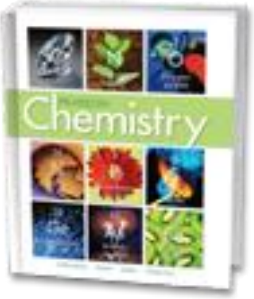


Chapter 16
Solutions

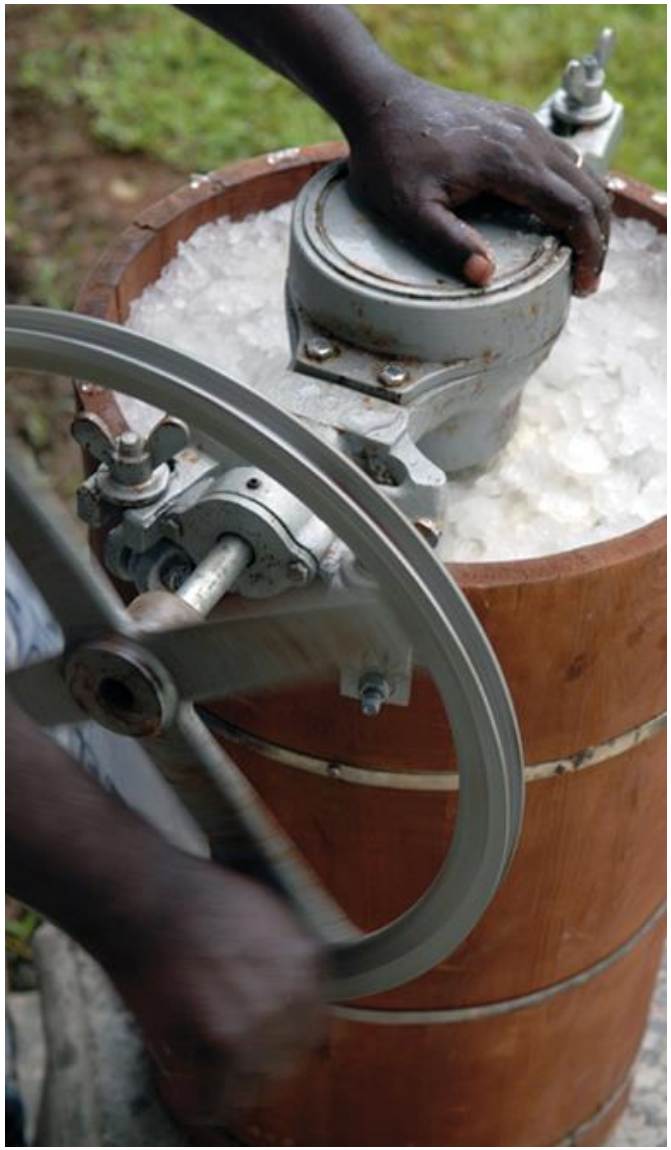
16.1 Properties of Solutions
16.2 Concentrations of Solutions

16.3 Colligative Properties of Solutions

16.4 Calculations Involving Colligative Properties

Why do you need salt to make ice cream?

Ice-cream makers know that if you add rock salt to ice, the mixture freezes at a few degrees below 0° C.



Tea is not the same as pure water.

- Some of these differences in properties have little to do with the specific identity of the solute.
- Instead, they depend upon the mere presence of solute particles in the solution.

A **colligative property** is a property of solutions that depends only upon the number of solute particles, not upon their identity.

