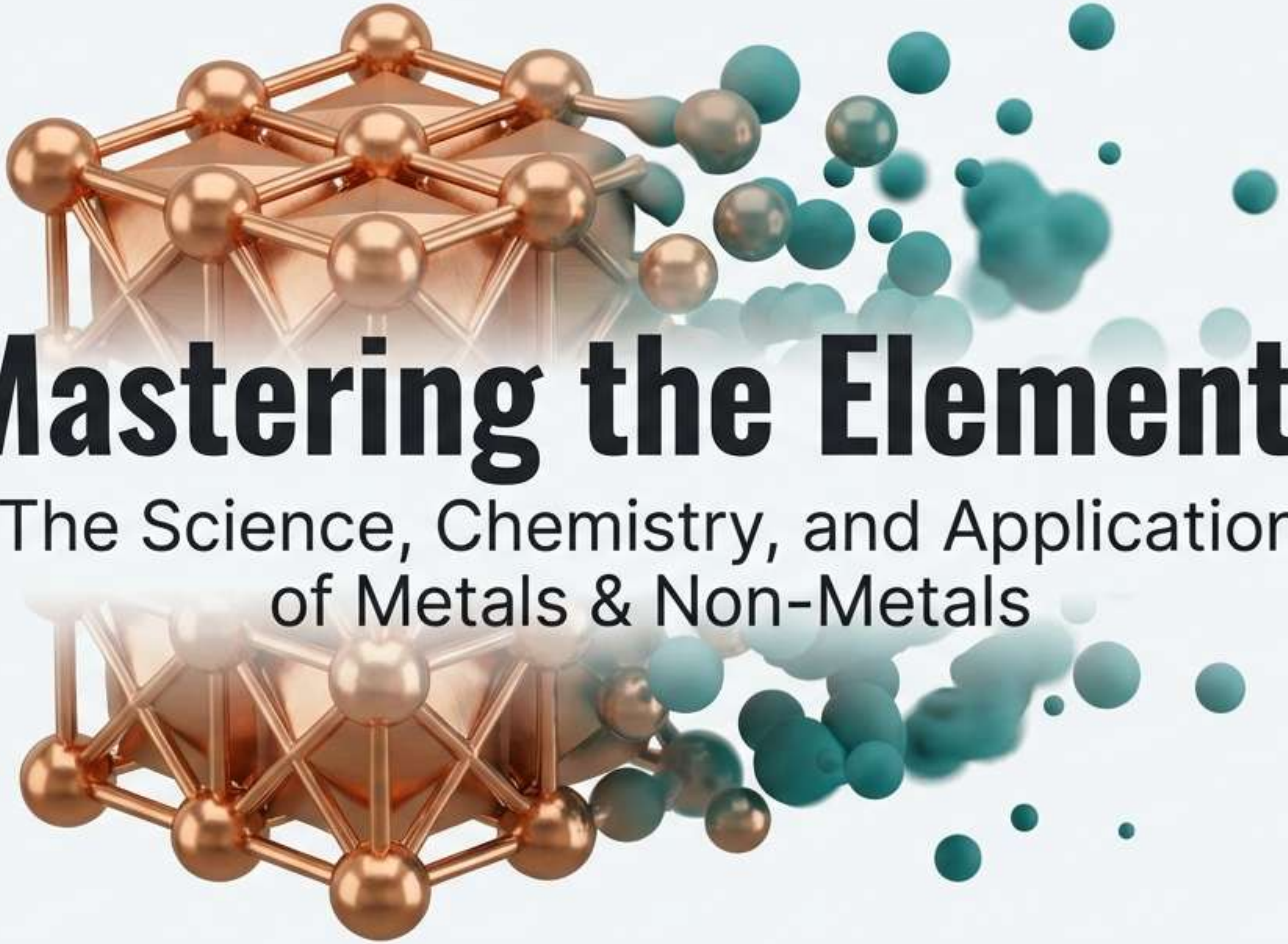
SHIKSHA NATION



Mastering the Elements

The Science, Chemistry, and Application of Metals & Non-Metals

The Elemental Divide

Metals

State: Solids at room temperature

Appearance: Lustrous (shining surfaces)

Conduction: Good conductors of heat and electricity

Structure: Hard, high density, highly malleable (can be wrapped as foil) and ductile (drawn into fine wires)

Acoustics: Sonorous (produces "tin cry" when bent)

Chemical Nature: Electropositive (lose electrons to form cations), 1 to 3 outermost electrons.

