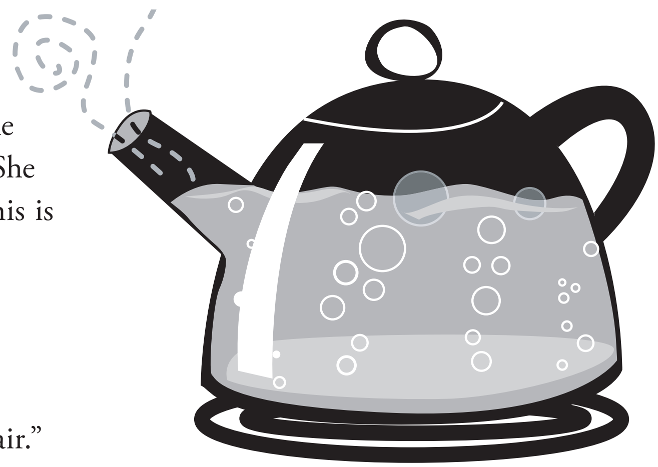
What's in the Bubbles?

Hannah is boiling water in a glass tea kettle. She notices bubbles forming on the bottom of the kettle that rise to the top and wonders what is in the bubbles. She asks her family what they think, and this is what they say:



Dad: "They are bubbles of heat."

Calvin: "The bubbles are filled with air."

Grandma: "The bubbles are an invisible form of water."

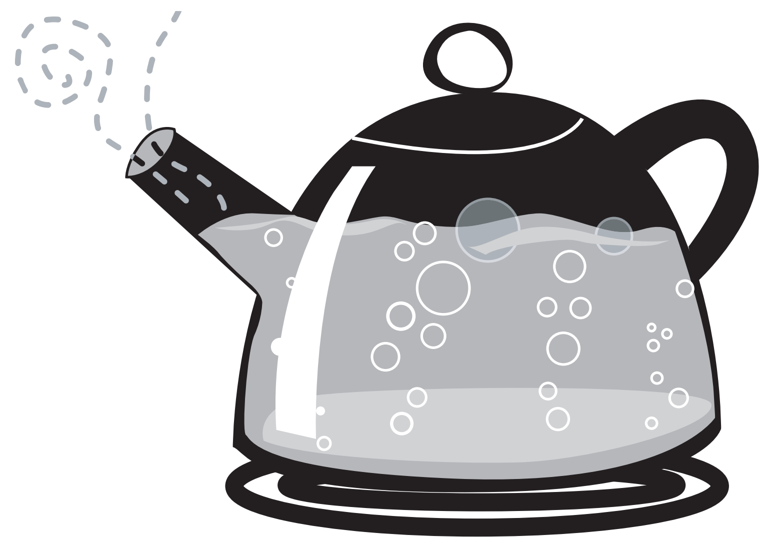
Mom: "The bubbles are empty—there is nothing inside them."

Lucy: "The bubbles contain oxygen and hydrogen that separated from the water."

Which person do you most agree with and why? Explain your thinking.

What's in the Bubbles?

Teacher Notes



Purpose

The purpose of this assessment probe is to elicit students' ideas about particles during a change in state. The probe is designed to find out if students recognize that the bubbles formed when water boils are the result of liquid water changing into water vapor.

Related Concepts

atoms or molecules, boiling and boiling point, change in state, energy

Explanation

The best response is Grandma's: The bubbles are an invisible form of water. This invisible water is called water vapor, a gaseous form of water that is not visible; it is unlike steam, which contains some condensed liquid water. When water is heated, the energy supplied to the system results in an increase in molecular motion. If enough heat is supplied, the molecules have so much energy that they can no longer remain loosely connected, sliding past one another as they do in a liquid. The energy now allows the attractive forces between water molecules to be overcome, and they form an "invisible" gas in the form of water vapor. Since the molecules in the gas phase are so much farther apart than in the liquid phase, they have a much lower density, are more buoyant (causing them to "bubble up"), and escape into the air. The bubble is the invisible water vapor.

