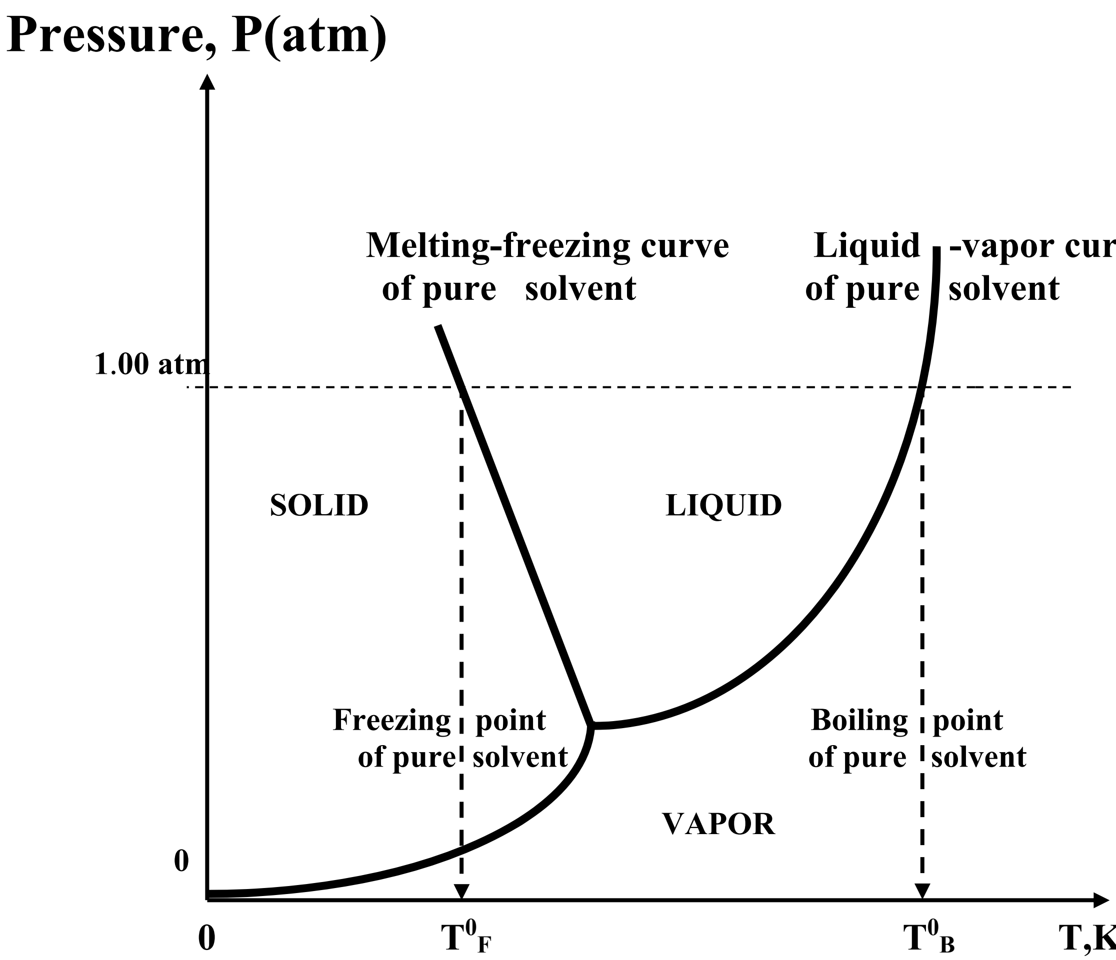
Experiment on Colligative properties

Colligative properties are the properties of solutions that depend on the TOTAL concentration of solute particles in solution.

The list of colligative properties includes:
a) lowering vapor pressure above a solution;
b) freezing temperature depression;
c) boiling temperature elevation;
d) osmotic pressure.

These properties depend only on the **TOTAL CONCENTRATION OF ALL THE SOLUTE PARTICLES IN THE SOLUTION** and completely ignore the chemical origin of solute species.

