N35 - SOLUTIONS

Colligative Properties

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Colligative Properties

Target: I can take into account how the number of particles in a solution affects various properties.

Ionic Solutes

Colligative properties

Properties whose value depends only on the number of solute particles, and not on what they are.

- **Value of the property depends on the concentration of the solution.**

The difference between the solution and the pure substance is related to the different attractive forces present in the solution, and the solute particles occupying solvent molecules positions.

Colligative Properties

Colligative properties are those that depend on the concentration of particles in a solution, not upon the identity of those properties.

- Boiling Point Elevation
- Freezing Point Depression
- Vapor Pressure Lowering
- Osmotic Pressure

The van't Hoff Factor, *i*

Electrolytes may have two, three or more times the effect on boiling point, freezing point, and osmotic pressure, depending on its dissociation.

Ionic Comp.	$\mathbf{AB \rightarrow A^+ + B^-}$		$\mathbf{C_2D \rightarrow 2C^- + D^{2-}}$
#particles	1 2		1 3
Nonelectrolyte	$\mathbf{XY(s) \rightarrow XY(aq)}$		
#particles	1 1		

Dissociation Equations and *i*

$NaCl(s) \rightarrow Na^{+}(aq) + Cl^{-}(aq)$ — *i* = 2

$AgNO_3(s) \rightarrow Ag^{+}(aq) + NO_3^{-}(aq)$ — *i* = 2

$MgCl_2(s) \rightarrow Mg^{2+}(aq) + 2\ Cl^{-}(aq)$ — *i* = 3

$Na_2SO_4(s) \rightarrow 2\ Na^{+}(aq) + SO_4^{2-}(aq)$ — *i* = 3

$AlCl_3(s) \rightarrow Al^{3+}(aq) + 3\ Cl^{-}(aq)$ — *i* = 4

Ideal vs. Real van’t Hoff Factor

The ideal van’t Hoff Factor is only achieved in VERY DILUTE solution.

	Molality, *m*					
Solute	**1.0**	**0.10**	**0.010**	**0.0010**	**…**	**Inf dil***
NaCl	1.81	1.87	1.94	1.97	…	2
$MgSO_4$	1.09	1.21	1.53	1.82	…	2
$Pb(NO_3)_2$	1.31	2.13	2.63	2.89	…	3

Boiling Point Elevation

Each mole of solute particles raises the boiling point of 1 kilogram of water by 0.51 degrees Celsius.

$$\Delta T = i \cdot K_b \cdot m_{solute}$$

K_b = kilogram/mol (for water 0.51 °C)

m = molality of the solution

i = van’t Hoff factor

Freezing Point Depression

Each mole of solute particles lowers the freezing point of 1 kilogram of water by 1.86 degrees Celsius.