Non-Metals

State: Gases or solids

Appearance: Generally dull surfaces

Conduction: Mostly poor conductors

Structure: Quite soft, non-malleable, non-ductile, very low melting/boiling points.

Acoustics: Not sonorous.

Chemical Nature: Electronegative (gain electrons to form anions).

The Rule Breakers

SHIKSHA NATION

Mercury & Bromine

The Liquid Exceptions

Metals are solids, but Mercury (Hg) is liquid. Non-metals are gases/solids, but Bromine (Br) is liquid.

Diamond

The Hardness Exception

Non-metals are soft and have low melting points, but Diamond (an allotrope of Carbon) is exceptionally hard with a high melting point.

Graphite

The Conduction Exception

Non-metals are poor conductors, but Graphite (Carbon) is a good conductor of electricity.

Sodium & Potassium

The Softness Exception

Metals are hard, but Alkali metals like Sodium (Na) and Potassium (K) are so soft they can be cut with a knife.

The Language of Metals

SHIKSHA NATION

Noble Metals:
Resistant to corrosion or oxidation. Inert. (Examples: Gold, Platinum, Rhodium)

Precious Metals:
Rare, high economic value, high luster. Used in coinage and jewelry. (Examples: Gold, Silver)

Base Metals:
Oxidize or corrode relatively easily. React variably with dilute HCl. (Examples: Iron, Nickel, Lead, Zinc, Copper)

Ferrous Metals:
Derived from Latin for "containing iron." Often magnetic. (Examples: Wrought iron, Steel)

Strategic Metals:
Critical for economy and defense (atomic energy, jet engines, space science). (Examples: Titanium, Chromium, Manganese, Zirconium)

Chemical Reactions: Air & Water

SHIKSHA NATION

Reaction with Oxygen (O_2)

Forms basic oxides.

High Intensity
Sodium and Potassium catch fire in moist air (must be kept in kerosene).

Moderate Intensity
Magnesium burns only on heating. Iron filings burn vigorously.

The Amphoterics
Aluminum and Zinc form amphoteric oxides (react with both acids and bases).

Noble
Ag and Au do not react even at high temperatures.

Reaction with Water (H_2O)

Forms metal oxide/hydroxide + Hydrogen (H_2).

Cold Water
K and Na react violently (hydrogen catches fire). Ca reacts less violently and floats.

Hot Water
Mg reacts and floats.

Steam Only
Al, Fe, and Zn.

No Reaction
Pb, Cu, Ag, Au.

Chemical Reactions: Acids & Halogens

SHIKSHA NATION

Acids: Metals generally react with dilute mineral acids to liberate H_2 gas.

Formula: Metal + Dilute Acid → Metal Salt + Hydrogen

The Nitric Acid Exception: Hydrogen gas is not evolved with Nitric Acid (HNO_3) because it is a strong oxidizing agent (oxidizes H_2 to water).

Exception to the exception: Mg and Mn react with very dilute HNO_3.

Halogens: Metals combine with chlorine to form stable, well-defined crystalline ionic solids (e.g., NaCl, $MgCl_2$).

During this, metals lose electrons (oxidation) and chlorine gains them (reduction).

Spotlight: Aqua Regia ("Royal Water")

A highly corrosive fuming acid mixture of 3 parts concentrated HCl to 1 part concentrated HNO_3. It has the unique power to dissolve noble metals like Gold and Platinum.

