Cooling by evacuation with Cobra4 (Item No.: P2340660)

Curricular Relevance

Area of Expertise: Physics
Education Level: University
Topic: Thermodynamics
Subtopic: Thermal Properties and Processes
Experiment: Cooling by evacuation with Cobra4

Difficulty	Preparation Time	Execution Time	Recommended Group Size
Difficult	20 Minutes	50 Minutes	2 Students

Additional Requirements:

- PC with USB interface, Windows XP or higher

Experiment Variations:

Keywords:

vacuum, gas pressure, boiling temperature

Overview

Short description

Principle
When the air pressure above a water surface is reduced, the water begins to boil at a certain temperature.
The temperature of the water is hereby reduced and further evacuation can finally bring it to 0 °C and even lower.

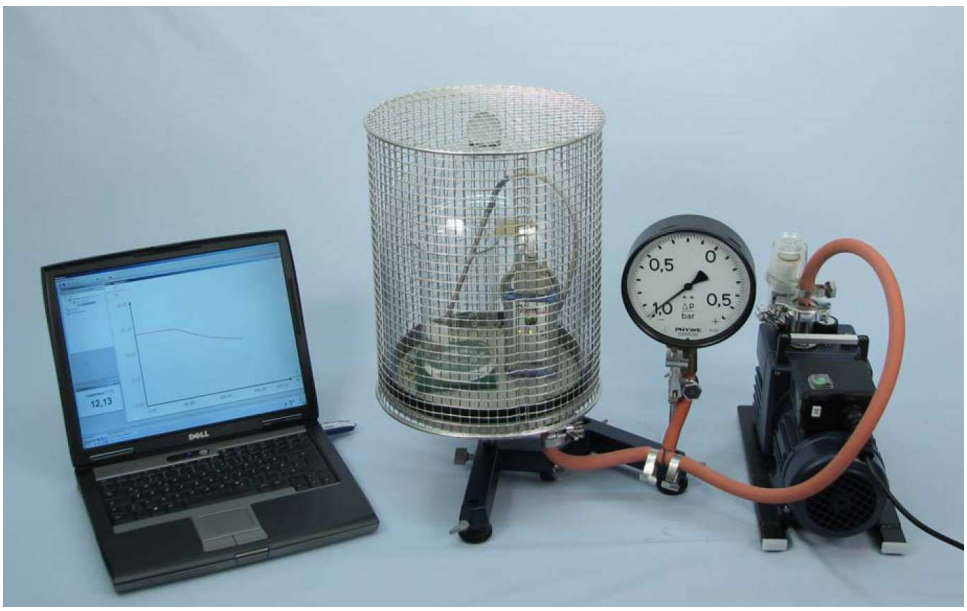

Fig. 1: Experimental set-up

Equipment

Position No.	Material	Order No.	Quantity
1	Cobra4 Wireless/USB-Link incl. USB cable	12601-10	1
2	Cobra4 Sensor-Unit Temperature	12640-00	1
3	Rubber tubing,vacuum,i.d.8mm	39288-00	2
4	Hose clamp for 15-22 mm diameter	40999-00	5
5	Rotary valve vacuum pump, one stage	02740-95	1
6	Oil mist filter, DN 16 KF	02752-16	1
7	Pump plate, complete	02668-88	1
8	Hose nipple DN 10	02668-12	1
9	Support base DEMO	02007-55	1
10	Bell jar, with knob and sealing ring	02668-10	1
11	Protection cylinder for bell-jar	02668-14	1
12	Manometer -1.0...0.6 bar	03105-00	1
13	Universal clamp	37715-00	1
14	Tubing connect.,T-shape,ID 8-9 mm	47519-03	1
15	Beaker, high, BORO 3.3, 1000 ml	46030-00	1
16	Boiling beads, 200 g	36937-20	1
17	curricuLAB measureLAB	14580-61	1
18	Felt sheet, 100 x 100 mm	04404-20	2

Tasks

Determine the temperature curve of water during pumping.

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Set-up and procedure

Set-up

- Set up the experiment as shown in Fig. 1.
- Fill about 100 ml of water (room temperature) in the beaker and add two boiling stones.
- Place the beaker on the pump plate and lay the felt sheets under the beaker as insulation.
- Dip the temperature sensor in the water. Connect it to the Cobra4 Wireless-Link and switch this on.
- Place the bell jar with rubber sealing ring and the protection cylinder on the pump plate.
- Fit the oil mist filter to the vacuum pump and connect the vacuum pump to the manometer and the pump plate (Fig. 1).

Procedure

- Start the PC
- Connect the Cobra4 Wireless-/USB-Link to the PC.
- Start measureLAB
- Load experiment. All necessary settings for measured value recording are now loaded.
- Start measured value recording in measureLAB with clicking on
- Switch on the vacuum pump and check on the manometer that there is no leak in the vacuum line that would be detrimental to evacuation. The pressure should drop below 100 mbar within the first minute of pumping.
- Switch the vacuum pump off after about 40 minutes.
- End measurement in the programme with clicking on .

