Preview

- Objectives
- Solutions
- Suspensions
- Colloids
- Solutes: Electrolytes Versus Nonelectrolytes

Objectives

- **Distinguish** between electrolytes and nonelectrolytes.
- **List** three different solute-solvent combinations.
- **Compare** the properties of suspensions, colloids, and solutions.
- **Distinguish** between electrolytes and nonelectrolytes.

End Of Slide

Solutions

- You know from experience that sugar dissolves in water. Sugar is described as “soluble in water.” By **soluble** we mean capable of being dissolved.
- When sugar dissolves, all its molecules become uniformly distributed among the water molecules. The solid sugar is no longer visible.
- Such a mixture is called a solution. A **solution** is a homogeneous mixture of two or more substances in a single phase.

End of Slide

Solutions

Click below to watch the Visual Concept.

Visual Concept

Solutions, *continued*

- The dissolving medium in a solution is called the **solvent,** and the substance dissolved in a solution is called the **solute.**

- Solutions may exist as gases, liquids, or solids. There are many possible solute-solvent combinations between gases, liquids, and solids.

  - example: Alloys are solid solutions in which the atoms of two or more metals are uniformly mixed.
    - Brass is made from zinc and copper.
    - Sterling silver is made from silver and copper.

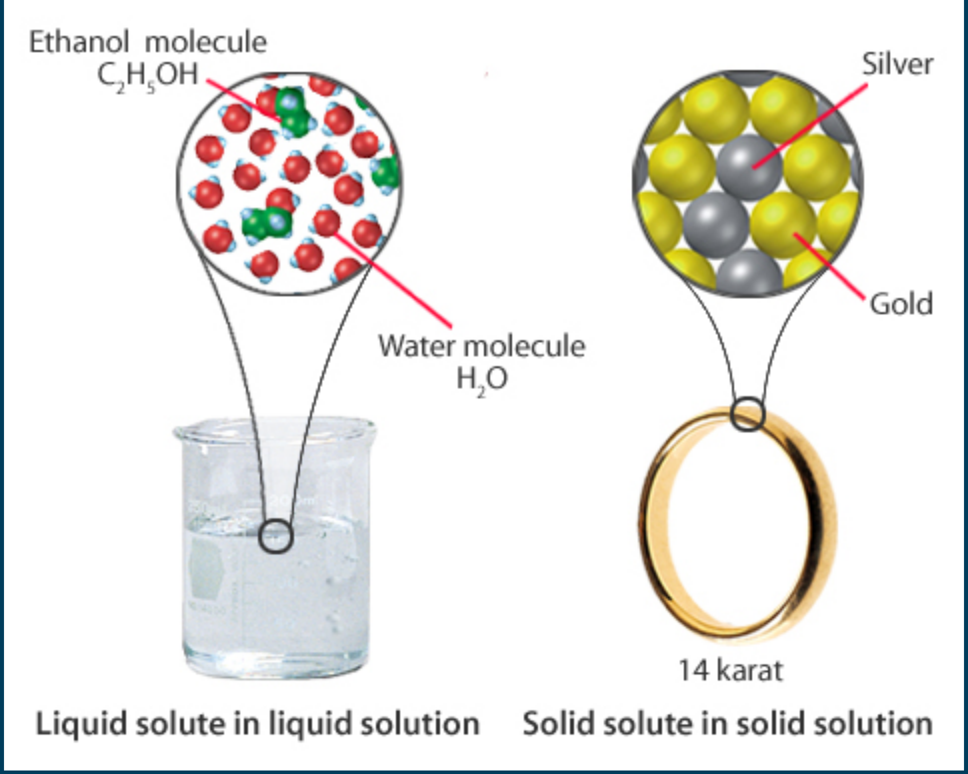
End Of Slide

Solutes, Solvents, and Solutions

Click below to watch the Visual Concept.

Visual Concept

Types of Solutions



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Particle Models for Gold and Gold Alloy

24-karat gold is pure gold.

14-karat gold is an alloy of gold with silver and copper. 14-karat gold is 14/24, or 58.3%, gold.

Suspensions

- If the particles in a solvent are so large that they settle out unless the mixture is constantly stirred or agitated, the mixture is called a **suspension.**
  - For example, a jar of muddy water consists of soil particles suspended in water. The soil particles will eventually all collect on the bottom of the jar, because the soil particles are denser than the solvent, water.
- Particles over 1000 nm in diameter—1000 times as large as atoms, molecules or ions—form suspensions.

Suspensions

Click below to watch the Visual Concept.

Visual Concept

Colloids

- Particles that are intermediate in size between those in solutions and suspensions form mixtures known as colloidal dispersions, or simply **colloids.**
  - The particles in a colloid are small enough to be suspended throughout the solvent by the constant movement of the surrounding molecules.
- Colloidal particles make up the *dispersed phase,* and water is the *dispersing medium.*
  - example: Mayonnaise is a colloid.
    - It is an emulsion of oil droplets in water.

End of Slide

Colloids, *continued*

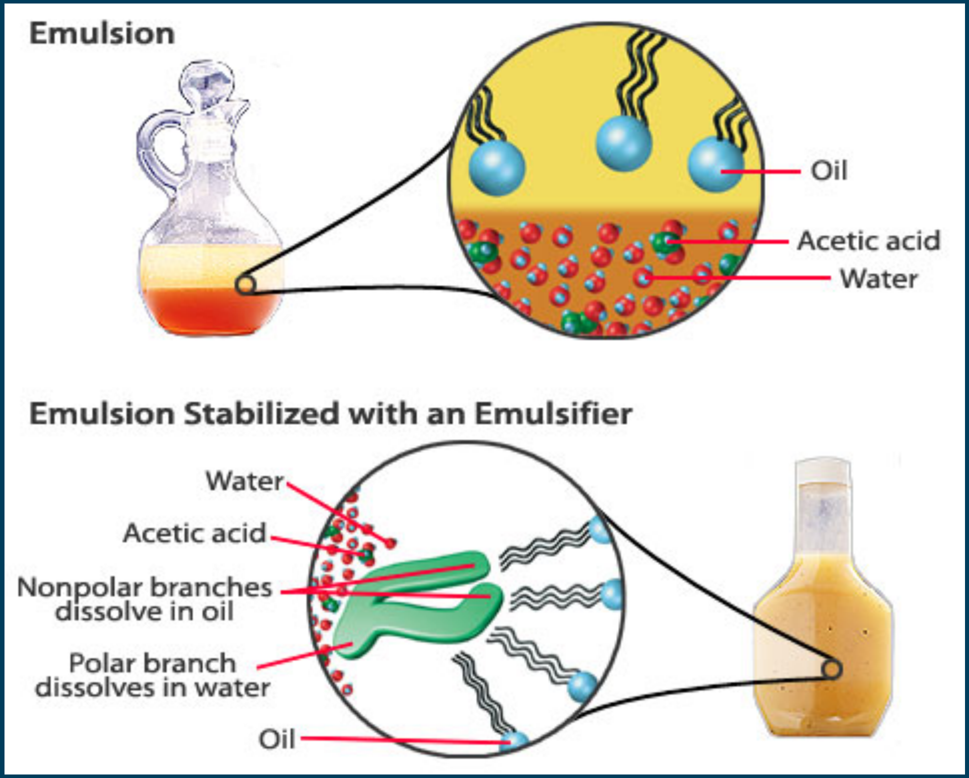
Tyndall Effect

- Many colloids look similar to solutions because their particles cannot be seen.
- The *Tyndall effect* occurs when light is scattered by colloidal particles dispersed in a transparent medium.
  - example: a headlight beam is visible from the side on a foggy night.
- The Tyndall effect can be used to distinguish between a solution and a colloid.