$$\Delta T = i \cdot K_f \cdot m_{solute}$$

K_f **= kilogram/mol (for water 1.86 °C)**

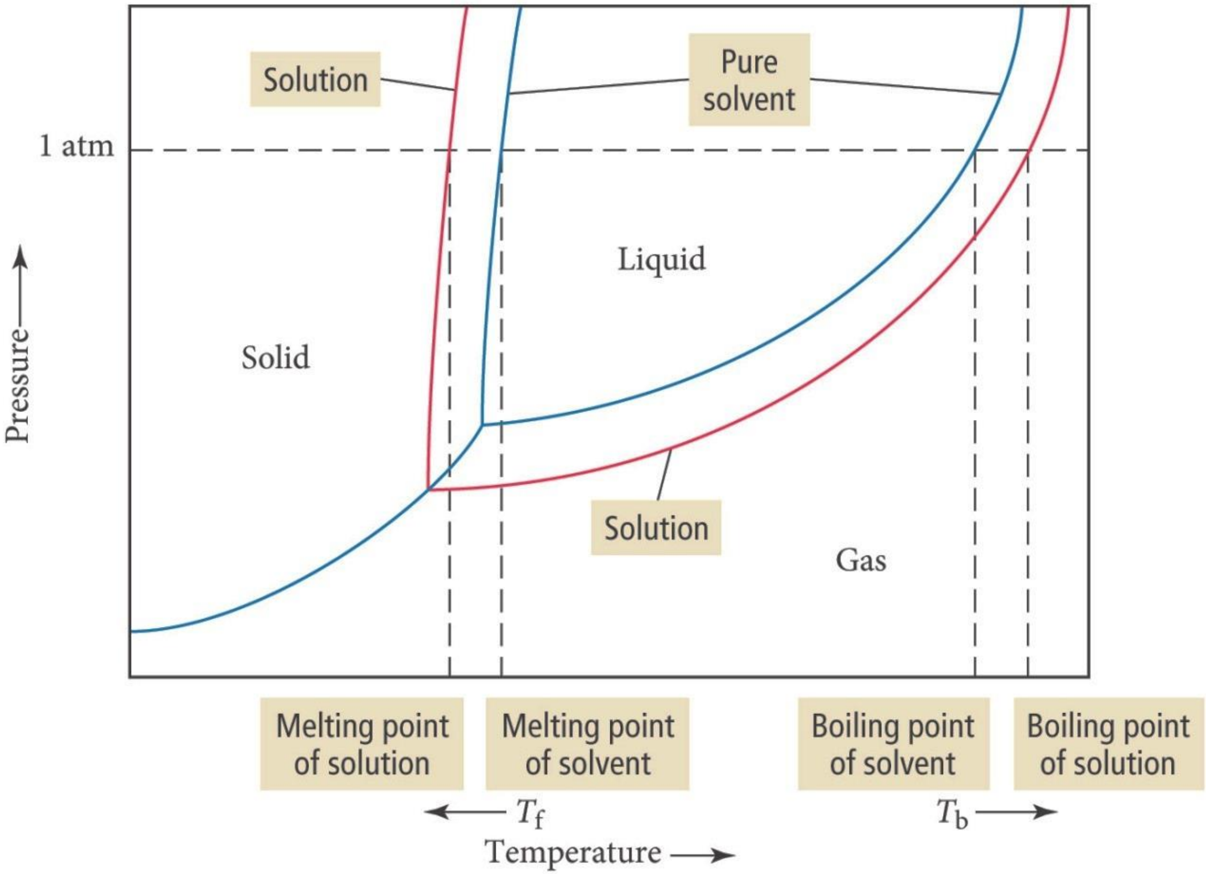
m **= molality of the solution**

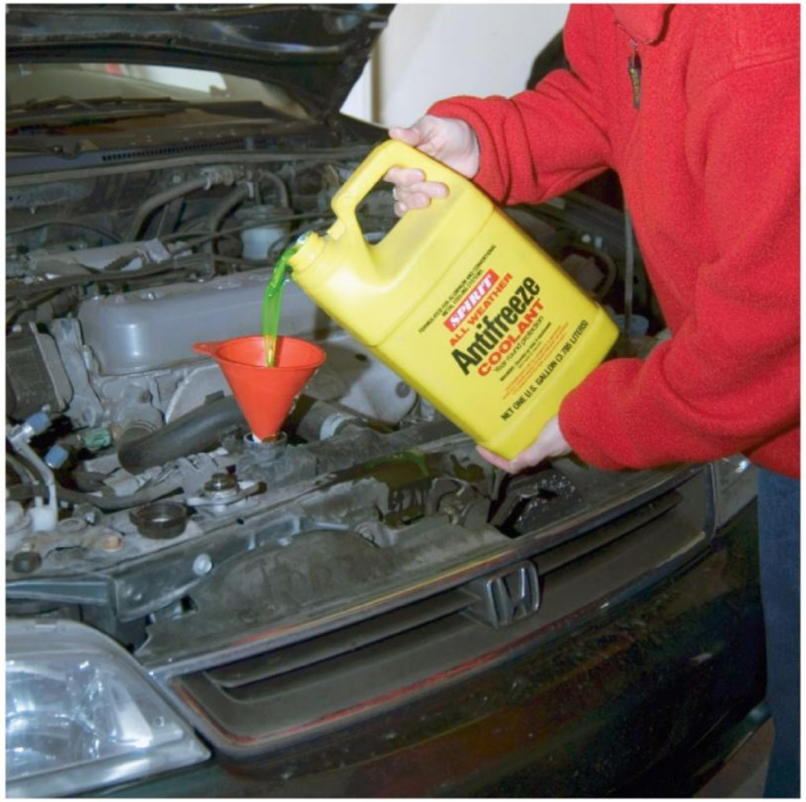
i **= van’t Hoff factor**

Freezing Point Depression and Boiling Point Elevation Constants, °C/m

Solvent	K_f	K_b
Acetic acid	3.90	3.07
Benzene	5.12	2.53
Nitrobenzene	8.1	5.24
Phenol	7.27	3.56
Water	1.86	0.512

