

MUNOZ NATIONAL HIGH SCHOOL (MAIN) - SENIOR HIGH SCHOOL
SCIENCE, TECHNOLOGY, ENGINEERING AND MATHEMATICS (STEM) STRAND

GENERAL CHEMISTRY 2

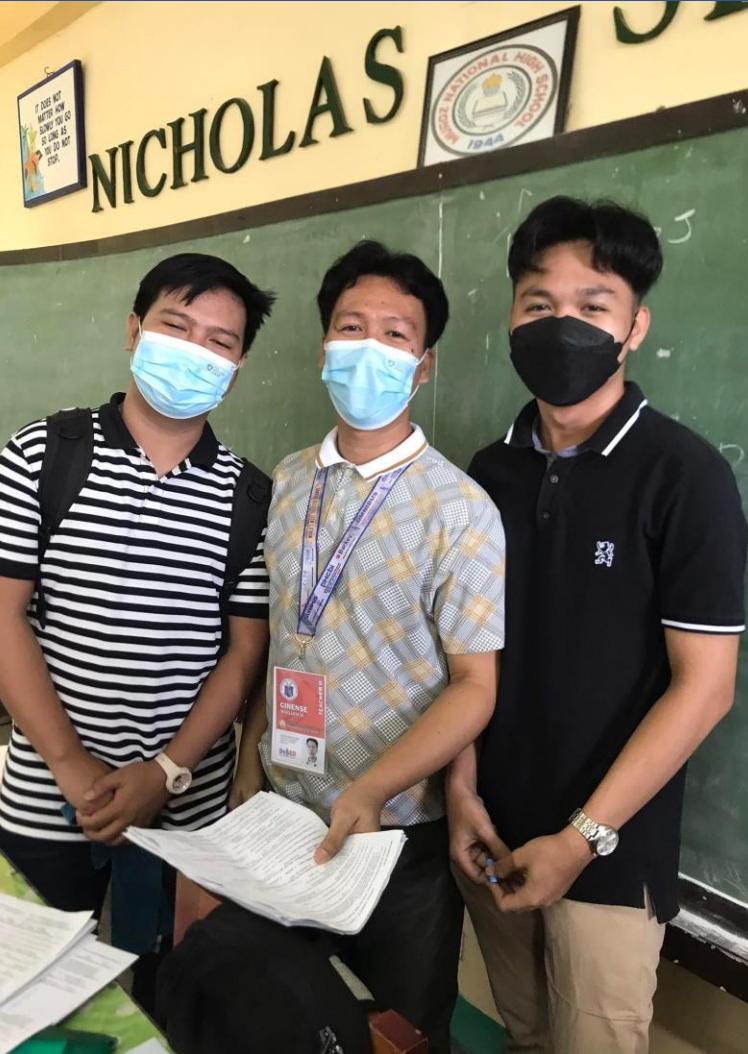
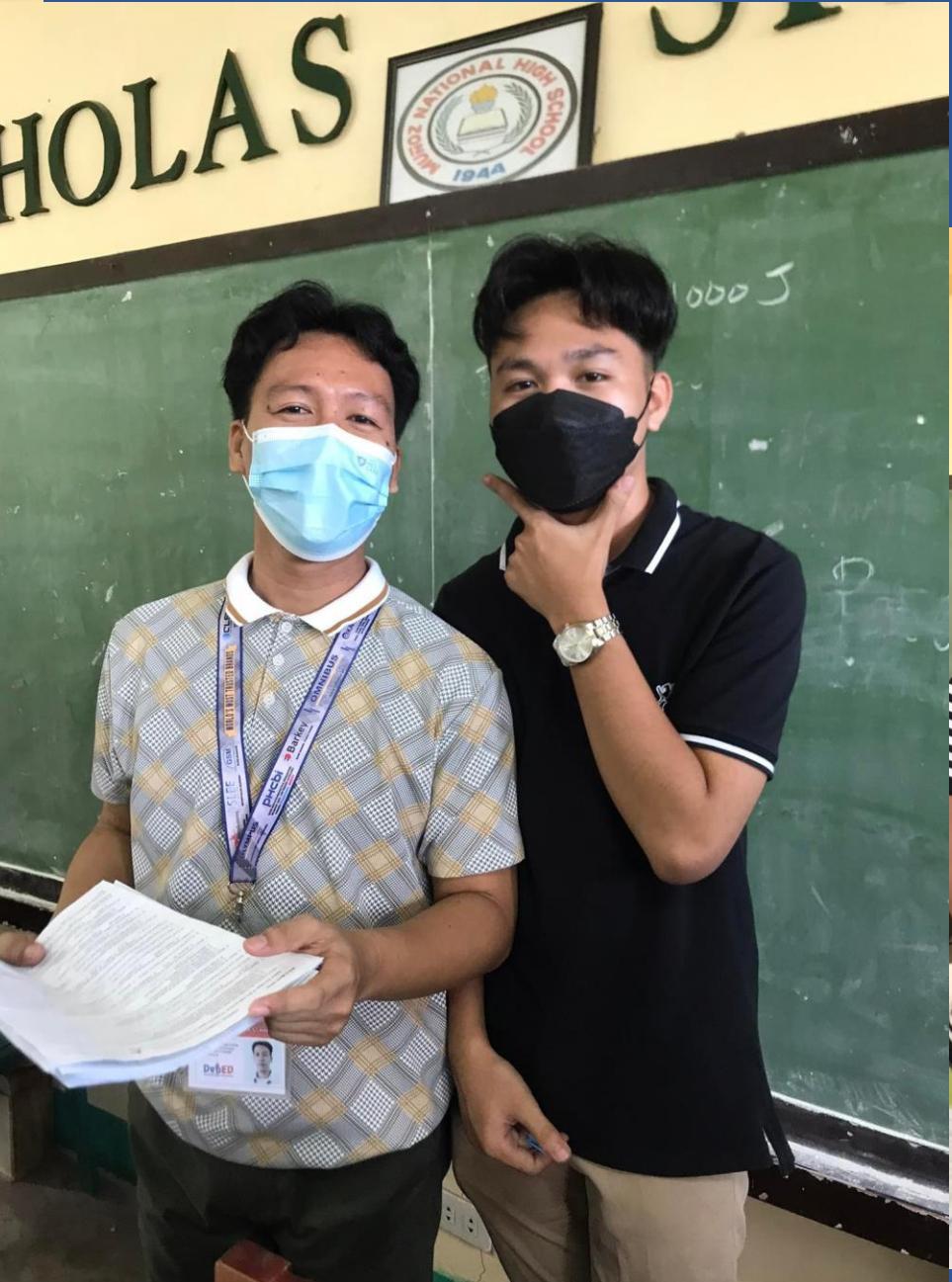
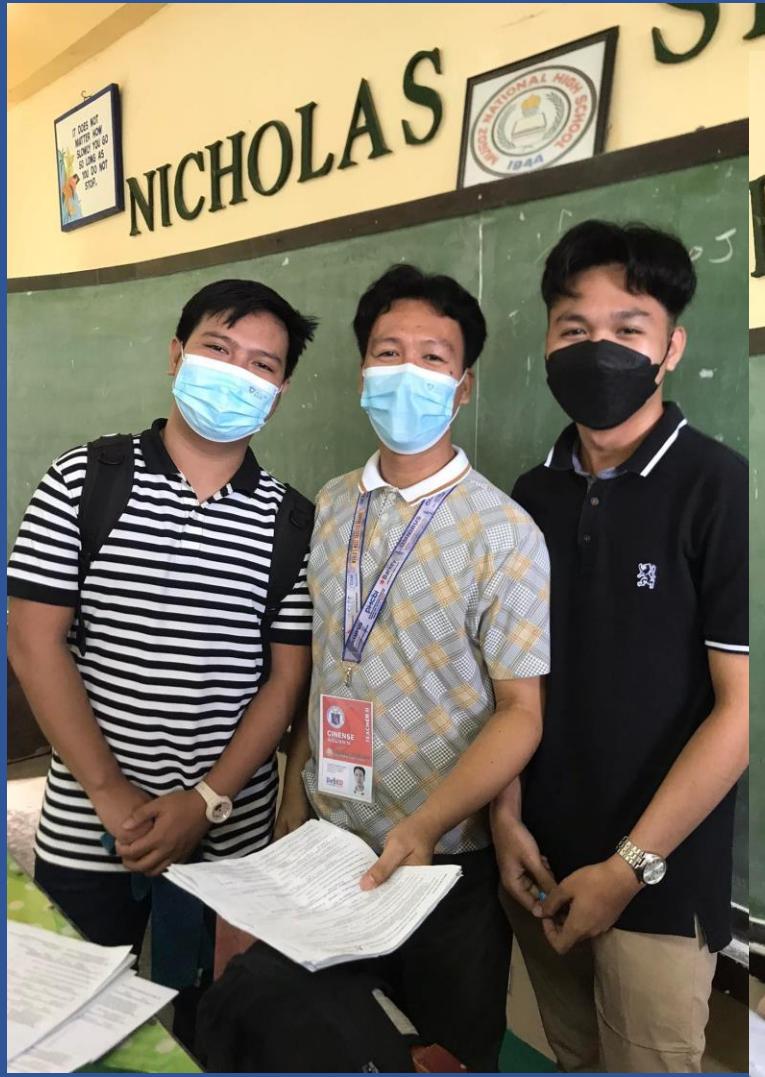
1ST SEMESTER, 2021-2022

