

Five White Jars: An Evidence Jigsaw

Learning target: I can combine evidence cards from different tests with a team to identify five white solids, explain which cards decide each identity, and recognize evidence that does not help.

Collaborative investigation

About 50 min

Jigsaw

MS-PS1-2 · practice

collaboration

discussion

data analysis

Standards connections

MS-PS1-2 (practice): Students analyze density, solubility, melting behavior and flammability results against a reference table to identify substances. These are the properties named in the PE's assessment boundary; the task builds the analysis habit before students compare properties before and after a reaction.

Purpose: practice · **Time:** about 50 minutes · **Format:** jigsaw

Answers with reasoning

A retired teacher left five unlabeled jars of white solids in the stockroom, marked only A, B, C, D and E. The new teacher ran a series of tests on tiny samples (students did not do the heating or flame tests) and wrote each result on a card. Your job is to decide what is in each jar. Every value on the cards is a teaching result, invented to be realistic.

Eleven evidence cards (teaching results)

1 Card 1: Appearance under a hand lens

A: clear-white irregular crystals that sparkle. B: tiny white cubes. C: very fine, soft powder that squeaks when pressed between fingers. D: fine, dull white powder, slightly gritty. E: translucent waxy flakes, slippery to the touch.

2 Card 2: Density of A and B

Because A and B dissolve in water, their volumes were measured by displacement in cooking oil instead. A: 8.0 g of crystals displaced 5.0 cm³. B: 11.0 g of crystals displaced 5.0 cm³.

3 Card 3: Density of C, D and E

Measured by displacement in water. C: 7.5 g displaced 5.0 cm³. D: 13.5 g displaced 5.0 cm³. E: 4.5 g displaced 5.0 cm³, and the flakes floated on the water.

4 Card 4: One gram in 20 mL of room-temperature water, stirred one minute

A: disappeared completely; the water stayed clear. B: disappeared completely; the water stayed clear. C: water turned cloudy; a soft layer settled on the bottom after ten minutes. D: water turned cloudy; a gritty layer settled within a minute. E: flakes floated and looked unchanged.

5 Card 5: How much will dissolve

More solid was stirred into 20 mL of room-temperature water, one gram at a time. B stopped dissolving after about 7 g; extra crystals sat on the bottom. A kept dissolving past 30 g, and the liquid became thick and syrupy.

6 Card 6: Gentle heating (teacher; test tubes in a 90 °C water bath)

A, B, C and D: no change. E: melted into a clear liquid at about 60 °C and hardened again into a white solid when cooled.

7 Card 7: Strong heating (teacher; burner, tube contents reached about 500 °C)

A: melted into a clear syrup, turned brown, then black, with a caramel smell. B: no change; still white crystals. C: turned brown, then black, and smelled like burnt toast; never became a clear liquid. D: no change. E: became liquid, then its vapor caught fire at the mouth of the tube.

8 Card 8: Flammability (teacher; lit splint touched to a small heap)

E: caught fire and burned with a yellow, smoky flame. A and C: blackened and glowed at the edges but went out when the splint was removed. B and D: no change at all.

9 Card 9: One gram in 20 mL of warm cooking oil, stirred

E: dissolved and disappeared into the oil. A, B, C and D: did not dissolve; each settled to the bottom of the oil.

10 Card 10: Mass of each jar's contents

A: 180 g. B: 250 g. C: 120 g. D: 300 g. E: 95 g.

11 Card 11: The old supply list

The stockroom records show that only six white solids were ever ordered: table salt, sugar, cornstarch, chalk powder (calcium carbonate), paraffin wax and baking soda. One of the six is not in any jar.

Reference table: the six possible solids (real rounded values)

Solid	Density (g/cm ³)	Dissolves in water at room temperature?	Behavior when heated	Burns?
Table salt (sodium chloride)	2.17	yes, up to about 36 g per 100 g of water; clear	no change until it melts at 801 °C	no
Sugar (sucrose)	1.59	yes, about 200 g per 100 g of water; clear	melts and starts to break down near 186 °C, turning brown (caramel)	chars; burns with difficulty
Cornstarch	about 1.5	no; cloudy, settles slowly	browns and chars; no clear melt	chars; burns slowly
Chalk powder (calcium carbonate)	2.71	no; practically none, settles fast	no change below about 800 °C	no
Paraffin wax	0.90	no; floats	melts between about 50 and 70 °C	yes, yellow smoky flame
Baking soda (sodium bicarbonate)	2.20	yes, up to about 10 g per 100 g of water; clear	breaks down above about 80 °C, giving off gas and losing mass; no melt	no

Part A: Expert round (one set per person)

1. Your expert set: _____. Using only your cards and the reference table, write (a) one jar your set can identify on its own, with the card that does it, and (b) two jars your set cannot tell apart on its own and why.