End of Slide

Colloids

Emulsions



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< Back Next > Preview Main

Properties of Solutions, Colloids, and Suspensions

Solutions	Colloids	Suspensions
Homogeneous	Heterogeneous	Heterogeneous
Particle size: 0.01–1 nm; can be atoms, ions, molecules	Particle size: 1–1000 nm, dispersed; can be aggregates or large molecules	Particle size: over 1000 nm, suspended; can be large particles or aggregates
Do not separate on standing	Do not separate on standing	Particles settle out
Cannot be separated by filtration	Cannot be separated by filtration	Can be separated by filtration
Do not scatter light	Scatter light (Tyndall effect)	May scatter light, but are not transparent

Solutes: Electrolytes Versus Nonelectrolytes

- A substance that dissolves in water to give a solution that conducts electric current is called an **electrolyte.**

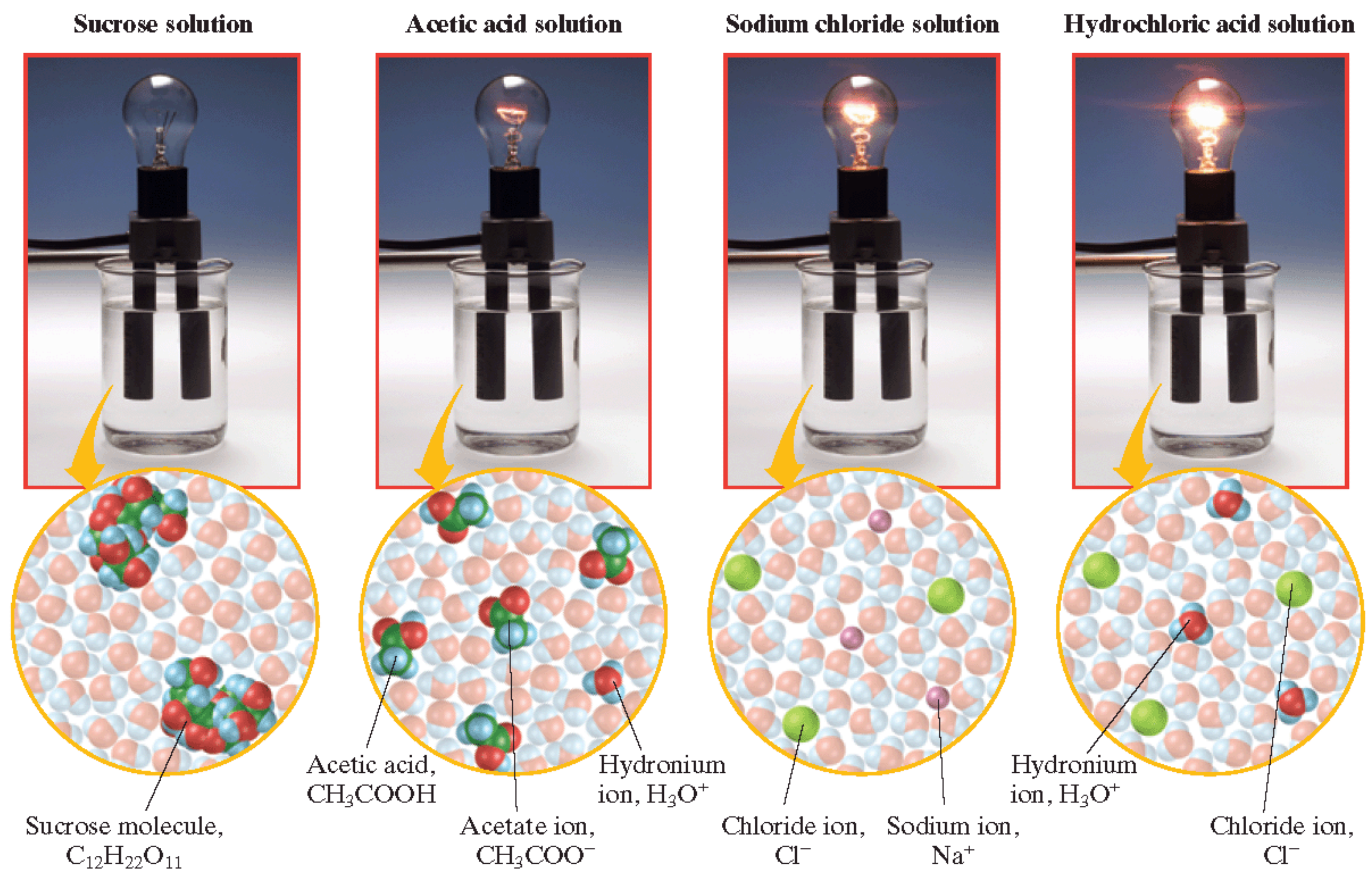
- Any soluble ionic compound, such as sodium chloride, NaCl, is an electrolyte.

- The positive and negative ions separate from each other in solution and are free to move, making it possible for an electric current to pass through the solution.

Solutes: Electrolytes Versus Nonelectrolytes, *continued*

- A substance that dissolves in water to give a solution that does not conduct electric current is called a **nonelectrolyte.**
- Sugar is an example of a nonelectrolyte.
- Neutral solute molecules do not contain mobile charged particles, so a solution of a nonelectrolyte cannot conduct electric current.

Electrical Conductivity of Solutions



Preview

Objectives

- **List** and explain three factors that affect the rate at which a solid solute dissolves in a liquid solvent.
- **Explain** solution equilibrium, and distinguish among saturated, unsaturated, and supersaturated solutions.
- **Explain** the meaning of "like dissolves like" in terms of polar and nonpolar substances.

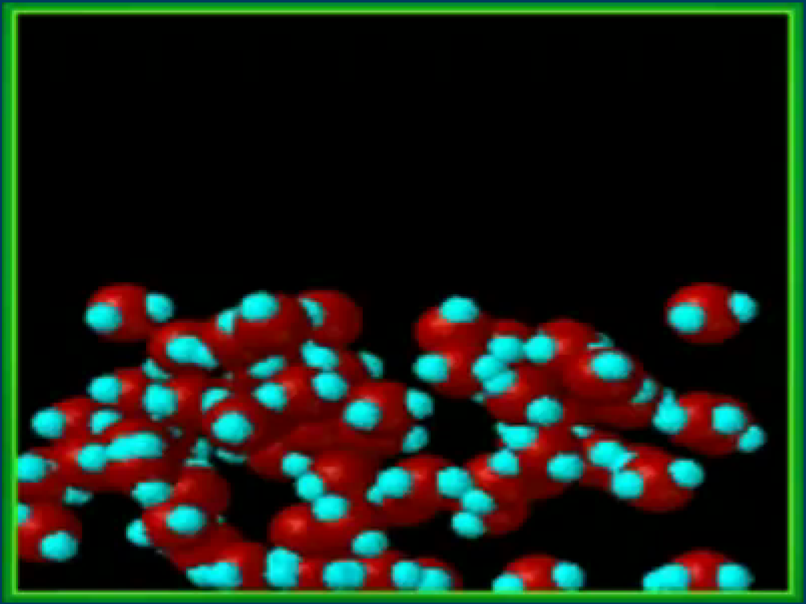
Objectives, *continued*

- **List** the three interactions that contribute to the enthalpy of a solution, and explain how they combine to cause dissolution to be exothermic or endothermic.