COLLIGATIVE PROPERTIES OF SOLUTIONS

WILLIAM M. CINENSE













How to prepare 1.0 M NaCl solution?

1. Weigh 14.50 grams of NaCl. Prepare a paper box to contain the NaCl crystals.
2. Place it in a 250-mL beaker.
3. Put 200.00 mL of distilled water using graduated cylinder.
4. Then, transfer the solution into a 250.00 mL volumetric flask.
5. Add water until you reach the line in the volumetric flask.
6. Use wash bottle in adding small amounts of water.
7. Shake the solution by gently turning the flask upside down.

How to prepare 1.0 M sugar ($C_{12}H_{22}O_{11}$) solution?

1. Weigh 85.50 grams of sugar. Prepare a paper box to contain the sugar crystals.
2. Place it in a 250-mL beaker.
3. Put 200.00 mL of distilled water using graduated cylinder.
4. Then, transfer the solution into a 250.00 mL volumetric flask.
5. Add water until you reach the line in the volumetric flask.
6. Use wash bottle in adding small amounts of water.
7. Shake the solution by gently turning the flask upside down.

Determining the boiling point.

1. Place a 200.00 mL of each solutions (1.0 M NaCl, 2.0 M NaCl, 3.0 M NaCl, 1.0 M sugar soln, 2.0 M sugar soln, 3.0 M sugar soln and distilled water) in separate 250.00 mL beaker.

2. Set up the hot plate.

3. Place the beakers containing the solutions on top of the hot plate.

Caution: Hot surface of the hot plate and the beakers.

4. When the solutions starts to boil which can be observed. Measure their boiling temperature using the thermometer.

5. When taking the temperature, do not touch the bulb of thermometer on the walls of the beaker.

6. Record your data.

Laboratory Report (parts)

- I. Title (you can make your own title)
- II. Introduction (focus on boiling point elevation)
- III. Procedure (in paragraph form, past tense)
- IV. Results and Discussion (tabular form)
- V. Conclusion (explains what causes an increase in the boiling point of the solution and how it occurs in molecular level)
- VI. References
- VII. Documentations

Laboratory Report (Format)

