Experiment 6

Molar Mass Determination
Using Freezing Point Depression Measurements

Freezing Point Depression: the phenomenon of a solvent's freezing point decreasing as a solute is added to the solvent

Colligative Property: when solute effects on solvent are 'independent' of nature or type of solute.

These properties are often used to determine the molar mass of a substance.

example 1 - boiling point elevation by addition of a solute to solvent.

Adding salt to water at high elevation to increase boiling point

$T_b(H_2O) \sim 100^0C$ at 1 atmosphere
at high elevation, T_b __ as P __
if add enough salt, T_b __ as [salt] __

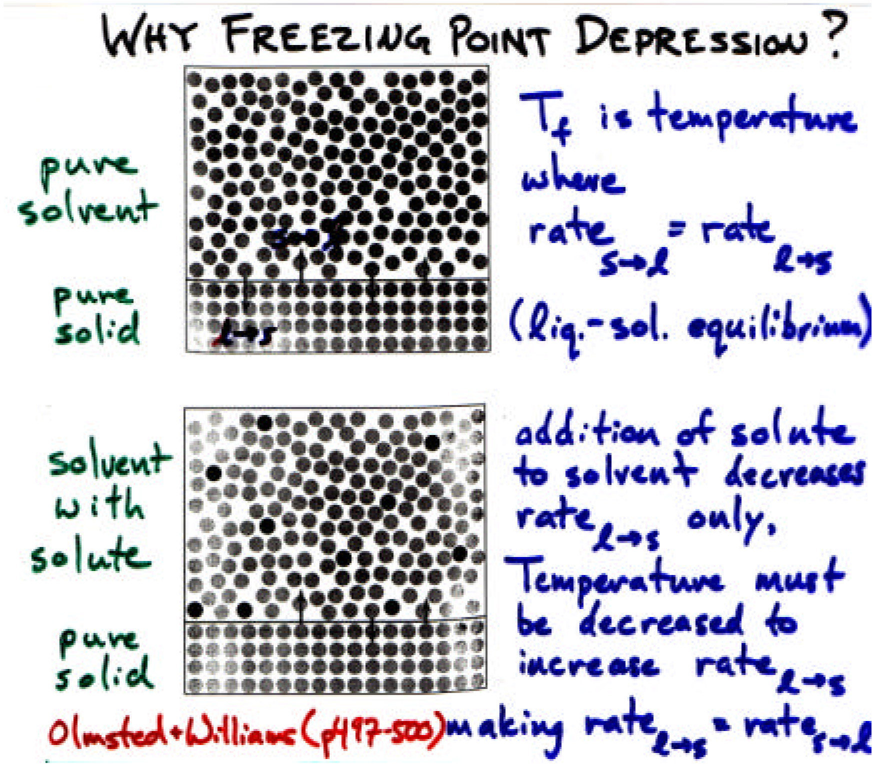
explanation: salt atoms at the surface decrease H_2O molecules probability for escape

example 2 - freezing point depression by addition of a solute to solvent.

Adding salt to ice on roads to decrease melting point

$T_f(H_2O) \sim 0^0C$ at 1 atmosphere
as add salt, T_f __ as [salt] __

explanation: solute molecules at solid/liquid interface decrease rate of solute molecule freezing, but do not affect rate of melting

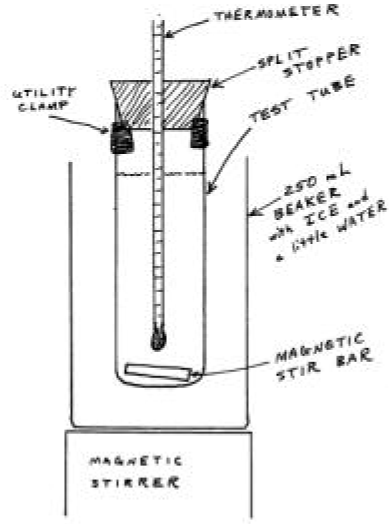


$$\text{Freezing Point Depression} \equiv \Delta T_f \equiv T_f(\text{solvent and solute}) - T_f(\textit{pure}\text{ solvent})$$

$$\Delta T_f \propto [\text{solute}]$$

$$\Delta T_f = -k_f[\text{solute}] = -k_f\left(\frac{n_{solute}}{m_{solvent[kg]}}\right) = -k_f\left(\frac{m_{solute[g]}}{MM_{solute}m_{solvent[kg]}}\right)$$ <u>The Equation of the Day</u>

