

What Is in the Unlabeled Bottle? A Claim-Evidence-Reasoning Case

Learning target: I can use measured properties (density, solubility in water, boiling point, flammability) and a reference table to argue which substance an unknown liquid is.

Claim, evidence, reasoning

About 40 min

Individual

MS-PS1-2 · practice

writing

data analysis

Standards connections

MS-PS1-2 (practice): Students analyze property data against a reference table to identify a substance, using exactly the properties the PE's assessment boundary names. The substances do not interact here, so the task practices the analysis the PE needs rather than assessing the PE itself.

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

Answers with reasoning

The scenario

While cleaning the school makerspace, Ms. Dao finds a half-full plastic bottle with a faded label. The only readable words are 'clear liquid' and 'store away from heat.' Before she can decide how to dispose of it, she needs to know what it is. The makerspace supply list shows that only five clear liquids were ever ordered: water, isopropyl alcohol, acetone, glycerin and mineral oil. Ms. Dao runs four tests herself, behind a safety shield, and records the results. Students were not present for the flame test.

Ms. Dao's test record for the unknown liquid (teaching dataset)

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

Test	What was done	Result
1. Density	Measured the mass of 25.0 mL of the liquid in a pre-weighed cup	19.7 g for 25.0 mL
2. Mixing with water	Added 5 mL of the liquid to 20 mL of water and swirled	Mixed completely; one clear layer, no separation after 10 minutes
3. Boiling point	Heated 10 mL gently in a test tube with a thermometer in the vapor	Trial 1: 82.0 °C; Trial 2: 83.0 °C; Trial 3: 82.5 °C
4. Flammability	Teacher touched a lit splint to a few drops on a watch glass	Caught fire at once; pale blue flame, hard to see

Simulated results for teaching. Boiling point measured three times with a thermometer that reads to 0.5 °C.

The five candidate liquids (real rounded values at normal air pressure)

Liquid	Density (g/cm ³)	Mixes with water?	Boiling point (°C)	Flammable?
Water	1.00	yes (it is water)	100	no
Isopropyl alcohol	0.79	yes, completely	82	yes
Acetone	0.78	yes, completely	56	yes, very
Glycerin	1.26	yes, completely	290	not easily
Mineral oil	0.84	no, forms a layer	above 300	burns only when very hot

Warm-up: organize the evidence

1. Calculate the density of the unknown from Test 1 (1 mL = 1 cm³). Which candidates are within 0.05 g/cm³ of your result, and which are ruled out?

Answer: Density = $19.7 \text{ g} \div 25.0 \text{ cm}^3 = 0.788 \text{ g/cm}^3$, about 0.79 g/cm³. Within 0.05: isopropyl alcohol (0.79) and acetone (0.78). Ruled out: water (1.00), glycerin (1.26) and mineral oil (0.84, which is 0.05 away and on the edge; most students will exclude it).

Why: The two alcohol-like liquids are nearly identical in density by design; mineral oil at 0.84 is a deliberate borderline case.

Also acceptable: A student who keeps mineral oil in play after Test 1 is being careful; Test 2 removes it anyway.

2. Explain why Test 1 by itself leaves more than one candidate, no matter how carefully the density was measured.

Answer: Isopropyl alcohol (0.79) and acetone (0.78) differ by only 0.01 g/cm³, which is smaller than the measurement can reliably tell apart. Two different substances can have almost the same density, so repeating or refining the density test cannot separate them; a different property is needed.

Why: This is the central lesson: an identifying property narrows the list but may not finish it.

Also acceptable: Accept 'the thermometer and balance aren't precise enough to tell 0.78 from 0.79.'

- Notes the near-identical densities with numbers
- States that a different property is needed

3. Find the average of the three boiling-point trials. Which single candidate does it match, and by how many degrees does it miss the next-closest candidate?

Answer: Average = $(82.0 + 83.0 + 82.5) \div 3 = 247.5 \div 3 = 82.5 \text{ }^\circ\text{C}$. This matches isopropyl alcohol (82 °C). The next-closest candidate is water at 100 °C, 17.5 degrees away; acetone (56 °C) is 26.5 degrees away.

Why: The averaged boiling point lands on one candidate with a wide margin.

Also acceptable: Accept 82.5 °C with either comparison (water or acetone) as the next-closest, as long as the subtraction is right.

Your argument

Answer: Claim: The bottle contains isopropyl alcohol. Evidence: (1) Density $19.7 \text{ g} \div 25.0 \text{ mL} = 0.79 \text{ g/cm}^3$, matching isopropyl alcohol (0.79) and acetone (0.78) and ruling out water (1.00), glycerin (1.26) and mineral oil (0.84). (2) It mixed completely with water with no layer, ruling out mineral oil, which forms a layer. (3) Boiling point averaged 82.5°C , matching isopropyl alcohol (82°C) and ruling out acetone (56°C), water (100°C) and glycerin (290°C). (4) It caught fire at once with a pale blue flame, consistent with isopropyl alcohol and acetone and ruling out water and glycerin. Reasoning: Density, boiling point and flammability are identifying properties: every sample of a substance has the same values, so matching the measured values to the table identifies the substance. Density alone left two candidates because acetone and isopropyl alcohol differ by only 0.01 g/cm^3 . The boiling point settled it, because 82.5°C is 26 degrees from acetone's value and matches isopropyl alcohol within the thermometer's precision. Flammability and mixing with water agree with that identity. The results would have been the same for a larger or smaller sample because identifying properties do not depend on the amount: 50 mL would have had twice the mass but the same mass per milliliter and the same boiling point.

