

Fixing Priya's Notebook: Seven Reaction Claims That Break the Atom Rule

Learning target: I can find the error in a claim about atoms, equations or mass in a chemical reaction, explain what went wrong, and rewrite the claim so it follows the rule that atoms are only regrouped.

Error analysis

About 35 min

Individual

MS-PS1-5 · practice

writing

independent practice

Standards connections

MS-PS1-5 (practice, the atom-count model and the reasoning from counts to mass): Every entry in the notebook misuses the chapter's model in a common way: heat counted as matter, a subscript read as a total, a subscript changed to fix a count, a gas treated as massless, atoms described as breaking, molecules confused with atoms. Diagnosing and repairing these claims strengthens the model the PE asks for. Equations are given already correct; students count, they do not balance.

Purpose: practice · **Time:** about 35 minutes · **Format:** individual

Answers with reasoning

Priya's lab notebook, page 12 — Entry 1. Steel wool: 2.00 g before burning, 2.14 g after. The heat from the flame got stored inside the metal, and that stored heat is the extra 0.14 g. **Entry 2.** Equation for splitting water: $2\text{H}_2\text{O} \rightarrow 2\text{H}_2 + \text{O}_2$. Counting: on the left, H has 2 atoms (the small 2) and O has 1. On the right, H has 2 and O has 2. So the reaction created one oxygen atom. **Entry 3.** To fix Entry 2, I rewrote the water as H_2O_2 so both sides would have 2 oxygen atoms. Now it balances. **Entry 4.** Vinegar and baking soda in an open cup: 162.0 g before, 161.0 g after. The bubbles are just gas, and gas does not weigh anything, so 1.0 g of matter was destroyed by the reaction. **Entry 5.** When methane burns ($\text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O}$), the carbon atom breaks apart into smaller pieces, and the pieces become the carbon dioxide. **Entry 6.** In the methane reaction there are 3 molecules before and 3 after, so the number of molecules is conserved in every reaction, just like atoms. **Entry 7.** The capped bottle stayed at 165.5 g during the fizzing because the cap kept the heat in, and heat is what the balance was weighing.

Priya's atom tally for burning magnesium: $2\text{Mg} + \text{O}_2 \rightarrow 2\text{MgO}$

Element	Atoms before (reactants)	Atoms after (products)	Priya's conclusion
Mg	2	2	same
O	2	1	one oxygen atom disappeared

Priya's counting is wrong in one cell. Magnesium oxide (MgO) is an extended structure, so MgO is one repeating unit, not a molecule.

Part A: Sort the entries

1. For each entry, name the error type from this list: *energy counted as matter*, *subscript read as a total*, *subscript changed*, *gas treated as massless*, *atoms said to break*, *molecules confused with atoms*. Two entries share the same type. Then write one thing Priya observed or did correctly in that entry, because every entry has a correct observation inside it.

Answer: Entry 1: energy counted as matter; correct part: the two readings (2.00 g and 2.14 g) and that the pad gained mass. Entry 2: subscript read as a total; correct part: the equation and the oxygen count on the right (2). Entry 3: subscript changed; correct part: she noticed that the two sides must have the same count. Entry 4: gas treated as massless; correct part: both readings and the observation of bubbles. Entry 5: atoms said to break; correct part: the equation and that carbon ends up in carbon dioxide. Entry 6: molecules confused with atoms; correct part: the molecule counts of 3 and 3 for the methane reaction. Entry 7: energy counted as matter (shared type with Entry 1); correct part: the reading stayed at 165.5 g.

Why: The sort checks that students can name the kind of error before repairing it. Entries 1 and 7 both treat heat as something the balance weighs, which is the shared type.

Also acceptable: Accept 'subscript read as a total' for Entry 3 if the student explains that the two entries are the same mistake continued; the intended type for Entry 3 is 'subscript changed'.

