PHY2048L Lab 5 Heat Fusion

Latent Heat Of Fusion

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1. Introduction

The purpose of this experiment was to determine two key thermal properties of a phase-changing material (PCM): (1) its melting temperature, and (2) its latent heat of fusion. These quantities were obtained by heating a PCM headband in a controlled water bath while monitoring temperature changes over time. During the melting period, the PCM maintains a nearly constant temperature, allowing the melting point to be measured directly.

After establishing the melting temperature (Part 1 of the lab), the experiment proceeded to quantify the thermal energy absorbed by the PCM during melting by analyzing the water's temperature rise under a known heater power. This allowed for determining the total heat input Q, the heat absorbed by the water, and finally the latent heat of fusion using:

$$L_f = \frac{Q - m_w c_w \Delta T_w}{m_{\text{PCM}}}.$$

Thermal energy, internal energy, work, and power all play central roles in this lab. Thermal energy refers to the internal kinetic and potential energy of molecules; work describes energy transfer; and power quantifies the rate of energy delivery. The concepts of specific heat, heat of fusion, and phase changes were reviewed using the Part 1 lecture slides before data collection.

On Monday, November 24, 2025, the lab section re-measured the PCM headband under improved conditions. The heating power of 270 W (provided by another lab section) was used to calculate total heat input from $Q = P\Delta t$. A thermometer was used to record water temperature every fixed time interval while the PCM melted, and mass measurements for both the PCM and the surrounding water were taken for later calculations. This report presents the theoretical background, experimental setup, calculations, and conclusions for determining the latent heat of fusion of the PCM.

2. Principles

Thermal energy is the internal energy associated with the random motion and interactions of atoms and molecules. This internal energy consists of kinetic contributions (translational, rotational, vibrational motion) and potential contributions arising from intermolecular forces, expressed as:

$$E_{\text{internal}} = E_K + E_P.$$

When a substance absorbs heat, its internal energy increases, which may manifest as a temperature increase or a phase transition.

Heat, Work, and Power. Heat Q is the transfer of thermal energy between systems due to temperature differences. Work corresponds to energy transfer resulting from forces acting over distances. Power is the rate of energy transfer, defined as:

$$P = \frac{Q}{\Delta t}.$$

In this experiment, knowing the heater power (270 W) allowed for computing the total thermal energy delivered during melting.

Specific Heat. The specific heat capacity c of a substance quantifies the energy required to raise the temperature of 1 kg by 1°C. Heat transferred to water in this experiment is described by:

$$Q_w = m_w c_w \Delta T_w.$$

Latent Heat and Phase Change. During phase transitions, temperature remains constant even as heat continues to be absorbed. This energy does not raise temperature but instead alters the microscopic structure, such as breaking intermolecular bonds during melting. The latent heat of fusion L_f is the energy required to melt 1 kg of material:

$$Q_{\text{melt}} = m_{\text{PCM}} L_f.$$

This lab focuses on determining L_f for the PCM headband by analyzing how much energy remains after accounting for the water's temperature rise.

The theoretical concepts described above were directly relevant to analyzing the data collected during Part 1 of the lab assignment and performing the calculations completed on November 24, 2025.

3. Experimental Setup

The experiment involved heating a PCM headband immersed in a beaker of water placed on an electric stovetop set to level 3. A digital scale was used to measure the mass of the PCM and the water. A thermometer (initially two or three thermometers) recorded temperature readings at fixed intervals while the PCM melted.

Early attempts overheated the PCM too quickly due to excessive heat transfer, resulting in unusable temperature data. The procedure was adjusted by reducing the number of thermometers, lengthening the measurement interval, and stabilizing the heating rate. These improvements were implemented in the repeated trial conducted on Monday, November 24, 2025.

The final procedure consisted of:

- Measuring the mass of the PCM: **193.9 g = 0.1939 kg**.

- Measuring the mass of the surrounding water: **489.9 g = 0.4899 kg**.

- Recording the water's initial and final temperatures.

- Applying a heater with known power: 270 W.

- Recording temperature every fixed time interval while the PCM melted at a constant temperature plateau.

- Measuring the heating duration: **587.2 seconds**.

This setup ensures sufficient heat transfer to melt the PCM while keeping the melting interval long enough to observe the temperature plateau and accurately measure the thermal energy delivered.

4. Results

The recorded measurements and calculated results are summarized below. All computational steps were performed using the Excel sheet created during lab.

- Mass of PCM: 0.1939 kg

- Mass of water: 0.4899 kg

- Temperature change of water: $\Delta T_w = 50.9°C$

- Specific heat of water: $c_w = 4.19 \times 10^3 \, \text{J}/(\text{kg} \, °\text{C})$

- Heater power: $P = 270 \, \text{W}$

- Heating time: $\Delta t = 587.2 \, \text{s}$

The total thermal energy delivered by the heater was:

$$Q = P\Delta t = 270 \times 587.2 = 1.58544 \times 10^5 \, \text{J}.$$

The thermal energy absorbed by the water was:

$$Q_w = m_w c_w \Delta T_w = 0.4899 \times (4.19 \times 10^3) \times 50.9 = 1.04481 \times 10^5 \, \text{J}.$$

The remaining energy was absorbed by the PCM during melting:

$$Q_{\text{melt}} = Q - Q_w = 5.4063 \times 10^4 \, \text{J}.$$

Finally, the latent heat of fusion for the PCM was calculated as:

$$L_f = \frac{Q_{\text{melt}}}{m_{\text{PCM}}} = \frac{5.4063 \times 10^4}{0.1939} \approx 2.79 \times 10^5 \, \text{J/kg}.$$

These values match the Excel screenshots and handwritten calculations performed during lab.