Curricular and Instructional Considerations

Elementary Students

At the elementary level, students have experiences observing changes in state. The idea of change is connected to physical properties of materials by subjecting materials to heating and freezing. Water is often used as a familiar material for observing phase changes. Elementary students know change in states of water from the solid to liquid to gas phase, although the change from liquid to gas phase is a more abstract idea developed more fully in upper elementary grades.

In early elementary grades, students' experience with bubbles that result when water boils is primarily observational and is often linked to experiences at home boiling water on a stove. It is too early to introduce the abstract idea of invisible water molecules that make up water vapor. However, students can develop the precursor idea that water, in the form of invisible water vapor, escapes from the surface of an uncovered liquid. It may be too soon to introduce the idea that bubbles of boiling water contain water vapor, although students can observe steam going into the air from water that boils, even though steam contains some tiny droplets of water. Students must understand the simpler idea that water goes into the air in a form we cannot see before the idea of kinetic molecular theory, which helps explain why bubbles form and what they are, is introduced in middle school. The notion that water vapor is a gas is a grade-level expectation in the national standards. Children develop conceptions about bubbles early on through their everyday experiences, so it is not too early to ask students their ideas about boiling and bubbles. However, it is best to hold off on expecting a scientific explanation until students are ready.

SCILINKS THE WORLD'S A CLICK AWAY

Topic: Changes of State
Go to: *www.scilinks.org*
Code: USIS2H67

Middle School Students

In middle school, students have opportunities to examine the characteristics of different states of matter, and they begin to conceptualize the particle movements associated with phase changes from solid to liquid to gas. Students observe and measure characteristic properties such as boiling point and melting point. Students have had varied experiences with boiling water. They compare evaporation of a liquid under ordinary ambient conditions as well as in situations where increased application of heat is involved, such as boiling water. This probe is useful in determining students' preconceptions related to the common phenomenon of bubbles forming in boiling water.

High School Students

During high school, instructional opportunities connect the macroscopic properties of substances studied in middle school to a microscopic level. An understanding of kinetic molecular theory is a grade-level expectation in the standards that can be used to explain what the bubbles in boiling water are. This probe may be useful in determining if students revert to their earlier preconceptions about bubbles or if they can explain what is happening at a molecular level.

Administering the Probe

You may wish to use visual props for this probe. Bring a beaker of water or some other clear glass, boiling-safe container to a full boil so that students can see the bubbles forming and rising to the surface. Be sure students are wearing safety goggles and are not too close to the heat source if they are observing the boiling up close. Continue to heat the boiling water as students respond to the probe and explain their thinking. Teachers may want to continue to probe students' ideas about boiling by combining this probe with the "Turning the Dial" (p. 47) and "Boiling Time and Temperature" (p. 53) probes.

Related Ideas in *National Science Education Standards* (NRC 1996)

K–4 Properties of Objects and Materials

- Materials can exist in different states—solid, liquid, and gas. Some common materials, such as water, can be changed from one state to another by heating or cooling.

5–8 Properties and Changes in Properties of Matter

- A substance has characteristic properties, such as density, a boiling point, and solubility, all of which are independent of the amount of the sample. A mixture of substances often can be separated into the original substances using one or more of the characteristic properties.

9–12 Structure and Properties of Matter

★ Solids, liquids, and gases differ in the distances and angles between molecules or atoms and therefore the energy that binds them together. In solids the structure is nearly rigid; in liquids molecules or atoms move around each other but do not move apart; and in gases molecules or atoms move almost independently of each other and are mostly far apart.

Related Ideas in *Benchmarks for Science Literacy* (AAAS 1993)

3–5 Structure of Matter

- Heating and cooling cause changes in the properties of materials. Many kinds of changes occur faster under hotter conditions.

3–5 The Earth

★ When liquid water disappears, it turns into a gas (vapor) in the air and can reappear as a liquid when cooled, or as a solid if cooled below the freezing point of water. Clouds and fog are made up of tiny droplets of water.

6–8 Structure of Matter

★ Atoms and molecules are perpetually in motion. Increased temperature means greater average energy of motion, so most substances

★ Indicates a strong match between the ideas elicited by the probe and a national standard's learning goal.

expand when heated. In solids, the atoms are closely locked in position and can only vibrate. In liquids, the atoms or molecules have higher energy, are more loosely connected, and can slide past one another; some molecules may get enough energy to escape into a gas. In gases, the atoms or molecules have still more energy and are free of one another except during occasional collisions.