- All seven error types correctly assigned
- Entries 1 and 7 given the same type
- A genuine correct observation named for each entry

Part B: Explain and rewrite

2. Entry 1. Explain why heat cannot be the extra 0.14 g, and say what the balance was actually weighing. Then rewrite the entry correctly in Priya's voice.

Answer: Heat is energy, not matter; it has no atoms, so a balance cannot weigh it. A hot object and a cold object of the same atoms read the same. The balance was weighing the iron atoms plus the oxygen atoms from the air that bonded to them, making iron oxide. Rewrite: 'Steel wool: 2.00 g before, 2.14 g after. The extra 0.14 g is oxygen atoms from the air that joined the iron atoms to make iron oxide. The heat came out of the reaction and left; it is not on the balance.'

Why: This is the chapter's second listed misconception; the repair must name oxygen from the air as the source of the mass and keep heat off the balance.

Also acceptable: Accept 'the balance reads atoms only' as the first point.

- States that heat is energy and has no mass
- Names oxygen from the air as the extra mass
- Rewrite keeps the readings and corrects the cause

3. Entries 2 and 3. Redo Priya's count for $2\text{H}_2\text{O} \rightarrow 2\text{H}_2 + \text{O}_2$, showing the multiplication for every term. Explain the counting mistake in Entry 2, then explain why the 'fix' in Entry 3 is worse than the original mistake. Rewrite both entries as one correct entry.

Answer: Correct count: $2\text{H}_2\text{O}$ gives $\text{H} = 2 \times 2 = 4$ and $\text{O} = 2 \times 1 = 2$. 2H_2 gives $\text{H} = 2 \times 2 = 4$. O_2 gives $\text{O} = 1 \times 2 = 2$. Left: 4 H, 2 O; right: 4 H, 2 O. Nothing was created. Entry 2's mistake: Priya read the subscript as the total and ignored the coefficient 2 in front of H_2O , which multiplies every atom in the formula. Entry 3 is worse because H_2O_2 is not water; it is hydrogen peroxide, a different substance. Changing a subscript changes what substance the equation describes, so Priya's 'fixed' equation now describes a reaction that is not the one she observed. The equation was already correct; only her counting was wrong. Rewrite: 'Splitting water: $2\text{H}_2\text{O} \rightarrow 2\text{H}_2 + \text{O}_2$. Left: $\text{H} = 2 \times 2 = 4$, $\text{O} = 2 \times 1 = 2$. Right: $\text{H} = 2 \times 2 = 4$, $\text{O} = 2$. The counts match, so no atom was created. I must multiply the coefficient by the subscript, and I may never change a subscript.'

Why: This pairs the chapter's coefficient-versus-subscript rule with its 'never change a subscript' misconception. The count must be shown term by term.

Also acceptable: Accept the rewrite in any wording that keeps the equation unchanged and states the matching counts.

- Shows 4 H and 2 O on each side with multiplications
- Explains the ignored coefficient
- Explains that H_2O_2 is a different substance
- Single corrected entry

4. Entry 4. Priya's two readings are correct. Explain what is wrong with 'gas does not weigh anything' and with 'matter was destroyed,' then rewrite the entry so it says where the 1.0 g went and how she could check.

Answer: Gases are made of atoms, and every atom has mass, so a gas has mass; carbon dioxide can be weighed if it is trapped. 'Destroyed' is wrong because the atoms in the gas still exist; they moved out of the open cup into the room, so the balance stopped weighing them. Rewrite: 'Vinegar and baking soda in an open cup: 162.0 g before, 161.0 g after. The reaction made carbon dioxide gas, and about 1.0 g of it bubbled out of the cup into the room. No matter was destroyed; it left. To check, I could run the reaction in a capped bottle on the balance and expect the reading to stay at the starting value.'

Why: The repair needs both corrections (gas has mass; atoms moved rather than vanished) and a checkable sealed-container test.