Three important colligative properties of solutions are

- vapor-pressure lowering
- freezing-point depression
- boiling-point elevation

Vapor-Pressure Lowering

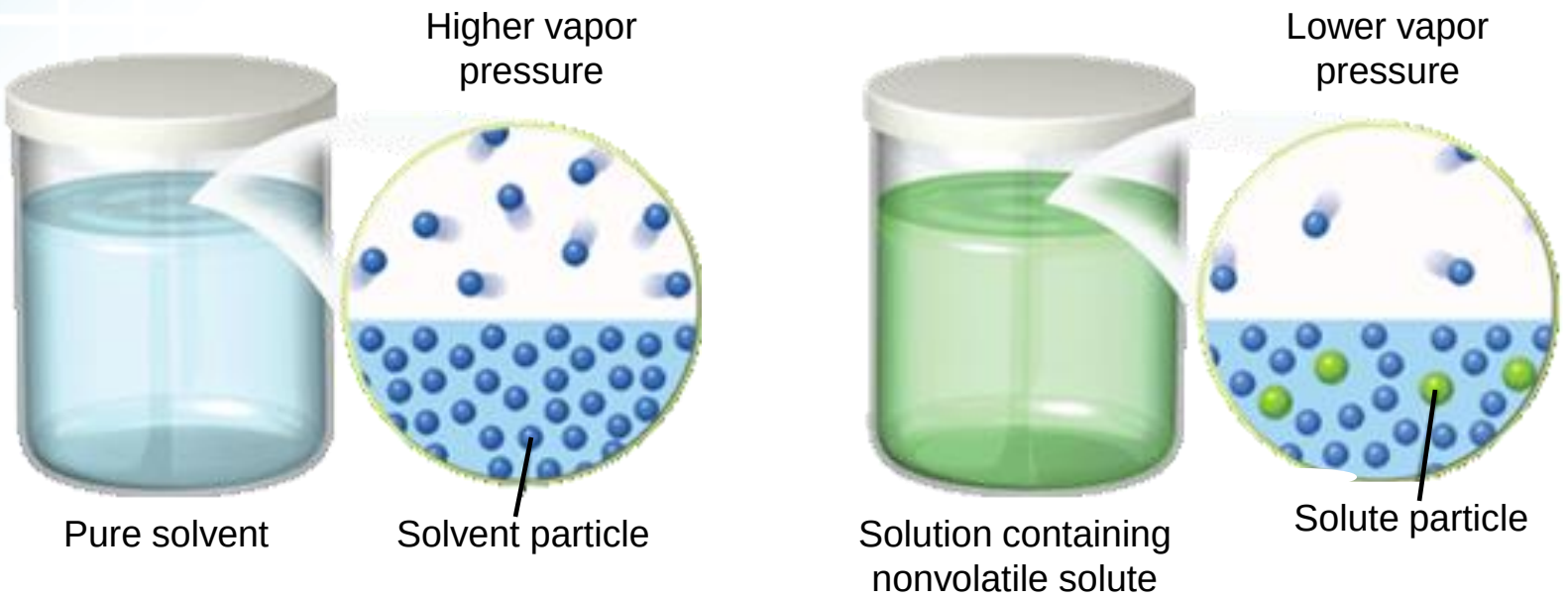
Vapor pressure is the pressure exerted by a vapor that is in dynamic equilibrium with its liquid in a closed system.

Vapor-Pressure Lowering

Vapor pressure is the pressure exerted by a vapor that is in dynamic equilibrium with its liquid in a closed system.

- A solution that contains a solute that is nonvolatile (not easily vaporized) always has a lower vapor pressure than the pure solvent.

Vapor-Pressure Lowering



Equilibrium is established between the liquid and vapor in a pure solvent.

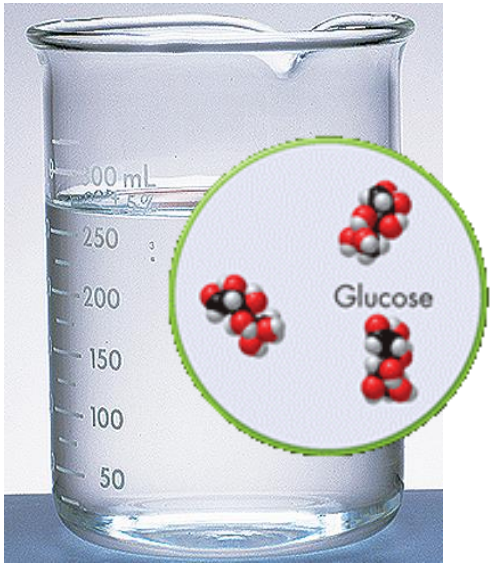
In a solution, solute particles reduce the number of solvent particles able to escape the liquid. Equilibrium is established at a lower vapor pressure.

