The Material Divide: Metals and Non-Metals

Properties, Reactivity, and the Science of Extraction

The Journey of the Element: From Atom to Alloy

The Observable Properties

METALS
Metallic Gold (#D4AF37)

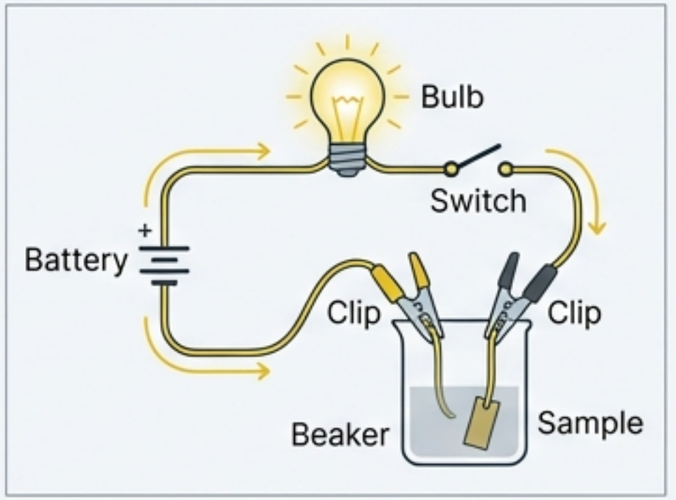
- Lustrous (Shiny)
- Hard & Malleable (Sheets)
- Ductile (Wires)
- Sonorous (Rings)
- Good Conductors (Heat/Electricity)

NON-METALS
Matte Carbon Black

- Dull
- Brittle
- Non-Sonorous
- Poor Conductors

THE EXCEPTIONS

- **Mercury:** Liquid Metal
- **Diamond (Carbon):** Hardest Substance
- **Graphite (Carbon):** Conducts Electricity
- **Iodine:** Lustrous Non-Metal
- **Sodium/Potassium:** Soft Metals



Combustion: Reaction with Air

$$2Mg + O_2 \rightarrow 2MgO$$

Nature of Oxides

Metal Oxides = Basic (Turn Red Litmus Blue)
Non-Metal Oxides = Acidic

AMPHOTERIC OXIDES

Aluminium Oxide (Al_2O_3)
Zinc Oxide (ZnO)

$$Al_2O_3 + 6HCl \rightarrow 2AlCl_3 + 3H_2O$$
$$Al_2O_3 + 2NaOH \rightarrow 2NaAlO_2 + H_2O$$

Reactivity with Water: A Spectrum of Violence

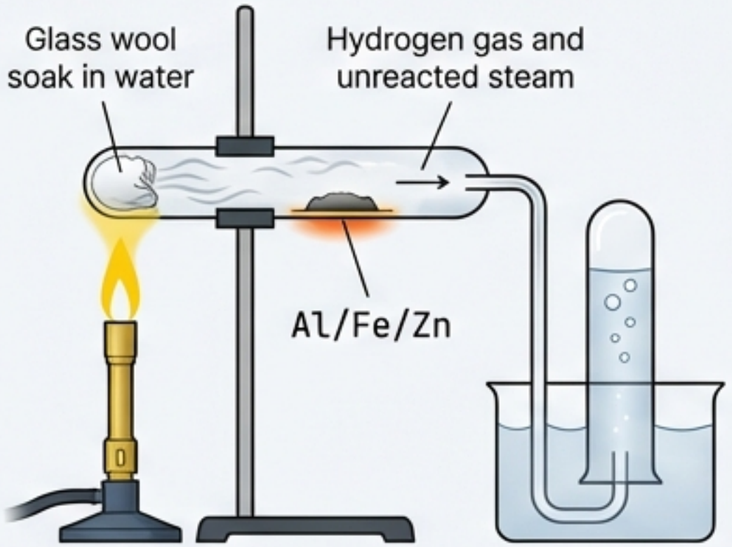
Violent Reaction (Cold Water)

Potassium & Sodium.
Exothermic: Hydrogen catches fire.

Moderate Reaction (Hot Water)

Magnesium.
Reacts with hot water.
Floats due to H_2 bubbles.

Steam Only



Aluminium, Iron, Zinc.

