# Physics 524, Unit 5: Cooling and Thermal Management

## Lab Experiment

## The latent heat of melting (fusion) of ice

# Theory, Definition

## Introduction

The Latent heat of melting ***L*** (J/kg), also known as the latent heat (or enthalpy) of fusion, is the heat energy needed to supply to or take away from a substance in order for it to change phase from solid to liquid or from liquid to solid, respectively. In this experiment, we measure the latent heat of melting of water by melting ice in warm water, and measuring the temperature change.

In a non-phase-changing situation the heat transferred to the fluid, ***Q***, (J) is quantified by the relationship:

$$Q = c \cdot m \cdot \Delta T \qquad \text{Eq. (1)}$$

where $c$ is the specific heat capacity (expressed in units of J/kg/K) of a sample of a substance of mass $m$ (kg) and $\Delta T$ (K) is the measured change in temperature of the substance.

However when there is a change of phase, there is no change in temperature of the phase changing component, so the quantity of latent heat $L$ (expressed in units of J/kg) of melting/fusion (or for that matter evaporation/condensation) must be introduced, so that:

$$Q = m \cdot L \qquad \text{Eq. (2)}$$

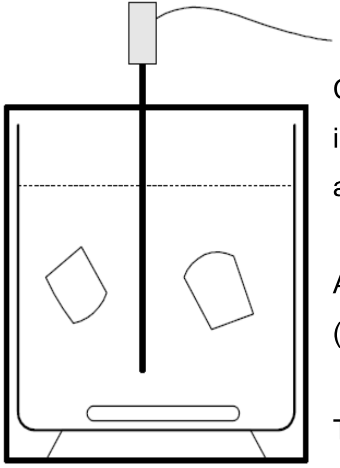
In this experiment we will measure the latent heat of melting of ice $\boldsymbol{L}$ by considering a mass $\boldsymbol{M_i}$ of ice completely melting in a mass $\boldsymbol{m_w}$ of warm water. The heat taken from the warm water and the calorimeter that holds it (a glass beaker held in an insulating foam container - only the mass of the beaker (and magnetic stirrer, if used) needs to be considered in the calculation of calorimeter mass, as we shall see later) - must be equal to the heat gained by the ice and the additional water that is melted from the ice. This leads to the following energy equivalence equation:

$$M_i.L + M_i.c_w\,(t_2 - t_0) = (K_k + m_w c_w)\,(t_1 - t_2) \qquad \text{Eq. (3)}$$

where $\boldsymbol{M_i}$ is the mass of the ice; $\boldsymbol{m_w}$ is the mass of warm water; $\boldsymbol{c_w}$ is the specific heat capacity of water; $\boldsymbol{K_k}$ is the heat capacity (J/kg) of the calorimeter (to be calculated from its measured mass); $\boldsymbol{t_0}$ is the initial temperature of the ice (assumed to be 0°C), $\boldsymbol{t_1}$ the initial temperature of the warm water and calorimeter (around 40°C: to be measured), and $\boldsymbol{t_2}$ the final temperature of the entire system, after all ice has melted.

The right hand side of Eq. (3) therefore accounts for the heat lost by the warm water and the calorimeter, while the left hand side accounts for the heat gained (absorbed) by the melting ice and the warming of its own meltwater from 0˚C to the temperature $t_2$. (This is obviously simplistic, ignoring heat ingress/egress from/to the environment.)

**Figure 1**



Calorimeter composed of a plastic insulating case, glass beaker and agitator.

Agitation – occasional gentle shakes (preferred)

Temperature sensor

## Equations

From Eq. (3) in the introduction, we can develop an equation to find $L$:

$$L = \frac{(K_k + \ m_w c_w).(t_1 - t_2)}{M_i} - c_w.(t_2 - t_0) \qquad \text{Eq. (4)}$$

All of the above quantities are either measured or known, so this is the only necessary equation for this experiment.

## Measurement Procedure

The mass of the empty glass beaker ($m_{glass}$) is first measured to determine its heat capacity using the specific heat capacity of glass ($c_{glass}$), which is given. Water is preheated to around 40°C and poured into the calorimeter, which is weighed again and recorded as ‘mass of calorimeter with water ($m_A$). The mass of the water $m_w$ in the calorimeter is then computed as the difference between $m_A$ and $m_{glass}$. The temperature probe is inserted into the water and calorimeter insulating lid is fitted. After the temperature of the warm water $t_1$ is measured, ice is added to the calorimeter, and the rest of the measurements are allowed to proceed without intrusion other than occasional agitation of the insulating box by hand to equilibrate the temperature through the water volume.

After the ice is melted, the final temperature of the water $t_2$ and the final mass of water + beaker $m_B$ are measured. The mass of ice added to the beaker $M_i$ is computed from the difference between $m_A$ and $m_B$.

Example of a beaker wrapped by insulating material:

## Error Analysis

There are many factors affecting the precision of the measurement that are difficult to describe or quantify. In particular heat ingress/egress from/to the environment are ignored. Also the effect of heat capacity if the temperature sensor, and its own heat capacity are also ignored. Therefore these measurements are probably reliable to about 10%.

# Latent Heat of Melting Data Sheet

Mass of the empty glass beaker: $m_{\text{glass}}$ = ____________

Heat capacity of the beaker: $K_k = c_{glass}\, m_{\text{glass}}$ = _____________
($c_{glass}$ = 780 J/kg/K)

Prepare insulating material to wrap around the beaker and an insulating lid.

Pour water of ~40°C to the beaker. Mass of beaker + warm water:
$m_A$= ____________.

Wrap the beaker with the insulating material and then measure the initial temperature of the warm water:
$t_1$ = ____________

Add ice to the calorimeter; close the insulating lid; stir the system; wait for ice to melt.

Final temperature: $t_2$ = ___________.

Final mass of the beaker + water: $m_B$ = _______________.

Mass of warm water: $m_w = m_A - m_{\text{glass}}$ = _____________

Mass of ice added: $M_i = m_B - m_A$ = ______________

Calculate the latent heat of fusion ($c_w$ = 4180 J/kg/K, $t_0$ = 0°C):

$$L = \frac{(K_k + m_w c_w).(t_1 - t_2)}{M_i} - c_w.(t_2 - t_0)$$

$L$ = _______________

Expected value of $L$ = 333.6 kJ/kg.

Fractional difference between the measured and expected $L$ = _______________.