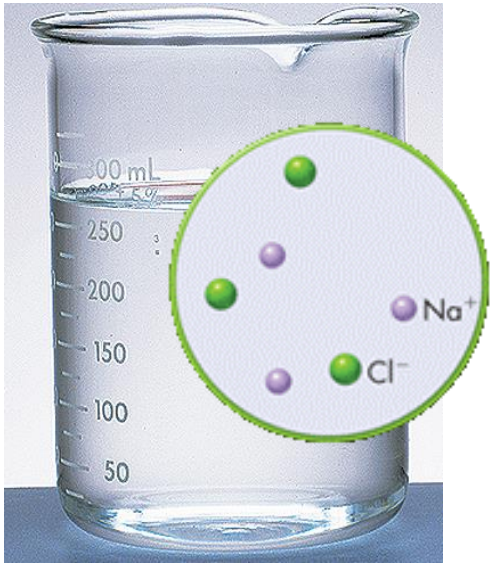
Vapor-Pressure Lowering

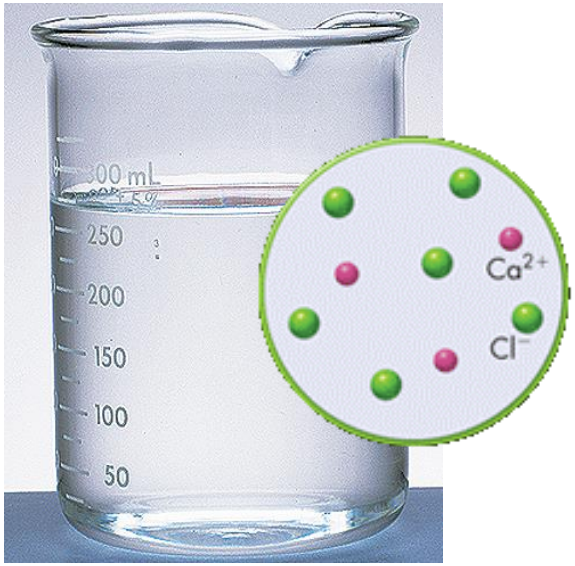
The decrease in a solution's vapor pressure is proportional to the number of particles the solute makes in solution.

Vapor-Pressure Lowering

Which solution has the lowest vapor pressure?







Vapor-Pressure Lowering

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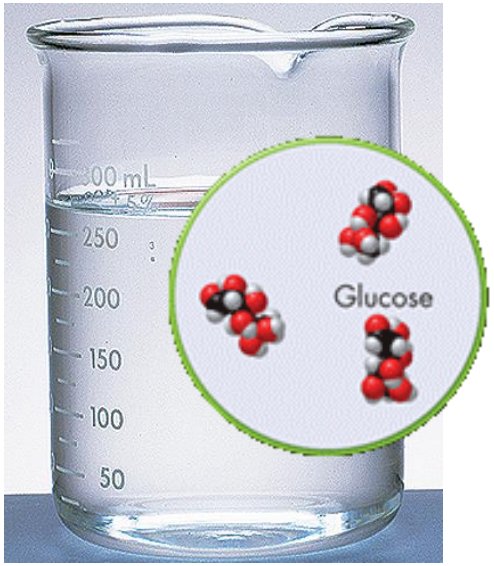
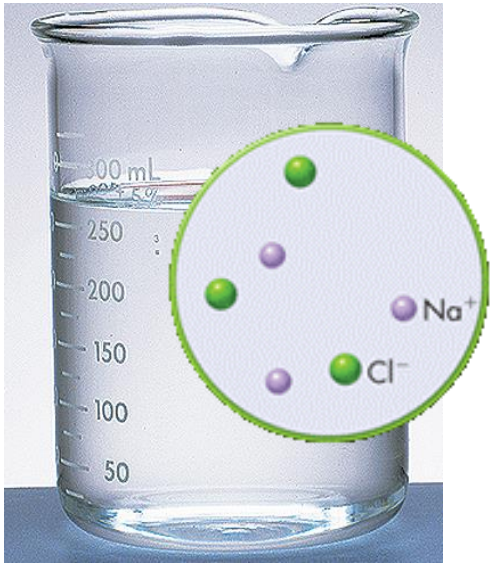
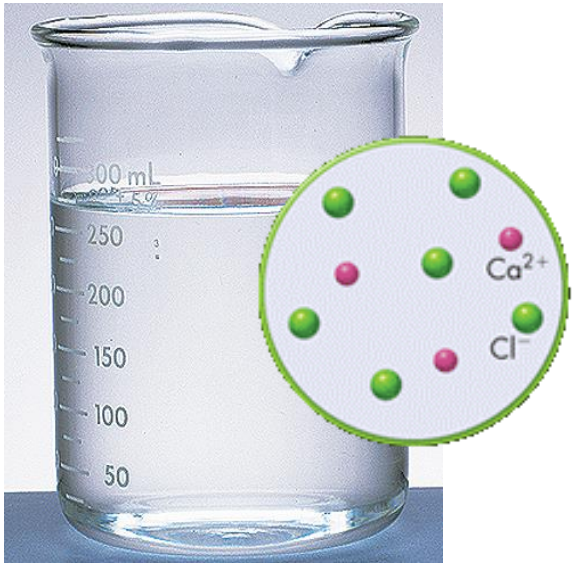


