



# T-05 Freezing Point Depression and Molar Mass Determination

## Collect:

- Digital thermometer
- Apparatus for simple distillation
- Apparatus for freezing point determination  
(**Dry the test-tube set in oven**)

## Prepare:

- Hot plate/magnetic stirrer
- Plastic beaker (1 L)
- Glass rod



# Objective and Technique

## Objective:

Determine the molar mass of unknown solute by freezing point depression

$$\Delta T_f = K_f \cdot m$$

## Technique:

- Operation of weighing, dispenser, and simple distillation
- Calibration of thermometer



# Calibration of Thermometer

- The temperature of phase transition of pure substance is constant

- For example:

Boiling point (bp) of  $\text{H}_2\text{O}$  at 760 mmHg is  $100\text{ }^\circ\text{C}$

Freezing point (fp) of pure cyclohexane is  $6.47\text{ }^\circ\text{C}$

- Calibration curve

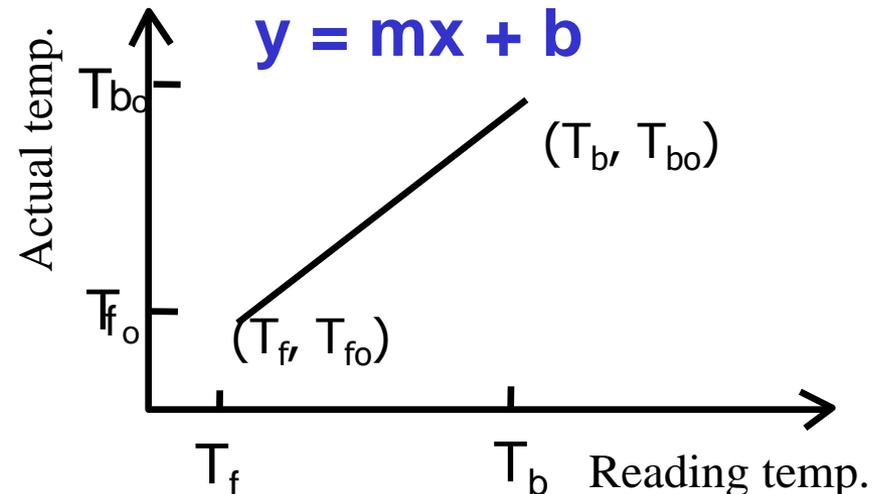
$(T_f, T_{fo})$  and  $(T_b, T_{bo})$

$$y = mx + k$$

y: actual temperature

x: reading temperature

m, k: constant





# Colligative Property: Freezing Point Depression

## ■ Freezing point depression, $\Delta T$ :

For an ideal solution

$$\Delta T_f = K_f \cdot m$$

$K_f$ : molal freezing-point depression constant

$m$ : molality (mol/kg solvent)

