Heat of condensation of water (Item No.: P1044900)

Curricular Relevance

Area of Expertise: Physics

Education Level: Age 14-16

Topic: Thermal physics

Subtopic: States of matter: Melting, boiling, evaporation

Experiment: Heat of condensation 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
- Glycerol, 250 ml 30084-25
- Boiling beads, 200 g 36937-20
- Matches

Experiment Variations:

Keywords:

Task and equipment

Information for teachers

Additional Information

Water vapour is conducted into a calorimeter containing cold water. From the mix temperature and the mass increase of the cold water, the specific heat of condensation of water is calculated. It is as large as the specific heat of vaporisation of water; i.e. the heat required for vaporisation is released on condensation.

The student gains a feeling for the size of this quantity of heat when he mixes the same quantity of boiling water – instead of water vapour – with the cold water. The calculation of this mix temperature is undertaken in point 3 of the evaluation. However, the impression on the students is even more lasting when this supplementary experiment is conducted.

Remarks

1. As far as possible only water vapour and not water should emerge from the glass tube. To ensure this the wire gauze is positioned just above the burner so that the water boils strongly. The tubing must not be too long (approx. 35 cm). Additionally, one should wait 2 min after the boiling has begun before conducting the water vapour into the calorimeter so that the tubing and glass tube are too hot for water to condense in them.
2. The glass tube holder should be clamped close to the middle of the glass tube. With it the glass tube can be moved to the calorimeter where its tip is inserted through the lid to the bottom of the calorimeter; and the glass tube holder rests on the lid as an additional support.
3. When determining the final volume, the values should be estimated to the nearest 0.5 ml.

The literature value for the specific heat of condensation is q = 2256 J/g.

The value determined in the experiment is generally smaller than the value given in the literature since it is nearly impossible to prevent water which has already condensed from flowing into the calorimeter.

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Task and equipment

Task

How much heat is released during the condensation of water?

Conduct hot water vapour into cold water. Measure the quantity of the conducted water vapour and the mix temperature.

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	1
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	Lid for student calorimeter	04404-01	1
10	Felt sheet, 100 x 100 mm	04404-20	2
11	Silicone tubing i.d. 7mm	39296-00	1
12	Agitator rod	04404-10	1
13	Glass tubes,l.250 mm, pkg.of 10	36701-68	1 piece
14	Glass tube, straight, l=80 mm, 10/pkg.	36701-65	1 piece
15	Graduated cylinder 100 ml, PP transparent	36629-01	1
16	Pipette with rubber bulb	64701-00	1
17	Students thermometer, -10...+110°C, l = 230 mm	38005-10	1
18	Beaker, low form, plastic, 100 ml	36011-01	1
19	Glass beaker DURAN®, short, 250 ml	36013-00	1
20	Glass beaker DURAN®, short, 400 ml	36014-00	1
21	Erlenmeyer flask 100 ml, wide-neck SB 29	36428-00	1
22	Rubber stopper 26/32, 1 hole 7 mm	39258-01	1
Additional material:			
23	Butane burner, Labogaz 206 type	32178-00	1
24	Butane cartridge C206, without valve	47535-01	1
25	Glycerol, 250 ml	30084-25	15 ml
26	Boiling beads, 200 g	36937-20	1
27	Matches		

Set-up and procedure

Set-up

Attention!

1. Hot water vapour is conducted through the tubing and the glass tubes! Always hold the tube so that the end points straight down.
2. During the heating of the water the support ring and the wire gauze become extremely hot!
3. Always insert the thermometer or glass tubes in the rubber stopper using glycerol.

Setup

- Set up the support stand according to the following pictures. The wire gauze should be only 1 cm above the burner's opening so that the water boils strongly.

