Solution Chemistry

Parts of a Solution Review

Solute

A solute is the dissolved substance in a solution.

Salt in salt water

Sugar in soda drinks

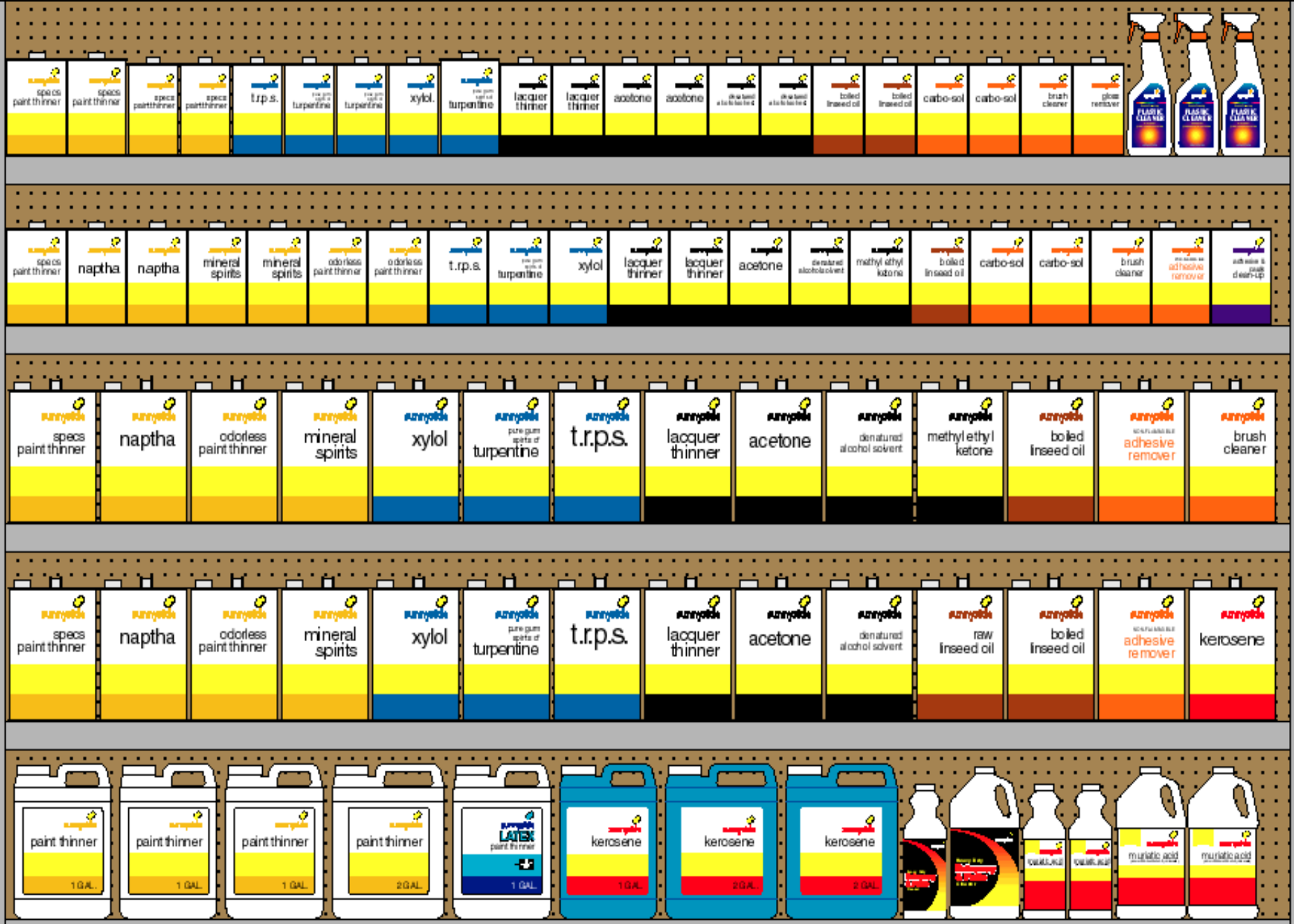
Carbon dioxide in soda drinks

Solvent

A solvent is the dissolving medium in a solution.