Related Research

- In a study by Barker (2004), many students ages 8–17 thought that the bubbles seen in boiling water are made of heat, air, oxygen, or hydrogen. Another conception was a change in state model that involved molecules breaking up on boiling and reforming on condensing. Barker also discovered that students find it hard to appreciate the reversibility of phase changes, thinking of each process as a separate event.
- Students' understanding of boiling precedes their understanding of evaporation from surfaces such as dishes and roads. In a sample of students ages 6–8, 70% understood that when water boils vapor comes from it and that the vapor is made of water. However, the same students did not recognize that when a wet surface dries, the water turns to water vapor (Driver et al. 1994).

Suggestions for Instruction and Assessment

- Use the phenomenon of bubbles to explain what happens to water molecules during a change in state from boiling liquid to gas.
- Encourage students to draw the stages of what they think is happening to the water as it is heated. Continue drawing right up to the stage where bubbles are formed and rising to the top and bursting. Carefully note how students get to the bubble stage—do the bubbles appear spontaneously in their drawings, or does the act of drawing help them make sense of what is happening to the water to form bubbles?
- Students may have trouble accepting that water vapor is in the bubbles if they do not understand the idea that water vapor is invisible. Help students contrast the concept of invisible water vapor with visible water in the air such as clouds and fog, which are made of tiny suspended droplets rather than water molecules spread far apart.
- Ask students to observe and describe what happens to the water level as the water boils. Encourage them to explain where the water went. How was it able to leave the glass container? Probe students to consider how the bubbles were involved in decreasing the water level. Challenge students who had the idea that the bubbles were air or nothing to explain how their model could account for the decreased water level.
- Consider how to present phase changes as reversible. Allow students to see heating and cooling cycles for themselves, so they can realize that phase changes do not result in a new substance being formed. This cycle may help them see that the water escapes as a gas in the bubbles and can be recovered again through cooling.

- By upper elementary grades, students should begin using terminology such as *water vapor*. Using the correct terminology and developing an understanding that water is in the air may help them overcome the idea that water changes into air rather than remaining the same substance but in a form that you cannot see.
- Be cautious when using the term *steam* with students to describe the gas or vapor form of water. What students are actually seeing over the boiling water when they refer to steam is a wispy mist—it is visible because it is water in a gaseous state that also contains tiny water droplets. Those tiny droplets scatter light at their surfaces, allowing us to "see" the "steam" in much the same way that we can see fog or clouds. The common use of the word steam is different from the way scientists or engineers use the word *steam*. To them, steam and vapor are both invisible forms of water in the gaseous state. However, when students (and often teachers) use the word *steam* in the context of this probe, they are usually calling the visible substance that forms above the boiling water a gas. Technically this common use of the word *steam* is incorrect since a gas is invisible. The Standards use the term *vapor* (not steam) to describe the invisible, gaseous form of water and explicitly point out that clouds and fog are made up of tiny droplets of water in order to distinguish forms of water in the air that we can see from forms we cannot see. Older students may be introduced to the scientific use of the word *steam* and compare it to how it is commonly used in our everyday language, once they have grasped the idea that substances in the gaseous state are not visible.

Related NSTA Science Store Publications and NSTA Journal Articles

See articles and publications listed on page 58.

Related Curriculum Topic Study Guides
(Keeley 2005)
"Physical Properties and Change"
"States of Matter"

References

American Association for the Advancement of Science (AAAS). 1993. *Benchmarks for science literacy.* New York: Oxford University Press.

Barker, V. 2004. *Beyond appearances: Students' misconceptions about basic chemical ideas. A report prepared for the Royal Society of Chemistry*. Cambridge, England.

Driver, R., A. Squires, P. Rushworth, and V. Wood-Robinson. 1994. *Making sense of secondary science: Research into children's ideas.* London: RoutledgeFalmer.

Keeley, P. 2005. *Science curriculum topic study: Bridging the gap between standards and practice*. Thousand Oaks, CA: Corwin Press.

National Research Council (NRC). 1996. *National science education standards.* Washington, DC: National Academy Press.