

Why Atoms Shrink Across and Grow Down

Measuring the Unmeasurable: The Quantum Mechanics of Atomic Radius

PERIODIC TRENDS

REF: SEC_3.7.1(b)

Atomic radius generally decreases across a period due to increased effective nuclear charge (Z_{eff}), drawing electrons closer.

- Example (Period 3): Na (186 pm) > Mg (160 pm) > ... > Ar (98 pm)

PHYSICAL LIMITATIONS

EXCEPTIONS & LIMITS

Measurement is challenging as atoms have no defined boundaries; radius is probabilistic. Trends are not absolute.

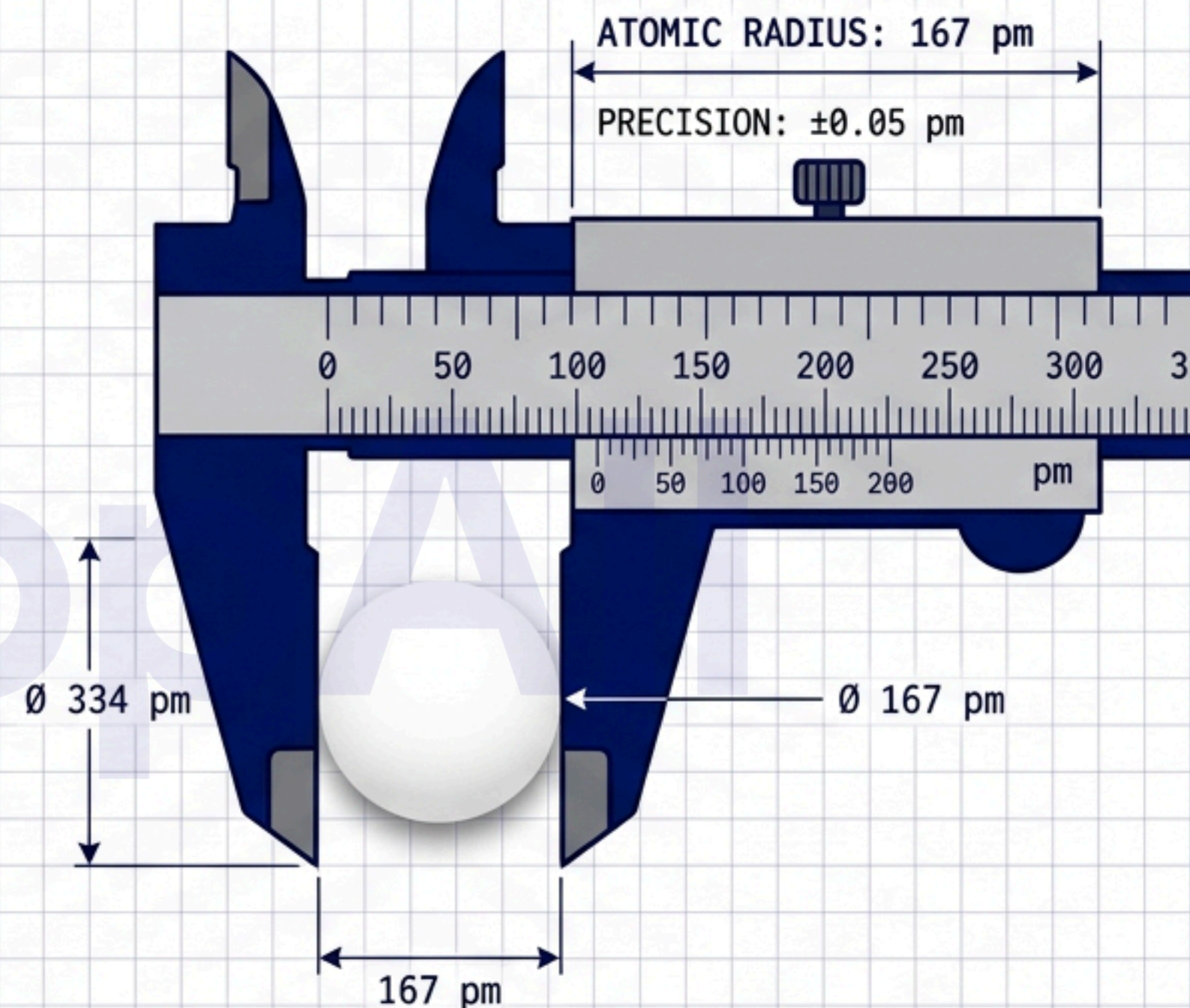
- Anomaly: Noble gases often have larger calculated van der Waals radii than predicted trends.