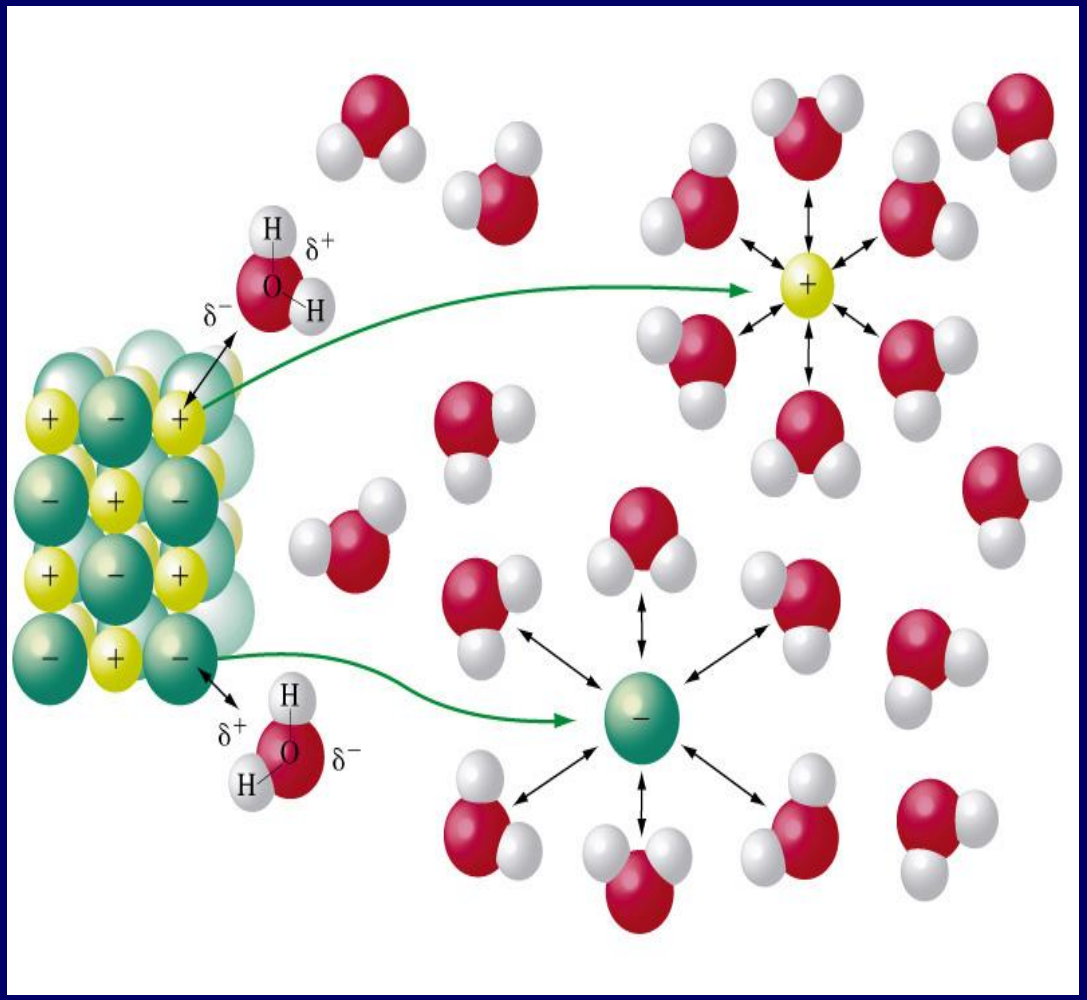
Water in salt water

Water in soda



Solvents at the hardware store

Dissolution of sodium Chloride

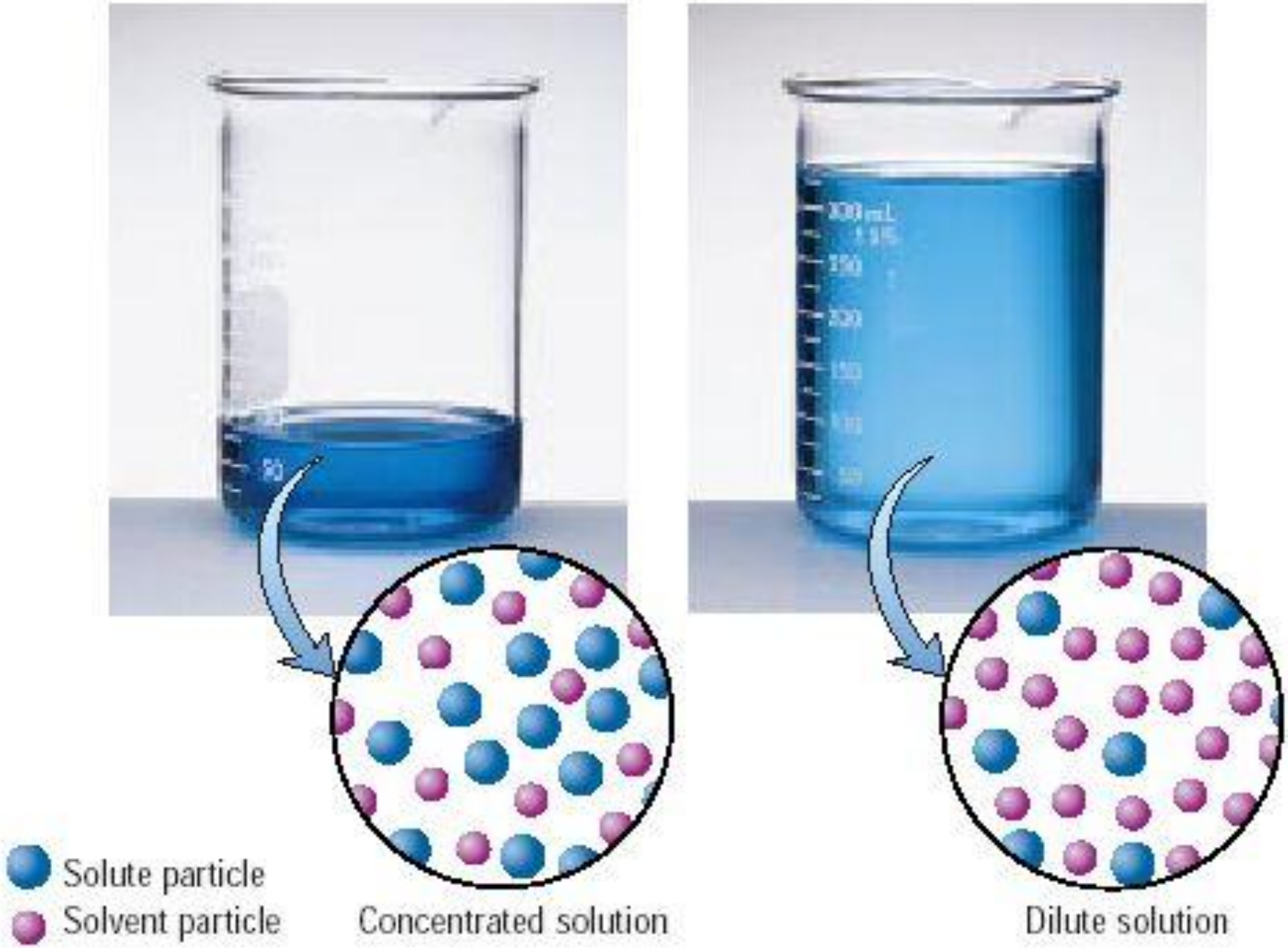


This Process is called solvation-

if the solvent is water it is called hydration

General Terms (qualitative) to describe how much solute is dissolved in the solvent

- Dilute- a little solute per solvent
- Concentrated- a lot of solute per solvent
- *Sometimes color of the solution can help- the lighter color more dilute the darker color the more concentrated*


Solute particle
Solvent particle
Concentrated solution
Dilute solution

SOLUBILTY

- The solubility of a substance is the amount of solute that dissolves in a given quantity of a solvent at a specified temperature and pressure to produce a saturated solution.

