

Temperature or Pressure? A Twelve-Card Evidence Sort on Changing States

Learning target: I can work with my group to sort real observations by whether temperature or pressure caused a change, explain each with particle collisions and motion, and build part of water's state diagram from evidence.

Collaborative investigation

About 50 min

Small group

MS-PS1-4 · practice

collaboration

discussion

data analysis

Name _____

Date _____

Period _____

Directions

Work in groups of four. Step 1 (10 minutes): each person takes one set of three cards (Set A: cards 1-3, Set B: cards 4-6, Set C: cards 7-9, Set D: cards 10-12), reads them and completes Part A alone. Step 2 (25 minutes): take turns teaching your cards to the group, then do the group task in Part B together. Every member must be able to explain every card. Step 3 (15 minutes): complete Part C on your own.

You will need: One set of twelve cards per group, cut from the card sheet, One copy of this worksheet per student, Ruler, Pencils

Twelve evidence cards (real observations and reference values)

1 Bottle from the summit

A hiker finishes her water on the summit of Mount Whitney, where the air pressure is about 58 kPa, and screws the cap tightly onto the empty plastic bottle. When she reaches the trailhead far below, where the air pressure is much higher, the bottle has caved in.

2 Noodles on the summit

On the same summit, a camp-stove pot of water boils hard at about 85 °C. The noodles take noticeably longer to soften than they do at home near sea level.

3 Pressure cooker

A sealed pressure cooker traps water vapor, so the pressure inside rises to about 200 kPa. The water inside does not boil until it reaches about 120 °C, and dry beans cook in a fraction of the usual time.

4 Dry ice on a plate

A block of solid carbon dioxide sits on a plate at sea level. It stays at about −78.5 °C, gives off cold, invisible gas and shrinks steadily, but it never leaves a puddle.

5 Fire extinguisher

A carbon dioxide fire extinguisher at room temperature holds liquid carbon dioxide that sloshes when the tank is shaken. The pressure inside the tank is more than 50 times sea-level air pressure.

6 Gallium in a hand

A small bar of pure gallium sits solid on a desk in a 22 °C room. Held in a closed hand, it slowly turns into a silvery liquid. Gallium's melting point is about 30 °C at sea-level pressure.

7 Squeezed syringe

A student seals the tip of a plastic syringe full of air and pushes the plunger halfway in. The farther it goes, the harder it is to push. When she lets go, the plunger springs back.

8 Warm tires

A driver checks her tire pressure on a cold morning and again after an hour of highway driving. The tires feel warm, and the pressure reading is about one tenth higher, even though no air was added.

9 Boiling at room temperature

A teacher puts a beaker of 22 °C water inside a sealed chamber and pumps most of the air out. When the pressure inside falls to about 2.6 kPa, the water begins to boil, even though nothing has heated it.

10 Propane tank

A barbecue's propane tank holds liquid propane under pressure. At sea-level pressure, propane boils at about −42 °C, so when the valve opens and the pressure on it drops, liquid propane turns into the gas that feeds the flame.

11 Melting iron

In a foundry at sea level, a block of pure iron in a furnace glows red, then orange, and stays solid until it reaches about 1,538 °C. Then it melts into a liquid that can be poured into molds.

12 Ice tray

Water in an ice-cube tray in a −18 °C freezer at sea level cools to 0 °C, stays at 0 °C while it turns to ice, and then keeps cooling toward −18 °C.

Part A: Expert round (on your own)

- For each of your three cards, write what changed (the cause), what happened (the effect), and whether a change of state happened.

Card number	What changed (cause)	What happened (effect)	Change of state? (yes or no)
First card			
Second card			
Third card			