The Reactivity Series

SHIKSHA NATION

Most Reactive

- Potassium (K)
- Sodium (Na)
- Barium (Ba)
- Calcium (Ca)
- Magnesium (Mg)
- Aluminum (Al)
- Zinc (Zn)
- Iron (Fe)
- Nickel (Ni)
- Tin (Sn)
- Lead (Pb)
- Hydrogen (H)
- Copper (Cu)
- Mercury (Hg)
- Silver (Ag)
- Gold (Au)

Least Reactive

Top: Potassium (K), Sodium (Na), Barium (Ba), Calcium (Ca), Magnesium (Mg)

Middle: Aluminum (Al), Zinc (Zn), Iron (Fe), Nickel (Ni), Tin (Sn), Lead (Pb)

The Benchmark: Hydrogen (H)

Bottom: Copper (Cu), Mercury (Hg), Silver (Ag), Gold (Au)

The Golden Rule of Displacement:

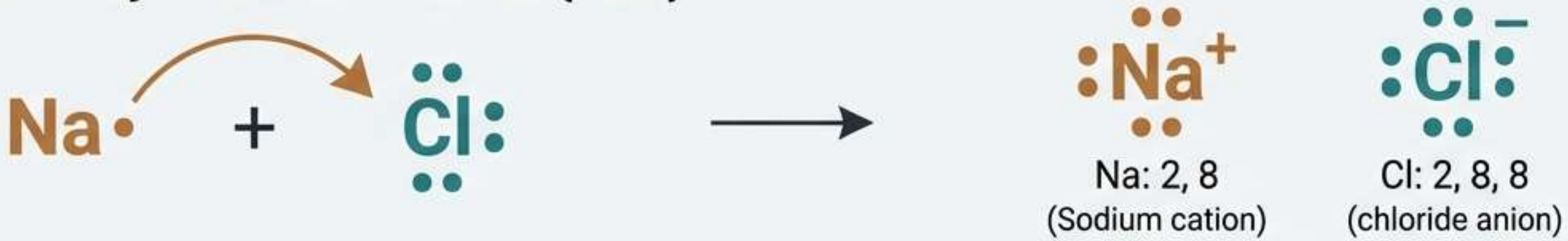
A more electropositive metal (higher up) will displace a less electropositive metal from its salt solution.
(e.g., $Fe + CuSO_4 \rightarrow FeSO_4 + Cu$).

WHEN WORLDS COLLIDE: IONIC BONDING

Concept: Atoms seek a completely filled valence shell (a stable octet).

SHIKSHA NATION

Visual Case Study 1: Sodium Chloride (NaCl)

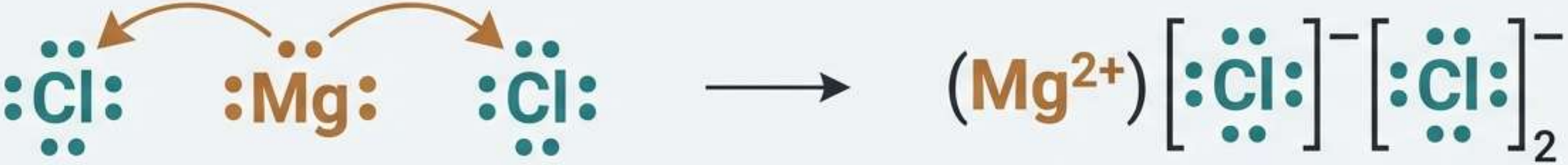


Step 1: Sodium (Na: 2,8,1) wants to lose 1 electron.
Chlorine (Cl: 2,8,7) wants to gain 1 electron.

Step 2: Transfer occurs. Na becomes Na^{+} (cation).
Cl becomes Cl^{-} (anion).

Step 3: Electrostatic attraction locks them into NaCl.

Visual Case Study 2: Magnesium Chloride ($MgCl_2$)



Step 1: Mg (2,8,2) needs to lose 2 electrons.