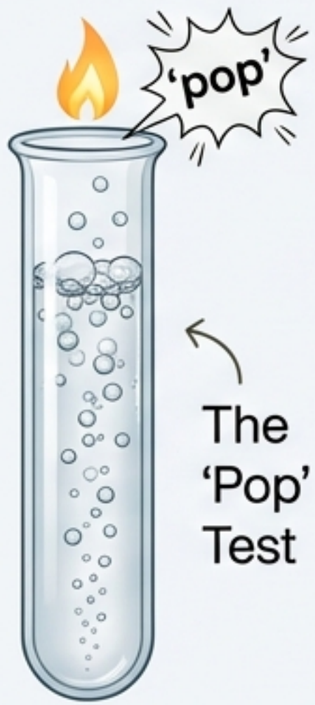
No Reaction: Lead, Copper, Silver, Gold

Elemental Editorial

Acid Attacks & The Royal Water

Standard Acid Reaction

`Metal + Dilute Acid → Salt + Hydrogen`



Copper does NOT react with dilute HCl.

The Nitric Acid Exception

HNO_3 is a strong oxidizer.

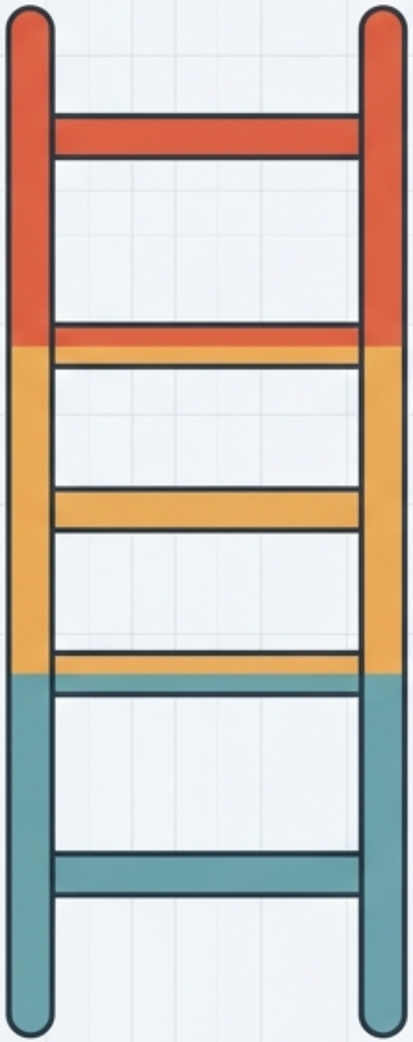
Produces H_2O instead of H_2 gas (except with Mg/Mn).

Aqua Regia (Royal Water)

Mixture: Concentrated HCl + Concentrated HNO_3 (Ratio 3:1)

One of the few reagents able to dissolve Gold and Platinum.

The Reactivity Series

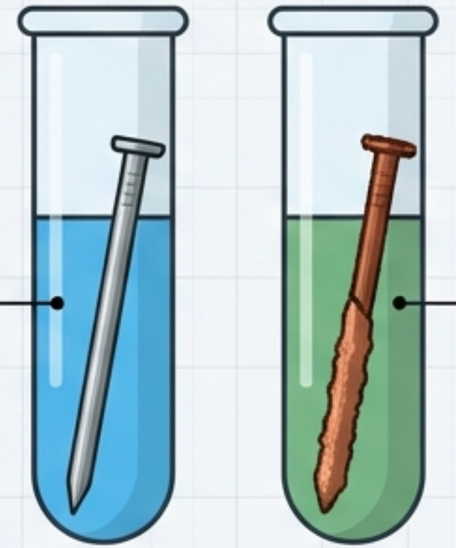


Most Reactive
Potassium (**K**)
Sodium (**Na**)
Calcium (**Ca**)

Magnesium (**Mg**)
Aluminium (**Al**)
Zinc (**Zn**)
Iron (**Fe**)
Lead (**Pb**)

Least Reactive
Copper (**Cu**)
Mercury (**Hg**)
Silver (**Ag**)
Gold (**Au**)