- Solubility is often expressed in grams of solute per 100 g of solvent.

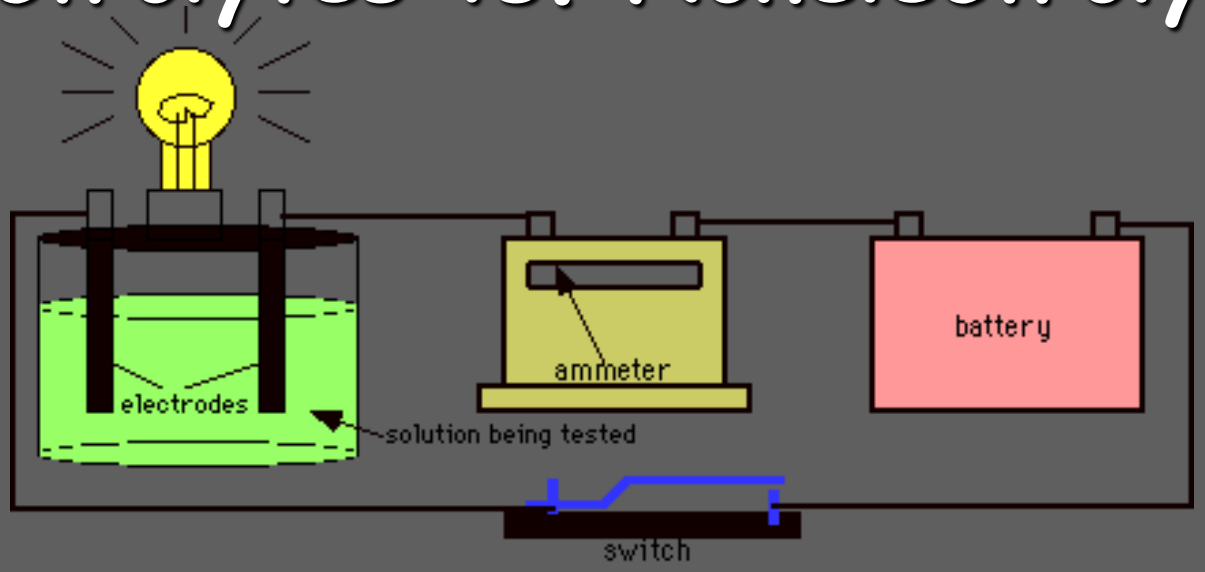
- Solubility of NaCl in water @25°C: 36.2g/100g

Heat of Solution

The **Heat of Solution** is the amount of heat energy absorbed (endothermic) or released (exothermic) when a specific amount of solute dissolves in a solvent.

Substance	Heat of Solution (kJ/mol)
NaOH	-44.51
NH_4NO_3	+25.69
KNO_3	+34.89
HCl	-74.84

Electrolytes vs. Nonelectrolytes



The ammeter measures the flow of electrons (current) through the circuit.

- If the ammeter measures a current, and the bulb glows, then the solution conducts.
- If the ammeter fails to measure a current, and the bulb does not glow, the solution is non-conducting.

Definition of Electrolytes and Nonelectrolytes

An electrolyte is:

- A substance whose aqueous solution conducts an electric current.

A nonelectrolyte is:

- A substance whose aqueous solution does not conduct an electric current.

Try to classify the following substances as electrolytes or nonelectrolytes…

Electrolytes?

1. Pure water
2. Tap water
3. Sugar solution
4. Sodium chloride solution
5. Hydrochloric acid solution
6. Lactic acid solution
7. Ethyl alcohol solution
8. Pure sodium chloride

ELECTROLYTES:

- Tap water (weak)
- NaCl solution
- HCl solution
- Lactate solution (weak)

NONELECTROLYTES:

- Pure water
- Sugar solution
- Ethanol solution
- Pure NaCl

But why do some compounds conduct electricity in solution while others do not…?

Answers to Electrolytes

Suspensions and Colloids

Suspensions and colloids are NOT solutions.

Suspensions: The particles are so large that they settle out of the solvent if not constantly stirred.

Colloids: The particle is intermediate in size between those of a suspension and those of a solution.

Types of Colloids

Examples	Dispersing Medium	Dispersed Substance	Colloid Type
Fog, aerosol sprays	Gas	Liquid	Aerosol
Smoke, airborne bacteria	Gas	Solid	Aerosol
Whipped cream, soap suds	Liquid	Gas	Foam
Milk, mayonnaise	Liquid	Liquid	Emulsion
Paint, clays, gelatin	Liquid	Solid	Sol
Marshmallow, Styrofoam	Solid	Gas	Solid foam
Butter, cheese	Solid	Liquid	Solid emulsion
Ruby glass	Solid	Solid	Solid sol

The Tyndall Effect

- The scattering of visible light by colloidal particles is called the Tyndall effect.

Factors Effecting Solubility

- The solubility of MOST solids increases with temperature. *(more collisions)*
- The rate at which solids dissolve increases with increasing surface area of the solid.*(more solvent solute interaction)
- The rate of dissolving a solid into a liquid increases when agitated *(fresh solvent to solute)*
- The solubility of gases decreases with increases in temperature. (MOVEMENT SPEEDS UP ESCAPE IS EASIER)
- The solubility of gases increases with the pressure above the solution.(KEEPS GASES INSIDE THE LIQUID PHASE)

Solution Formation

- A cube of sugar in cold tea dissolves slowly.

Solution Formation

- Granulated sugar dissolves in cold water more quickly than a sugar cube, especially with stirring.

Solution Formation

- Granulated sugar dissolves very quickly in hot tea.

Therefore…

Solids tend to dissolve best when:

- Heated -Kinetic energy is higher collisions occur more often between solute and solvent

- Stirred- brings fresh solvent to solute

- Ground into small particles- more surface area for solvent solute interactions

Gas in a Liquid tend to dissolve best when:

- The solution is cold- slows molecules down don't escape as fast
- Pressure is high- keeps molecules in solution

Saturation of Solutions

- A solution that conta ins less solute than a saturated solution under existing conditions is **unsaturated**.
- A solution that contains the maximum amount of solute that may be dissolved under existing conditions is **saturated**.
- A solution that contains more dissolved solute than a saturated solution under the same conditions is **supersaturated**.