- **Compare** the effects of temperature and pressure on solubility.

Dissolving Process

Click below to watch the Visual Concept.



Factors Affecting the Rate of Dissolution

- Because the dissolution process occurs at the surface of the solute, it can be speeded up if the surface area of the solute is increased.
- Stirring or shaking helps to disperse solute particles and increase contact between the solvent and solute surface. This speeds up the dissolving process.
- At higher temperatures, collisions between solvent molecules and solvent are more frequent and of higher energy. This helps to disperse solute molecules among the solvent molecules, and speed up the dissolving process.

End Of Slide

Factors Affecting the Rate of Dissolution

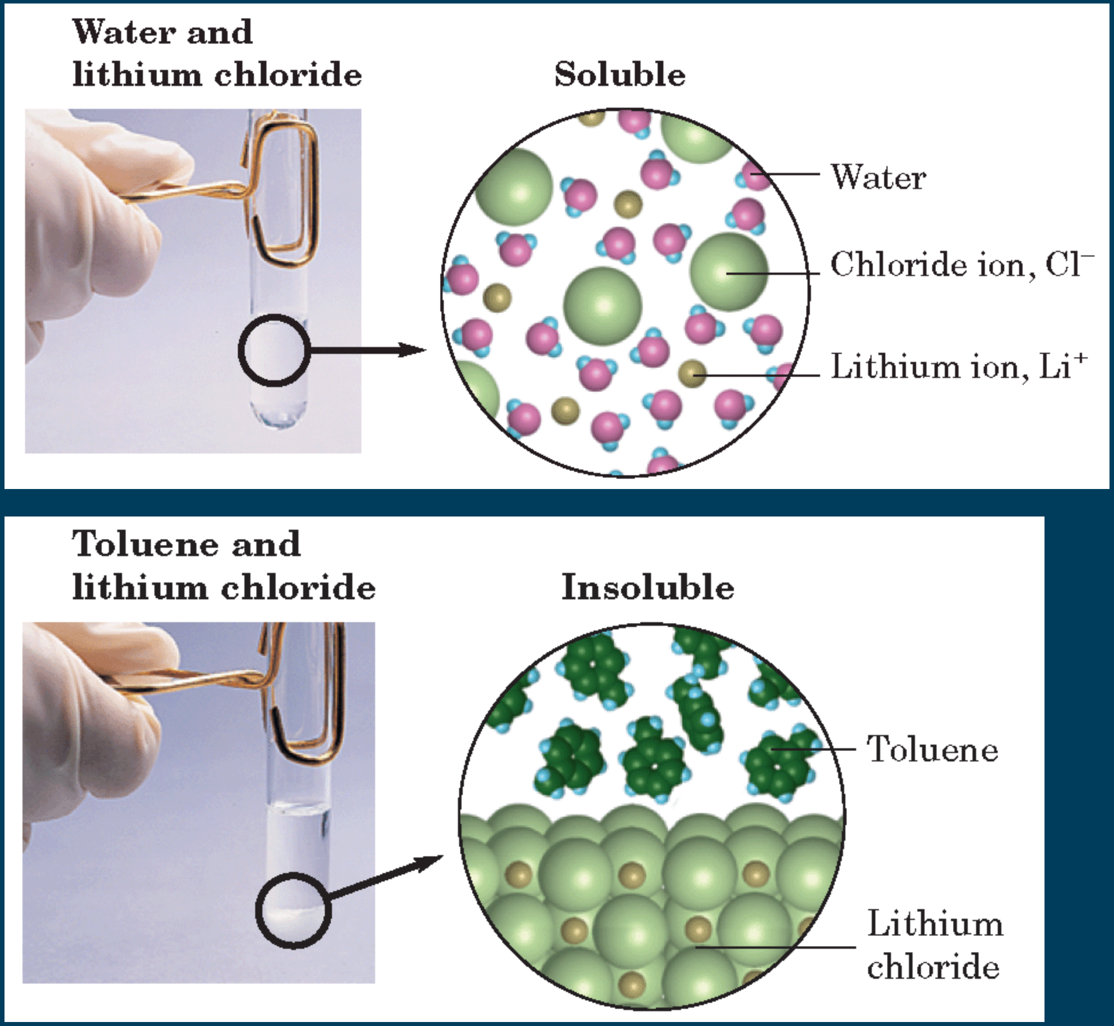
Click below to watch the Visual Concept.

