Specific energy of vaporization

FizziQ activity · High school · 85 min

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Boiling water loses mass at a steady rate: a connected balance tracked in FizziQ Connect links power and mass to the latent heat, near 2260 kJ/kg. High school.

Learning objectives

- Measure mass loss during boiling with a connected balance
- Calculate the energy supplied from power and time
- Determine the specific heat of vaporization from $L = E/\Delta m$
- Compare with the theoretical value of 2260 kJ/kg
- Understand the concept of latent heat and phase change

Instruments and sensors

Mini-balance (mass measurement) · Force sensor (M5 Stack via FizziQ Connect)

Materials

- Smartphone or tablet with FizziQ Connect
- M5 Stack with force sensor (balance)
- Calorimeter or insulated beaker
- Immersion heater
- Power meter (wattmeter)
- Electric kettle for initial boiling
- Lab stand and clamp
- Note: the protocol remains adaptable to any comparable continuous mass data-acquisition tool.

Protocol

1. Open FizziQ Connect and select 'External sensors'. Connect to the M5 Stack and select the mass (force) measurement.
2. Boil water in the kettle. Pour the boiling water into the calorimeter (or insulated beaker).
3. Place the calorimeter on the mini-balance and tare (zero) the reading.
4. Place the immersion heater in the water, attached to the lab stand with a clamp. The heater must not rest on the balance (only the water and calorimeter contribute to the mass).
5. Connect the power meter between the outlet and the heater. Note the power P displayed (in watts).
6. Turn on the heater and wait for a vigorous boil to establish.
7. Once boiling is steady, start the recording in FizziQ Connect (REC) and start the timer.
8. Record for 15 minutes. The mass should decrease steadily on the FizziQ screen.
9. Stop the recording (STOP). Note the mass of water evaporated Δm and the total time Δt.
10. Calculate the energy supplied $E = P \times \Delta t$, then the specific heat of vaporization $L_{vap} = E / \Delta m$. Compare with the theoretical value of 2260 kJ/kg.

Expected results

Mass decreases linearly over time, confirming constant vaporization rate at constant power. Over a typical 240-second interval with a 500W heater, about 50 g of water evaporates, giving $L \approx 500 \times 240 / 0.050 = 2400$ kJ/kg. This is close to but slightly above the theoretical 2260 kJ/kg due to heat losses.

Questions

- Why does the temperature remain constant during boiling even though energy is being supplied?
- What happens to the hydrogen bonds during vaporization?
- Why is the experimental value typically higher than the theoretical one?
- How does atmospheric pressure affect the boiling temperature and vaporization energy?
- Why does the mass decrease linearly rather than exponentially?
- How much energy would it take to completely evaporate 1 liter of water from room temperature?

Going further

- Repeat at different power levels and verify that L_vap is independent of heating power
- Compare the vaporization energy of water with that of ethanol (about 840 kJ/kg)
- Calculate the total energy needed to heat water from 20°C to steam at 100°C
- Investigate the effect of adding salt on the boiling temperature and vaporization rate
- Use the data to estimate heat losses by comparing the measured L_vap with the theoretical value