1. Paper

1. Size (A4)
2. Margins (Normal)
3. Line Spacing (1.5)

2. Font

1. Style (time new roman)
2. Size (12)

MUNOZ NATIONAL HIGH SCHOOL -MAIN
SENIOR HIGH SCHOOL

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GENERAL CHEMISTRY 2
LABORATORY ACTIVITY NO. 1

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TITLE

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GROUP MEMBERS
GROUP MEMBERS

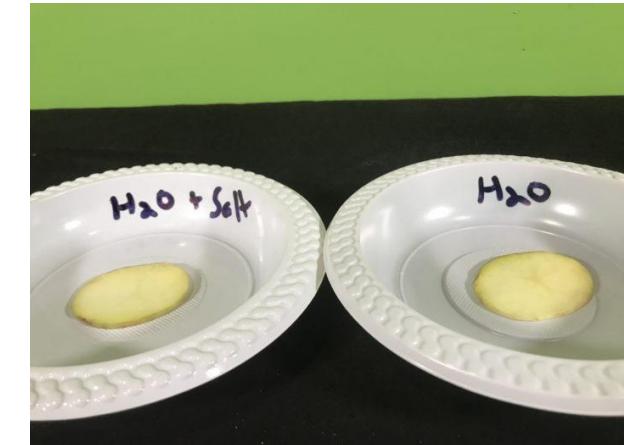
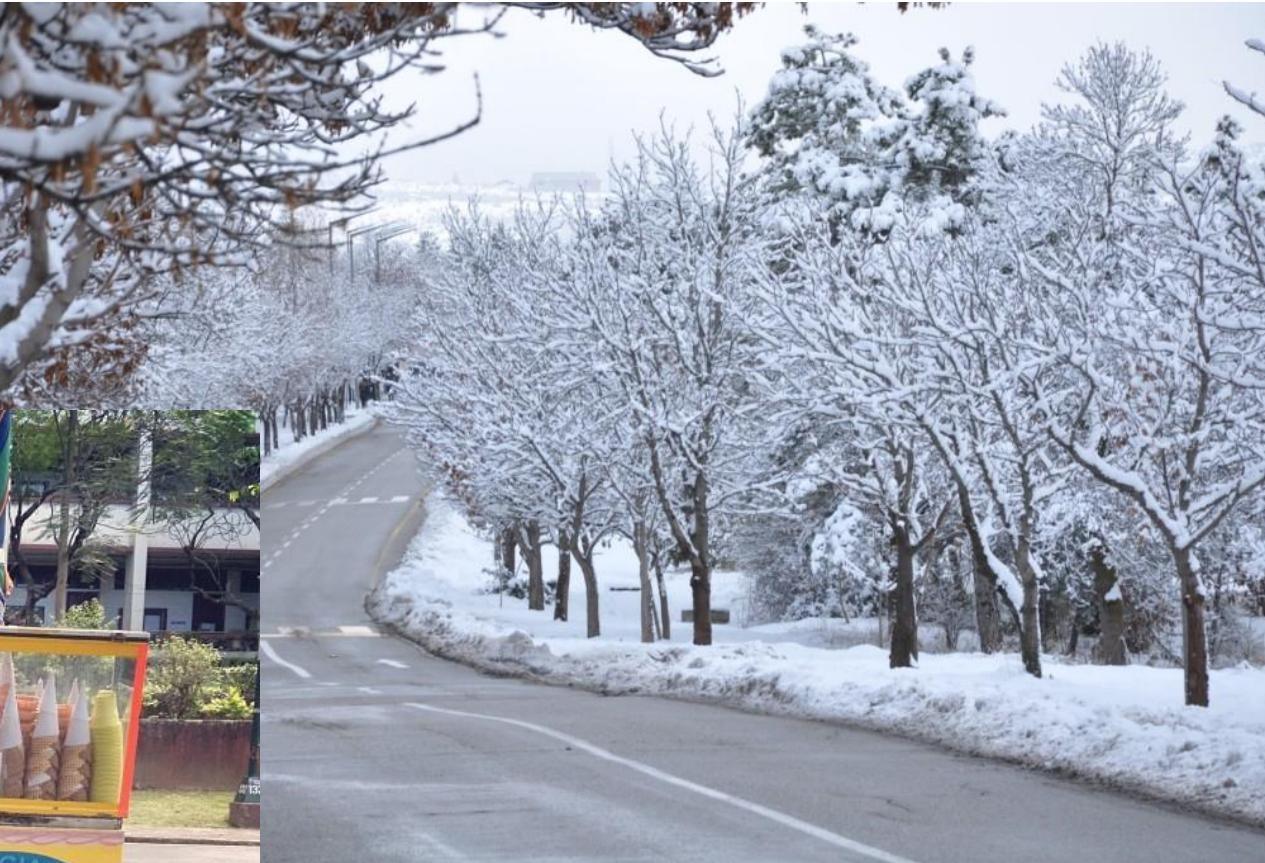
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WILLIAM M. CINENSE

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DATE SUBMITTED

TITLE PAGE



LEARNING OBJECTIVES

- define colligative properties of solution
- describe the colligative properties
- describe the effect of concentration on the colligative properties of solutions
- differentiate the colligative properties of non-electrolyte solutions and of the electrolyte solutions
- calculate boiling point elevation, freezing point depression, vapor pressure lowering and osmotic pressure from the concentration of a solute in a solution
- calculate molar mass from colligative property data

Colligative Properties of Solutions

When a nonvolatile solute is added to a solvent, physical properties of the solvent will change.

Colligative properties of a solution depend only on the number of solute particles in a solution and not on the nature of those particles.

Colligative Property

- the interaction between the solute and solvent changes the property of solution form that of the pure solvent
- properties that depend solely on the number of particles of solute present but not on the kind and nature of solute
- depend on the amount of the solute and not on their chemical identities

ELECTROLYTE VS. NON-ELECTROLYTE SOLUTES

- Non-electrolyte solute does not ionizes in solution, the number of solute particles will be less in a solution containing non-electrolyte solute than in a solution containing electrolyte solute
- The effect of an electrolyte solute will be greater than a non-electrolyte solute in a solution

COLLIGATIVE PROPERTIES

1. VAPOR PRESSURE LOWERING
2. BOILING POINT ELEVATION
3. FREEZING POINT DEPRESSION
4. OSMOTIC PRESSURE

VAPOR PRESSURE

A substance that evaporates readily is called VOLATILE.

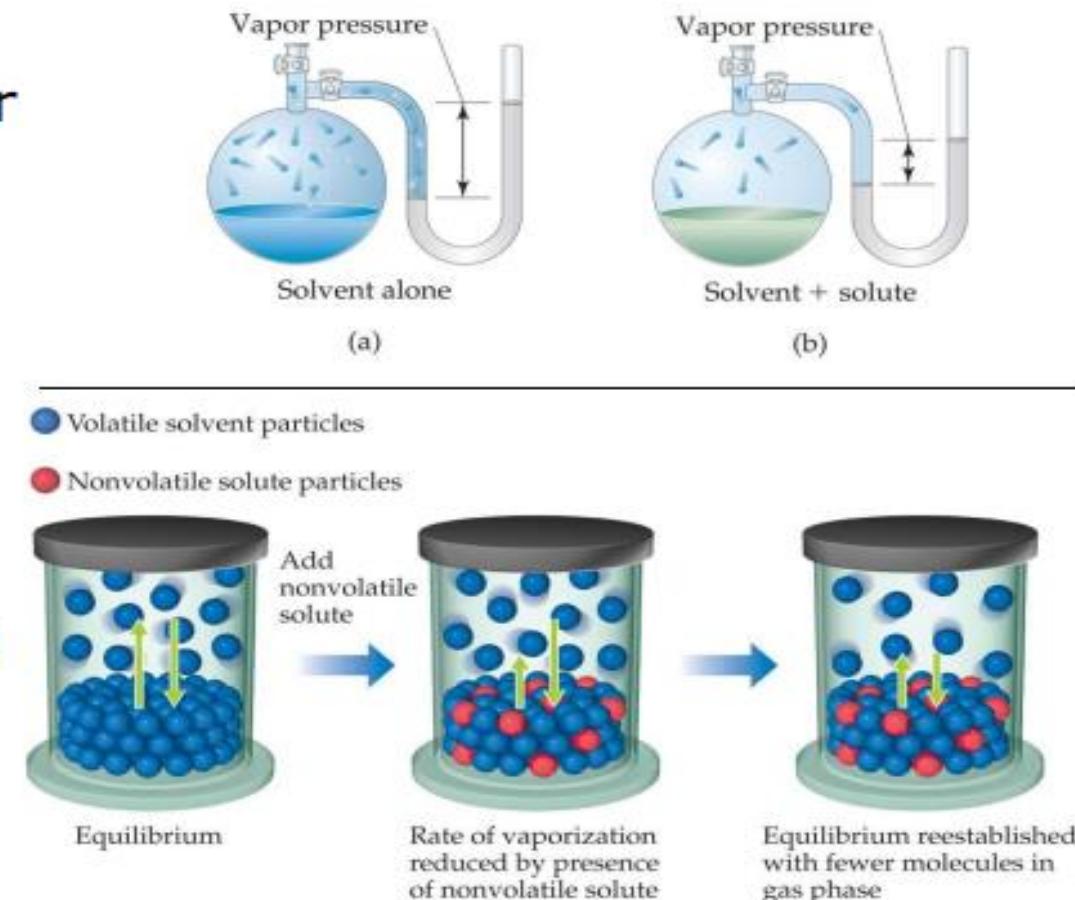
- *escaping tendency is high
- * high vapor pressure