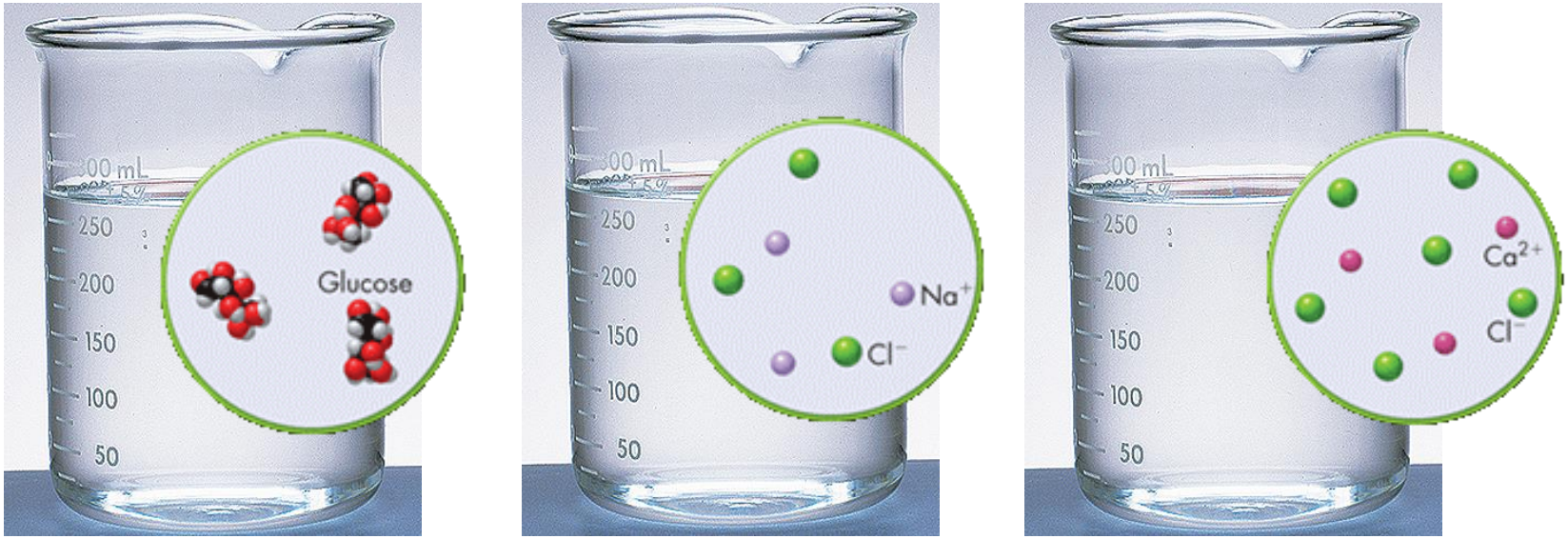




- The vapor-pressure lowering caused by 0.1 mol of NaCl in 1000 g of water is twice that caused by 0.1 mol of glucose in the same quantity of water.

Vapor-Pressure Lowering

Which solution has the lowest vapor pressure?



- In the same way, 0.1 mol of $CaCl_2$ in 1000 g of water produces three times the vapor-pressure lowering as 0.1 mol of glucose in the same quantity of water.

Freezing-Point Depression

When a substance freezes, the particles of the solid take on an orderly pattern.

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- The presence of a solute in water disrupts the formation of this pattern.

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When a substance freezes, the particles of the solid take on an orderly pattern.

- The presence of a solute in water disrupts the formation of this pattern.
- As a result, more kinetic energy must be withdrawn from a solution than from the pure solvent to cause the solution to solidify.

Freezing-Point Depression

The freezing point of a solution is lower than the freezing point of the pure solvent.

Freezing-Point Depression

The freezing point of a solution is lower than the freezing point of the pure solvent.

- The difference in temperature between the freezing point of a solution and the freezing point of the pure solvent is called the **freezing-point depression**.

Freezing-Point Depression

Freezing-point depression is another colligative property.

- The magnitude of the freezing-point depression is proportional to the number of solute particles dissolved in the solvent and does not depend upon their identity.

Freezing-Point Depression

The freezing-point depression of aqueous solutions plays an important role in helping keep travelers safe in cold, icy weather.

Freezing-Point Depression

The freezing-point depression of aqueous solutions plays an important role in helping keep travelers safe in cold, icy weather.

- The truck spreads a layer of salt on the icy road to make the ice melt.
- The melted ice forms a solution with a lower freezing point than that of pure water.

Boiling-Point Elevation

The boiling point of a substance is the temperature at which the vapor pressure of the liquid phase equals atmospheric pressure.

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- Adding a nonvolatile solute to a liquid solvent decreases the vapor pressure of the solvent.

Boiling-Point Elevation

The boiling point of a substance is the temperature at which the vapor pressure of the liquid phase equals the atmospheric pressure.

