

Twice the Ice: What Changes When the Sample Is Bigger?

Learning target: I can graph heating data for two masses of ice, calculate how long each plateau lasts and how fast each temperature rises, and explain the results with a particle model.

Data and graphing

About 45 min

Individual

MS-PS1-4 · practice

MS-PS3-4 · supports

data analysis

independent practice

Standards connections

MS-PS1-4 (practice, using data to describe temperature and state as thermal energy is added): Students use graphed data to describe when the temperature of water rises and when it holds steady during melting and boiling, then explain the pattern with particles. This builds the evidence base for the predictive model the PE asks for; the sheet analyzes data rather than having students construct the model.

MS-PS3-4 (supports, only the relationship between mass and the energy needed, read from given data): MS-PS3-4 is a California Grade 6 PE. Comparing a 100 g and a 200 g sample on identical heaters revisits its idea that the energy needed depends on mass. Students analyze a given dataset; they do not plan the investigation, and no question calculates an amount of energy.

Purpose: practice · **Time:** about 45 minutes · **Format:** individual

Answers with reasoning

The investigation

A science team wanted to know whether a bigger sample of ice melts at a different temperature or just takes longer. They took two beakers of crushed ice from a freezer at -20°C : one held 100 g of ice and the other held 200 g. Each beaker sat on its own hot plate, and both hot plates delivered energy at the same steady rate. The team stirred both samples and read the temperatures every minute. The room was at normal sea-level air pressure.

Temperature of two ice samples heated on identical hot plates (teaching dataset)

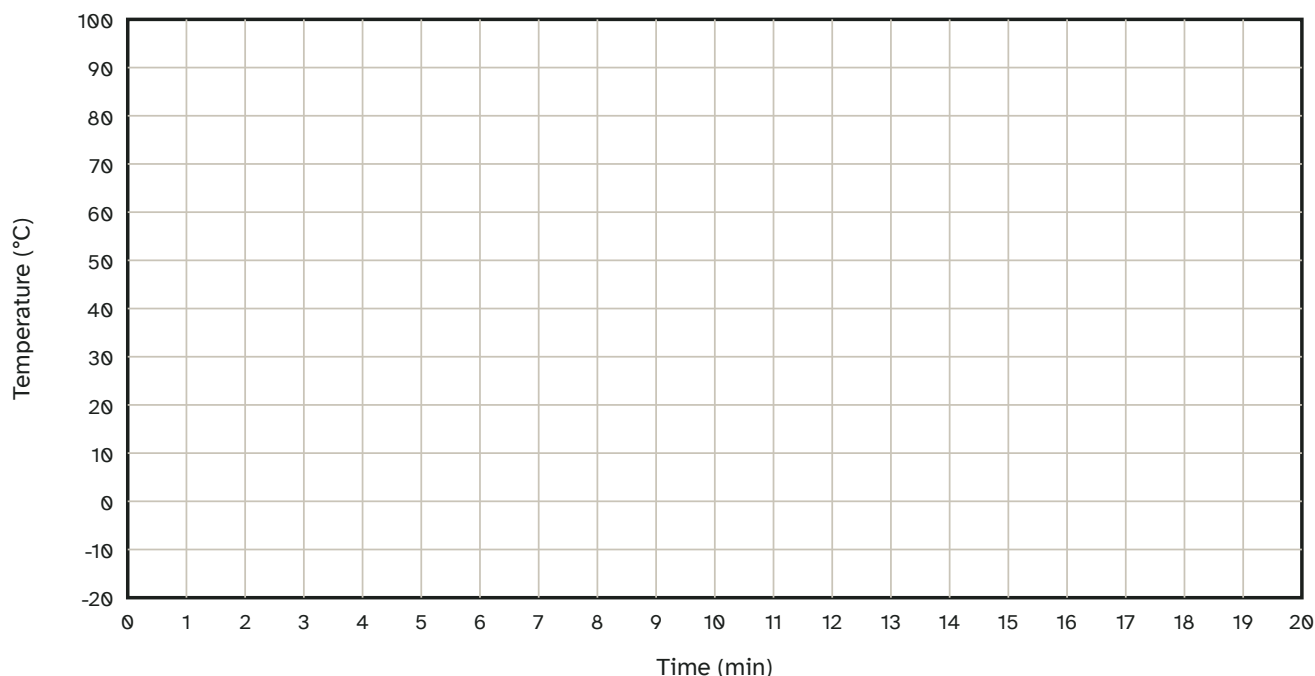
Simulated teaching dataset: the numbers are invented to be realistic, not measured.