Displacement Logic



Blue solution (Copper Sulphate) with a clean Iron nail

Greenish solution (Iron Sulphate) with a copper-coated nail

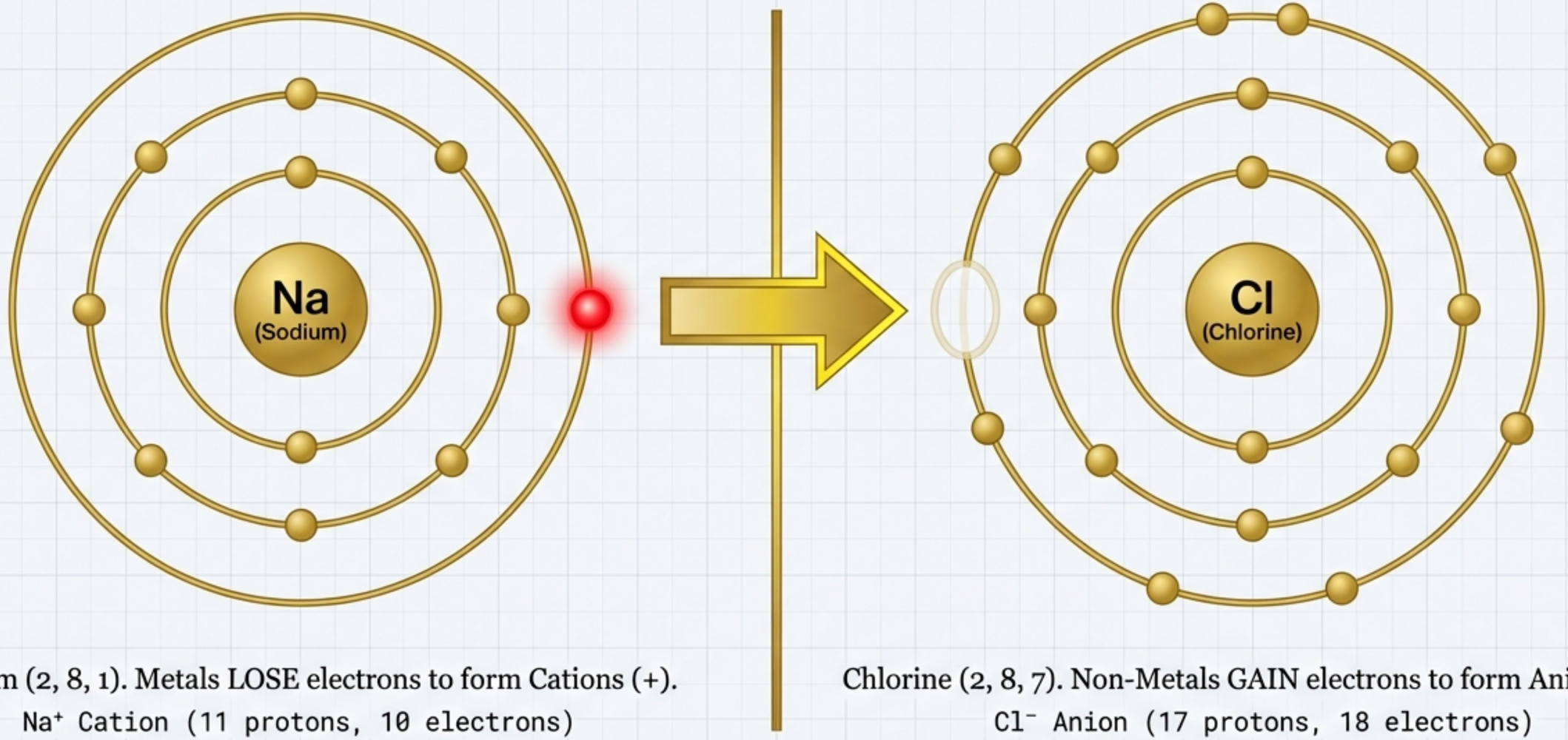
Test Tube A Test Tube B

$$Fe(s) + CuSO_4(aq) \rightarrow FeSO_4(aq) + Cu(s)$$

Iron displaces Copper because Iron is higher on the ladder.

The Atomic Driver: Electronic Configuration

Why do elements react? To achieve a full valence shell.



Sodium (2, 8, 1). Metals LOSE electrons to form Cations (+).

`Na⁺ Cation (11 protons, 10 electrons)`

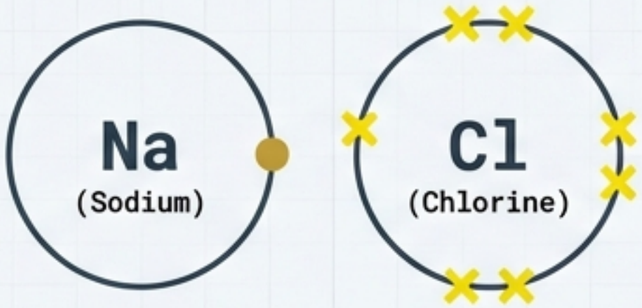
Chlorine (2, 8, 7). Non-Metals GAIN electrons to form Anions (-).

