Lecture 8 CH131 Summer 1
Tuesday, June 4, 2019

- Relative boiling points

Ch11: Solutions
- Vapor pressure lowering, $P_1 = x_1 P°_1$
- Boiling point elevation, $T_b - T°_b = K_b m_c$
- Freezing point depression, $T°_f - T_f = K_f m_c$
- Osmotic pressure, $\Pi = RTM_c$

Next lecture: Begin ch12: Thermodynamic processes and thermochemistry

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Relative boiling points

Effects of
- Dispersion — always, but weak
- Dipole-dipole interaction — polar molecules, moderate
- Hydrogen bonding — N-H, O-H, F-H, strongest

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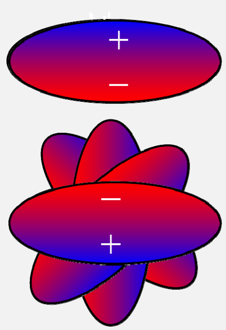
Dipole can be attractive or repulsive



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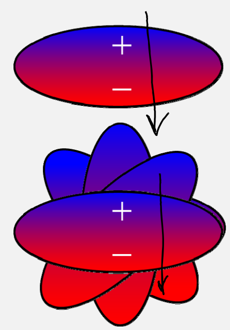
Dispersion always attractive



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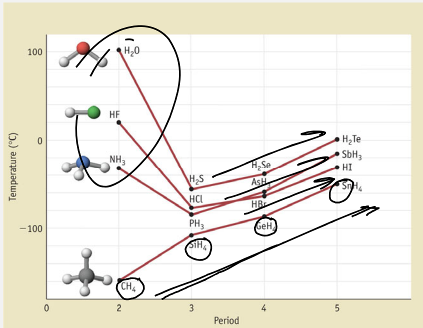
Relative boiling points



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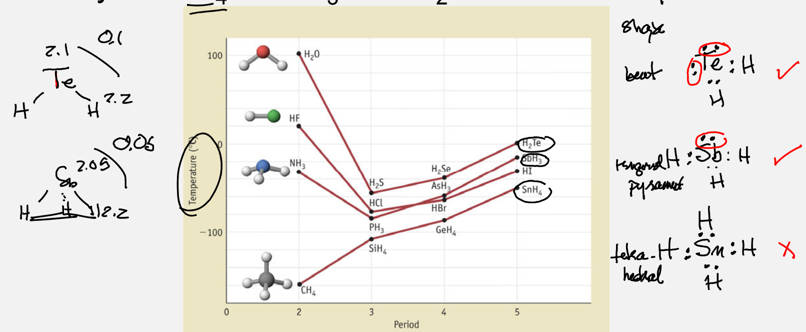
Why is SnH_4 < SbH_3 < TeH_2?



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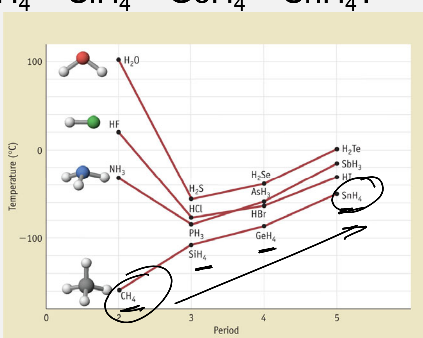
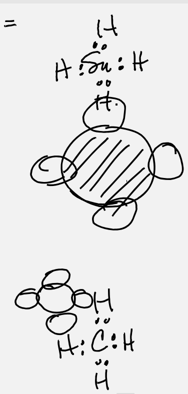
Why is CH_4 < SiH_4 < GeH_4 < SnH_4?





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[TP] The correct order of polarity of HBr, HCl and HI is (least to most) ...