Visual Concept

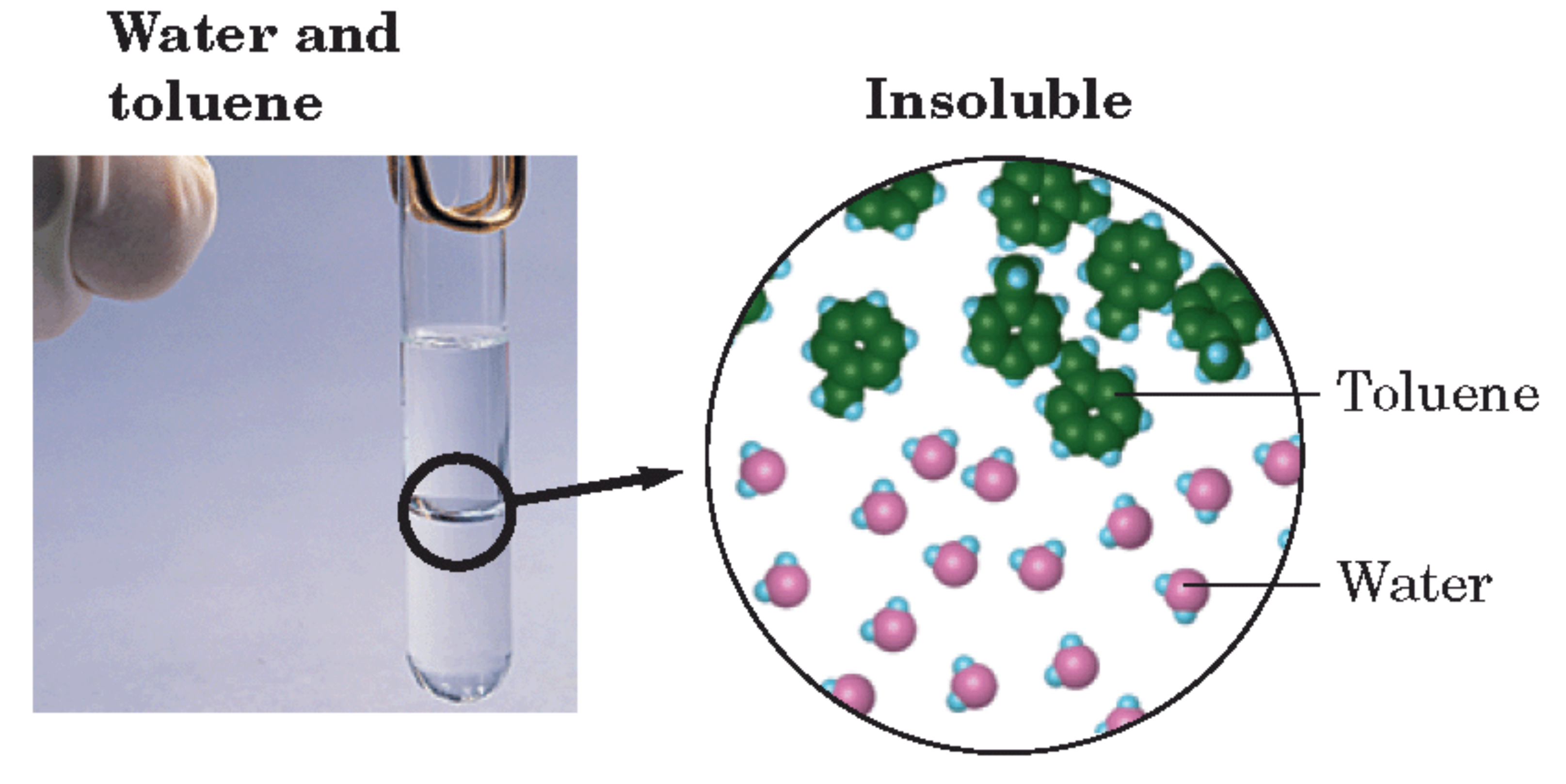
Solubility

- If you add spoonful after spoonful of sugar to tea, eventually no more sugar will dissolve.
- This illustrates the fact that for every combination of solvent with a solid solute at a given temperature, there is a limit to the amount of solid that can be dissolved.
- The point at which this limit is reached for any solute-solvent combination depends on the nature of the solute, the nature of the solvent, and the temperature.

Particle Model for Soluble and Insoluble Substances



Particle Model for Soluble and Insoluble Substances



Solubility, *continued*

- When a solute is first added to a solvent, solute molecules leave the solid surface and move about at random in the solvent.
- As more solute is added, more collisions occur between dissolved solute particles. Some of the solute molecules return to the crystal.
- When maximum solubility is reached, molecules are returning to the solid form at the same rate at which they are going into solution.

Solubility, *continued*

- **Solution equilibrium** is the physical state in which the opposing processes of dissolution and crystallization of a solute occur at the same rates.

End Of Slide

Solution Equilibrium

Click below to watch the Visual Concept.

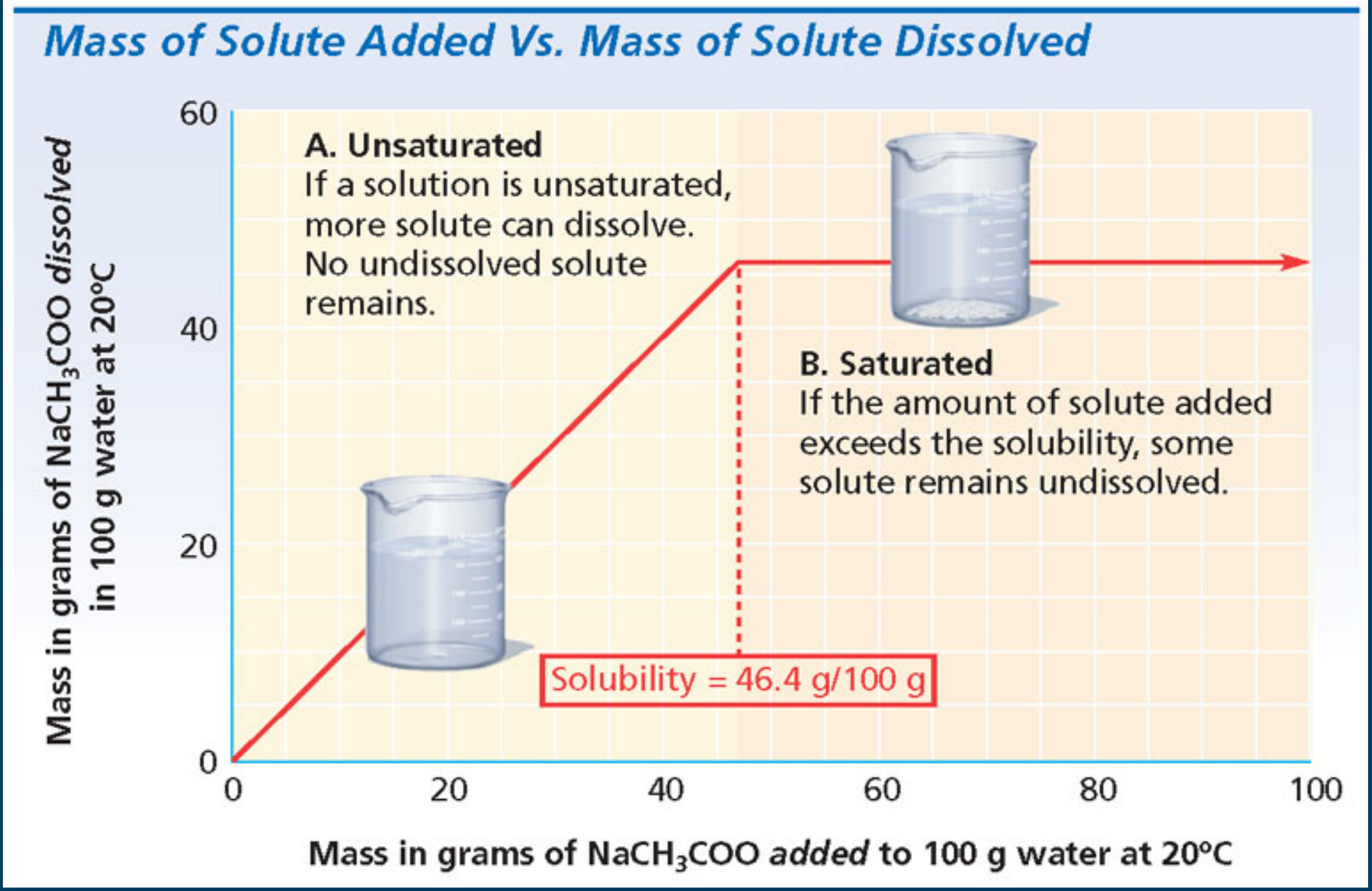
Visual Concept

Solubility, *continued*

Saturated Versus Unsaturated Solutions

- A solution that contains the maximum amount of dissolved solute is described as a **saturated solution.**
  - If more solute is added to a saturated solution, it falls to the bottom of the container and does not dissolve.
  - This is because an equilibrium has been established between ions leaving and entering the solid phase.
- A solution that contains less solute than a saturated solution under the same conditions is an **unsaturated solution.**

Mass of Solute Added Versus Mass of Solute Dissolved



Solubility, *continued*

Supersaturated Solutions

- When a saturated solution is cooled, the excess solute usually comes out of solution, leaving the solution saturated at the lower temperature.
- But sometimes the excess solute does not separate, and a **supersaturated solution** is produced, which is a solution that contains more dissolved solute than a saturated solution contains under the same conditions.
- A supersaturated solution will form crystals of solute if disturbed or more solute is added.