Time (min)	100 g sample ($^{\circ}\text{C}$)	200 g sample ($^{\circ}\text{C}$)
0	-20	-20
1	0	-10
2	0	0
3	0	0
4	0	0

Time (min)	100 g sample (°C)	200 g sample (°C)
5	0	0
6	0	0
7	0	0
8	0	0
9	0	0
10	10	0
11	20	0
12	30	0
13	40	0
14	50	0
15	60	0
16	70	0
17	80	0
18	90	0
19	100	5
20	100	10

Simulated, idealized data for teaching: no energy is lost to the room, and readings are rounded to the nearest degree.

Temperature of two ice samples over time



Part A: Read and calculate

1. Describe the shape of each line in one sentence. Name each part as sloping up or level.

Answer: 100 g: slopes up steeply from -20°C to 0°C in 1 minute, stays level at 0°C until minute 9, slopes up from 0°C to 100°C between minutes 9 and 19, then is level at 100°C . 200 g: slopes up from -20°C to 0°C in 2 minutes, stays level at 0°C until minute 18, then slopes up slowly to 10°C at minute 20.

Why: The graph should show two plateaus for the 100 g sample (0°C and the start of one at 100°C) and one long plateau for the 200 g sample.

Also acceptable: Accept descriptions such as 'up, flat, up, flat' with the matching temperatures.

- Both lines described
- Sloping and level parts identified with times or temperatures

2. How many minutes did each sample spend level at 0°C ? Use the first and last minute at 0°C after the ice warmed up. How many times longer was the 200 g plateau?

Answer: 100 g: $9\text{ min} - 1\text{ min} = 8\text{ min}$. 200 g: $18\text{ min} - 2\text{ min} = 16\text{ min}$. $16 \div 8 = 2$, so the 200 g plateau lasted 2 times as long.

Why: Each sample reaches 0°C when its ice has warmed up (minute 1 or 2) and leaves 0°C when the last ice melts (after minute 9 or 18).

Also acceptable: Accept 9 and 17 min (counting the readings at 0°C) if the method is stated and the ratio is close to 2.

- 8 min and 16 min with subtraction shown
- Ratio of 2

3. After melting, how fast did the liquid warm? Find the rate for the 100 g sample from minute 10 to minute 18, and for the 200 g sample from minute 18 to minute 20. Give both in °C per minute.

Answer: 100 g: $(90\text{ °C} - 10\text{ °C}) \div (18\text{ min} - 10\text{ min}) = 80 \div 8 = 10\text{ °C per minute}$. 200 g: $(10\text{ °C} - 0\text{ °C}) \div (20\text{ min} - 18\text{ min}) = 10 \div 2 = 5\text{ °C per minute}$.

Why: With the same energy per minute, twice the mass warms half as fast.

Also acceptable: Accept any two points on the straight parts that give the same rates.

- 10 °C/min for 100 g
- 5 °C/min for 200 g
- Calculations shown

4. How fast did the ice warm before it started to melt? Find the rate in °C per minute for each sample. For the 100 g sample, which warmed faster, the solid ice or the liquid water, and by what factor?

Answer: 100 g ice: $(0\text{ °C} - (-20\text{ °C})) \div 1\text{ min} = 20\text{ °C per minute}$. 200 g ice: $20\text{ °C} \div 2\text{ min} = 10\text{ °C per minute}$. For the 100 g sample the solid ice warmed faster: $20 \div 10 = 2$ times as fast as the liquid.

Why: With the same energy per minute, ice's temperature rises about twice as fast as liquid water's, because ice needs about half as much energy per degree. Students only need to read this from the data.

Also acceptable: Accept 'the ice heated up twice as fast' with the two rates shown.

- 20 °C/min and 10 °C/min
- Ice warmed faster, by a factor of 2

Part B: Interpret and predict

5. Did doubling the mass change the temperature at which the ice melted? Give the evidence from the data.

Answer: No. Both samples stayed level at exactly 0 °C while melting: the 100 g sample from minute 1 to 9 and the 200 g sample from minute 2 to 18.

Why: The melting point is a property of the substance (at a given pressure), not of the amount.

Also acceptable: None.

- Answers no
- Cites the 0 °C plateau in both samples

6. Predict how many minutes the 0 °C plateau would last for a 300 g sample and for a 50 g sample on the same kind of hot plate. Explain the pattern you used.

Answer: 300 g: $8\text{ min} \times 3 = 24\text{ min}$. 50 g: $8\text{ min} \div 2 = 4\text{ min}$. The plateau length is proportional to the mass: 8 minutes for every 100 g on this hot plate.