SYNTHESIZED CONCLUSION

KEY INSIGHT

Radius is a balance between nuclear attraction and electron-electron repulsion. Down a group, increased shell number dominates, enlarging the atom.

- Trend Down Group 1: Li (152 pm) < Na (186 pm) < K (227 pm) < Rb (248 pm)



The Measurement Paradox



Extreme Scale

Atom radius is incredibly small
($\sim 1.2 \text{ \AA}$ or $1.2 \times 10^{-10} \text{ m}$).



Quantum Boundary

Electrons do not possess a sharp physical boundary.



Isolation

Individual atoms cannot be practically isolated for singular measurement.

ALERT: Direct measurement of an isolated atomic radius is physically impossible.

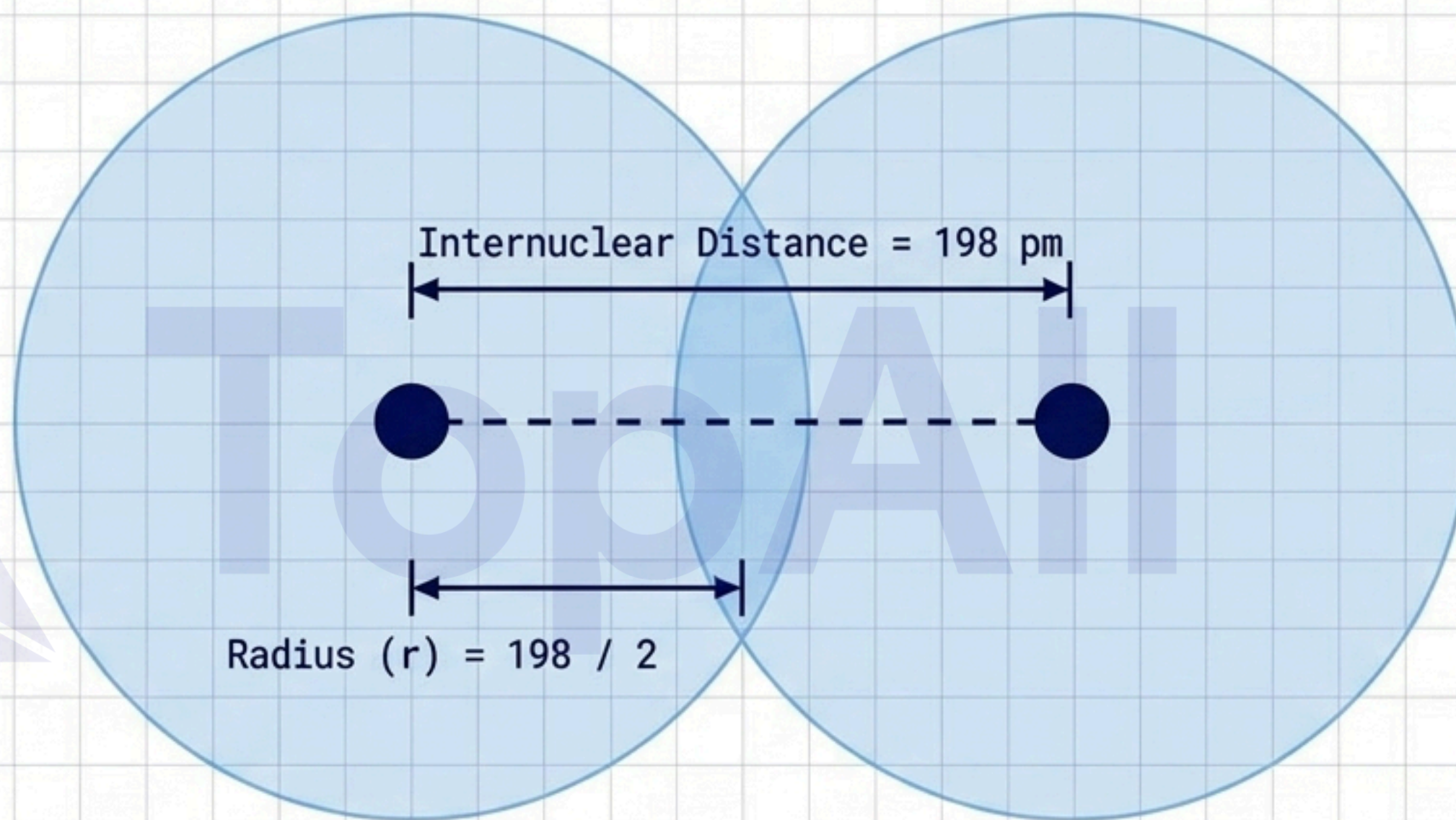
SOLUTION: We use proxy measurements by calculating the internuclear distance between bonded atoms.

