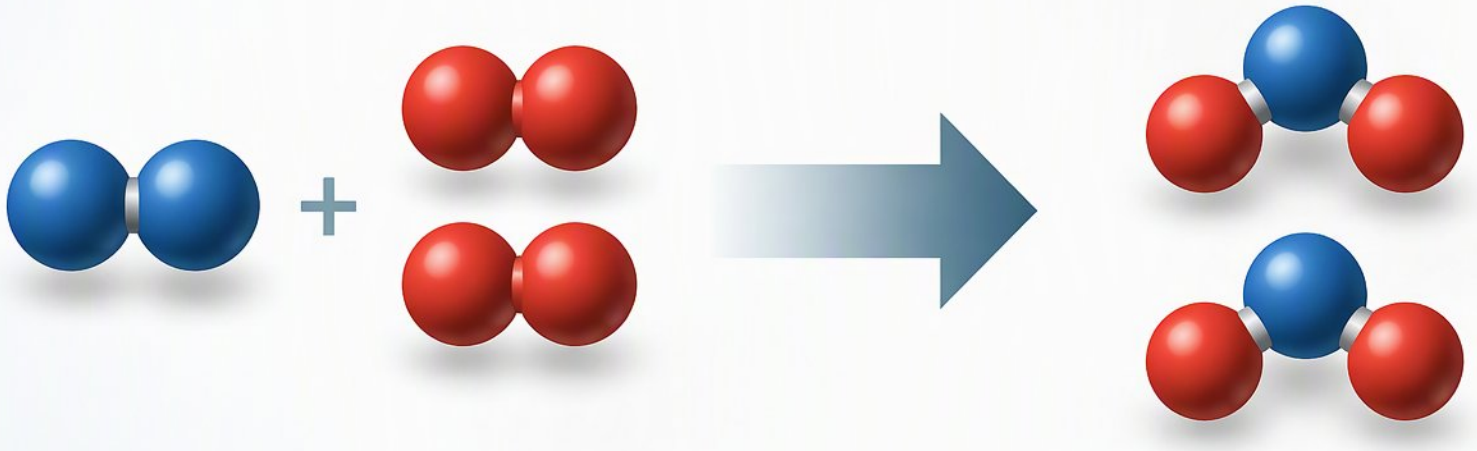
Balancing Chemical Equations:
Conservation of Mass

- Balancing equations links atomic theory to measurable chemistry
- Core principle: matter is rearranged, never created or destroyed
- Learn to read, verify, and systematically balance equations
- Roadmap: atom counting, balancing methods, worked examples, real-world evidence
- Practice with teaching transfer for educators and learners



