Heat of vaporization of water (Item No.: P1044800)

Curricular Relevance

Area of Expertise: Physics

Education Level: Age 14-16

Topic: Thermal physics

Subtopic: States of matter: Melting, boiling, evaporation

Experiment: Heat of vaporization of water

Difficulty	Preparation Time	Execution Time	Recommended Group Size
Intermediate	10 Minutes	10 Minutes	2 Students

Additional Requirements:

- Butane burner, Labogaz 206 type 32178-00
- Butane cartridge C206, without valve 47535-00
- Boiling beads, 200 g 36937-20
- Matches

Experiment Variations:

Keywords:

Task and equipment

Information for teachers

Additional Information

To begin with, the course of the water's temperature during heating is measured so that the burner's thermal output can be determined. From this the quantity of energy required to vaporise a specific quantity of water can be calculated.

According to the literature, the specific heat of vaporisation of water is q_v = 2256 J/g (see Question 6 in the report).

Remarks

1. The burner's flame must have a constant size throughout the entire experiment since a constant thermal output is prerequisite for the evaluation.
2. The stop watch should run continuously throughout the entire experiment.The course of the temperature is only measured in the first part of the experiment for a period of 9 min (Table 1). During this period the water has already begun to boil so that the constancy of the water's temperature during boiling can be observed.The thermometer should then be removed (including glass tube holder, rod and bosshead) to prevent them from being unnecessarily exposed to the hot steam.
3. The boiling period does not have to be exactly 10 min; the important thing is that the start and end times are recorded.
4. Even before the boiling point has been reached water evaporates. Since the resulting error can be neglected if the boiling period is sufficiently long, the boiling period should thus be longer than 5 minutes. Additionally, the use of the small Erlenmeyer flask has proved to be appropriate since the water that evaporates before boiling begins cannot escape easily.
5. The final water volume should be estimated to the nearest 0.5 ml.
6. The boiling point determined in this experiment is greater than 100 °C since the whole thermometer is exposed to the hot water vapour. The scale of this thermometer is, however, only exact when only the immersed part of the thermometer is exposed to the temperature to be measured and the shaft above it has a temperature of 20 °C. (The upper part of the thermometer can, e.g., be protected with a rubber stopper which, however, must not block the flask's mouth: water should evaporate!)

The time of commencement of boiling can sometimes only be inexactly determined by extrapolation of the straight line from the warming-up phase to the boiling point. Since the thermometer shows the temperature with a slight delay due to its time lag, the value obtained in this way for t_1 is likely to be too large.

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Task and equipment

Task

How much heat is required to vaporise water?

1. Bring a measured quantity of water to a boil and measure the temperature increase as a function of time.
2. Let the water boil over the same flame for 10 minutes and determine how much water has evaporated.

Equipment

Position No.	Material	Order No.	Quantity
1	Support base, variable	02001-00	1
2	Support rod, stainless steel, l = 250 mm, d = 10 mm	02031-00	1
3	Support rod, stainless steel, l = 600 mm, d = 10 mm	02037-00	1
4	Boss head	02043-00	2
5	Glass tube holder with tape measure clamp	05961-00	1
6	Ring with boss head, i. d. = 10 cm	37701-01	1
7	Universal clamp	37715-00	1
8	Wire gauze with ceramic, 160 x 160 mm	33287-01	1
9	Erlenmeyer flask 100 ml, wide-neck SB 29	36428-00	1
10	Pipette with rubber bulb	64701-00	1
11	Graduated cylinder 100 ml, PP transparent	36629-01	1
12	Students thermometer, -10...+110°C, l = 230 mm	38005-10	1
13	Stop watch 4	03078-00	1
Additional material:			
14	Butane burner, Labogaz 206 type	32178-00	1
15	Butane cartridge C206, without valve	47535-01	1
16	Boiling beads, 200 g	36937-20	1
	Matches		

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Set-up and procedure

Set-up

Attention!

1. During the heating of the water the support ring and the wire gauze become extremely hot! To pour the hot water the Erlenmeyer flask should be held with the universal clamp.
2. The burner's flame must remain the same size throughout the experiment.
3. The stop watch should run continuously during the entire experiment.

Setup

- Set up the support stand according to the following pictures.

