

The Bath and the Melting Ice: Where Does the Energy Go?

Investigation question: When a cup of ice sits in a warm bath, energy flows into it the whole time. What happens to the temperature and the particles of the ice while it melts, and after it has melted?

Collaborative systems modeling

Groups of 4

1 session

Setup 8 · Activity 35 · Cleanup 7 min

MS-PS1-4 · assesses

MS-PS3-4 · supports

Scientific purpose

Students define a system (the ice and its meltwater in a cup) and its surroundings (a tub of warm water), predict the shape of the temperature curve, then read both temperatures every minute as the ice melts and the meltwater warms. They graph the two curves on one set of axes, use the cooling bath as evidence that energy kept entering the cup during the flat stretch at 0 °C, and draw a three-panel particle model explaining what that energy did before, during and after melting.

Why this helps students with this chapter

Students readily accept that 'heating makes things hotter', and a textbook curve with a flat stretch is easy to memorize without believing. Watching a thermometer sit at 0 °C for ten minutes while their own bath thermometer keeps falling makes the puzzle undeniable: energy is clearly going in, yet the temperature is not changing. Having to name the system, the surroundings and the boundary forces them to track where the energy goes, and the three-panel drawing turns the flat stretch into a particle explanation they built themselves.

Standards connections

MS-PS1-4 (assesses, a model that predicts and describes particle motion, temperature and state as thermal energy is added to a pure substance): Students predict the curve, measure it, and then develop a drawn particle model that describes what the particles are doing in each stretch and explains why the temperature holds at the melting point while the state changes. The drawing and the written explanations (q5, q6, drawing) are evidence for the PE, and no energy is calculated.

MS-PS3-4 (supports, the bath's temperature change as evidence of energy transferred): This is a California Grade 6 PE. The falling bath temperature serves as evidence that energy is being transferred into the cup, which draws on the Grade 6 idea that a sample's temperature change reflects energy gained or lost; students do not plan an investigation of mass and energy here.

Roles (rotate each session)

- **Ice tender:** Steadies the cup in the bath by its rim, stirs the ice gently and constantly with a plastic spoon, keeps the thermometer bulb in the middle of the ice, and calls out what the cup contains each minute.

- **Bath tender:** Stirs the bath with the second spoon before each reading and reads the bath thermometer at every call.
- **Timer and reader:** Calls each minute, reads the cup thermometer at eye level, and notes the exact time the last piece of ice disappears.
- **Recorder:** Writes both temperatures and the cup observations in the data table, then leads the group graph.

Materials

Item	Quantity	Per	Note
Crushed ice straight from a freezer	150 g (about 1 1/4 cups loosely packed)	group	Keep it in the freezer until the moment of use so it starts below 0 °C. A bag of store ice crushed in a towel works.
Thin clear plastic cup, 9 to 12 oz (270 to 350 mL)	1 plus 1 spare	group	
Plastic tub or mixing bowl holding at least 3 L	1	group	
Warm tap water at 40 to 45 °C, prepared and checked by the teacher	2 L	group	Never warmer than 45 °C for students.
Thermometer: alcohol-filled glass lab thermometer (–10 to 110 °C) or digital probe thermometer	2	group	No mercury thermometers.
Plastic spoons or wooden stir sticks	2	group	
Stopwatch or classroom timer	1	group	
Kitchen scale reading to 1 g	1 or 2	class	
Tray or baking sheet and paper towels	1 tray, several towels	group	
Recording sheet with graph grid	1	student	

Estimated cost: About 5 per class with thermometers on hand; about 30 to 70 if alcohol thermometers must be bought (more for digital probes) (an estimate; Estimate: a bag of ice about \$3 and a sleeve of plastic cups about \$3; alcohol lab thermometers about \$2 to \$4 each and digital probe thermometers about \$8 to \$12 each, two per group for 6 to 8 groups; tubs, spoons, trays and the scale are classroom or kitchen stock.)

Safety

- Water above about 50 °C can scald. Only the teacher prepares or handles warm water, and students receive water no warmer than 45 °C. Report any water that feels uncomfortably hot.
- Glass thermometers can break and cut. Never stir with a thermometer; rest it on the tray, not at the edge of a table; tell the teacher at once if one breaks and do not pick up the pieces.
- Spilled water and melting ice make floors slippery. Work over the tray and wipe spills right away.

