

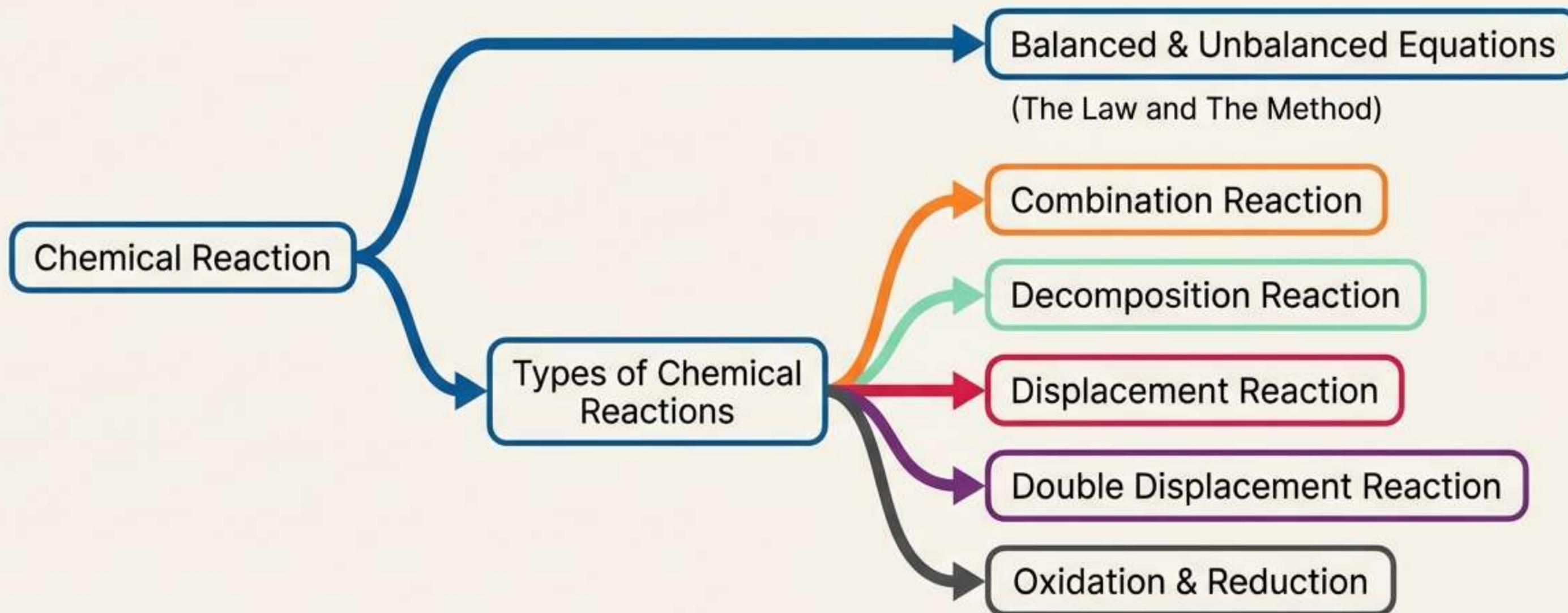


# The Anatomy of Chemical Change



# Mapping the Landscape of Chemistry

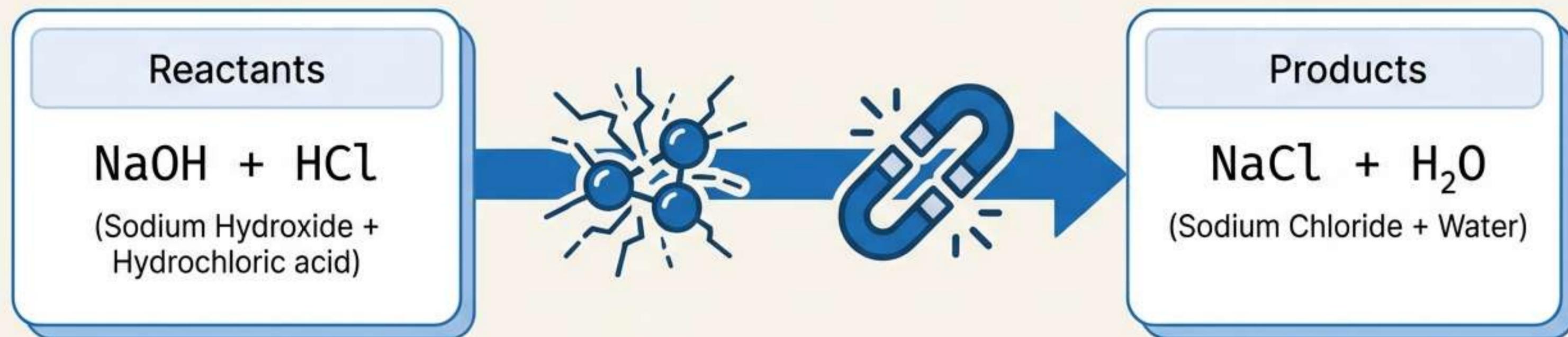
A chemical reaction is the process that transforms substances into entirely new materials. To understand this, we must master how to write them, how to balance them, and how to categorize them.



# Breaking Bonds, Making Bonds

“Change is the law of nature, but not all change is equal.”

- **Physical Changes:** The identity is maintained. Only the state changes (e.g., melting ice). Reversible.
- **Chemical Changes:** The original identity is completely lost. Bonds break and new ones form. Irreversible.



# Four Signs of Transformation

We cannot see atoms rearranging, but we can observe the macro-effects of their new bonds.



