

# Atoms in Chemical Reactions: Mastery Check

**Learning target:** I can count atoms in a given equation, sort a reaction by how its atoms regroup, predict and explain balance readings in open and closed systems, and compute the efficiency of a chemical process from mass data.

Retrieval and mastery check

About 35 min

Individual

MS-PS1-5 · assesses

MS-ETS1-3 · practice

independent practice

writing

visual modeling

## Standards connections

**MS-PS1-5** (assesses, the whole PE, through counting, a drawn model and reading predictions): Items ask students to tally atoms in given equations, draw a before-and-after model for a reaction, predict sealed and open readings, and explain both a mass loss and a mass gain with the same rule. All equations are supplied already balanced and no atomic masses appear, so the quiz stays inside the assessment boundary.

**MS-ETS1-3** (practice): One item computes process efficiency from mass data and one asks why combining two improvements can beat either alone, retrieving the engineering reasoning from the lesson's green chemistry spread. This PE is listed for grades 6-8 in the California sequence.

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

## Answers with reasoning

### Part A: Retrieval items (24 points)

1. In the equation  $4\text{Fe} + 3\text{O}_2 \rightarrow 2\text{Fe}_2\text{O}_3$  (steel wool burning), which substances are the reactants? 1 pt

**Answer:** B, Fe and  $\text{O}_2$ .

**Why:** Reactants are written to the left of the arrow; iron oxide is the only product.

*Also acceptable:* None.

2. In the same equation, how many oxygen atoms are in  $3\text{O}_2$ , and how many are in  $2\text{Fe}_2\text{O}_3$ ? Show the multiplication for each. 2 pts

**Answer:**  $3\text{O}_2$ :  $3 \times 2 = 6$  oxygen atoms.  $2\text{Fe}_2\text{O}_3$ :  $2 \times 3 = 6$  oxygen atoms. (Iron: 4 and  $2 \times 2 = 4$ .)

**Why:** Coefficient times subscript on each side; the match (6 and 6) shows oxygen is conserved. One point per correct count with its multiplication.

*Also acceptable:* None; the counts must be 6 and 6.

3. In  $2\text{NH}_3$  (two ammonia molecules), the small 3 is a: 1 pt

**Answer:** B, subscript; it counts hydrogen atoms in each molecule.

**Why:** The small number after H is a subscript and applies to hydrogen only; the 2 in front is the coefficient that counts molecules.

*Also acceptable:* None.

4. True or false: During a chemical reaction, atoms break apart into smaller pieces, and the pieces build the products. 1 pt

**Answer:** False. Bonds between atoms break and new bonds form; the atoms themselves stay whole and keep their identity.

**Why:** This is the chapter's central accuracy point; nuclear changes that alter atoms are outside this lesson.

*Also acceptable: Credit 'false' with any correct one-line reason.*

5. Tally the atoms in  $2\text{Mg} + \text{O}_2 \rightarrow 2\text{MgO}$  (magnesium burning; MgO is an extended structure counted in repeating units). 3 pts

**Answer:** Mg: 2 before ( $2 \times 1$ ), 2 after ( $2 \times 1$ ), yes. O: 2 before ( $1 \times 2$ ), 2 after ( $2 \times 1$ ), yes. Total: 4 before, 4 after, yes.

**Why:** One point per row. The common error is O after = 1, from skipping the coefficient on MgO.

*Also acceptable: None.*

6. Sort each reaction by how its atoms regroup: breaking apart, joining together, or swapping partners. (a)  $2\text{H}_2\text{O}_2 \rightarrow 2\text{H}_2\text{O} + \text{O}_2$  (b)  $2\text{Mg} + \text{O}_2 \rightarrow 2\text{MgO}$  (c)  $\text{AgNO}_3 + \text{NaCl} \rightarrow \text{AgCl} + \text{NaNO}_3$ . Give a one-phrase reason for each. 3 pts

**Answer:** (a) Breaking apart: one substance becomes two. (b) Joining together: two substances become one. (c) Swapping partners: two substances become two new substances with the partners exchanged (silver now with chlorine, sodium now with the nitrate group).

**Why:** The sort is by counting substances on each side and seeing how the groups changed. One point per correct pattern with a reason.

