Engineering Physics (2025)
Course code 25PY101
Unit 1: Metals and Semiconductors

Course Instructor:
Dr. Sreekar Guddeti
Assistant Professor in Physics
Department of Science and Humanities
Vignan's Foundation for Science, Technology and Research

September 23, 2025

Unit 1 Plan

1. Condensed matter
2. Metals

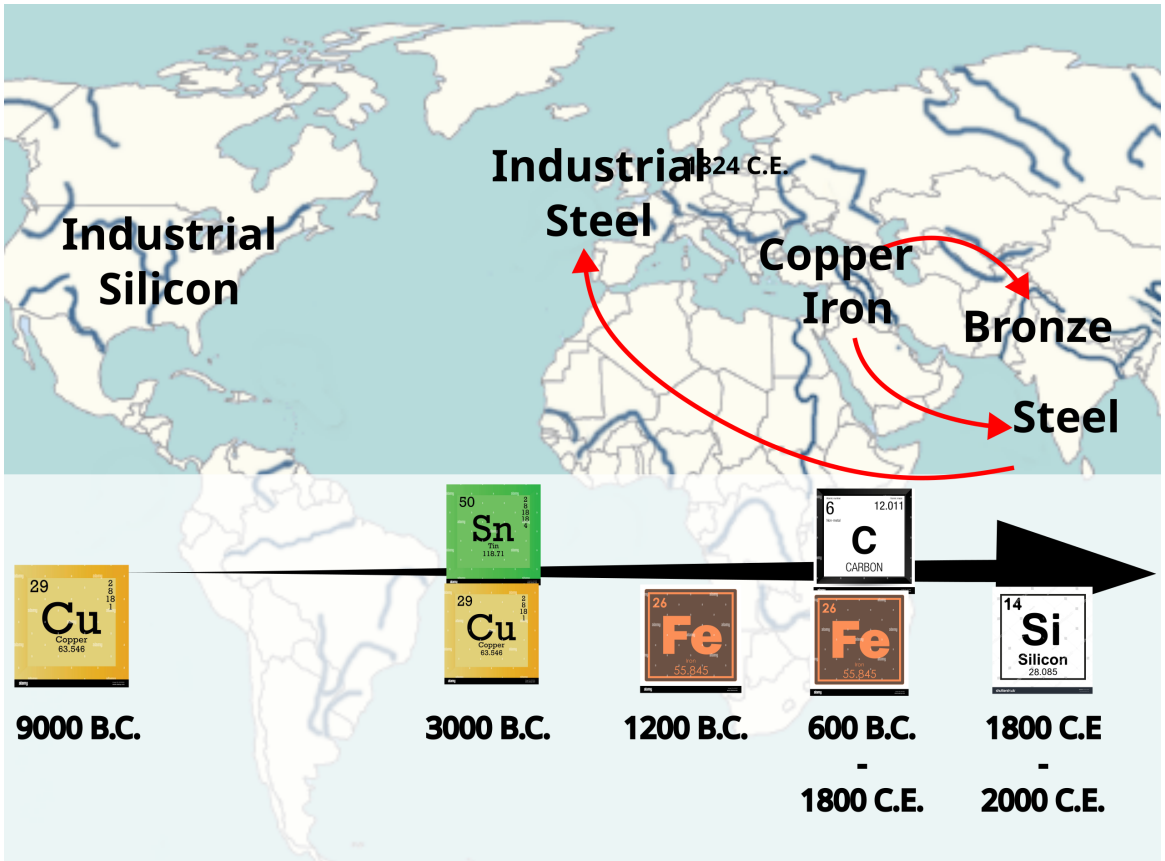
Unit 1 Plan

Lecture plan

Learning Objectives

- Condensed matter at macroscopic scale
- Classification of condensed matter based on conductivity
- Nature of metals
- Classical electron theory of metals – Assumptions
- Ohm's law for metals – Conductivity
- Application of metallic conductivity

Discovery of material



Civilization spacetimeline: Copper $\rightarrow$ Bronze $\rightarrow$ Iron $\rightarrow$ Steel $\rightarrow$ Silicon

Key Insight

Material defines the age.