Non-Metals: The Covalent Radius Proxy



METHOD 01: COVALENT

For non-metals, we measure the distance between two atoms bound by a single covalent bond, then halve that value.

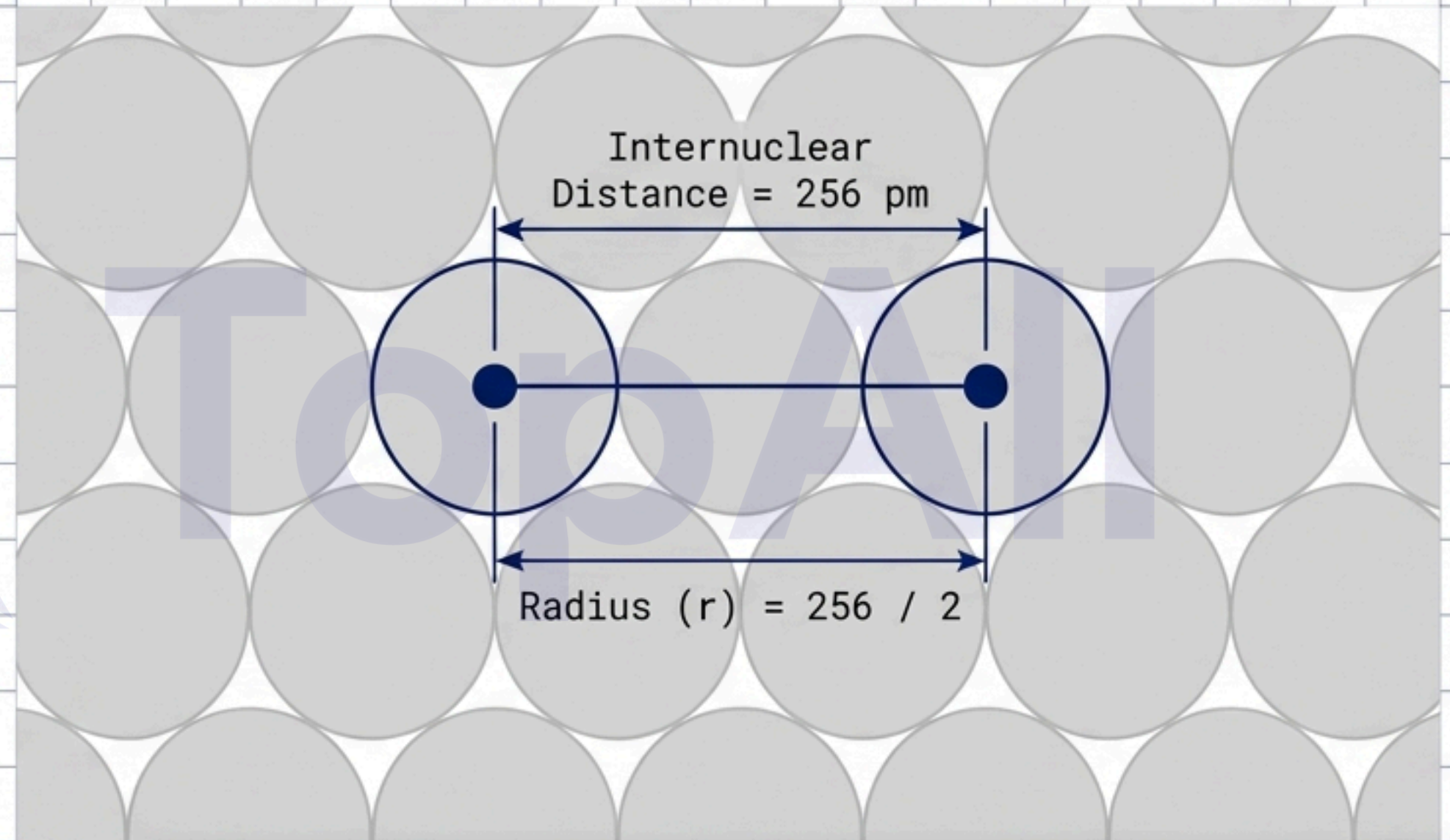
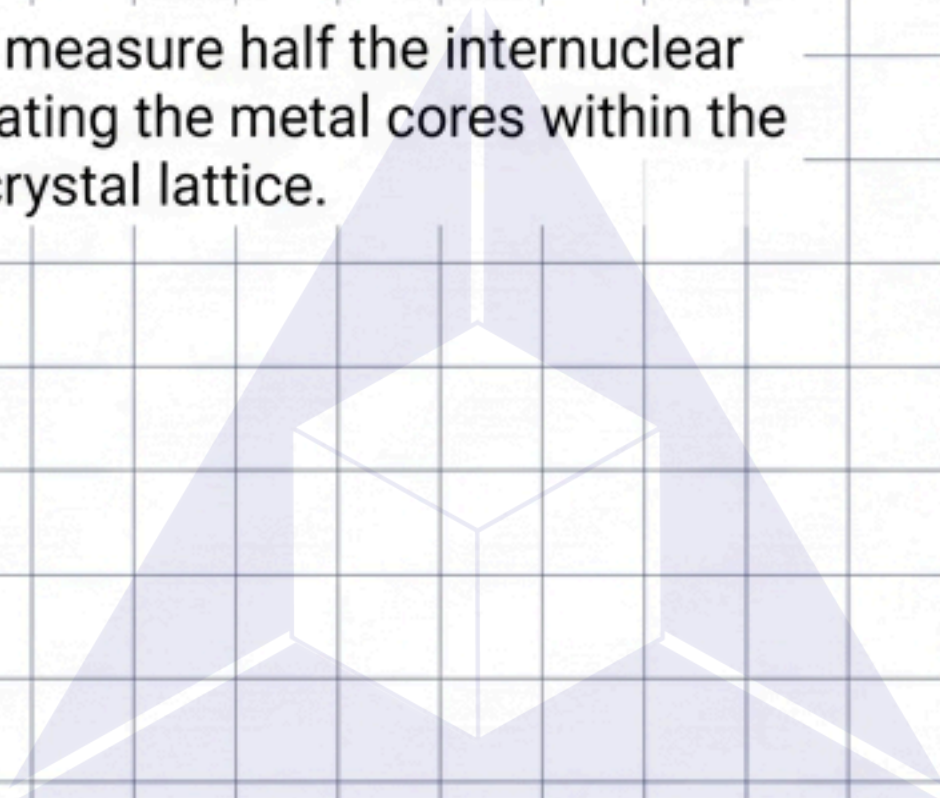


