

Where Did the Mass Go? A Twelve-Card Evidence Sort

Learning target: I can work with a group to sort balance-reading evidence from twelve changes into cases where mass left, joined or stayed, explain each case with atoms crossing or not crossing a boundary, and write one rule that fits every card.

Collaborative investigation

About 50 min

Small group

MS-PS1-5 · practice

collaboration

discussion

data analysis

Standards connections

MS-PS1-5 (practice, using the conserved-atoms model to explain mass readings): Each card is a balance reading from a physical or chemical change in an open or closed system. Groups must use the atom model to explain every reading and defend one rule, which is the reasoning the PE asks students to show with a model. No atomic masses and no balancing are involved.

Purpose: practice · **Time:** about 50 minutes · **Format:** small-group

Answers with reasoning

Twelve evidence cards (teaching values; cut apart before class)

1 Card 1: Fizzing tablets in an open glass

A glass of water on a balance reads 231.60 g with two fizzing antacid tablets resting on the rim. The tablets are dropped in. They fizz for two minutes and disappear. Final reading: 230.40 g.

2 Card 2: Fizzing tablet in a capped bottle

The same kind of tablet is dropped into a rigid plastic bottle of water, and the cap is screwed on at once. Reading before: 238.20 g. The bottle fizzes and feels firm. Reading after two minutes: 238.20 g.

3 Card 3: Nail left out in the rain

A clean iron nail reads 5.40 g. It is left outdoors for a rainy week, then dried. It is covered with orange-brown flakes and reads 5.47 g.

4 Card 4: Candle burning in open air

A candle in a dish reads 48.20 g. It burns for ten minutes in the open. A cold glass held above the flame fogs with water droplets. Reading after: 46.60 g.

5 Card 5: Ice melting in a sealed bag

An ice cube sealed in a zip bag reads 24.80 g. An hour later it has completely melted. Reading: 24.80 g.

6 Card 6: Copper pad on a hot plate

A shiny copper scouring pad reads 2.40 g. It is heated on a hot plate for ten minutes in open air, turns black, and cools. Reading: 2.58 g.

7 Card 7: Sugar stirred into tea

A mug of warm tea reads 310.50 g, and a spoon of sugar beside it reads 4.00 g. The sugar is stirred into the open mug until it disappears. Reading of mug and tea: 314.50 g.

8 Card 8: Glow stick snapped in its tube

A sealed glow stick reads 18.30 g. It is snapped and glows brightly for an hour, then fades. Reading: 18.30 g.

9 Card 9: Match burned to ash

A wooden match reads 0.12 g. It is struck and burns completely in open air, leaving a black, curled stick. Reading: 0.03 g.

10 Card 10: Bread dough rising

A bowl of yeast dough, loosely covered with a cloth, reads 820.00 g. After an hour the dough has doubled in size and smells yeasty. Reading: 818.60 g.

11 Card 11: Magnesium ribbon burned (teacher demo)

A strip of magnesium metal reads 0.24 g. The teacher burns it in open air behind a shield; it gives a blinding white light and leaves a white powder. The powder, collected carefully, reads 0.40 g.

12 Card 12 (challenge): Baking soda and vinegar in a sealed zip bag

Vinegar in a zip bag with a packet of baking soda reads 171.30 g. The bag is sealed, the packet is tipped into the vinegar, and the bag puffs up tight. Nothing leaks. Reading: 170.80 g. Hint: the puffed bag sits on the pan a little like a balloon would.

Part A: Predict alone (before sorting)

1. Read only the first sentence of Cards 3, 5 and 9 (not the readings). For each, predict whether the reading will go up, down or stay the same, and give a one-phrase reason. You will check these after the sort.

Answer: Card 3 (nail in rain): likely 'up' or 'same'; a reason such as 'rust is added' or 'nothing is added'. Card 5 (ice in sealed bag): 'same', because melting makes no new substance and the bag is sealed. Card 9 (match): likely 'down', because it burns away. Any prediction with a reason earns credit; the check comes in q4.