## Change in Temperature

Flask becomes warm ( $\text{Zn} + \text{H}_2\text{SO}_4$ ) or cooler ( $\text{Ba}(\text{OH})_2 + \text{NH}_4\text{Cl}$ ).



## Evolution of a Gas

Hydrogen gas escaping the solution ( $\text{Zn} + \text{dil. HCl}$ ).



## Change in Colour

Black iron nails developing brown rust, or  $\text{Pb}(\text{NO}_3)_2 + \text{KI}$  forming a yellow precipitate.



## Change in State

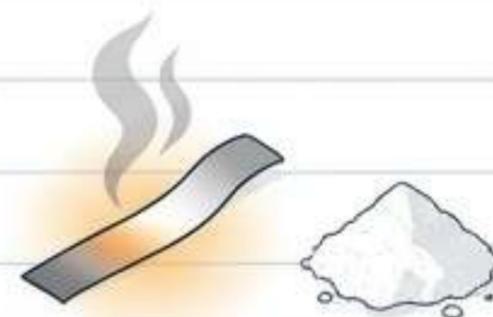
Gaseous  $\text{O}_2$  and solid  $\text{Mg}$  transforming into solid  $\text{MgO}$ .

# The Universal Language of Chemistry

Describing chemical changes in sentences is inefficient. Chemists use shorthand to link **Reactants** (left) to **Products** (right) separated by an arrow ( $\rightarrow$ ).

## Level 1: The Event

Magnesium ribbon burns in oxygen to form a white powder of magnesium oxide.