Covalent Radius of Chlorine = 99 pm

Metals: The Metallic Radius Proxy

METHOD 02: METALLIC

For metals, we measure half the internuclear distance separating the metal cores within the solid metallic crystal lattice.



Metallic Radius of Copper = 128 pm



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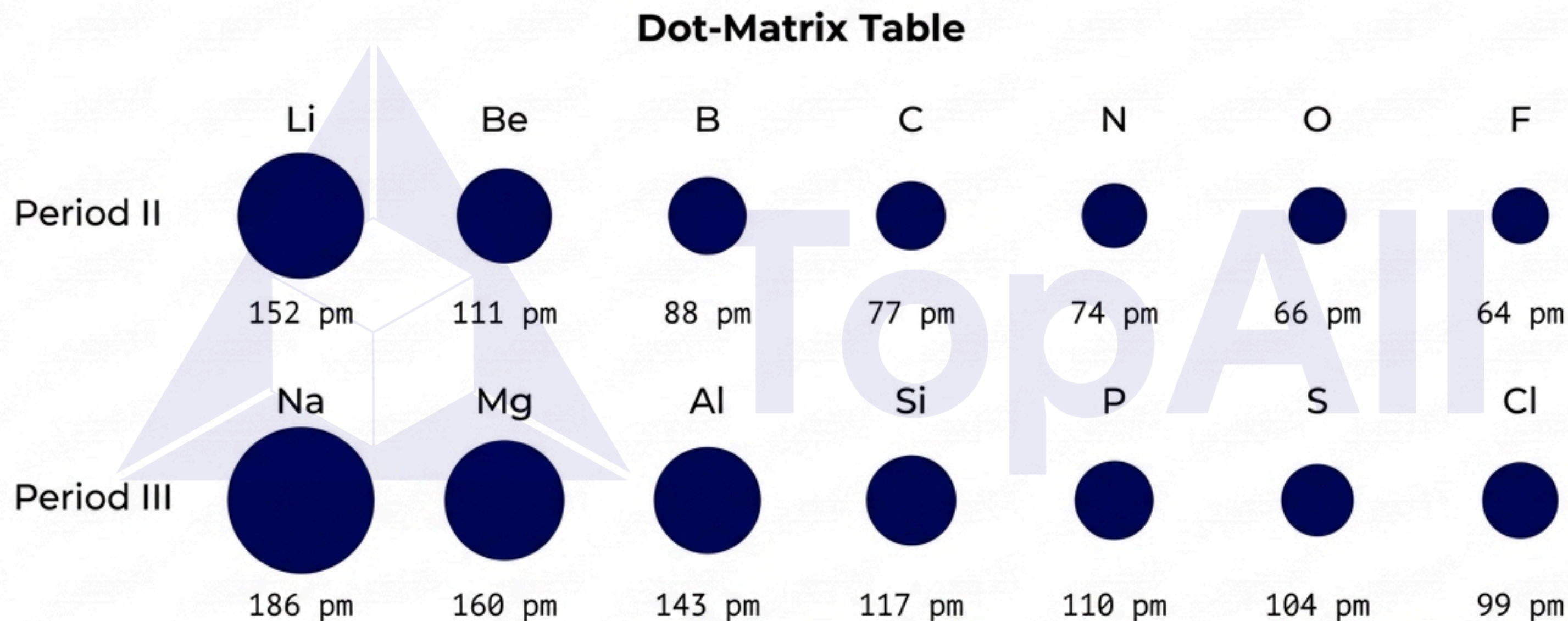
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Horizontal Trend: Shrinking Across Periods



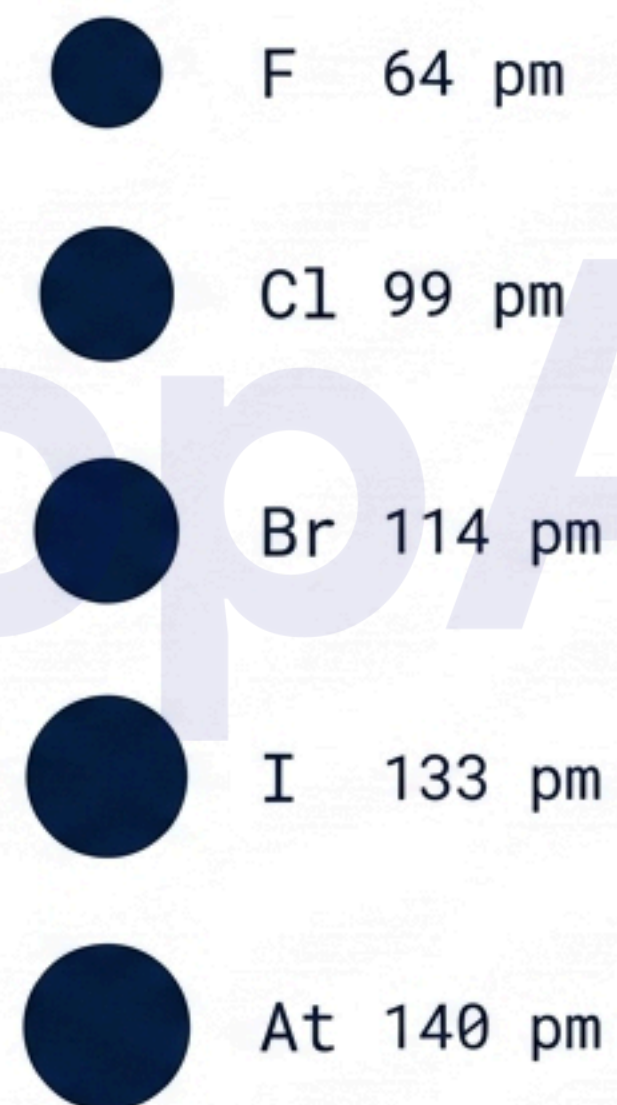
EXCLUSION: Noble Gases are omitted. As monatomic gases, their non-bonded (van der Waals) radii are exceptionally large and cannot be directly compared to covalent radii.