0%	1.	HBr < HCl < HI
0%	2.	HBr < HI < HCl
18%	3.	HCl < HBr < HI
6%	4.	HCl < HI < HBr
0%	5.	HI < HCl < HBr
76%	6.	HI < HBr < HCl

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[TP] The correct order of boiling point of HBr, HCl and HI is (lowest to highest) …

0%	1.	HBr < HCl < HI
0%	2.	HBr < HI < HCl
31%	3.	HCl < HBr < HI — observed
6%	4.	HCl < HI < HBr
13%	5.	HI < HCl < HBr
50%	6.	HI < HBr < HCl — expect

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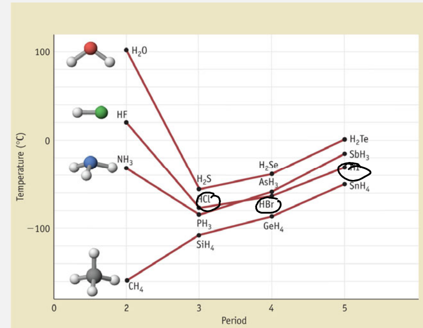
Why is HCl < HBr < HI?



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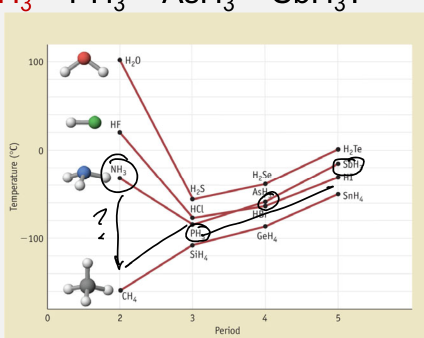
Why is NH_3 > PH_3 < AsH_3 < SbH_3?



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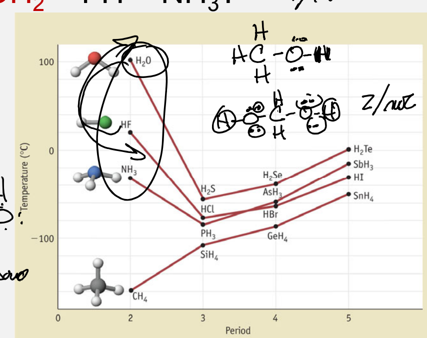
Why is OH_2 > FH > NH_3?

most polar, most dispersion
least dispersion



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Colligative properties

Non-volatile solute (negligible vapor pressure) …

- lowers vapor pressure of solvent: $P_1 = x_1 P^\circ_1$, $\Delta P = P^\circ_1 - P_1 = x_2 P^\circ_1$

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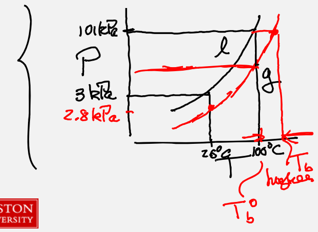
Colligative properties

Non-volatile solute (negligible vapor pressure) …

- lowers vapor pressure of solvent: $P_1 = x_1 P^\circ_1$, $\Delta P = P^\circ_1 - P_1 = x_2 P^\circ_1$
- raises boiling point of solvent: $T_b - T^\circ_b = i\, m_{solute} K_b = m_c K_b$



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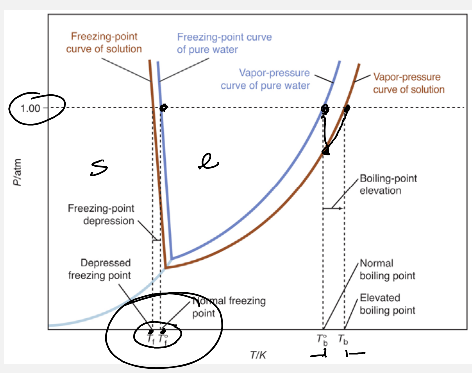
Effect of solute on vapor pressure (Fig 16.4)



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The more particles, the greater the effect

Sugar in water, 1 mol of particles per mol of sugar, so $i = 1$

NaCl in water, 2 mol of particles per mol of NaCl, so $i = 2$

Na_2SO_4 in water, 3 mol of particles per mol of Na_2SO_4, so $i = 3$

$Na_2SO_4(s) \rightarrow 2\,Na^+(aq) + SO_4^{2-}(aq)$

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Colligative properties

Non-volatile solute (negligible vapor pressure) …

- lowers vapor pressure of solvent: $P_1 = x_1 P°_1$, $\Delta P = P°_1 - P_1 = x_2 P°_1$
- raises boiling point of solvent: $T_b - T°_b = i\, m_{solute}\, K_b = m_c K_b$
- lowers freezing point of solvent: $T°_f - T_f = i\, m_{solute}\, K_f = m_c K_f$