- Ice straight from a freezer can stick to dry skin and cause cold injury with long contact. Move it with a spoon or scoop and hold it only briefly.
- Lab ice and water are not for eating or drinking; cups and spoons used here stay in the lab kit.
- Keep phones, kettles and other electrical devices away from the trays of water.

Teacher preparation and setup

1. Check every thermometer the day before: stir it for two minutes in a cup packed with crushed ice and a little water. It should read 0 °C within 1 °C. Label any that read high or low with their correction, and set aside any that are off by more than 2 °C.
2. Run one trial yourself with your cups and tubs so you know the length of the flat stretch (expect roughly 8 to 15 minutes) and can adjust the bath temperature or the ice mass to fit the period.
3. Crush the ice and keep it in the freezer in a covered container. Weigh each group's 150 g into its cup at the last moment, or have groups do it at the scale.
4. Prepare the warm water by mixing hot and cold tap water in pitchers or buckets to 40 to 45 °C, and check each pitcher with a thermometer before students pour. If you warm water in a kettle, mix it yourself; students never handle water above 45 °C.
5. Optional teacher demonstration for the boiling plateau: heat water in an electric kettle or on a hot plate behind a barrier, with a thermometer clamped in the water, and let students watch the reading hold near 100 °C (a little lower at higher elevation) while it boils. Only the teacher handles this water.

Investigation design

Independent variable	Time elapsed while energy flows from the warm bath into the cup, which stands in for the amount of energy that has entered the system.
Dependent variable	The temperature and the state of the cup's contents; the bath temperature is recorded as evidence of the energy leaving the surroundings.
Controlled	Mass of ice (150 g) and its starting condition (straight from the freezer); Volume (2 L) and starting temperature (40 to 45 °C) of the bath; The same kind of cup for every group; Constant gentle stirring of the cup and stirring of the bath before each reading; Thermometer bulb kept in the middle of the cup, away from the wall
Trials	One run per group; the class chart pools the flat-stretch temperature and length from every group so students can see which features repeat.
Comparison	The cup's temperature during the flat stretch compared with before and after it, and the bath's fall during the flat stretch compared with after the ice is gone; across groups, the flat-stretch temperatures compared with each other.

Student procedure

1. Predict before you touch anything. On the recording sheet (q1), each student sketches the graph they expect for the cup's temperature over 25 minutes, with a dashed line for the bath.
2. Map the system. As a group, fill in the system table: the system is the ice and its meltwater in the cup; the surroundings are the bath and the room air; the boundary is the cup wall. Add an arrow showing

which way you expect energy to flow.

3. Set up the bath. Pour 2 L of the teacher's warm water into the tub on the tray. The bath tender stirs it, reads it and records the starting bath temperature in q2.
4. Start the cup. Weigh 150 g of crushed freezer ice into the plastic cup and record the mass. Push the cup thermometer into the middle of the ice, wait 30 seconds, and record the reading as minute 0. Then lower the cup into the bath, hold it upright by the rim, and start the timer.
5. Every minute, the timer calls 'read'. The reader reads the cup thermometer, the bath tender stirs and reads the bath, the ice tender says what is in the cup (all ice, ice and water, slush, a few chunks, all liquid), and the recorder writes all three in the data table. The ice tender stirs the ice gently and constantly between readings, using the spoon, never the thermometer, and keeps the bulb away from the cup wall.
6. Watch for the moment the last piece of ice disappears and write that time in q3. Keep reading every minute until at least 10 minutes after the last ice is gone, or until minute 25.
7. Graph both temperatures against time on the same axes, using one symbol for the cup and another for the bath. Draw a smooth line through each set of points and mark where the ice finished melting.
8. Clean up: pour the water into the sink, dry the thermometers and lay them in their case, and wipe the tray.
9. Complete the three-panel particle drawing and answer the analysis questions individually. Post your group's flat-stretch temperature and length on the class chart.

Expected observations

- With ice straight from a freezer, the minute 0 reading is typically between -2°C and -10°C , and it rises to 0°C within one to three minutes as the ice warms (the thermometer itself lags a little).
- The cup then holds at 0°C , within the thermometer's accuracy of about 1°C , for as long as ice remains, typically 8 to 15 minutes depending on the bath temperature, the cup and how well the ice is stirred.
- The bath falls steadily during the flat stretch, by several degrees (for example from about 43°C to about 36°C), and falls more slowly after the ice is gone.
- Within a minute of the last ice disappearing, the cup's temperature climbs quickly, then more slowly as it approaches the bath temperature; it never rises above the bath.
- If stirring stops, readings during melting can drift a degree or more above 0°C , because water near the thermometer is not in contact with ice.

