

Mercury or Alcohol? A Claim-Evidence-Reasoning Case for a Polar Winter

Learning target: I can write a claim, evidence and reasoning argument that uses a particle model and melting points at a stated pressure to predict what happens to a pure liquid's particle motion, temperature and state as it is cooled.

Claim, evidence, reasoning

About 45 min

Individual

MS-PS1-4 · assesses

writing

data analysis

Name _____

Date _____

Period _____

Directions

Read the scenario, the reference table and the cold-chamber results. Answer the three warm-up questions first; they organize your evidence. Then write your Claim, Evidence and Reasoning in the boxes. Strong evidence uses exact numbers and times from the tables. Strong reasoning explains the evidence with particles, not just with the word 'cold'. Finish with the three prediction questions.

You will need: This worksheet, Pencil

The scenario

A research team is preparing a weather station deep inside Antarctica, where winter air temperatures often fall below $-60\text{ }^{\circ}\text{C}$. Their electronic sensors need a backup: a liquid-in-glass thermometer, the kind in which a thin thread of liquid rises and falls inside a glass tube as the temperature changes. The team has two old thermometers. One is filled with **mercury**, a silvery metal that is a liquid at room temperature. The other is filled with **ethanol**, a pure alcohol dyed red so it is easy to see. Before shipping, an engineer seals a small vial of each liquid, with a temperature probe inside, into a cold chamber at sea-level pressure and slowly lowers the chamber's temperature.

Reference values for three pure substances at 101 kPa (sea-level pressure)

Substance	Melting (freezing) point	Boiling point
Mercury	$-38.8\text{ }^{\circ}\text{C}$	$357\text{ }^{\circ}\text{C}$
Ethanol	$-114\text{ }^{\circ}\text{C}$	$78\text{ }^{\circ}\text{C}$
Water	$0\text{ }^{\circ}\text{C}$	$100\text{ }^{\circ}\text{C}$

Real reference values, rounded. Melting points change by much less than $1\text{ }^{\circ}\text{C}$ with ordinary changes in air pressure; boiling points can change by many degrees. A substance freezes at the same temperature at which it melts.

Cold-chamber test of two sealed vials (teaching dataset)

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

Time (min)	Chamber air (°C)	Mercury vial (°C)	What the mercury looks like	Ethanol vial (°C)	What the ethanol looks like
0	0	0	Shiny liquid; flows when the vial is tipped	0	Clear red liquid; flows
10	-15	-12	Shiny liquid; flows	-12	Flows
20	-30	-27	Shiny liquid; flows	-27	Flows
30	-45	-39	Dull gray crystals forming on the inside wall	-41	Flows
40	-60	-39	About half solid	-54	Flows
50	-60	-39	Almost all solid	-58	Flows a little more slowly
60	-60	-50	Solid; does not move when tipped	-60	Flows slowly
70	-60	-58	Solid	-60	Flows slowly

A teaching dataset; the readings follow the real behavior of mercury and ethanol but were not taken in a specific test. Probe readings are rounded to the nearest degree.

Warm-up: organize the evidence

1. Compare the two vials from 0 to 20 minutes. How did their temperatures change, and what does that tell you about the motion of the particles inside both?

2. For about how many minutes did the mercury vial read -39°C ? Use the first and last times in the table that show this reading.

3. From 30 to 50 minutes the chamber air was colder than the mercury, so energy kept leaving the mercury. Which observations show that something in the mercury was still changing, even though its temperature reading did not change?

Your argument

CLAIM

Claim: Which liquid should the team rely on for a backup thermometer that must work at $-60\text{ }^{\circ}\text{C}$, and what will happen to the other liquid at that temperature?

EVIDENCE

Evidence: Give at least three specific pieces of evidence with numbers, from both the reference table and the cold-chamber test. One must describe what the mercury did between 30 and 50 minutes.

REASONING

Reasoning: Use a particle model to explain your evidence. Describe what happens to the motion and arrangement of the mercury particles and to the mercury's temperature as energy keeps leaving, before, during and after freezing. Then explain why the ethanol particles can still slide past one another at $-60\text{ }^{\circ}\text{C}$.

Predict with your model

4. The frozen mercury vial ($-58\text{ }^{\circ}\text{C}$) is carried into a $20\text{ }^{\circ}\text{C}$ room. Predict what its temperature will do until it reaches room temperature. Include the temperature where it will pause, and describe what the particles are doing during the pause.

5. The ethanol thermometer also has a limit. Below what temperature would it stop working, and what would happen to its particles there?

6. The air pressure at an inland Antarctic station is much lower than at sea level. Does that change your claim? Use the note under the reference table.

Sentence frames

Claim: 'The team should use _____, because at $-60\text{ }^{\circ}\text{C}$ _____ will be a _____. ' Evidence: 'The reference table shows that mercury freezes at _____ and ethanol freezes at _____. ' 'In the test, the mercury stayed at _____ from _____ to _____ minutes while _____. ' Reasoning: 'As energy leaves a liquid, its particles _____, so its temperature _____. When it reaches its freezing point, the particles _____ instead, so the temperature _____ until _____. '

Colder than ethanol can handle

Some places on the Antarctic plateau have been measured at close to $-90\text{ }^{\circ}\text{C}$, and laboratories sometimes need thermometers for even colder conditions. Research the freezing points of pentane and toluene, two other liquids used in low-temperature thermometers. Make a table like the reference table, decide which liquid would cover the widest range of cold temperatures, and write two sentences explaining your choice with the particle model. Note that both are flammable and must stay sealed.