Factors Affecting Solubility

- A supersaturated solution contains more solute than it can theoretically hold at a given temperature.

- The crystallization of a supersaturated solution can be initiated if a very small crystal, called a seed crystal, of the solute is added.

- A supersaturated solution is clear before a seed crystal is added.

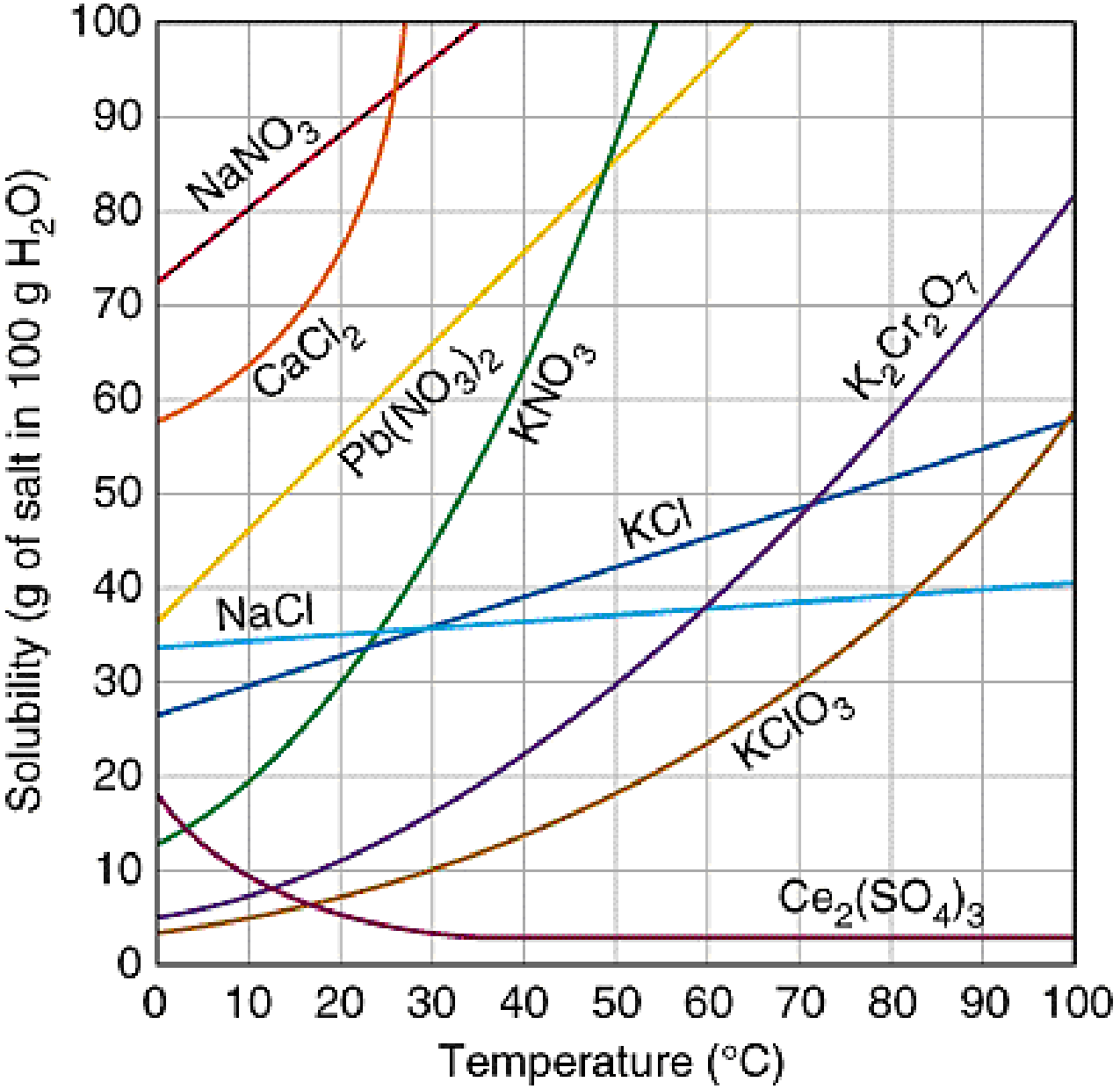
- Crystals begin to form in the solution immediately after the addition of a seed crystal.

- Excess solute crystallizes rapidly.

Scientific Rain Making

- Clouds are sometimes "seeded" to make rain.
- Tiny silver iodide crystals (AgI) are dusted onto a cloud, which contains masses of air supersaturated with water vapor.
- Water molecules are attracted to the AgI ions and form droplets that are seeds for other water molecules.
- When the droplets get large enough, they fall as rain.

Solubility Chart



- Solutions

II. Concentration

A. Concentration

- The amount of solute in a solution.
- <u>Describing Concentration</u>
  - % by mass - medicated creams
  - % by volume - rubbing alcohol
  - ppm, ppb - water contaminants
  - molarity - used by chemists
  - molality - used by chemists

1. Molarity (M)= $\frac{\text{moles}}{\text{liter}}$ (of solute) (of solvent)

- What is the molarity of a solution when 56.9 grams of calcium chloride are dissolved in 750.0 ml of water?

- $56.9 \text{ grams} \left| \frac{1 \text{ mol } CaCl_2}{111.1 \text{ grams}} \right| \frac{1}{0.750 \text{ l}} \Bigg| =$

0.683 Molar

To find solute give concentration:

- 1. How many grams of sodium chloride are needed to make a 0.500 M solution in a 750 ml vessel?

