Balancing Equations

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Chemical Reactions / Equations

Reactants ⟶ Products

Color change
Solid forms (Cloudiness … precipitation)
Bubbles form (gas generated)
Heat, light, or flame produced
Heat is absorbed (cooling)

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Chemical Reactions/Equations

Reactants ⟶ Products

$2\ Na + 2\ H_2O \longrightarrow H_2 + 2\ NaOH$

Reactants (Left Side of Reaction Arrow)
- **Substances present at the beginning**
- **Starting materials**
- **Initial materials that enter into the reaction; things consumed**

Products (Right Side of Reaction Arrow)
- **Substances present at the end of the reaction**
- **New materials formed**
- **Ending materials; things produced**

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Chemical Equations

Reactants (A + B) ⟶ Products (C + D)

+ is read as
"plus"
"and"

⟶ is read as
"yields"
"produces"
"forms"

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State Symbols

Reactants (A + B) ⟶ Products (C + D)

May use "state symbols" (often as subscript):

(aq) = aqueous, dissolved in water
(s) = solid, precipitate; also ↓ or ppt
(l) = liquid
(g) = gas; also ↑

Clue to classifying reaction types
Used primarily in introductory classes

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Chemical Equations

Reactants (A + B) ⟶ Products (C + D)

Must be "balanced"
follow the Law of Conservation of Mass
- **Total mass reactants = Total mass products**
- **No mass is lost during chemical reaction**
- **No atoms destroyed during ordinary reactions**
- **Atoms recombined into new materials (products)**

Total # atoms reactants = Total # atoms products

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Chemical Equations

Reactants (A + B) ⟶ Products (C + D)

# of each element BEFORE a reaction (REACTANTS) = # of same elements AFTER the reaction (PRODUCTS)

Start with correct chemical formulas
WORK WITH COEFICIENTS
(Trial and error until atoms on both sides are equal)

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Chemical Equations

For Hydrogen + Oxygen yields water
Write Starting Materials and Products
Pay attention to diatomic

$H_{2(g)} + O_{2(g)} \rightarrow H_2O_{(l)}$

Count atoms => must be same on both sides

2 H 2 O ➔ 2 H 1 O

There is a tendency (wrong) to balance with subscripts:

$H_{2(g)} + O_{2(g)} \rightarrow H_2O_{2(l)}$

2 H 2 O ➔ 2 H 2 O

But, H_2O is not the same as H_2O_2

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Chemical Equations

For Hydrogen + Oxygen yields water
Write Starting Materials and Products

$H_{2(g)} + O_{2(g)} \rightarrow H_2O_{(l)}$

Count atoms => must be same on both sides

2 H 2 O ➔ 2 H 1 O

Oxygen unbalanced; Try

$H_{2(g)} + O_{2(g)} \rightarrow 2\ H_2O_{(l)}$

Count atoms => must be same on both sides

2 H 2 O ➔ 4 H 2 O

Oxygen now balanced, try

$2\ H_{2(g)} + O_{2(g)} \rightarrow 2\ H_2O_{(l)}$

Count atoms => must be same on both sides

4 H 2 O ➔ 4 H 2 O

Success!

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Chemical Equations

Which is correct for the formation of water?

$H_{2(g)} + O_{2(g)} \rightarrow H_2O_{(l)} + O_{(g)}$

$H_{2(g)} + O_{(g)} \rightarrow H_2O_{(l)}$

$H_{2(g)} + O_{2(g)} \rightarrow H_2O_{2(l)}$

$2\ H_{2(g)} + O_{2(g)} \rightarrow 2\ H_2O_{(l)}$

Pay attention To:
- **Correct Formulas**
- **Diatomics**
- **Atom Count**

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Hints for Balancing

Work with whole numbers …
fractional coefficients tend to confuse

Bottom line:
No fixed rule … every reaction is different
Requires practice to develop balancing skills
My two guidelines:
- **Start with a metal or most complex reaction material**
- **Save water (or diatomic gasses) last step**

Genius is 10% inspiration and 90 % perspiration.
Thomas Alva Edison

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Balance This Chemical Equation

$TiCl_4 + H_2O \rightarrow TiO_2 + HCl$

Safety Tip: HCl is a corrosive acid; lab precautions needed

Start with Chlorine:

$TiCl_4 + H_2O \rightarrow TiO_2 + 4\ HCl$

Atom Count: 1 Ti; 4 Cl; 2 H; 1 O ➔ 1 Ti; 4 Cl; 4 H; 2 O
Ti & Cl balanced; H and O are not
4 H suggests 2 waters, so try 2 H_2O

$TiCl_4 + 2\ H_2O \rightarrow TiO_2 + 4\ HCl$

Atom Count: 1 Ti; 4 Cl; 4 H; 2 O ➔ 1 Ti; 4 Cl; 4 H; 2 O

Success!

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Balance This Chemical Equation

$Fe_3O_4 + H_2 \rightarrow Fe + H_2O$

Start with Iron

$Fe_3O_4 + H_2 \rightarrow 3\ Fe + H_2O$

Atom Count: 3 Fe; 2 H; 4 O ➔ 3 Fe; 2 H; 1 O
Fe & H balanced; O is not … suggests water is key
4 O on the start side suggests 4 waters on product side; try 4 H_2O

$Fe_3O_4 + H_2 \rightarrow 3\ Fe + 4\ H_2O$

Atom Count: 3 Fe; 2 H; 4 O ➔ 3 Fe; 8 H; 4 O
Fe & O balanced; H is not … finish by balancing H

$Fe_3O_4 + 4\ H_2 \rightarrow 3\ Fe + 4\ H_2O$

Atom Count: 3 Fe; 8 H; 4 O ➔ 3 Fe; 8 H; 4 O

Success!