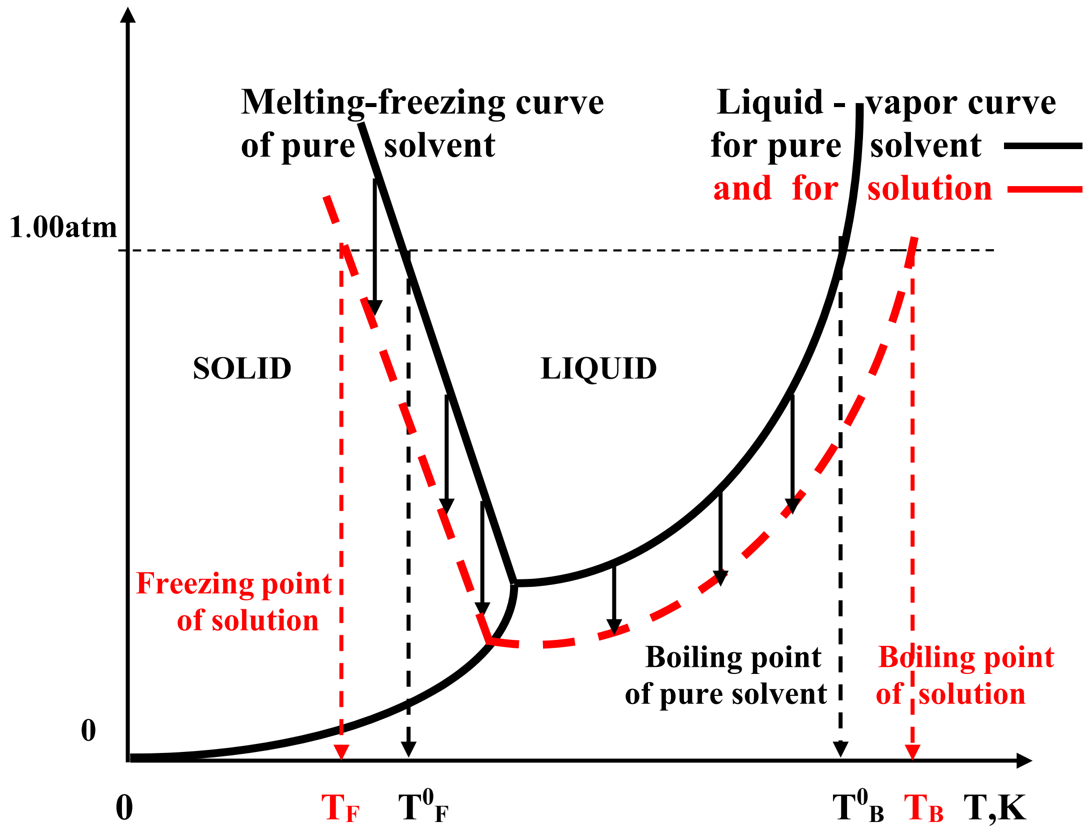
Phase diagram for a pure solvent



All colligative properties are based on the lowering of the vapor pressure above the liquid state after dissolution of solute particles in the solvent.

$P_{\text{above solution}} < P_{\text{above pure solvent}}$

Pressure, P(atm)



Freezing point depression effect in solutions: $T_F < T^0_F$

Boiling point elevation in solutions: $T_B > T^0_B$

Main formulas for colligative property effects:

$$\Delta T_{boiling} = (T_B - T^0_B) = K_b\, m\, i \qquad (1)$$

$$\Delta T_{freezing} = (T_F - T^0_F) = -K_F\, m\, i \qquad (2)$$

1. **New unit of concentration:** **Molality, *m***

Molality, *m* = #solute moles in solution / Mass of solvent (kg)

2. **K_F and K_b – are positive boiling and freezing constatnts for the solvent used in the experiment.**

3. **Don't forget:**

$$\Delta T_{boiling} = (T_B - T^0_B) > 0 \quad (\text{because } T_B > T^0_B)$$

$$\Delta T_{freezing} = (T_F - T^0_F) < 0 \quad (\text{because } T_F < T^0_F)$$

4. ***i*** **– van't Hoff factor (takes into account the dissociation of ionic solute molecules to ions)**

For non-dissociative molecules (as urea, sucrose) *i* =1. For ionic solutes *i* = number of ions the solute molecule dissociates to in solution.