## Level 2: Word Equation

Magnesium + Oxygen  $\rightarrow$  Magnesium oxide

## Level 3: Symbol Equation



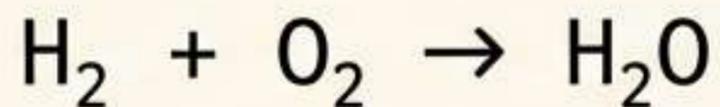
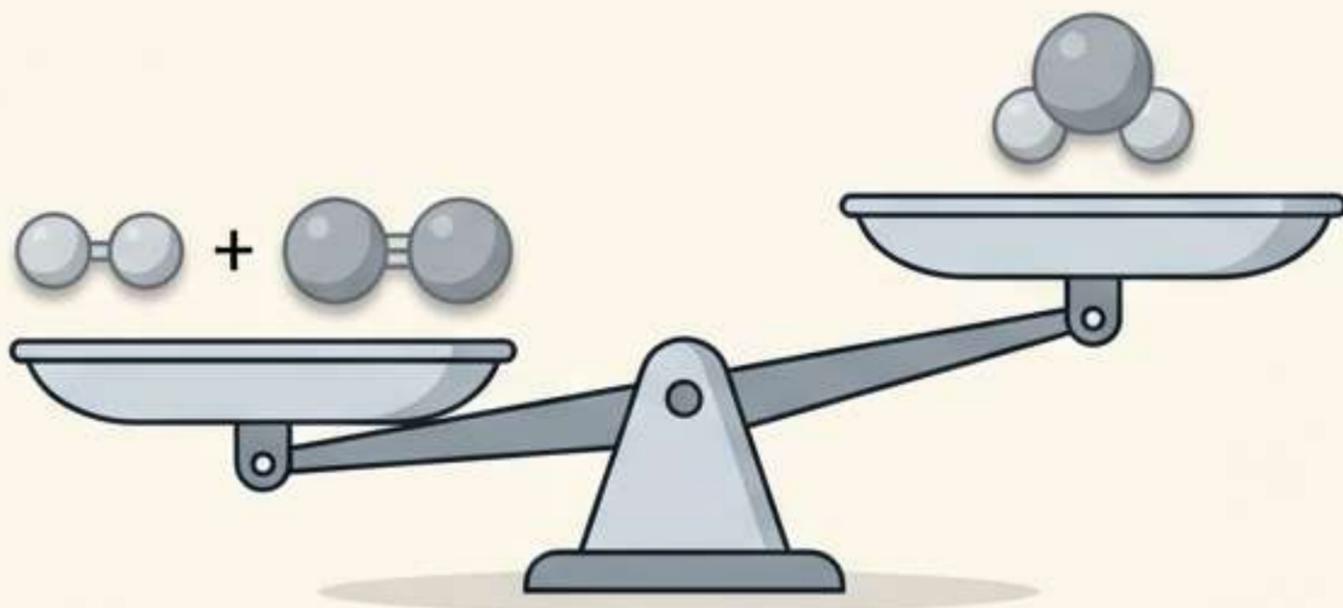
This is a skeletal (unbalanced) equation.

# The Law of Cosmic Accounting

Atoms are neither created nor destroyed. They simply exchange partners. Therefore, the total mass of the reactants must equal the total mass of the products.