Why: This is a pre-sort prediction, graded on having a reason, not on being right. Many students predict 'same' for the nail; the sort revises that.

Also acceptable: Any reasoned prediction.

- Three predictions
- Each with a reason

Part B: Group sort

1. Sort Cards 1 to 11 into three piles by what the reading did: FELL, ROSE, or STAYED THE SAME. Write the change for each card with a sign and units.
2. For each card, decide whether the system on the balance was open (matter could cross its boundary) or closed (nothing could cross). Mark each card O or C with a sticky note.
3. For every FELL card, name what left and what it was made of. For every ROSE card, name what joined and where it came from. For every STAYED card, say why nothing crossed the boundary, and whether a reaction happened at all.
4. Fill in the group record table. Then write one sentence, your group rule, that explains all eleven readings. It must mention atoms and a boundary.

5. Now read Card 12. Test your rule against it. If the rule says the reading should not have changed, do not throw the rule out; look for a reason the balance might read low without any atoms leaving. Write your best explanation in q3.
6. Swap rules with a neighboring group. Pick your hardest card and ask them to explain it with their rule. Record the strongest challenge you received and how you answered it.

Group record (fill in)

Card	Change (g, with sign)	Open or closed?	What crossed the boundary (or nothing)	Where those atoms are now
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				

2. Group answer: Write your group rule in one sentence. Then list which cards go in each pile (FELL, ROSE, STAYED).

Answer: Model rule: 'Atoms are never created or destroyed; a balance reading changes only when atoms cross the boundary of what is on the balance, leaving as a gas or joining from the air.' FELL: Cards 1 (−1.20 g), 4 (−1.60 g), 9 (−0.09 g), 10 (−1.40 g). ROSE: Cards 3 (+0.07 g), 6 (+0.18 g), 11 (+0.16 g). STAYED: Cards 2, 5, 7, 8 (0.00 g each). Open systems: 1, 3, 4, 6, 7, 9, 10, 11. Closed: 2, 5, 8 (and 12).

Why: Changes: Card 1: $230.40 - 231.60 = -1.20$; Card 3: $5.47 - 5.40 = +0.07$; Card 4: $46.60 - 48.20 = -1.60$; Card 6: $2.58 - 2.40 = +0.18$; Card 7: $314.50 - (310.50 + 4.00) = 0.00$; Card 9: $0.03 - 0.12 = -0.09$; Card 10: $818.60 - 820.00 = -1.40$; Card 11: $0.40 - 0.24 = +0.16$. FELL cards all made a gas that left (carbon dioxide from the tablets, yeast and the burning match and candle; water vapor from the flame). ROSE cards all took oxygen (and, for rust, water) from the air into a solid. STAYED cards are sealed (2, 5, 8) or open with no gas crossing (7). Card 7 is a mix and no reaction; Card 5 is a melt and no reaction; Card 8 is a reaction that gives off light, which has no mass. Card 10's drop is partly carbon dioxide and water vapor escaping through the cloth and partly the same lift as Card 12, because the dough doubled in volume; credit either explanation.

Also acceptable: Accept a rule phrased as 'mass only changes when a gas leaves or air joins.' Card 7 may be placed in STAYED with the note 'open but nothing left.'

- Rule mentions atoms conserved and a boundary crossing
- All eleven cards in the correct pile with signed changes

3. Group answer: Card 12 is sealed, yet the reading fell by 0.50 g. Does this break your rule? Explain what your group thinks is happening, using the hint on the card, and describe one change to the setup that would test your idea.

Answer: The rule is not broken: the bag is sealed, so every atom, including the carbon dioxide, is still inside and still has its mass. The reading fell because of the balance, not the atoms. The puffed bag takes up more room, and the surrounding air pushes up on it a little, the way air lifts a balloon, so the pan feels slightly less push. The gas is inside; the balance just cannot feel all of it. Test: run the same reaction in a rigid capped bottle that cannot puff up; the reading should stay the same. Or weigh the puffed bag again after letting the gas out: the reading should then fall by the mass of the gas, more than 0.50 g.