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Theory and evaluation

Results

- It can be seen that the water starts to boil after about 1-2 minutes.
- After about five minutes the water has cooled by about 10°C.
- After about half an hour the temperature of the water reaches the freezing point, a layer of ice starts to form on the water surface.

Evaluation

- When a liquid boils, molecules of the liquid exit from the liquid into the gas space above it. The heat of evaporation that is required for this is drawn from the water. To be able to exit from the water, the molecules of the liquid must have a defined kinetic energy that is greater the higher the gas pressure above the liquid is.
- According to the kinetic gas theory, the square of the average speed of the molecules of the liquid is proportional to the temperature of the liquid. This means on the one hand that the boiling temperature is reduced at lower gas pressures, and on the other hand that the molecules having the most kinetic energy exit the liquid, so that the temperature of the remaining liquid is reduced. The "hottest" water molecules are pumped off, so that average speed of the molecules of liquid, and so the temperature of the liquid, continually decreases.
- In the last part of the curve (Fig. 2), a slight rise in the measured temperature can be seen after about 1,800 seconds. The explanation for this is that the water is first supercooled a little, but then the surface froze whereby heat of fusion was released that led to the observed temperature rise measured at the bottom of the vessel.

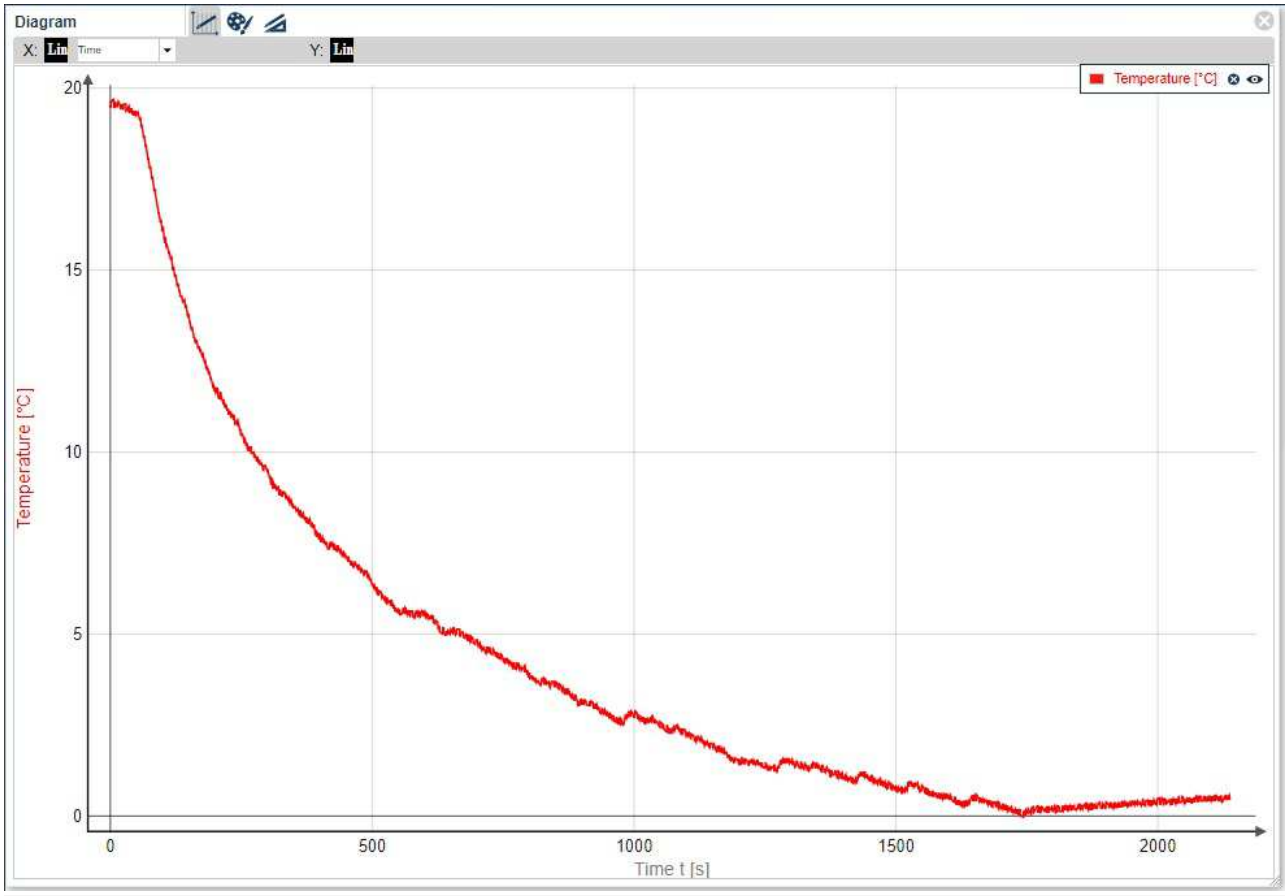

Fig. 2: Temperature curve of the water during pumping. The boiling temperature of water is dependent on the pressure of the air that burdens it. When the air pressure is reduced, the boiling point is also reduced. The boiling water then cools until it finally reaches a point on the steam pressure curve where it is again in equilibrium with the prevailing pressure. Cooling can so finally bring the temperature to below freezing point.