A nonvolatile substance has low vapor pressure and low escaping tendency.

If a nonvolatile solute is dissolved in water, the solute molecules take up space at the surface and thus preventing the escape of solvent molecules.

Vapor Pressure

- Because of solute-solvent intermolecular attraction, higher concentrations of nonvolatile solutes make it harder for solvent to escape to the vapor phase.
- Therefore, the vapor pressure of a solution is lower than that of the pure solvent.



VAPOR PRESSURE LOWERING

- The vapor pressure of solution is lower than the vapor pressure of pure solvent
- The greater the concentration of solution, the greater the vapor pressure is lowered.
- Since the number of solute is greater in solution containing electrolyte solute, the vapor pressure will be lower than that of solution with non-electrolyte solutes.

Vapor pressure: Raoult's Law

The extent to which a nonvolatile solute lowers the vapor pressure is proportional to its concentration.

$$P_{\text{solution}} = X_{\text{solvent}} P^{\circ}_{\text{solvent}}$$

- X is the mole fraction of the *SOLVENT*
- P° is the normal vapor pressure of *SOLVENT* at that temperature

Vapor pressure lowering, ΔP

$$\Delta P = X_{\text{solute}} P^{\circ}_{\text{solvent}}$$

Example

At 20 °C the vapor pressure of water is 17.5 torr.
If we add enough glucose, $C_6H_{12}O_6$, to obtain

$$X_{H_2O} = 0.800$$

$$X_{C_6H_{12}O_6} = 0.200$$

What is the vapor pressure?

$$P_{\text{solution}} = 0.99 \times 47.1 = 46.63 \text{ torr}$$

Calculate the vapor pressure of a solution made by dissolving 50.0 g glucose, $\text{C}_6\text{H}_{12}\text{O}_6$, in 500 g of water. The vapor pressure of pure water is 47.1 torr at 37°C

K_b

The ebullioscopic constant is also called the molal elevation constant.

It is defined as **the elevation in boiling point when one mole of non-volatile solute is added to one kilogram of solvent**.

It is denoted by K_b .

The unit of an ebullioscopic constant is K Kg mol^{-1} .

K_f

Cryoscopic constant or the Molal depression constant is defined as the depression in freezing point when one mole of non-volatile solute is dissolved in one kilogram of solvent.

Its unit is K.Kg.mol^{-1} .

BOILING POINT ELEVATION

- The boiling point of pure water is 100°C.
- Sea water boils at higher temperature.
- The burn caused by boiling syrup is more severe than that is caused by boiling pure water.

BOILING POINT ELEVATION

The interaction between solute-solvent is greater than solvent-solvent and solute-solute

Thus, longer time to equalize the vapor pressure of the liquid (solution) and the atmospheric pressure.

BOILING POINT ELEVATION

The boiling point of solution, therefore; is greater than the boiling point of the pure solvent.

Boiling point elevation

$$\Delta T_b = T_b(\text{solution}) - T_b(\text{solvent}) = iK_b m$$

K_b is the molal boiling point elevation constant, a solvent dependent property.

TABLE 13.3 Molal Boiling-Point-Elevation and Freezing-Point-Depression Constants

Solvent	Normal Boiling Point (°C)	K_b (°C/m)	Normal Freezing Point (°C)	K_f (°C/m)
Water, H ₂ O	100.0	0.51	0.0	1.86
Benzene, C ₆ H ₆	80.1	2.53	5.5	5.12
Ethanol, C ₂ H ₅ OH	78.4	1.22	-114.6	1.99
Carbon tetrachloride, CCl ₄	76.8	5.02	-22.3	29.8
Chloroform, CHCl ₃	61.2	3.63	-63.5	4.68

ΔT_b is added to the normal boiling point of the solvent.

Each solvent shows a characteristic:

freezing point depression constant

boiling point elevation constant

Table 14.5 Freezing Point Depression and Boiling Point Elevation Constants of Selected Solvents

Solvent	Freezing point of pure solvent (°C)	Freezing point depression constant, K_f $\left(\frac{\text{°C kg solvent}}{\text{mol solute}} \right)$	Boiling point of pure solvent (°C)	Boiling point elevation constant, K_b $\left(\frac{\text{°C kg solvent}}{\text{mol solute}} \right)$
Water	0.00	1.86	100.0	0.512
Acetic acid	16.6	3.90	118.5	3.07
Benzene	5.5	5.1	80.1	2.53
Camphor	178	40	208.2	5.95

Table 13.5 Molal Boiling Point Elevation and Freezing Point Depression Constants of Several Solvents

Solvent	Boiling Point (°C)*	K_b (°C/m)	Melting Point (°C)	K_f (°C/m)
Acetic acid	117.9	3.07	16.6	3.90
Benzene	80.1	2.53	5.5	4.90
Carbon disulfide	46.2	2.34	-111.5	3.83
Carbon tetrachloride	76.5	5.03	-23	30.
Chloroform	61.7	3.63	-63.5	4.70
Diethyl ether	34.5	2.02	-116.2	1.79
Ethanol	78.5	1.22	-117.3	1.99
Water	100.0	0.512	0.0	1.86