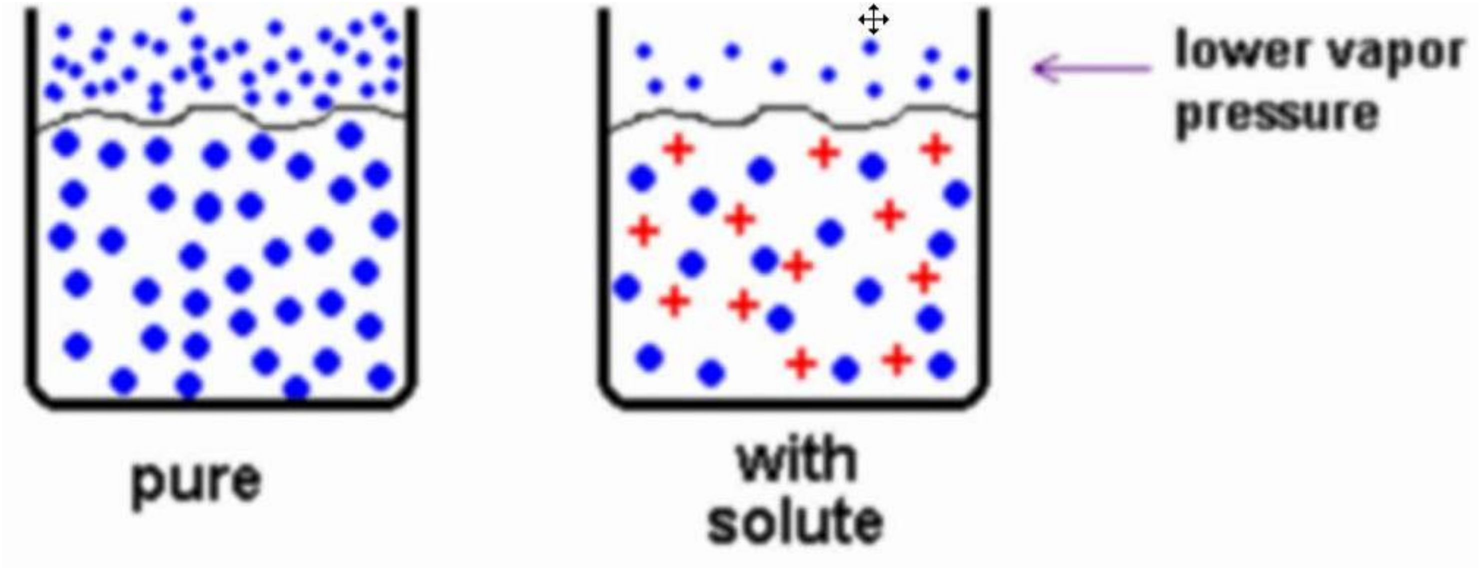
Freezing Point Depression and Boiling Point Elevation





