**Freezing point**

Salol is a chemical that melts at 41.5oC.

Its melting point is 41.5oC

Its freezing point is 41.5oC.

Some salol was warmed to 60oC in a boiling tube and allowed to cool.

As it cools its temperature is measured using a thermometer.

**1.** As it cools, when does salol reach its freezing point?

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

|  |  |  |
| --- | --- | --- |
| **A** | As soon it starts to change into its solid state. |  |
|  |  |  |
| **B** | When about half of it is in a solid state. |  |
|  |  |  |
| **C** | Only when all of it is in a solid state. |  |

**2.** After it reaches its freezing point, when does the temperature of salol start to fall again?

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

|  |  |  |
| --- | --- | --- |
| **A** | As soon it starts to change into its solid state. |  |
|  |  |  |
| **B** | When about half of it is in a solid state. |  |
|  |  |  |
| **C** | Only when all of it is in a solid state. |  |

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

|  |
| --- |
| **Diagnostic question** |
| **Freezing point** |

**Overview**

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| --- | --- |
| 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 cooling curve and explain physical changes to a substance that is cooled from the liquid state to the solid state. |
| Question type: | Simple multiple choice |
| Key words: | Freezing point, melting point, solid state, liquid state |

**What does the research say?**

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 that shows a similar plateau when a substance melts can be produced by heating salol in a boiling tube in a water bath. A heating curve is easier to explain than a cooling curve and easier for most students to understand (Millar, 2011).

Adadan and Yavuzkaya (2018) found that 29% of 15- to 16-year-olds in their study thought that ice was always 0oC, and 32% that water cannot be 0oC. These students appear to be relying on recall of factual knowledge rather than clear understanding. In other studies, students believed that the temperature of ice cubes existing in a warm room must be above 0°C, and that water cannot exist at 0°C even if ice cubes remain in a puddle of water (Chu et al., 2012; Kacovsky, 2015).

Cooling a substance without a change of state reduces the motion of particles and the temperature of the substance. As a substance changes state from a gas to a liquid, or from a liquid to a solid, the particles are pulled together by their electrostatic attraction. The attractive force accelerates particles as they move closer together and the particles’ increased movement prevents the temperature of the substance from falling until the change of state is complete.

**Ways to use this question**

Students should complete the question 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 answers to the question will show you whether students understood the concept sufficiently well to apply it correctly.

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**

1. A, as soon it starts to change into its solid state.

2. C, only when all of it in a solid state.

**How to respond - what next?**

The temperature of salol falls as energy is transferred from the salol to its surroundings by heating. When it reaches its freezing point, particles in salol are able to form closer connections with each other because they are not moving as quickly. Attractive electrostatic forces pull the particles closer together. The forces accelerate the particles, which stops the average speed of the particles from falling. This keeps the temperature of salol at its freezing point until *all* particles have formed closer connections with neighbouring particles and all the salol is in its solid state.

This question addresses misunderstandings about what happens when a substance freezes and changes into its solid state.

A significant number of students may not have much of an idea what happens as a substance freezes and some of their answers are likely to be guesses. If they are guessing, they are likely to get one or both answers wrong.

Students with the misunderstanding that temperature continues to fall as a substance changes state will most likely select the same answer for both questions. In effect, they are choosing a consistent point in the process at which the temperature could be defined as being the freezing point. If students have the misunderstanding that a substance cannot be in its solid and liquid state at the same temperature, they are more likely to choose either answer A for both questions or answer C for both.

If students have misunderstandings about explaining the physical changes to a substance that is cooled from the liquid state to the solid state, it can help to challenge their thinking with direct observation. Regular readings of temperature as salol freezes, or a real-time plot using a temperature probe, clearly show a fall in temperature stops during freezing and continues only after all the salol has changed into its solid state.

**Acknowledgments**

Developed by Peter Fairhurst (UYSEG).

Images: Peter Fairhurst (UYSEG).

**References**

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.

Chu, H.-E., et al. (2012). Evaluation of Students' Understanding of Thermal Concepts in Everyday Contexts. *International Journal of Science Education,* 34:10**,** 1509-1534.

Kacovsky, P. (2015). Grammar school students' misconceptions concerning thermal phenmomena. *Journal of Baltic Science Education,* 14(2)**,** 194-206.

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