`Cl⁻ Anion (17 protons, 18 electrons)`

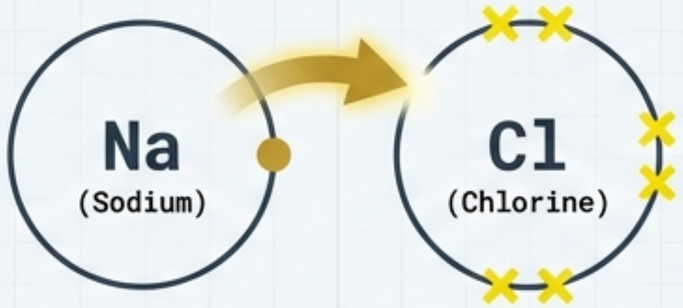
Formation of Ionic Bonds

Ionic (Electrovalent) Bond: Electrostatic force of attraction between oppositely charged ions.

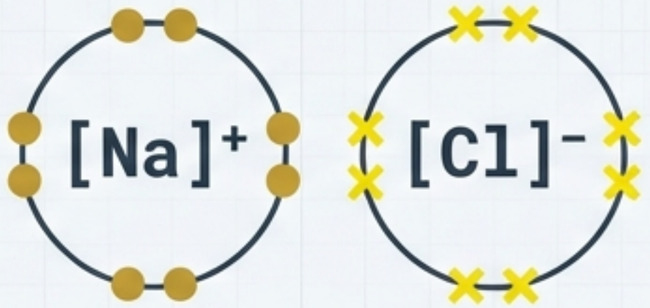
Sodium Chloride (NaCl)



Step 1



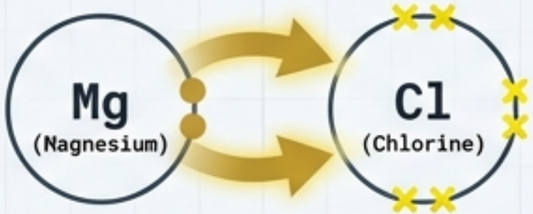
Step 2



Step 3

Magnesium Chloride ($MgCl_2$)