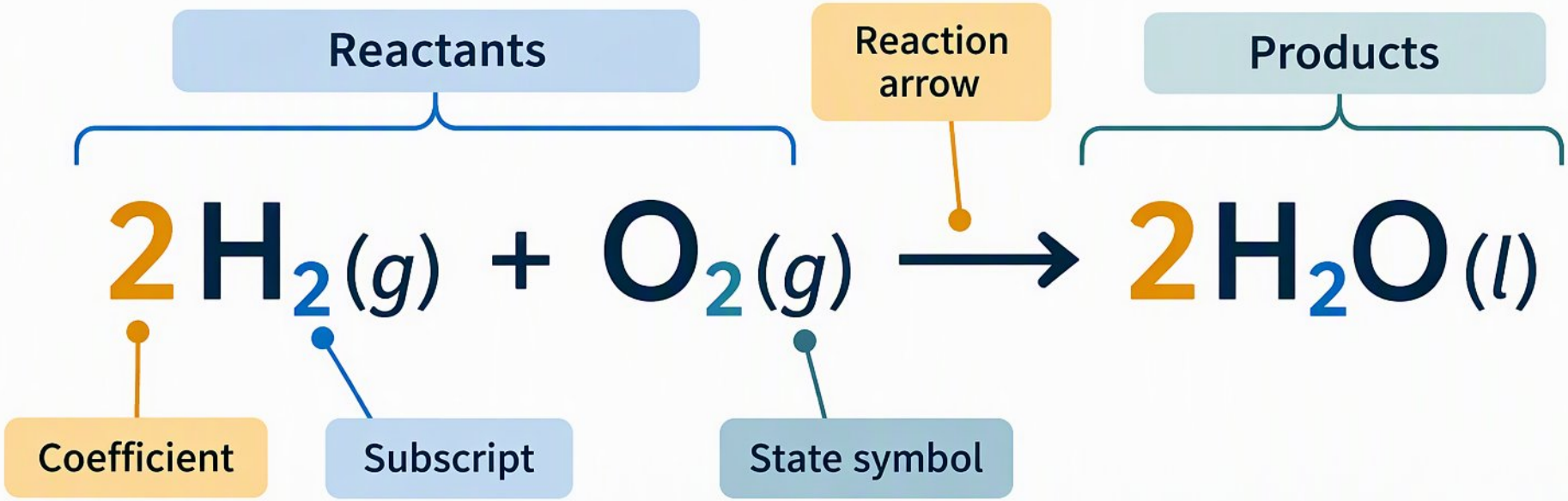
Why Equations Must Balance



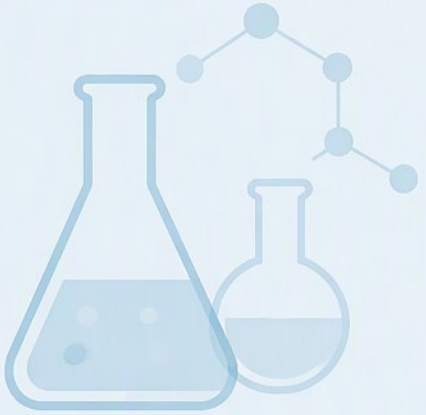
- Atoms are rearranged in reactions—never created or destroyed
- A balanced equation shows equal atoms of each element on both sides
- Unbalanced equations imply matter appearing or disappearing
- Lavoisier's mass measurements established the law in closed systems
- Coefficients give reacting ratios used in all stoichiometry

Anatomy of a Chemical Equation

EXPLORE
THINK
LEARN



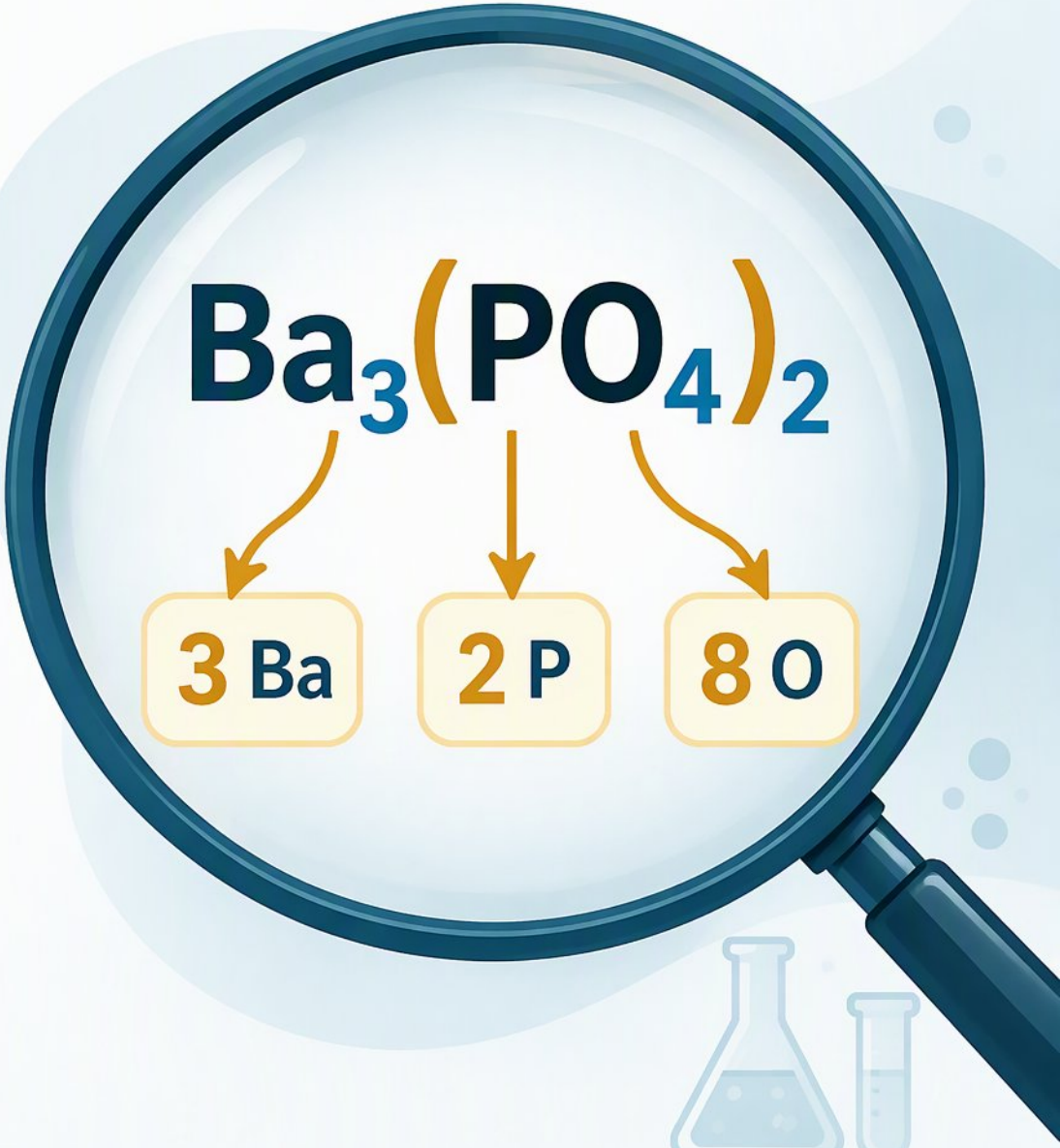
- Reactants left, products right, separated by a reaction arrow
- Plus signs separate multiple species on each side
- Subscripts show composition; coefficients count formula units
- State symbols (*s*), (*l*), (g), (*aq*); conditions above or below arrow
- Translate word equations into correct formulas before balancing