Fig. 1

Fig. 2

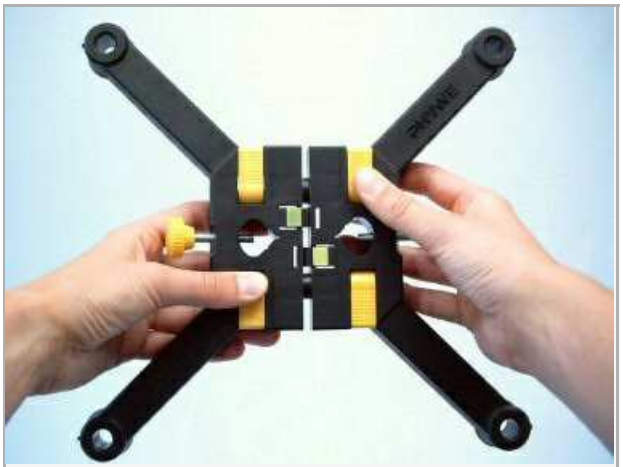

Fig. 3

Fig. 4

Fig. 5

Fig. 6

Fig. 7

- Insert the short tube into the stopper.

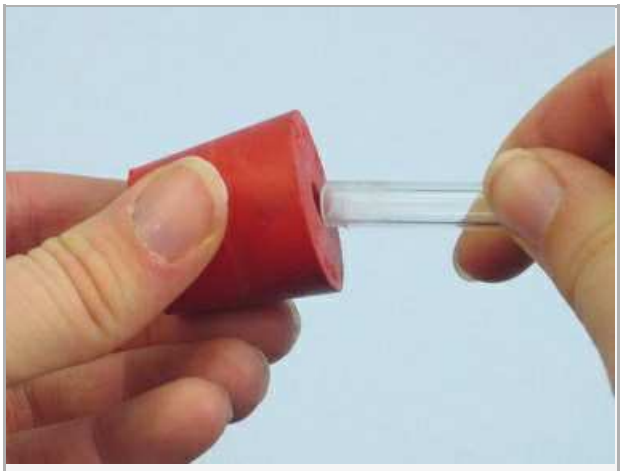

Fig. 8

- Pour about 75 ml of water into the Erlenmeyer flask, add two beads and seal the flask with the stopper.

Fig. 9

Fig. 10

Fig. 11

- Place the Erlenmeyer flask onto the wire gauze and clamp it into place with the universal clamp.

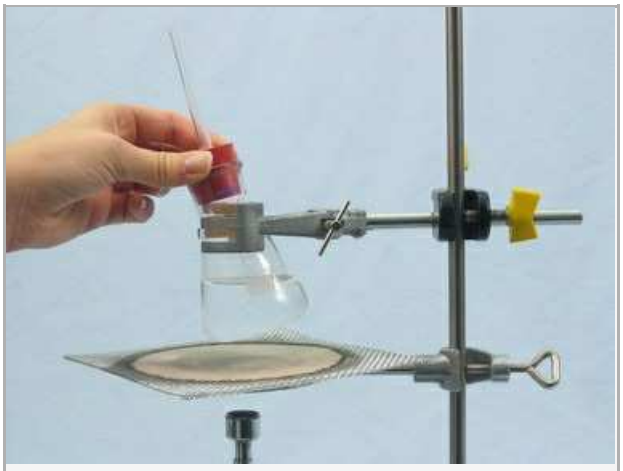

Fig. 12

- Slip a piece of tubing which is about 35 cm long over the end of the short glass tube and insert the long one into the other end of the tubing.

Fig. 13

- Using the glass tube holder, hold the long glass tube and place the small plastic beaker under it.

Fig. 14

Fig. 15

- Assemble a thermally insulated vessel (calorimeter) using the two glass beakers (250 ml and 400 ml) and two felt sheets.

