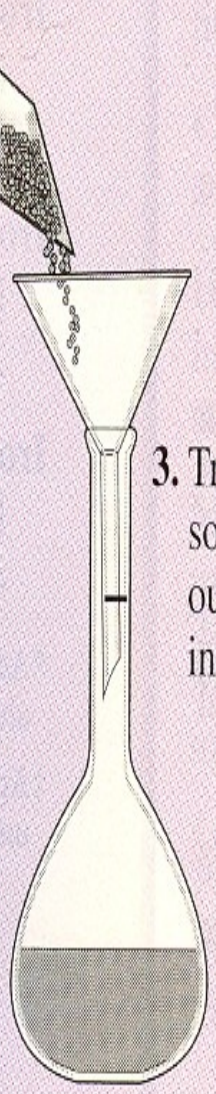
Make a Solution



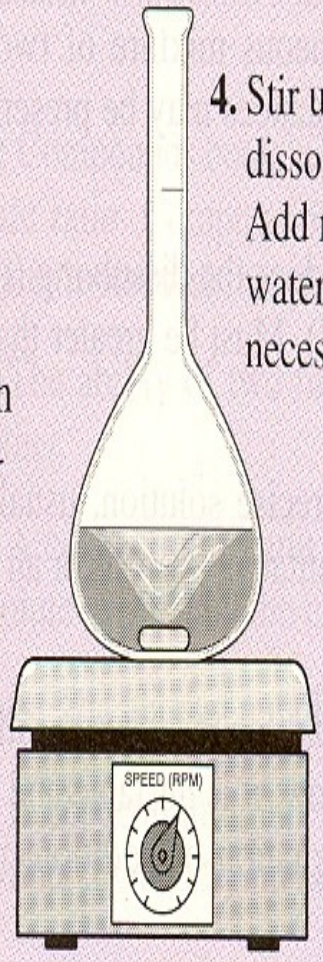
1. Weigh solid.



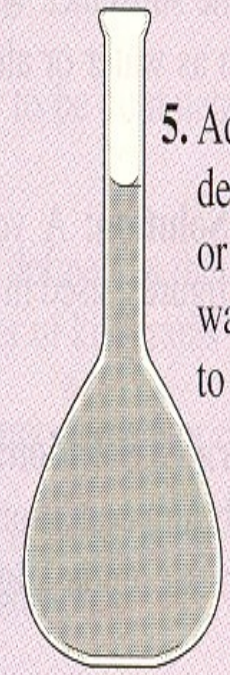
2. Fill volumetric flask ⅓–½ full with deionized or distilled water.



3. Transfer solid, wash out weighing dish.



4. Stir until dissolved. Add more water if necessary.



5. Add deionized or distilled water up to mark.

Molarity: a unit of concentration

- Molarity = $\frac{\text{n (moles of solute)}}{\text{V (liters of solution)}}$
  - Abbreviated with a capital M, such as 6.0 M
  - Units M or mol/L
- This is the most widely used concentration unit used in chemistry.

1. How many grams of sodium chloride, NaCl, do you need to prepare 250.mL of a 0.5M NaCl solution? Molar mass NaCl= 58.5 g/mol

2. What volume of a 1.0M NaCl solution can you prepare if you have 45.0g of NaCl? Molar mass NaCl = 58.5g / mol?

Classwork : p 54 # 19-21