Properties of matter – boiling point (Item No.: P7150301)

Curricular Relevance

Area of Expertise: Natural Sciences
Education Level: Age 11-14
Topic: Nature and technology
Subtopic: Substances in daily use
Experiment: Properties of matter – boiling point

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

Additional Requirements:

Experiment Variations:

Keywords:

boiling temperature, material property, temperature measurement

Information for the teacher

Educational objective and competences

In this experiment, the students will observe the change from liquid to gas. The students will learn that the transition from the liquid state to the gaseous state occurs when the boiling temperature is reached (at a certain pressure). If the temperature is represented in a diagram, the phase transition (solid/liquid or liquid/gaseous) appears as an area with a constant temperature. In addition, the students will learn that solutions have a higher boiling point than pure solvents.

Standard experiment set-up

Experiment set-up for measurements with a tablet PC

Competences

Process-related competences:

The students can...

K06 – execute simple experiments independently based on written instructions.
K09 – plan, execute and document simple experiments by themselves.
K11 – identify trends, structures and relationships in acquired data.

K: Knowledge gain
C: Communication
A: Assessment

C03 – acquire measurement data and extract them from age-appropriate representations.
C04 – prepare reports under guidance about knowledge that they have acquired.
C05 – present their results with the aid of specified media.
C07 – work in groups on their own initiative.
C09 – read age-appropriate, relevant texts and relay the content thereof.

A04 – follow the safety instructions and identify environmental aspects and explain their purpose/significance.

Content-related competences:

The students can... **S:** Specialised knowledge

S22 – describe and identify materials/substances based on their typical properties.
S24 – identify material properties under guidance and with the help of suitable measurement methods and devices.
S27 – explain states of matter and their temperature-dependence.

Equipment

Position No.	Material	Order No.	Quantity
1	Beaker, low, BORO 3.3, 250 ml	46054-00	2
2	Graduated cylinder, 25 ml, transparent, PP	36635-00	1
3	Spoon, stainless steel, l = 210 mm	40874-00	1
4	Students thermometer, -10..+110°C, l = 230 mm	38005-10	1
5	Glass rod, boro 3.3, l = 200 mm, d = 5 mm	40485-03	1
6	Watch glass, d =100 mm	34574-00	1
7	Portable Balance, OHAUS YA 302, 300 g / 0,05	49213-00	1
8	Protecting glasses, clear glass	39316-00	1
Additionally required:			
9	Heating hotplate, d = 90 mm, 500 W, 230 V	04028-93	1
10	Sodium chloride, 250 g	30155-25	1
11	Water, distilled 5 l	31246-81	1

Additional material for measurements with a tablet PC

In order to perform the experiment with digital measurement data recording via a tablet PC, the following additional material is

required.

The thermometer is not required.

Position No.	Material	Order No.	Quantity
1	Cobra4 Wireless/USB-Link	12601-09	1
2	Cobra4 Sensor-Unit Temperature, −20...110 °C	12640-00	1
3	Apple iPad		1
4	PHYWE measure App		1

Saefty information

During the experiment, everyone present in the room must wear safety goggles!

As a general precaution, burn hazards must be avoided (e.g. by shielding). Special protective measures, e.g. the use of a heatproof mat, must be taken.

Didactic notes

Technical terms

- The boiling-point elevation is covered in a quantitative manner by Raoult's law which includes the boiling-point elevation as a function of the added amount of substances as a substance-specific constant. A more precise interpretation of the experiment based on the vapour pressure equilibrium would be too difficult for students of this age group. If a substance is dissolved in a pure solvent, the solution has a higher boiling point than the pure solvent. In a simplified manner, this can be explained as follows: the particles of the dissolved substance hinder the particles of the pure solvent from transitioning to the gaseous phase, thereby shifting the vapour pressure (compared to the pure solvent) towards a higher temperature. Another (slightly superficial) interpretation in the sense that the dissolved particles prevent the solvent particles from leaving the solution is also permissible for this age group.
- Under normal conditions (ambient pressure approx. 1 bar), the boiling temperature of water is always the same and, thereby, a characteristic of water. Like water, numerous other substances can be brought to a boil (e.g. common salt at 1,413°C). This boiling temperature is a characteristic of the substance in question.