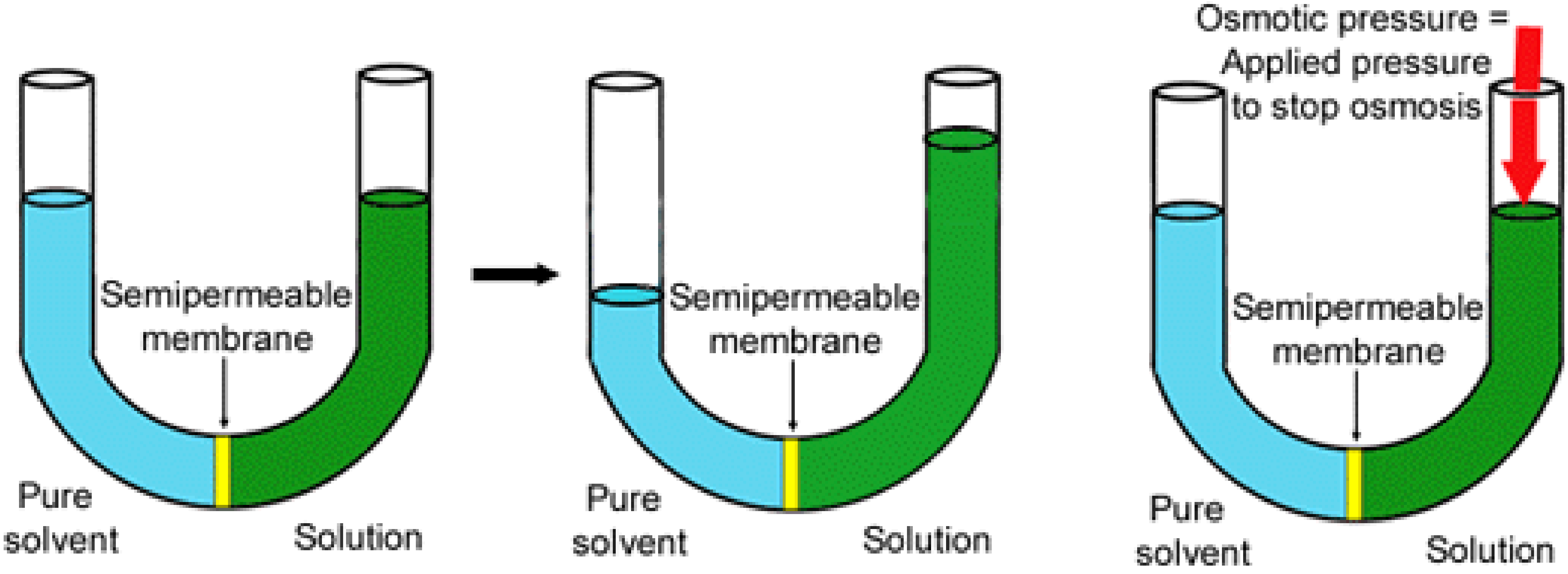
Vapor Pressure Lowering

$$P_1 = X_1 P_1^0$$



Osmotic Pressure

The minimum pressure that stops the osmosis is equal to the osmotic pressure of the solution



Osmotic Pressure Calculations

$$\Pi = iMRT$$

Π = **Osmotic pressure**

M = **Molarity of the solution**

R = **Gas Constant = 0.08206 L·atm/mol·K**

T = **Absolute Temperature (K)**

Suspensions and Colloids

Suspensions and colloids are NOT solutions.

Suspensions - The particles are so large that they settle out of the solvent if not constantly stirred.

Colloids - The particles intermediate in size between those of a suspension and those of a solution.