Likely difficulties

- The cup floats and tips in a deep bath. The ice tender must hold the rim at all times; if it keeps tipping, use less bath water so the cup rests nearer the bottom, or a heavier cup such as a thin metal tumbler.
- Students stop stirring the ice during the flat stretch because 'nothing is happening', and the reading creeps up. Remind them that steady stirring is a controlled variable.
- The thermometer bulb rests against the cup wall and reads the bath's influence instead of the ice water. Keep it centered.

- Groups confuse the two series on the graph. Require two different symbols and a key before the first point is plotted.
- Some students conclude the flat stretch means 'the bath stopped working'. Use the bath column to show it was still cooling.

Structured debrief

1. Post the class chart of flat-stretch temperatures. Nearly every group should land within a degree of 0 °C even though their bath temperatures, stirring and timing differed. Ask what a result that repeats across eight groups tells us: the melting point is a property of water, not of the setup.
2. Put one group's two curves on the board and point to the bath line during the flat stretch. Ask: if the bath lost energy and the cup did not warm up, where is the energy? Push students to say it went into freeing water molecules from the solid's fixed arrangement, and that thermal energy rose even though temperature did not.
3. Compare the slope of the cup's line right after melting with its slope at the end of the run. It warmed fastest when the temperature difference with the bath was biggest. Connect this to Lab 3: a smaller temperature difference, or a better insulator, slows the energy flow.
4. Return to slide 2's stubborn thermometer: the glass of ice water in the warm room is the same system with the room air as its surroundings. Ask students to write one sentence explaining why the glass held at 0 °C for most of an hour.

Recording sheet: what students fill in

Lab 1 recording sheet: The bath and the melting ice

In this lab the **system** is the ice and its meltwater inside the cup. Everything around it is the **surroundings**. Energy can cross the boundary between them. Your job is to track the temperature of the system and of the bath, and to explain with particles what the energy entering the system is doing.

System map

Part of the model	In our setup
System	
Surroundings	
Boundary energy crosses	
Direction energy flows (from → to)	

1. Prediction: sketch the graph you expect for the cup's temperature over 25 minutes, starting from ice straight out of the freezer. Add a dashed line for the bath. Write one sentence explaining your prediction.

Answer: Any prediction earns credit if it is sketched with labeled axes and explained. A scientifically accurate prediction shows the cup starting below 0 °C, rising to 0 °C, holding flat while ice remains, then rising toward but not above the bath, while the bath line falls the whole time.

Why: This is a prediction made before the evidence, so it is not graded for correctness. Keep it: many students draw a steady rise, and comparing that sketch with their data is the most powerful moment of the lab.

- Sketch has labeled axes and a cup line
- Includes a bath line
- One sentence of reasoning

2. Starting readings: mass of ice ____ g; cup temperature at minute 0 ____ °C; bath temperature at minute 0 ____ °C.

Answer: Group-specific. Expected: about 150 g of ice; cup about –2 to –10 °C at minute 0; bath about 40 to 45 °C.

Why: Values outside these ranges suggest the ice sat out too long (cup already at 0 °C) or the bath water was not checked. A cup already at 0 °C at minute 0 still gives a good flat stretch.

Data table

Time (min)	Cup (°C)	Bath (°C)	What is in the cup
0			
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			