$i\, m_{solute} = m_c$

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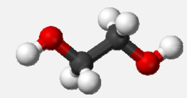
Freezing point example

Calculate the freezing point of 3.00 kg of water to which has been added 525 g of ethylene glycol, OHC_2H_4OH, $K_f = 1.86$ K kg/mol

Answer: –5.24 ºC



$T°_f - T_f = m_c K_f$

$m_c = \frac{1 * 525\,g / 62.1\,g/mol}{3.00\,kg}$

$T°_f - T_f = \frac{(525/62.1)\,mol}{3.00\,kg}\, 1.86\,K\,\frac{kg}{mol}$

$= 5.25\,K$, $T_f = -5.25\,°C$

$T°_f = 0\,°C$

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Freezing point example again

Calculate the freezing point of 3.00 kg of water to which has been added 525 g of sodium chloride, NaCl, $K_f = 1.86$ K kg/mol

Answer: –11.1 ºC

$NaCl(s) \rightarrow Na^+(aq) + Cl^-(aq)$

NaCl = 58.4 g/mol

$T°_f - T_f = \frac{2 * 525\,g / 58.4\,g/mol}{3.00\,kg}\, 1.86\,K\,kg/mol$

$= 11.1$

$T_f = -11.1\,°C$

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[TP] A non-volatile solute lowers the vapor pressure of the solvent. This in turn means the boiling point of the solvent must increase. Why? Because …

0% 1. higher temperature is necessary to evaporate the solute
35% 2. the solute particles stick to the solvent particles, analogous to van der Waals a
65% 3. at the normal boiling point the vapor pressure of the solvent will be too low
0% 4. the solute vapor pressure is so low
0% 5. Some other reason

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[TP] The vapor pressure of water at 32 °C is 4.76 kPa. A glass of water is sealed in a 1.00 L container filled with air at 32 °C. After the water comes to equilibrium with the air in the container, the total pressure is 1 bar and there is 500. g of liquid water in the glass, and the partial pressure of water vapor in the container is …

- 12% 1. less that 4.76 kPa
- 88% 2. 4.76 kPa
- 0% 3. more than 4.76 kPa
- 0% 4. Further information required

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[Quiz] Then, 35.0 g of ethylene glycol if dissolved in the liquid water. After the water returns to equilibrium, the mass of the liquid water …

- 35% 1. will have decreased
- 0% 2. will be unchanged
- 65% 3. will have increased
- 0% 4. Further information required

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Effect of solute on vapor pressure

The vapor pressure of water at 32 °C is 4.76 kPa. A glass of water is sealed in a container filled with air at 32 °C. After the water comes to equilibrium with the air in the container, the total pressure is 1.00 bar, there is 500. g of liquid water in the glass, and the volume of the container in addition to the glass and liquid water is 1.00 L

Then 35.0 g of ethylene glycol if dissolved in the water.

Calculate change in the mass of the liquid water after it has returned to equilibrium.

Answer: The mass of liquid water will increase by 0.000673 g

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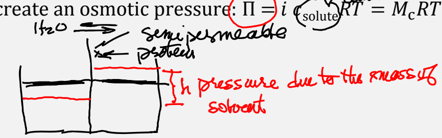
Colligative properties

Non-volatile solute (negligible vapor pressure) …

- lowers vapor pressure of solvent: $P_1 = x_1 P°_1$, $\Delta P = P°_1 - P_1 = x_2 P°_1$
- raises boiling point of solvent: $T_b - T°_b = i\, m_{solute}\, K_b = m_c K_b$
- lowers freezing point of solvent: $T°_f - T_f = i\, m_{solute}\, K_f = m_c K_f$

If solute cannot pass through a membrane …

- the solvent will create an osmotic pressure: $\Pi = i\, c_{solute} RT = M_c RT$



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Roadmap of osmotic pressure calculations

Osmotic pressure $\Pi = i\,c\,R\,T$.

