

Heat, Temperature and State Changes: Mastery Check

Learning target: I can show that I can tell heat, temperature and thermal energy apart, predict which way energy moves, name and model all six changes of state, read a heating curve, and explain why substances change state at different temperatures.

Retrieval and mastery check

About 40 min

Individual

MS-PS1-4 · assesses

MS-PS3-4 · supports

independent practice

writing

Standards connections

MS-PS1-4 (assesses, the whole PE: drawn and written models that predict and describe particle motion, temperature and state as thermal energy is added or removed): Items 4, 5, 7 and 12 ask students to predict and describe particle motion, temperature and state for pure substances gaining or losing thermal energy, including a drawn particle model and a heating-curve story for a new substance. All items are qualitative or read temperatures and times; none calculates energy.

MS-PS3-4 (supports, only the ideas that temperature is an average and that the energy needed depends on mass): MS-PS3-4 is a California Grade 6 PE. Items 2 and 10 revisit its idea that thermal energy and the energy a change needs depend on mass as well as temperature. Students do not plan an investigation or calculate energy.

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

Answers with reasoning

Part A: Retrieval (items 1-11)

1. Which statement about temperature is correct?

2 pts

Answer: B. It measures the average kinetic energy of a sample's particles.

Why: A describes thermal energy; C confuses heat (energy in transfer) with stored energy; D confuses an average with a total.

Also acceptable: None.

2. A 2-liter pot of water and a 200-milliliter mug of water are both at 60 °C. Which statement is true? 2 pts

Answer: B. They have the same temperature, and the pot has more thermal energy.

Why: Temperature is an average, so equal readings mean equal temperature; thermal energy is a total, and the pot has ten times as much water.

Also acceptable: None.

3. A metal spoon at 22 °C is placed in a bowl of soup at 70 °C. Which way does energy move as heat? 3 pts
What happens to the temperature of each object, and when does the overall transfer stop?

Answer: Energy moves as heat from the warmer soup into the cooler spoon. The spoon's temperature rises and the soup's falls (only slightly, because there is much more soup). The overall transfer stops when the spoon and the soup reach the same temperature; after that, equal amounts of energy pass each way.

Why: Heat flows from warmer to cooler until temperatures are equal.

Also acceptable: Accept 'the soup cools a tiny bit' or 'the soup barely changes' for the soup.

- Soup to spoon
- Spoon warms, soup cools
- Stops at equal temperatures

4. Name the change of state in each case and say whether thermal energy goes into or out of the substance that changes. 3 pts

Answer: a. Sublimation; into the carbon dioxide. b. Condensation; out of the water vapor (into the cooler grass). c. Freezing (solidifying); out of the chocolate. d. Boiling; into the soup's water.

Why: Each change is named from its start and end states; changes toward freer particles take energy in and the reverse changes give energy off.

Also acceptable: b: accept 'condensation, energy out to the cold grass'. d: accept 'evaporation (boiling)'. Award 3 points for all eight cells, 2 for six or seven, 1 for four or five.

- Four changes correct
- Four energy directions correct

Heating an unknown pure solid at a steady rate (teaching dataset)

Simulated teaching dataset: the numbers are invented to be realistic, not measured.

Time (min)	Temperature (°C)
0	20
2	32
4	44
6	54
8	54
10	54
12	54
14	62
16	70

Simulated data for items 5a to 5c. The sample started as a solid.

5. Use the table. (a) What is the melting point of the substance? (b) How fast did its temperature rise from minute 0 to minute 4, in °C per minute? Show the calculation. (c) What state or states were present at minute 9? 3 pts

Answer: (a) 54 °C. (b) $(44\text{ °C} - 20\text{ °C}) \div (4\text{ min} - 0\text{ min}) = 24 \div 4 = 6\text{ °C per minute}$. (c) Solid and liquid together; the substance was melting.

Why: The level stretch at 54 °C from about minute 6 to minute 12 is the melting plateau, and minute 9 falls in the middle of it.

Also acceptable: For (c), accept 'melting' alone.

- 54 °C
- 6 °C/min with work shown
- Solid and liquid at minute 9

6. True or false: 'Adding thermal energy to a substance always raises its temperature.' Circle your answer and use the table above to explain. 2 pts

Answer: False. From about minute 6 to minute 12 the hot plate kept adding energy, but the temperature stayed at 54 °C, because the energy was freeing particles from the solid instead of raising their average kinetic energy.

Why: During a change of state at steady pressure, a pure substance's temperature holds steady.

Also acceptable: Accept an explanation using water melting at 0 °C if it names the plateau idea.

- Marks false
- Cites the level stretch in the table
- Says where the energy goes

7. Draw two particle boxes: water vapor in the air near a cold window, and the same water after it has condensed on the glass. Show spacing and motion, and draw one arrow showing which way energy moves between the water and the window. 3 pts

Answer: Before: a few water molecules far apart with long motion lines (gas). After: molecules touching in a small drop on the glass, sliding past one another, with shorter motion lines (liquid). Arrow from the water to the cold window.

Why: The vapor loses energy to the colder glass, slows, and its attractions hold the molecules together as liquid. Molecules stay the same size.

Also acceptable: Accept a single box with the window drawn in, as long as both states and the arrow appear.