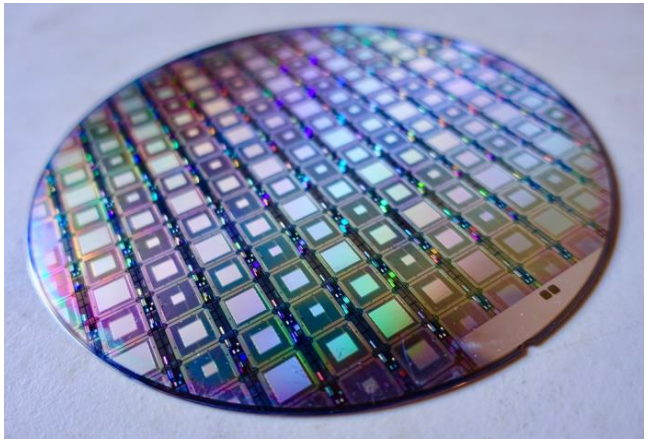
Condensed matter

- Material in the liquid or solid form is called **condensed matter**.
- Condensed matter is further sub-classified based on electrical, optical, magnetic, thermal, mechanical properties at the **macroscopic** scale. In the case of electrical property, we apply electric field and classify the materials based on their conductivity.
- The macroscopic behaviour is related to the **microscopic** behaviour of electrons under applied "forces".

Learning Objectives

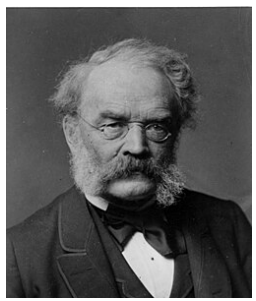
To relate the macroscopic properties with the microscopic behaviour of electrons in condensed matter.

Classification of Condensed Matter by Conductivity


(a) Gold, a metal, (b) Silicon, a semiconductor, (c) Diamond, an insulator

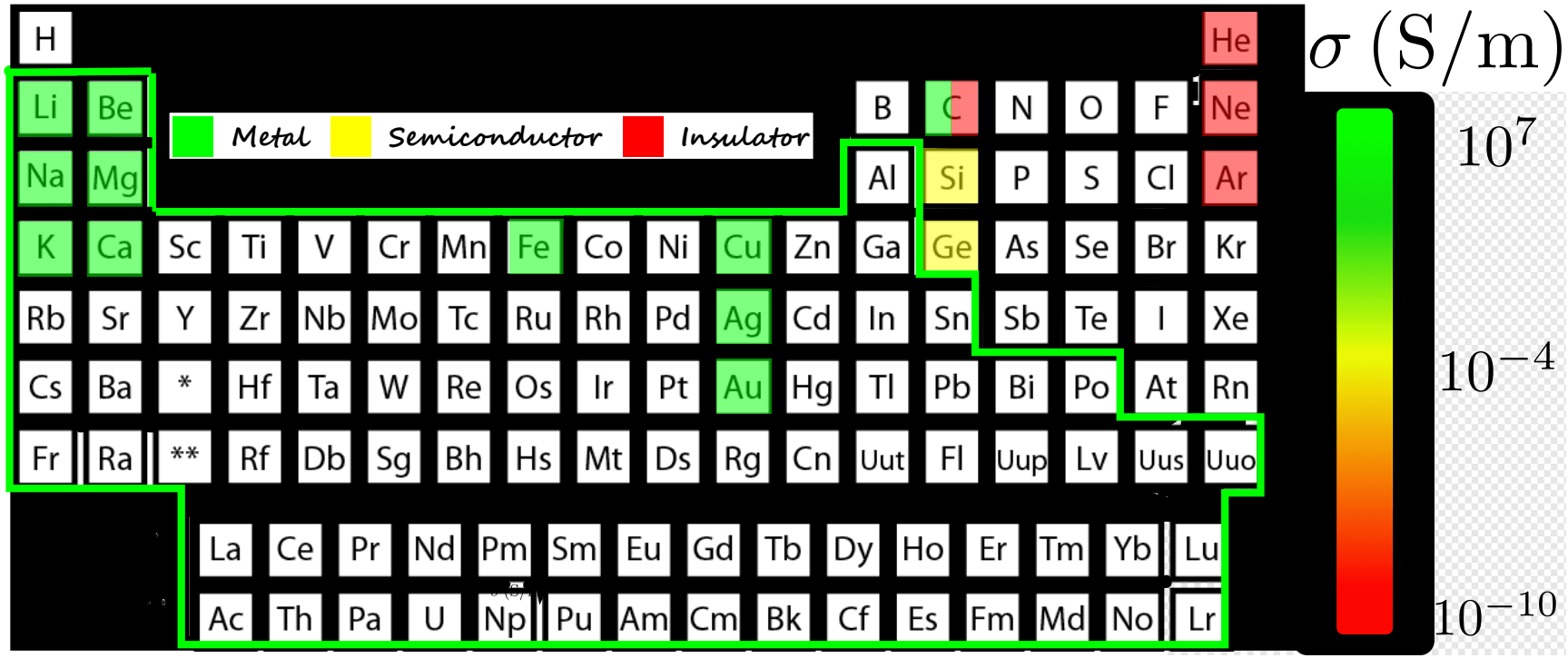
- Conductivity is the measure of how easily electrons move under applied electric field. Its unit is $\Omega^{-1}\,\mathrm{m}^{-1}$ or $\mathrm{S}\,\mathrm{m}^{-1}$ (S for Siemens).
- Materials can be classified based on conductivity as:
  1. **Metals**: High ($\sigma \sim 10^{7}$ S/m).
  2. **Semiconductors**: Intermediate ($\sigma \sim 10^{-4}$ S/m).
  3. **Insulators**: Negligible ($\sigma \sim 10^{-10}$ S/m).



