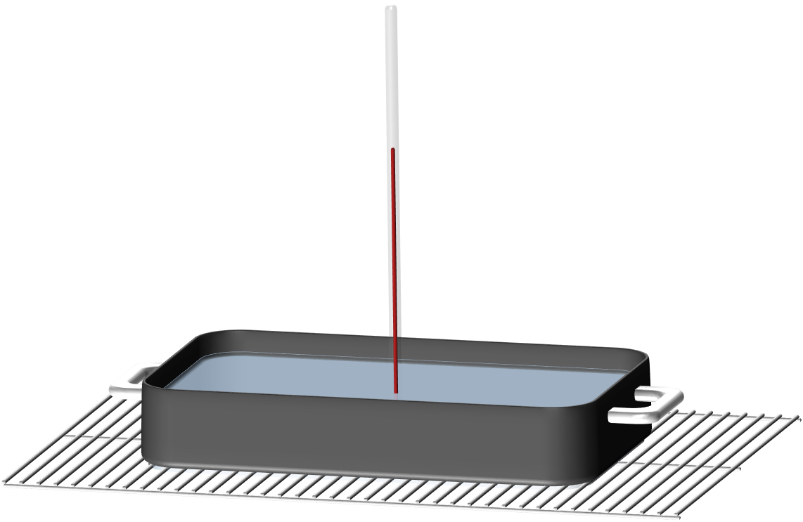
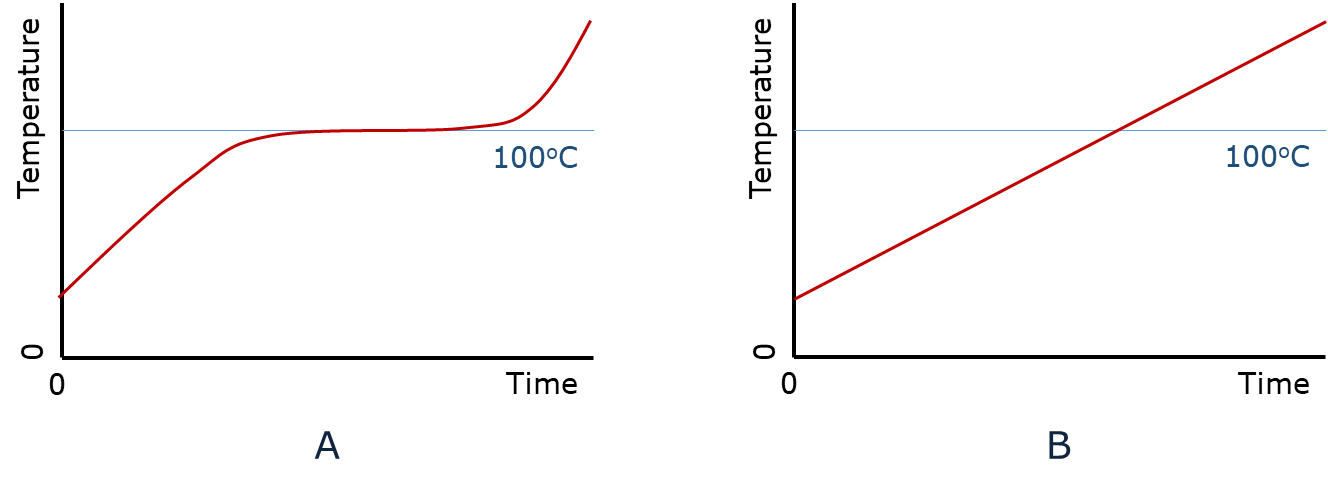
**Boiling point**



A tray of water is heated in an oven.

The temperature of the water is measured as it heats up and turns to steam.

**a.** Which graph shows how temperature changes as the water is heated?



**b.** What do you think is the best reason for your last answer?

*Put a tick (✓) in the box next to the best answer.*

|  |  |  |
| --- | --- | --- |
| **A** | At the boiling point heating separates molecules. |  |
|  |  |  |
| **B** | At the boiling point heating splits molecules into atoms. |  |
|  |  |  |
| **C** | At the boiling point heating increases the speed of molecules. |  |
|  |  |  |
| **D** | At the boiling point heating gives molecules more temperature. |  |

*Physics > Big idea PMA: Matter > Topic PMA3: Energy of moving particles > Key concept PMA3.3: Specific latent heat*

|  |
| --- |
| **Diagnostic question** |
| **Boiling point** |

**Overview**

|  |  |
| --- | --- |
| Learning focus: | Specific latent heat (of a particular change of state) is the amount of energy needed to change the state of 1 kg of a substance without changing its temperature. |
| Observable learning outcome: | Interpret a heating curve and explain physical changes to a substance that is heated from the liquid state to the gas state. |
| Question type: | Two-tier multiple choice |
| Key words: | Particle, molecule, atom, liquid state, gas state, boiling point |

**What does the research say?**

Heating a substance without a change of state increases the motion of particles and the temperature of the substance. When melting or vaporising a substance, its particles are moved apart against their electrostatic attraction, a very small amount for melting and rather more for vaporisation (Millar, 2011). As particles move apart against the attractive force that holds them together, their movement slows and prevents the temperature of the substance from rising until the change of state is complete.

