

Vapor Pressure of Solutions

- the vapor pressure of a solvent above a solution is lower than the vapor pressure of the pure solvent
 - ✓ the solute particles replace some of the solvent molecules at the surface

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1

Thirsty Solutions

- a concentrated solution will draw solvent molecules toward it due to the natural drive for materials in nature to mix
- similarly, a concentrated solution will draw pure solvent vapor into it due to this tendency to mix
- the result is reduction in vapor pressure

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2

Raoult's Law

- the vapor pressure of a volatile solvent above a solution is equal to its mole fraction of its normal vapor pressure, P°

$$P_{\text{solvent in solution}} = \chi_{\text{solvent}} \cdot P^\circ$$

- ✓ since the mole fraction is always less than 1, the vapor pressure of the solvent in solution will always be less than the vapor pressure of the pure solvent

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Ionic Solutes and Vapor Pressure

- according to Raoult's Law, the effect of solute on the vapor pressure simply depends on the number of solute particles
- when ionic compounds dissolve in water, they dissociate – so the number of solute particles is a multiple of the number of moles of formula units
- the effect of ionic compounds on the vapor pressure of water is magnified by the dissociation
 - ✓ since NaCl dissociates into 2 ions, Na⁺ and Cl⁻, one mole of NaCl lowers the vapor pressure of water twice as much as 1 mole of C₁₂H₂₂O₁₁ molecules would

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Effect of Dissociation

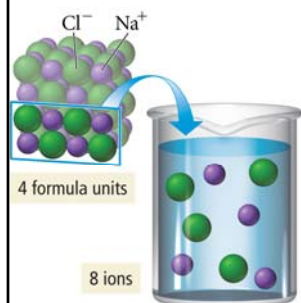


TABLE 12.9 Van't Hoff Factors at 0.05 *m* Concentration in Aqueous Solution

Solute	<i>i</i> Expected	<i>i</i> Measured
Nonelectrolyte	1	1
NaCl	2	1.9
MgSO ₄	2	1.3
MgCl ₂	3	2.7
K ₂ SO ₄	3	2.6
FeCl ₃	4	3.4

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5

Raoult's Law for Volatile Solute

- when both the solvent and the solute can evaporate, both molecules will be found in the vapor phase
- the total vapor pressure above the solution will be the sum of the vapor pressures of the solute and solvent
 - ✓ for an ideal solution

$$P_{\text{total}} = P_{\text{solute}} + P_{\text{solvent}}$$

- the solvent decreases the solute vapor pressure in the same way the solute decreased the solvent's

$$P_{\text{solute}} = \chi_{\text{solute}} \cdot P_{\text{solute}}^{\circ} \quad \text{and} \quad P_{\text{solvent}} = \chi_{\text{solvent}} \cdot P_{\text{solvent}}^{\circ}$$

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6

Ideal vs. Nonideal Solution

- in ideal solutions, the made solute-solvent interactions are equal to the sum of the broken solute-solute and solvent-solvent interactions
 - ✓ ideal solutions follow Raoult's Law
- effectively, the solute is diluting the solvent
- if the solute-solvent interactions are stronger or weaker than the broken interactions the solution is nonideal

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7

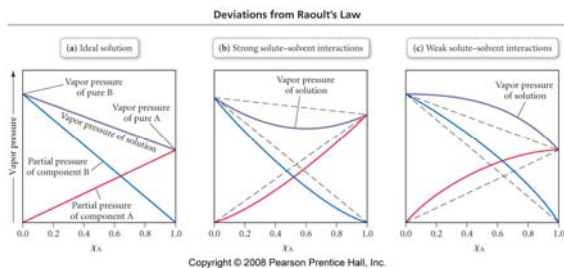
Vapor Pressure of a Nonideal Solution

- when the solute-solvent interactions are stronger than the solute-solute + solvent-solvent, the total vapor pressure of the solution will be less than predicted by Raoult's Law
 - ✓ because the vapor pressures of the solute and solvent are lower than ideal
- when the solute-solvent interactions are weaker than the solute-solute + solvent-solvent, the total vapor pressure of the solution will be larger than predicted by Raoult's Law