Answer: Set 1 (cards 1 to 3): can identify E alone (density $4.5 \div 5.0 = 0.90$ g/cm³, floats; only paraffin is below 1); cannot separate B (2.2) from baking soda (2.20) or salt (2.17), and cannot separate C (1.5) from A (1.6) with confidence. Set 2 (cards 4, 5, 9): can identify E (floats in water, dissolves in oil, matching wax) and can separate A from B by solubility limit (card 5); cannot separate C from D (both cloudy and settling) without density. Set 3 (cards 6 to 8): can identify E (melts at 60 °C, burns) and separate A (caramel) from C (burnt toast) by card 7; cannot separate B from D (no change in either test). Set 4 (cards 10, 11, table): can rule out nothing by itself; card 10 is useless and card 11 only limits the candidates.

Why: Each set was built so that it solves part of the puzzle and leaves part unsolved, so the home group needs everyone.

Also acceptable: For Set 4 accept 'our set cannot identify any jar alone; it tells the group which candidates are possible.'

- Names a jar the set can identify with the deciding card
- Names two jars the set cannot separate with a reason

Part B: Home group task

1. Each expert teaches their cards to the group in two minutes. Listeners write down which jars each card helps with.

2. Work out the density for every jar from cards 2 and 3 (mass ÷ volume) and write the five values in the group record.
3. For each jar, agree on the identity and list every card number that supports it. A card counts as support only if the group can say what the card rules out.
4. Decide which candidate from the supply list is missing from all five jars, and name the cards that rule it out of each jar it might have matched.
5. Find the card that gave no useful evidence. Write one sentence saying why.
6. Prepare to defend the record to a neighboring group with cards, not opinions.

Group record (fill in)

Jar	Density (g/cm ³)	Identity	Cards that decide it	Candidate it could be confused with, and the card that rules it out
A				
B				
C				
D				
E				

2. Group answer: Which jar could be identified from a **single** card? Name the card and explain why one value was enough for that jar but not for the others.

Answer: Jar E, from card 3 alone: $4.5 \text{ g} \div 5.0 \text{ cm}^3 = 0.90 \text{ g/cm}^3$, and it floats. Only paraffin wax (0.90) in the reference table is less dense than water, so one value settles it. The other jars have densities (1.5, 1.6, 2.2, 2.7) that are close to two or more candidates, so a second property is needed for each of them.

Why: A single property identifies a substance only when no other candidate shares a nearby value.

Also acceptable: Accept card 6 (melts at about 60 °C) or card 9 (dissolves in oil) as a single deciding card for E; each value is unique in the table.

- Jar E and card 3
- Explains uniqueness of the value in the table

3. Group answer: Which candidate on the supply list is in none of the jars? Name the jar it most nearly matched and the two cards that rule it out.

Answer: Baking soda is in none of the jars. It most nearly matched jar B: both have a density of about 2.2 g/cm^3 and both dissolve clear in water. Card 5 rules it out (B dissolved about 7 g in 20 mL, which is about 35 g per 100 g, matching salt's 36 g, while baking soda would stop near 2 g in 20 mL), and card 7 rules it out again (B showed no change at about 500°C , while baking soda breaks down and gives off gas above about 80°C). Card 1's tiny cubes also fit salt.

Why: The decoy shares density with salt by design so that solubility limit and heating behavior must do the work.

Also acceptable: Accept card 1 (cube-shaped crystals) as supporting evidence but not as one of the two deciding cards.

- Baking soda named
- Jar B named as the near-match
- Cards 5 and 7 cited with what each shows

Part C: Individual accountability (complete alone)

4. Calculate the density of jar D from card 3 and name the solid it matches. Then explain why card 4 alone could not have separated jar D from jar C.

Answer: Density of D = $13.5 \text{ g} \div 5.0 \text{ cm}^3 = 2.70 \text{ g/cm}^3$, matching chalk (calcium carbonate, 2.71). Card 4 alone could not separate D from C because both made cloudy water and both settled; the only difference on card 4 is how fast they settled, which is a hint, not a measurement. Card 3 gives C a density of $7.5 \div 5.0 = 1.5 \text{ g/cm}^3$, which matches cornstarch, not chalk.

Why: Two insoluble powders need density or heating behavior to be told apart.

Also acceptable: Accept 'card 7 also separates them: C chars and D does not' as the second property.

5. Jars A and C both turned brown and black under strong heating (card 7). Name two cards that separate A from C and say what each shows.

Answer: Any two: card 4 (A dissolved clear; C made a cloudy mixture that settled); card 5 (A dissolved past 30 g in 20 mL, which only sugar can do); card 2 and card 3 (A is 1.6 g/cm^3 , C is 1.5 g/cm^3 , a small difference but in the right direction); card 7's detail (A melted into a clear syrup before browning, C never melted); card 1 (A sparkles as crystals, C is a squeaky powder).

Why: Solubility in water is the cleanest separator; the melting detail on card 7 is a second good one.

Also acceptable: Density (cards 2 and 3) is acceptable only if the student notes that the difference (0.1 g/cm^3) is small.

- Two cards named
- What each shows is stated correctly

6. Card 10 gives the mass of each jar's contents. Explain why this card cannot help identify any jar, using the words *object* and *substance*.