Fig. 1

Fig. 2

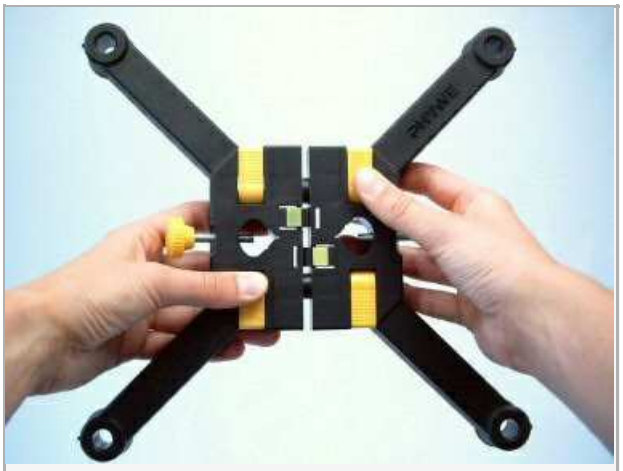

Fig. 3

Fig. 4

Fig. 5

Fig. 6

Fig. 7

Fig. 8

- Fill the graduated cylinder with 100 ml of water (exact measurement using the pipette).
- Pour the measured quantity of water in the Erlenmeyer flask and place two beads in it.

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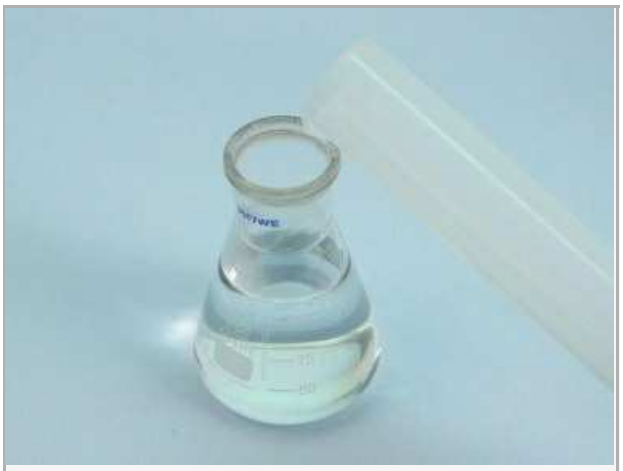
Fig. 9


Fig. 10

- Secure the Erlenmeyer flask with the universal clamp.
- Lower the thermometer until the bulb is in the middle of the Erlenmeyer flask.

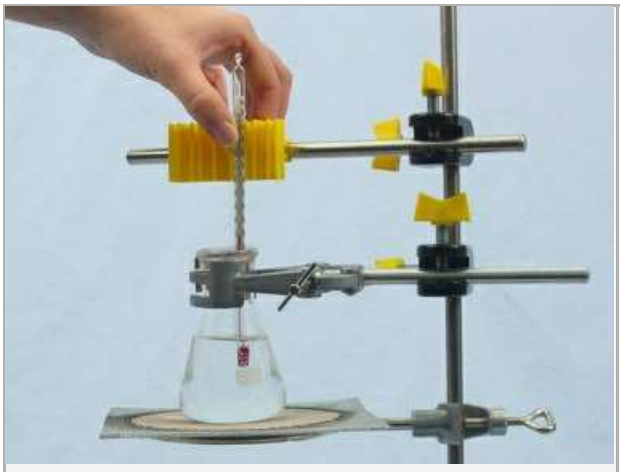
Fig. 11


Fig. 12


Fig. 13

Procedure

- Note the initial volume V_1 of water under Result - Observation 1 in the report.
- Measure the initial temperature ϑ of the water and record it at t = 0 min.
- Light the burner and start the stop watch.
- Read the water temperature at 1 min intervals (Table 1).
- When the water boils (strongly bubbles!), record the beginning of boiling t_1 in the report, and let the water boil for about 10 min from this time onwards (the stop watch is still running!).
- When Table 1 is completed, you can remove the thermometer. The water should, however, still be boiling!
- When the water has boiled for 10 minutes after the beginning at time t_1, turn off the burner and note the exact time t_2 at which boiling ends.
- First, allow the Erlenmeyer flask to cool slightly. To do this lift it from the hot wire gauze by shifting the bosshead to one side.
- Then pour the hot water carefully into the graduated cylinder (without the beads!). To do this slip the universal clamp out of the bosshead and use it as a handle.
- Record the final water volume V_2 (estimate to the nearest 0.5ml!).

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Report: Heat of vaporization of water

Result - Observation 1

Initial water volume V_1 = ... ml.