## ➤ Molar mass of unknown solute, $M_w$

$\Delta T$ : freezing point depression

$M_w$ : molar mass of solute

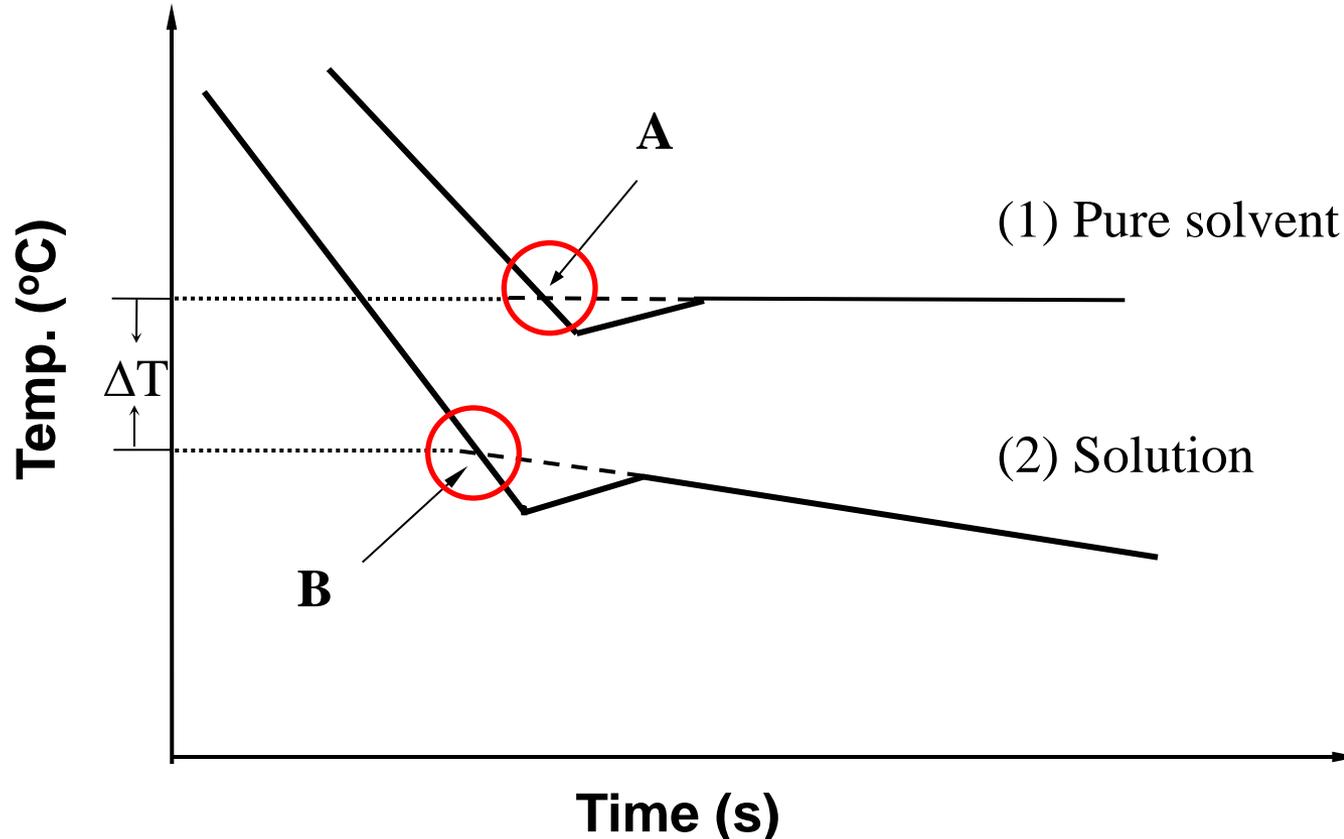
$a$ : mass of solute (g)

$b$ : mass of solvent (g)

