

Interactive Classroom

Glencoe Science

CHEMISTRY

MATTER AND CHANGE

Chapter 14
Mixtures and Solutions

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Mixtures and Solutions

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Section 14.1 Types of Mixtures

Objectives

- **Compare** the properties of suspensions, colloids, and solutions.
- **Identify** types of colloids and types of solutions.
- **Describe** the electrostatic forces in colloids.

MAIN **Idea**

Mixtures can be either heterogeneous or homogeneous.

Review Vocabulary

solute: a substance dissolved in a solution

New Vocabulary

[suspension](#)

[colloid](#)

[Brownian motion](#)

[Tyndall effect](#)

[soluble](#)

[miscible](#)

[insoluble](#)

[immiscible](#)

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Mixtures

- a physical blend of two or more substances.
- have variable compositions.
- may be classified as either:

heterogeneous mixtures


homogeneous mixtures

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Heterogeneous Mixtures

- mixtures that are not uniform in composition.
- composition of this type of mixture can vary from one sample to another.
- consist of two or more **phases**, parts of a system with uniform composition and properties.



Soil is an example of a heterogeneous mixture.

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Heterogeneous Mixtures

May be a suspension or a colloid.

- **Suspensions** are mixtures containing particles that settle out if left undisturbed.

Example:

- Italian salad dressing



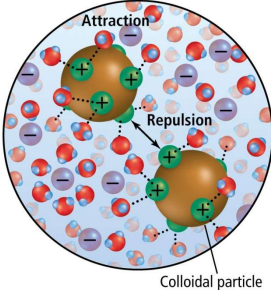
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Heterogeneous Mixtures (cont.)

- **Colloids** are heterogeneous mixtures of intermediate sized particles (between 1 nm and 1000 nm) and do not settle out.
- The most abundant substance in a mixture is the dispersion medium.
- Colloids are categorized according to the phases of their particles.




The diagram shows a circular field of small red and blue spheres representing the dispersion medium. Two larger brown spheres, labeled 'Colloidal particle', are shown. Dotted lines with '+' signs connect the two brown particles, labeled 'Attraction'. Dotted lines with '-' signs connect each brown particle to the surrounding medium, labeled 'Repulsion'. A double-headed arrow is at the bottom right.

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Heterogeneous Mixtures (cont.)

Category	Example	Dispersed Particles	Dispersing Medium
Solid sol	colored gems	solid	solid
Sol	blood, gelatin	solid	liquid
Solid emulsion	butter, cheese	liquid	solid
Emulsion	milk, mayonnaise	liquid	liquid
Solid foam	marshmallow, soaps that float	gas	solid
Foam	whipped cream, beaten egg white	gas	liquid
Solid aerosol	smoke, dust in air	solid	gas
Liquid aerosol	spray deodorant, fog, clouds	liquid	gas




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Heterogeneous Mixtures (cont.)

- **Brownian motion** is the jerky, random movements of particles in a liquid colloid, from the results of particle collisions.
[Video](#)
- The **Tyndall effect** is when dispersed colloid particles scatter light.
[Video](#)




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Homogeneous Mixtures

- Have a completely uniform composition.
- Have components that are evenly distributed throughout each sample.
- Consist of a single phase because all components are evenly distributed.
- A **solution** is a homogeneous mixture.



Sea water and air are both examples of homogeneous mixtures.


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Table 14.2 Types and Examples of Solutions

Type of Solution	Example	Solvent	Solute
Gas	air	nitrogen (gas)	oxygen (gas)
Liquid	carbonated water	water (liquid)	carbon dioxide (gas)
	ocean water	water (liquid)	oxygen gas (gas)
	antifreeze	water (liquid)	ethylene glycol (liquid)
	vinegar	water (liquid)	acetic acid (liquid)
	ocean water	water (liquid)	sodium chloride (solid)
Solid	dental amalgam	silver (solid)	mercury (liquid)
	steel	iron (solid)	carbon (solid)



 Click here to view an animated version of this graphic.



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Solutions:

Consist of two parts:

- solvent - the dissolving medium.**
- solute - particles dissolved in the solvent.**

- are homogeneous and stable.
- will not separate if they are filtered. Solvent and solute will both pass through the filter.
- may consist of solvents and solutes that are gases, liquids, or solids.



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Aqueous Solutions:

- make up nearly all of the water people consume.
- provide efficient means of transporting nutrient in plants, animals, and people.
- have solutes that are ionic compounds or polar covalent molecules.



• **Distilled water is the only non-aqueous solution people consume.** ← →

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Polar vs. Non-polar Molecules:

- Covalent bonds share pairs of electrons. If these electron pairs are equally shared, the molecule is a non-polar molecule.
- In some covalently bonded molecules, one element holds the shared electron pairs more than the others. The atom with the extra shared pair becomes more negative. The remaining atoms become more positive.

← →

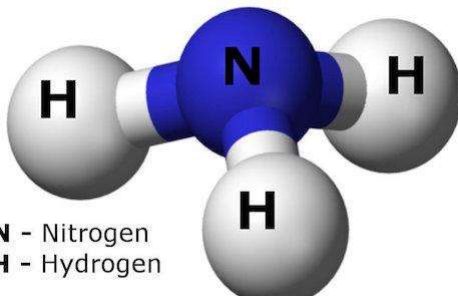
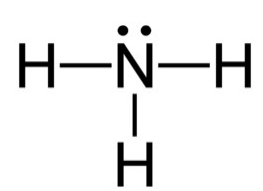
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Ammonia: polar covalent molecule.

N - Nitrogen
H - Hydrogen

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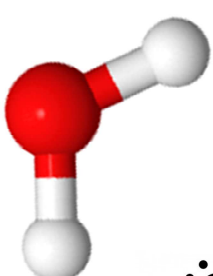
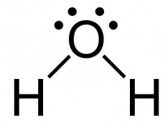
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Water: Polar

- The oxygen atom holds the shared electron pairs and becomes partially negative. The hydrogen atoms become partially positive.





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$\text{H}:\ddot{\text{Cl}}:$

HCl: Polar

- The chlorine atom holds the shared electron pair and becomes partially negative. The hydrogen atom become partially positive.

← →

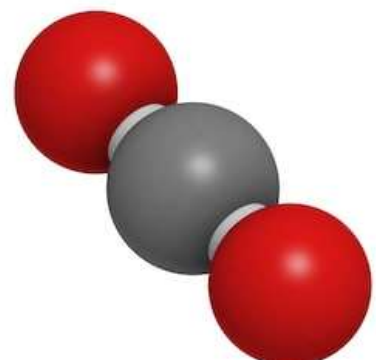
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CO₂: Non-Polar

- The carbon and Oxygen atoms share the electron pairs almost evenly. There is no partially positive or partially negative areas on a non-polar molecule.