- $\frac{0.500\ M}{1} \quad \frac{0.750\ L}{} \quad \frac{58.5\ g}{1\ mol} =$

- 21.9 grams

2. Molality = m= molal

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

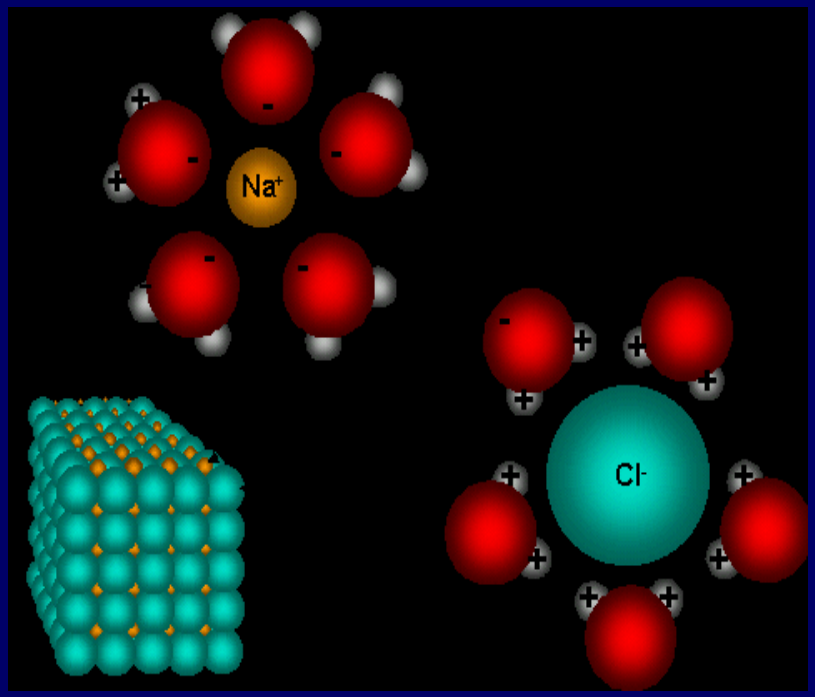
mass of solvent only !

$$0.25m = \frac{0.25\ mol}{1\ kg}$$

1 kg water = 1 L water

Concentrations of Ions in Solution

Ionic Solids break up when dissolved in water



You must be able to determine the number and types of ions released

- $MgCl_2$ →
- $AlBr_3$ →
- CH_3OH →
- $Ca(NO_3)_2$ →

Molarity Of IONS (M)= $\frac{\text{moles ions}}{\text{liter}}$ (of solvent)

- What is the molarity of chloride ions in solution when 56.9 grams of calcium chloride are dissolved in 750.0 ml of water?

- 56.9 grams $\left|\frac{1 \text{ mol } CaCl_2}{111.1 \text{ grams}}\right| \frac{1}{0.750 \text{ l}} \left|\frac{2\ Cl^{-1}}{1\ CaCl_2}\right| =$

1.37 Molar Cl^{-1}

To find solute given concentration of ions needed:

- 1. How many grams of magnesium chloride are needed to make a 0.500 M chloride ion solution in a 750 ml vessel?

- $\frac{0.500\ M\ Cl^{-1}}{} \left| \frac{1\ mol\ MgCl_2}{2\ Mol\ Cl^{-1}} \right| \frac{95.2g}{1\ mol\ MgCl_2} \left| \frac{0.750\ L}{1} \right| =$

- 17.8 grams of solute

* Purity will decrease the molarity of solution

- *What is the molarity of chloride ions in solution when 56.9 grams of 95.5 % pure calcium chloride are dissolved in 750.0 ml of water?*

- $\frac{\text{X grams pure}}{\text{56.9 grams impure}} = \frac{95.5}{100}$

- 54.3 grams $\left| \frac{1 \text{ mol } CaCl_2}{111.1 \text{ grams}} \right| \frac{1}{0.750 \text{ l}} \left| \frac{2\ Cl^{-1}}{1\ CaCl_2} \right| =$

1.30 Molar Cl^{-1}

* Purity will change the amount of grams needed by increasing solute mass

- *How many grams of a stock magnesium chloride solid with a 95.5% purity are needed to make a 0.500 M chloride ion solution in a 750 ml vessel?*

- $\frac{0.500\ M\ Cl^{-1}}{} \quad \frac{1\ mol\ MgCl_2}{2\ Mol\ Cl^{-1}} \quad \frac{95.2g}{1\ mol\ MgCl_2} \quad \frac{0.750\ L}{1} =$

- 17.8 grams of solute of pure

- $\frac{17.8\ grams\ pure}{X\ \ grams\ impure} = \frac{95.5}{100}$ = 18.6 grams

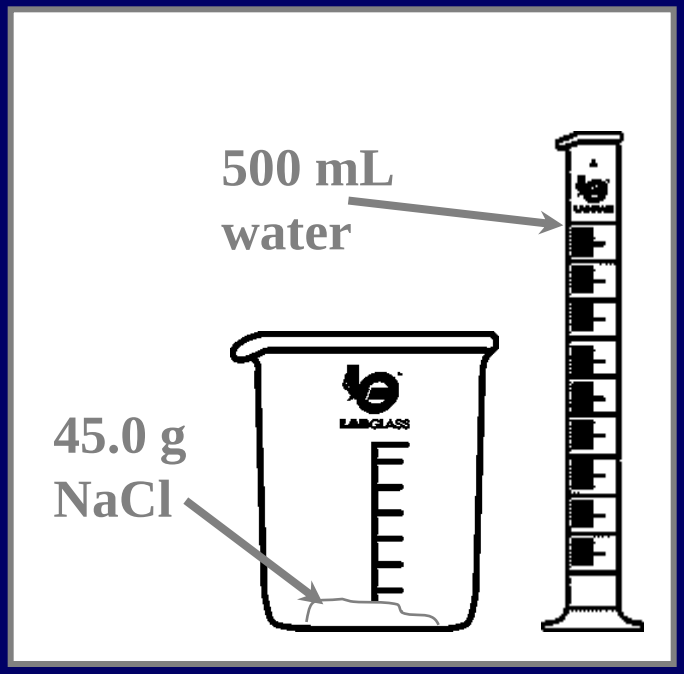
3. Dilution

- Preparation of a desired solution by adding water to a concentrate.
- Moles of solute remain the same.