5. Discussion

The melting temperature plateau observed during data collection confirmed that the PCM undergoes a phase transition at a nearly constant temperature, consistent with the theoretical behavior of phase-changing materials. The calculated latent heat of fusion, approximately 2.8×10^5 J/kg, is comparable in magnitude to that of water (3.33×10^5 J/kg), suggesting the PCM behaves similarly to water-based materials often used in thermal regulation devices.

One source of experimental error includes heat loss to the surrounding air, which reduces the effective thermal energy reaching the PCM and water. Additionally, thermometer lag and inconsistent stirring may have influenced temperature uniformity. Variations in stovetop output and heat conduction through the container also contributed to uncertainty. Despite these limitations, the overall results were consistent and physically reasonable.

The first trial produced unreliable data due to excessively rapid heating, underscoring the importance of controlled thermal input. Adjustments in the second trial resolved this issue and allowed for more accurate observation of the phase-change plateau and resulting calculations.
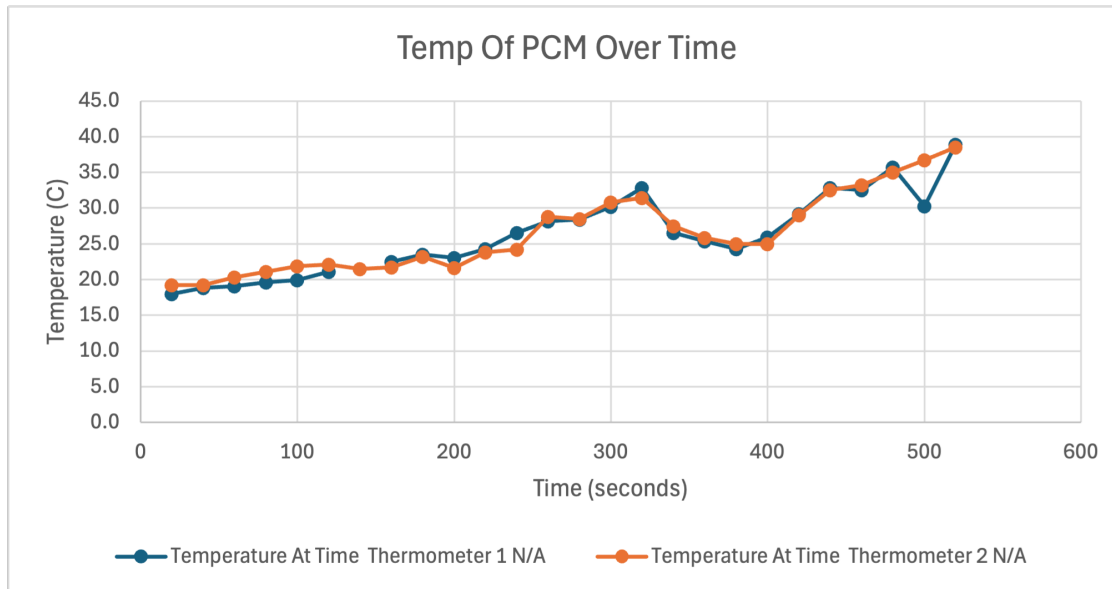

Figure 1: Temperature of PCM over time during the initial unsuccessful trial. Rapid heating prevented a stable melting plateau from forming.

6. Conclusion

This experiment successfully determined the melting temperature and latent heat of fusion of a PCM headband. By measuring the mass of the PCM, recording the temperature change of the surrounding water, and calculating total heat input from the heater power and heating duration, the latent heat of fusion was found to be approximately:

$$L_f \approx 2.8 \times 10^5 \text{ J/kg}.$$

The results are consistent with expected values for commercially used PCM materials. The experiment provided practical experience with heat transfer, energy conservation, and phase-change physics, while also demonstrating the importance of controlled heating conditions and precise temperature measurements.

Disclaimer: Portions of this report were refined with the assistance of AI-based proofreading tools and the LaTeX online PDF guide. The analysis, calculations, and final interpretations remain entirely my own work.

Figure 1 illustrates the temperature evolution of the PCM during the initial experimental attempt. As shown, the PCM temperature increased too rapidly, preventing the formation of a clearly defined melting plateau. Instead of maintaining a constant temperature during the phase transition—as expected for a material undergoing fusion—the graph shows continuous temperature rise with noticeable fluctuations between the two thermometers. These inconsistencies indicate that the heating rate was too high, causing the PCM to melt faster than the experiment could reasonably measure. This failure informed the adjustments implemented on November 24, 2025, where the heating conditions were stabilized, the number of thermometers was reduced, and the measurement interval was increased. The refined approach produced smoother temperature behavior and allowed for more reliable analysis in the successful trial.