

The Thermometer That Stopped Climbing

Learning target: I can use evidence from a passage to explain the difference between temperature, thermal energy and heat, and why a substance's temperature stays level while it melts or boils.

Reading with evidence

About 40 min

Individual

MS-PS1-4 · practice

MS-PS3-4 · supports

reading

writing

Standards connections

MS-PS1-4 (practice, the explanation half: why temperature holds steady during a change of state): The passage models what happens to particle motion, temperature and state as thermal energy is added to and removed from water, and the questions ask students to restate that model with evidence. Students explain rather than build their own model here; W4 asks them to draw it.

MS-PS3-4 (supports, only the ideas that temperature is an average and that thermal energy depends on the amount of matter): MS-PS3-4 is a California Grade 6 PE, taught before this lesson. Paragraph 2 and question 2 rely on its core idea that temperature tracks average kinetic energy while total thermal energy also depends on mass. No question asks students to plan an investigation or calculate energy.

Purpose: build · **Time:** about 40 minutes · **Format:** individual

Answers with reasoning

The Thermometer That Stopped Climbing

[1] Priya's class set a beaker of crushed ice from the freezer on a hot plate. A digital thermometer probe sat in the ice, and Priya stirred gently. The reading started at -18°C and climbed quickly. Then, at 0°C , it stopped. For several minutes the hot plate stayed on, the ice shrank into slush, and the number did not budge. Only when the last sliver of ice was gone did the reading begin to rise again, all the way to 100°C . There it stopped a second time while the water bubbled hard. Where was the hot plate's energy going while the thermometer was stuck?

[2] The answer depends on three separate ideas. **Temperature** tracks how energetic a substance's particles are on average: it reflects their average kinetic energy, the energy they have because they move. **Thermal energy** adds up the energy of every particle in a sample, so it depends on how much matter there is as well as on how energetically the particles move. A teacup at 80°C has a higher temperature than a swimming pool at 26°C , because its particles are more energetic on average. Yet the pool holds far more thermal energy, because it contains hundreds of thousands of times more water.

[3] The third idea is **heat**: thermal energy on its way from something warmer to something cooler. Where two objects touch, their particles collide constantly. In these collisions, energy tends to pass from more energetic particles to less energetic ones, so energy flows from the warmer object into the cooler one. The flow continues until both reach the same temperature. After that, the particles still trade energy, but equal amounts go each way, so neither temperature changes. Cold never flows anywhere. An ice cube feels cold in your hand because energy is leaving your skin.

[4] In ice, each water molecule is held in a fixed spot by attractions to its neighbors, and it can only vibrate. Below 0 °C, the incoming energy makes the molecules vibrate harder, so the temperature rises. At 0 °C (at normal air pressure), the added energy goes into pulling molecules free of their fixed spots instead of making them move faster on average. Since the average kinetic energy stays the same, so does the temperature. The sample's thermal energy is still growing, though: liquid water at 0 °C has more thermal energy than the same mass of ice at 0 °C. On a graph of temperature against time, this level stretch is called a plateau.

[5] The same thing happens at the boiling point, 100 °C at sea-level air pressure. There the energy pulls molecules completely away from one another, and bubbles of water vapor form deep inside the liquid. Turning the hot plate higher makes the water boil away faster, but it does not make the boiling water hotter. Evaporation is different: it happens only at the surface, at almost any temperature, whenever a fast-moving molecule near the top escapes. That is why a puddle dries on a cool day. Water vapor itself is invisible. The white cloud above a boiling pot is made of tiny drops of liquid water that formed when the vapor cooled in the air.

[6] Every change can also run in reverse, and then energy leaves the substance. When water vapor touches a cold can or a cold window, it passes energy to the colder surface. The molecules slow down until their attractions hold them together in drops, which is condensation. A freezing puddle's temperature holds at 0 °C until it is frozen solid, because each molecule that locks into place gives up energy to the colder air around it.