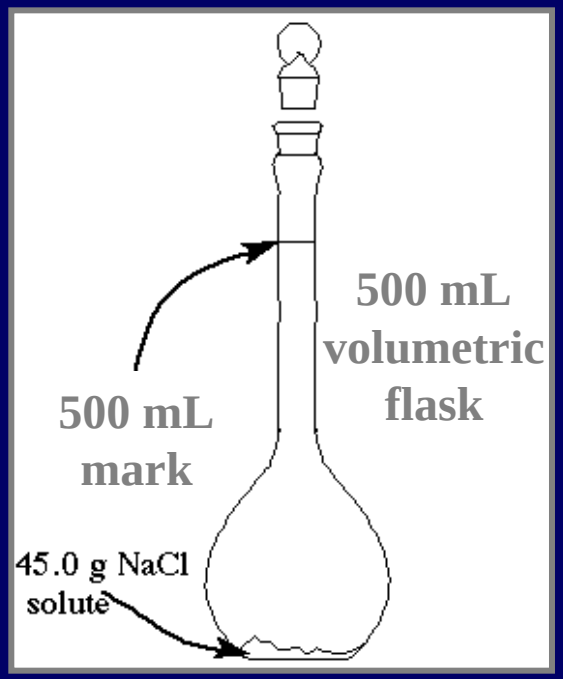
$$M_1V_1 = M_2V_2$$

D. Preparing Solutions

- **1.54*m* NaCl in 0.500 kg of water**
  - mass 45.0 g of NaCl
  - add 0.500 kg of water



- 500 mL of 1.54*M* NaCl
  - mass 45.0 g of NaCl
  - add water until <u>total</u> volume is 500 mL



D. Preparing Solutions

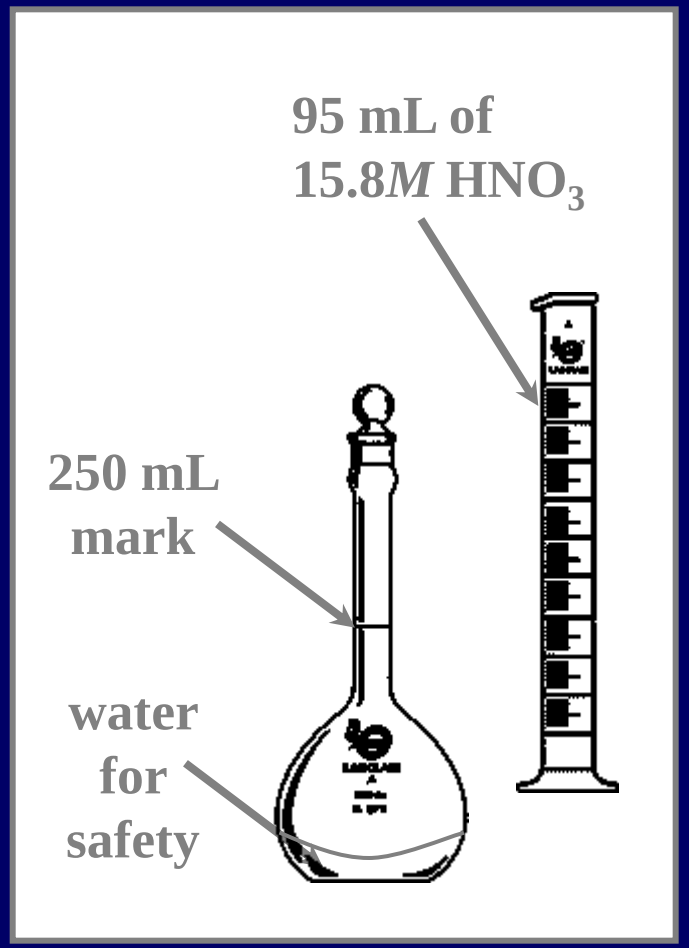
(above: “Filling the volumetric flask”)

D. Preparing Solutions

(above: “Using your hand as a stopper”)

D. Preparing Solutions

- 250 mL of 6.0*M* HNO_3 by dilution given a stock of 15.8 M
  - **measure 95 mL of 15.8*M* HNO_3**
  - combine with water until <u>total</u> volume is 250 mL
  - **Safety:** "Do as you oughtta, add the acid to the watta!"



Solution Preparation Lab

- Turn in one paper per team.
- Complete the following steps:
  - A) Show the necessary calculations.
  - B) Write out directions for preparing the solution.
  - C) Prepare the solution.
- For each of the following solutions:
  - 1) 100.0 mL of 0.50*M* NaCl
  - 2) 0.25*m* NaCl in 100.0 mL of water
  - 3) 100.0 mL of 3.0*M* HCl from 12.1*M* concentrate.

Calculations of Solution Concentration

Concentration - A measure of the amount of solute in a given amount of solvent or solution

- **Grams per liter** - the mass of solute divided by the volume of solution, in liters
- **Molarity** - moles of solute divided by the volume of solution in liters
- **Parts per million** – the ratio of parts (mass) of solute to one million parts (mass) of solution
- **Percent composition** - the ratio of one part of solute to one hundred parts of solution, expressed as a percent

- Solutions

III. Colligative Properties

Colligative Properties

Colligative properties are those that depend on the concentration of particles in a solution, not upon the identity of those properties.

- Boiling Point Elevation
- Freezing Point Depression
- Vapor Pressure increases
- Osmotic Pressure

16.3 Colligative Properties of Solutions

- The wood frog is a remarkable creature because it can survive being frozen.
- Scientists believe that a substance in the cells of this frog acts as a natural antifreeze, which prevents the cells from freezing.
- You will discover how a solute can change the freezing point of a solution.