Why: This is the solved model response. Full credit requires the correct claim, three or more pieces of evidence with numbers and what each rules out, and reasoning that invokes identifying properties, explains why density was not enough, names the boiling point as decisive, and addresses sample size.

Also acceptable: A student who claims acetone has ignored the boiling point; award evidence credit but not claim credit. A student who includes odor as a fourth piece of evidence should be pointed to q5.

- Claim names isopropyl alcohol
- At least three evidence items with numbers compared with the table
- Each evidence item states which candidates it rules out
- Reasoning explains that identifying properties are the same for every sample and do not depend on amount
- Reasoning explains why density alone was insufficient and why boiling point settled it

4. Suppose Test 3 had given 56°C in all three trials, with every other result the same. What would your claim be, and which single piece of evidence would have changed it?

Answer: The claim would become acetone. The boiling point is the only evidence that changed: 56°C matches acetone and no longer matches isopropyl alcohol (82°C). Density, mixing with water and flammability all fit both liquids, so they would not change the claim.

Why: Shows which property carried the decision.

Also acceptable: None.

- New claim: acetone
- Identifies boiling point as the deciding evidence
- Notes the other evidence fits both

5. Ms. Dao also noticed the liquid had a sharp smell. She chose not to list odor as evidence. Give one reason odor is a weaker identifying property than the four tests she recorded.

Answer: Any one: smell cannot be measured as a number and compared with a table; different people describe the same smell differently; several different substances smell alike (acetone and isopropyl alcohol both smell sharp); some substances have no odor at all; and smelling an unknown liquid is unsafe. The four recorded tests give numbers or yes/no results that can be compared with reference values.

Why: Odor is within the PE's list of properties, but it is a weak identifier and an unsafe test for unknowns; the sheet treats it accordingly.

Also acceptable: Accept any of the listed reasons.

- One sound reason odor is weaker (not numeric, subjective, shared, absent, unsafe)

Scoring rubric

Criterion	4 • Exemplary	3 • Proficient	2 • Developing	1 • Beginning
Claim	Names isopropyl alcohol in one clear statement that answers the question asked.	Names isopropyl alcohol but hedges or adds a second candidate without choosing.	Names acetone or another candidate consistent with some but not all of the evidence.	No claim, or a claim unrelated to the test record.
Evidence	Three or more test results quoted with numbers, each compared with the reference table and each stating which candidates it rules out.	Three results quoted, but one lacks a number or does not say what it rules out.	One or two results, or results listed without comparison to the table.	Evidence missing, invented or contradicting the record.
Reasoning	Explains that identifying properties are the same for every sample, why density alone left two candidates, why the boiling point was decisive, and why sample size would not change the result.	Covers identifying properties and the decisive boiling point but omits the sample-size point or the density limitation.	Restates the evidence without the identifying-property idea, or asserts the claim without linking it to the numbers.	No reasoning, or reasoning that treats mass or volume as identifying.
Scientific language and accuracy	Uses density, boiling point, solubility (mixes with water), flammability and identifying property correctly; units on every number; no errors.	Terms mostly correct; one slip (for example, a missing unit or 'weight' for mass).	Several terms used loosely (for example, 'melts' for 'dissolves', 'heavy' for 'dense').	Scientific language absent or consistently wrong.

Teacher notes

Reference values are real and rounded: isopropyl alcohol density 0.786 g/cm^3 and boiling point $82.5 \text{ }^\circ\text{C}$; acetone 0.784 g/cm^3 and $56 \text{ }^\circ\text{C}$; glycerin 1.26 g/cm^3 and $290 \text{ }^\circ\text{C}$; mineral oil about 0.84 g/cm^3 with a boiling range above $300 \text{ }^\circ\text{C}$; water 1.00 and $100 \text{ }^\circ\text{C}$. The isopropyl-acetone density overlap is the designed obstacle so that students must combine properties. The test record is a scenario; do not reproduce the flame test or boil flammable liquids with students present. Mixing with water is the solubility test for liquids (the textbook's 'liquids soluble in liquids'). If a student argues that the pale blue flame identifies alcohol specifically, note that acetone also burns with a mostly blue flame, so flame color is supporting rather than decisive. The

extension's ethanol (78 °C) is 4.5 degrees from the measured average, resolvable with a 0.5 °C thermometer but not with a 5 °C one; a more precise density measurement would not work as the fifth test (ethanol 0.789 versus isopropyl alcohol 0.786 is too close for school equipment), so the fifth test would have to be a chemical test, which students should recognize needs research before use.

Scaffold offered to students: A ruling-out grid

On scrap paper, write the five candidates across the top and the four tests down the side. In each box write 'fits' or 'out' with a two-word reason (for example, 'out: too dense', 'out: wrong boiling point'). The one column with 'fits' in every row is your claim, and each 'out' is a piece of evidence you can copy into your CER with its number.

Extension: A sixth candidate

Ethanol (the alcohol in hand sanitizer) has a density of 0.79 g/cm³, mixes completely with water, boils at 78 °C and is flammable. Suppose it had also been on the supply list. Rewrite your Evidence section so that it rules ethanol out, and explain why a thermometer that reads only to the nearest 5 °C would have left the case unsolved. Then propose a fifth test that could separate isopropyl alcohol from ethanol, and say what you would need to look up before trusting it.