Step 2: It gives one electron to two separate Chlorine atoms.

Step 1: Mg (2,8,2) needs to lose 2 electrons.

Step 3: Forms Mg^{2+} and two Cl^{-}, creating $MgCl_2$.

ANATOMY OF IONIC COMPOUNDS

SHIKSHA NATION

PHYSICAL NATURE

Solid and somewhat hard. They exist not as single molecules, but as **aggregates of oppositely charged ions held by strong electrostatic forces.**

HIGH MELTING & BOILING POINTS

Considerable energy is required to break the strong inter-ionic attraction.

SOLUBILITY RULES

Generally soluble in water. Insoluble in organic solvents like kerosene and petrol.

ELECTRICAL CONDUCTIVITY

They do not conduct electricity in a solid state. They do conduct electricity when in a molten state or dissolved in water (ions are free to move).

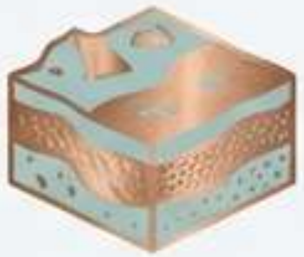
EARTH'S BOUNTY: MINERALS VS. ORES

"All ores are minerals, but not all minerals are ores."

MINERALS VS. ORES: THE DIFFERENCE

- **Minerals:** Solid compounds of metals naturally found in the earth's crust. (e.g., Aluminum exists in both Bauxite and China Clay).
- **Ores:** Minerals from which metals can be extracted profitably on a commercial scale. (e.g., We extract Aluminum from Bauxite, making Bauxite the true ore).

- **The Enemy:** Gangue (or Matrix) – the unwanted soil, sand, and rocky impurities mined alongside the ore.



KEY ORES TO KNOW

Iron	→	Haematite (Fe_2O_3), Magnetite
Aluminum	→	Bauxite ($Al_2O_3 \cdot 2H_2O$)
Mercury	→	Cinnabar (HgS)
Zinc	→	Zinc blende (ZnS)

THE METALLURGICAL JOURNEY

SHIKSHA NATION

1 ENRICHMENT (DRESSING)

Removing the gangue from the raw ore based on physical/chemical property differences.

2 CONVERSION

Turning the enriched ore into a metal oxide (the most optimal state for extraction).

3 REDUCTION

Extracting the pure metal from the metal oxide.

4 REFINING

Purifying the extracted metal for industrial use.

CONVERSION & REDUCTION EXPLAINED

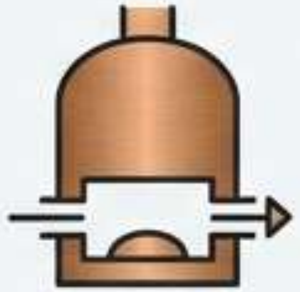
ZONE 1: CONVERSION: ROASTING VS. CALCINATION

ROASTING

For Sulphide ores (e.g., ZnS). Heated in an excess supply of air to convert to oxide.

Equation: $ZnS \rightarrow ZnO$

CALCINATION



For Carbonate ores (e.g., $ZnCO_3$). Heated in a limited supply of air to convert to oxide.

Equation: $ZnCO_3 \rightarrow ZnO$

ZONE 2: THE ROLE OF FLUX & SLAG

Impurity (e.g., Acidic SiO_2) + **Flux** (e.g., Basic CaO) = **Slag** (Fusible waste: $CaSiO_3$)

During smelting, non-fusible impurities must be removed.

3. REDUCTION STRATEGY

- Depends on reactivity.
- Low-tier metals (Hg, Cu) can be reduced by heating alone.

THE THREAT OF CORROSION

SHIKSHA NATION

The Problem: Corrosion is the slow eating away of metal due to attacks from air, moisture, and chemical reagents.

THE ARSENAL OF PREVENTION

Barrier Protection: Painting, oiling, and greasing.