Final water volume V_2 = ... ml.

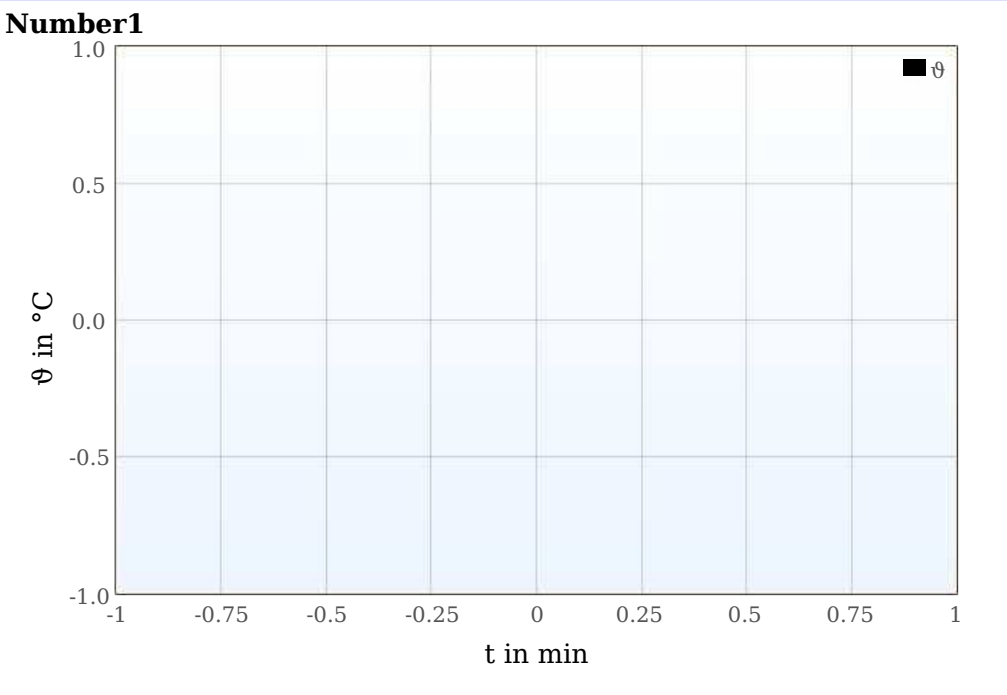
Boiling began at t_1 = ... s.

Boiling ended at t_2 = ... s.

Result - Table 1

Note your measured values in the table.

t in min	ϑ in °C
0	1 ±0
1	1 ±0
2	1 ±0
3	1 ±0
4	1 ±0
5	1 ±0
6	1 ±0
7	1 ±0
8	1 ±0
9	1 ±0



Evaluation - Question 1

From the measured volume calculate the initial and final mass of water as well as the mass of the evaporated water (density ρ = 1 g/ml):

Inital water mass m_1 = ...g

Final water mass m_2 =.....g.

Evaporated water mass Δm =.....g.

Evaluation - Question 2

Watch the chart on the Results page. Why should the initial and the final values of the warming phase not be considered when calculating the slope of the graph?

.....

.....

.....

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Evaluation - Question 3

Calculate the thermal output of the burner from the temperature increase of the water.

To heat the water with a mass of m_1 = 100 g

with the specific heat capacity c = 4.19 J/g°C

and a temperature difference $\Delta\vartheta$ the following quantity of heat is required:

$Q = c \cdot m_1 \cdot \Delta\vartheta$.

The temperature difference $\Delta\vartheta$ is reached in a period of time t. From this the thermal output of the burner can be determined:

$P = c \cdot m_1 \cdot \Delta\vartheta / \Delta t$

From the linear temperature increase in the chart, determine the ratio (i.e., the slope of the line)

$\Delta\vartheta/\Delta t$ = ... °C/s

and from this calculate the burner's thermal output:

P =.....W.

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Evaluation - Question 4

Calculate the period of time t_s in which the water boiled.

$t_s = t_2 - t_1 =$ ..... s.

Evaluation - Question 5

Calculate the quantity of heat required to vaporise the mass of water Δm

$Q = P \cdot t_s =$ ..... J.

Evaluation - Question 6

Calculate the specific heat of vaporisation of water, i.e. the quantity of heat required to vaporise 1 g of water.

$q_v = Q / \Delta m =$ ..... J/g.