Vertical Trend: Growing Down Families

Group 1 - Alkali Metals



Group 17 - Halogens

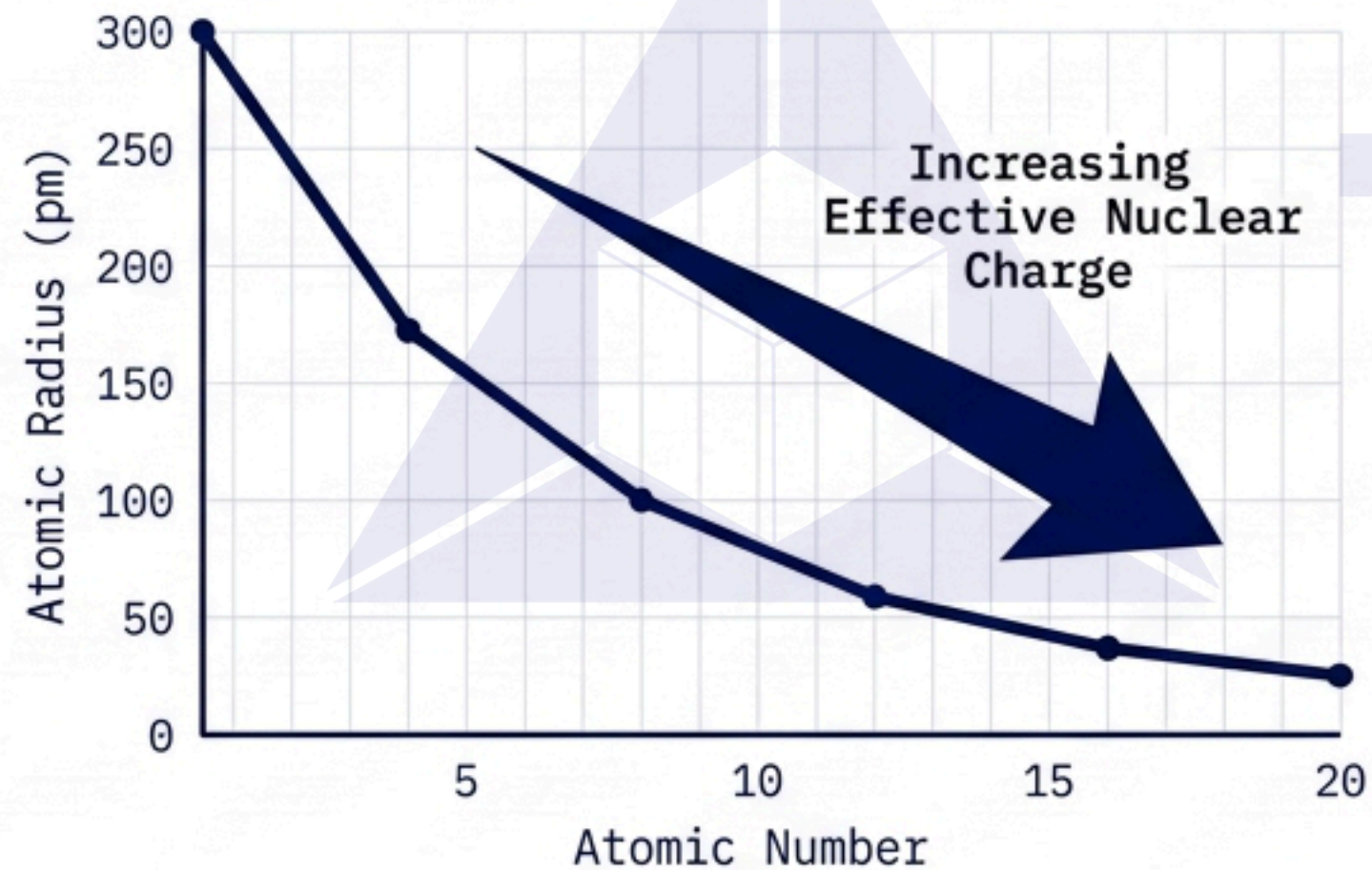


Note: Both groups exhibit strict sequential expansion regardless of their baseline starting size.