Galvanisation: Coating steel/iron with a thin layer of Zinc. Protects against rusting even if the coating is broken.

Anodising: Electrolyzing Aluminum with dilute H_2SO_4 to purposefully build a thick, protective oxide layer that resists further corrosion (and can be dyed).

Chrome Plating & Alloying: Altering the surface or chemical makeup entirely.

SUPERCHARGING ELEMENTS: ALLOYS

SHIKSHA NATION

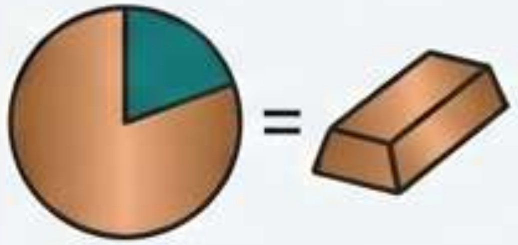
Definition: A homogeneous mixture of two or more metals (or a metal and non-metal) designed to modify pure metals into something less brittle, harder, or completely resistant to corrosion.

THE ALLOY RECIPE BOOK

Brass: Copper + Zinc

Used for decorative items, musical instruments, and applications requiring low friction.

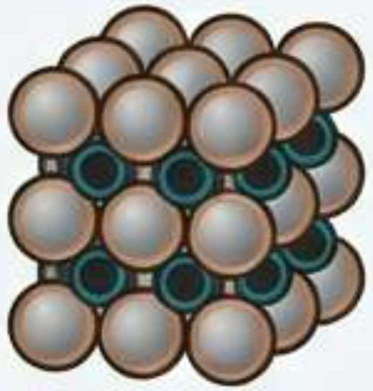
Bronze: Copper + Tin



Known for its toughness and corrosion resistance; used in sculptures, bearings, and medals.

Steel: Iron + Carbon

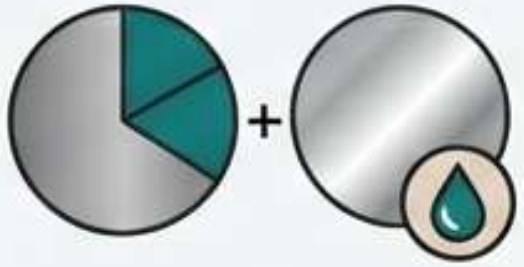
(Adds hardness)



The most widely used alloy; essential for construction, infrastructure, and tools.

Stainless Steel: Iron + Nickel + Chromium

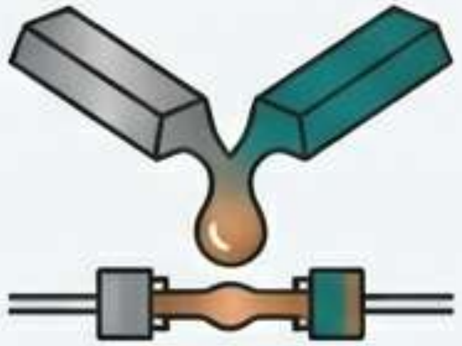
(Adds severe corrosion resistance)



Resistant to rust and staining; used in cutlery, cookware, and medical instruments.

Solder: Lead + Tin

(Lowers melting point for electronics)