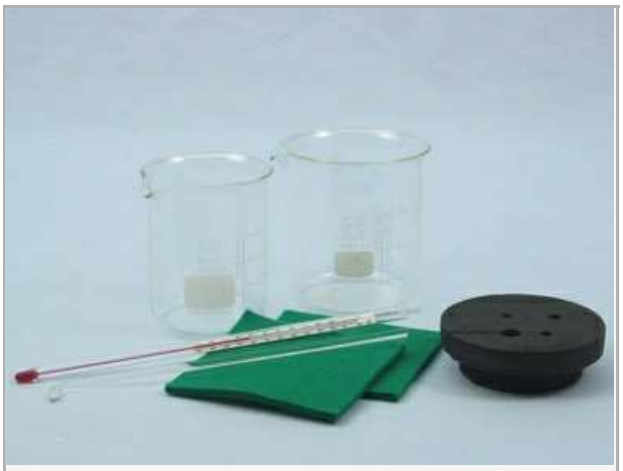
Fig. 16


Fig. 17

- Insert the thermometer (d = 8 mm) and the agitator rod (d = 5 mm) through the respective holes in the lid (not through the holes in the slit).


Fig. 18

Procedure

- Pour exactly 150 ml of cold water in the calorimeter (exact measurement using the graduated cylinder and the pipette); record this value V_1 in the report.

Fig. 19

- Measure the temperature in the calorimeter and records its value ϑ_1 (report).
- Bring the water in the Erlenmeyer flask to a boil.
- Observe the emergence of hot steam from the glass tube.
- Wait about 2 min after boiling has begun so that only steam and no water droplets emerge.
- Pick up the glass tube using the glass tube holder and insert it through the large opening in the slot in the calorimeter's lid so that water vapour flows into the calorimeter.

Fig. 20

Fig. 21

Fig. 22

- Let the water vapour flow in for about 2 min, i.e. until the water temperature is about 50°C.

- Turn off the burner, remove the glass tube from the calorimeter and clamp it on the support rod.
- Stir the water carefully. Measure and record the water temperature (intermediate temperature) ϑ_m.
- Measure the quantity of water V_3 which is now in the calorimeter by pouring it into the graduated cylinder and record the value (when determining the volume estimates the sub volumes to the nearest 0.5 ml).

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Report: Heat of condensation of water

Result - Observation 1

Volume of the cold water V_1 = ... ml

Temperature of the cold water ϑ_1 = ... °C

Intermediate temperature ϑ_m = ... °C

Temperature of the water vapour ϑ_2 = 100 °C

Final volume V_3 = ... ml

Evaluation - Question 1

Calculate the mass of cold water m_1 and the final (total) mass m_3 (density ρ = 1 g/ml).

m_1 = ... g

m_3 = ... g

Evaluation - Question 2

From this calculate the mass of the conducted water vapour $m_2 = m_3 - m_1$ = ... g

Evaluation - Question 3

How large would the intermediate temperature $\vartheta_{m'}$ be, if, instead of water vapour with mass m_2, boiling water with a mass m_2 were added to the cold water under the same experimental conditions? Calculate

$\vartheta_m' = (m_1 \cdot \vartheta_1 + m_2 \cdot \vartheta_2) / (m_1 + m_2)$ = ... °C.

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Evaluation - Question 4

Steps for calculating the specific heat of condensation of water:

1. Calculate the heat Q_1 absorbed by the cold water (specific heat capacity of water c = 4.19 J/g °C)
   $Q_1 = c \cdot m_1 \cdot (\vartheta_m - \vartheta_1)$ = ...J.
2. The mass m_2 of condensed water cools from ϑ_2 = 100 °C down to the mix temperature ϑ_m; while doing so it releases a quantity of heat Q_2. Calculate Q_2:
   $Q_2 = c \cdot m_2 \cdot (\vartheta_2 - \vartheta_m)$ =.....J.
3. The quantity of heat Q released by the conversion of water vapour with a mass m_2 into water is given by
   Q = $Q_2 - Q_1$ =.....J.
4. Using this value calculate the specific heat of condensation q, i.e. the quantity of heat that is released during the condensation of 1 g of water vapour:
   $q = Q / m_2$ =.....J/g.

Evaluation - Supplementary problem 1

Take the heat capacity of the calorimeter (C_{cal} = 80 J/°C) into account in your evaluation.

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