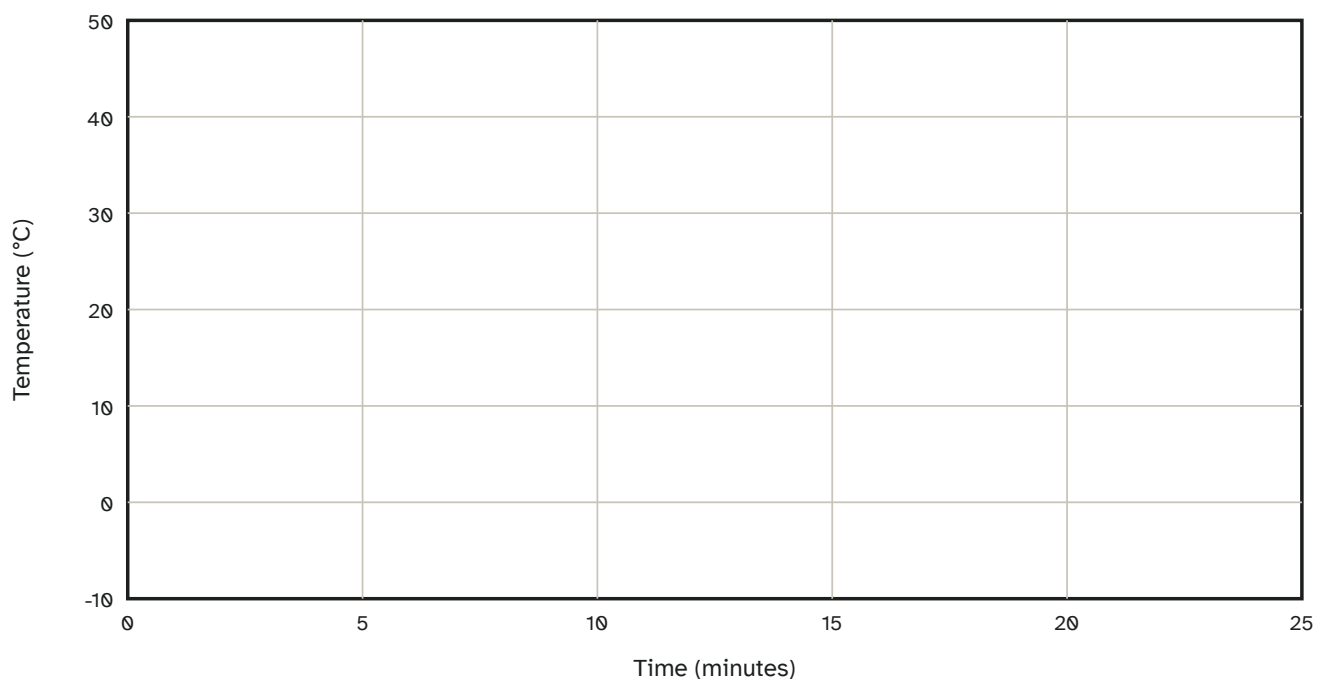
Time (min)	Cup (°C)	Bath (°C)	What is in the cup
15			
16			
17			
18			
19			
20			
21			
22			
23			
24			
25			

3. The last piece of ice disappeared at minute _____. The cup's temperature at that moment was _____ °C.

Answer: Group-specific, typically minute 8 to 15. The cup temperature at that moment is still close to 0 °C (0 to 2 °C).

Why: The reading rises only once the last ice has melted; a reading well above 0 °C while ice was still visible signals poor stirring.

Temperature of the cup and the bath over time



- Three-panel particle model of the water in the cup: (a) at minute 0, before the reading reached 0 °C; (b) halfway through the flat stretch; (c) five minutes after the last ice disappeared. Draw particles as dots with short motion lines, and an arrow for energy entering from the bath. Under each panel write one sentence saying what the incoming energy is doing to the particles.

Answer: (a) Particles packed in a regular arrangement, each vibrating in place with short motion lines; energy entering makes them vibrate harder, so the temperature rises toward 0 °C. (b) A mix: some particles still locked in the solid arrangement, others freed and sliding nearby, with motion lines about the same length as in (a) at 0 °C; the incoming energy is pulling particles free of their fixed positions, not speeding them up on average, so the temperature stays at 0 °C. (c) All particles close together but sliding past each other with longer motion lines; the incoming energy now makes them move faster on average, so the temperature rises.

Why: This is the core MS-PS1-4 model. The key distinction is panel (b): the energy goes into changing the arrangement, so average motion and temperature stay the same.

Also acceptable: Accept drawings in which panel (b) is split into a solid region and a liquid region, and any clear symbol for faster motion (longer lines, more lines).

- Panel (a) fixed, vibrating particles; panel (c) close, sliding particles
- Panel (b) shows both states together
- Captions say what the energy does in each panel: speeds up, frees particles, speeds up
- An energy arrow from the bath in every panel

Analysis questions: answer key

4. Describe your cup's curve in three stretches. For each stretch give the minutes it covered, what the temperature did, and what was in the cup.

Answer: Example from expected data: Stretch 1, minute 0 to about 2: the temperature rose from about -6 °C to 0 °C, and the cup was all ice. Stretch 2, about minute 2 to about 11: the temperature stayed at 0 °C while the cup held ice and water, from crushed ice to slush to a few chunks. Stretch 3, after about minute 11: the temperature rose, quickly at first then more slowly, toward the bath temperature, and the cup was all liquid.