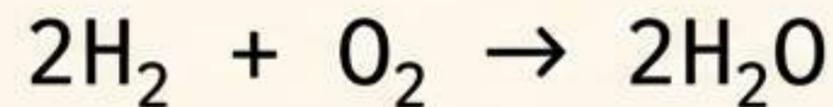
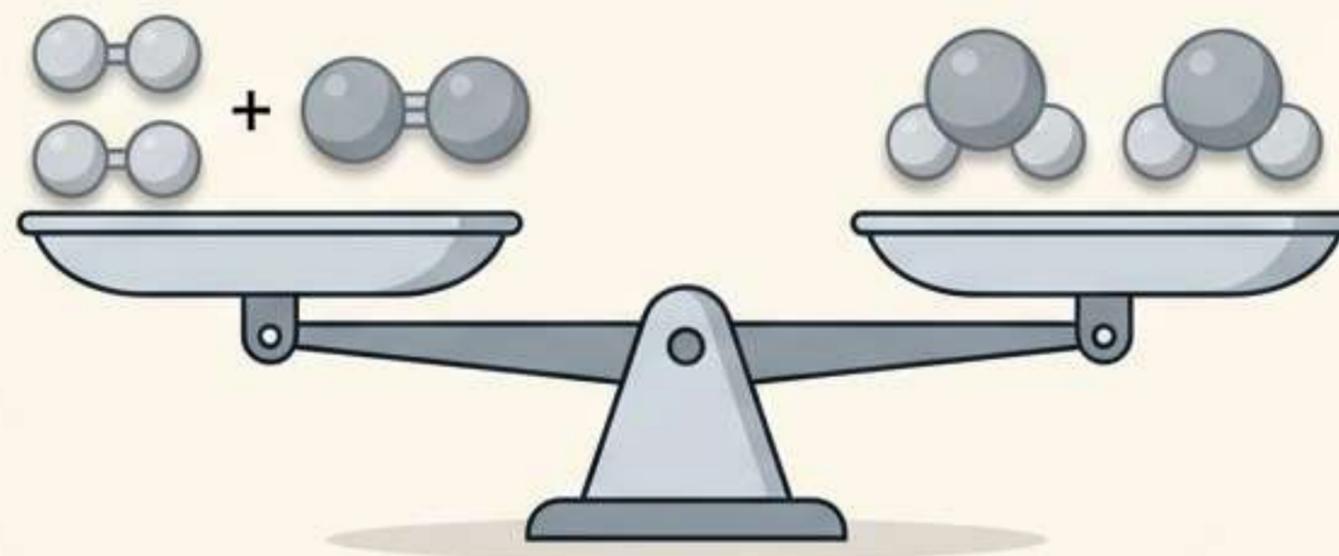
A "skeletal" equation violates this law and must be balanced.

## Skeletal Equation



Oxygen atoms: 2 Left vs 1 Right

## Balanced Equation

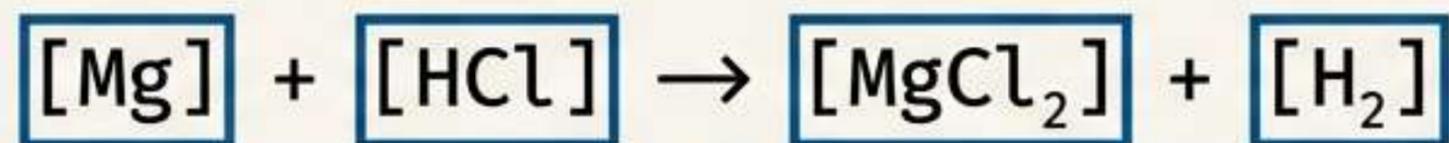


Atom counts match perfectly

# The Hit and Trial Method

Balancing requires adjusting coefficients (the numbers before the formulae) until the atom counts on both sides match. Never change the underlying formula.

**Step 1: Write the skeletal equation**

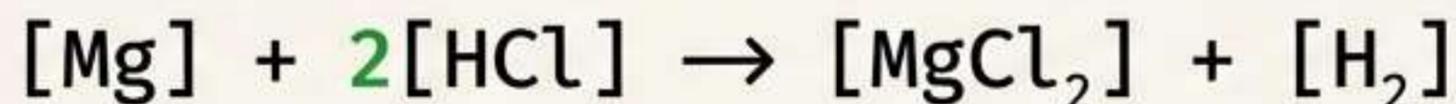


**Step 2: The Audit**

Element	L.H.S	R.H.S
Mg	1	1
H	1	2
Cl	1	2



**Step 3: The Fix**

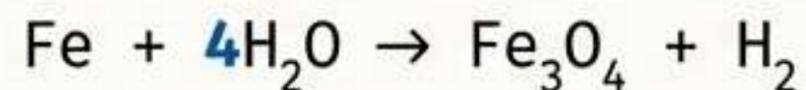


Element	L.H.S	R.H.S
Mg	1	1
H	2	2
Cl	2	2

# Scaling the Method

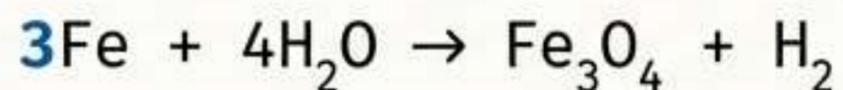
Start balancing with the most complex molecule. For iron reacting with steam, we target  $\text{Fe}_3\text{O}_4$  first to balance the oxygen.