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Balance This Chemical Equation

$MnO_2 + HCl \rightarrow MnCl_2 + Cl_2 + H_2O$

Safety Tip: Cl_2 is toxic; lab precautions needed

Mn Balanced: Start with 4 Chlorine on product side

$MnO_2 + 4\ HCl \rightarrow MnCl_2 + Cl_2 + H_2O$

Atom Count: 1 Mn; 4 Cl; 4 H; 2 O ➔ 1 Mn; 4 Cl; 2 H; 1 O
O is odd on product side, try making it even

$MnO_2 + 4\ HCl \rightarrow MnCl_2 + Cl_2 + 2\ H_2O$

Atom Count: 1 Mn; 4 Cl; 4 H; 2 O ➔ 1 Mn; 4 Cl; 4 H; 2 O

Success!

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Balance This Chemical Equation

$NH_3 + O_2 \rightarrow N_2 + H_2O$

Reaction has odd/even combination of diatomic molecules

Start with Nitrogen … try

$2\ NH_3 + O_2 \rightarrow N_2 + H_2O$

Atom Count: 2 N; 6 H; 2 O ➔ 2 N; 2 H: 1 O

Oxygen unbalanced … try

$2\ NH_3 + O_2 \rightarrow N_2 + 2\ H_2O$

Atom Count: 2 N; 6 H; 2 O ➔ 2 N; 4 H: 2 O

Hydrogen unbalanced … try changing N in product

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Continuing With: $4\ NH_3 + O_2 \rightarrow 2\ N_2 + 2\ H_2O$

$4\ NH_3 + O_2 \rightarrow 2\ N_2 + 2\ H_2O$

Atom Count: 4 N; 12 H; 2 O → 4 N; 4 H: 2 O

H & O unbalanced … try balancing H with water

$4\ NH_3 + O_2 \rightarrow 2\ N_2 + 6\ H_2O$

Atom Count: 4 N; 12 H; 2 O → 4 N; 12 H: 6 O

Only O unbalanced …finish with O on starting side

$4\ NH_3 + 3\ O_2 \rightarrow 2\ N_2 + 6\ H_2O$

Atom Count: 4 N; 12 H; 6 O → 4 N; 12 H: 6 O

Success!

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Balance This Chemical Equation

$FeS_2 + O_2 \rightarrow Fe_2O_3 + SO_2$

Safety Tip: SO_2 is a corrosive acid; lab precautions needed

Atom Count: 1 Fe; 2 S; 2 O → 2 Fe; 1 S; 5 O

Everything unbalanced … start with iron … try

$2\ FeS_2 + O_2 \rightarrow Fe_2O_3 + 4\ SO_2$

Atom Count: 2 Fe; 4 S; 2 O → 2 Fe; 4 S; 11 O

Oxygen odd & unbalanced … try another Fe on product side

$4\ FeS_2 + O_2 \rightarrow 2\ Fe_2O_3 + 4\ SO_2$

Atom Count: 4 Fe; 8 S; 2 O → 4 Fe; 4 S; 14 O

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Continuing With: $FeS_2 + O_2 \rightarrow Fe_2O_3 + SO_2$

$4\ FeS_2 + O_2 \rightarrow 2\ Fe_2O_3 + 4\ SO_2$

Atom Count: 4 Fe; 8 S; 2 O → 4 Fe; 4 S; 14 O

Sulfur unbalanced … try to balance Sulfur

$4\ FeS_2 + O_2 \rightarrow 2\ Fe_2O_3 + 8\ SO_2$

Atom Count: 4 Fe; 8 S; 2 O → 4 Fe; 8 S; 22 O

Only Oxygen unbalanced … finish by balancing Oxygen

$4\ FeS_2 + 11\ O_2 \rightarrow 2\ Fe_2O_3 + 8\ SO_2$

Atom Count: 4 Fe; 8 S; 22 O → 4 Fe; 8 S; 22 O

Success!

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Balance This Chemical Equation

$C_7H_{16} + O_2 \rightarrow CO_2 + H_2O$

Atom Count: 7 C; 16 H; 2 O ➔ 1 C; 2 H; 3 O

Start with the most complex: carbon and hydrogen

$C_7H_{16} + O_2 \rightarrow 7\ CO_2 + 8\ H_2O$

Atom Count: 7 C; 16 H; 2 O ➔ 7 C; 16 H; 22 O

Finish with the only stand alone element, oxygen

$C_7H_{16} + 11\ O_2 \rightarrow 7\ CO_2 + 8\ H_2O$

Atom Count: 7 C; 16 H; 22 O ➔ 7 C; 16 H; 22 O

Success!

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Balance This Chemical Equation

$C_7H_{15} + O_2 \rightarrow CO_2 + H_2O$

Atom Count: 7 C; 15 H; 2 O ➔ 1 C; 2 H; 3 O

Start with carbon and hydrogen; H odd/even issue

$4\ C_7H_{15} + O_2 \rightarrow 28\ CO_2 + 30\ H_2O$

Atom Count: 28 C; 60 H; 2 O ➔ 28 C; 60 H; 86 O

Finish with the only stand alone element, oxygen

$4\ C_7H_{16} + 43\ O_2 \rightarrow 28\ CO_2 + 30\ H_2O$

Atom Count: 28 C; 60 H; 86 O ➔ 28 C; 60 H;86 O

Success!

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Practice Improves Performance

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