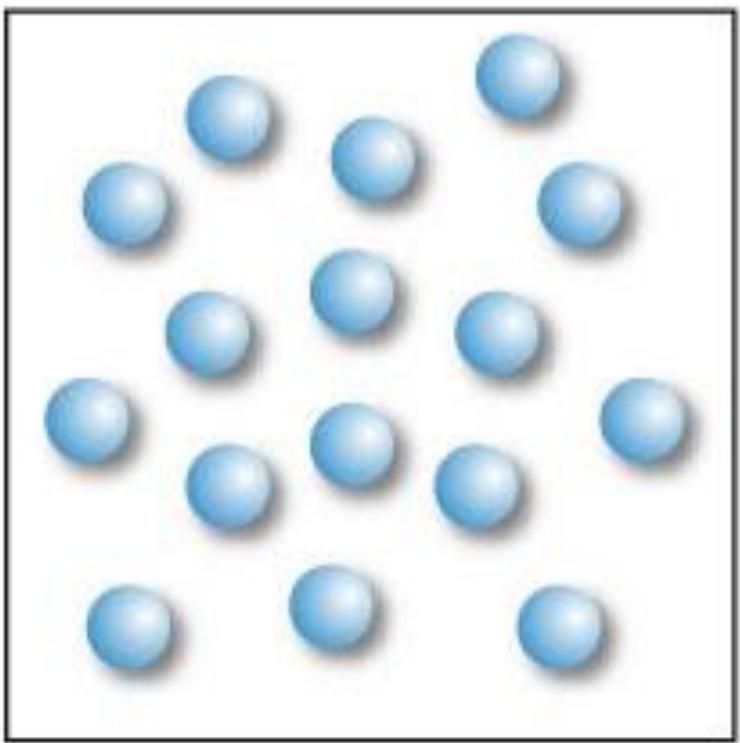
FREEZING POINT

- The temperature at which the solid and liquid phases coexist

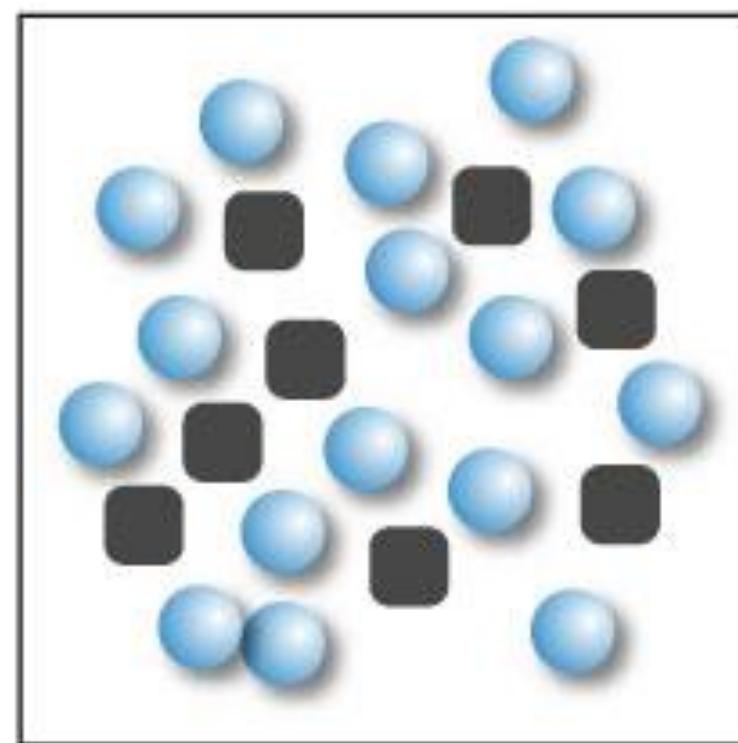


FREEZING POINT DEPRESSION

- If a nonvolatile solute is added to a solvent, the freezing point of the solvent is lowered and the reduction in the freezing point depends on the number of moles of solute present.
- The freezing point of solution is lower than the freezing point of the pure solvent.



Water



The salt hinders the water molecules from forming ice crystals

Freezing point depression

$$\Delta T_f = T_f(\text{solution}) - T_f(\text{solvent}) = -iK_f m$$

K_f is the molal freezing point depression constant of the solvent.

TABLE 13.3 Molal Boiling-Point-Elevation and Freezing-Point-Depression Constants

Solvent	Normal Boiling Point (°C)	K_b (°C/m)	Normal Freezing Point (°C)	K_f (°C/m)
Water, H ₂ O	100.0	0.51	0.0	1.86
Benzene, C ₆ H ₆	80.1	2.53	5.5	5.12
Ethanol, C ₂ H ₅ OH	78.4	1.22	-114.6	1.99
Carbon tetrachloride, CCl ₄	76.8	5.02	-22.3	29.8
Chloroform, CHCl ₃	61.2	3.63	-63.5	4.68

ΔT_f is subtracted from the normal freezing point of the solvent.

Colligative Properties of Electrolytes and the van't Hoff factor

Properties depend on the number of particles dissolved, solutions of electrolytes show greater changes than those of nonelectrolytes.

$$\Delta T_b = iK_b m$$

$$\Delta T_f = -iK_f m$$

for dilute solutions,
 $i \approx$ whole number

Note: The van't Hoff factor can also be used in other colligative properties.

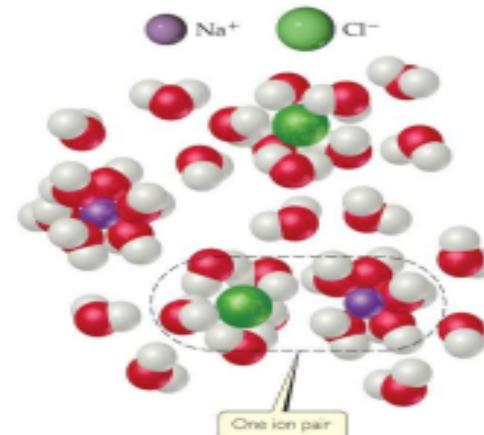


Table 13.4 Measured and Expected van't Hoff Factors for Several Substances at 25 °C

Compound	Concentration			Expected Value
	0.100 m	0.0100 m	0.00100 m	
Sucrose	1.00	1.00	1.00	1.00
NaCl	1.87	1.94	1.97	2.00
K ₂ SO ₄	2.32	2.70	2.84	3.00
MgSO ₄	1.21	1.53	1.82	2.00

The freezing point depression and the boiling point elevation are directly proportional to the number of **moles** of solute per **kilogram** of solution.

$$\text{molality} = \frac{\text{mol solute}}{\text{kg solution}}$$

Symbols used in the calculation of colligative properties

- m = molality
- Δt_f = freezing point depression: °C
- Δt_b = boiling point elevation: °C
- K_f = freezing point depression constant
- K_b = boiling point elevation constant

What is the molality (m) of a solution prepared by dissolving 2.70 g CH₃OH in 25.0 g H₂O?