W. Siemens [1816-1892]

Elemental phases

- The electrical state of condensed matter is also called a **phase** – similar to solid phase, liquid phase, etc.

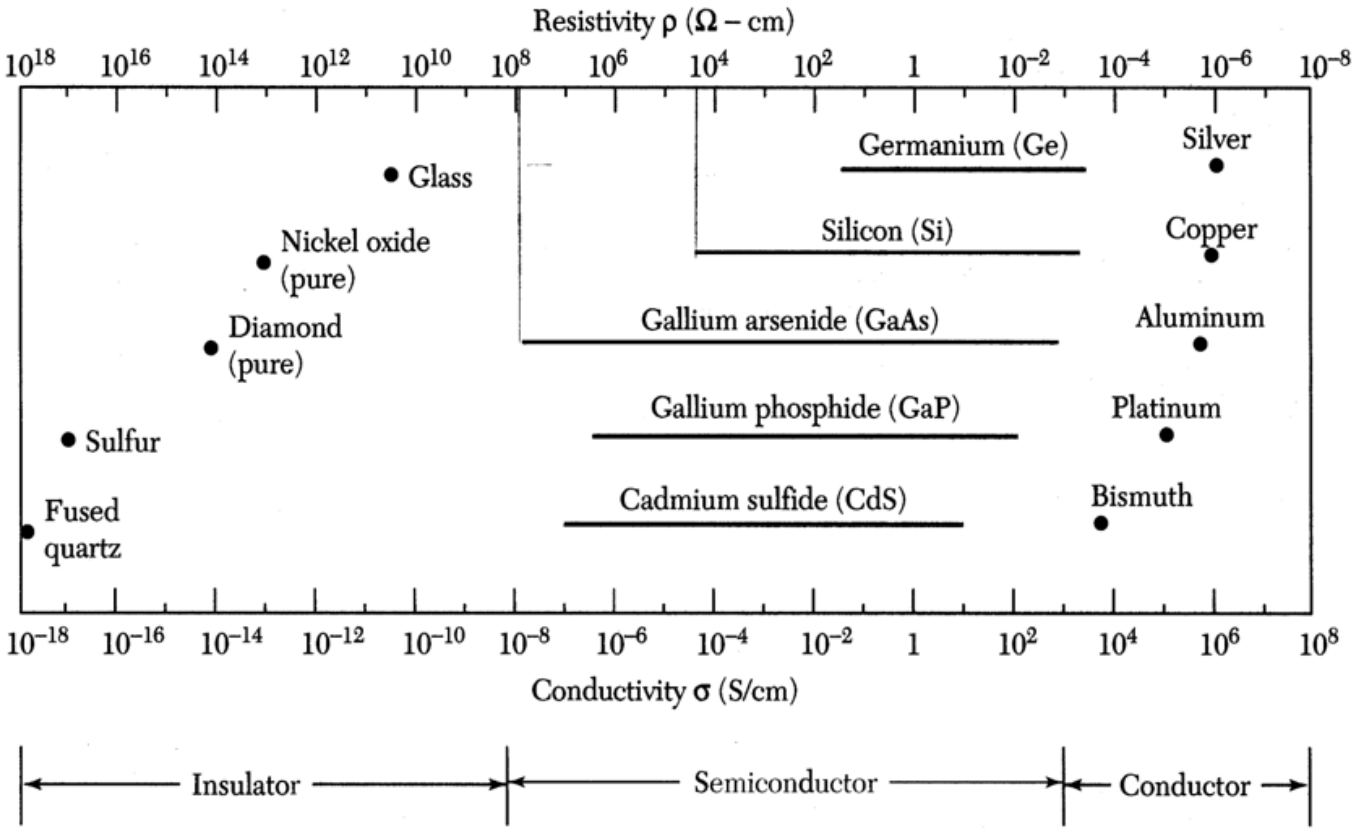


Key Insight

Most elemental phases are metals.

Conductivity of phases

- Conductivity σ is inversely related to resistivity ρ by $\rho = \frac{1}{\sigma}$