SMALL DETAILS
BIG UNDERSTANDING

Counting Atoms: Subscripts, Parentheses, and Coefficients

- Subscript applies only to the atom or group immediately before it
- Coefficient multiplies every atom in the formula that follows
- Parentheses multiply everything inside: $Ba_3(PO_4)_2$ → 3 Ba, 2 P, 8 O
- Keep polyatomic ions intact: nitrate, sulfate, phosphate
- Activity: build a full atom-tally table for both sides before balancing



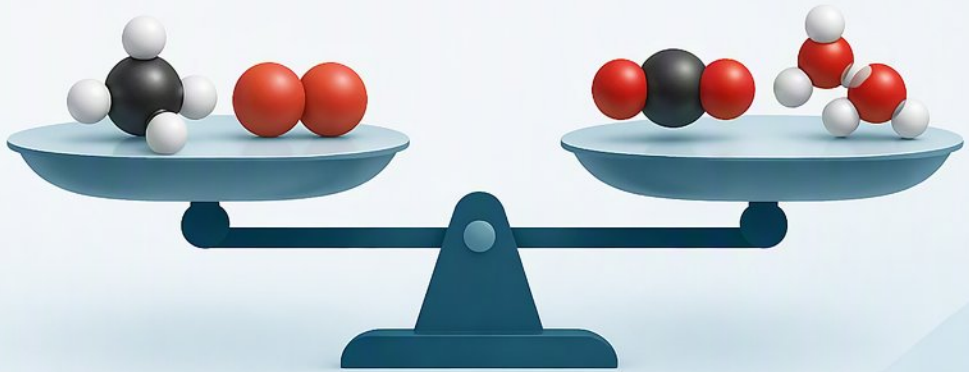
Is It Balanced? A Systematic Check

1. List every element; tally atoms on each side, then compare
2. Use a tally table so every coefficient change is re-checked
3. Worked check: $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ (C 1=1, H 4=4, O 4=4)
4. Watch for changed subscripts, miscounted polyatomic ions, ignored coefficients
5. Recount after every change; reduce to smallest whole-number coefficients

Worked Check

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

Element	Left Side	Right Side	Match?
C	1	1	✓
H	4	4	✓
O	4	4	✓



Same atoms. Both sides.

The Balancing Process: Inspection Method



Balance in this order:

1. Metals
2. Nonmetals
3. Hydrogen
4. Oxygen last

- Inspect both sides, adjust one coefficient, then re-inspect — repeat
- Start with the most complex formula; balance metals first, oxygen last
- Verbalize each choice so learners see the decision, not just the result
- Worked: $H_2O \rightarrow H_2 + O_2$ becomes $2H_2O \rightarrow 2H_2 + O_2$
- Finish by reducing to smallest whole numbers, e.g., $N_2 + 3H_2 \rightarrow 2NH_3$



Fractions as Scaffolds and the Algebraic Method

Fractional Coefficients as a Scaffold

$$C_2H_6 + \frac{7}{2} O_2 \longrightarrow 2CO_2 + 3H_2O$$

Clear fractions by multiplying every coefficient by the lowest common multiple of the denominators

$$2C_2H_6 + 7O_2 \longrightarrow 4CO_2 + 6H_2O$$

Algebraic Method

Assign *a*, *b*, *c*... to coefficients, write one equation per element, solve.