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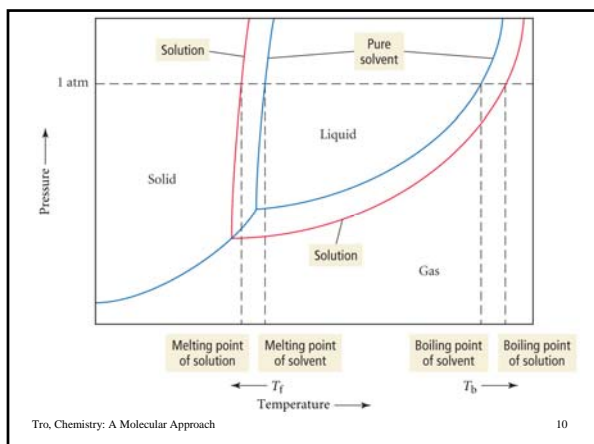
8

Deviations from Raoult's Law



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9



Freezing Point Depression

- the freezing point of a solution is lower than the freezing point of the pure solvent
 - ✓ for a nonvolatile solute
 - ✓ therefore the melting point of the solid solution is lower
- the difference between the freezing point of the solution and freezing point of the pure solvent is directly proportional to the molal concentration of solute particles

$$(FP_{\text{solvent}} - FP_{\text{solution}}) = \Delta T_f = m \cdot K_f$$
- the proportionality constant is called the Freezing Point Depression Constant, K_f
 - ✓ the value of K_f depends on the solvent
 - ✓ the units of K_f are $^{\circ}\text{C}/m$

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K_f

TABLE 12.8 Freezing Point Depression and Boiling Point Elevation Constants for Several Liquid Solvents

Solvent	Normal Freezing Point ($^{\circ}\text{C}$)	K_f ($^{\circ}\text{C}/m$)	Normal Boiling Point ($^{\circ}\text{C}$)	K_b ($^{\circ}\text{C}/m$)
Benzene (C_6H_6)	5.5	5.12	80.1	2.53
Carbon tetrachloride (CCl_4)	-22.9	29.9	76.7	5.03
Chloroform (CHCl_3)	-63.5	4.70	61.2	3.63
Ethanol ($\text{C}_2\text{H}_5\text{OH}$)	-114.1	1.99	78.3	1.22
Diethyl ether ($\text{C}_4\text{H}_{10}\text{O}$)	-116.3	1.79	34.6	2.02
Water (H_2O)	0.00	1.86	100.0	0.512

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Boiling Point Elevation

- the boiling point of a solution is higher than the boiling point of the pure solvent
 - ✓ for a nonvolatile solute
- the difference between the boiling point of the solution and boiling point of the pure solvent is directly proportional to the molal concentration of solute particles

$$(\text{BP}_{\text{solution}} - \text{BP}_{\text{solvent}}) = \Delta T_b = m \cdot K_b$$

- the proportionality constant is called the Boiling Point Elevation Constant, K_b
 - ✓ the value of K_b depends on the solvent
 - ✓ the units of K_b are $^{\circ}\text{C}/m$

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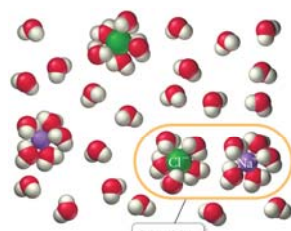
13

Colligative Properties

- colligative properties** are properties whose value depends only on the number of solute particles, and not on what they are
 - ✓ Vapor Pressure Depression, Freezing Point Depression, Boiling Point Elevation, Osmotic Pressure
- the **van't Hoff factor, i** , is the ratio of moles of solute particles to moles of formula units dissolved
- measured van't Hoff factors are often lower than you might expect due to ion pairing in solution

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14



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15