- Adding a nonvolatile solute to a liquid solvent decreases the vapor pressure of the solvent.
- Because of the decrease in vapor pressure, additional kinetic energy must be added to raise the vapor pressure of the liquid phase of the solution to atmospheric pressure and initiate boiling.

Boiling-Point Elevation

The boiling point of a solution is higher than the boiling point of the pure solvent.

Boiling-Point Elevation

The boiling point of a solution is higher than the boiling point of the pure solvent.

- The difference in temperature between the boiling point of a solution and the boiling point of the pure solvent is the **boiling-point elevation**.

Boiling-Point Elevation

The fluid circulating through a car's cooling system is a solution of water and ethylene glycol, or antifreeze.

- The antifreeze doesn't just lower the freezing point of the water in the cooling system.
- It also elevates the boiling point, which helps protect the engine from overheating in the summer.

Boiling-Point Elevation

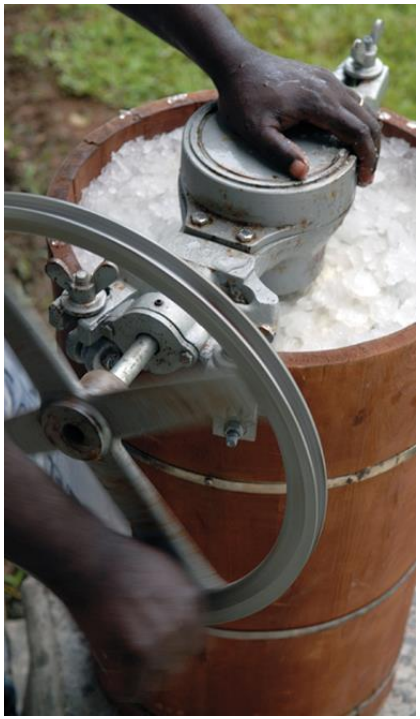
Boiling-point elevation is a colligative property; it depends on the concentration of particles, not on their identity.

Boiling-Point Elevation

Boiling-point elevation is a colligative property; it depends on the concentration of particles, not on their identity.

- The magnitude of the boiling-point elevation is proportional to the number of solute particles dissolved in the solvent.
  - The boiling point of water increases by 0.512°C for every mole of particles that the solute forms when dissolved in 1000 g of water.

Solutes other than NaCl could be used to produce the same freezing-point depression in an ice-cream machine. What factors do you think make NaCl a good choice?



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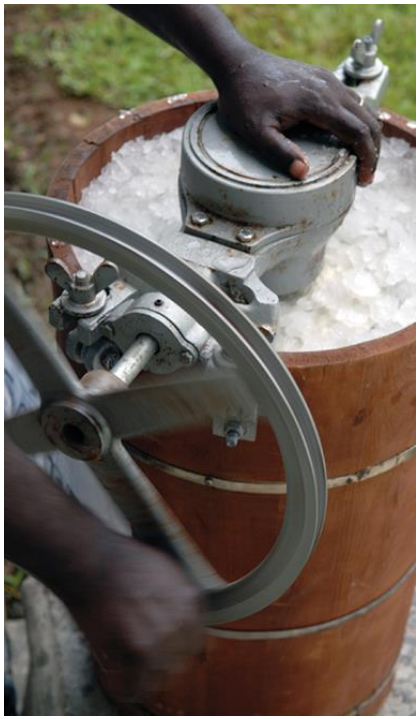

NaCl, or rock salt, is readily available, inexpensive, and non-toxic. It is an ionic compound. It produces twice the freezing-point depression of a molecular solid such as sucrose, or table sugar.

Checkpoint

You have 500 mL of 1*M* solutions of NaCl, Na_2SO_4, Na_3PO_4, and $Al_2(SO_4)_3$. Which solution will have the highest boiling point?

A. NaCl(*aq*)

B. $Na_2SO_4(aq)$

C. $Na_3PO_4(aq)$

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Colligative properties of solutions include vapor-pressure lowering, freezing-point depression, and boiling-point elevation.

- **colligative property:** a property of a solution that depends only upon the number of solute particles, and not upon their identities; boiling-point elevation, freezing-point depression, and vapor-pressure lowering are colligative properties

- **freezing-point depression:** the difference in temperature between the freezing point of a solution and the freezing point of the pure solvent
- **boiling-point elevation:** the difference in temperature between the boiling point of a solution and the boiling point of the pure solvent

BIG IDEA

The Mole and Quantifying Matter

Solubility, miscibility, concentration, and colligative properties are used to describe and characterize solutions.

END OF 16.3