$$KMnO_4 + HCl \rightarrow KCl + MnCl_2 + Cl_2 + H_2O$$

Gives **2, 16 → 2, 2, 5, 8**

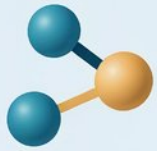
- Fractional coefficients are a valid temporary scaffold: $C_2H_6 + \frac{7}{2} O_2 \rightarrow 2CO_2 + 3H_2O$
- Clear fractions by multiplying every coefficient by the lowest common multiple of the denominators
- Algebraic method: assign *a*, *b*, *c*... to coefficients, write one equation per element, solve
- Worked example: $KMnO_4 + HCl \rightarrow KCl + MnCl_2 + Cl_2 + H_2O$ gives 2, 16 → 2, 2, 5, 8
- Choose inspection for simple equations, algebra for many species; always verify with a tally

Worked Examples: Building Fluency Step by Step

1 Synthesis

- Synthesis: $2Mg + O_2 \rightarrow 2MgO$; verify with a full tally table

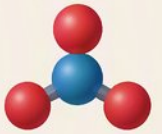
Left Side	Right Side



2 Decomposition

- Decomposition: $2KClO_3 \rightarrow 2KCl + 3O_2$; NH_4NO_3 case balances oxygen last

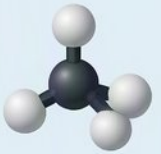
Left Side	Right Side



3 Combustion

- Combustion: $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$ — C, then H, then O

Left Side	Right Side



4 Replacement

- Replacement: $Al_2(SO_4)_3 + 3Ca(OH)_2 \rightarrow 2Al(OH)_3 + 3CaSO_4$, keep polyatomic ions intact

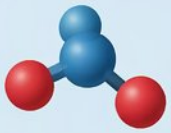
Left Side	Right Side



5 Multi-species

- $Cu + 4HNO_3 \rightarrow Cu(NO_3)_2 + 2NO_2 + 2H_2O$, track a running tally

Left Side	Right Side



Common Mistakes and How to Avoid Them

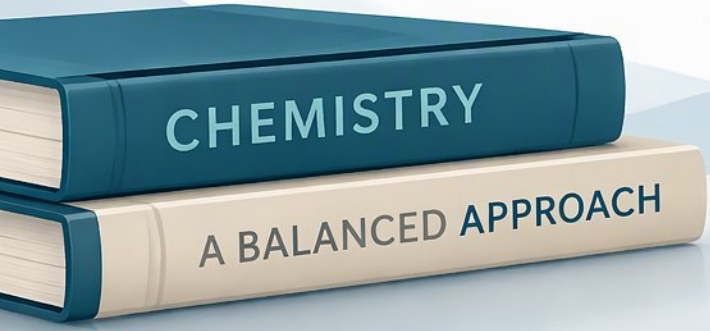
- Never change a subscript: H_2O is water, H_2O_2 is hydrogen peroxide
- Never place a coefficient inside a formula: 2KCl is correct, K_2Cl is not
- After using a fractional coefficient, multiply every coefficient by the same factor
- Don't break polyatomic ions (nitrate, sulfate) into separate elements unnecessarily
- Don't stop at 'nearly balanced'—confirm with a full atom tally on both sides

Changing a subscript

H_2O_2	H_2O
✗	✓
(hydrogen peroxide)	(water)

Coefficient vs. subscript

K_2Cl	2KCl
✗	✓





Teaching Strategies That Prevent Errors

Think
Check
Explain

- Model the inspection method with a visualizer; talk through every decision aloud.
- Use 'grouping and protecting' ($MgCl_2$ as MgClCl, ringed) as a temporary scaffold, then remove it.
- Mini whiteboards and pencil-and-erase routines lower fear and let you scan the room.
- A 'write to learn' protocol exposes misconceptions that a correct answer can hide.
- Compare methods in small groups so learners build a toolkit, not a single procedure.



