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Ask the Experts

March 2004

Providing answers to science questions
Send questions to *tst@nsta.org*

Q A recent email debate among science teachers focuses on the explosive nature of "superheated" microwaved water. Could someone address the real science that either debunks or supports this notion?

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A In this context superheating means the heating of a liquid above its normal boiling point. The superheated state is unstable and it can very rapidly turn into liquid at the boiling point, plus a substantial quantity of vapor. Superheated water produced in microwave ovens can cause serious burns to individuals who remove a container of liquid water in which the temperature is slightly more than 100°C.

In "normal" boiling in an electric kettle, the hottest water is next to the heating element, which is where bubbles of steam are first produced. A bubble grows as more water evaporates until its buoyancy overcomes the forces of surface tension and it floats to the surface.

In microwave heating, however, the water is usually hotter than the container because water absorbs energy from the microwaves better than most other materials. If the container has microscopic cracks, which retain trapped air, evaporation may occur at the air-water interface, and again bubbles of modest size will begin to rise through the water. If the container is really smooth, however, where will a bubble first start?

If there is nothing to nucleate the bubble, water can be heated somewhat above 100°C. This means that heat is added to the water without causing the production of steam. When the first bubbles form, the amount of heat produced by cooling the water down to 100°C is available to evaporate water. This can produce a surprisingly large volume of steam. Suddenly producing a large volume of steam in the middle of the water, rather than at its surface, causes the water to fly out—with possibly painful consequences.

You are probably wondering how the water temperature can exceed 100°C? At the surface between air and water, or between steam and water, water boils at 100°C. Water boils at 100°C if there is already a bubble of steam (or air) present. But in the absence of bubbles, water can be heated above 100°C.

Don't worry, it is still safe to use boiling water to calibrate thermometers. Once boiling has started, there are already bubbles and, at a water-steam interface, water goes from liquid to steam and back again at 100°C and atmospheric pressure. The production of the first steam bubble in pure water in a smooth walled container is, however, much less likely than further evaporation at the surface of an existing bubble. Similarly, pure water can be cooled below 0°C without freezing, in the absence of freezing nuclei.

The following steps should be followed in order to avoid being burned by superheated water:

- Before putting the water into the oven, insert a non-metal object with a surface that is not smooth (e.g., a wooden stirrer).
- Use a container in which the surface is at least a little scratched.
- Do not heat for longer than the recommended time for the quantity of water used.
- Tap the outside of the container a few times with a solid object while it is still in the oven. Use a long object so that your hand remains outside the oven.
- Alternatively, and still keeping your hand outside the oven, insert a stirrer while the container is still in the oven. (Thus, if vigorous boiling occurs, most of the boiling water will strike the inside of the oven.)
- Keep your face well away from the open oven door and from the container.

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