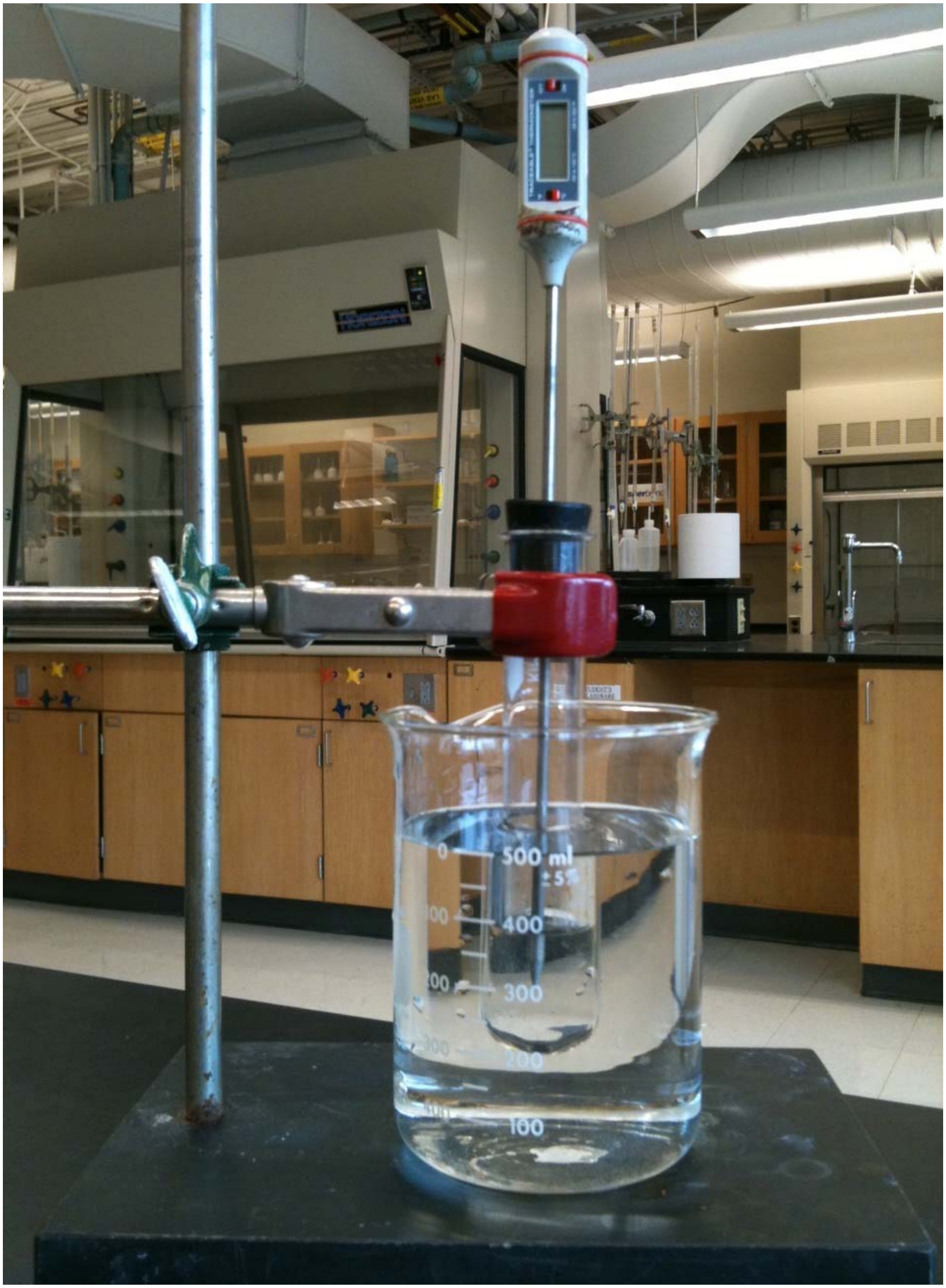
Examples:

For NaCl: i = 2

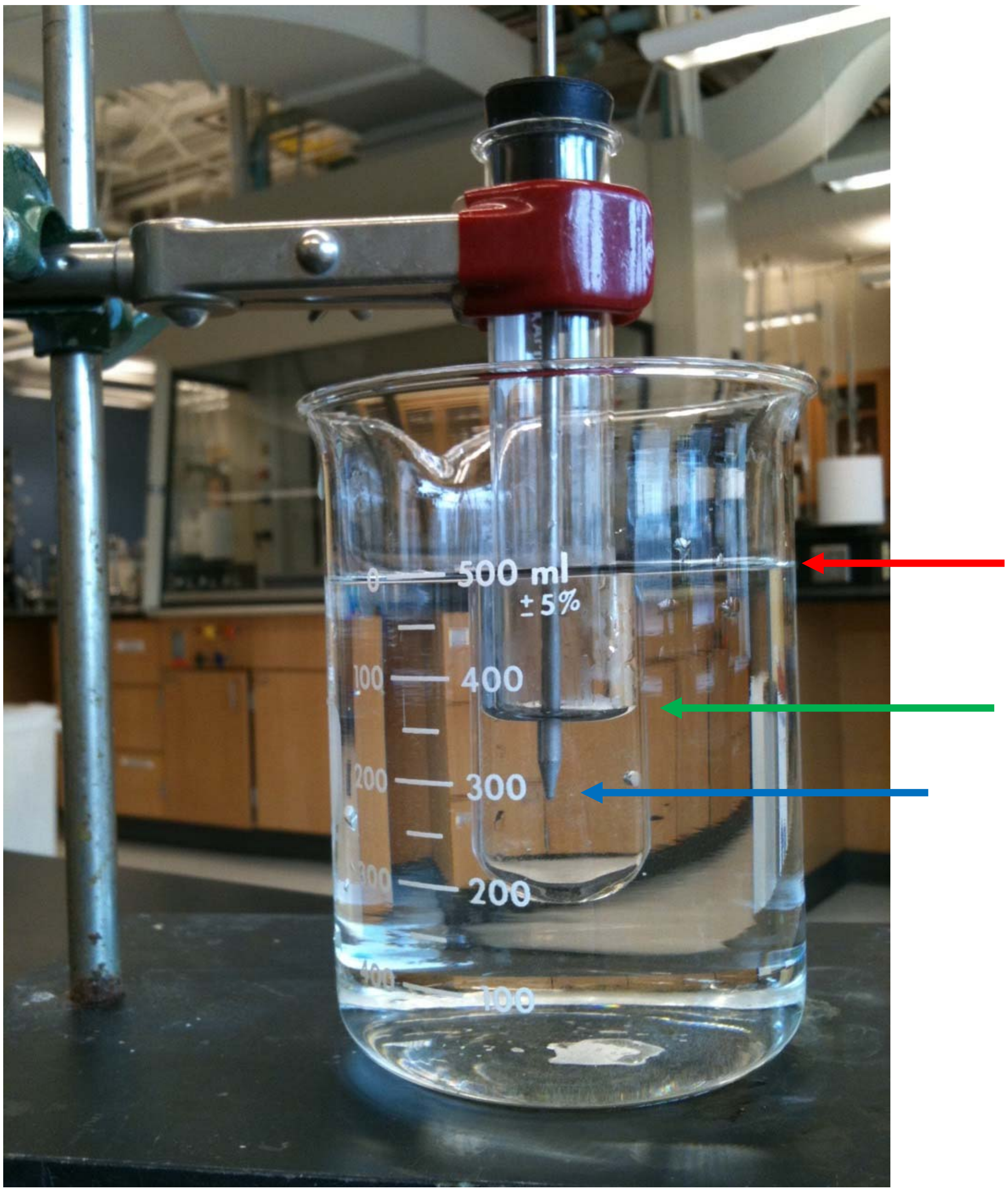
For urea, $CO(NH_2)_2$: i = 1

For $Fe(NO_3)_3$: i = 4

<u>Experimental set up</u>



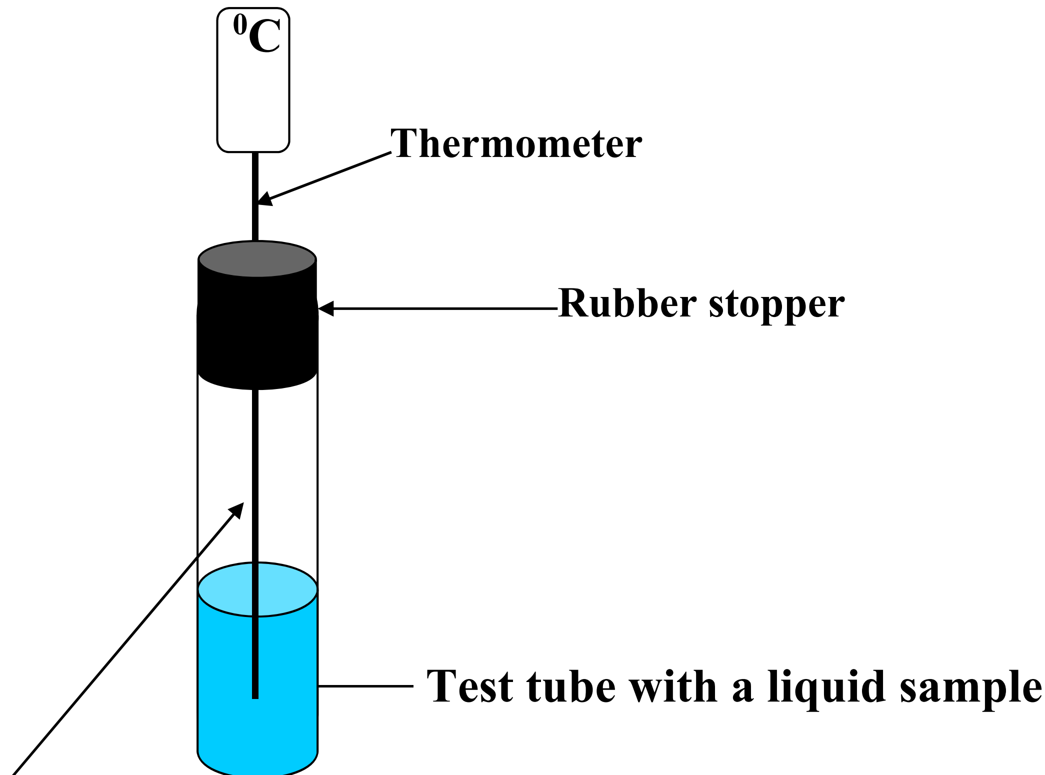