  The boiling temperature plays numerous roles. For example, it provides information about the state of matter (liquid, gaseous) that a substance will have at a certain temperature under normal conditions.
  In addition, the boiling temperature is also a characteristic with which it is possible to prove whether a substance is actually a pure substance or a mixture of substances.
- Within the framework of the curriculum, the three classic states of matter should also be illustrated. Students often consider substances (solids, liquid and gases) as "unchangeable" in terms of their state. This experiment shows that every substance can assume several different states depending on the temperature.
- When the students heat water and prepare a corresponding diagram, they will see that there are areas where the temperature increases nearly linearly and other areas where the temperature remains constant over a longer period of time. The constant temperature indicates that a change of state occurs. Alternatively, ice can be heated for this experiment. This enables the graphical evaluation of the melting process and the corresponding melting temperature.

Procedure

- Some students may assume that the gas bubbles in the boiling water are air or carbon dioxide. In this case, a test tube can be held over the boiling water so that the students can see how the water vapour condenses. This illustrates that the gas bubbles, which rise in the boiling water, are in fact water in its gaseous form.
- The exact quantity of salt that is added is not important, since the boiling point shift is not to be determined in a quantitative manner (as a function of the salt quantity) in this age group.

Tablet PC option

In addition to the classic variant, you can also let the students perform the experiment with the Cobra4 equipment and tablet PCs. The digital measurement data recording method enables the students to quickly acquire the measurement data, understand them more readily and to evaluate them in a particularly comfortable way.

- Remove the thermometer from the set-up and replace it with the Sensor-Unit Temperature connected to the Cobra4 Wireless/USB-Link. The students perform the same measurements with the Sensor-Unit and evaluate the temperature development in the diagram of the "measure" app. With the diagram, the temperature rise during the measurement can be better captured.

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Properties of matter – boiling point (Item No.: P7150301)

Standard experiment

Introduction

Surely, you have already observed water being heated on a hob. At a certain temperature, you can see how small bubbles develop and then rise in the water in the pot.

This is the temperature at which the water starts to boil. The temperature at which the water starts to boil is the boiling temperature.

Application

In your everyday life, you can find several examples where the boiling point plays an important role:

- Brake fluid tester
- Pressure cooker

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Task

In the following experiment, you will determine the boiling temperature of water.

Check whether you can change the boiling point of water by adding sodium chloride to the water.

Experiment set-up

Assumption

Initial question

At which temperature does water boil at normal pressure?

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.....

.....

Equipment and procedure

You will need the following material for the experiment:

Position No.	Material	Order No.	Quantity
1	Beaker, low, BORO 3.3, 250 ml	46054-00	2
2	Graduated cylinder, 25 ml, transparent, PP	36635-00	1
3	Spoon, stainless steel, l = 210 mm	40874-00	1
4	Students thermometer, -10..+110°C, l = 230 mm	38005-10	1
5	Glass rod, boro 3.3, l = 200 mm, d = 5 mm	40485-03	1
6	Watch glass, d =100 mm	34574-00	1
7	Portable Balance, OHAUS YA 302, 300 g / 0,05	49213-00	1
8	Protecting glasses, clear glass	39316-00	1
Additionally required:			
9	Heating hotplate, d = 90 mm, 500 W, 230 V	04028-93	1
10	Sodium chloride, 250 g	30155-25	1
11	Water, distilled 5 l	31246-81	1

Procedure

You must wear safety goggles during the experiment!

First part of the experiment

Fill approximately 50 ml of water into the beaker (Fig. 1). Wait a moment and then measure the temperature of the water with the aid of a thermometer (Fig. 2).

