Molecular Mass Determination by Boiling Point Elevation Method

<u>Aim of experiment :</u>

To determine the molar mass, M of an unknown compound by boiling point elevation method.

When a non-volatile solute is added to a pure solvent, the resultant solution would have a higher boiling point than the pure solution. The boiling point of a solution is a colligative property and is dependent on the concentration of the solute in the solution but not on what the solute and solvent are. This boiling point can be measured by an ebullioscope.

$\mathbf{T_1 - T_2 = \Delta T = K_b . m}$
where ΔT is the magnitude of the boiling point elevation
K_b is the ebullioscopic constant of the solvent
m is the molality of the solution
Using the equation above, the molality of the solution can be determined. Consequently, the molar mass and nature of the unknown sample can be determined.

Given that the magnitude of the boiling point elevation ΔT is:
$\mathbf{T_1 - T_2 = \Delta T = K_b . m}$

where m = molality of the solution
K_b = ebullioscopic constant of solvent

$$M = \frac{\text{no. of moles (solute)}}{\text{mass of solvent (kg)}}$$

When a non-volatile solute, such as a salt, is added to a pure solvent, the boiling point of the resultant solution will be raised above that of the pure solvent. The magnitude of the boiling point elevation ΔT can be written as:

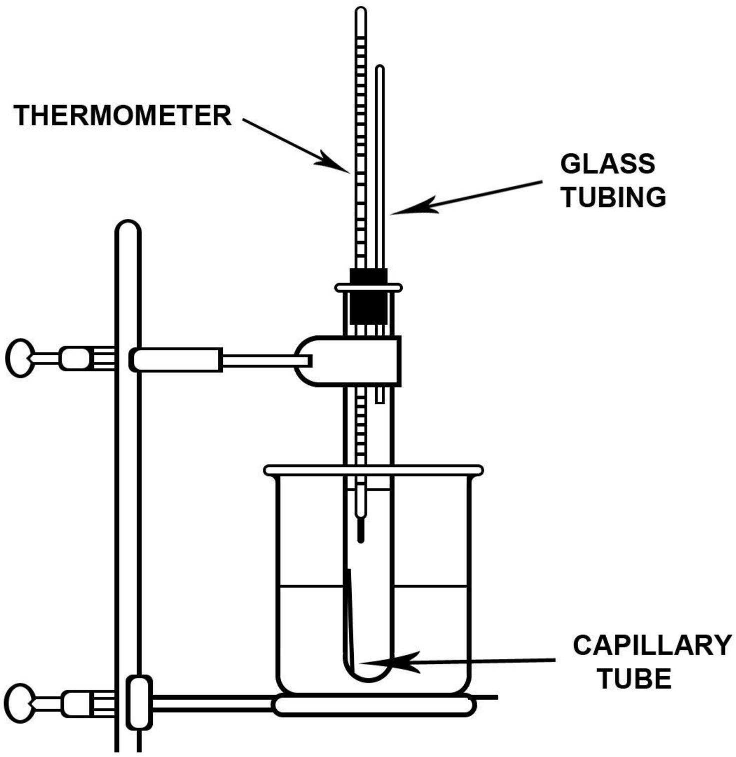
$$\Delta T = K_b \cdot m \cdot i$$

where ΔT is the magnitude of the boiling point elevation,
K_b is the ebullioscopic constant of the solvent,
m is the molality of the solution and
i is the number of particles formed by a compound in solution.(Van't Hoff factor)

Boiling point elevation is a colligative property and is dependent on the number of solute particles present and not on their chemical identity. The Van't Hoff factor, *i*, of the unknown sample is 1 – the unknown does not ionize – which is why it is excluded during calculations. From this, we can postulate that the unknown sample does not ionize in ethanol.

Furthermore, with its ability to dissolve in ethanol, a polar solvent, the unknown is either polar or ionic in nature since the hypothesis of bonding states that for dissolution to take place, the solvent-solute interaction formed has to be greater or similar in strength with the polar solvent-solvent and solute-solute interactions.

It is possible to determine the molecular mass of the unknown sample through boiling point elevation method as the unknown substance is less volatile than the ethanol solvent. This is evident as, at room temperature, ethanol is a volatile solvent while the sample is a solid.



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Experimental set-up for the determination of the molecular mass by Ebullioscopic method (CM1131 Laboratory Manual, 2010)

Experimental part :

Procedure :

1- Place a hot plate on the base of a ring stand.
2- Measure 50 mL of distilled water carefully with a 100 mL graduated cylinder and pour it into a 150 mL beaker.
3- Add several boiling chips to the water.
4- Place the beaker on the hot plate.
5- Carefully clamp a thermometer to the ring stand and position the bottom of the thermometer about one centimeter from the bottom of the beaker.
6- Turn on the hot plate and heat until the water comes to a rolling boil. The temperature should be constant.
7- Record the temperature of the boiling water as accurately as possible. Is this temperature 100 °C? Why is or is not the temperature 100 °C?
8- Turn off the hot plate and let it cool.
9- Weigh a clean dry 150 mL beaker on the Centigram balance. Remember to report all your weights to 1 mg (0.001 g).
10- Add 5 grams of unknown solute.
11- This does not need to be exactly 5.000 grams but be sure to record your exact weight.
12- Record the weight of the beaker with the solute.
13- Measure 50 mL of distilled water carefully with a 100 mL graduated cylinder and pour into the beaker with the solute.
14- Now weigh the beaker with the solute and water and record the weight. Stir the solution until all the unknown solute has dissolved.
15- Add a few boiling chips to the solution in the beaker. Place the beaker with the solution on the cool hot plate.
16- Position the bottom of the thermometer about one centimeter from the bottom of the beaker. Heat until the solution comes to a rolling boil.
17- The temperature should be constant. Record the temperature of the boiling solution as accurately as possible.

<u>Reliability of the results</u>

The molality of a solute is referred to as the number of moles of solute per kilogram of solvent. Therefore, the mass of solvent used is crucial as it is involved in the calculation of the molecular mass of the unknown sample. Any spills or vaporization causing the loss of solvent will directly cause a deviation of the empirical molecular mass from its literature value. Thus, any steps involving the transfer of ethanol has to be handled with great care, as ethanol is a volatile liquid.

The boiling tube is cooled in an ice bath before the stopper was carefully removed. This is to lower the temperature of the solution so that boiling will stop and the ethanol molecules will not escape. This allows for the accurate determination of the molality of the solution.

Also the temperature of the water bath must not be too high. If the temperature of the water bath is much higher than the boiling point of ethanol, the ethanol sample will be vaporized excessively, leading to a loss in accuracy of results.

The first bubbles observed from the capillary do not necessarily suggest boiling. It may be due to the escape of dissolved air in ethanol. A steady stream of bubbles must be observed to ascertain the boiling point.

Besides observing the steady stream of bubbles originating from the capillary, the boiling point of ethanol can be confirmed and made more reliable with other additional observations. Firstly, droplets of ethanol will condense on the internal walls of the boiling tube and thus, indicate that boiling is taking place. Also, ethanol will condense and form droplets in the glass tubing. Additionally, during boiling, the temperature of the solution remains constant. When all four phenomenon are observed, it can be safely concluded that the temperature recorded is indeed the boiling point of the solution.