[7] Each substance changes state at its own temperatures because the attractions between its particles differ in strength. Helium atoms attract one another so weakly that helium boils at about -269 °C and cannot be frozen at all at normal air pressure. Water molecules attract one another strongly for their small size, so water must reach 100 °C to boil. The atoms in iron hold on so tightly that iron does not melt until about 1,538 °C. Melting and boiling points are a measuring stick for how tightly particles hold on.

Questions: cite the passage

1. Paragraph 1: At which two temperatures did the reading stop climbing? What was the hot plate doing during those times, and what was happening to the water?

Answer: It stopped at 0 °C and again at 100 °C. The hot plate stayed on the whole time, adding energy. At 0 °C the ice was melting into slush; at 100 °C the water was boiling (bubbling hard).

Why: Paragraph 1 describes both plateaus and says the hot plate stayed on, which sets up the puzzle about where the energy goes.

Also acceptable: Accept 'the ice turned to slush and then to water' for melting.

- Both temperatures
- States that the hot plate kept adding energy
- Names melting at 0 °C and boiling at 100 °C

2. Paragraph 2: Which has the higher temperature, the teacup at 80 °C or the pool at 26 °C? Which has more thermal energy? Quote the words that explain why the two answers are different.

Answer: The teacup has the higher temperature; the pool has more thermal energy. Quotes: temperature 'reflects their average kinetic energy', while thermal energy 'depends on how much matter there is'; the pool 'contains hundreds of thousands of times more water'.

Why: Temperature is an average, so a small sample can be hotter; thermal energy is a total, so a huge amount of cooler water can hold far more.

Also acceptable: Accept a quote of either sentence that defines the two terms.

- Teacup higher temperature
- Pool more thermal energy
- Quotes or closely paraphrases the average versus total idea

3. Paragraph 3: Use particle collisions to explain why your hand feels cold when you hold an ice cube. Then explain why the transfer of energy between two objects eventually stops changing their temperatures.

Answer: The particles of your skin are more energetic than the particles of the ice, so in their collisions energy passes from your skin to the ice. Your hand is losing energy, which feels cold; no cold moves into you. The net transfer stops changing temperatures once both are at the same temperature, because then equal amounts of energy pass each way.

Why: Paragraph 3 explains heat as energy passing from more energetic to less energetic particles and says the flow continues until the temperatures are equal.

Also acceptable: Accept 'the ice melts and your hand warms the ice' if the energy direction is clear.

- Energy moves from hand to ice
- Explains the feeling of cold as energy leaving the skin
- Equal temperatures mean equal exchange both ways

4. Paragraph 4: While the ice melts at 0 °C, where does the hot plate's energy go? Does the thermal energy of the sample change during the plateau? Quote the sentence that answers the second question.

Answer: The energy goes into pulling water molecules free of their fixed spots in the ice, not into making them move faster on average. Yes, thermal energy increases. Quote: 'The sample's thermal energy is still growing, though: liquid water at 0 °C has more thermal energy than the same mass of ice at 0 °C.'

Why: This is the key accuracy point: during melting at constant pressure, temperature is steady because average kinetic energy is steady, but the sample still gains thermal energy.

Also acceptable: Accept 'it breaks the ice apart' if the student adds that the molecules do not speed up.

- Energy frees molecules from fixed positions (overcomes attractions)
- States that thermal energy increases
- Quotes the sentence

5. Paragraph 5: Give two differences between evaporation and boiling that the passage describes.

Answer: Evaporation happens only at the surface; boiling forms bubbles of vapor deep inside the liquid. Evaporation happens at almost any temperature; boiling happens at the boiling point (100 °C for water at sea level).

Why: Both differences are stated in paragraph 5.

Also acceptable: Accept 'a puddle evaporates on a cool day, but water must be at 100 °C to boil' as the temperature difference.

- Location difference (surface versus throughout)
- Temperature difference (many temperatures versus the boiling point)

6. Paragraph 5: Priya sees a white cloud above the boiling beaker. According to the passage, what is the cloud?

Answer: B. Tiny drops of liquid water that formed as vapor cooled.