The conversion is:

$$\frac{2.70 \text{ g CH}_3\text{OH}}{25.0 \text{ g H}_2\text{O}} \rightarrow \frac{\text{mol CH}_3\text{OH}}{25.0 \text{ g H}_2\text{O}} \rightarrow \frac{\text{mol CH}_3\text{OH}}{1 \text{ kg H}_2\text{O}}$$

The molar mass of CH₃OH 32.04 g/mol

$$\left(\frac{2.70 \text{ g CH}_3\text{OH}}{25.0 \text{ g H}_2\text{O}} \right) \left(\frac{1 \text{ mol CH}_3\text{OH}}{32.04 \text{ g CH}_3\text{OH}} \right) \left(\frac{1000 \text{ g H}_2\text{O}}{1 \text{ kg H}_2\text{O}} \right)$$
$$= \frac{3.37 \text{ mol CH}_3\text{OH}}{1 \text{ kg H}_2\text{O}}$$

A solution is made by dissolving 100 g of ethylene glycol ($\text{C}_2\text{H}_6\text{O}_2$) in 200 g H_2O . What is the freezing point of the solution?

Calculate moles of $\text{C}_2\text{H}_6\text{O}_2$:

$$(100 \cancel{\text{g C}_2\text{H}_6\text{O}_2}) \left(\frac{1 \text{ mol C}_2\text{H}_6\text{O}_2}{62.07 \cancel{\text{g C}_2\text{H}_6\text{O}_2}} \right) = 1.61 \text{ mol C}_2\text{H}_6\text{O}_2$$

Calculate kilograms of H_2O

$$200. \cancel{\text{g H}_2\text{O}} \left(\frac{1 \text{ kg}}{1000 \cancel{\text{g}}} \right) = 0.200 \text{ kg H}_2\text{O}$$

A solution is made by dissolving 100 g of ethylene glycol ($\text{C}_2\text{H}_6\text{O}_2$) in 200 g H_2O . What is the freezing point of the solution?

Calculate the freezing point depression.

$$\Delta t_f = \left(\frac{1.61 \text{ mol } \text{C}_2\text{H}_6\text{O}_2}{0.200 \text{ kg } \text{H}_2\text{O}} \right) \left(\frac{1.86^\circ\text{C kg } \text{H}_2\text{O}}{1 \text{ mol } \text{C}_2\text{H}_6\text{O}_2} \right) = 15.0^\circ \text{ C}$$

freezing point solution = freezing point solvent – Δt_f .

$$= 0^\circ\text{C} - 15^\circ\text{C} = -15^\circ\text{C}$$

A solution made by dissolving 4.71 g of a compound of unknown molar mass in 100.0 g of H₂O has a freezing point of -1.46°C. What is the molar mass of the compound?

$$\Delta t_f = +1.46^\circ\text{C}$$

$$\Delta t_f = mK_f$$

$$m = \frac{\Delta t_f}{K_f}$$

$$m = \frac{1.46^\circ\text{C} \times \text{mol solute}}{1.86^\circ\text{C} \times \text{kg H}_2\text{O}} = \frac{0.785 \text{ mol solute}}{\text{kg H}_2\text{O}}$$

Convert 4.71 g solute/100 g H₂O to g/mol.

$$\left(\frac{4.71 \text{ g solute}}{100 \text{ g H}_2\text{O}} \right) \left(\frac{1000 \text{ g H}_2\text{O}}{1 \text{ kg H}_2\text{O}} \right) \left(\frac{1 \text{ kg H}_2\text{O}}{0.785 \text{ mol solute}} \right) = 60.0 \text{ g mol}$$

molar mass of
the compound

Example

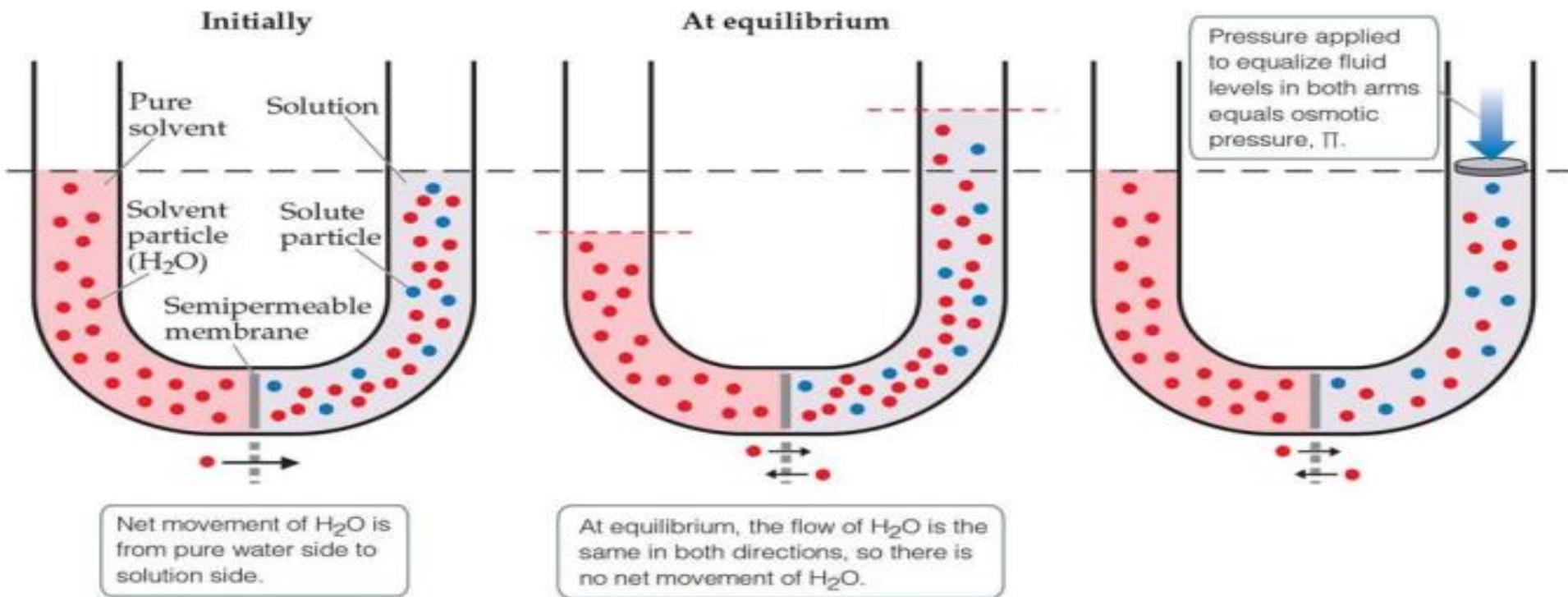
Antifreeze consists of ethylene glycol, $C_2H_6O_2$, a nonvolatile nonelectrolyte. Calculate the boiling point and freezing point of a 25.0% (weight) aqueous solution. $K_{b,H_2O} = 0.51^\circ C/m$, $K_{f,H_2O} = 1.86^\circ C/m$

Example

Arrange the following aqueous solutions in order of decreasing freezing point.