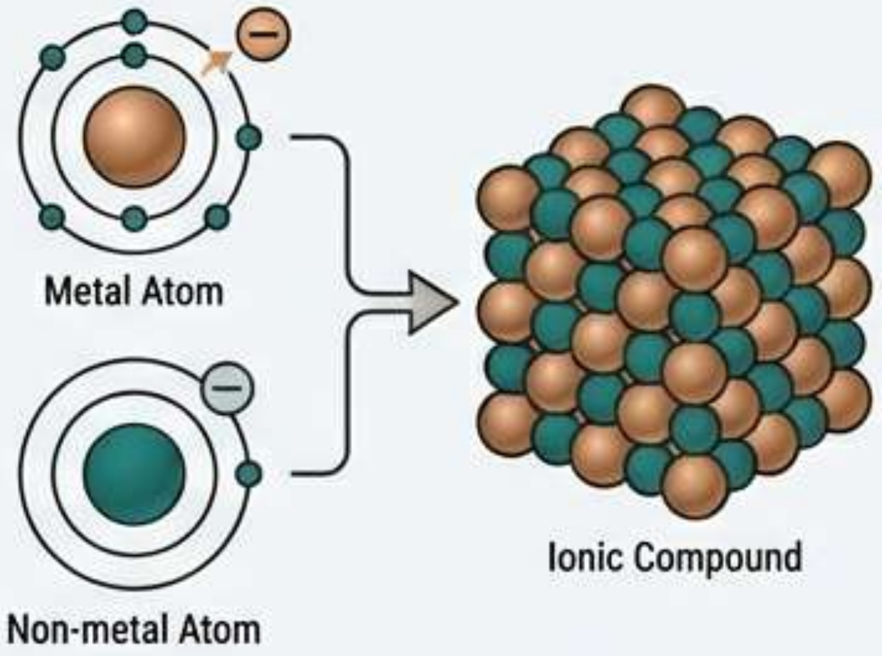
Used for joining electrical components and pipes; low melting point facilitates connections.

Note: Electrical conductivity of an alloy is generally less than that of its pure parent metals.

Mastering the Elements: Key Takeaways

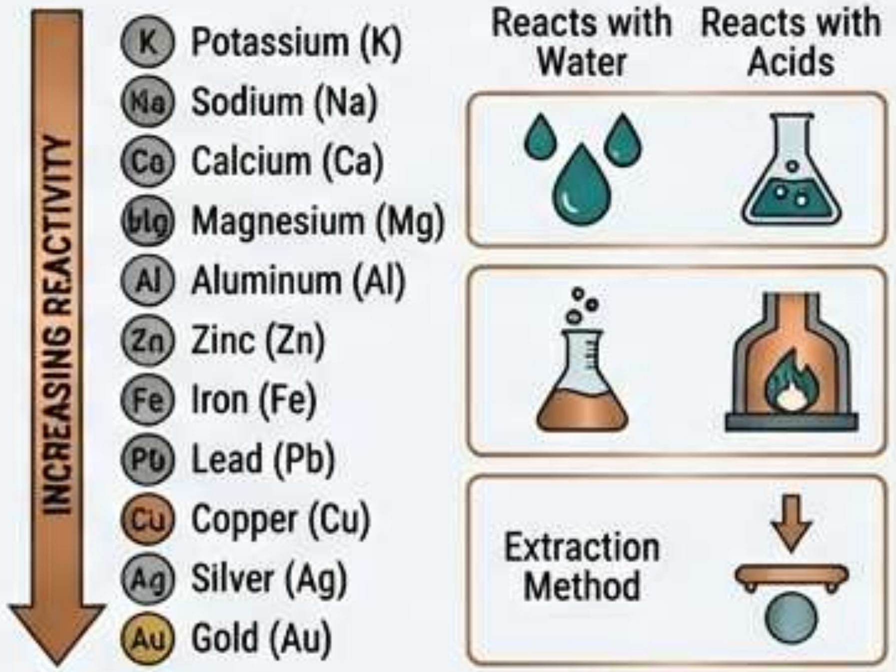
1 Chemical Identity

Metals are electropositive elements defined by their tendency to lose electrons; Non-metals are electronegative elements that gain them. Their collision creates robust, high-melting ionic compounds.



2 The Reactivity Hierarchy

An element's position on the Reactivity Series dictates everything from how it reacts with water and acids to the specific metallurgical methods required to extract it from the earth.



3 Industrial Application

Raw earth minerals must be enriched, converted, and reduced into metals. Once purified, techniques like Galvanisation, Anodising, and Alloying are essential to protect them and unlock their full mechanical potential.