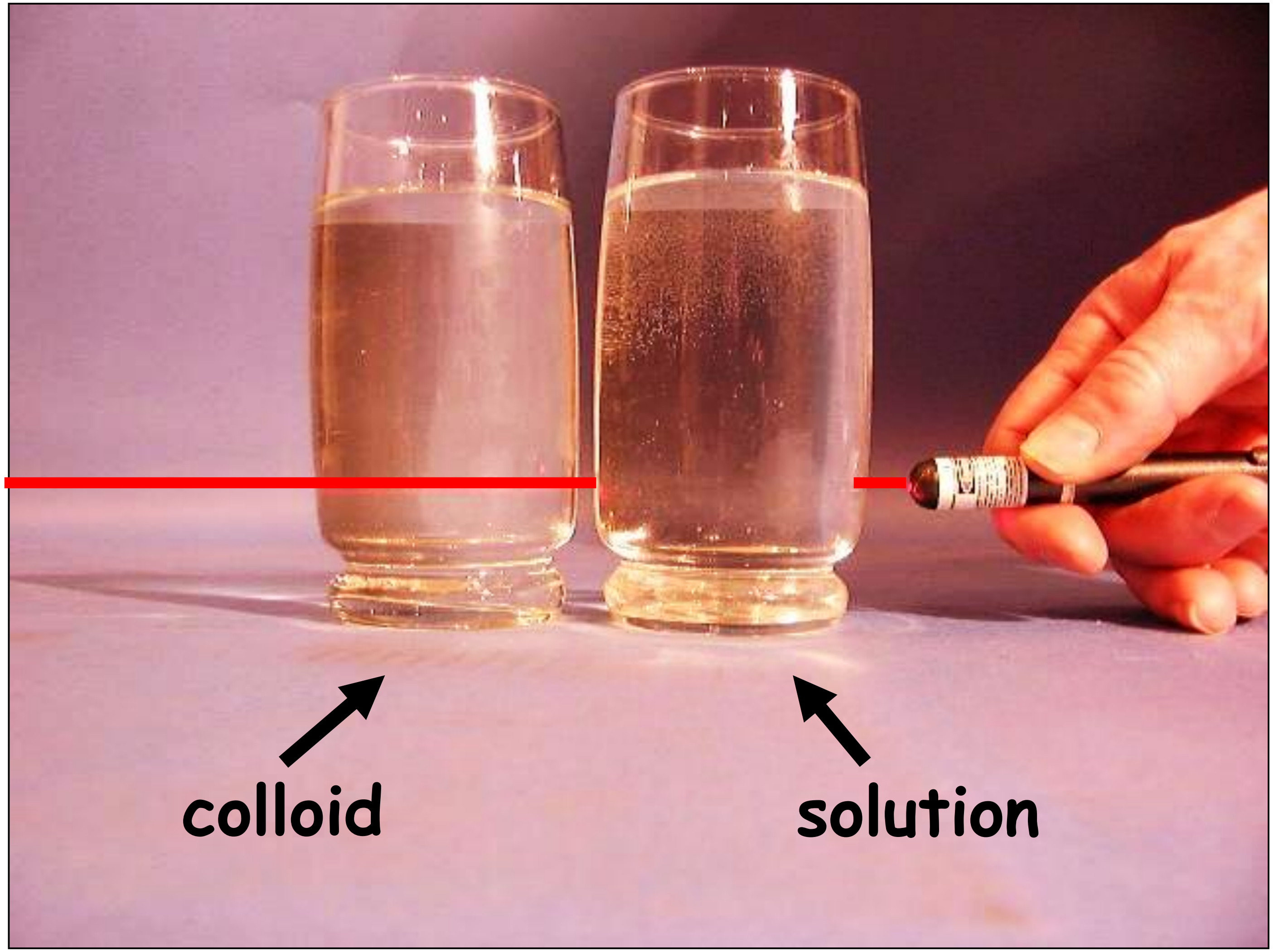
Types of Colloids

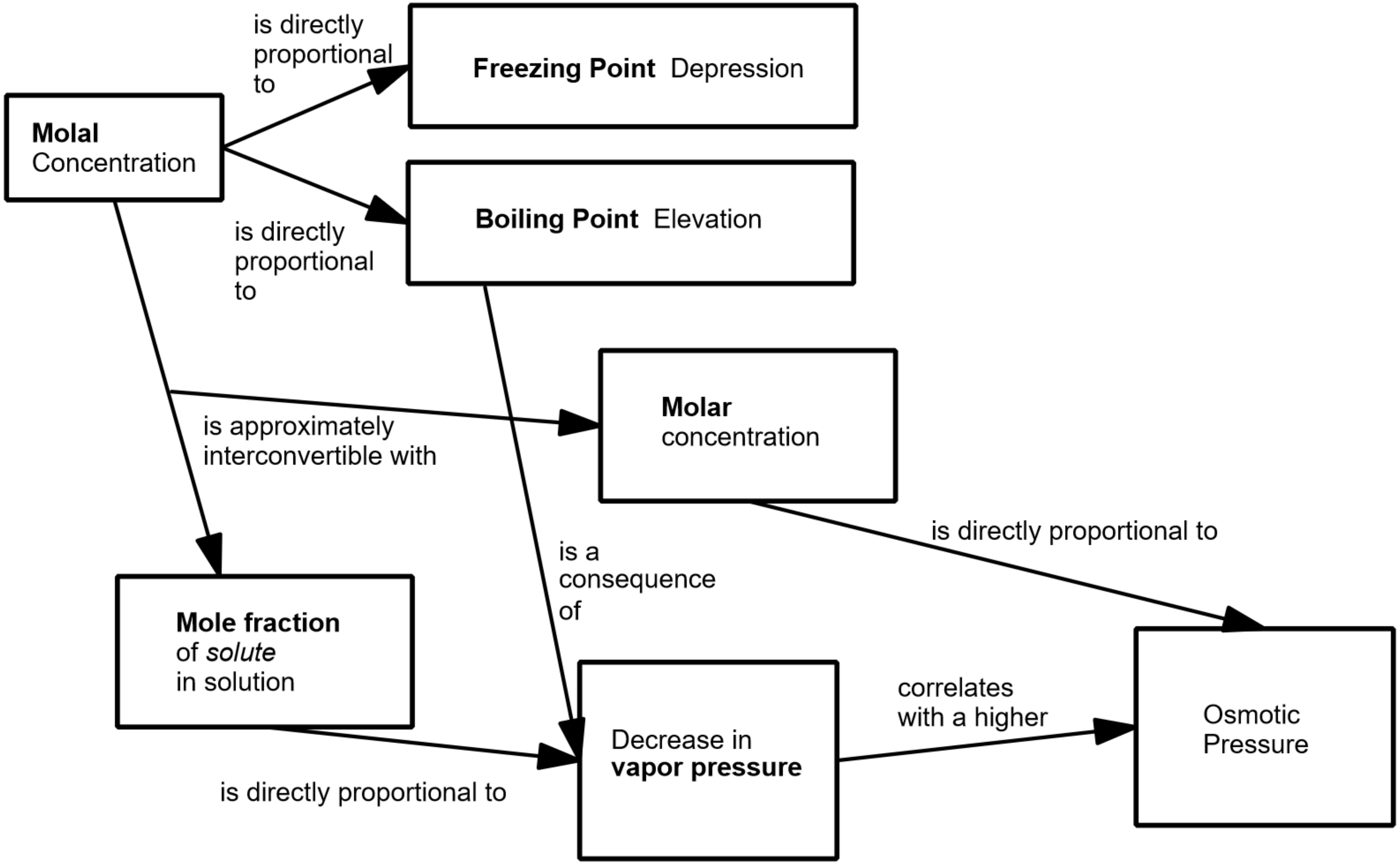
Examples	Dispersing Medium	Dispersed Substance	Colloid Type
Fog, aerosol sprays	Gas	Liquid	Aerosol
Smoke, airborn germs	Gas	Solid	Aerosol
Whipped cream, soap suds	Liquid	Gas	Foam
Milk, mayonnaise	Liquid	Liquid	Emulsion
Paint, clays, gelatin	Liquid	Solid	Sol
Marshmallow, Styrofoam	Solid	Gas	Solid Foam
Butter, cheese	Solid	Liquid	Solid Emulsion
Ruby glass	Solid	Solid	Solid sol

The Tyndall Effect

Colloids scatter light, making a beam visible. Solutions do not scatter light.

Which glass contains a colloid?





Molal Concentration
is directly proportional to
Freezing Point Depression
is directly proportional to
Boiling Point Elevation
is approximately interconvertible with
Molar concentration
is a consequence of
is directly proportional to
Mole fraction of solute in solution
is directly proportional to
Decrease in vapor pressure
correlates with a higher
Osmotic Pressure

All of the following are colligative properties except:

A. Osmotic Pressure

B. Boiling Point elevation

C. Freezing Point depression

D. Density elevation

E. None of these

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- A Osmotic Pressure
- B Boiling Point elevation
- C Freezing Point depression
- D **Density elevation**
- E None of these

121.2 g of NaCl completely dissolve (producing Na^+ and Cl^- ions) in 1.00 Kg of water at 25°C. The VP of pure water at this temp is 23.8 torr. Determine the VP of the solution

- A 22.1 torr
- B 22.9 torr
- C 20.6 torr
- D 19.9 torr
- E 23.8 torr

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121.2g	1mol	2mol ions
	58.44g	1mol NaCl

= 4.15 mol

1000g	1mol
	18.02g

= 55.5mol

$$X_{H2O} = \frac{55.5}{(4.15 + 55.5)} = 0.930$$

P = (0.930)(23.8) = 22.1torr

At 40°C, heptane has a vapor pressure of about 92.0 torr and octane has a vapor pressure of about 31.2 torr. Assuming ideal behavior, what is the vapor pressure of a solution that contains twice as many moles of heptane as octane?