Answer: The mass of a jar's contents is a property of that particular object (how much was left in the jar), not of the substance. Any substance can be present in any amount: 300 g of chalk and 300 g of salt are both ordinary. Identifying a substance requires properties that are the same for every sample, such as density, solubility limit or melting behavior.

Why: Card 10 is the decoy for the object-versus-substance distinction.

Also acceptable: Accept 'the teacher could have poured some out and the number would change but the substance would not.'

- Says mass depends on the amount, an object property
- Says identity needs substance properties

7. Jar E did not dissolve in water (card 4) but did dissolve in warm oil (card 9). What does this pair of results show about the property called solubility?

Answer: Solubility is a property of a pair of substances, not of one substance alone. Wax has very low solubility in water and noticeable solubility in warm oil. Saying 'wax is insoluble' is incomplete; a scientist says 'insoluble in water' and names the liquid every time.

Why: This is the pair idea from the lesson's marker-ink example, applied to the jigsaw.

Also acceptable: Accept 'it depends what you try to dissolve it in.'

- States that solubility depends on both substances
- Uses the E results as evidence

8. A sixth jar, F, turns up: density 2.2 g/cm³, dissolves clear in water but only about 2 g in 20 mL, and gives off gas and loses mass when heated strongly. Identify it and name the two results that separate it from jar B.

Answer: Jar F is baking soda: density 2.2 matches (2.20), the low solubility limit (about 2 g in 20 mL, which is 10 g per 100 g) matches, and breaking down with gas and mass loss on strong heating matches. The two results that separate it from jar B (salt) are the solubility limit (B dissolved about 7 g in 20 mL) and the heating behavior (B showed no change at about 500 °C).

Why: Students apply the same decoy logic from q3 in reverse.

Also acceptable: Density alone is not a separating result since B and F share it; do not credit it as one of the two.

- Identifies baking soda
- Names solubility limit and heating behavior as the separating results

Scoring rubric

Criterion	4 • Exemplary	3 • Proficient	2 • Developing	1 • Beginning
Expert teaching	Each expert states clearly what their cards can and cannot decide, and listeners record which jars each card helps with.	Experts explain their cards; one expert overstates or understates what the set can decide.	Cards are read aloud without saying what they rule out; listeners record little.	One or two members do all the teaching; others do not present their cards.

Group record	All five densities computed correctly; all five identities correct; every supporting card listed with what it rules out; baking soda identified as missing with two ruling-out cards.	All identities correct; one density error or one jar's supporting cards incomplete.	Three or four identities correct, or identities correct but supporting cards missing for two or more jars.	Two or fewer identities correct, or identities asserted without cards.
Use of evidence in the check with a neighboring group	Disagreements settled by pointing to specific cards and reference values; the group changes its record when the evidence requires it.	Cards cited, but one disagreement settled by majority or confidence rather than evidence.	Groups compare answers without discussing why they differ.	No check, or the group copies the neighbor's record.
Individual accountability (Part C)	All five Part C answers accurate; the density calculation is shown; the object-versus-substance and solubility-pair ideas are explained in the student's own words.	Four accurate; one thin or partly incorrect.	Two or three accurate; others restate group answers without reasoning.	Part C mostly blank or inaccurate.

Teacher notes

Jar identities: A sugar (1.6 g/cm³, dissolves past 30 g in 20 mL, caramelizes), B table salt (2.2, about 7 g in 20 mL, no change at 500 °C), C cornstarch (1.5, cloudy and settles, chars with a burnt-toast smell, squeaks), D chalk (2.7, insoluble, no change), E paraffin wax (0.90, floats, melts about 60 °C, burns, dissolves in warm oil). Baking soda is the decoy: it shares salt's density but has a far lower solubility limit (about 10 g per 100 g of water) and breaks down on heating. Card 10 is the object-property decoy. Reference values are real and rounded (sodium chloride 2.17 g/cm³, solubility about 36 g per 100 g water at 20 °C, melting point 801 °C; sucrose 1.59, about 200 g per 100 g, decomposes from about 186 °C; cornstarch about 1.5; calcium carbonate 2.71, essentially insoluble, decomposes above about 800 °C; paraffin 0.90, melting 50 to 70 °C; sodium bicarbonate 2.20, about 10 g per 100 g, decomposes above about 80 °C). The card results are simulated. Densities of soluble solids are measured by displacement in oil in real labs for the reason card 2 gives. Print the cards, shuffle each deck, and keep the reference table separate so experts in Set 4 hold it. No heating or flame tests are done by students; the cards are the only source of those results.

Scaffold offered to students: Start with the easy jar

If the group is stuck, begin with the only solid that floats on water. Its density is below 1 g/cm³, and only one candidate in the reference table is that light. Identify that jar first, cross that candidate off the list, and then look for the next jar that has a value no other remaining candidate shares. Each time you identify a jar, cross a candidate off; the list gets shorter and the choices get easier.

Extension: Design the minimum test set

Your group used eleven cards. Suppose the teacher could run only three tests on every jar. Choose the three tests (from the eleven) that would still identify all five jars and rule out the missing candidate. Write out the reasoning jar by jar, and then explain which single test you would add back first if a seventh unknown white solid appeared, and why.