$\ddot{\text{O}}=\text{C}=\ddot{\text{O}}:$

← →

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Aqueous Solutions:

- Non-polar covalent molecules like gasoline and grease can not dissolve in water.
- Grease will, however, dissolve in gasoline.

Why the difference?

- “Like dissolves like” is an expression chemists use when predicting the solubility of substances. It means that dissolving occurs when there is a similarity between solvent and solute.




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- Ionic compounds or polar covalent molecules dissolve in polar solvents.
- Non-polar molecules dissolve in non-polar solvents.
- NaCl (solute) is an ionic compound. Water (solvent) is a polar covalent molecule. Because these substances both are polar, dissolving takes place.



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- Grease (solute) and gasoline (solvent) are both non-polar. Because these substances are both non-polar, dissolving takes place.
- Non-polar vegetable oil will not dissolve in polar water.

The process in which a solute dissolves in a solvent is called solvation or hydration.

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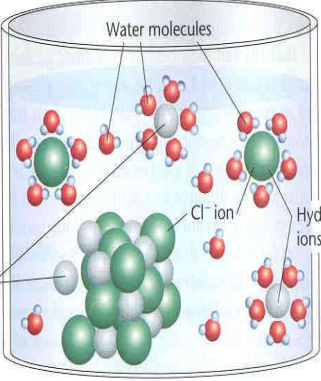
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Solvation/Hydration:

- Water molecules are in continuous motion because of their kinetic energy.
- When a crystal of NaCl is placed in water, the water molecules collide with it.
- The solvent (H_2O) molecules attract the ions of the NaCl.



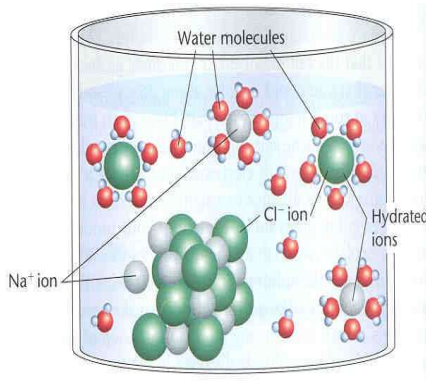
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Solvation/Hydration:



The diagram shows a cylindrical container filled with water. At the bottom, a cluster of green spheres represents a NaCl crystal. Labels point to a 'Na⁺ ion' (a single green sphere) and a 'Cl⁻ ion' (a single white sphere) that have broken away from the crystal. 'Water molecules' are shown as red and white spheres. 'Hydrated ions' are shown as a green sphere surrounded by four red spheres (oxygen atoms) and a white sphere surrounded by four red spheres (hydrogen atoms).

As individual Na⁺ and Cl⁻ ions break away from the crystal, the NaCl dissolves and each ion becomes solvated or hydrated (surrounded by solvent molecules).

[Video](#)

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Solution Formation:

The nature of a solvent affects whether a substance will dissolve in a solvent. Three factors affect how fast dissolving rate:

1. [Agitation/shaking of the container](#). Stirring a solution increases the rate at which the solute dissolves.
2. [Temperature](#). Most substances dissolve more rapidly in hot water than in cold water.
3. [Particle size](#). The greater the surface area of the solute, the faster the rate of dissolving.

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Solubility:

The **kinetic molecular theory** can explain why solute dissolves in aqueous solutions:

1. Water molecules are in constant motion.
2. Collisions of water molecules with the solute results in **solvation** of its particles.
3. Agitating/crushing solute particles increase the rate of dissolving by exposing solute particles to fresh solvent particles.
4. Raising temperature of the solution increases the **kinetic energy** of the solvent particles, increasing the rate and number of collisions with particles of solute.




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Solubility:

- Eventually a state of dynamic equilibrium exists between the solution and the solute. At this point, the solvent has dissolved the maximum amount of solute it can, provided the temperature remains constant.
- The solution is **saturated**. A saturated solution contains the maximum amount of solute for a given amount of solvent at a constant temperature.




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Solubility:

- The solubility of a substance is the amount of a substance that dissolves in a given quantity of solvent at a given temperature to produce a saturated solution.
- Solubility is usually measured in grams of solute/100g of solvent.

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Solubilities of Some Substances in Water at Various Temperatures					
Substance	Formula	Solubility (g/100 g of H ₂ O)			
		0°C	20°C	50°C	100°C
Barium sulfate	BaSO ₄	0.00019	0.00025	0.00034	—
Lead(II) chloride	PbCl ₂	0.60	0.99	1.70	—
Lithium carbonate	Li ₂ CO ₃	1.5	1.3	1.1	0.70
Potassium chlorate	KClO ₃	4.0	7.4	19.3	56.0
Potassium chloride	KCl	27.6	34.0	42.6	57.6
Sodium chloride	NaCl	35.7	36.0	37.0	39.2
Sodium nitrate	NaNO ₃	74	88.0	114.0	182
Sodium sulfate	Na ₂ SO ₄	4.76	62	50.0	41.0
Silver nitrate	AgNO ₃	122	222.0	455.0	733
Lithium bromide	LiBr	143.0	166	203	266.0
Cane sugar	C ₁₂ H ₂₂ O ₁₁	179	203.9	260.4	487
Hydrogen*	H ₂	0.00019	0.00016	0.00013	0.0
Oxygen*	O ₂	0.0070	0.0043	0.0026	0.0
Carbon dioxide*	CO ₂	0.335	0.169	0.076	0.0

*Gas at 760 mm Hg total pressure


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Solubility:

- When the temperature of a saturated solution is raised, the excess solid usually dissolves. If the solution is then cooled slowly and undisturbed to its original temperature, the excess solute does not always crystallize immediately. A supersaturated solution has been produced.
- A **supersaturated** solution is a solution that contains more solute than it can theoretically hold at a given temperature.
- Dynamic equilibrium cannot exist in a supersaturated solution - there is no undissolved solute.




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Homogeneous Mixtures (cont.)

- A substance that dissolves in a solvent is **soluble**.
- Two liquids that are soluble in each other in any proportion are **miscible**.
- A substance that does not dissolve in a solvent is **insoluble**.
- Two liquids that can be mixed but separate shortly after are **immiscible**.



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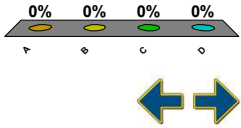
Section 14.1 Assessment

Checkpoint

Miscible substances are:

- A. two liquids that are not soluble in each other
- B. solids that dissolve in liquids
- C. solids that do not dissolve in liquids
- D. two liquids that are soluble in each other**

0% 0% 0% 0%



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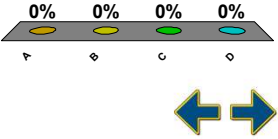
Section 14.1 Assessment

Checkpoint

The jerky, random movement of particles in a liquid colloid is known as ____.