In a large study of Turkish students (n=656), Adadan and Yavuzkaya (2018) found that 20% of those age 13-16 thought that heating always increases the temperature of a substance, even as it is boiling. This misunderstanding can be challenged effectively by direct measurement if students complete practical work to measure temperatures of a substance over the time that it changes state (Adadan and Yavuzkaya, 2018; Bauer and Chan, 2019). Temperature can be observed clearly to reach a constant value as water boils. A heating curve is easier to explain than a cooling curve and easier for most students to understand (Millar, 2011).

In a very large study of students in the United States, called Project 2061, the American Association for the Advancement of Science (AAAS) found that 34% of students (n=1105) age 14-18 held the misunderstanding that molecules of a substance break down into individual atoms when the substance boils. For example, molecules of water become atoms of hydrogen and oxygen when water boils.

**Ways to use this question**

Students should complete the questions individually. This could be a pencil and paper exercise, or you could use an electronic ‘voting system’ or mini white boards and the PowerPoint presentation. The follow on question will give you insights into how they are thinking and highlight specific misconceptions that some may hold.

If there is a range of answers, you may choose to respond through structured class discussion. Ask one student to explain why they gave the answer they did; ask another student to explain why they agree with them; ask another to explain why they disagree, and so on. This sort of discussion gives students the opportunity to explore their thinking and for you to really understand their learning needs.

*Differentiation*

You may choose to read the questions to the class, so that everyone can focus on the science. In some situations it may be more appropriate for a teaching assistant to read for one or two students.

**Expected answers**

a. A

b. A, at the boiling point heating separates molecules.

**How to respond - what next?**

When energy is transferred to water by heating its temperature increases when it is not at its boiling point because the average speed of its particles is caused to increase. At its boiling point the energy transferred by heating enables water molecules to overcome electrostatic forces of attraction between them and they separate to form a gas. Overcoming the electrostatic forces of attraction slows the particles and so their average speed is prevented from increasing (temperature does not increase) whilst this is happening.

A few students may struggle to interpret what the graphs are showing.

In part a, a minority of students may think wrongly that temperature continues to rise as water is boiling. For these students, answer C in part b is the most likely reason, but some may hold the misunderstanding that temperature is some form of substance that flows into the water with heating (answer D).

In part b, a significant number of students (34% in one large study) may think that heating is splitting the molecules of water into their constituent atoms. This is not the case as the electrostatic forces that hold atoms together in molecules are much stronger than those between molecules. It can be observed using a lighted splint that hydrogen and oxygen (a highly explosive rocket fuel mixture) do not form above boiling water.

If students have misunderstandings about interpreting a heating curve and explaining physical changes to a substance that is heated from the liquid state to the gas state, it can help to challenge their thinking with direct observation. Regular readings of temperature as water is heated, or a real-time plot using a temperature probe, clearly show a rise in temperature stops during boiling, although showing the continued increase in temperature after boiling is not easily done in a laboratory.

The following BEST ‘response activity’ could be used in follow-up to this diagnostic question:

* Response activity: Faster melting

**Acknowledgments**

Developed by Peter Fairhurst (UYSEG).

Images: Peter Fairhurst (UYSEG).

**References**

AAAS. *Science Assessment Topic: Atoms, Molecules and States of Matter* [Online]. Available at: <http://assessment.aaas.org/> [Accessed July 2020].

Adadan, E. and Yavuzkaya, M. N. (2018). Examining the progression and consistency of thermal concepts: a cross age study. *International Journal of Science Education,* 40 (4)**,** 371-396.

Bauer, C. F. and Chan, J. Y. K. (2019). Non-science majors learn about heat, temperature, and thermodynamics using the particulate nature of matter and guided-inquiry instruction. *American Journal of Physics,* 87**,** 550-557.

Millar, R. (2011). Energy. In Sang, D. (ed.) *Teaching Secondary Physics.* London: Hodder Education.