

Boiling point as a matter of geography

Developers: Relly Shore

Institute: The Weizmann Institute of Science
Country: Israel

Subject: Chemistry Times

Grade level: 10-12 graders

Curriculum content: steaming, boiling, evaporation, evaporating material, gas laws, and fume pressure.

Kind of activity: Inquiry laboratory

Anticipated time: 2 lessons of 90 minutes each + 1 lesson of 45 minutes.

Objectives/Competences

Scientific concepts: the dependence of the boiling temperature of a liquid on the pressure.

Skills: performing an experiment, asking questions, formulating an inquiry question and a hypothesis, planning an experiment, concluding conclusions, writing a report

Task description

The subject of this inquiry-laboratory activity is the possibility to boil water in a temperature that is different from 100⁰C. This phenomenon is connected to many situations that the students meet at real life, like: pressure cooker, different cooking time on high mountains, using pressure suits by pilots and astronauts etc. The inquiry laboratory activity gives the students the opportunity to explore their own questions and to experience all the stages of scientific inquiry.

Teaching guide

Discussion – driving question...

The objective of this activity in chemistry teaching is clarifying terms such as: steaming, boiling, evaporation, evaporating material, gas laws, and fume pressure.

In inquiry teaching, the main objective in the experiment is to improve specific inquiry skills. Since the experiment is not complex and doesn't require much time for its performance, it is possible to extend and develop inquiry skills before the teacher's selection.

It is possible to perform the experiment at various inquiry levels, but since time is not a constraint, it is recommended to perform the experiment as an open one after the students have already experienced 2-3 inquiry experiences in order to exercise, improve, and to deepen selected inquiry skills. I chose to extend and to deepen the subject in asking questions and phrasing the inquiry question and hypothesis in the first part, and to interpret and observe analysis in the second part.

Time Frame:

The task includes three sections:

1. The pre-inquiry phase: about 90 minutes (1 double lesson)
2. The inquiry phase: about 90 minutes (1 double lesson)
3. Presenting the outputs and the inquiry conclusion: about 45 minutes (1 lesson)

Beginning the activity

The activity can start by discussing the question: is the boiling temperature of water always 100°C ?

This experiment support the hypothesis that the boiling temperature varies, and it can initiate the discourse about the reasons for this phenomenon.

Specific Safety Notes:

- During the heating stage, a Bunsen or a small gas burner is used, and thus you should pay attention that the students work only while standing and with their hair tied up.
- The warm containers: isolating cloth should be used in order to prevent touching with hands.
- In some cases, the students are asked to examine what happens if the container is heated from various directions while they attempt to tilt the small gas burner in order to heat it from the side. It is prohibited to allow this. The small gas burner or the Bunsen must stand on the stable table and they must not be tilted.
- In case the students ask to replace the water with flammable liquid, you should strictly have it heated on an electric plate and not on the small gas burner or the Bunsen.
- Never use an Erlenmayer flask in this experiment, because of the danger of an inside explosion!!

Boiling by cooling – Notes for the teacher

Pre-Requirement Knowledge:

Contents: The students should be familiar with the 3 states of matter, attributes and models, as well as the terms pressure and temperature.

Skills: It is desired to perform the experiment after the students have already conducted 2-3 inquiry experiments, have been exposed to all the inquiry skills, and have faced difficulties in certain skills. In this activity, we try to handle these difficulties.

Linkage to the Syllabus:

The experiment can suit each of the following topics:

- State of matter
- Cross-molecular forces
- Energy
- Equilibrium
- Thermodynamics
- Gas laws

Position in the Teaching Sequence:

The experiment can be incorporated in various points of the teaching sequence. In most cases, the experiment is performed in the energy chapter during or after learning the chapter. It can also be integrated in other chapters, such as chemical structure and bonding, thermodynamics, etc.

Examples for Questions Asked by the Students:

- How does the water volume inside the container affect the creation of bubbles during the cooling phase?
- What is the relationship between the amount of the fumes that were condensed on the container wall due to the heating and the bubbles' pace after the cooling?
- How does the water volume in the container affect the creation of the bubbles?
- What is the relationship between the time of closing the container (flask) with the cork and the occurrence of the phenomenon of boiling while cooling?

Scientific Background to the Experiment

The experiment "boiling through cooling" starts when the container is open and contains water. Above the liquid phase there is a gas phase, which mostly contains air (in addition to the air, there are water fumes due to the water evaporation in the container). When heating the water until its boiling point, the water evaporation pace is accelerated and the concentration of the water fume in the gas phase is increased.

During the evaporation and the boiling, the water fumes push the air outside, and during the boiling, the concentration of the water fume in the container is very high. The instruction in the experiment is to boil the water for 2-3 minutes before closing the container so that most of the gas molecules that compose the air will leave the container and the gas phase will mostly contain water fumes.

During the cooling, the water is condensed (the water fumes will condense in a higher temperature than the gas molecule in the air) and the pressure in the container drops significantly (the more water fumes are present in the container, the more significant the change in the pressure). In the created pressure, the water may also boil at lower temperature.

It is possible to use this experiment to emphasize the terms evaporation, boiling and the things that come between them, the dependency of the boiling temperature in the pressure, to discuss the equilibrium during the transformation between state of matter, and it is possible to discuss the phases' diagram.

- Evaporation: A process that occurs in the liquid surface area. Molecules that contain high energy depart the liquid phase to the gas phase. The molecules that accumulate in the gas phase create the fumes that activate pressure on the liquid - "the fume pressure."

The higher the temperature, the bigger the average energy capacity of the particles and the larger the number of molecules that depart the liquid. The fumes pressure increases.

Under this topic, one can develop additional discussions regarding sweating (the body cooling mechanism), drying laundry at common temperature, the sense of "chill" upon leaving the shower room or when alcohol touches the skin.

- Boiling: The boiling temperature of a liquid is when the fumes' pressure inside the bubbles equals the external pressure. For water, 100⁰C is the boiling temperature in an atmospheric pressure (at sea level).

The heating of a liquid to a high enough temperature enables the creation of water fume bubbles inside the liquid and not only on its surface area. As long as the fumes' pressure inside the bubbles is lower than the liquid surface area pressure, the bubbles burst. As long as the temperature is increased, the fumes' pressure inside the bubbles is increased; they manage to exist, and due to their low density, compared to the liquid, they surface and burst, and the fumes are released to the gas phase.

External lower pressure compared to the pressure of one atmosphere (1 atm) will enable the water to boil at a lower than 100⁰C temperature. Thus, in higher locations where the pressure is lower than the one at sea level, the water boiling temperature is lower, the chemical reactions during cooking are slower, and the cooking time is longer. In a pressure cooker, the pressure that is created inside the cooker is higher than the atmospheric one, and the water boiling point is

higher than the boiling temperature in an open cooker. This is the reason why the cooking time is shorter.

Bibliography:

Whitten, K. W., Davis, R. E., Peck, L. M., & Stanley, G. G. (2006). General Chemistry, 8th edition. Stamford, CT: Thomson Learning.