Freezing Point Depression

Each mole of solute particles lowers the freezing point of 1 kilogram of water by 1.86 degrees Celsius.

$$K_f = 1.86\ ^\circ C \cdot \text{kilogram/mol}$$

Boiling Point Elevation

Each mole of nonvolatile solute particles raises the boiling point of 1 kilogram of water by 0.51 degrees Celsius.

$$K_b = 0.51\ ^\circ C \cdot \text{kilogram/mol}$$

Freezing Point Depression and Boiling Point Elevation Constants

Solvent	K_f	K_b
Acetic acid	3.90	3.07
Benzene	5.12	2.53
Nitrobenzene	8.1	5.24
Phenol	7.27	3.56
Water	1.86	0.512

Values correspond to freezing-point depressions and boiling-point elevations, in degrees Celsius, due to 1 mol of solute particles dissolved in 1 kg of solvent in an ideal solution. Units: °C kg solvent (mol solute)$^{-1}$ or °C m^{-1}.

A. Definition

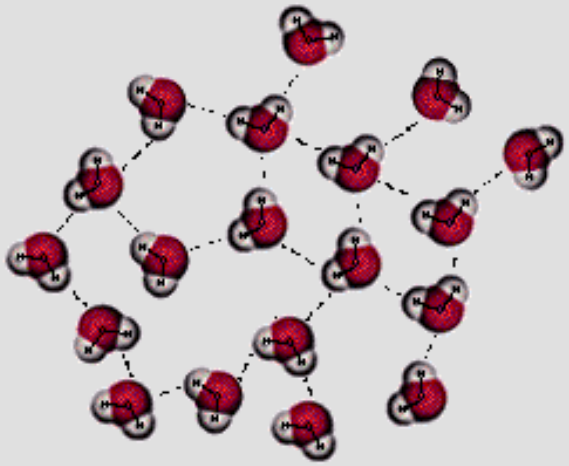
- Colligative Property
  - property that depends on the concentration of solute particles, not their identity

B. Types for Calculations

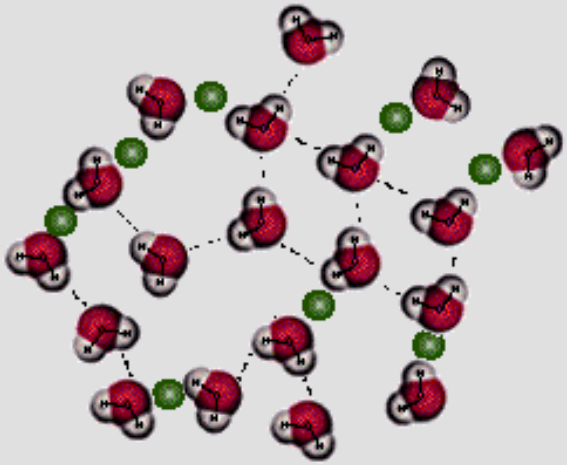
- Freezing Point Depression (Δt_f)
  - f.p. of a solution is lower than f.p. of the pure solvent
- Boiling Point Elevation (Δt_b)
  - b.p. of a solution is higher than b.p. of the pure solvent

B. Types

Freezing Point Depression



When the solvent is absolutely pure, its individual particles can interact without any obstruction.

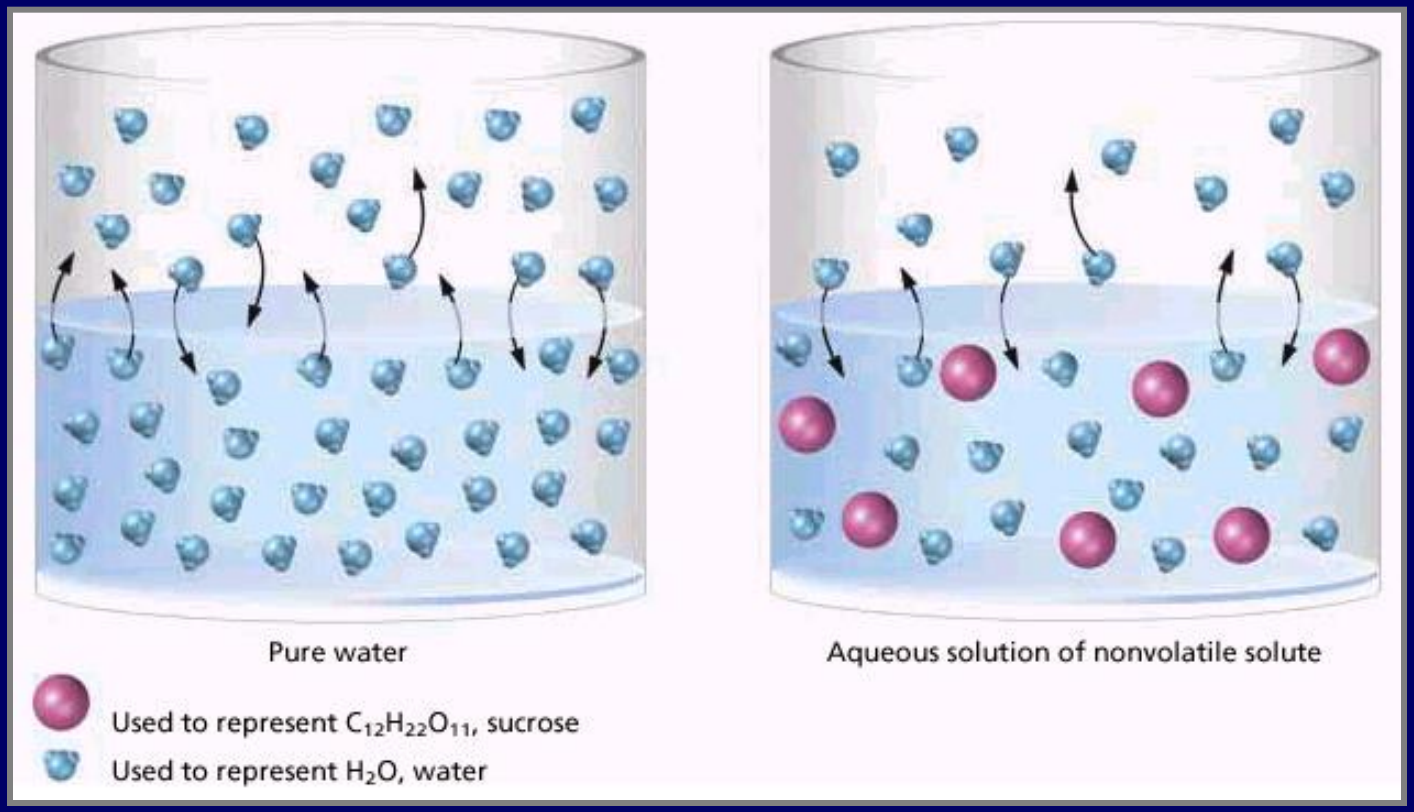


When impurities are introduced to the solution, they disturb the stabilizing intermolecular bonds between solvent molecules.