Procedure



1. Clean test tube. Dry and rinse with cyclohexane.

2. Weigh empty test tube and stir bar.

3. Add ~20ml of cyclohexane and reweigh.

4. Cool in ice-water slurry. At ~13^{o}C, begin temperature-time measurements

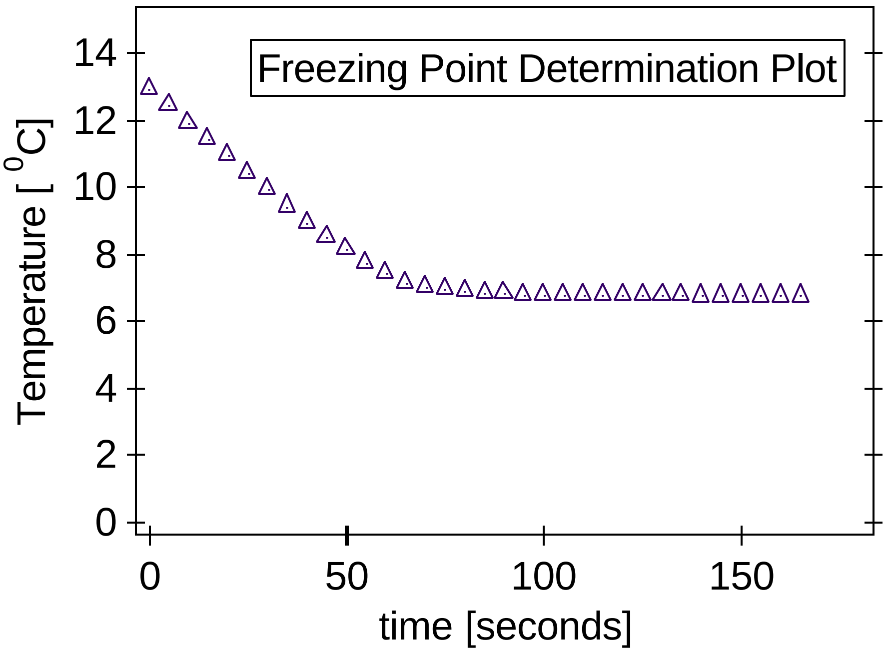
T (^{o}C)	t (seconds)

Record T every 5 seconds, until ΔT becomes small (every 10 seconds).
Take several measurements at minimal change (long time).

5. For ΔT_f = f(molality), add solute to cyclohexane
(weigh the solute on the analytical balance)
Repeat step 4.

Data Analysis

From time-Temperature data, prepare Freezing Point Determination graphs.



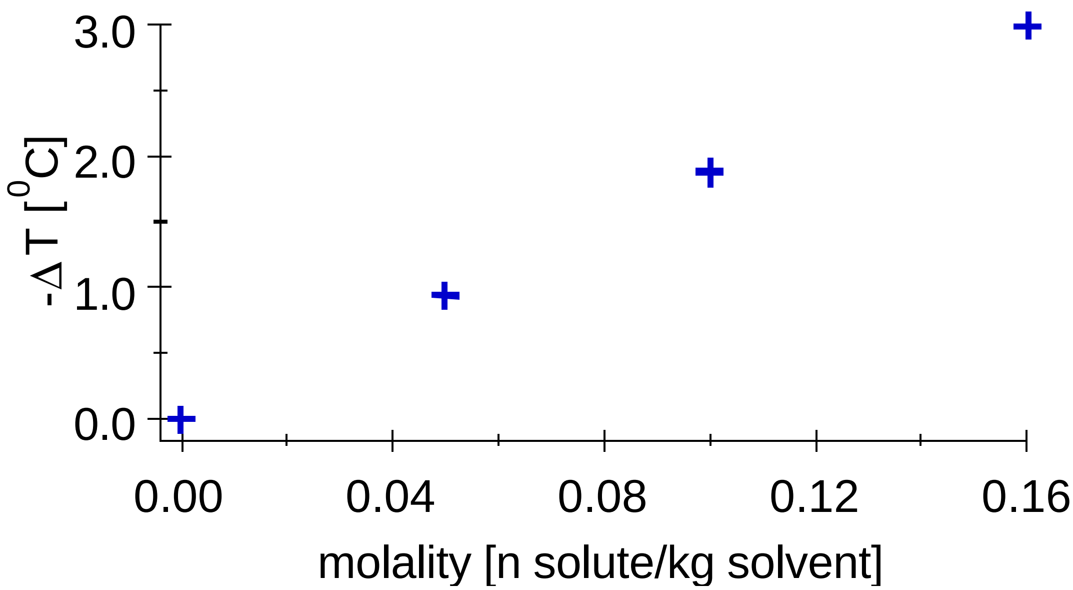
T_f = _____

Results Table prepared from analysis of Freezing Point Determination graphs.

T_f (^{o}C)	ΔT_f (^{o}C)	[solute] (molality)

Use results in the following K_f determination graph.

K_f determination for cyclohexane.
Using $\Delta T_f = -K_f$ [solute],
graph ___ versus _____
and determine slope, K_f.



slope = K_f because $-\Delta T_f = K_f$ [solute].

Determination of unknown molar mass.

$$\text{rearranging } \Delta T_f = -K_f\left(\frac{m_{\text{solute (g)}}}{MM_{\text{solute}}\, m_{\text{solvent (kg)}}}\right)$$

$$\text{gives } MM_{\text{solute}} = \frac{-K_f \cdot m_{\text{solute (g)}}}{\Delta T_f \cdot m_{\text{solvent (kg)}}}$$