- (a) 0.20 m ethylene glycol
- (b) 0.12 m potassium sulfate
- (c) 0.10 m magnesium chloride
- (d) 0.12 m potassium bromide

Osmosis

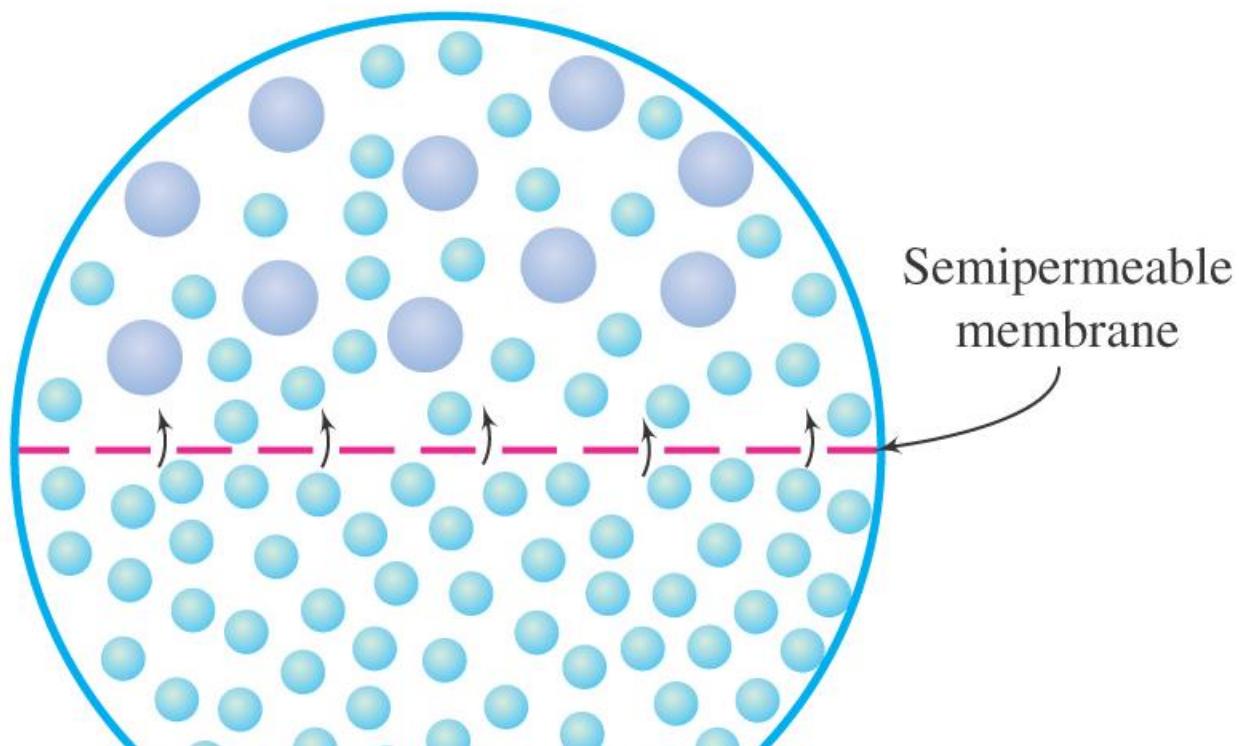


In osmosis, there is net movement of solvent from the area of **higher solvent concentration** (*lower solute concentration*) to the area of **lower solvent concentration** (*higher solute concentration*).

Osmosis is the diffusion of water, either from a dilute solution or from pure water, through a semipermeable membrane into a solution of higher concentration.

Semipermeable membrane: A semipermeable membrane allows the passage of water (solvent) molecules through it in either direction, but it prevents the passage of larger solute molecules.