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Fig. 1


Fig. 2

Heat the water carefully on the hotplate until it starts to boil (Fig. 3). If it is heated carefully, the boiling temperature can be determined.

Measure the temperature every 30 seconds and enter the values into Table 1 of the experiment report.

Stop the experiment when the temperature remains constant after five measurement values.


Fig. 3

Second part of the experiment

Fill approximately 50 ml of water into the second beaker (Fig. 1). Weigh approximately 2 g of sodium chloride on a watch glass (Fig. 4) and fill it into the beaker (Fig. 5).


Fig. 4


Fig. 5

While stirring, heat the water carefully until it starts to boil (Fig. 6).

If it is heated carefully, the boiling temperature can be determined.

Measure the temperature every 30 seconds and enter the values into the experiment report.

Stop the experiment when the temperature remains constant after five measurement values.


Fig. 6

Take the beaker with the saline solution off the hotplate and let the water cool a little.
Please note that the beaker can be hot (risk of burns).

Weigh another 2 g of sodium chloride and add it to the saline solution.

Heat this solution as well until it boils and measure the boiling temperature. Enter the result into the experiment report.

Evaluation

Go back to the experiment report and answer the remaining questions.

Experiment (with a tablet PC)

Introduction

Surely, you have already observed water being heated on a hob. At a certain temperature, you can see how small bubbles develop and then rise in the water in the pot.

This is the temperature at which the water starts to boil. The temperature at which the water starts to boil is the boiling temperature.

Application

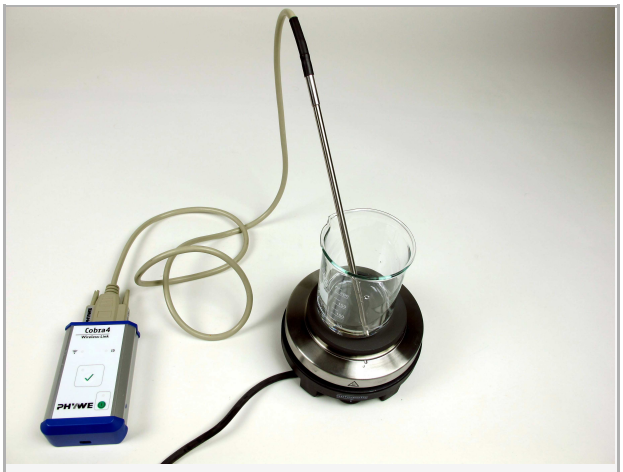
In your everyday life, you can find several examples where the boiling point plays an important role:

- Brake fluid tester
- Pressure cooker

Task

In the following experiment, you will determine the boiling temperature of water. For this experiment, you will use a temperature sensor instead of a thermometer for the temperature measurement. The temperature sensor will record the temperature automatically. The result is a temperature-time diagram which shows you the temperature development and boiling temperature.

First, measure the boiling temperature of pure water. Then, check whether you can change the boiling point of water by adding sodium chloride to the water.



Experiment set-up

Assumption

Initial question

At which temperature does water boil at normal pressure?

.....

.....

.....

.....

Equipment and procedure

You will need the following material for the experiment:

Position No.	Material	Order No.	Quantity
1	Beaker, low, BORO 3.3, 250 ml	46054-00	2
2	Graduated cylinder, 25 ml, transparent, PP	36635-00	1
3	Spoon, stainless steel, l = 210 mm	40874-00	1
4	Glass rod, Boro 3.3, l = 200 mm, d = 5 mm	40485-03	1
5	Watch glass, d = 100 mm	34574-00	1
6	Portable Balance, OHAUS YA 302, 300 g / 0,05	49213-00	1
7	Protecting glasses, clear glass	39316-00	1
8	Wireless/USB-Link	12601-09	1
9	Cobra4 Sensor-Unit Temperature, -20...110 °C	12640-00	1
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10	Heating hotplate, d = 90 mm, 500 W, 230 V	04028-93	1
11	Sodium chloride, 250 g	30155-25	1
12	Water, distilled 5 l	31246-81	1
13	Apple iPad		1
14	PHYWE measure App		1

Procedure

You must wear safety goggles during the experiment!