End Of Slide

Solubility, *continued*

Solubility Values

- The **solubility** of a substance is the amount of that substance required to form a saturated solution with a specific amount of solvent at a specified temperature.
  - example: The solubility of sugar is 204 g per 100 g of water at 20°C.
- Solubilities vary widely, and must be determined experimentally.
  - They can be found in chemical handbooks and are usually given as grams of solute per 100 g of solvent at a given temperature.

Solubility of Common Compounds

Compounds containing these ions are soluble in water . . .		. . . unless they also contain these ions, which make them insoluble.
ammonium	NH_4^+	
potassium	K^+	
sodium	Na^+	
acetate	$C_2H_3O_2^-$	Fe^{3+}, Al^{3+}, Hg_2^{2+}
chlorate	ClO_3^-	
chloride	Cl^-	Ag^+, Hg_2^{2+}, Pb^{2+}
nitrate	NO_3^-	
sulfate	SO_4^{2-}	Ca^{2+}, Ba^{2+}, Pb^{2+}, Sr^{2+}, Hg_2^{2+}

Solubility of Common Compounds

Compounds containing these ions are insoluble in water . . .		. . . unless they also contain these ions, which make them soluble.
carbonate	CO_3^{2-}	K^+, Li^+, Na^+, NH_4^+
hydroxide	OH^-	K^+, Li^+, Ba^{2+}, Na^+
oxide	O^{2-}	
phosphate	PO_4^{3-}	K^+, Na^+, NH_4^+
silicate	SiO_3^{2-}	K^+, Na^+
sulfide	S^{2-}	K^+, Na^+, NH_4^+
sulfite	SO_3^{2-}	K^+, Na^+, NH_4^+

Solubility of a Solid in a Liquid

Click below to watch the Visual Concept.

Visual Concept

Solute-Solvent Interactions

- Solubility varies greatly with the type of compounds involved.
- "Like dissolves like" is a rough but useful rule for predicting whether one substance will dissolve in another.
- What makes substances similar depends on:
  - type of bonding
  - polarity or nonpolarity of molecules
  - intermolecular forces between the solute and solvent

Like Dissolves Like

Click below to watch the Visual Concept.

Visual Concept

Solute-Solvent Interactions, *continued*

Dissolving Ionic Compounds in Aqueous Solution

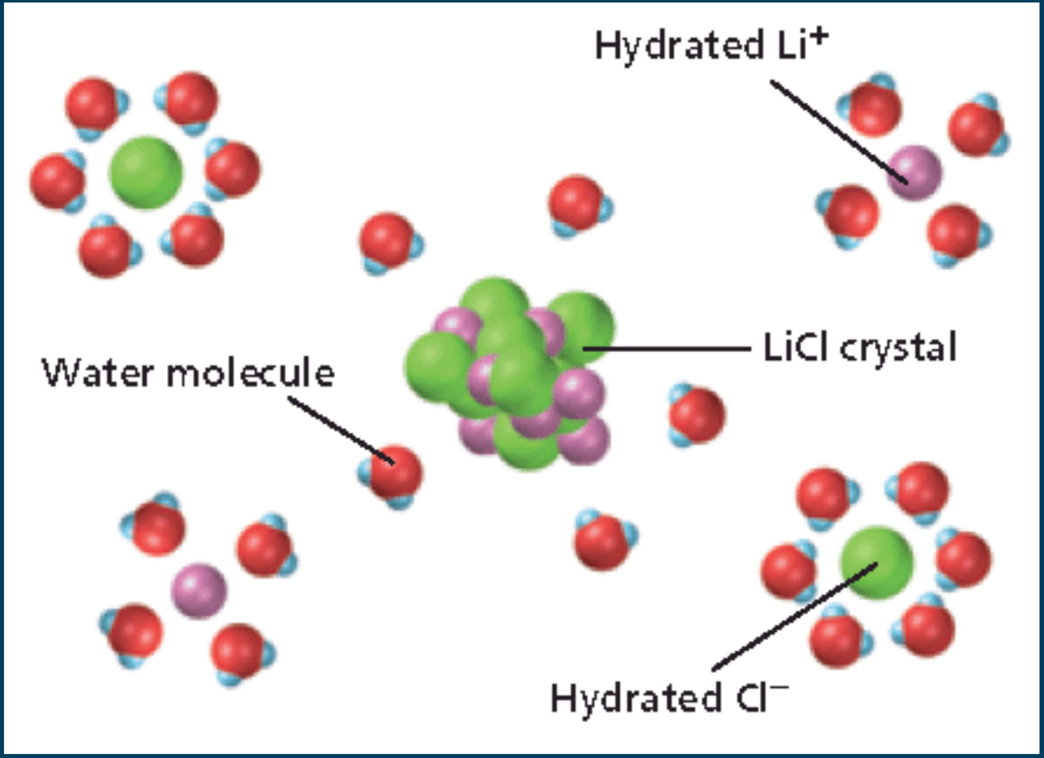
- The polarity of water molecules plays an important role in the formation of solutions of ionic compounds in water.
- The slightly charged parts of water molecules attract the ions in the ionic compounds and surround them, separating them from the crystal surface and drawing them into the solution.
- This solution process with water as the solvent is referred to as **hydration.** The ions are said to be *hydrated.*

End of Slide

Solute-Solvent Interactions, *continued*

Dissolving Ionic Compounds in Aqueous Solution

The hydration of the ionic solute lithium chloride is shown below.



Solute-Solvent Interactions, *continued*

Nonpolar Solvents

- Ionic compounds are generally not soluble in nonpolar solvents such as carbon tetrachloride, CCl_4, and toluene, $C_6H_5CH_3$.
- The nonpolar solvent molecules do not attract the ions of the crystal strongly enough to overcome the forces holding the crystal together.
- Ionic and nonpolar substances differ widely in bonding type, polarity, and intermolecular forces, so their particles cannot intermingle very much.

Solute-Solvent Interactions, *continued*

Liquid Solutes and Solvents

- Oil and water do not mix because oil is nonpolar whereas water is polar. The hydrogen bonding between water molecules squeezes out whatever oil molecules may come between them.
- Two polar substances, or two nonpolar substances, on the other hand, form solutions together easily because their intermolecular forces match.
- Liquids that are not soluble in each other are **immiscible.** Liquids that dissolve freely in one another in any proportion are **miscible.**

Comparing Miscible and Immiscible Liquids

Click below to watch the Visual Concept.