Why: This is buoyancy: an inflated bag displaces more air and reads lighter by the mass of the extra air displaced, roughly half a gram for the gas this much baking soda makes. Groups are not expected to use the word buoyancy; they should refuse to abandon conservation and should propose a rigid container as the test. The strongest groups say the atoms are still inside and blame the measurement.

Also acceptable: A group that says 'something about the balance, not the atoms' without the balloon idea earns most of the credit; a group that abandons the rule and says matter was destroyed has not met the criterion.

- States that all atoms are still inside the sealed bag
- Offers the balloon-like lift as the reason the reading dropped
- Proposes a rigid container or another fair test

Part C: Individual accountability (complete alone)

4. Check your Part A predictions against the cards. Which were right? For any that were wrong, say what you now know that you did not know before.

Answer: Students report their own hits and misses. Typical: Card 5 correct (same); Card 9 correct (down); Card 3 often predicted 'same' but rose, and the new knowledge is that rust is iron plus oxygen (and water) from the surroundings, so a rusting object gains mass.

Why: Graded on honest comparison and a specific new idea for any miss.

Also acceptable: A student with three correct predictions should instead state which card surprised the group.

- Compares each prediction to the card
- Names what was learned for any miss

5. Choose one FELL card and one ROSE card. For each, explain the reading with atoms: which atoms crossed the boundary, which direction, and what new substance they are part of now.

Answer: Example FELL, Card 1: carbon and oxygen atoms from the tablets regrouped into carbon dioxide molecules, which bubbled out of the open glass into the room; those atoms are now in carbon dioxide in the air. Example ROSE, Card 6: oxygen atoms from the air crossed into the pad and bonded to copper atoms; they are now part of the black copper oxide coating. Any FELL and ROSE pair with the atoms, the direction and the new substance named earns credit.

Why: The response must track atoms across the boundary in the correct direction and name the product. For Card 9 the gases are carbon dioxide and water vapor; for Card 10, carbon dioxide from the yeast; for Card 11, oxygen joining magnesium to make magnesium oxide; for Card 3, oxygen and water joining iron to make rust.

Also acceptable: Accept 'oxygen from the air' without naming the oxide for Cards 3, 6 and 11 if the direction is clear.

- One FELL and one ROSE card chosen
- Atoms and direction named for each
- New substance named for each

6. Cards 5 and 7 both STAYED, but Card 7 is an open mug. Explain why an open system can keep its mass, and say whether a chemical reaction happened on either card.

Answer: An open system keeps its mass as long as no atoms actually cross the boundary. In Card 7 the sugar dissolved: its molecules spread between the water molecules, but every one of them stayed in the mug, so $310.50 + 4.00 = 314.50$ g. Neither card is a chemical reaction: melting (Card 5) and dissolving (Card 7) make no new substance; the molecules are the same, just arranged differently. Both show that atoms are conserved in physical changes too.

Why: This distinguishes 'open' from 'something left' and reinforces that the atom rule covers physical changes. Card 7 would lose a little mass over time to evaporation, which is a fair extension point but not required.

Also acceptable: A student who notes that warm tea slowly loses water vapor, so the mug would eventually read lower, is correct and should be credited.

- Says an open system keeps its mass if nothing crosses the boundary
- Shows $310.50 + 4.00 = 314.50$
- States that neither card is a chemical reaction

7. Pick Card 4, 9 or 10. Describe one change to the setup that would make its reading stay the same, and explain, using the atoms, why your change works. Then explain why that steady reading would still not mean the reaction had stopped.

Answer: Example, Card 4: burn the candle under a sealed, rigid glass jar on the balance (with the air inside). The carbon dioxide and water vapor still form, but they cannot cross the glass, so every atom stays on the balance and the reading holds. Example, Card 10: let the dough rise in a sealed rigid container; the yeast still makes carbon dioxide, but it stays inside. Example, Card 9: burn the match inside a sealed jar; the gases stay. The steady reading would not mean the reaction stopped, because the atoms are still regrouping inside; the candle still shortens, the dough still swells, the match still chars. A steady reading tells you nothing crossed the boundary, not that nothing happened.