$c = \frac{\text{mol of solute}}{\text{L of solution}} = \text{molarity}$

1. Use measured osmotic pressure, Π, and temperature, T, to evaluate concentration, $c = \Pi/(i\,R\,T)$, in mol/L.
2. Use cell volume to express concentration in terms of moles, $n = c\,V$.
3. Use solute mass to calculate molar mass, $M = \text{mass}/n$.

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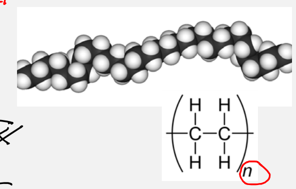
Osmotic pressure $\Pi = i\,c\,R\,T$

1.40 g of polyethylene ($i = 1$) dissolved in 100. mL of benzene generates an osmotic pressure of 0.248 kPa at 25 °C. Calculate the molar mass of the polyethylene.

1. Calculate the concentration…



$c = \frac{\Pi}{RT} = \frac{248\ \text{Pa K mol}}{8.314\ \text{Pa}\ 10^3\ \text{L} \times 298\ \text{K}} = 1.00 \times 10^{-4}\ \text{mol/L}$

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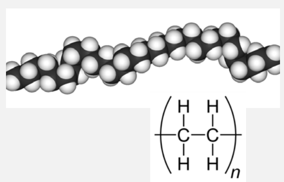
Osmotic pressure $\Pi = i\,c\,R\,T$

1.40 g of polyethylene ($i = 1$) dissolved in 100. mL of benzene generates an osmotic pressure of 0.248 kPa at 25 °C. Calculate the molar mass of the polyethylene.

1. Calculate the concentration…

1.00×10^{-4} mol/L



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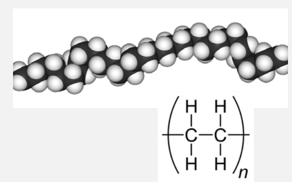
Osmotic pressure $\Pi = i\,c\,R\,T$

1.40 g of polyethylene ($i = 1$) dissolved in 100. mL of benzene generates an osmotic pressure of 0.248 kPa at 25 °C. Calculate the molar mass of the polyethylene.

1. Calculate the concentration…

1.00×10^{-4} mol/L

2. Calculate the moles…



$\frac{1.00 \times 10^{-4}\ \text{mol}}{\text{L}} \times \frac{100\ \text{mL} \times 1\ \text{L}}{1000\ \text{mL}} = 1.00 \times 10^{-5}\ \text{mol}$

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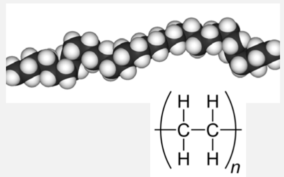
Osmotic pressure $\Pi = i\,c\,R\,T$

1.40 g of polyethylene ($i = 1$) dissolved in 100. mL of benzene generates an osmotic pressure of 0.248 kPa at 25 °C. Calculate the molar mass of the polyethylene.



1. Calculate the concentration…

   1.00×10^{-4} mol/L

2. Calculate the moles…

   1.00×10^{-5} mol

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Osmotic pressure $\Pi = i\,c\,R\,T$

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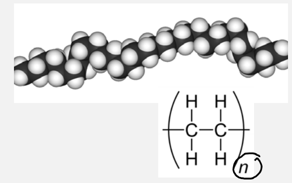

1. Calculate the concentration…

   1.00×10^{-4} mol/L

2. Calculate the moles…

   10^{-5} mol

3. Calculate the molar mass…

   $\frac{1.40\ g}{1.00 \times 10^{-5}\ mol} = 1.40 \times 10^{5}$ g/mol

   How many n?

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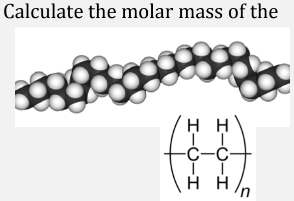
Osmotic pressure $\Pi = i\,c\,R\,T$

1.40 g of polyethylene ($i = 1$) dissolved in 100. mL of benzene generates an osmotic pressure of 0.248 kPa at 25 °C. Calculate the molar mass of the polyethylene.



1. Calculate the concentration…

   1.00×10^{-4} mol/L

2. Calculate the moles…

   10^{-5} mol

3. Calculate the molar mass…

   $1.40 \times 10^{+5}$ g/mol

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