Lecture 31: Solutions 5

Read: BLB 13.5–13.6
HW: BLB 13:9,58,61,67,69,75
     Sup13:12–18

Know:
• colligative properties
  vapor pressure lowering
  boiling point elevation
  freezing point depression
  osmotic pressure

Need help?? Get help!! TAs in CRC (211 Whitmore) and SI—hours
on Chem 110 website; my office hours (Mon 12:30–2 & Tues
10:30–12 in 324 Chem Bldg [or 326 Chem])

Bonus deadline for BST #9: Solutions & dilutions, April 2
Bonus deadline for BST #10: Net ionic equations, April 16

Review chemical nomenclature (e.g., BST #5, Lecture 8 …);
§ memorize those strong acids § bases (BLB Table 4.2)

Check out the grade-u-lator

Exam #3: Monday, April 6 @ 6:30 pm; Sign up for the conflict
exam, if needed. Last day to sign up is TODAY Wed, April 1. No
text-programmable calculators (PDAs, iPods, etc). Bring PSU ID and
several pencils;

Late drop deadline: Friday, April 10 @ 11:59 pm via elion
Colligative properties

• properties that depend *only* on the quantity ( ) of the *solute particles*, not on their *identity*

• *colligative property examples*
  - vapor pressure of solutions
  - BP elevation
  - freezing point depression
  - osmotic pressure

• the *extent of dissociation* determines the concentration of solute particles (**memorize** strong acids & bases [BLB Table 4.2])

<table>
<thead>
<tr>
<th>solute</th>
<th>type</th>
<th># particles</th>
<th>particle conc, if 0.5 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHCl₃</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CH₃COOH</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NaCl</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>K₂SO₄</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Time to learn those strong acids & bases!!

You absolutely **must know** this table!

<table>
<thead>
<tr>
<th>Strong Acids</th>
<th>Strong Bases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrochloric, HCl</td>
<td>Group 1A metal hydroxides (LiOH, NaOH, KOH, RbOH, CsOH)</td>
</tr>
<tr>
<td>Hydrobromic, HBr</td>
<td>Heavy group 2A metal hydroxides [Ca(OH)₂, Sr(OH)₂, Ba(OH)₂]</td>
</tr>
<tr>
<td>Hydroiodic, HI</td>
<td></td>
</tr>
<tr>
<td>Chloric, HClO₃</td>
<td></td>
</tr>
<tr>
<td>Perchloric, HClO₄</td>
<td></td>
</tr>
<tr>
<td>Nitric, HNO₃</td>
<td></td>
</tr>
<tr>
<td>Sulfuric, H₂SO₄</td>
<td></td>
</tr>
</tbody>
</table>

Revisit the flowchart from Lecture 28 to learn how to identify strong electrolytes, weak electrolytes & non-electrolytes; critical for the next few weeks (including exam 3)!!!
Flashback (eek!) to Chap 4

Electrolytes

• strong or weak electrolytes are *NOT* determined by *how much* of a compound goes into solution

• rather, strong or weak electrolytes are determined by *what the compound does* once it is in solution!

**examples:**
• CH₃COOH: very soluble in water *but* weak electrolyte (partially ionizes)

• Ba(OH)₂: very slightly soluble in water *but* strong electrolyte (completely ionizes) once it gets into solution

**Differences between strong and weak electrolytes**

• assume all salts are strong electrolytes

• *memorize* strong acids and bases (BLB Table 4.2)

  If a compound is an acid or a base, but *NOT* one of the strong acids or bases, then it *MUST* be a weak electrolyte

• *Common misconception:* all electrolytes are ionic compounds; *NOT TRUE*

• *strong electrolytes* – ionic or molecular compounds that *ionize completely* in solution.

• *weak electrolytes* – molecular compounds that are *partially ionized* in solution (in equilibrium—more later on in semester)

• *nonelectrolytes* – molecular compounds that *do not ionize* in solution
Example
A What is the molality of KBr in a solution made by dissolving 2.21 g of KBr in 897 g of water?
B What is the molality of “particles”?  
C What is the molarity of KBr?  Density = 1.1 g/mL.
More about colligative properties

Example

0.2 \textit{m} solution of Pb(NO_3)_2; is a

concentrations of individual species

total concentration of “particles”

0.5 \textit{m} solution of C_2H_3OOH (acetic acid); is a

C_2H_3OOH (aq) \rightleftharpoons H^+(aq) + C_2H_3OO^-(aq)

• solution has a concentration of particles
Vapor pressure (VP) lowering

- VP lowering is a colligative property; depends on concentration of non-volatile solute **BUT not** on solute identity