$$M_w = \frac{K \cdot 1000 \cdot a / b}{\Delta T}$$



# Freezing Points of Pure Solvent and Solution



Cooling curves and freezing points of  
(1) pure solvent and (2) solution



# Outline of Procedures

## I. Calibration of thermometer:

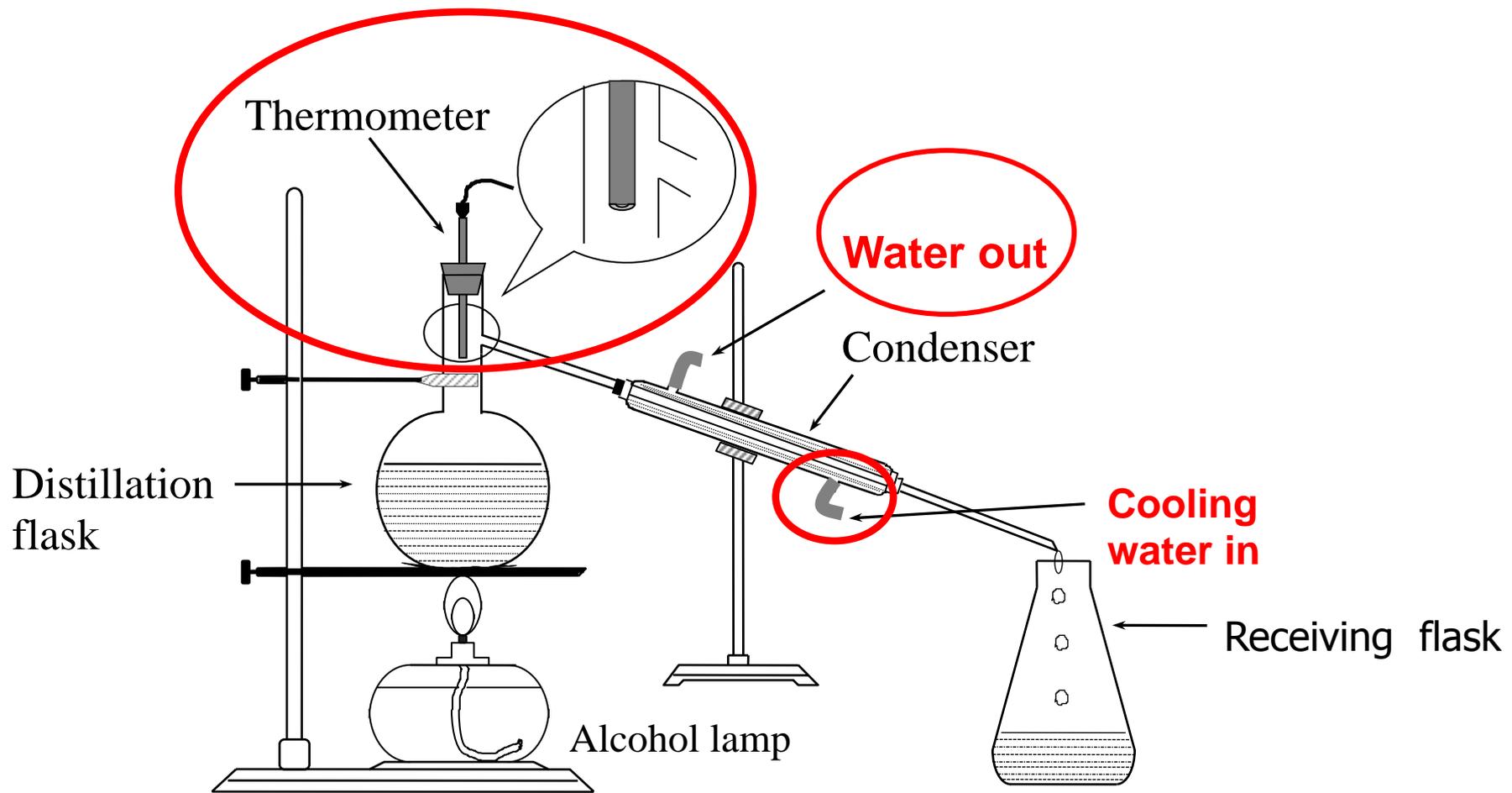
- Measure the bp of water ( $T_b$ ) and atmospheric pressure
- Calculate the actual bp of water ( $T_{bo}$ ) by Clausius-Clapeyron eqn.
- Measure the fp of cyclohexane ( $T_f$ )
- Obtain the calibration curve,  $y = mx + b$ , from ( $T_b, T_{bo}$ ) and ( $T_f, T_{fo}$ )

## II. Molar mass of unknown:

- Weigh and dissolve the unknown in cyclohexane
- Determine the fp of cyclohexane solution ( $T_x$ )
- Apply to the calibration curve and get the actual fp ( $T_{xo}$ ) of unknown cyclohexane solution
- Calculate  $\Delta T$  and molar mass of unknown