Also acceptable: Accept 'catch the gas in a balloon on the cup' as the check if the student expects the reading to fall much less than 1.0 g and to fall the rest of the way when the balloon is removed; a puffed balloon reads somewhat low because the air lifts it, so a rigid capped bottle is the cleaner test.

- States that gas is matter with mass
- Says the 1.0 g left the cup as carbon dioxide
- Proposes a sealed test with the expected result

5. Entry 5. What really breaks when methane burns, and what stays whole? Rewrite the sentence so the carbon atom survives the reaction.

Answer: Bonds break, not atoms: the bonds between the carbon atom and its four hydrogen atoms break, and the bonds between the two oxygen atoms in each oxygen molecule break. The carbon atom stays whole and bonds to two oxygen atoms. Rewrite: 'When methane burns, the bonds holding the carbon atom to its hydrogen atoms break, and the same carbon atom, still whole, bonds to two oxygen atoms to make carbon dioxide.'

Why: The chapter's accuracy note: atoms do not break apart in chemical reactions; only nuclear changes alter an atom, and those are outside this lesson.

Also acceptable: Any rewording where the carbon atom survives and bonds are what break earns credit.

- Says bonds break, atoms stay whole
- Rewrite keeps the carbon atom intact and ends in carbon dioxide

6. Entry 6. Use the equation $2\text{H}_2\text{O}_2 \rightarrow 2\text{H}_2\text{O} + \text{O}_2$ (hydrogen peroxide breaking down) to show Priya a reaction where her claim fails. Count molecules and atoms on each side, then rewrite the entry so it says what is always conserved and what only sometimes stays the same.

Answer: $2\text{H}_2\text{O}_2 \rightarrow 2\text{H}_2\text{O} + \text{O}_2$: molecules 2 before, 3 after, so the number of molecules changed. Atoms: H = $2 \times 2 = 4$ before and $2 \times 2 = 4$ after; O = $2 \times 2 = 4$ before and $2 \times 1 + 2 = 4$ after; total 8 and 8. Rewrite: 'In the methane reaction there happened to be 3 molecules on each side, but that is a coincidence. What is always conserved is the number of atoms of each element, and therefore the mass. The number of molecules can change, as it does when 2 hydrogen peroxide molecules become 3 molecules.'

Why: A counterexample with full counts is required; the rewrite must separate the always-true rule (atoms) from the sometimes-true observation (molecules).

Also acceptable: Accept $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$ (3 molecules to 2) as an alternative counterexample if the student supplies it with correct counts.

- Counts molecules 2 and 3
- Counts atoms 8 and 8 with H 4/4 and O 4/4
- Rewrite states atoms are always conserved, molecules are not

7. Entry 7. Priya's reading is right and her reason is wrong. Explain what the cap really kept in, and rewrite the entry.

Answer: The cap kept the carbon dioxide gas in, not the heat; energy can still pass through the plastic walls, and heat has no mass anyway. The reading held because every atom, including the atoms in the gas, stayed inside the bottle on the balance. Rewrite: 'The capped bottle stayed at 165.5 g because the cap kept the carbon dioxide gas inside, so the balance was still weighing all of the atoms. The mixture actually cooled slightly, because this reaction takes in energy, but heat has no mass either way and is not what the balance reads.'

Why: Same repair as Entry 1 applied to a closed system: trapped atoms, not trapped energy, explain the steady reading.

Also acceptable: Accept 'the gas could not leave, so nothing crossed the boundary.'

- Says the cap trapped the gas (atoms), not heat
- Says heat has no mass
- Rewrite explains the steady reading with trapped atoms

8. Redo Priya's magnesium tally for $2\text{Mg} + \text{O}_2 \rightarrow 2\text{MgO}$. Below the table, write which cell she got wrong, the multiplication she skipped, and the corrected conclusion.