- *pure solvent*   
  - rate of evaporation: ↓
  - vapor pressure of solvent: ↓

- *Raoult’s law:* \( P_A = X_A P_A^\circ \)
  - \( P_A \equiv \) vapor pressure of *solution*
  - \( X_A \equiv \) mole fraction of *solvent in the soln*
  - \( P_A^\circ \equiv \) vapor pressure of *pure solvent*

- \( P_{solution} \)       
  - \( P_{pure \ solvent} \)
What’s your point?  
boiling point elevation

• **boiling point (bp):** when $VP = P_{ext}$

• so… if colligative properties *lower* the vapor pressure, then a **temperature increase** is required to reach the boiling point; **bp** with **solute concentration**

$$\Delta T_b = K_b m$$

• $K_b = molal boiling point elevation constant$; property of a particular **solvent**; e.g., $K_b$ for water = 0.51°C/m; $K_b$ for benzene = 2.53°C/m

• $m \equiv$ molality of **solute “particles”** in the solution (*not* m, as in meters!)

<table>
<thead>
<tr>
<th>Solvent</th>
<th>Normal Boiling Point (°C)</th>
<th>$K_b$ (°C/m)</th>
<th>Normal Freezing Point (°C)</th>
<th>$K_f$ (°C/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water, H$_2$O</td>
<td>100.0</td>
<td>0.51</td>
<td>0.0</td>
<td>1.86</td>
</tr>
<tr>
<td>Benzene, C$_6$H$_6$</td>
<td>80.1</td>
<td>2.53</td>
<td>5.5</td>
<td>5.12</td>
</tr>
<tr>
<td>Ethanol, C$_2$H$_5$OH</td>
<td>78.4</td>
<td>1.22</td>
<td>-114.6</td>
<td>1.99</td>
</tr>
<tr>
<td>Carbon tetrachloride, CCl$_4$</td>
<td>76.8</td>
<td>5.02</td>
<td>-22.3</td>
<td>29.8</td>
</tr>
<tr>
<td>Chloroform, CHCl$_3$</td>
<td>61.2</td>
<td>3.63</td>
<td>-63.5</td>
<td>4.68</td>
</tr>
</tbody>
</table>
What’s your point? (cont.)
freezing point depression

• colligative properties the freezing point; depends on concentration of a particular solute, not its properties

\[ \Delta T_f = K_f m \]

• \( K_f \) = molal freezing point depression constant; property of a particular solvent; e.g., \( K_f \) for water = 1.86°C/m; \( K_f \) for benzene = 5.12°C/m

**example:** What is the freezing point of seawater? Ocean salinity is primarily \(~ (35 \text{ g salt})/(1 \text{ kg seawater})\): mainly: \( \text{Cl}^- \), \( \text{Na}^+ \), \( \text{SO}_4^{2-} \), \( \text{Mg}^{2+} \), \( \text{Ca}^{2+} \), \( \text{K}^+ \). Assume all is NaCl (MW = 58.5 g/mol).

• why NaCl is used on icy roads & sidewalks
Osmosis

- flow of molecules through a semi-permeable membrane; NET movement of solvent is toward solution with higher solute concentration; movement of solvent continues until osmotic pressure builds up to stop it

- osmotic pressure ($\pi$): pressure needed to stop osmotic flow of a molecule through a membrane

$$\pi = \left(\frac{n}{V}\right)RT = MRT$$

- $\pi$ is osmotic pressure (what units will this be in???)
- R is gas constant in (L atm)/(mol K)
- T is temperature in K
- M is concentration in molarity (mol/L)

- what does this equation remind you of???
• reverse osmosis: exert pressure on a concentrated solution, forcing solvent molecules through a membrane; solute molecules are trapped in concentrated portion; used to purify water
Consequence of osmotic pressure

• red blood cells: the cell membrane of red blood cells is a semi-permeable membrane

cell in **hypertonic sol’n**

![Diagrams showing osmotic pressure effects on red blood cells](image)

(a) Low solute concentration, high solute concentration (b) High solute concentration, low solute concentration
Example
A 25 mL aqueous solution containing 0.420 g of hemoglobin has an osmotic pressure of 4.6 torr at 27°C. What is the molar mass of hemoglobin?
Before next class:

Read: BLB 13.5–13.6
HW: BLB 13:9,58,61,67,69,75
      Sup13:12–18

Know:
• colligative properties
  vapor pressure lowering
  boiling point elevation
  freezing point depression
  osmotic pressure
• colloids

Answers:
p. 5: \textbf{A} 0.0207 \textit{m}; \textbf{B} 0.0414 \textit{m}; \textbf{C} 0.0227 \text{M}
p. 10: \textit{–2.25°C}
p. 14: $6.84 \times 10^4 \text{ g/mol}$