Determining the specific latent heat of ice

Objects of the experiments

- Measuring the mixing temperature ϑ_M of ice and water.
- Calculating the specific latent heat of ice.

Principles

When heat is transferred to a substance at constant pressure, the temperature of the substance in general increases. If, however, a phase transition takes place, the temperature does not increase as the transferred heat is consumed in the phase transition. As soon as the phase transition is finished, the temperature increases again if the heat transfer is continued. A well-known example of a phase transition is given by the melting of water to ice. The heat consumed per mass unit is called the specific latent heat Q_S.

In the experiment, the specific latent heat Q_S of ice is determined by means of a calorimeter filled with ice. The ice cools warm water to the mixing temperature ϑ_m and melts to water with the mixing temperature ϑ_m. In addition, it absorbs the latent heat. Besides the mixing temperature, the initial temperature ϑ_2 and the mass m_2 of the warm water as well as the mass m_1 of the ice are measured so that the latent heat can be calculated as follows:

The heat absorbed by the ice is the sum of the heat

$$\Delta Q_1 = c \cdot m_1 \cdot (\vartheta_M - 0°C) \quad \text{(I)},$$

c: specific heat of water

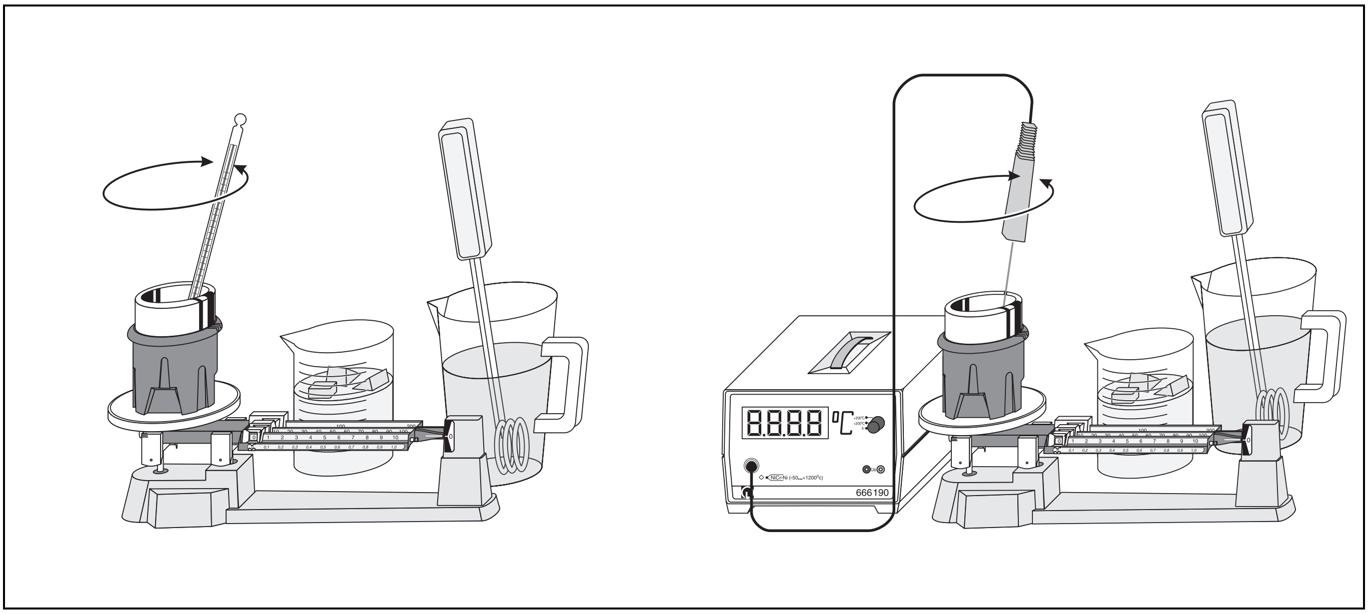
which the melted water absorbs in warming up from $\vartheta_1 \approx 0$ °C to the temperature ϑ_M, and the heat,

$$\Delta Q_2 = m_1 \cdot Q_S \quad \text{(II)},$$

which is absorbed in the process of melting from ice to water. The heat taken from the warm water when it is mixed with ice is

$$\Delta Q_3 = c \cdot m_2(\vartheta_2 - \vartheta_M) \quad \text{(III)}.$$

Fig. 1 Experimental setup for the determination of the specific latent heat of ice.
Left: temperature measurement with a thermometer
Right: temperature measurement with a temperature sensor



Apparatus

1 Dewar vessel	386 48
1 school and lab. balance 610 Tare, 610 g	315 23
1 thermometer, –10° to + 110 °C	382 34
or	
1 temperature sensor NiCr-Ni	666 193
1 digital thermometer	666 190
1 immersion heater	303 25
1 beaker, 400 ml, ss, hard glass	664 104
1 plastic beaker, 1000 ml	590 06

Additionally required:

about 100 g ice cubes

At the same time heat is taken from the calorimeter. This heat can be calculated since the water equivalent m_K of the calorimeter is known*:*

$$\Delta Q_4 = c \cdot m_K(\vartheta_2 - \vartheta_M) \text{ with } m_K = 20\text{ g} \qquad \text{(IV)}$$

As the absorbed heat $\Delta Q_1 + \Delta Q_2$ and the emitted heat $\Delta Q_3 + \Delta Q_4$ are equal,

$$\frac{Q_S}{c} = \frac{(m_2 + m_K)}{m_1} \cdot (\vartheta_2 - \vartheta_M) - (\vartheta_M - 0°C) \qquad \text{(V)}$$

is found.

Setup

The experimental setup is illustrated in Fig. 1. While the experiment is carried out, the Dewar vessel is placed on the school and lab. balance.

- Put the ice cubes into the beaker, which should be filled with cold water to a quarter so that the ice reaches a temperature of 0 °C (check with the thermometer or the temperature sensor respectively).
- Place the thermometer or the temperature sensor NiCr-Ni upright into the Dewar vessel.

Carrying out the experiment

- Read the mass of the empty Dewar vessel.
- Warm water up to a temperature between 40 °C and 50 °C in the plastic beaker.
- Fill about 200 g of the warm water into the Dewar vessel and determine its mass m_2 and temperature ϑ_2 (stir).
- Put 50 g of “dry” ice cubes into the warm water.
- Stir until the ice has completely melted and read the temperature ϑ_M.

Measuring example

Mass m_2 of the warm water:	200 g
Temperature ϑ_2 of the warm water:	45.8 °C
Mass of water and ice:	251 g
Mixing temperature ϑ_M of the cooled water:	23.0 °C

Evaluation and results

m_1 = 251 g – 200 g = 51 g

m_2 = 200 g

ϑ_2 = 45.8 °C

ϑ_M = 23.0 °C

Water equivalent of the Dewar vessel: m_K = 20 g

Specific heat of water: $c = 4.19 \frac{\text{kJ}}{\text{kg} \cdot \text{K}}$

Inserting these values into Eq. (V) leads to

$$\frac{Q_s}{c} = 75.3\text{ K and } Q_S = 316 \frac{\text{kJ}}{\text{kg}}.$$

Value quoted in the literature:

$$Q_S = 334 \frac{\text{kJ}}{\text{kg}}.$$