- A. 61.3 torr
- B. 51.5 torr
- C. 71.7 torr
- D. 82.1 torr
- E. None of these

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D. 82.1 torr

E. None of these

Octane = 1 mol

Heptane = 2 mol

$$P = X_1P_1 + X_2P_2$$

$$P = \left(\frac{1}{3}\right)(31.2) + \left(\frac{2}{3}\right)(92.0)$$

P = 71.7 torr

What is the boiling point change for a solution containing 0.681 moles of naphthalene (a nonvolatile, nonionizing compound) in 250. g of liquid benzene? (K_b = 2.53 °C/m for benzene)

- A. 6.89 °C
- B. 0.93 °C
- C. 3.72 °C
- D. 1.723 °C
- E. 0.431 °C

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D. 1.723 °C

E. 0.431 °C

$\Delta T = iKm$

$m = mol_{solute}/kg_{solvent}$

$$= \frac{0.681\ mol}{0.250\ kg} = 2.724\ m$$

$\Delta T = (1)(2.53)(2.724) = 6.89°C$

A 7.12 g sample of a compound is dissolved in 250. grams of benzene. The freezing point of this solution is 1.02°C below that of pure benzene. What is the molar mass of this compound? ($K_{f\ benzene}$ = 5.12 °C/m). Ignore sig. figs.

- A) 35.7 g/mol
- B) 143 g/mol
- C) 286 g/mol
- D) 5.67 g/mol
- E) 71.5 g/mol

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- B **143 g/mol**
- C 286 g/mol
- D 5.67 g/mol
- E 71.5 g/mol

$\Delta T = iKm$

$1.02 = (1)(5.12)(m)$

$m = 0.199\ mol_{solute}/kg_{solvent}$

$$0.199 = \frac{x\ mol}{0.250\ kg} = 0.04975\ \text{moles}$$

mm = g/mol = 7.12g/0.04975mol

= 143g/mol

Determine the Osmotic Pressure of a solution that contains 0.017 g of a hydrocarbon solute (molar mass = 340 g/mol) dissolved in benzene to make 350-ml solution. The temperature is 20.0°C

A. 0.18 torr

B. 0.9 torr

C. 1.2 torr

D. 2.6 torr

E. 2.4 torr

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A. 0.18 torr

B. 0.9 torr

C. 1.2 torr

D. **2.6 torr**

E. 2.4 torr

$$\Pi = iMRT$$

0.017g	1mol
	340g

$= 5x10^{-5}$ mol

$(5x10^{-5}\text{mol})/(0.350\text{L}) = 1.43x10^{-4}$ M

$$\Pi = (1)(1.43x10^{-4})(62.4)(293)$$

= 2.6 torr

YouTube Link to Presentation

https://youtu.be/pvzXm1hauo8

Can stop here!

Henry's Law not covered anymore. You can keep going if interested though!

Henry's Law (removed from AP)

- The solubility of a gas (S_{gas}) is directly proportional to its partial pressure, (P_{gas}).

$$S_{gas} = k_H P_{gas}$$

- k_H is called the **Henry's law constant**.

TABLE 12.4 Henry's Law Constants for Several Gases in Water at 25 °C

Gas	k_H (M/atm)
O_2	1.3×10^{-3}
N_2	6.1×10^{-4}
CO_2	3.4×10^{-2}
NH_3	5.8×10^{1}
He	3.7×10^{4}

A correct statement of Henry's law is:

A. the concentration of a gas in solution is inversely proportional to temperature.

B. the concentration of a gas in solution is directly proportional to the mole fraction of solvent.

C. the concentration of a gas in solution is independent of pressure.

D. the concentration of a gas in a solution is inversely proportional to pressure.

E. none of these

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The solubility of O_2 in water is 0.590g/L at an oxygen pressure of around 14.7 atm. What is the Henry's Law constant for O_2 (in units of mol/L·atm)?

- A) $4.01E^{-2}$
- B) $1.25E^{-3}$
- C) $7.97E^{2}$
- D) $2.71E^{-1}$
- E) None of them are within 5% of the correct answer

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B. **$1.25E^{-3}$**

C. $7.97E^{2}$

D. $2.71E^{-1}$

E. None of them are within 5% of the correct answer

S = kP

0.590g	1mol
	32g

=0.0184 mol

(0.0184 mol/L) = K (14.7atm)

K = 1.25E-3