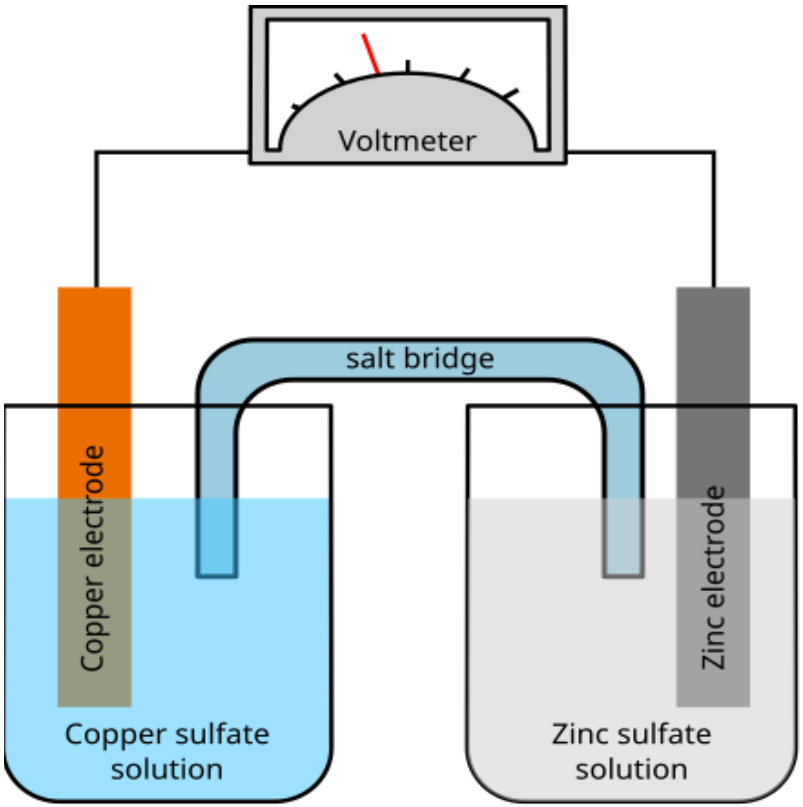


	ρ Ω m
Cu	10^{-7}
Si	10^{4}
SiO_2	10^{10}

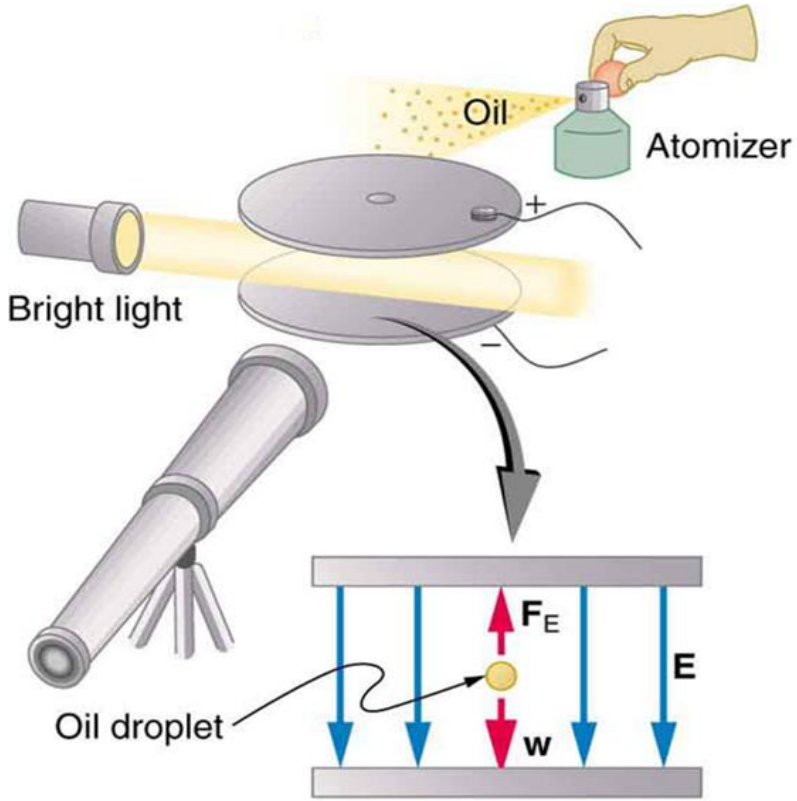
Key Insight

Conductivity spans "orders of magnitude" across phases.

Early experiments:Avogadro number and Electron charge

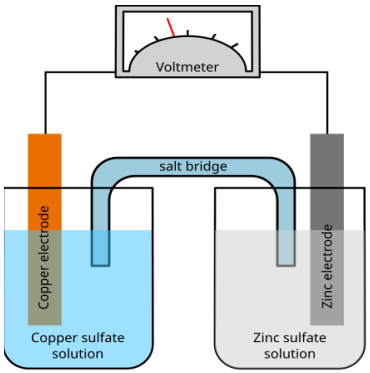


Electrochemical cell

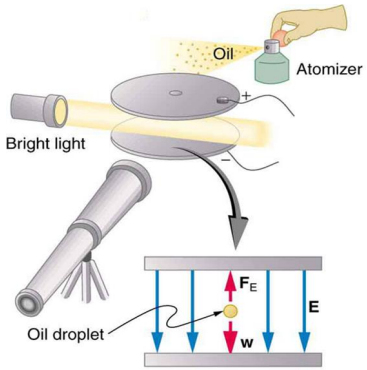


Oil drop experiment

Macroscopic → microscopic

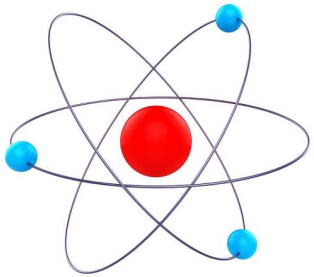


Electrochemical cell



Oil drop experiment

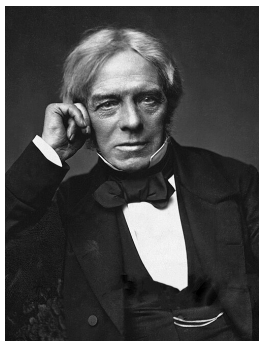
Macroscopic Copper



Microscopic Copper

Estimate: Avogadro number N_A

To electroplate 63.5 g of copper, it takes 2 F of charge. [Hint: 1F (F for Faraday)= 96.485 C, charge of electron $e = 1.602 \times 10^{-19}$ C]