## 1. Balance O



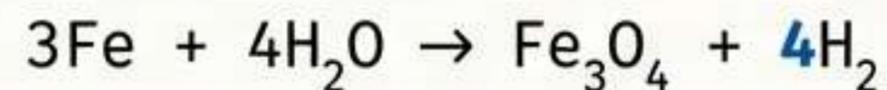
Element	L.H.S	R.H.S
Fe	1	3
H	8	2
O	4	4

## 2. Balance Fe



Element	L.H.S	R.H.S
Fe	3	3
H	8	2
O	4	4

## 3. Balance H (Final)



Element	L.H.S	R.H.S
Fe	3	3
H	8	8
O	4	4

# Adding Context to the Code

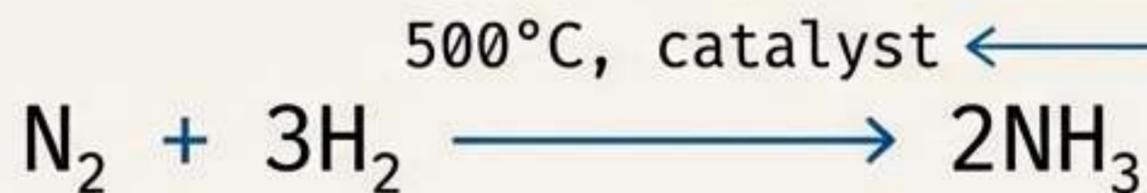
A balanced equation tells us *what* happens, but state symbols and markers tell us *how* it happens.



Aqueous (dissolved in water).

Solid, Liquid, Gas  
physical states.

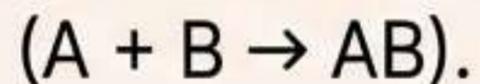
Gas evolved. (A ↓ arrow means  
a solid precipitate formed).



Specific reaction conditions  
(temperature, pressure,  
catalysts) sit upon the arrow.

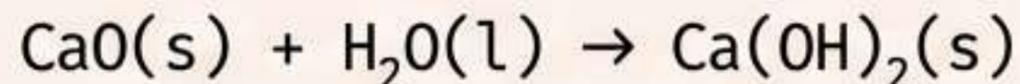
# Category 1: Combination Reactions

Two or more substances combine to form a single new substance.



Quick lime

Slaked lime

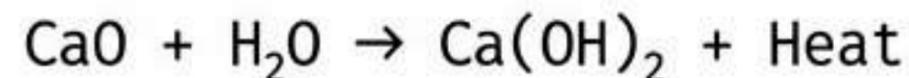


Booster  
Concept

## Exothermic Reactions

Reactions that release heat energy into their surroundings are **exothermic**. This is indicated by “+ Heat” on the product side.

- Slaked lime reaction:



- Human Respiration:

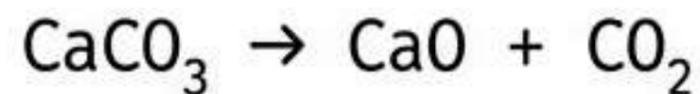


# Category 2: Decomposition Reactions

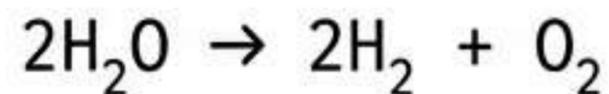
A single compound breaks down into two or more simpler substances.

( $AB \rightarrow A + B$ ). This requires an input of energy to break the bonds.