- A. Brownian motion**
- B. Tyndall effect
- C. Charles's Law
- D. kinetic energy

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Section 14.1 Assignment

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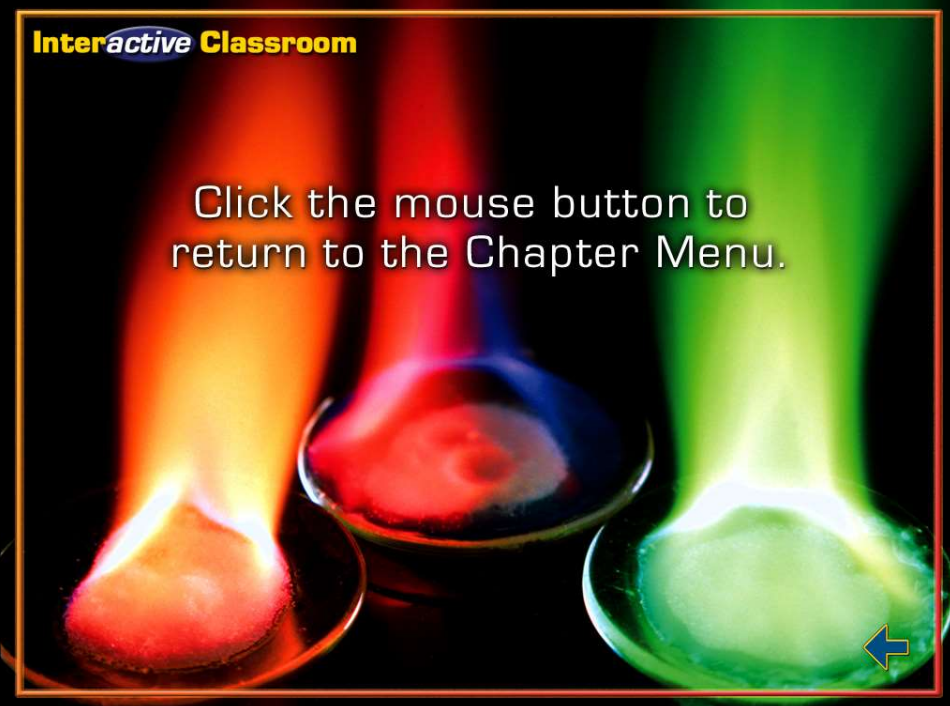
- 14-1 (page 479): #1-7 (8 optional)



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Section 14.2 Solution Concentration

Objectives

- **Describe** concentration using different units.
- **Determine** the concentrations of solutions.
- **Calculate** the molarity of a solution.

Review Vocabulary

solvent: the substance that dissolves a solute to form a solution

New Vocabulary

[concentration](#)

[molarity](#)

[molality](#)

[mole fraction](#)

MAIN Idea Concentration can be expressed in terms of percent or in terms of moles.

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Expressing Concentration

- The **concentration** of a solution is a measure of how much solute is dissolved in a specific amount of solution.
- Concentration can be described as concentrated or dilute.

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Expressing Concentration (cont.)

Concentration Description	Ratio
Percent by mass	$\frac{\text{mass of solute}}{\text{mass of solution}} \times 100$
Percent by volume	$\frac{\text{volume of solute}}{\text{volume of solution}} \times 100$
Molarity	$\frac{\text{moles of solute}}{\text{liter of solution}}$
Molality	$\frac{\text{moles of solute}}{\text{kilogram of solvent}}$
Mole fraction	$\frac{\text{moles of solute}}{\text{moles of solute} + \text{moles of solvent}}$

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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
- But, there are ways to express solution concentration *quantitatively* . . .

[Simulation](#)



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- Percent by Mass
- Percent by Volume
- Molarity

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Percent by Mass (w/w):

- Describes solid dissolved in liquid sol'ns.

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

- **Percent by Mass (w/v):**

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

← →

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Percent by Volume (v/v):

- Describes liquid dissolved in liquid sol'ns

Percent by volume = $\frac{\text{volume of solute}}{\text{volume of solution}} \times 100$




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- Vinegar is a 5% (v/v) solution of acetic acid, CH_3COOH .
- This means there are 5 volumes of acetic acid for every 100 volumes of solution.
- 95 of the volumes are water!



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- Most common unit of solution concentration.

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

- Units are ***M***, molar
- 1.0*M*, 12*M*, 0.01*M*
- Must work with litres

[Simulation](#)




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If 0.435 g of KMnO_4 is dissolved in enough water to give 250. mL of solution, what is the molarity of KMnO_4 ?



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- As is almost always the case, the first step is to convert the mass of material to moles.

$$\text{KMnO}_4 = 39.09\text{g/mol} + 54.94\text{g/mol} + 4(16.00\text{g/mol}) = 158.03\text{g/mol}$$

$$0.435\text{ g KMnO}_4 \cdot \frac{1\text{ mol KMnO}_4}{158.03\text{ g KMnO}_4} = 0.00275\text{ mol KMnO}_4$$

$$250.\text{ mL} = 0.250\text{ L}$$

$$\text{Molarity} = \frac{\text{mol}}{\text{L}} = \frac{0.00275\text{ mol KMnO}_4}{0.250\text{ L solution}} = 0.0110\text{ M}$$

↔

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- Pour in a small amount of solvent.
- Then add the solute .
- Agitate to dissolve solute.
- Carefully fill to final volume.

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- How many grams of NaCl are needed to make 6.0 L of a 0.75 M NaCl solution?

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$$M = \frac{\text{mol}}{L} \quad M = 0.75M \quad L = 6.0L$$

$$\text{mol} = M \cdot L$$

$$\text{mol} = 0.75M \cdot 6.0L$$

$$\text{mol} = 4.5 \text{ mol NaCl}$$

$$\text{NaCl} = 22.99\text{g/mol} + 35.45\text{g/mol} = 58.44\text{g/mol}$$

$$4.5 \text{ mol} \times \frac{58.44\text{g NaCl}}{1 \text{ mol}} = 262.98\text{g} = 260 \text{ g NaCl}$$

← →

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How to prepare a 1 molar NaCl solution.

1 mole NaCl (58.44 g)

Water

Add water until solid is dissolved. Then add additional water until the 1 liter mark is reached.