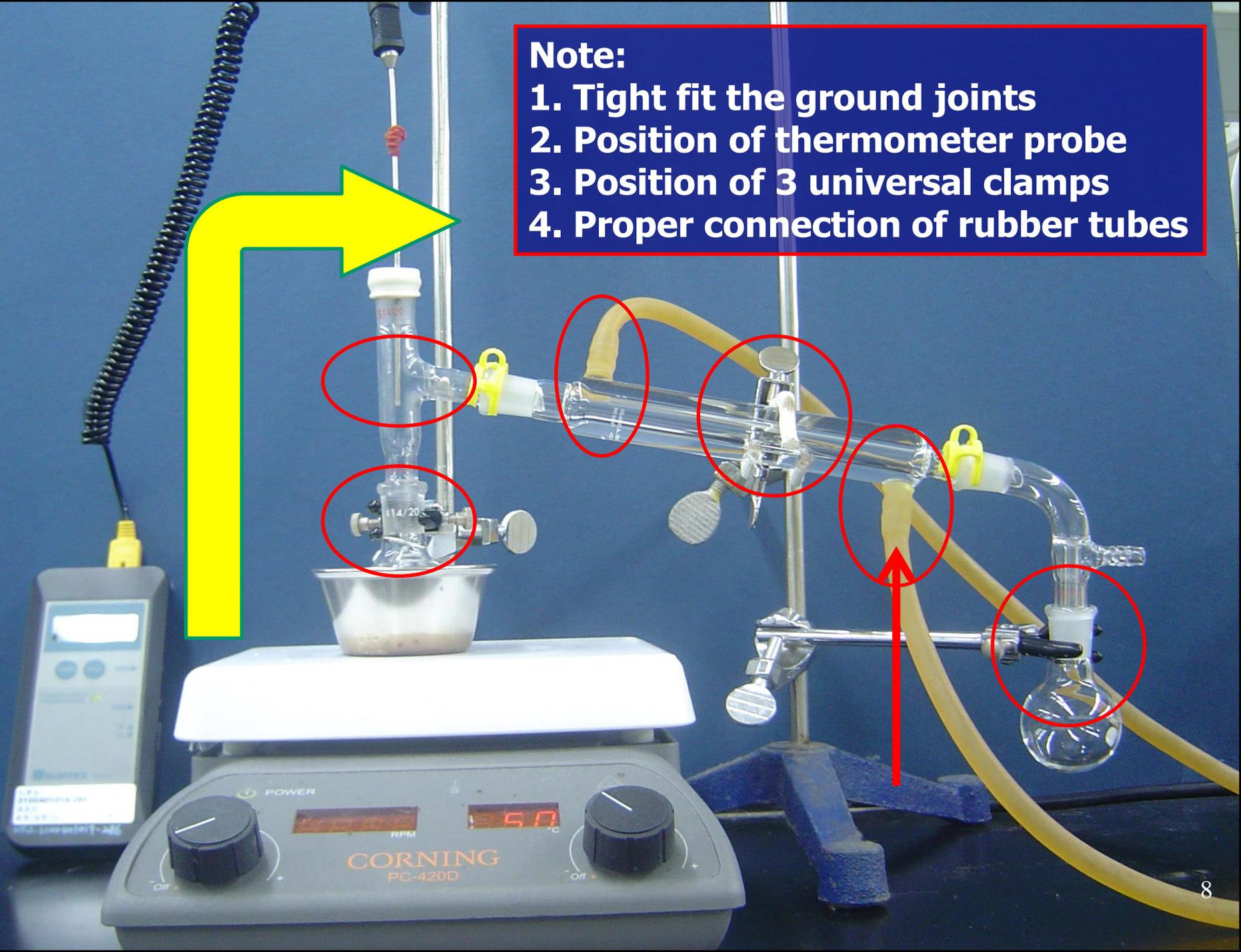


# Apparatus for Boiling-Point Determination



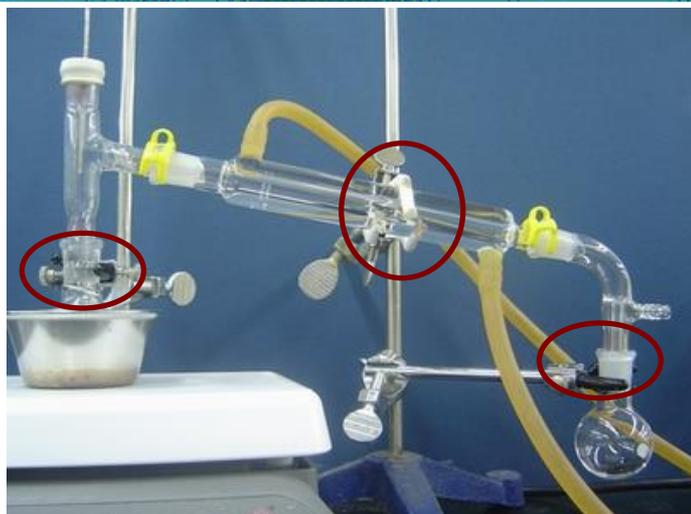
## Note:

