Core practical 13: Determine a value for the specific latent heat of ice

Objective

- To determine the specific latent heat of ice by measuring the drop in temperature of water containing melting ice

Safety	Specification links
• Students are assessed against CPAC 3b and the evidence will in part be their risk assessment and also the result of observation and some comments in their report.	• Practical techniques 1, 2, 3 • CPAC 2b, 2d, 3b, 4b

Procedure	Notes on procedure
1. Place the ice (approximately 50 g) in the funnel and allow the ice to warm up to 0 °C. You will need to catch the melted ice in a container. 2. Determine the mass m_0 of the empty and dry beaker. It will be easier if you use grams as the unit of mass throughout this practical. 3. Put approximately 100 cm^3 of water in the beaker and determine the mass m_1 of the beaker, plus the water. Measure the temperature θ_1 of the water. 4. Add approximately 20 g of ice at 0 °C to the beaker. Stir until the ice melts. 5. Record the lowest temperature θ_2 reached by the ice water mixture. This will occur as the last of the ice melts. 6. Determine the mass m_2 of the beaker, plus water, plus melted ice.	• This experiment requires good technique to obtain an accurate final value. The ice should be crushed finely so that it melts quickly, and there should be water dripping from the funnel to show that it is close to 0 °C. • It will help if students can be shown what 20 g of ice looks like, as adding too much ice increases the heat gained from the room. • This method has the merit of requiring little apparatus, yet produces a reasonable value. However, there are more sophisticated ways to determine a specific latent heat, if the apparatus is available for any other method. • CPAC 2b will need an observation alongside students' laboratory notebooks, and CPAC 4b and CPAC 3b should be evidenced in their laboratory notebook. • If a student needs an opportunity to meet CPAC 2d, this can come from observation in the laboratory and what they write in Q4 of their analysis.

Answers to questions

1. The uncertainty in temperature measurement is probably 0.5 °C. The uncertainty in a temperature difference is therefore 1 °C, since two temperatures are subtracted.
2. The method does not account for any heat the ice would absorb in rising to 0 °C.
3. As the ice and water mixture is below room temperature, it is absorbing heat from the room. If this time is minimised, then the error introduced by the heat gained is reduced.
4. Since there is more heat entering the ice on the left hand side of the heat balance equation, the value for L will be too small. This is because the heat entering means that θ_2 is not as low as it might be (and $m_w > m_i$).

Sample data

Initial temperature of water = θ_1 = 23 °C

Final temperature of water = θ_2 = 7 °C

Mass of beaker = m_0 = 100.3 g

Mass of beaker plus water = m_1 = 202.4 g

Mass of water = m_w = 102.1 g

Mass of beaker plus water and ice = 224.7 g

Mass of ice = m_i = 22.3 g

Specific heat capacity of water c = 4.2 J g^{-1} °C^{-1}

Heat balance:

$$102.1 \times 4.2 \times (23 - 7) = (22.3 \times L) + 22.3 \times 4.2 \times (7 - 0)$$

$$6861 = (22.3 \times L) + 656$$

$$L = \frac{6205}{22.3} = 278 \text{ J g}^{-1}$$

The accepted value is 336 J g^{-1}. This gives a percentage difference of 17%.

These data are for a beaker without lagging.

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Safety

- You are assessed against CPAC 3b and should produce an appropriate risk assessment.

All the maths you need

- Recognise and make use of appropriate units in calculations.
- Use ratios, fractions and percentages.
- Use an appropriate number of significant figures.
- Identify uncertainties in measurements and use simple techniques to determine uncertainty when data are combined by addition, subtraction, multiplication, division and raising to powers.
- Change the subject of an equation, including non-linear equations.
- Substitute numerical values into algebraic equations using appropriate units for physical quantities.

Equipment

- funnel, supported by retort stand
- approximately 50 g of crushed ice
- container to catch melted ice
- 250 cm^3 beaker
- thermometer and stirrer
- access to mass balance

Procedure

1. Place the ice in the funnel and allow the ice to warm up to 0 °C. You will need to catch the melted ice in a container.
2. Determine the mass m_0 of the empty and dry beaker. It will be easier if you use grams as the unit of mass throughout this practical.
3. Put approximately 100 cm^3 of water in the beaker and determine the mass m_1 of the beaker, plus the water. Measure the temperature θ_1 of the water.
4. Add approximately 20 g of ice at 0 °C to the beaker. Stir until the ice melts.
5. Record the lowest temperature θ_2 reached by the ice and water mixture. This will occur as the last of the ice melts.
6. Determine the mass m_2 of the beaker, plus water, plus melted ice.

Analysis of results

1. Calculate the mass m_w of the water, where $m_w = m_1 - m_0$.
2. Calculate the mass m_i of the ice, where $m_i = m_2 - m_1$
3. Assume that the temperature of the ice when it was added to the water was 0 °C. The specific heat capacity c of water is 4.20 J g^{-1} $°C^{-1}$.

   In order to calculate the specific latent heat L of ice, consider the heat balance where:

   heat lost by cooling water = heat gained by ice and warming melted ice
   $m_w \times c \times (\theta_1 - \theta_2) = (m_i \times L) + (m_i \times c \times (\theta_2 - 0))$
   Calculate a value for L.
4. Discuss how successful you were when measuring a value for L, and describe how you might improve your method.

Learning tip
● When quantities are subtracted, the uncertainties have a much larger effect.

Questions
1. Consider the uncertainty in your measurement of temperature and comment on the outcome of your experiment.
2. Explain why it is important that the ice is melting before it is put into the beaker.
3. Explain why it is important that the ice is crushed so that it melts quickly.
4. Explain the effect of any heat gained from the room on your value for *L*.

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Objective	Safety
• To determine the specific latent heat of ice by measuring the drop in temperature of water containing melting ice	• Ice might need careful handling if it has just been removed from a freezer.
Equipment per student/group	**Notes on equipment**
funnel, supported by retort stand	
approximately 50 g of crushed ice	Ice should be crushed finely, but when melting it should drain down the funnel without falling through it.
container to catch melted ice	
250 cm^3 beaker	A standard beaker may be used, but thermal lagging will improve the outcome. A lid does not help a great deal.
thermometer and stirrer	The thermometer should read from a few degrees below zero Celsius up to room temperature.
access to top pan balance	Resolution 0.1 g
Notes	