First part of the experiment

Connect the ''Wireless/USB-Link" and the sensor and switch the device on.

Connect your tablet PC with the "Wireless/USB-Link" and open the "measure" app.

Select the connected sensor.

Fill approximately 50 ml of water into the beaker (Fig. 1). Wait a moment and then measure the temperature of the water with the aid of the temperature sensor (Fig. 2). To do so, insert the temperature sensor into the beaker.

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Fig. 1


Fig. 2

Open the diagram window and start the measurement in the app.

Heat the water carefully on the hotplate until it starts to boil. If it is heated carefully, the boiling temperature can be determined based on a time-temperature diagram.

Stop the experiment when the temperature remains constant for approximately 1 minute.

Then stop the measurement.

Second part of the experiment

Fill approximately 50 ml of water into the second beaker (Fig. 1). Weigh approximately 2 g of sodium chloride on a watch glass (Fig. 3) and fill it into the beaker (Fig. 4). Stir with a glass rod. Then, insert the temperature sensor into the beaker.

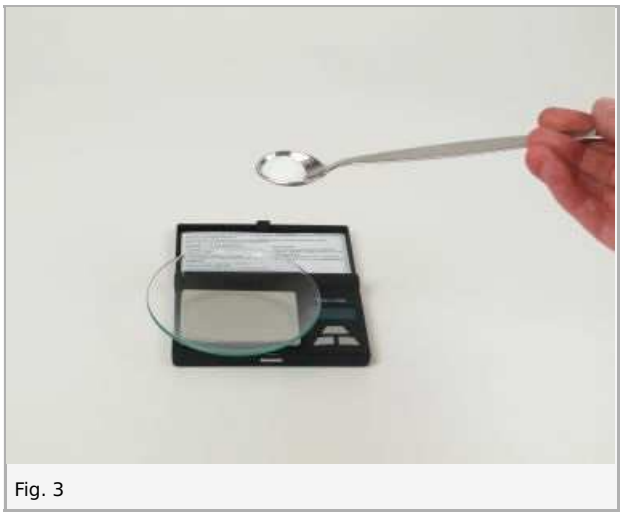
Fig. 3


Fig. 4

Starte a new measurement.

While stirring, heat the water (saline solution) carefully until it starts to boil (Fig. 5). If it is heated carefully, the boiling temperature can be determined based on a time-temperature diagram.

Measure the temperature and enter the result into the experiment report.

Stop the experiment when the temperature remains constant for approximately 30 seconds.

Then stop the measurement.

Take the beaker with the saline solution off the hotplate and let the water cool a little. Please note that the beaker can be hot (risk of burns).

Weigh another 2 g of sodium chloride and add it to the saline solution. After stirring with a glass rod, insert the temperature sensor into the beaker.

Heat this solution as well until it boils and measure the boiling temperature. Enter the result into the experiment report.

Evaluation

Go back to the experiment report and answer the remaining questions.

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Report: Properties of matter – boiling point

Observation 1

Pure water boils at 99.6 °C.

The boiling temperature of the saline solution (2 g of sodium chloride in 50 ml of water) is 101.4 °C.

The boiling temperature of the saline solution (4 g of sodium chloride in 50 ml of water) is 103.2 °C.

Evaluation - question 1

How does the addition of sodium chloride change the boiling temperature of water?

The boiling temperature is elevated.

Evaluation - question 2

What is the effect on the boiling temperature when even more sodium chloride is added to the saline solution?

When more common salt is added, the boiling temperature is further elevated.

Evaluation - question 3

The boiling temperature of nitrogen is -196°C. What is the state of nitrogen at room temperature (at normal pressure)?

Gaseous.

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Initial question (repeated)

At which temperature does water boil at normal pressure?

Write down the temperature again 99.6 °C.