*Also acceptable: For (c), accept 'the metals traded places' or 'silver and sodium switched.'*

7. A fizzing reaction runs inside a sealed rigid bottle on a balance. Before: 240.0 g. What does the balance read after the fizzing stops? Explain in one sentence. 2 pts

**Answer:** 240.0 g. The bottle is sealed, so the gas produced stays inside and every atom is still on the balance; no matter crossed the boundary.

**Why:** One point for the unchanged value, one for the sealed-boundary reason.

*Also acceptable: Accept 'the same, 240.0 g' with the reason.*

8. The same reaction runs in an open dish. Before: 85.6 g. After: 84.9 g. How much gas left the dish? Show the subtraction and name what carried the mass away. 2 pts

**Answer:**  $85.6 \text{ g} - 84.9 \text{ g} = 0.7 \text{ g}$  of gas left the dish. The mass was carried away by the gas (carbon dioxide) that escaped into the air; the atoms still exist.

**Why:** One point for the subtraction, one for naming the escaping gas as what carried the mass.

*Also acceptable: Accept 'the gas that bubbled out' if carbon dioxide is not named.*

9. Steel wool reads 2.00 g before burning and 2.14 g after. The best explanation for the extra 0.14 g is: 1 pt

**Answer:** B, oxygen atoms from the air bonded to the iron atoms.

**Why:** Heat has no mass (A), drift cannot explain a gain that comes back every time a pad is burned and reweighed cold (C), and atoms are never created (D).

*Also acceptable: None.*

10. Nitrogen and hydrogen react to form ammonia:  $\text{N}_2 + 3\text{H}_2 \rightarrow 2\text{NH}_3$ . Draw a BEFORE box and an AFTER box. Draw every atom as a labeled circle (N or H) with lines for bonds: nitrogen gas is two N atoms bonded together, hydrogen gas is two H atoms bonded together, and each ammonia molecule is one N atom bonded to three H atoms. Write the tally (N = \_\_, H = \_\_) under each box. 4 pts

**Answer:** BEFORE box: one  $\text{N}_2$  (two N circles joined by a line) and three  $\text{H}_2$  (three pairs of H circles, each pair joined by a line); tally N = 2, H = 6. AFTER box: two  $\text{NH}_3$  (each one N circle with three H circles attached); tally N = 2, H = 6. Total 8 atoms in each box.

**Why:** Four points: one for the correct BEFORE molecules, one for the correct AFTER molecules, one for matching tallies (2 N, 6 H in each box), one for consistent circle labels and bonds. The drawing is the model MS-PS1-5 asks for: the same eight atoms, regrouped.

*Also acceptable: Ammonia drawn flat or as a pyramid is acceptable; color-coded circles are acceptable with a key.*

- BEFORE shows 1  $\text{N}_2$  and 3  $\text{H}_2$  as bonded pairs
- AFTER shows 2  $\text{NH}_3$  with one N bonded to three H each
- Tallies written and matching: N 2/2, H 6/6
- Atoms labeled consistently in both boxes

11. A process uses 300 kg of reactants per batch and produces 120 kg of the wanted product; everything else is waste. (a) How much waste is made per batch? (b) What is the efficiency, as the percentage of reactant mass that becomes wanted product? Show both calculations. 2 pts

**Answer:** (a) Waste:  $300 \text{ kg} - 120 \text{ kg} = 180 \text{ kg}$  per batch. (b) Efficiency:  $120 \div 300 = 0.40 \rightarrow 40\%$ .

**Why:** Conservation gives the waste by subtraction; efficiency is the wanted-product share. One point each.

*Also acceptable: None.*

12. One sentence states the law of conservation of matter. Another sentence explains why it is true. Write both sentences and label which is the law and which is the explanation. 2 pts

**Answer:** Law: In any ordinary chemical or physical change, matter is neither created nor destroyed, so the total mass after equals the total mass before. Explanation: Matter is made of atoms; in a reaction atoms only change partners as bonds break and form, and every atom keeps its mass, so rearranging them cannot change the total.

**Why:** One point for a correct law stated as a pattern about mass, one for an atom-level explanation, with the two labeled correctly.