Faraday, Millikan

Estimate: Radius of atom

The density of copper is 8.96 g cm^{-3}.

Unit 1 Plan

1. Condensed matter
2. Metals

Lecture Plan

Learning Objectives

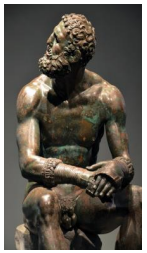
Learn the concept of

- electrical conductivity,
- mobility, and
- relaxation time

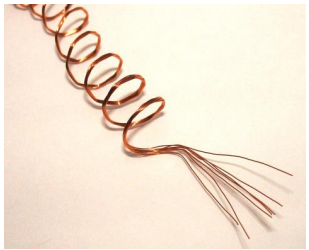
Nature of Metal

(1)

(2)



(3)



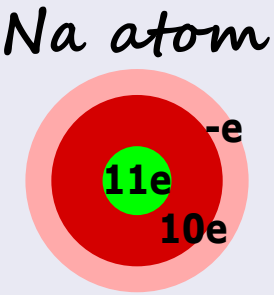
(4), (6)

(5)

1. Lustre (Shine)
2. Solid with high 1000 °C melting points
3. Malleable (capable of being shaped)
4. Good electrical conductor
5. Good thermal conductor
6. Ductile (easy to draw wires)