Mix

First add 1 mole of NaCl. A 1 molar NaCl solution

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Dilution

- When a solution is diluted, solvent is added to lower its concentration.
- The amount of Dilution solute remains constant before and after the dilution:

moles BEFORE = moles AFTER

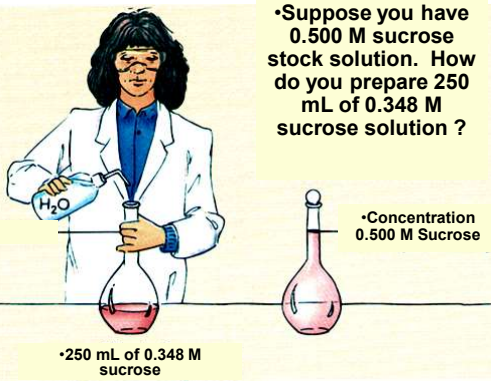
$$M_1V_1 = M_2V_2$$
- **Stock solutions** are pre-made to known Molarity

↔

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Practice



•Suppose you have 0.500 M sucrose stock solution. How do you prepare 250 mL of 0.348 M sucrose solution ?

•250 mL of 0.348 M sucrose

•Concentration 0.500 M Sucrose

$$M_1 = 0.500M \quad M_2 = 0.348M$$

$$V_1 = ? \quad V_2 = 0.250L$$

$$M_1V_1 = M_2V_2$$

$$V_1 = \frac{M_2V_2}{M_1}$$

$$V_1 = \frac{(0.348M)(0.250L)}{0.500M}$$

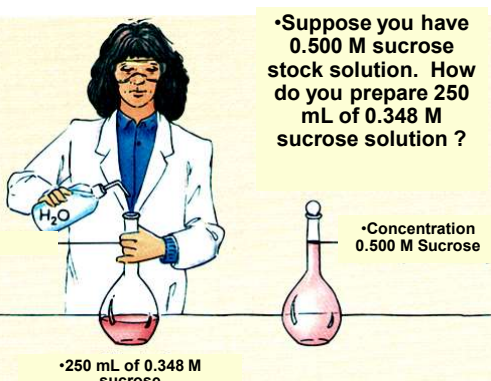
$$V_1 = 0.174 L$$

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Practice



•Suppose you have 0.500 M sucrose stock solution. How do you prepare 250 mL of 0.348 M sucrose solution ?

•250 mL of 0.348 M sucrose

•Concentration 0.500 M Sucrose

- Add 0.174 L of 0.500M solution to enough distilled H₂O to produce 0.250L of solution.
- A volumetric flask is used to when preparing solutions.

← →

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How to make 5.00 L of a 1.50 M KCl from a 12.0 M stock solution.

0.625 L 12.0 M stock solution

1.50 M KCl

Dilute with water to total volume of 5.00 L

$$M_1V_1 = M_2V_2$$

$$\frac{12.0 \text{ mol}}{\cancel{\text{L}}} \times 0.625 \cancel{\text{L}} = \frac{1.50 \text{ mol}}{\cancel{\text{L}}} \times 5.00 \cancel{\text{L}}$$

$$7.50 \text{ mol} = 7.50 \text{ mol}$$

← →

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- Section 15.2 questions #8 – 24, 28,30
- Review Questions:
#54, 55, (69 – 79, odd) , (#80 – 85, all)

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Section 14.2 Assessment

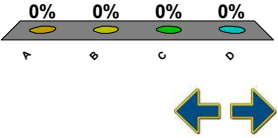
Checkpoint

Which is NOT a quantitative measure of concentration?

- A. molarity
- B. molality
- C. percent by mass
- D. dilute**

0% 0% 0% 0%

A B C D



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Section 14.2 Assessment

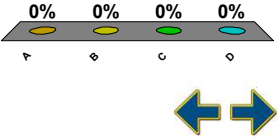
Checkpoint

The number of moles of solute divided by liters of solution is called _____.

- A. molarity**
- B. molality
- C. percent by volume
- D. percent by mass

0% 0% 0% 0%

A B C D




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Section 14.2 Assignment

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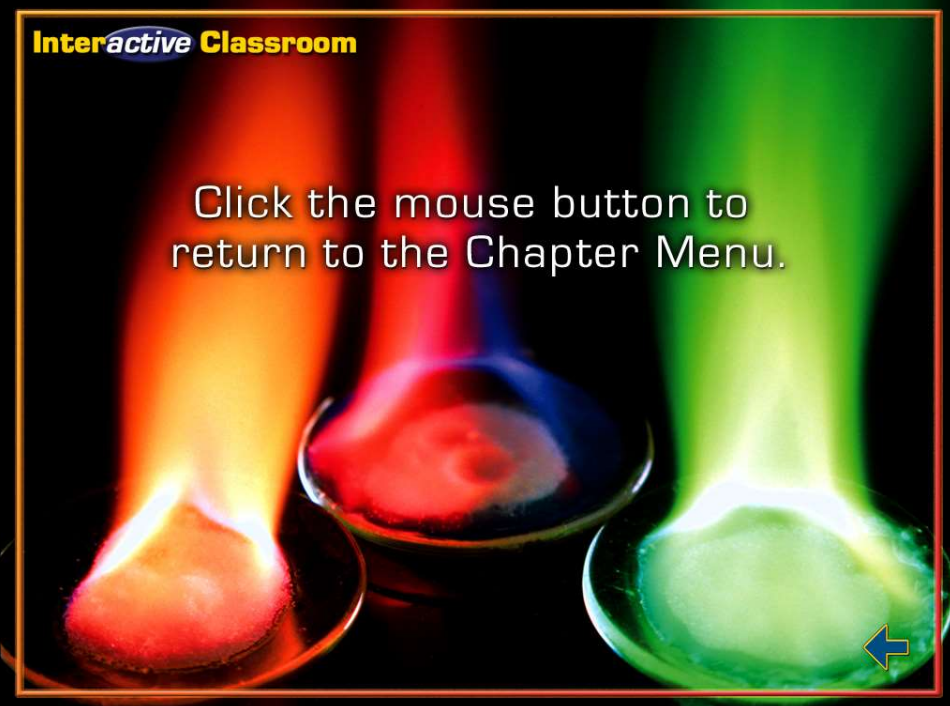
- 14-2 (pages 481-488): #9-12, 16-18, 20-22, 24-26, 33-35



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Section 14.3 Factors Affecting Solvation

Objectives

- **Describe** how intermolecular forces affect solvation.
- **Define** solubility.
- **Understand** what factors affect solubility.

Review Vocabulary

exothermic: a chemical reaction in which more energy is released than is required to break bonds in the initial reactants



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Section 14.3 Factors Affecting Solvation (cont.)

New Vocabulary

[solvation](#)

[heat of solution](#)


[unsaturated solution](#)

[saturated solution](#)

[supersaturated solution](#)

[Henry's law](#)

MAIN Idea Factors such as temperature, pressure, and polarity affect the formation of solutions.




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The Solvation Process

- **Solvation** is the process of surrounding solute particles with solvent particles to form a solution.
- Solvation in water is called hydration.
- The attraction between dipoles of a water molecule and the ions of a crystal are greater than the attraction among ions of a crystal.