Step 1

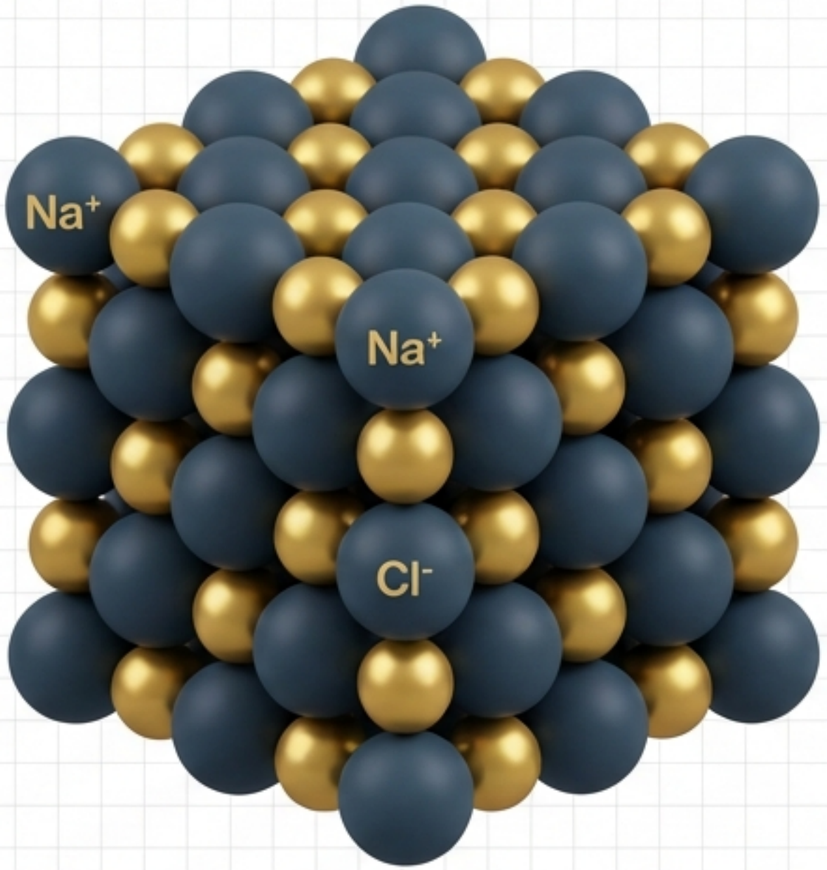


Step 2

Step 3

Properties of Ionic Compounds

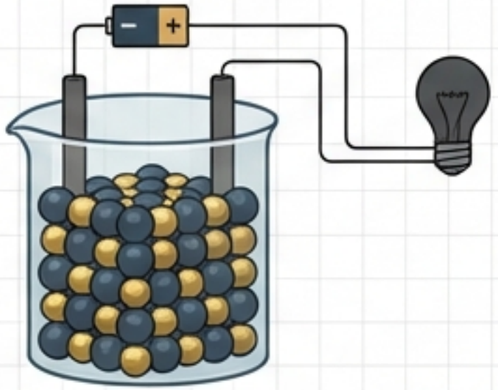
Cubic Crystal Lattice



Solid, Hard, Brittle. High Melting Point (NaCl = 1074 K).

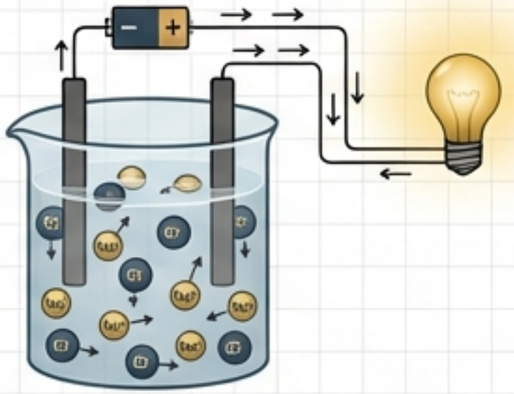
Electrical Conductivity

Solid State



Ions fixed in lattice. No bulb glow.