1. Tight fit the ground joints
2. Position of thermometer probe
3. Position of 3 universal clamps
4. Proper connection of rubber tubes





# Procedure I: Boiling Point of Water



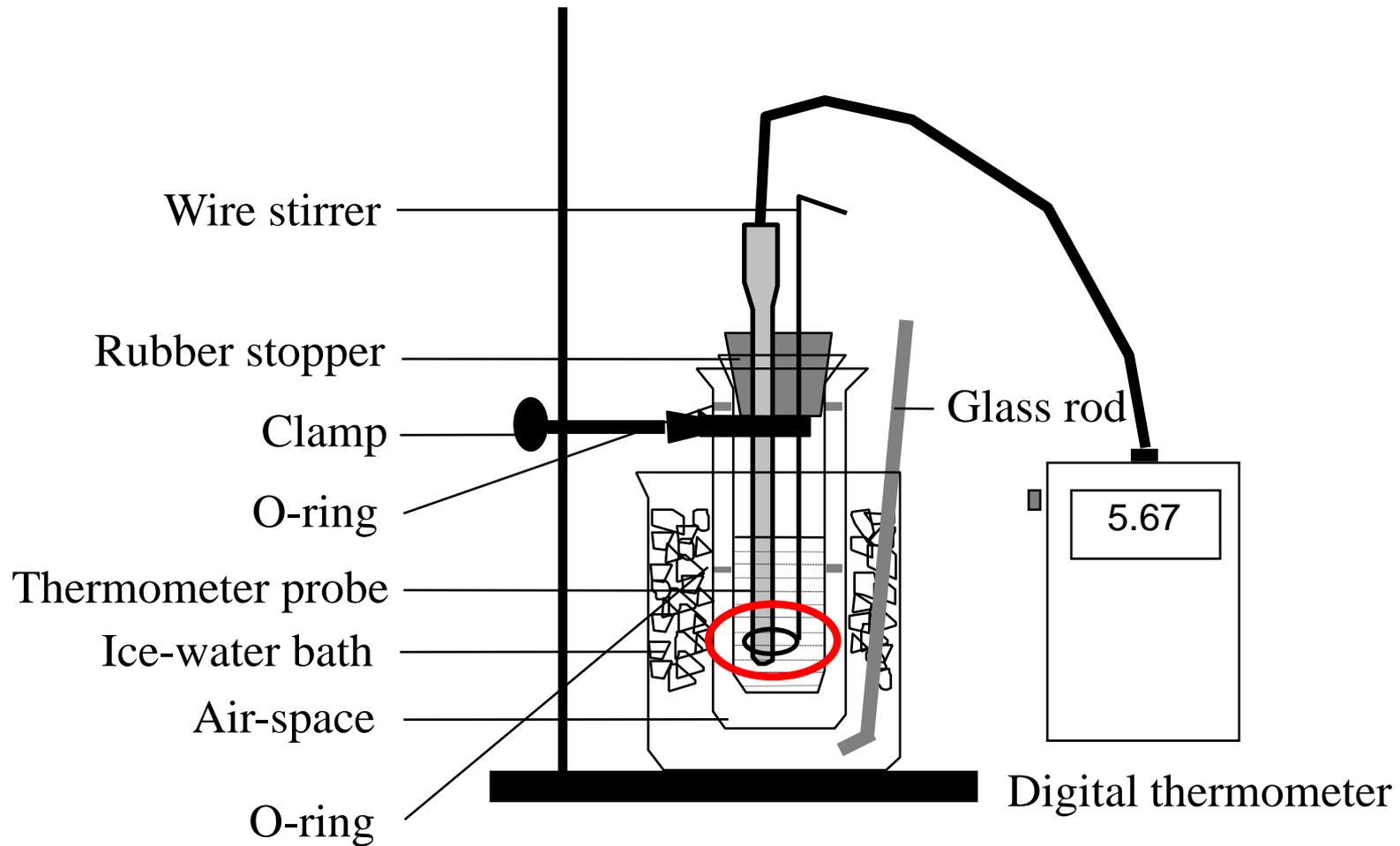
- Fill a 25 mL distillation flask with 15 mL of water
- Add 2-3 boiling chips
- Hold the neck of bottle with clamp and sit in the sand bath
- Set up the apparatus as shown