*Also acceptable: Accept 'mass before = mass after' as the law.*

- Law stated as a pattern about mass before and after
- Explanation uses atoms keeping their mass while changing partners
- Each labeled

## Part B: Synthesis (6 points)

13. A cup of vinegar and baking soda on a balance lost 1.1 g while it fizzed. A pad of steel wool on a balance gained 0.14 g while it burned. Explain both readings using one rule about atoms. Your answer must: say what crossed the boundary in each case and in which direction; state what would happen to each reading inside a sealed container; and explain why a chemical engineer who wants less waste cares about this same rule. 6 pts

**Answer:** Model response: The rule is that atoms are never created or destroyed in a reaction; they only regroup, and a balance reading changes only when atoms cross the boundary of what is being weighed. In the cup, atoms from the vinegar and baking soda regrouped into carbon dioxide gas, which left the open cup for the room, so the reading fell by the mass of that gas, 1.1 g. In the steel wool, oxygen atoms from the air crossed into the pad and bonded to iron atoms to make iron oxide, so the reading rose by the mass of the oxygen that joined, 0.14 g. In a sealed container, neither reading would change: the carbon dioxide would stay inside and still be weighed, and the oxygen the iron used would come from the air sealed inside, so the total would be the same before and after. A chemical engineer cares because the same rule means every reactant atom must end up somewhere: in the product, in a by-product or in waste. Waste is not atoms that vanished; it is atoms that went to the wrong place. To make less waste, the engineer redesigns the process so more of the same atoms end up in useful products, for example by using a catalyst to need fewer reactants or by capturing a by-product and selling it.

**Why:** Six points: two for the rule stated once and applied to both readings with the correct direction of crossing; two for the sealed-container predictions for both cases; two for the engineering connection that waste is atoms in the wrong place and efficiency means redirecting them.

*Also acceptable: A student who adds that the open-cup loss is slightly less than the gas made because some stays dissolved is correct; do not deduct for it. A student who notes that a puffed-up sealed bag would read somewhat low because the surrounding air lifts it, while its mass stays the same, is also correct.*

- One rule covers both the loss and the gain
- Names carbon dioxide leaving and oxygen joining, with directions
- Predicts no change in a sealed container for both
- Connects conservation to waste and process efficiency

## Teacher notes

Scoring: Part A 24 points (q1 1, q2 2, q3 1, q4 1, q5 3, q6 3, q7 2, q8 2, q9 1, q10 4, q11 2, q12 2), Part B 6 points, total 30. All equations are given balanced and students only count, which respects the MS-PS1-5 assessment boundary; no atomic masses appear anywhere. Expected tallies:  $4\text{Fe} + 3\text{O}_2 \rightarrow 2\text{Fe}_2\text{O}_3$  has 4 Fe and 6 O per side;  $2\text{Mg} + \text{O}_2 \rightarrow 2\text{MgO}$  has 2 Mg and 2 O;  $\text{N}_2 + 3\text{H}_2 \rightarrow 2\text{NH}_3$  has 2 N and 6 H. Item (c) in q6 uses silver nitrate and sodium chloride, a swap reaction that gives a white solid; it is a counting and sorting example only, with no procedure. The steel-wool equation uses  $\text{Fe}_2\text{O}_3$  as the model product, following the chapter's accuracy note; do not mark down a student who knows other iron oxides can form. If students struggle on q10, the chapter's W4 drawing task is the reteach; for q13, W5 and W6 are the reteach. The textbook's printed steel-wool equation contains a misprint (F for Fe); this quiz uses the correct symbols.

### **Scaffold offered to students: Before you start**

Counting rule: multiply the big number in front (coefficient) by the small number after a symbol (subscript); a symbol with no subscript counts as 1. Add every element across the whole side of the arrow before you compare sides. Reading rule: in a sealed, rigid container the balance reading does not change; in an open one, the reading falls if a gas leaves and rises if atoms from the air join a solid. Efficiency rule:  $\text{wanted product mass} \div \text{reactant mass} \times 100$ .

### **Extension: Write the hardest fair item**

Write one quiz item of your own that a classmate could only answer by using the atom model, not by memory. It must include an equation (already correct), a sealed or open container, and a balance reading, and it must have a single defensible numerical answer. Write the full answer key for it, including the calculation and one wrong answer a student might give with the misconception that produces it.