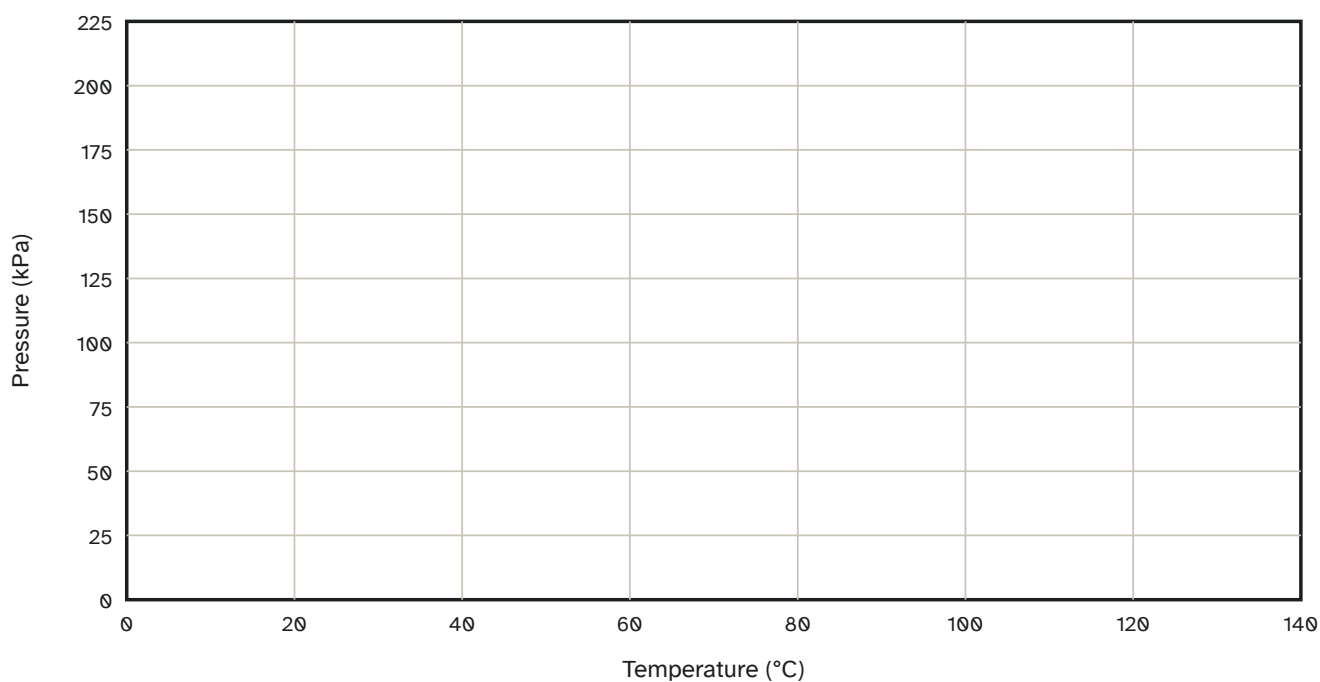
Part B: Group task

- Teach your three cards to the group in one minute each. Listeners may ask one question per card.
- Sort all twelve cards into three groups: (1) a change of state caused by a temperature change at about the same pressure; (2) a change of state, or the temperature at which it happens, set by pressure; (3) no change of state, but the pressure of a gas changes. Record the sort in q2.
- Find the four cards or facts that tell you a pressure and a temperature at which water boils. One is a fact you already know: 100 °C at 101 kPa. Plot all four points on the group graph and draw one smooth curve through them.
- Label the side of your curve where water is a liquid and the side where it is a gas, then answer q3 to q5 together.

2. Group record: write the card numbers in each group and what the cards in that group have in common.

Group	Card numbers	What these cards have in common
1: Temperature change causes a change of state		
2: Pressure sets the change of state		
3: No change of state; gas pressure changes		

Water's boiling line, built from the cards



3. Group answer: Describe the curve your group drew. Which side is liquid and which side is gas? Explain how your group decided.

4. Group answer: Use your curve to decide whether water at 100 °C is a liquid or a gas at 200 kPa, and at 58 kPa. Explain each answer.

5. Group answer: Cards 1, 7 and 8 show pressure changing without any change of state. Explain each one using collisions of gas particles.

Part C: Individual accountability (complete alone)

6. Card 9: Explain, using particles, how water can boil at 22 °C. Why doesn't the same water boil on a classroom desk?

7. Cards 4 and 5 are both about carbon dioxide. Why is carbon dioxide a liquid inside the extinguisher but never a liquid on a plate at sea level?

8. Which statement best explains why a boiling point should always be reported with a pressure?

- ☐ A. Thermometers read differently at different pressures.
- ☐ B. The pressure pushing on a liquid's surface changes the temperature at which its particles can escape into bubbles of gas.
- ☐ C. Particles are squeezed smaller at high pressure, so they need more energy to boil.
- ☐ D. Pressure only affects gases, so it changes the boiling point of the gas but not of the liquid.

9. Lena says, 'Temperature decides a substance's state. Pressure only matters for gases in containers, like tires.' Use evidence from at least **two** cards to argue against her, and name **one** card she could fairly use to support part of her idea.

Cause, effect, particles

For every card, finish three sentence starters before you sort it: 'The thing that changed was _____.'
'Because of that, _____ happened.' 'At the particle level, _____.' If the thing that changed is how hard something is pushing on an area, the cause is pressure. If the thing that changed is how hot or cold the sample got, the cause is temperature. A card can show temperature causing a pressure change (look at card 8).

Add the solid

Your graph shows only the boundary between liquid and gas. Water's boundary between solid and liquid is almost a straight up-and-down line at about 0 °C over the whole pressure range on your graph. Draw it in, label the solid region, and use card 12 to justify where it goes. Then explain why the solid-liquid line is nearly vertical while the liquid-gas line slants, and predict whether a pressure cooker at 200 kPa would change the temperature at which ice melts by much.