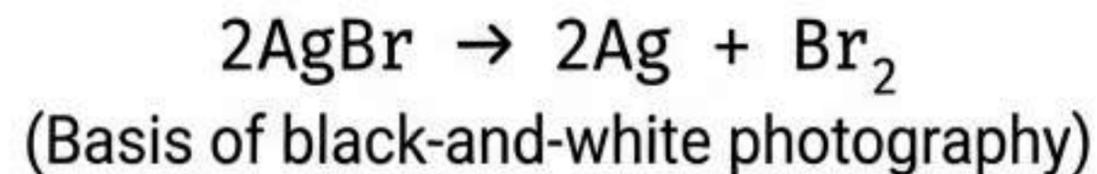
**Thermal  
(Heat)**



**Electrolytic  
(Electricity)**



**Photolytic  
(Light)**



**Endothermic Reactions**

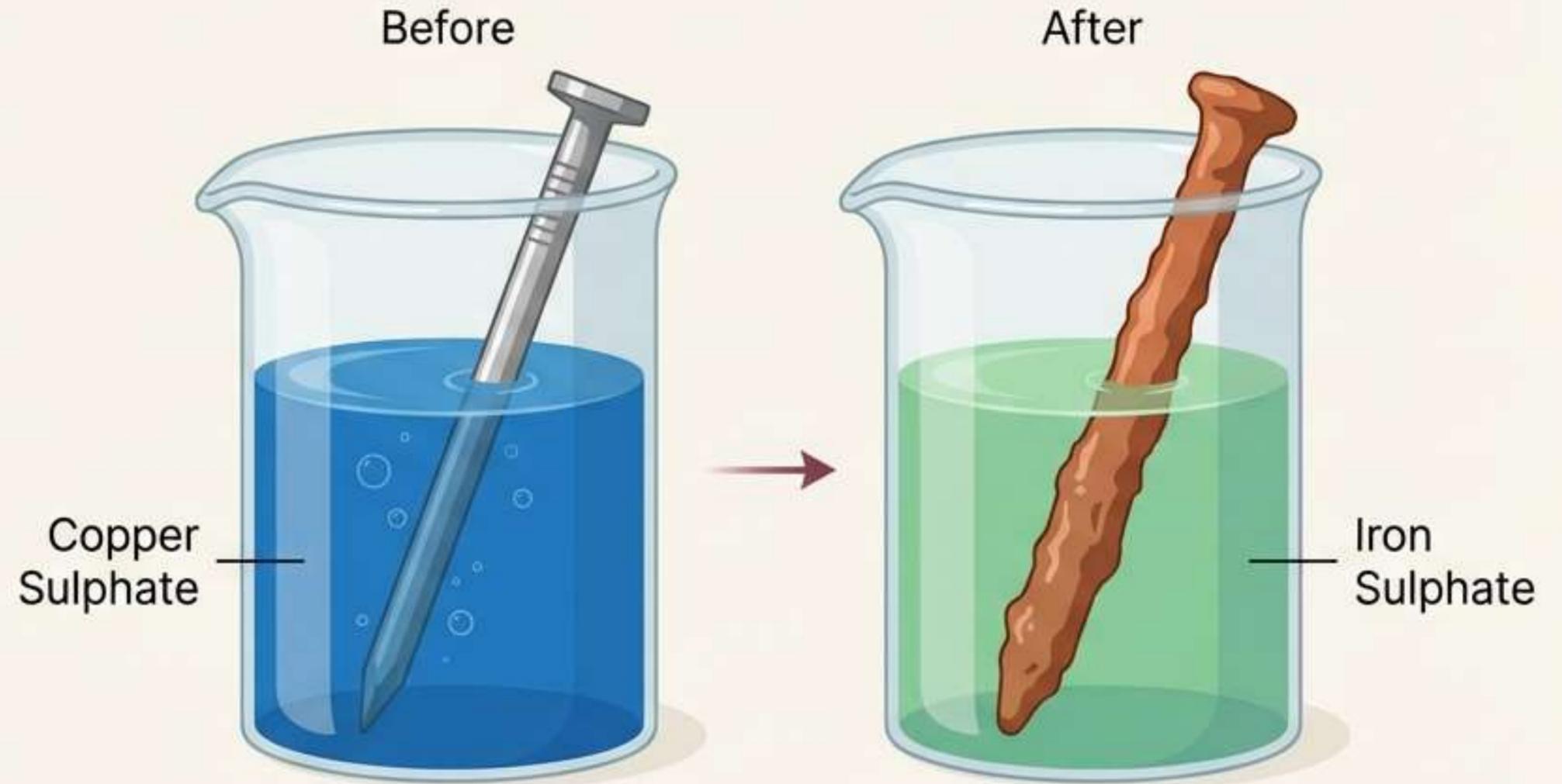
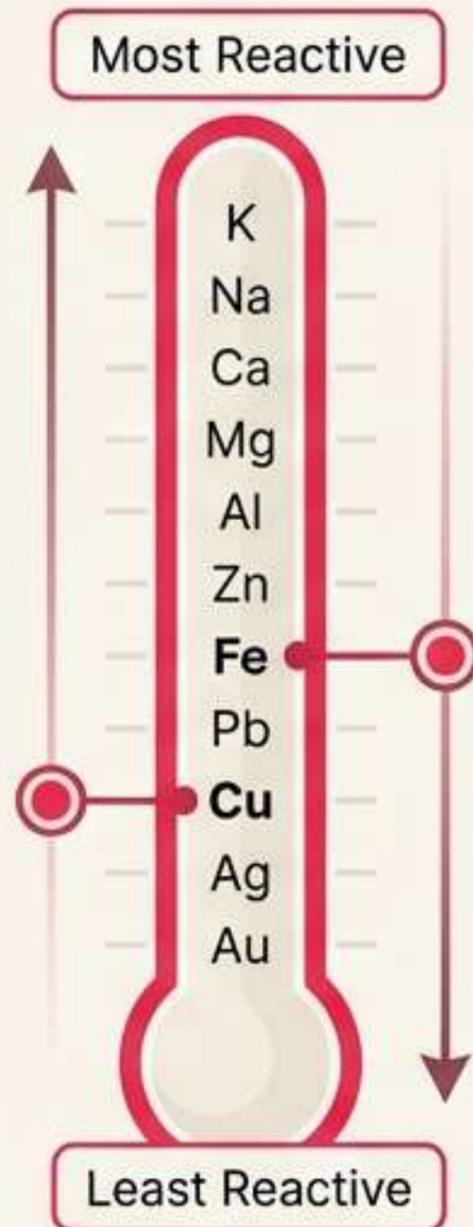