Cross section on
molecular level



Sugar molecule

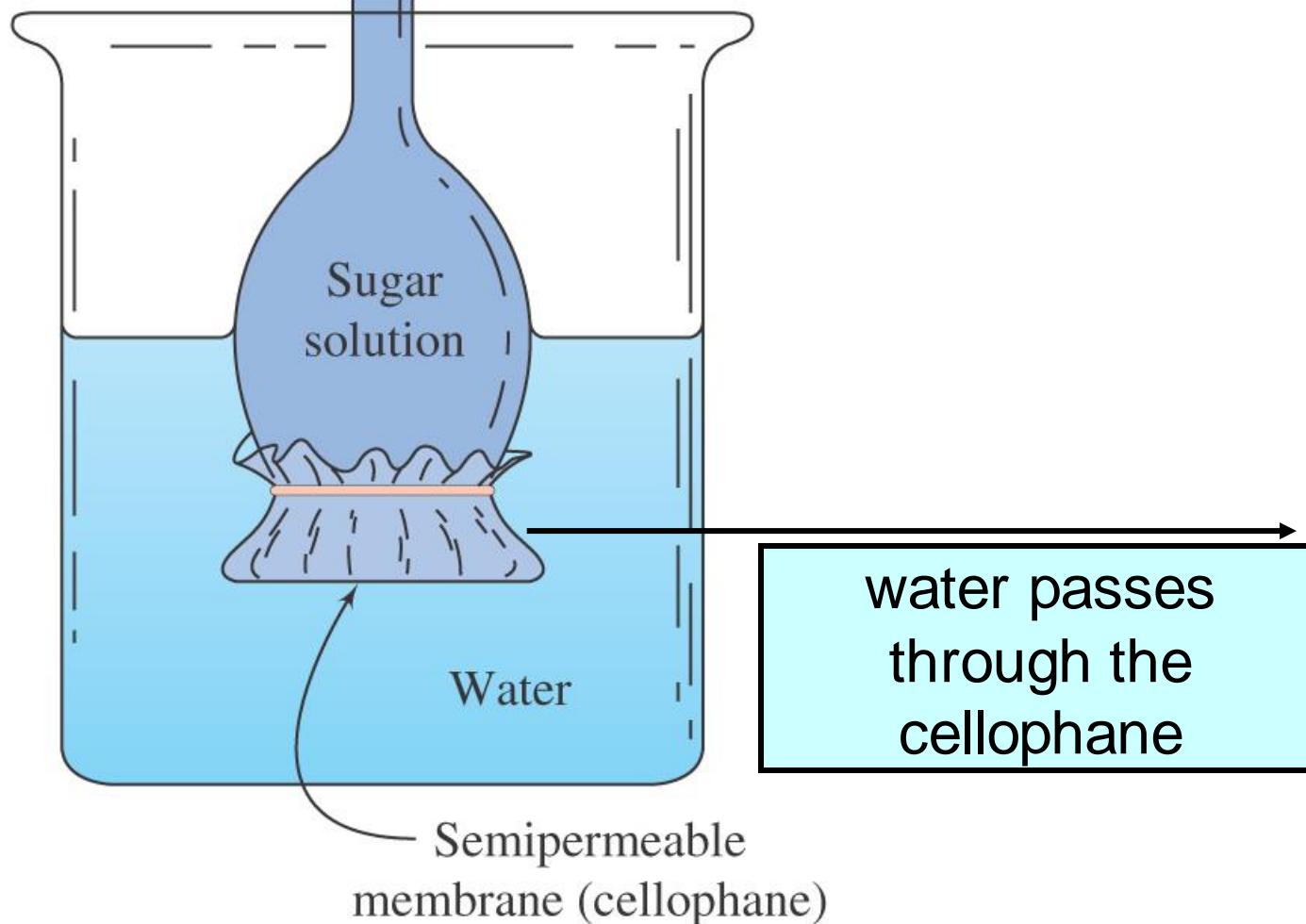


Water molecule

Rising
solution
level

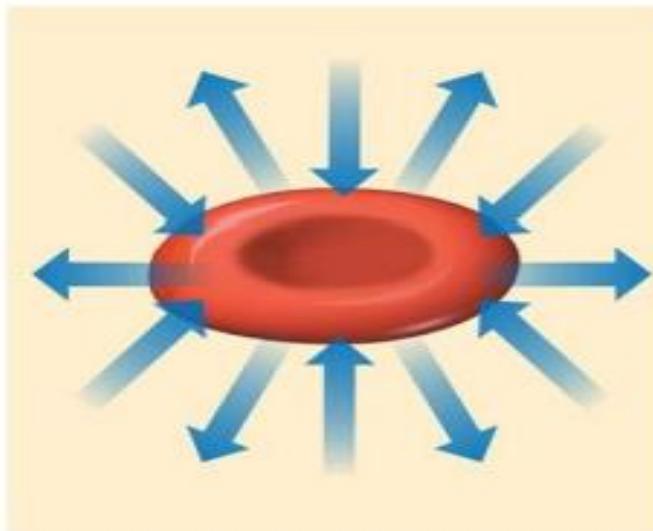
Thistle
tube

In osmosis, the net transfer of solvent is always from the more concentrated to the less concentrated solution.

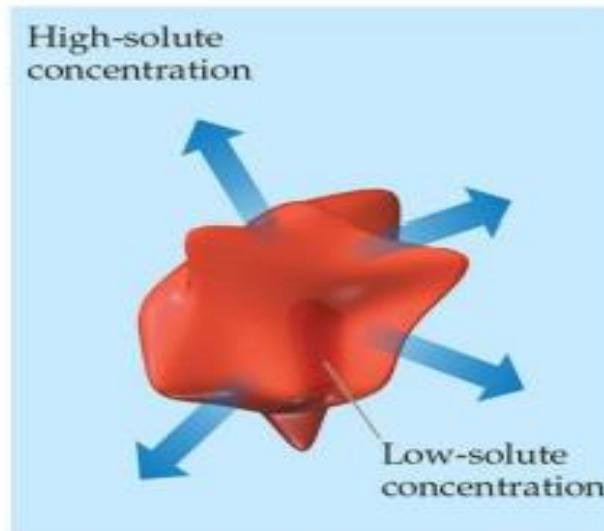


Osmosis in cells

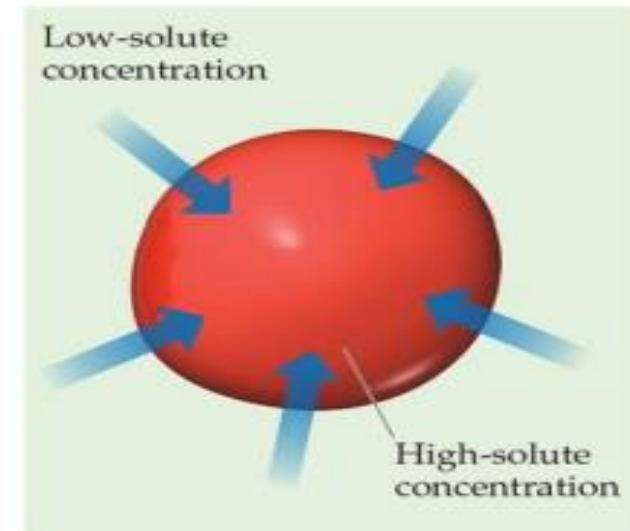
The arrows represent the net movement of water molecules.



Red blood cell in isotonic medium
neither swells nor shrinks.



Crenation of red blood cell placed
in hypertonic environment



Hemolysis of red blood cell placed
in hypotonic environment

If the osmotic pressure is the same on both sides of a membrane (i.e., the concentrations are the same), the solutions are **isotonic**.

Osmotic pressure is the pressure that must be exerted to prevent osmosis of solvent particles through a semipermeable membrane that is separating two solutions of different solute concentrations.

Osmotic pressure is a colligative property.

- A 0.90% solution of sodium chloride in water is known as physiological saline solution. It is isotonic with blood plasma.
 - Red blood cells swell in a hypotonic solution.
 - Red blood cells do not shrink or swell in an isotonic solution.
 - Red blood cells shrink in a hypertonic solution.

OSMOTIC PRESSURE

The pressure required to stop osmosis, known as **osmotic pressure**, Π , is

$$\Pi = i\left(\frac{n}{V}\right)RT = iMRT$$

where M is the molarity of the solution

Example

3.50 mg of a protein is dissolved in water to form a 5.00 mL solution. The osmotic pressure was found to be 1.54 torr at 25 ° C. Calculate the molar mass of the protein.



End of the Presentation