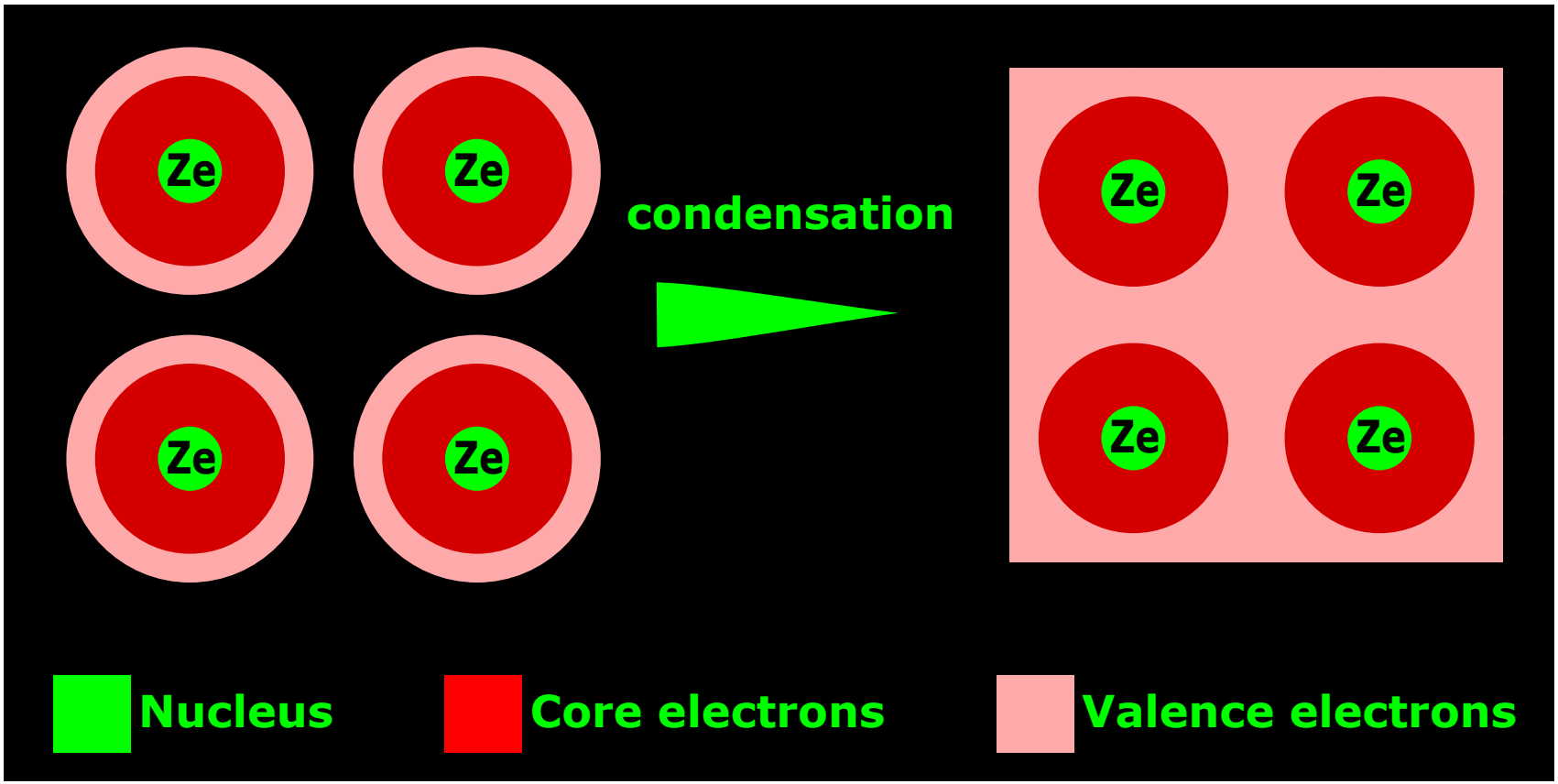
Chemistry

- Metallic bonding
- Screening



$$Z_{eff} = +e$$

Metallic bonding $\leftrightarrow$ electron gas



Valence electrons to electron "gas"

Key Insight

The properties of electron "gas" determines the nature of metal.

Electron theories of metals

1. Classical free electron theory
2. Quantum free electron theory [M2 U3]
3. Quantum band theory [M2 U3]