Visual Concept

Solute-Solvent Interactions, *continued*

Effects of Pressure on Solubility

- Changes in pressure have very little effect on the solubilities of liquids or solids in liquid solvents. However, increases in pressure increase gas solubilities in liquids.
- An equilibrium is established between a gas above a liquid solvent and the gas dissolved in a liquid.
- As long as this equilibrium is undisturbed, the solubility of the gas in the liquid is unchanged at a given pressure:

$$\text{gas} + \text{solvent} \rightleftharpoons \text{solution}$$

Solute-Solvent Interactions, *continued*

Effects of Pressure on Solubility, *continued*

- Increasing the pressure of the solute gas above the solution causes gas particles to collide with the liquid surface more often. This causes more gas particles to dissolve in the liquid.

$$\uparrow \text{gas} + \text{solvent} \rightleftharpoons \text{solution}$$

- Decreasing the pressure of the solute gas above the solution allows more dissolved gas particles to escape from solution.

$$\downarrow \text{gas} + \text{solvent} \leftrightharpoons \text{solution}$$

Pressure, Temperature, and Solubility of Gases

Click below to watch the Visual Concept.

Visual Concept

Solute-Solvent Interactions, *continued*

Henry's Law

- **Henry's law** states that the solubility of a gas in a liquid is directly proportional to the partial pressure of that gas on the surface of the liquid.
    - In carbonated beverages, the solubility of carbon dioxide is increased by increasing the pressure. The sealed containers contain CO_2 at high pressure, which keeps the CO_2 dissolved in the beverage, above the liquid.
    - When the beverage container is opened, the pressure above the solution is reduced, and CO_2 begins to escape from the solution.
- The rapid escape of a gas from a liquid in which it is dissolved is known as **effervescence.**

End Of Slide

Henry's Law

Click below to watch the Visual Concept.

Visual Concept

Effervescence

Click below to watch the Visual Concept.

Visual Concept

Solute-Solvent Interactions, *continued*

Effects of Temperature on Solubility

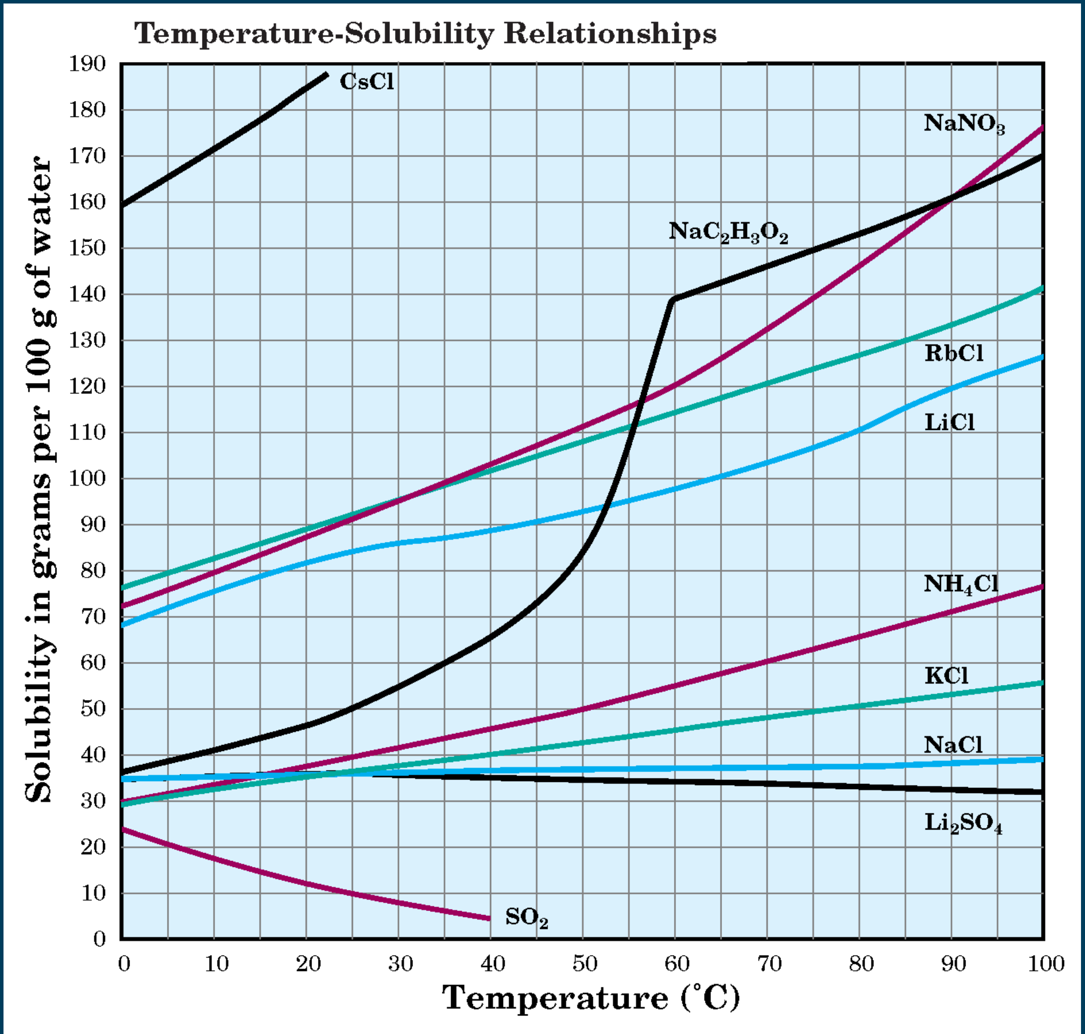
- Increasing the temperature usually decreases gas solubility.
  - As temperature increases, the average kinetic energy of molecules increases.
  - A greater number of solute molecules are therefore able to escape from the attraction of solvent molecules and return to the gas phase.
  - At higher temperatures, therefore, equilibrium is reached with fewer gas molecules in solution, and gases are generally less soluble.

Solute-Solvent Interactions, *continued*

Effects of Temperature on Solubility

- Increasing the temperature usually increases solubility of solids in liquids, as mentioned previously.
- The effect of temperature on solubility for a given solute is difficult to predict.
- The solubilities of some solutes vary greatly over different temperatures, and those for other solutes hardly change at all.
- A few solid solutes are actually *less* soluble at higher temperatures.