Details of the experimental set up



Three requirements for the experimental set up shown with color arrows are discussed in detail below

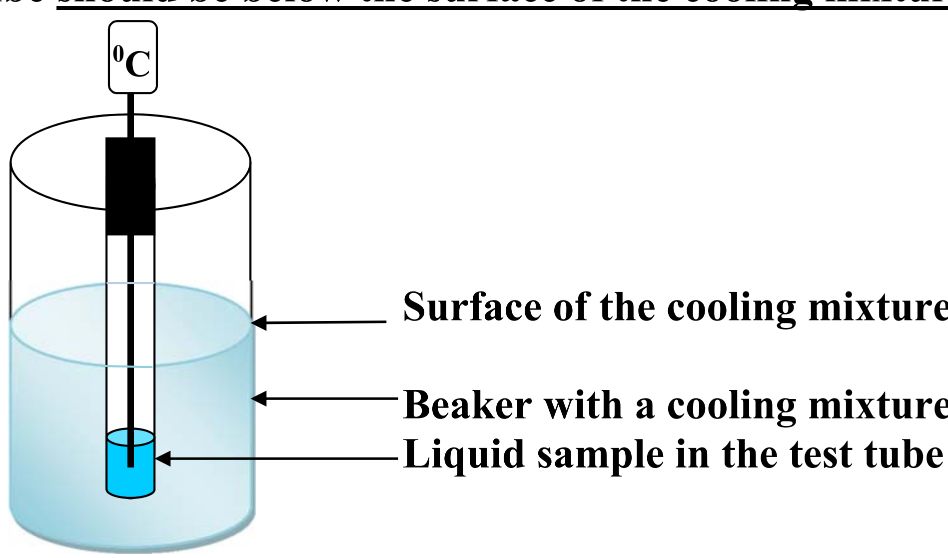
Experimental technique:

1. a) Thermometer's alignment; b) The position of the thermometer's tip in the cooling sample.

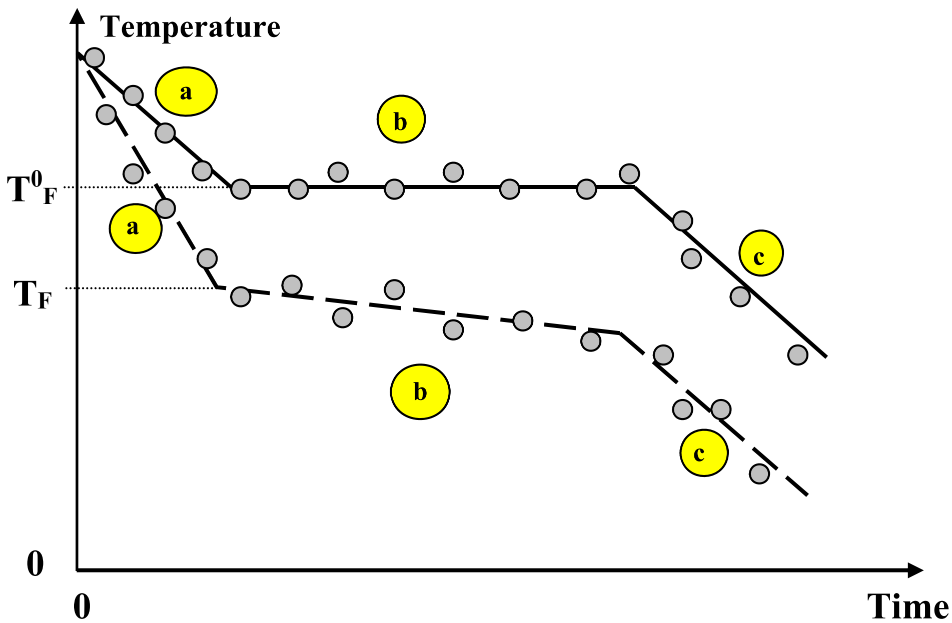


The thermometer should have a straight central alignment, with the central position of the thermometer's tip inside the liquid sample.

2. For the freezing experiment the entire liquid sample in the test tube <u>should be below the surface of the cooling mixture</u>.



Typical experimental cooling curves



Temperature versus time plots

for a pure solvent ——— ; **for a solution** — — -

○ - **Experimental data;**

T^0_F - the freezing point temperature of the pure solvent.

T_F - the freezing point temperature of the solution

a-line: Cooling liquid; b-line: Freezing liquid; c-line: Cooling ice

$$\Delta T_{freezing} = (T_F - T^0_F)$$

Determination of the unknown molar mass in experiments on freezing point depression.

$\Delta T_{freezing} = (T_F - T^0_F) = -K_F\, m\, i$

$\Delta T_{freezing}$ – will be determined in the lab experiment;

K_F is known (in ^{0}Ckg/mol);

$m = (m_{solute} / M_{solute}) / m_{solvent}$ (kg)

m_{solute} - mass of the unknown (determined in the lab)

$m_{solvent}$ - Mass of Solvent (kg)

M_{solute} - molar mass of the unknown- it is the goal of the experiment to determine it!

M_{solute}(g/mol) $= -K_F\, m_{solute} / (m_{solvent}\, \Delta T_{freezing})$