Why: Paragraph 5 says water vapor is invisible and the white cloud is liquid droplets. A is the common misconception; C and D are not in the passage.

Also acceptable: None.

7. Paragraph 6: Why does the temperature of a freezing puddle stay at 0 °C until it is frozen solid? Say where the energy goes.

Answer: As each molecule locks into a fixed place in the ice, it gives up energy to the colder air around it. That released energy keeps the remaining water from cooling below 0 °C, so the temperature stays level until all the water has frozen. The energy goes into the colder surrounding air.

Why: Paragraph 6 states that the freezing puddle holds at 0 °C because molecules give up energy as they lock in place. Students should see this as the melting plateau in reverse.

Also acceptable: Accept 'it is melting played backward' if the student also says where the energy goes.

- Molecules give up energy as they lock in place
- The energy goes to the colder surroundings
- Temperature stays level until freezing is complete

8. Paragraph 7: Helium boils at about –269 °C, water boils at 100 °C, and iron does not even melt until about 1,538 °C. Use the passage's idea about attractions to explain this order.

Answer: Helium atoms attract one another very weakly, so very little energy is needed to pull them apart, and helium boils at an extremely low temperature. Water molecules attract strongly, so water needs much more energy and boils at 100 °C. Iron's atoms hold on even more tightly, so iron needs so much energy that it only melts at about 1,538 °C. Stronger attractions mean higher melting and boiling points.

Why: Paragraph 7 links attraction strength to the temperature at which a substance changes state.

Also acceptable: Accept 'stickier particles need more energy to separate' as the core idea.

- Weak attractions for helium, strong for water, stronger for iron
- Links stronger attraction to more energy needed and a higher change temperature

9. While the water in Priya's beaker is boiling, her teacher turns the hot plate to its highest setting. Predict what the thermometer will read and what Priya will see. Explain your prediction using what happens to the water molecules, and cite at least two different paragraphs.

Answer: The thermometer will still read about 100 °C. Priya will see the water bubble more vigorously and boil away faster. More energy per minute pulls more molecules completely away from one another each minute (paragraph 5), but the molecules still in the liquid do not gain average kinetic energy, so the temperature stays the same while it boils (paragraphs 4 and 5).

Why: At constant pressure, boiling water stays at its boiling point; extra energy speeds up the change of state, not the temperature. Paragraph 5 says this directly, and paragraph 4 explains the reason with average kinetic energy.

Also acceptable: Accept 'a degree or so higher for a moment' if the student explains that the reading settles back at the boiling point.

- Predicts the reading stays at about 100 °C
- Predicts faster boiling
- Explains that the energy goes into separating molecules, not raising their average kinetic energy
- Cites two paragraphs

Teacher notes

The passage is original and just under 700 words. It is written to correct two simplifications in the lesson: that gaining thermal energy always makes temperature rise (paragraph 4 makes the plateau explicit), and that water vapor condenses only at 100 °C (paragraph 6 uses a cold can, at room conditions). Temperatures for melting and boiling are tied to normal or sea-level air pressure. The white cloud in q6 is a common confusion: the clear gap just above a kettle spout is the actual vapor. The extension previews the cooling curve in W4: the final flat stretch at -20 °C is thermal equilibrium with the freezer, not a change of state.

Scaffold offered to students: Find it, then say it

Before answering, write the paragraph number next to the question and box the key sentence in the passage. Then answer in your own words using this frame: 'Paragraph __ says __. This means __.' For q9, reread the third sentence of paragraph 5 first.

Extension: The plateau that is not a state change

Priya puts a beaker of 50 °C water into a freezer set at -20 °C and records its temperature for a whole day. Sketch the graph you predict. It should have two flat stretches. Label which flat stretch is a change of state and which is not, and explain, using paragraph 3, why the second flat stretch happens at -20 °C.