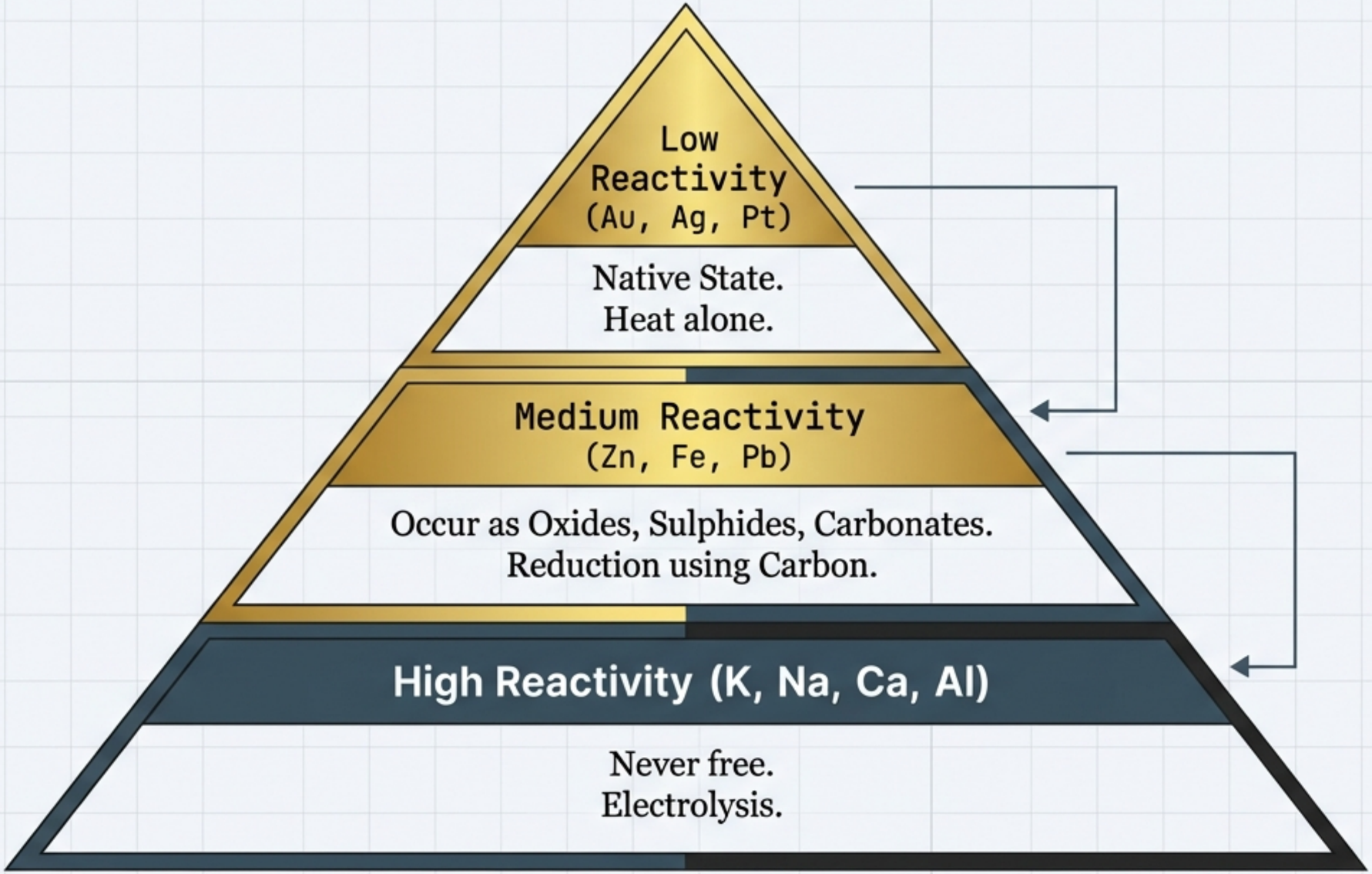
Molten/Aqueous State



Ions floating freely. Bulb glowing bright.

Conducts electricity only when molten or dissolved.

Occurrence & Extraction Strategy



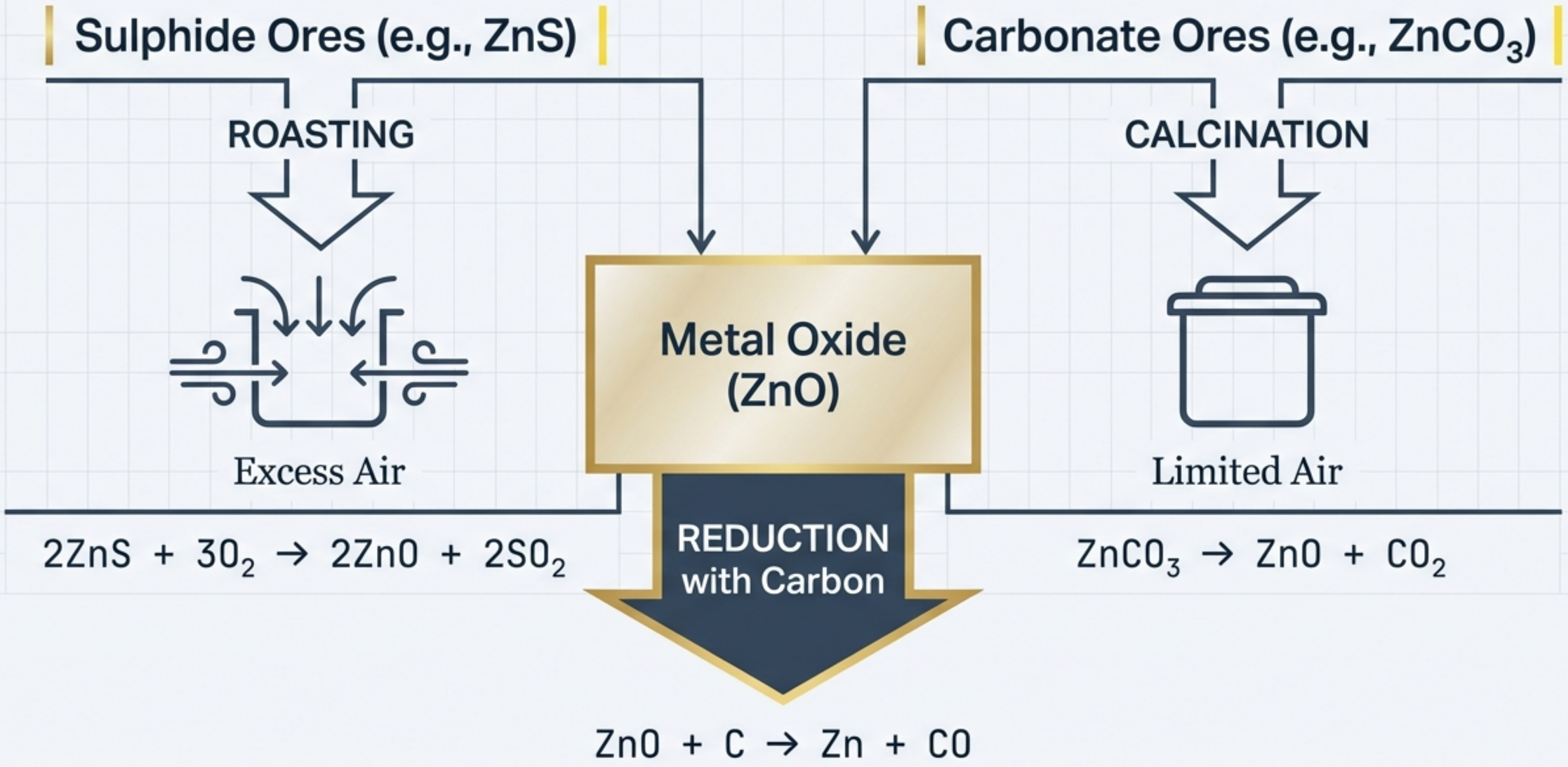
Definitions:

Helvetica
Now Display

Ore:
Mineral with high metal percentage.

Gangue:
Earthly impurities (sand/soil) to be removed.

Processing Medium Reactivity Metals



Displacement as Reduction: The Thermit Reaction

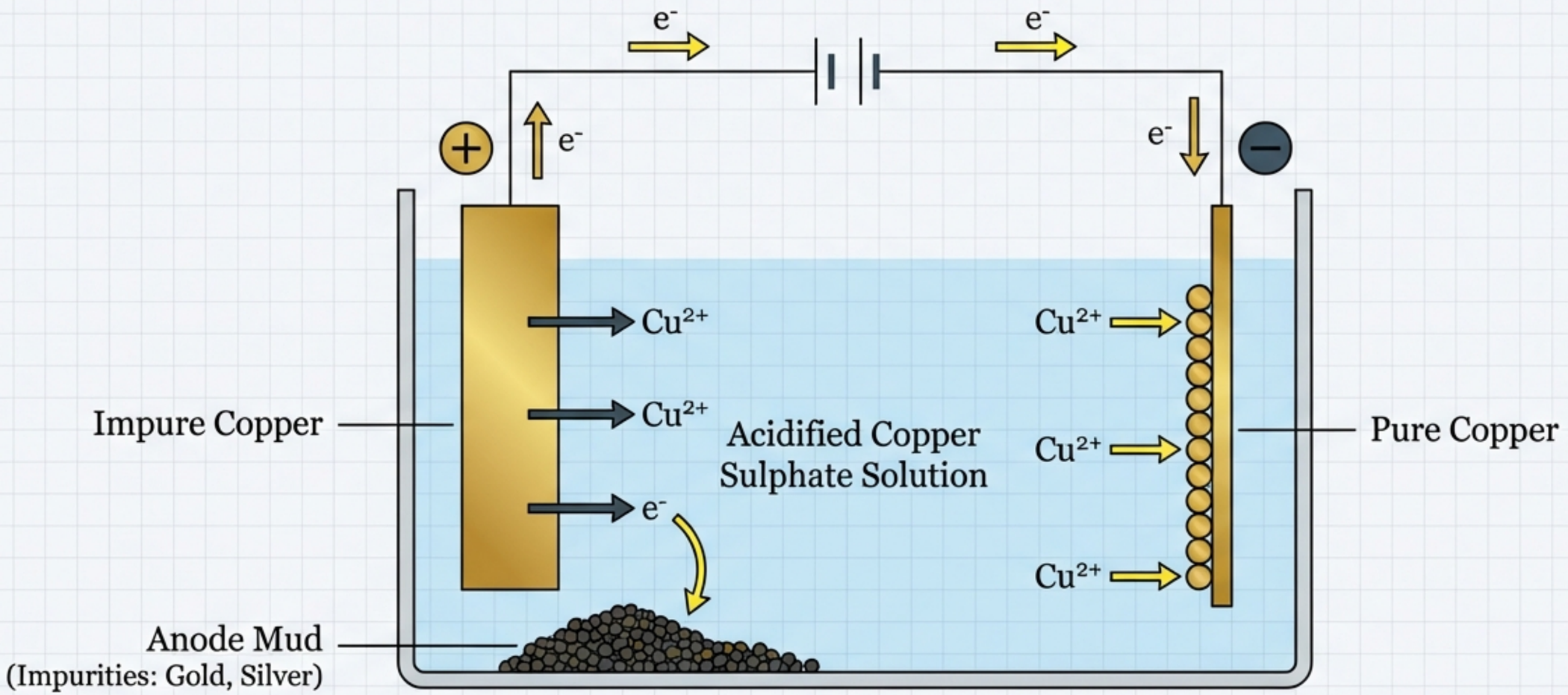
For highly reactive scenarios, we use a more reactive metal (Aluminium) to displace a less reactive one (Iron).