Why: Students should use their own minutes and readings. The essential features are three stretches, correctly matched to the cup's contents.

- Three stretches identified with times
- Temperature behavior in each (rising, flat at about 0 °C, rising)
- Cup contents matched to each stretch

5. During the flat stretch, was energy entering the cup? Use your bath readings as evidence, and explain why energy flows that way.

Answer: Yes. The bath kept cooling during the flat stretch (for example from about 42 °C to about 37 °C) while the cup stayed at 0 °C. Energy flows as heat from warmer matter to cooler matter, and the bath was warmer than the cup the whole time, so energy kept crossing the cup wall into the ice. The bath's lost energy went mostly into the cup (some also went into the room air).

Why: The bath column is the evidence that rules out 'nothing was happening'. Credit the mention of the room air as an additional energy path, but it does not replace the main claim.

- Says energy was entering the cup
- Cites the bath's falling temperature with numbers
- Explains direction using the temperature difference

6. Explain with particles what the energy entering the cup did during the flat stretch, and what it did after the last ice disappeared. Why did the thermometer behave so differently in the two stretches?

Answer: During the flat stretch the energy pulled water molecules out of the fixed arrangement of the ice so they could slide past each other as liquid. Because it went into changing the arrangement, not into making the molecules move faster on average, the average kinetic energy, and so the temperature, stayed at 0°C . After the last ice disappeared, there were no more molecules to free, so the incoming energy made the liquid's molecules move faster on average, and the thermometer rose.

Why: Full credit needs both halves and the link to the thermometer measuring average kinetic energy. 'The energy was used up' is not enough; the student must say what it was used for.

- Flat stretch: energy frees molecules from fixed positions (changes state)
- Average kinetic energy unchanged, so temperature unchanged
- After melting: energy increases average motion, so temperature rises

7. Another group used 300 g of ice with the same 2 L bath. Which prediction is best?

Answer: B. The flat stretch would sit at 0°C and last about twice as long, or a little longer.

Why: The melting point does not depend on the amount of ice, so the flat stretch stays at 0°C . Twice as much ice needs about twice as much energy to melt. The bath also cools further while it supplies that energy, so energy enters more slowly toward the end, which makes the stretch a little longer than double. A is wrong because the plateau temperature is a property of water; C is wrong because the bath is warmer than the ice, so energy still flows in; D reverses the effect of more ice.

8. Compare your flat-stretch temperature with the class chart. If one group's flat stretch read 1°C and another's read -1°C , give two reasons that have to do with the measurement rather than with the science of melting.

Answer: Any two measurement reasons: the thermometers are not perfectly calibrated (each can be off by about a degree); readings were taken at a slant instead of at eye level; the bulb touched the cup wall or sat in a pocket of meltwater away from the ice; the ice was not stirred, so water near the bulb warmed above 0°C ; a digital probe was read before it settled.

Why: Both values are within normal thermometer error of 0°C . The point is that the melting point is the same and the differences come from the measurement.

- Two distinct measurement-related reasons
- Neither reason claims the ice melted at a different temperature

9. Predict the opposite experiment: a cup of 20 °C water is placed in a -18 °C freezer and read every few minutes for two hours. Describe or sketch the curve and explain its flat stretch using energy leaving the water.

Answer: The temperature falls from 20 °C to 0 °C, then stays flat at 0 °C while the water freezes, then falls again below 0 °C toward -18 °C once all of it is solid. During the flat stretch energy is leaving the water as heat into the colder freezer air, but the molecules are locking into the fixed arrangement of ice and releasing energy as they do, so their average kinetic energy, and the temperature, stays at 0 °C until all the water has frozen.

Why: This is the cooling-direction version of the same model. Accept a sketch with a correct shape and labels. Some real cups dip slightly below 0 °C before freezing starts (supercooling) and then jump back to 0 °C; credit students who mention it, but it is not required.

- Curve falls, flattens at 0 °C, then falls again
- Flat stretch labeled freezing
- Energy leaving while particles lock into place; temperature constant until freezing is complete

10. Suppose the teacher kept heating the meltwater on a stove at sea level. At what temperature would the next flat stretch appear, and what would be happening to the particles during it?

Answer: At about 100 °C at sea level. During that flat stretch the water would be boiling: the added energy would pull molecules completely away from their neighbors into the gas state, forming bubbles of water vapor throughout the liquid, while the liquid's average kinetic energy held steady.