Better
Thinking
Brighter Learners

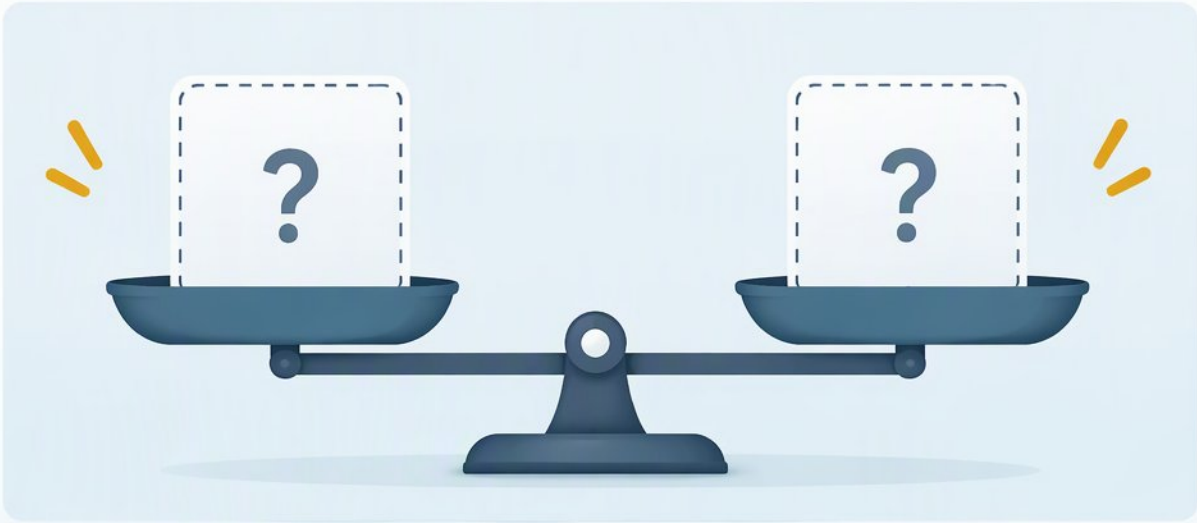
Conservation of Mass in the Real World

- Closed system: mass constant, no matter enters or escapes
- Open system: escaping or entering gases mimic lost or gained mass
- Burning magnesium seems to gain mass; a candle seems to lose it
- Everyday cases: vinegar and baking soda, rusting iron, dissolving sugar
- Weigh before and after to calculate the mass of gas produced



Interactive Practice: Simulations and Games

- Start with a balance-scale simulation; then hide the molecules to force symbol tallies.
- Game mode: five randomized equations per level; feedback flags any non-simplest coefficients.
- Ask explicitly: why can coefficients change but subscripts cannot?
- Draw the molecules behind each equation to link pictures and symbols.
- Debrief: groups compare strategies used on harder combustion equations.









Graduated Practice and Self-Assessment

Balance equations. Build accuracy. Grow confidence.

Same atoms. Both sides.

A Set A warm-up

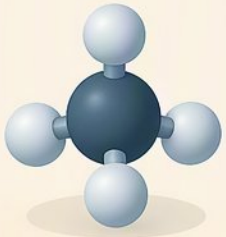
$H_2 + O_2$, $Na + Cl_2$, $Mg + O_2$, $Fe + S$



B Set B core

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

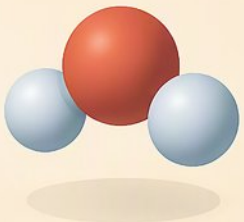
$4Al + 3O_2 \rightarrow 2Al_2O_3$



C Set C challenge

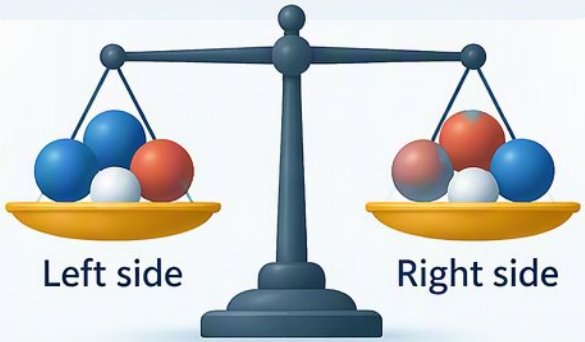
$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$

$4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$



Self-check

- formulas untouched
- full tally both sides
- smallest whole numbers
- no coefficient inside a formula



Answer key with reasoning traces shows where a miscount occurred.

Assessment, Teaching Transfer, and Next Steps

Formative check: one-equation exit ticket with balanced equation plus tally table

Differentiation: scaffolded prompts and word banks alongside unscaffolded versions; pair explanations

Sticky points: subscript vs. coefficient confusion, polyatomic ions as units, oxygen-last ordering

Discuss: why burned magnesium gains mass — what would you measure?

Next steps: stoichiometry, molar mass, reacting-mass calculations — all built on balanced equations

BUILDING UNDERSTANDING
FOR WHAT'S NEXT



$2Mg + O_2 \rightarrow 2MgO$

Stoichiometry

Molar mass

Reacting-mass calculations

SAME EQUATIONS.
BIGGER QUESTIONS AHEAD.

PRACTICE TODAY.
GREATER UNDERSTANDING TOMORROW.

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