$$Fe_2O_{3(s)} + 2Al_{(s)} \rightarrow$$
$$2Fe_{(l)} + Al_2O_{3(s)} + Heat$$

Exothermic: Iron is produced in MOLTEN state.

Electrolytic Refining

For High Reactivity Metals & Purification



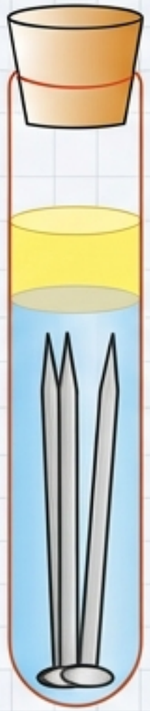
Corrosion: The Battle Against Nature

Iron Pillar (1600 years old, Rust-Free)

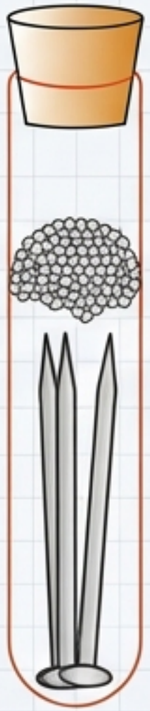
An extraordinary example of ancient metallurgy, remaining virtually rust-free despite exposure to the elements for centuries.

Conditions for Rusting

Tube A: Iron nails in Air + Water = RUST



Tube B: Iron nails in Water + Oil layer (No Air) = NO RUST



Tube C: Iron nails in Dry Air (Calcium Chloride) = NO RUST

Tube A: Iron nails in Air + Water = RUST

Tube B: Iron nails in Water + Oil layer (No Air) = NO RUST

Tube C: Iron nails in Dry Air (Calcium Chloride) = NO RUST

Conclusion: Rust requires BOTH Air and Moisture.

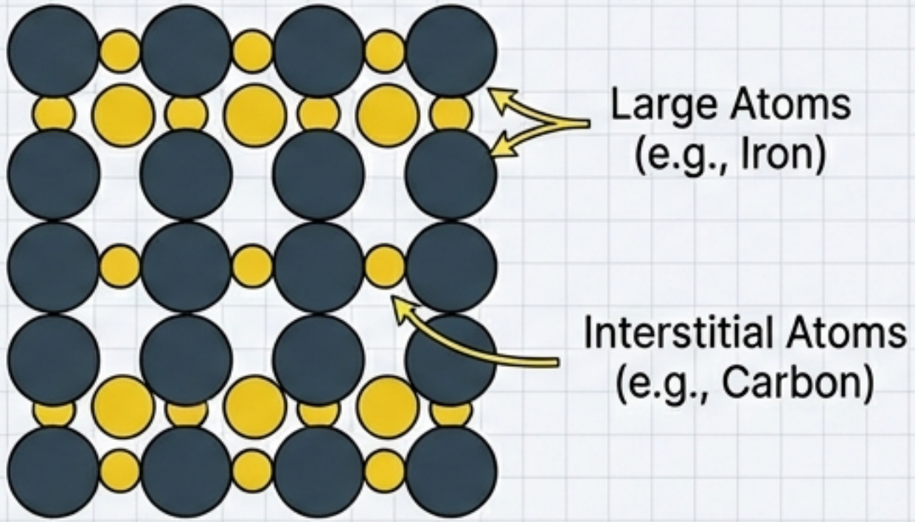
Prevention & Improvement: Alloys

Prevention Methods

Georgia Pro • Painting • Greasing • Chrome Plating

Galvanisation: Coating with Zinc. Zinc sacrifices itself to protect Iron.

Alloys (Homogeneous Mixtures)



Examples Table	
Brass	= Copper + Zinc
Bronze	= Copper + Tin
Solder	= Lead + Tin (Low Melting Point)
Stainless Steel	= Iron + Nickel + Chromium (Rust Proof)
Amalgam	= Mercury + Any Metal
Gold (22k)	= Au + Ag/Cu (Hardened for Jewelry)