- Gas spacing and motion before
- Liquid spacing and motion after
- Energy arrow from water to window
- Molecules the same size in both boxes

8. Helium boils at about -269 °C, but water boils at 100 °C. What best explains the difference? 2 pts

Answer: B. The attractions between helium atoms are much weaker than those between water molecules.

Why: Weaker attractions take less energy to overcome, so helium separates into a gas at a much lower temperature. A and C are not the lesson's explanation (and helium atoms are smaller than water molecules, not bigger). D is false: at the same temperature, the lighter helium atoms actually move faster on average than water molecules.

Also acceptable: None.

9. A puddle on the playground disappears on a 15 °C day. Which explanation is correct?

2 pts

Answer: B. The most energetic water molecules at the surface escaped into the air as vapor.

Why: Evaporation happens at many temperatures. A wrongly says the puddle boiled; C and D reflect the misconceptions that water turns into air or cannot become a gas below 100 °C.

Also acceptable: None.

10. Two identical hot plates heat a 150 g block and a 300 g block of ice, both already at 0 °C. The 150 g block takes 6 minutes to melt completely. How long should the 300 g block take? What does the thermometer read in each block while it melts? Explain briefly. 3 pts

Answer: 12 minutes: twice the mass of ice needs twice as much energy to melt, and the hot plates deliver energy at the same rate. Both thermometers read 0 °C while the ice melts.

Why: Mass affects how long the change takes, not the temperature at which it happens.

Also acceptable: Accept '6 × 2 = 12 min' with the 0 °C reading.

- 12 minutes
- 0 °C in both
- Reason: twice the mass needs twice the energy at the same rate

11. A cold can of juice gets covered in drops on a humid day but stays nearly dry in a room with very dry air. Explain where the drops come from and why the amount of water vapor in the air matters. 3 pts

Answer: The drops come from water vapor in the room air. The can is colder than the air, so heat flows from the air into the can; vapor touching the can loses thermal energy, slows down, and its attractions hold the molecules together as liquid drops (condensation). In very dry air there is very little water vapor to condense, so few or no drops form.

Why: Both a cold surface and water vapor are needed for condensation on the can.

Also acceptable: None.

- Source is water vapor in the air
- Energy flows from the air or vapor to the cold can
- Vapor slows and condenses
- Less vapor means fewer drops

Part B: Synthesis (item 12)

12. Ethanol melts at about -114°C and boils at about 78°C . A sample of solid ethanol at -130°C is heated at a steady rate until it is a gas at 90°C . In one paragraph, tell what happens to the particles' motion, the temperature and the state at each stage, including both level stretches and why the temperature holds steady in each. End by explaining why ethanol's melting and boiling points are lower than water's. 4 pts

Answer: Example: At -130°C the ethanol is a solid whose molecules vibrate in fixed positions. As energy is added, they vibrate harder and the temperature rises until it reaches -114°C . There the temperature holds steady while the solid melts, because the energy is freeing molecules from their fixed positions instead of raising their average kinetic energy. When all of it is liquid, the molecules slide past one another faster and faster, and the temperature rises again to 78°C . It holds steady a second time while the ethanol boils, because the energy is pulling molecules completely away from one another into gas, with bubbles of vapor forming throughout the liquid. Once it is all gas, the molecules move freely and faster as the temperature rises to 90°C . Ethanol melts and boils at lower temperatures than water because the attractions between its molecules are weaker, so less energy is needed to overcome them.

Why: This item asks for the whole PE in a new substance: motion, temperature and state through five stages, both plateaus explained, and attraction strength compared with water.

Also acceptable: Award 4 points for all four criteria, 3 for three, 2 for two, 1 for one.

- Five stages in the right order with correct states
- Both level stretches at -114°C and 78°C , each explained by energy separating molecules rather than speeding them up
- Particle motion increases in the sloping stages
- Weaker attractions than water explain the lower melting and boiling points

Teacher notes

Points: q1 2, q2 2, q3 3, q4 3, q5 3, q6 2, q7 3, q8 2, q9 2, q10 3, q11 3, q12 4; total 32. Items 5, 6, 10 and 12 test the chapter's main accuracy correction (temperature holds steady during a change of state), and items 1, 2 and 3 test temperature, thermal energy and heat; weight them in reteaching decisions. The unknown solid in item 5 is invented; its sloping stretches are consistent with steady heating (6°C per minute as a solid, 4°C per minute as a liquid). Item 12 uses ethanol on purpose so students apply the model to a substance other than water; its melting and boiling points are real. No item calculates energy, keeping the quiz inside the qualitative emphasis of MS-PS1-4.

Scaffold offered to students: Optional supports for this check

Students who need it may use a one-page reference with the six-change map (solid, liquid and gas joined by arrows marked energy in or energy out) and the sentence frame 'Temperature is the ___ ; thermal energy is the ___ ; heat is ___.' Items may be read aloud. For item 12, offer a five-box organizer: solid warming, melting, liquid warming, boiling, gas warming.

Extension: Write a question that would catch a misconception

Choose one misconception from this chapter (for example, cold flowing, temperature always rising when energy is added, or the white cloud being water vapor). Write a multiple-choice question with four options in which each wrong option matches a specific mistaken idea. Write a one-line note for each wrong option explaining which misconception it catches, and trade with a classmate to test it.