Reactions that **absorb** heat energy from their surroundings to proceed.

# Category 3: Displacement Reactions

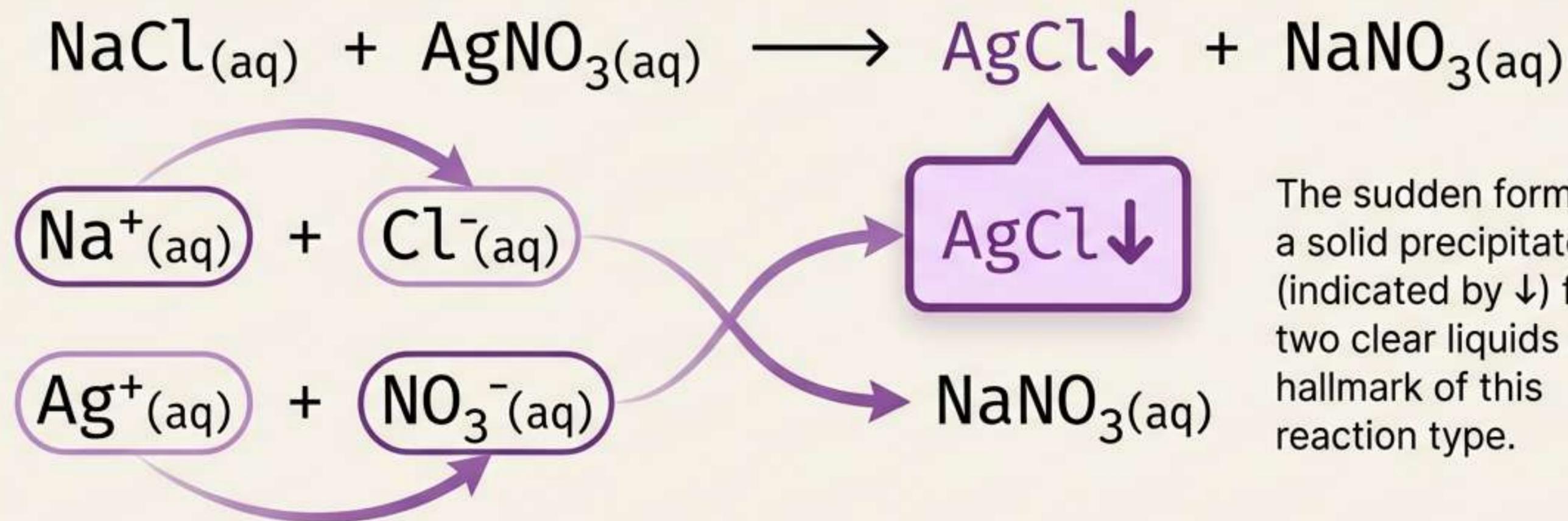
A more active element displaces a less active element from its compound. Think of it as a chemical hierarchy.

Activity Series of Metals



# Category 4: Double Displacement

Also known as Metathesis. Two compounds react by a mutual exchange of ions to form entirely new compounds.



The sudden formation of a solid precipitate (indicated by  $\downarrow$ ) from two clear liquids is a hallmark of this reaction type.

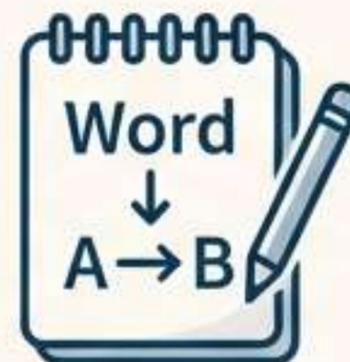
# The Complete Chemist's Toolkit

You can now observe the physical world, translate it into the universal code of chemistry, enforce the laws of mass conservation, and categorize the endless combinations of nature.



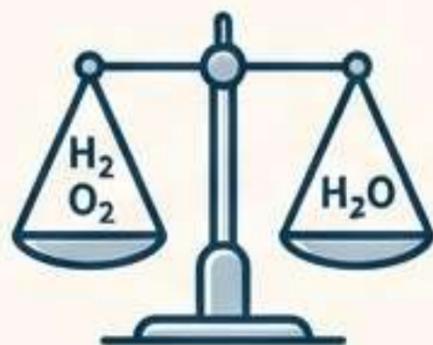
## Observe

The 4 signs of chemical change (State, Color, Gas, Temp).



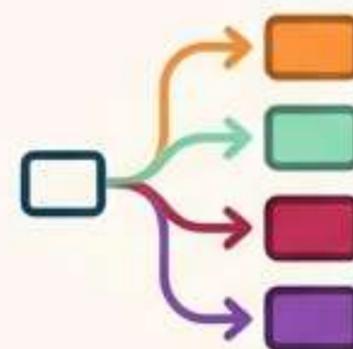
## Translate

Word → Skeletal Symbol Equation.



## Balance

Hit & Trial Method enforcing the Law of Conservation of Mass.



## Categorize

1. Combination (Orange)
2. Decomposition (Mint)
3. Displacement (Crimson)
4. Double Displacement (Purple)