Why: Students apply the plateau idea to boiling. Accept 'a little below 100 °C' if the student names a higher elevation.

- 100 °C at sea level
- Names boiling (liquid to gas)
- Energy separates molecules rather than raising temperature

11. Name two ways our setup differs from the idealized heating curve on slide 17, and one thing your particle drawing cannot show about real water.

Answer: Differences, any two: the bath cooled, so energy entered more and more slowly instead of at a steady rate; energy also entered from the room air and from stirring; the ice was not perfectly stirred, so the thermometer read only one spot; the corners of our curve are rounded rather than sharp; we measured only melting, not boiling. The drawing cannot show the attractions that hold the particles together, the real open, six-sided arrangement of ice that makes it less dense than liquid water, or the enormous number and speed of the molecules.

Why: Any accurate pair of setup differences and any accurate limit of the drawing earns credit.

- Two genuine differences between the lab and an idealized steady heating curve
- One real limitation of the particle drawing

Individual evidence of learning

Each student submits their own prediction sketch (q1), the group data table and graph with their own annotations, the three-panel particle drawing and individual answers to q4 through q11. The drawing, q5 and q6 are the main evidence for MS-PS1-4: they must connect energy entering the system to particle motion, temperature and state in each stretch.

Assessment criteria

Criterion	Proficient looks like
Data and graph	Both temperatures are recorded every minute, graphed with a key and labeled axes, and the time the last ice disappeared is marked; the flat stretch is visible and identified.
Energy evidence	Uses the bath's falling temperature during the flat stretch as evidence that energy kept entering the cup, and explains the direction with the temperature difference (q5).
Particle model	The three panels show vibrating particles in fixed positions, then a mix of fixed and freed particles at the same average motion, then sliding particles moving faster; each caption says what the incoming energy does (speeds particles up, frees them, speeds them up).
Prediction and transfer	Correctly predicts the 300 g case (q7), the freezing curve with a flat stretch at 0 °C as energy leaves (q9), and the boiling plateau at 100 °C at sea level (q10).
Model limits	Names real differences from the idealized curve, such as a bath that cools so the energy flow is not steady, energy also entering from the room air, or a thermometer that measures only one spot (q11).

Accessibility adaptations

- Use digital thermometers with large displays for students with low vision, and have the reader call every value aloud so the recorder does not need to see the instrument.
- Students with limited fine-motor control can take the recorder or timer role; provide a graph with pre-scaled axes and the first points plotted if plotting is a barrier.
- Offer the particle model as cut-out dots glued into three frames, or as a spoken explanation recorded on a device, instead of a freehand drawing.
- For multilingual learners, post a word bank for the cup observations (all ice, ice and water, slush, a few chunks, all liquid) and the frame 'The energy from the bath was ____, so the temperature ____.'

Low-cost alternative

With only one thermometer per group, read the cup every minute and the bath every three minutes, or have the teacher run one bath thermometer for the class and post its readings. With no thermometers at all, run it as a teacher demonstration with one digital probe projected under a document camera, and have groups record and graph the class data. A lidded jar of ice left in a sunny window also shows the flat stretch, more slowly.

Model limitations

This activity has not been physically tested by the authors; times and temperatures in the expected observations are estimates, which is why the prep asks for a trial run. The setup is not the steady heater of an idealized heating curve: the bath cools as it gives up energy, so energy enters the cup more slowly over time, and some energy also enters from the room air and the stirring. A thermometer measures only the water near its bulb, so poor stirring can hide the flat stretch. Tap-water ice contains a little dissolved material, which can lower its melting point by a small fraction of a degree, far less than the thermometer can show. The particle drawings show positions and motion but not the attractions between particles or the real,

irregular structure of ice, and they cannot show that ice is less dense than liquid water. Only melting is measured here; the boiling plateau is shown by teacher demonstration or on slide 17, not by students.

Teacher notes

The system table should read: system = ice and meltwater in the cup; surroundings = bath and room air; boundary = the cup wall (and the open top); energy flows from the bath into the cup. Check that the graph's flat stretch lines up with the time the last ice disappeared. The expected values above come from a teaching estimate, not a tested run; your own trial will set the real ranges. Slide 23 uses a simulated dataset of the same setup if a group's data fail. Do not ask students to calculate the energy that entered; the MS-PS1-4 model is qualitative.