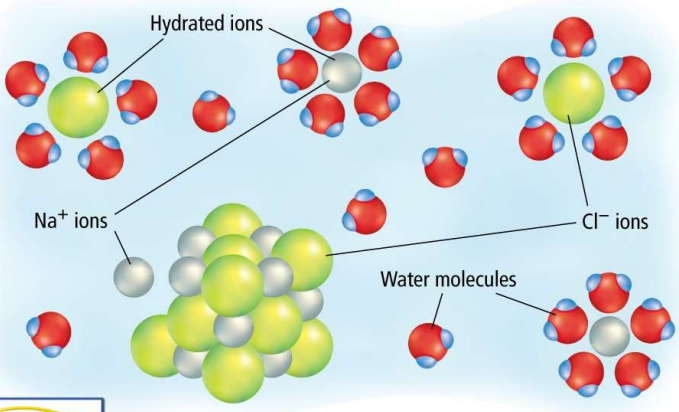


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The Solvation Process (cont.)

Solvation Process of NaCl




Hydrated ions

Na⁺ ions

Cl⁻ ions

Water molecules

Concepts in Motion
Click here to view an animated version of this graphic.



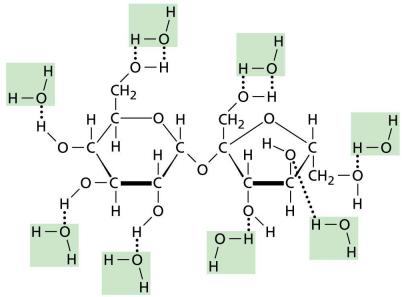
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The Solvation Process (cont.)

- Sucrose molecules have several O–H bonds, which become sites for hydrogen bonding with water molecules.
- Oil does not form a solution with water because there is little attraction between polar water molecules and nonpolar oil molecules.



The diagram shows a sucrose molecule, a disaccharide composed of glucose and fructose units linked by an oxygen atom. Several hydroxyl (-OH) groups are highlighted in green boxes. Dotted lines represent hydrogen bonds between these hydroxyl groups and the oxygen and hydrogen atoms of nearby water molecules (H-O-H). The water molecules are also highlighted in green boxes. This illustrates how the polar nature of sucrose allows it to interact with the polar water molecules.

← →

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The Solvation Process (cont.)

- During solvation, the solute must separate into particles and move apart, which requires energy.
- The overall energy change that occurs during solution formation is called the **heat of solution**.


← →

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Factors That Affect Solvation

- Stirring or shaking moves dissolved particles away from the contact surfaces more quickly and allows new collisions to occur.
- Breaking the solute into small pieces increases surface area and allows more collisions to occur.
- As temperature increases, rate of solvation increases.




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Solubility

- Solubility depends on the nature of the solute and solvent.
- **Unsaturated solutions** are solutions that contain less dissolved solute for a given temperature and pressure than a saturated solution.



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Solubility (cont.)

- **Saturated solutions** contain the maximum amount of dissolved solute for a given amount of solute at a specific temperature and pressure.
- Solubility is affected by increasing the temperature of the solvent because the kinetic energy of the particles increases.

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Solubility (cont.)

Solubilities as a Function of Temperature

Temperature (°C)	CaCl ₂ (g/100g H ₂ O)	KCl (g/100g H ₂ O)	NaCl (g/100g H ₂ O)	KClO ₃ (g/100g H ₂ O)	Ce ₂ (SO ₄) ₃ (g/100g H ₂ O)
0	60	28	35	5	18
10	75	32	36	8	15
20	95	38	37	12	12
30	>100	42	38	18	10
40	-	46	39	25	8
50	-	50	40	35	6
60	-	54	40	45	5
70	-	58	40	55	4
80	-	62	40	65	3
90	-	66	40	75	2
100	-	70	40	85	1

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Solubility (cont.)

- A **supersaturated solution** contains more dissolved solute than a saturated solution at the same temperature.
- To form a supersaturated solution, a saturated solution is formed at high temperature and then slowly cooled.
- Supersaturated solutions are unstable.


← →

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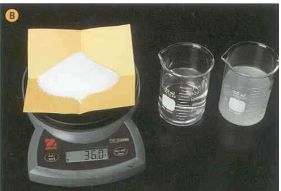
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Solubility:

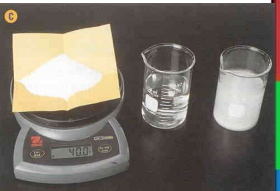
Where a solutions unsaturated or saturated depends upon how many grams of solute is dissolved in it.



20.0 g of NaCl produces an unsaturated solution in 100 g of H₂O.



36.0 g of NaCl produces a saturated solution in 100 g of H₂O.



40.0 g of NaCl produces a saturated solution in 100 g of H₂O. 36.0 g dissolves. 4.0 g is undissolved.

← →

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Solubility (cont.)

Table 14.4 Solubilities of Solutes in Water at Various Temperatures

Substance	Formula	Solubility (g/100 g H ₂ O)*			
		0°C	20°C	60°C	100°C
Aluminum sulfate	Al ₂ (SO ₄) ₃	31.2	36.4	59.2	89.0
Barium hydroxide	Ba(OH) ₂	1.67	3.89	20.94	--
Calcium hydroxide	Ca(OH) ₂	0.189	0.173	0.121	0.076
Lithium sulfate	Li ₂ SO ₄	36.1	34.8	32.6	--
Potassium chloride	KCl	28.0	34.2	45.8	56.3
Sodium chloride	NaCl	35.7	35.9	37.1	39.2
Silver nitrate	AgNO ₃	122	216	440	733
Sucrose	C ₁₂ H ₂₂ O ₁₁	179.2	203.9	287.3	487.2
Ammonia*	NH ₃	1130	680	200	--
Carbon dioxide*	CO ₂	1.713	0.878	0.359	--
Oxygen*	O ₂	0.048	0.031	0.019	--

* L/1 L H₂O of gas at standard pressure (101 kPa)




