Atoms and Mass

Connect atom counts, mole ratios, and conserved mass.

HS-PS1-7 · Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction. Clarification Statement: Emphasis is on using mathematical ideas to communicate the proportional relationships between masses of atoms in the reactants and the products, and the translation of these relationships to the macroscopic scale using the mole as the conversion from the atomic to the macroscopic scale. Emphasis is on assessing students' use of mathematical thinking and not on memorization and rote application of problem-solving techniques. Assessment Boundary: Assessment does not include complex chemical reactions.

Name _____ Date _____

Mass Stays Accounted For

A balanced equation preserves the number of each kind of atom. Its coefficients also give mole ratios. Mass = amount in mol × molar mass in g/mol. All calculations here assume the stated reaction goes to completion, with the stated reactant amounts in the balanced ratio and all products accounted for; rounded atomic molar masses are supplied.

Worked example

For $2Al + 3S \rightarrow Al_2S_3$, count atoms in the equation, then compare masses for 2 mol Al and 3 mol S. Use Al = 27 g/mol and S = 32 g/mol.

1. The table shows equal Al and S atom counts on both sides.
2. 2 mol Al × 27 g/mol = 54 g; 3 mol S × 32 g/mol = 96 g.
3. 1 mol Al_2S_3 has mass 1 mol × [2(27) + 3(32)] g/mol = 150 g.
4. 54 g + 96 g = 150 g; scaling atom ratios to moles preserves total mass.

150 g of reactants = 150 g of product.

Atoms in the balanced equation

Element	Left	Right
Al	2	2
S	3	3

1. Practice

For $2Mg + O_2 \rightarrow 2MgO$, use 2 mol Mg and 1 mol O_2. Mg = 24 g/mol; O = 16 g/mol. Count each kind of atom in the equation and compare total masses.

2. Practice

For $C + O_2 \rightarrow CO_2$, C = 12 g/mol and O = 16 g/mol. How many grams of CO_2 form from 1 mol C and 1 mol O_2?

3. Practice

For $4Li + O_2 \rightarrow 2Li_2O$, use 4 mol Li and 1 mol O_2. Li = 7 g/mol; O = 16 g/mol. Compare masses and explain the atom counts.

4. Practice

$CaCO_3 \rightarrow CaO + CO_2$. A model starts with 100 g $CaCO_3$ and forms 56 g CaO. Find the CO_2 mass. Explain why the solid residue alone is lighter.

5. Apply

In a hypothetical closed-system calculation, 2 mol $NaHCO_3$ fully decomposes: $2NaHCO_3$ -> Na_2CO_3 + H_2O + CO_2. Find the missing mass and verify the C and O atom counts.

Calculated mass accounting

Substance	Mass
2 mol $NaHCO_3$	168 g
Na_2CO_3	106 g
H_2O	18 g
CO_2	?

6. Apply

A model of iron oxidation uses $4Fe + 3O_2$ -> $2Fe_2O_3$. All 224 g Fe reacts with 96 g O_2. Fe = 56 g/mol; O = 16 g/mol. Find the product mass and amount in moles. Explain why the product weighs more than the iron alone.

7. Challenge

A model completely reacts 56 g N_2 with 12 g H_2: $N_2 + 3H_2$ -> $2NH_3$. N = 14 g/mol; H = 1 g/mol. Find the mass and moles of NH_3. Support conservation using both atom counts and mass.

What to accept

These are idealized paper calculations, not laboratory procedures. Require units and explanations connecting atom counts to mass, not just matching totals. A closed container alone does not guarantee complete reaction; completion and stoichiometric amounts are specified assumptions. Accept equivalent calculations using the supplied rounded values.

1. Practice

Mg: 2 atoms each side; O: 2 each side. Reactants: 2(24) + 32 = 80 g. Products: 2(24 + 16) = 80 g.

2. Practice

1 mol CO_2 forms: 12 g + 32 g = 44 g. C: 1 atom each side; O: 2 each side.

3. Practice

Reactants: 4(7) + 32 = 60 g. Products: 2[2(7) + 16] = 60 g. Li: 4 atoms each side; O: 2 each side.

4. Practice

44 g CO_2. The other 44 g is in the gaseous product; total matter has not disappeared.

5. Apply

44 g CO_2

168 - 106 - 18 = 44 g. C: 2 on the left, 1 + 1 = 2 on the right. O: 6 on the left, 3 + 1 + 2 = 6 on the right.

6. Apply

320 g Fe_2O_3; 2 mol Fe_2O_3

224 + 96 = 320 g. The molar mass of Fe_2O_3 is 2(56) + 3(16) = 160 g/mol, so 320 g ÷ 160 g/mol = 2 mol. Oxygen contributes the extra 96 g.

7. Challenge

56 + 12 = 68 g NH_3. NH_3 has molar mass 17 g/mol; 68 g ÷ 17 g/mol = 4 mol. The reactants are 2 mol N_2 and 6 mol H_2, twice the equation ratio. Both sides contain 4 mol N atoms and 12 mol H atoms. Atoms are rearranged, so 68 g remains accounted for.