Answer: Mg: 2 before (coefficient 2×1), 2 after (2×1 in 2MgO), yes. O: 2 before (1×2 in O_2), 2 after (2×1 in 2MgO), yes. Total: 4 before, 4 after, yes. Priya's wrong cell is 'O, atoms after = 1': she read the single O in MgO and skipped the coefficient 2 in front of MgO. The skipped multiplication is $2 \times 1 = 2$. Corrected conclusion: no oxygen atom disappeared; both oxygen atoms from the O_2 molecule are now bonded to magnesium atoms in magnesium oxide.

Why: Same coefficient error as Entry 2, in a joining reaction with an extended-structure product. The caption reminds students that MgO is counted as a repeating unit.

Also acceptable: Accept a note that MgO is a formula unit rather than a molecule; it is not required for credit.

Part C: A rule for next time

9. Write Priya a checking rule in three or four sentences that would have caught all seven errors. It must cover: what to multiply when counting atoms, what you may and may not change in a formula, what a balance can and cannot weigh, and what to do when an open container's reading changes.

Answer: Model rule: (1) To count atoms, multiply the coefficient in front of a formula by each subscript inside it, then add up every element across the whole side; the counts for each element must match on both sides. (2) You may never change a subscript, because that changes the substance; the equations we are given are already correct, so if counts do not match, recount. (3) A balance weighs atoms only; heat and light have no mass, so never use them to explain a reading. (4) If an open container's reading goes up or down, say which gas left or which atoms from the air joined, and check with a sealed container, where the reading should not change.

Why: The rule should cover counting, the subscript ban, energy versus matter, and open-system readings, which between them catch all seven entries.

Also acceptable: Accept any order or wording that includes all four parts; a student who adds 'bonds break, atoms do not' has covered Entry 5 as well.

- Multiply coefficient by subscript and compare each element
- Never change a subscript
- A balance weighs atoms, not energy
- Open-container changes mean atoms crossed the boundary; sealed is the check

Teacher notes

Priya and her notebook are fictional. The seven entries are built from the misconceptions listed in the chapter: heat as matter (1 and 7), coefficient and subscript (2, 3 and the tally), gas as massless and matter destroyed (4), atoms breaking (5), molecules versus atoms (6). All equations are given correct and balanced, so students only count. Expected counts: $2\text{H}_2\text{O} \rightarrow 2\text{H}_2 + \text{O}_2$ is 4 H and 2 O per side; $2\text{H}_2\text{O}_2 \rightarrow 2\text{H}_2\text{O} + \text{O}_2$ is 4 H and 4 O per side; $2\text{Mg} + \text{O}_2 \rightarrow 2\text{MgO}$ is 2 Mg and 2 O per side. Magnesium burning is a teacher demonstration in some classrooms; it gives a dangerously bright flame and is only a counting example here. Pair this sheet with students' own W1 first explanations: many wrote Entry 1 or Entry 4 in their own words, and repairing Priya's version is a low-stakes way to repair theirs. The most common student slip on this sheet is to 'fix' Entry 3 by writing a new coefficient instead of recounting; remind them the given equation already balances.

Scaffold offered to students: Three questions to ask every entry

Ask each entry three questions. First: is she counting atoms correctly? Count by multiplying the coefficient (the big number in front) by the subscript (the small number after a symbol) and add up each element across the whole side. Second: is she calling something matter that is not matter? Heat, light and energy do not sit on a balance; only atoms do. Third: if a reading changed, did she say where the atoms went or came from? If an entry says 'destroyed', 'created', 'broke apart' (about an atom) or 'weighs nothing' (about a gas), the entry needs repair.

Extension: Write the eighth entry

Write an Entry 8 for Priya's notebook about a reaction she has not seen in class: a glow stick snapped in a sealed tube reads 18.30 g before and 18.30 g after it stops glowing. Write it the way Priya would have written it with one of the seven error types hidden inside, then write the corrected version beside it and label which error type you planted. Finally, explain why light leaving the tube does not change the reading even though something clearly left.