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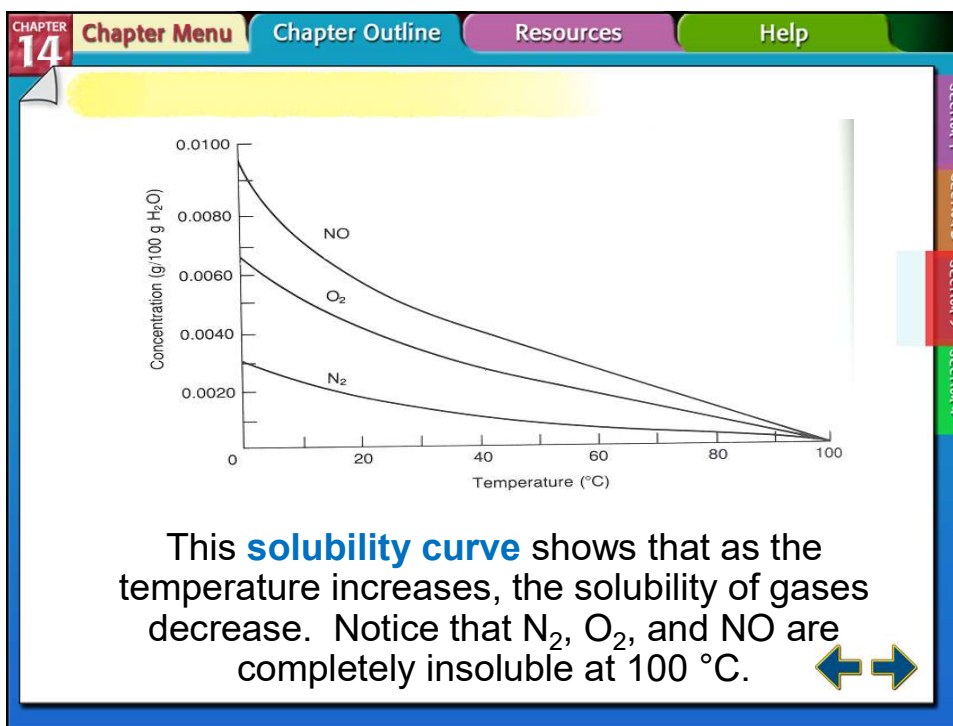
Factors Affecting Solubility:

Three factors affect solubility.

- 1. Molecule size:** Small molecules are more soluble than larger molecules.
- 2. Temperature:** The solubility of most solids increases with an increase in temperature. Increased kinetic energy breaks apart the bonds between particles.
 - The solubility of most liquids is not affected by temperature change.
 - The solubility of gases decrease as temperature increases. Gases lose kinetic energy when they dissolve in liquids. As liquids heat up, kinetic energy of gas particles increases and gases become less soluble.



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Pressure: Changes in pressure affect the solubility of gases in liquids.

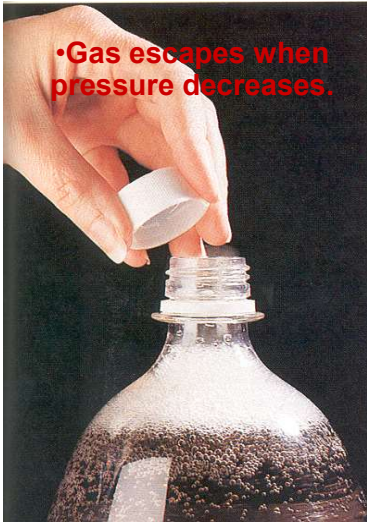
- As pressure increases, solubility increases.
- As pressure decreases, solubility decreases.

↔

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• Gas escapes when pressure decreases.

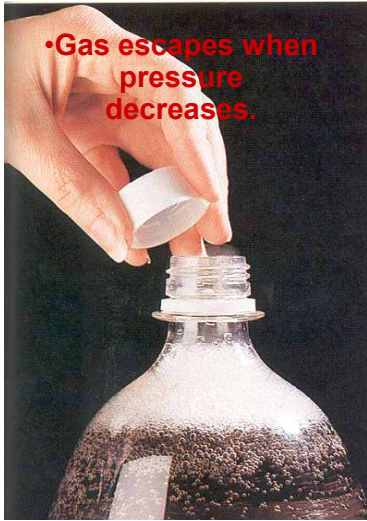
Pressure: Changes in pressure affect the solubility of gases in liquids. As pressure increases, solubility increases. As pressure decreases, solubility decreases.

← →

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• Gas escapes when pressure decreases.

- Pop is a **supersaturated** solution of CO_2 in H_2O . In unopened bottles, gas is dissolved under pressure in H_2O . When the bottle is opened, CO_2 trapped above the liquid escapes and pressure drops.
- **Henry's Law** explains this phenomenon.

← →

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High pressure, deep under water (30 m) causes an increased solubility of N_2 in the diver's blood. If they ascend to fast, decreasing pressure causes N_2 bubbles to form in their blood vessels.

This painful, and sometimes fatal condition is called "the bends."

Henry's Law explains this phenomenon.



•Scuba divers must surface slowly to avoid "the Bends."

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Henry's Law:

Henry's Law states that, at a given temperature, the solubility of a liquid (S) is directly proportional to the pressure of the gas above the liquid (P).

This relationship can be expressed with an equation:

$$\frac{S_1}{P_1} = \frac{S_2}{P_2}$$

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Example 1:

If the solubility of a gas in water is 0.77 g/L at 3.5 atm, what is its solubility, in g/L at 2.0 atm?

Temperature remains constant at 25 degrees C.



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•Solution:

$S_1 = 0.77 \text{ g/L}$ $P_1 = 3.5 \text{ atm}$ $S_2 = ?$ $P_2 = 2.0 \text{ atm}$

$$\frac{S_1}{P_1} = \frac{S_2}{P_2}$$

$$S_2 = \frac{S_1 \times P_2}{P_1}$$

$$= \frac{0.77 \text{ g/L} \times 2.0 \text{ atm}}{3.5 \text{ atm}}$$

$$= 0.44 \text{ g/L}$$


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Example 2:

A gas has a solubility in water at 0 °C of 3.6 g/L at 1.0 atm. At 0 °C, what pressure is required to produce an aqueous solution containing 9.5 g/L of the same gas?

← →

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Solution:

S1 = 3.6 g/L P1 = 1.0 atm S2 = 9.5 g/L P2 = ?

$$\frac{S1}{P1} = \frac{S2}{P2}$$

$$P2 = \frac{P1 \times S2}{S1}$$

$$= \frac{1.0 \text{ atm} \times 9.5 \text{ g/L}}{3.6 \text{ g/L}}$$

$$= 2.6 \text{ atm}$$

← →

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Section 14.3 Assessment

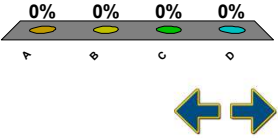
Checkpoint

For a given amount, which type of solution contains the LEAST amount of solute?

- A. solvated
- B. saturated
- C. supersaturated
- D. unsaturated

0% 0% 0% 0%

A B C D



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Section 14.3 Assessment

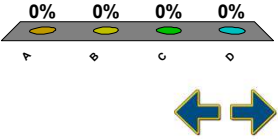
Checkpoint

At a given temperature, the solubility of a gas is directly proportional to what?