Why: Full credit needs a sealed, rigid container, an atom-level reason the reading holds, and the explicit point that a constant reading does not mean no reaction.

Also acceptable: A student who chooses Card 4 and notes that the sealed candle will go out when the oxygen runs out is reasoning well; the reading still holds.

- Proposes a sealed (preferably rigid) container
- Explains with atoms why the reading holds
- States that a steady reading does not mean the reaction stopped

Scoring rubric

Criterion	4 • Exemplary	3 • Proficient	2 • Developing	1 • Beginning
Sorting and boundary labels	All eleven cards in the correct pile with signed changes, and every card correctly labeled open or closed.	One card misplaced or one boundary label wrong.	Two or three cards misplaced, or boundary labels assigned without reasons.	Cards sorted by appearance or by whether a flame was involved rather than by the reading.
Atom-level explanations in the record	Every FELL and ROSE card names what crossed the boundary and where those atoms are now; STAYED cards say why nothing crossed and whether a reaction occurred.	Most cards explained with atoms; one or two say only 'gas left' or 'air joined' without naming the substance.	Explanations given for the dramatic cards only; STAYED cards left as 'nothing happened'.	Record lists readings without explanations.
Group rule and the challenge card	One-sentence rule mentions conserved atoms and boundary crossing; Card 12 is explained without abandoning the rule, with a fair test proposed.	Rule is correct; Card 12 is called 'a measuring problem' without a specific idea or test.	Rule is partial (for example, only covers FELL cards), or Card 12 is explained by matter being destroyed.	No rule, or a rule that contradicts the cards.
Individual accountability (Part C)	All four Part C answers accurate, use atoms and boundaries, and show the student understands the group's reasoning, not only its sort.	Three of four accurate; one thin or partly incorrect.	Two accurate; others restate the group result without reasoning.	Part C mostly blank or inaccurate.

Teacher notes

All card readings are teaching values and the sheet says so. They are realistic: two large fizzing antacid tablets (about 3 g each) release up to about 1.5 g of carbon dioxide as they dissolve, a little of which stays dissolved; a small candle burns about 0.16 g per minute; a heated copper pad and a burned magnesium strip gain mass from oxygen (magnesium oxide from 0.24 g of magnesium is about 0.40 g, which matches Card 11); a match loses most of its mass as gases. Card 12 is deliberate: an inflating sealed bag displaces more air and reads lighter because of buoyancy, about 1.2 g for every liter of puff (Card 12's 0.50 g is a puff of about 0.4 L), which teachers often see in the baking soda bag lab; a rigid capped bottle shows no drop. Do not tell groups the answer in advance; the point is that they keep the law and question the measurement. Card 11 is a teacher demonstration only, never a student activity, and the light is bright enough to damage eyes; do not look directly at it. Card 8 is useful for the discussion of energy versus matter: light leaves the sealed glow stick and the reading does not change, because light has no mass. The expert-set jigsaw structure is not used here; every group handles all twelve cards so that each student sees the full pattern.

Scaffold offered to students: Start with the boundary

If the sort feels hard, start by drawing an imaginary line around everything on the balance for each card and asking one question: could a gas get across this line? Sealed bottle, sealed bag, sealed tube: no. Open glass, open dish, cloth cover, open air: yes. Then ask whether the card describes a gas being made (fizzing, flame, yeast) or a gas from the air joining a solid (rust, black coating, white powder). Gas made and able to leave means FELL; gas from the air joining means ROSE; no gas crossing means STAYED. A change with no new substance (melting, dissolving) is not a reaction, but the atoms are still all there.

Extension: Two cards that look alike

Cards 3 and 6 both ROSE and both show a metal gaining mass from the air. A rusting nail needs both oxygen and water from its surroundings; the heated copper pad needs only oxygen. Design a pair of sealed experiments that could show whether water is needed for rust: describe what goes in each sealed container, what you would keep the same, what reading or appearance you would expect in each after a week, and why the sealed reading should be the same before and after in both containers no matter what happens to the nail.