Why: The data show that doubling the mass doubled the plateau, so the time per 100 g is constant for this heating rate.

Also acceptable: Accept '0.08 minutes per gram' as the pattern.

- 24 min and 4 min
- States the proportional pattern

7. If the team had kept going, at about what minute would the 200 g sample start to boil, and what would the thermometer read then? Show your reasoning.

Answer: At minute 18 the 200 g sample is at 0 °C and warming at 5 °C per minute. Reaching 100 °C needs $100\text{ °C} \div 5\text{ °C per min} = 20$ more minutes, so it would start to boil at about minute 38 and the thermometer would read 100 °C (at sea-level pressure).

Why: Extend the straight liquid-warming line until it reaches the boiling point; the 100 g sample did the same thing in 10 minutes.

Also acceptable: Accept 'twice as long as the 100 g sample, so 20 minutes after melting ends' with minute 38.

- About 38 minutes
- Reads 100 °C
- Shows $100 \div 5 = 20$ and $18 + 20$

8. A student says, 'At minute 5 the 200 g sample was colder than the 100 g sample because it had more ice in it.' Use the data to evaluate this claim.

Answer: The claim is wrong. At minute 5 both samples read 0 °C, so they had the same temperature. The 200 g sample did have more ice left, but having more ice does not make it colder; both were ice-water mixtures at the melting point.

Why: Temperature measures average kinetic energy, which was the same in both mixtures; the amount of ice affects how long the plateau lasts, not its temperature.

Also acceptable: Accept 'the 200 g sample needed more energy to finish melting, but it was not colder'.

- States both were at 0 °C
- Separates amount of ice from temperature

9. Explain, using particles, why doubling the mass doubled the length of the plateau but did not change its temperature. Your answer must mention what the hot plate's energy does to the water molecules during the plateau.

Answer: During the plateau the hot plate's energy goes into pulling water molecules free of their fixed spots in the ice, not into speeding them up, so the average kinetic energy, and therefore the temperature, stays at 0 °C in both samples. The 200 g sample has twice as many molecules to free, so with energy arriving at the same rate it takes twice as long. The melting temperature depends on how strongly water molecules attract one another, which is the same for any amount of water.

Why: This is the core particle explanation: amount affects how much energy the change needs; the substance's attractions set the temperature at which the change happens.

Also acceptable: Accept 'twice as much ice needs twice as much energy to melt' as the mass link if the particle explanation is present.

- Energy frees molecules from fixed positions during the plateau
- Temperature stays level because average kinetic energy does not change
- Twice the mass means twice as many molecules, so twice the time at the same heating rate
- Melting temperature is set by the substance, not the amount

- 10.** In a real classroom, some energy would also flow into the beakers from the warm room air. Would that make the real plateaus longer or shorter than in this dataset? Explain.

Answer: Shorter. Energy from the room would add to the energy from the hot plate, so the ice would melt sooner and each plateau would end earlier.

Why: The room (about 20 to 25 °C) is warmer than the ice at 0 °C, so heat flows into the beaker from the air as well as from the hot plate.

Also acceptable: Accept 'shorter, and the liquid would warm a little faster below room temperature'.

- Shorter
- Reason: extra energy flows in from the warmer room

Teacher notes

The dataset is idealized so that the ratios come out exactly: each stage of the 200 g sample takes twice as long as the 100 g sample's. The ratio of stage lengths for the 100 g sample (1 minute to warm the ice, 8 to melt it, 10 to warm the liquid to 100 °C) follows the real energy water needs per gram at each stage. Questions 2, 6 and 9 support MS-PS3-4's mass relationship without calculating energy; keep any discussion of joules out of this sheet. Expect some students to compute the plateau as 9 and 17 minutes by counting rows; accept it if they explain their method. The extension pushes toward planning a fair test, which is the Grade 6 practice students will meet again in later energy units.

Scaffold offered to students: Rates and durations step by step

A duration is end time minus start time: find where the line first reaches 0 °C and where it last reads 0 °C. A rate is change in temperature divided by change in time: pick two points on a straight, sloping part, subtract the temperatures, subtract the times, then divide. Example with made-up numbers: from 15 °C at 4 min to 27 °C at 7 min is $12\text{ °C} \div 3\text{ min} = 4\text{ °C per minute}$.

Extension: Double the hot plate

Suppose the 200 g sample had been heated by a hot plate delivering energy twice as fast as the others. Sketch its predicted temperature line on your graph in a third color, and explain why it would match one of the existing lines. Then describe how you could use two samples and two hot plates to test whether the time a plateau lasts depends on the mass, the heating rate, or both. Name what you would keep the same.