- Place the thermometer probe in proper position

- Add sea sand
- Turn on the hot plate to heat the solution
- Record the boiling temp. of thermometer



# Apparatus for Freezing Point Determination





# Procedure II: Freezing Point of $C_6H_{12}$



- Clean and dry the inner test tube in oven
- Take the weight of test tube after cooling
- Record the weight



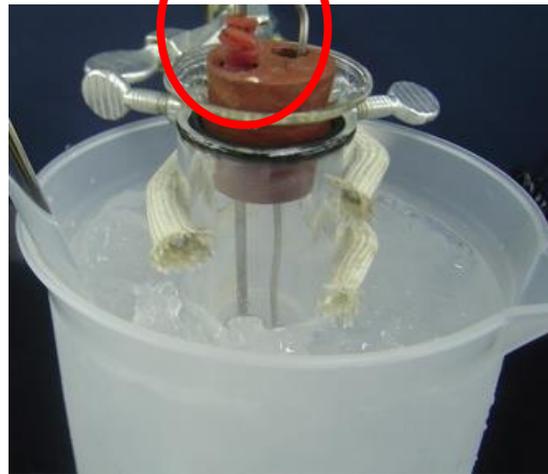
- Fill in ca. 13 mL  $C_6H_{12}$  from dispenser to the test tube
- Measure the wt. of test tube with  $C_6H_{12}$
- Get the wt. of  $C_6H_{12}$



- Fix and separate the inner and outer test tubes with O-rings
- Hold the test tubes with clamp



# Procedure II: Freezing Point of $C_6H_{12}$



- Adjust the thermometer probe in the center of liquid
- Set the wire stirrer around the probe

- Fill the 1 L-plastic beaker with 2/3 volume of ice and some water
- Place the freezing point determination apparatus in ice-water bath

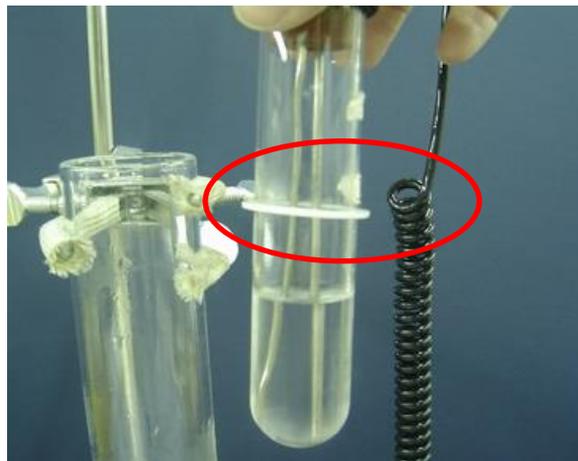
- Stir the liquid by sliding the wire stirrer up and down
- Record the temp. of  $C_6H_{12}$  every 15 s. when temp. drop to  $10\text{ }^{\circ}\text{C}$
- Stop reading when temp. remains unchanged for 2 min.



# Procedure III: Freezing Point of Unknown Solution



- Weigh ca. 0.1 g unknown and record the precise wt.
- Add the unknown to the previous  $C_6H_{12}$



- Mix the solution with wire stirrer to dissolve the unknown



- Refill the ice-water bath with more ice
- Reposition the apparatus
- Take and record the temp. of solution every 15 s.
- Stop reading when the drop in temp. slows down markedly, continue reading for 2 min.



# Notice

- Every group needs to determine  $M_w$  of one unknown solute
- Digital thermometer is expensive and operate with care
- Set up the distillation apparatus properly
- Cyclohexane is a volatile, flammable organic solvent and need to be recycled after use
- Separate the inner and outer test tubes with O-ring to keep the air space
- At the end of lab-work
  - Recycle sea sand, boiling chips, and  $C_6H_{12}$
  - Turning off the thermometer
  - Hand in stopwatch to part-time TA