- A. volume
- B. mass
- C. molarity
- D. pressure

0% 0% 0% 0%

A B C D




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Section 14.3 Assignment

Text Questions:

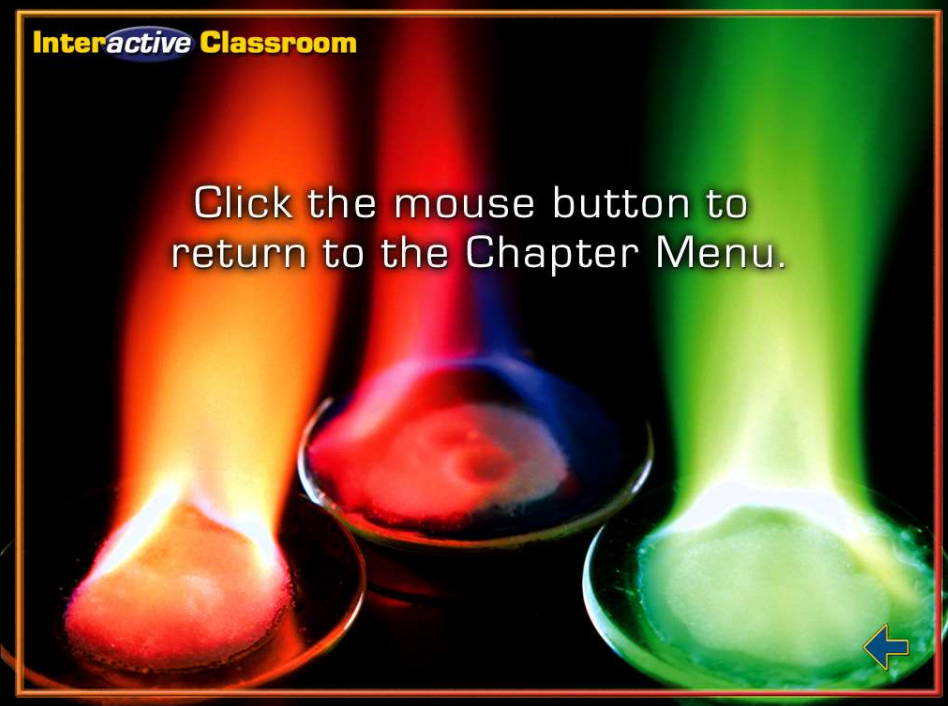
- 14-3 (page 497): #36-43 (44 optional)



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Interactive Classroom

Click the mouse button to return to the Chapter Menu.



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Section 14.4 Colligative Properties of Solutions

Objectives

- **Describe** colligative properties.
- **Identify** four colligative properties of solutions.
- **Determine** the boiling point elevation and freezing point depression of a solution.

Review Vocabulary

ion: an atom that is electrically charged




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Section 14.4 Colligative Properties of Solutions (cont.)

New Vocabulary

[colligative property](#)
[vapor pressure lowering](#)
[boiling point elevation](#)
[freezing point depression](#)
[osmosis](#)
[osmotic pressure](#)

MAIN  **Idea** Colligative properties depend on the number of solute particles in a solution.




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Electrolytes and Colligative Properties

- **Colligative properties** are physical properties of solutions that are affected by the number of particles but not by the identity of dissolved solute particles.
- Ionic compounds are electrolytes because they dissociate in water to form a solution that conducts electricity.
- Some molecular compounds are also electrolytes.




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Electrolytes and Colligative Properties (cont.)

- Electrolytes that produce many ions in solution are strong electrolytes.
- Many molecular compounds do not ionize when dissolved, and do not conduct electricity.
- They are called **non-electrolytes**.
- The effect of solutes on the melting and boiling points of a solution can be represented using a **phase diagram**.



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Phase Diagram

- Phase diagrams display the state of a substance at various pressures and temperatures and the places where equilibria exist between phases.

Phase Diagram

1 atm

Increasing Pressure

SOLID LIQUID GAS

Pure solvent

Solution

Freezing point of solution

Normal freezing point of water

Normal boiling point of water

Boiling point of solution

Increasing Temperature

ΔT_f

ΔT_b

Δp

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Vapor Pressure Lowering

- Adding a nonvolatile solute to a solvent lowers the solvent's vapor pressure.
- When a solute is present, a mixture of solvent and solute occupies the surface area, and fewer particles enter the gaseous state.
- The greater the number of solute particles, the lower the vapor pressure.

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Vapor Pressure Lowering (cont.)

- Vapor pressure lowering** is due to the number of solute particles in solution and is a colligative property of solutions.

Water Sucrose

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Boiling Point Elevation

- When a nonvolatile solute lowers the vapor pressure of a solvent, the boiling point is also affected.
- More heat is needed to supply additional kinetic energy to raise the vapor pressure to atmospheric pressure.


Water Sucrose

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Boiling Point Elevation (cont.)

- The temperature difference between a solution's boiling point and a pure solvent's boiling point is called the **boiling point elevation**.
- $\Delta T_b = K_b m$ where ΔT_b is the boiling point elevation, K_b is the molal boiling point elevation constant, and m represents molality.




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Boiling Point Elevation (cont.)

Table 14.5		Molal Boiling Point Elevation Constants (K_b)
Solvent	Boiling Point ($^{\circ}\text{C}$)	K_b ($^{\circ}\text{C}/m$)
Water	100.0	0.512
Benzene	80.1	2.53
Carbon tetrachloride	76.7	5.03
Ethanol	78.5	1.22
Chloroform	61.7	3.63



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Boiling Point Elevation - Application



- Adding salt to water when making Kraft Dinner raised the BP of the water.
- This cooks the noodles faster because the temperature of the water rises above 100°C.