Solubility vs. Temperature



Enthalpies of Solution

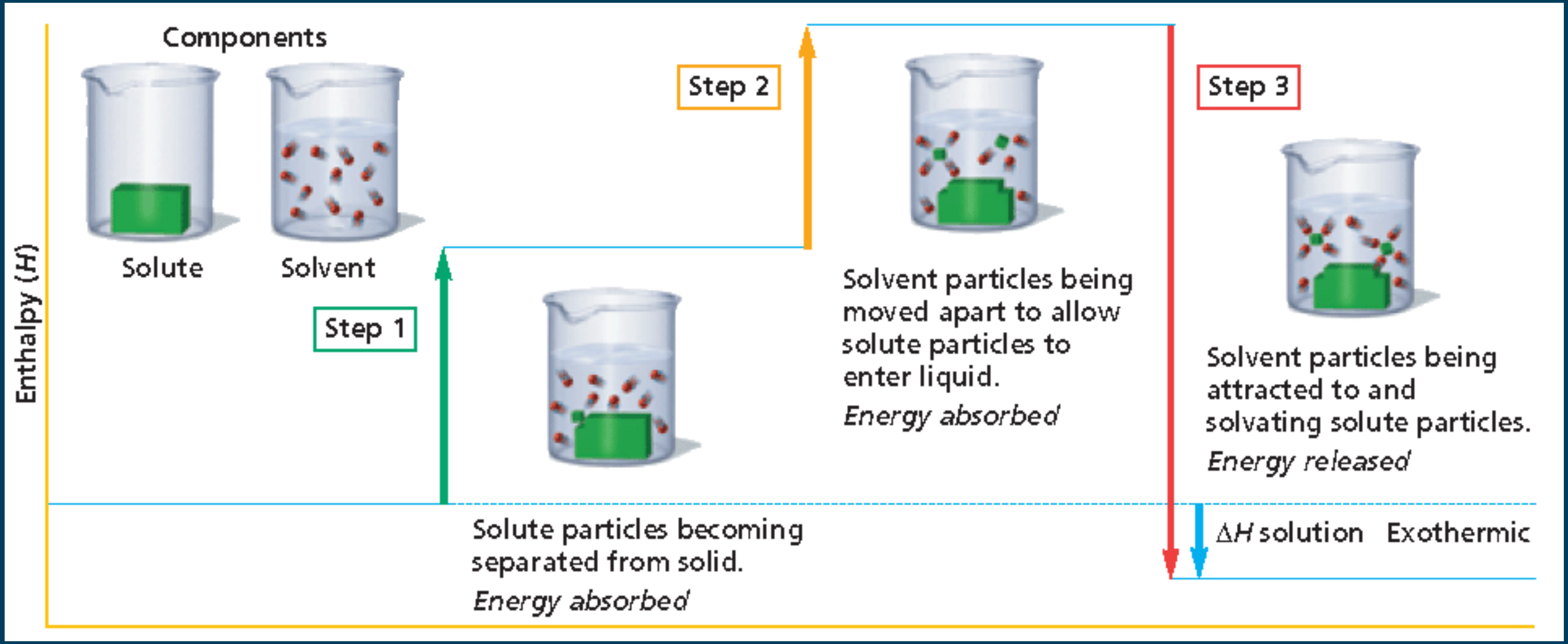
- The formation of a solution is accompanied by an energy change.
  - If you dissolve some potassium iodide, KI, in water, you will find that the outside of the container feels cold to the touch.
  - But if you dissolve some sodium hydroxide, NaOH, in the same way, the outside of the container feels hot.
  - The formation of a solid-liquid solution can either absorb energy (KI in water) or release energy as heat (NaOH in water)

Enthalpies of Solution, *continued*

- Before dissolving begins, solute particles are held together by intermolecular forces. Solvent particles are also held together by intermolecular forces.
- Energy changes occur during solution formation because energy is required to separate solute molecules and solvent molecules from their neighbors.
- A solute particle that is surrounded by solvent molecules is said to be **solvated.**

End of Slide

Enthalpies of Solution, *continued*



The diagram above shows the enthalpy changes that occur during the formation of a solution.

Enthalpies of Solution, *continued*

- The net amount of energy absorbed as heat by the solution when a specific amount of solute dissolves in a solvent is the **enthalpy of solution.**
- The enthalpy of solution is negative (energy is released) when the sum of attractions from Steps 1 and 2 is less than Step 3, from the diagram on the previous slide.
- The enthalpy of solution is positive (energy is absorbed) when the sum of attractions from Steps 1 and 2 is greater than Step 3.

End Of Slide

Preview

- Objectives
- Concentration
- Molarity
- Molality

Objectives

- **Given** the mass of solute and volume of solvent, calculate the concentration of solution.
- **Given** the concentration of a solution, determine the amount of solute in a given amount of solution.
- **Given** the concentration of a solution, determine the amount of solution that contains a given amount of solute.

End Of Slide

Concentration

- The **concentration** of a solution is a measure of the amount of solute in a given amount of solvent or solution.
- Concentration is a ratio: any amount of a given solution has the same concentration.
- The opposite of concentrated is *dilute.*
- These terms are unrelated to the degree to which a solution is saturated: a saturated solution of a solute that is not very soluble might be very dilute.

Concentration Units

Name	Abbr.	Units	Uses
grams/100. g	g/100. g	$\frac{\text{g solute}}{\text{100. g solvent}}$	solubility descriptions, medical products
mass percent or "weight percent"	%	$\frac{\text{g solute}}{\text{100. g solution}}$	biological research
parts per million	ppm	$\frac{\text{g solute}}{\text{1 000 000. g solution}}$ *	small concentrations
parts per billion	ppb	$\frac{\text{g solute}}{\text{1 000 000 000. g solution}}$ *	very small concentrations, as in pollutants or contaminants
parts per trillion	ppt	$\frac{\text{g solute}}{\text{1 000 000 000 000. g solution}}$ *	extremely small concentrations, as in isotopes used as tracers in medicine
molarity	M	$\frac{\text{mol solute}}{\text{L solution}}$	laboratory chemistry, where the solute may undergo a chemical change according to a mole ratio
molality	m	$\frac{\text{mol solute}}{\text{kg solvent}}$	calculation of special properties such as boiling-point elevation and freezing-point depression

*volume for gases

Concentration

Click below to watch the Visual Concept.

Visual Concept

Molarity

- **Molarity** is the number of moles of solute in one liter of solution.
- For example, a “one molar” solution of sodium hydroxide contains one mole of NaOH in every liter of solution.
- The symbol for molarity is M. The concentration of a one molar NaOH solution is written 1 M NaOH.

End Of Slide

< Back Next > Preview Main

Molarity, *continued*

- To calculate molarity, you must know the amount of solute in moles and the volume of solution in liters.
- When weighing out the solute, this means you will need to know the molar mass of the solute in order to convert mass to moles.
  - example: One mole of NaOH has a mass of 40.0 g. If this quantity of NaOH is dissolved in enough water to make 1.00 L of solution, it is a 1.00 M solution.

Molarity, *continued*

- The molarity of any solution can be calculated by dividing the number of moles of solute by the number of liters of solution:

$$\text{molarity (M)} = \frac{\text{amount of solute (mol)}}{\text{volume of solution (L)}}$$

- Note that a 1 M solution is *not* made by adding 1 mol of solute to 1 L of *solvent*. In such a case, the final total volume of the solution might not be 1 L.
    - Solvent must be added carefully while dissolving to ensure a final volume of 1 L.

End Of Slide

Preparation of a Solution Based on Molarity

Click below to watch the Visual Concept.

Visual Concept

Molarity, *continued*

Sample Problem A

You have 3.50 L of solution that contains 90.0 g of sodium chloride, NaCl. What is the molarity of that solution?

Molarity, *continued*

Sample Problem A Solution

Given: solute mass = 90.0 g NaCl

solution volume = 3.50 L

Unknown: molarity of NaCl solution

Solution:

$$90.0\ \text{g NaCl} \times \frac{1\ \text{mol NaCl}}{58.44\ \text{g NaCl}} = 1.54\ \text{mol NaCl}$$

$$\frac{1.54\ \text{mol NaCl}}{3.50\ \text{L of solution}} = \boxed{0.440\ \text{M NaCl}}$$

End of Slide

Molarity, *continued*

Sample Problem B

You have 0.8 L of a 0.5 M HCl solution. How many moles of HCl does this solution contain?