View Flash animation.

B. Types

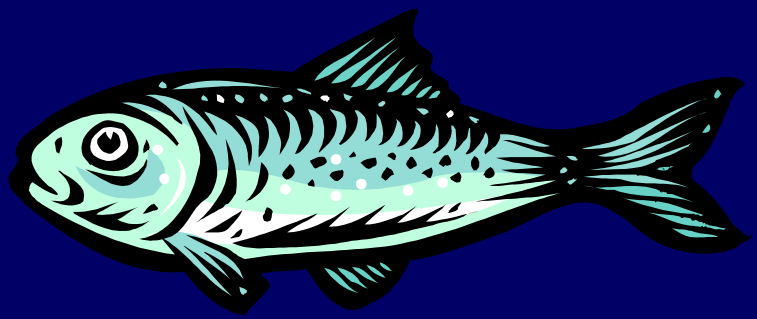
Boiling Point Elevation



Solute particles weaken IMF in the solvent.

B. Types

- Applications
  - salting icy roads
  - making ice cream
  - antifreeze
    - cars (-64°C to 136°C)
    - fish & insects



Do you remember how to tell if a compound is ionic or covalent?

Substance	I or C	# particles
KCl		
$C_6H_{12}O_6$		
$PbCl_4$		
SiO_2		
$Ba(NO_3)_2$		

C. Calculations

$$\Delta t = i \cdot m \cdot k$$

Δt: change in temperature (C)

k: constant based on the solvent ($C \cdot kg/mol$)

m: molality (m)

i: # of particles

C. Calculations

- # of Particles
  - Nonelectrolytes (covalent)
    - **remain intact when dissolved**
    - **1 particle**
  - Electrolytes (ionic)
    - **dissociate into ions when dissolved**
    - **2 or more particles**

    - **Please calculate how many particles in the following:**
    - **$MgCl_2$ CH_3OH $Sr(NO_3)_2$**

C. Calculations

- 1. At what temperature will a solution that is composed of 0.73 moles of glucose in 225 g of phenol boil?

GIVEN:	WORK:
b.p. = ? Δt_b = ? k_b = 3.60°C·kg/mol m = 3.2m n = 1 $\Delta t_b = k_b \cdot m \cdot n$	m = 0.73mol ÷ 0.225kg Δt_b = (3.60°C·kg/mol)(3.2m)(1) Δt_b = 12°C b.p. = 181.8°C + 12°C **b.p. = 194°C**

C. Calculations

- 2. 75.0 grams of methanol (CH_3OH) are dissolved in 500.0 ml of water. At what temperature will the solution boil?

C. Calculations

- Find the freezing point of a saturated solution of NaCl containing 28 g NaCl in 100. mL water.

For review: Liquid-Liquid Solubility

- Some liquids combine, while others don't mix at all.

- Two liquids are miscible if they dissolve in each other in all proportions. (alcohol and water)

- Two liquids are immiscible if they are insoluble in each other. (oil and water)

"Like Dissolves Like"

- Polar solvents such as water dissolve ionic compounds and polar compounds.
  - Ionic compounds & covalent compounds with polar bonds.

- Nonpolar solvents such as gasoline dissolve nonpolar compounds.
  - Covalent compounds with nonpolar bonds or symmetrical covalent compounds with polar bonds

The following are immiscible

Oil and water

Vinegar and Oil

Stoichiometry of Solution Reactions

Steps:

1. Write the balanced equations for the reaction. (For ions, write the net ionic equation)

2. Calculate moles of reactants (multiply volume and concentration)

3. Determine which reactant is limiting (send through mole ratio of desired product)

4. Convert to grams or other units if required (multiply by MW)

Given Volume and Concentration find Mass of Precipitate

- Do the calculation twice to find limiting reagent and maximum mass that can be produced:

- Molarity A $\left| \frac{\#\ \text{Liters}}{1} \right| \left| \frac{\#\ \text{B}}{\#\ \text{A}} \right| \left| \frac{\text{MW B}}{1\ \text{mol B}} \right| =$ Grams B

You Try:

- 25.0 ml of a 1.20 M solution of silver nitrate are mixed with 35.0 ml of a 0.750 M solution of calcium chloride.

- What is the mass of solid formed?

Can you handle this?

- 25.00 ml of a 1.75 M solution of aluminum nitrate are mixed with 30.00 ml of 0.750 M potassium hydroxide solution. Charlie collects 552 milligrams of solid. What is his percent yeild?

Given Grams Find Molarity of Solution

- Grams A $\left|\ \frac{1\ \text{mol}}{\text{MW A}}\ \right|\ \frac{\#\ \text{B}}{\#\ \text{A}}\ \left|\ \frac{1}{\text{liters used}}\ \right| =$ M B

What is the molarity of a silver nitrate solution if 20.0 mls reacted with an excess of 0.600 M Sodium Chloride solution forms 3.50 grams of solid?

Given Grams Find Volume of Reagent to Use

- Grams A $\left|\ \frac{1\ \text{mol}}{\text{MW A}}\ \right|\ \frac{\#\ \text{B}}{\#\ \text{A}}\ \left|\ \frac{1\ \text{liter}}{\text{Molarity B}}\ \right|$ = Volume B

How many milliliters of a 0.250 M sodium chloride solution are needed to react with an excess of 0.200 M silver nitrate solution to form 2.25 grams of solid?