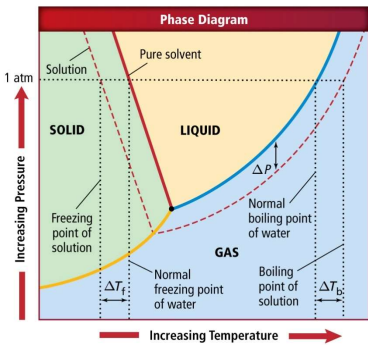
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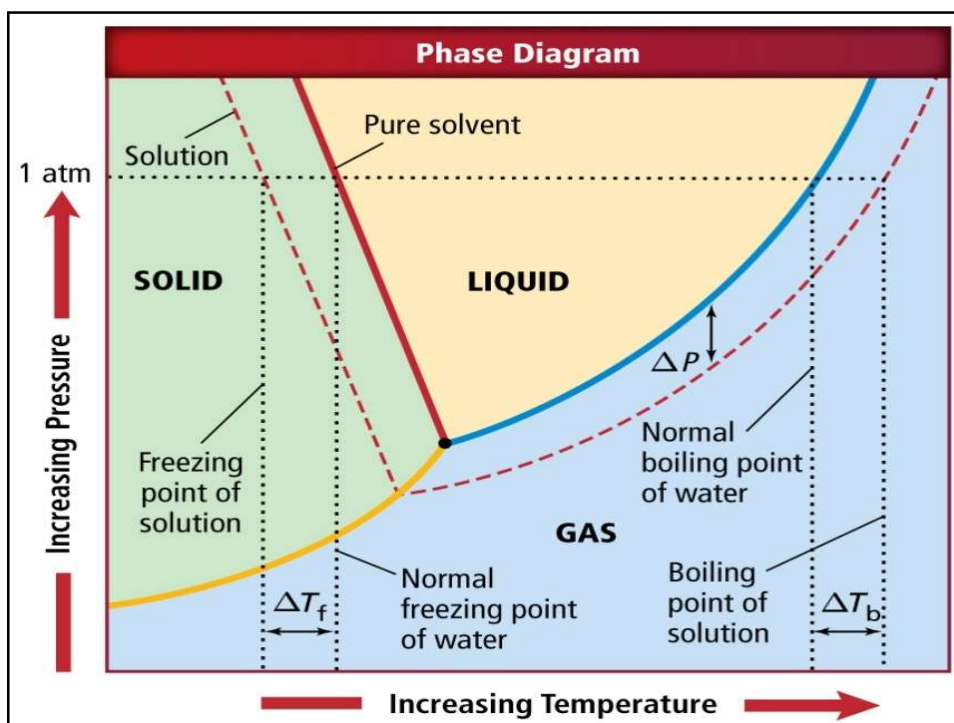
Freezing Point Depression

- At a solvent's freezing point temperature, particles no longer have sufficient kinetic energy to overcome interparticle attractive forces.
- The freezing point of a solution is always lower than that of the pure solvent.



← →

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Freezing Point Depression (cont.)

- Solute particles interfere with the attractive forces among solvent particles.
- A solution's **freezing point depression** is the difference in temperature between its freezing point and the freezing point of the pure solvent.
- $\Delta T_f = K_f m$ where ΔT_f is the freezing point depression, K_f is the freezing point depression constant, and m is molality.

← →

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Freezing Point Depression (cont.)

Table 14.6		Molal Freezing Point Depression Constants (K_f)
Solvent	Freezing Point ($^{\circ}\text{C}$)	K_f ($^{\circ}\text{C}/m$)
Water	0.0	1.86
Benzene	5.5	5.12
Carbon tetrachloride	-23.0	29.8
Ethanol	-114.1	1.99
Chloroform	-63.5	4.68


← →

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Freezing Point Depression - Application



- Many districts apply salt to roads in the winter.
- This lowers the temperature that the ice melts.

- As a result, ice on the street melts below 0°C .
- Temperature of -22°C achieved in a salt/ice/water mixture in the lab at VCI!

← →

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Osmotic Pressure

- Osmosis** is the diffusion of a solvent through a semipermeable membrane.

The diagram illustrates osmosis across a semipermeable membrane. On the left is a 'Dilute solution' with a 'Low concentration of solute', containing many blue water molecules and a few red solute molecules. On the right is a 'Concentrated solution' with a 'High concentration of solute', containing fewer blue water molecules and many red solute molecules. A vertical 'Semipermeable membrane' separates the two. A red arrow labeled 'Net movement of water' points from the dilute side to the concentrated side. Labels 'Water' and 'Solute' point to the respective particles. A logo for 'Concepts in Motion' is in the bottom left, and navigation arrows are in the bottom right.

Water

Semipermeable membrane

Solute

Net movement of water

Dilute solution
Low concentration of solute

Concentrated solution
High concentration of solute

Concepts in Motion
Click here to view an animated version of this graphic.

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Osmotic Pressure (cont.)

- Osmotic pressure** is the amount of additional pressure caused by water molecules that moved that moved into the concentrated solution.


Remember:

Osmosis is the process in which a solvent moves from a solution of **low concentration** to a solution of **higher concentration**.

Navigation arrows pointing left and right.

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Section 14.4 Assessment 

Nonvolatile solutes _____ the vapor pressure of a solution.

- A. increase
- B. decrease
- C. do not change
- D. unpredictably change

0% 0% 0% 0%


A B C D



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Section 14.4 Assessment 

Colligative properties of a solution depend on:

- A. the type of solute
- B. the type of solvent
- C. the vapor pressure of the solvent
- D. the number of particles of solute

0% 0% 0% 0%

A B C D



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Section 14.4 /Chapter Review Assignment

Text Questions:

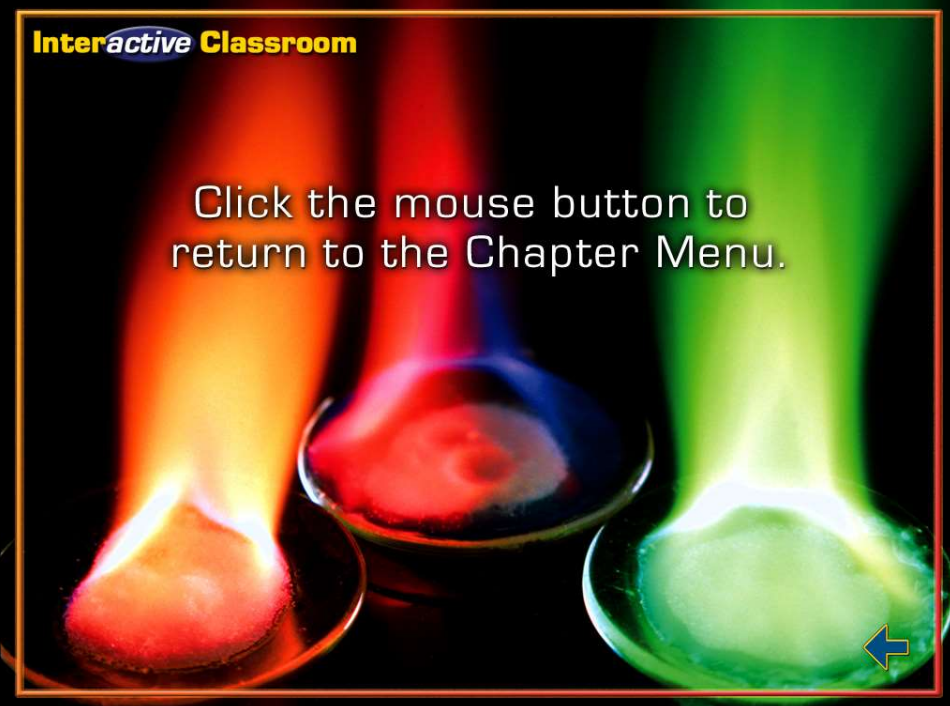
- 14-4 (page 504) #48-50
- Chapter Review pages 508-510: Optional



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