End Of Slide

Molarity, *continued*

Sample Problem B Solution

Given: volume of solution = 0.8 L

concentration of solution = 0.5 M HCl

Unknown: moles of HCl in a given volume

Solution:

$$\frac{0.5 \text{ mol HCl}}{1.0 \text{ L of solution}} \times 0.8 \text{ L of solution} = 0.4 \text{ mol HCl}$$

End of Slide

Molarity, *continued*

Sample Problem C

To produce 40.0 g of silver chromate, you will need at least 23.4 g of potassium chromate in solution as a reactant. All you have on hand is 5 L of a 6.0 M K_2CrO_4 solution. What volume of the solution is needed to give you the 23.4 g K_2CrO_4 needed for the reaction?

End Of Slide

Molarity, *continued*

Sample Problem C Solution

Given: volume of solution = 5 L

concentration of solution = 6.0 M K_2CrO_4

mass of solute = 23.4 K_2CrO_4

mass of product = 40.0 g Ag_2CrO_4

Unknown: volume of K_2CrO_4 solution in L

End of Slide

Molarity, *continued*

Sample Problem C Solution, *continued*

Solution:

$$1\text{ mol } K_2CrO_4 = 194.2\text{ g } K_2CrO_4$$

$$23.4\text{ g } K_2CrO_4 \times \frac{1\text{ mol } K_2CrO_4}{194.2\text{ g } K_2CrO_4} = 0.120\text{ mol } K_2CrO_4$$

$$6.0\text{ M } K_2CrO_4 = \frac{0.120\text{ mol } K_2CrO_4}{x\text{ L } K_2CrO_4\text{ solution}}$$

$$x = 0.020\text{ L } K_2CrO_4\text{ solution}$$

End Of Slide

Molality

- **Molality** is the concentration of a solution expressed in moles of solute per kilogram of solvent.
- A solution that contains 1 mol of solute dissolved in 1 kg of solvent is a "one molal" solution.
- The symbol for molality is *m,* and the concentration of this solution is written as 1 *m* NaOH.

End of Slide

Molality, *continued*

- The molality of any solution can be calculated by dividing the number of moles of solute by the number of kilograms of solvent:

$$\text{molality } (m) = \frac{\text{amount of solute (mol)}}{\text{mass of solvent (kg)}}$$

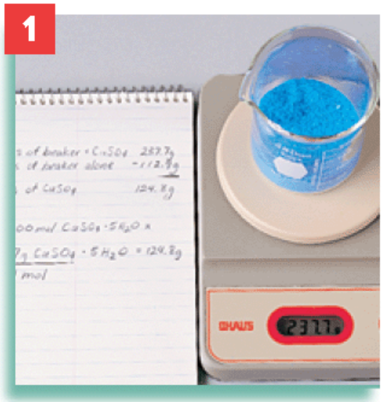
- Unlike molarity, which is a ratio of which the denominator is liters of *solution,* molality is per *kilograms* of *solvent.*
  - Molality is used when studying properties of solutions related to vapor pressure and temperature changes, because molality does not change with temperature.

Comparing Molarity and Molality

Click below to watch the Visual Concept.

Visual Concept

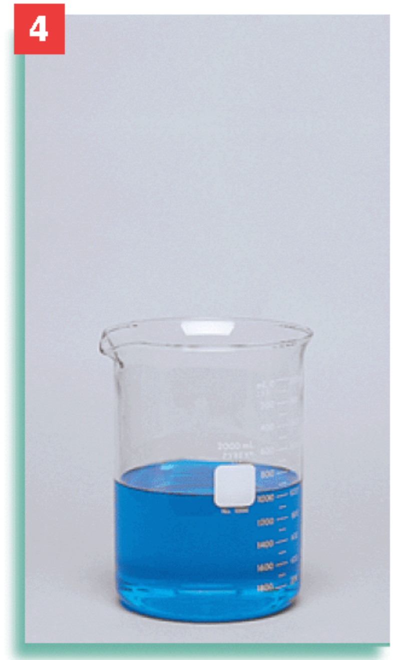
Making a Molal Solution



Calculate the mass of $CuSO_4 \cdot 5H_2O$ needed. To make this solution, each kilogram of solvent (1000 g) will require 0.5000 mol of $CuSO_4 \cdot 5H_2O$. This mass is calculated to be 124.8 g.

Add exactly 1 kg of solvent to the solute in the beaker. Because the solvent is water, 1 kg will equal 1000 mL.

Mix thoroughly.



The resulting solution has 0.5000 mol of solute dissolved in 1 kg of solvent.

Molality, *continued*

Sample Problem D

A solution was prepared by dissolving 17.1 g of sucrose (table sugar, $C_{12}H_{22}O_{11}$) in 125 g of water. Find the molal concentration of this solution.

Molality, *continued*

Sample Problem D Solution

Given: solute mass = 17.1 $C_{12}H_{22}O_{11}$

solvent mass = 125 g H_2O

Unknown: molal concentration

Solution: First, convert grams of solute to moles and grams of solvent to kilograms.

$$17.1\ \text{g}\ C_{12}H_{22}O_{11} \times \frac{1\ \text{mol}\ C_{12}H_{22}O_{11}}{342.34\ \text{g}\ C_{12}H_{22}O_{11}} = 0.0500\ \text{mol}\ C_{12}H_{22}O_{11}$$

$$\frac{125\ \text{g}\ H_2O}{1000\ \text{g/kg}} = 0.125\ \text{kg}\ H_2O$$

End Of Slide

Molality, *continued*

Sample Problem D Solution, *continued*

Then, divide moles of solute by kilograms of solvent.

$$\frac{0.0500 \text{ mol } C_{12}H_{22}O_{11}}{0.125 \text{ kg } H_2O} = 0.400\ m\ C_{12}H_{22}O_{11}$$

End of Slide

Molality, *continued*

Sample Problem E

A solution of iodine, I_2, in carbon tetrachloride, CCl_4, is used when iodine is needed for certain chemical tests. How much iodine must be added to prepare a 0.480 *m* solution of iodine in CCl_4 if 100.0 g of CCl_4 is used?

End Of Slide
< Back Next > Preview Main

Molality, *continued*

Sample Problem E Solution

Given: molality of solution = 0.480 m I_2

mass of solvent = 100.0 g CCl_4

Unknown: mass of solute

Solution: First, convert grams of solvent to kilograms.

$$\frac{100.0 \text{ g } CCl_4}{1000 \text{ g/kg}} = 0.100 \text{ kg } CCl_4$$

End of Slide

Molality, *continued*

Sample Problem E Solution, *continued*

Solution, *continued:* Then, use the equation for molality to solve for moles of solute.

$$0.480\ m = \frac{x\ \text{mol}\ I_2}{0.1\ \text{kg}\ H_2O} \qquad x = 0.0480\ \text{mol}\ I_2$$

Finally, convert moles of solute to grams of solute.

$$0.480\ \text{mol}\ I_2 \times \frac{253.8\ \text{g}\ I_2}{\text{mol}\ I_2} = 12.2\ \text{g}\ I_2$$

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End of Chapter 12 Show

< Back Next > Preview Main