The Invisible Forces Governing Size

Causal Force Map

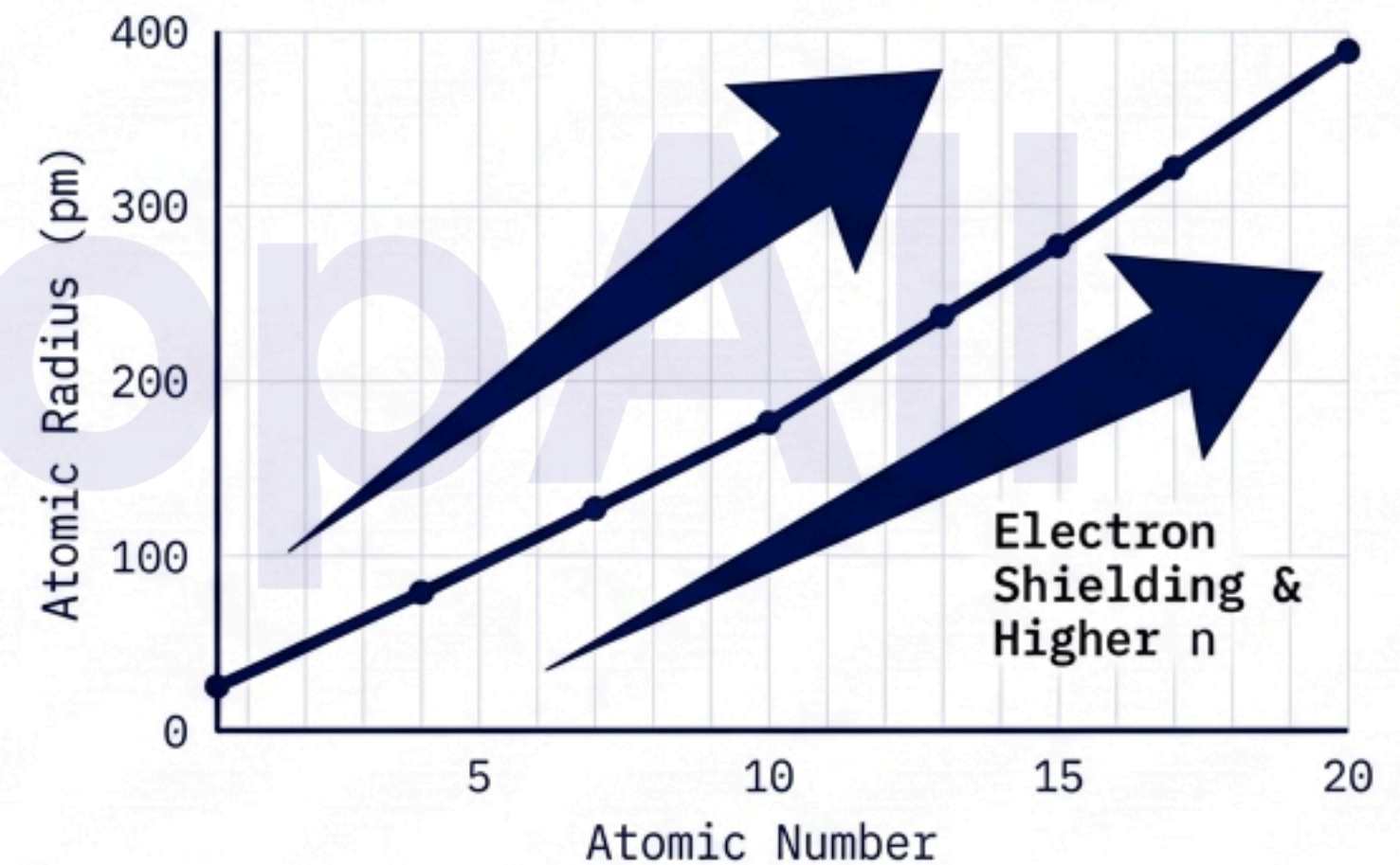
Across a Period (The Shrink)



Electrons enter the same valence shell.
Increasing nuclear charge pulls electrons tighter.

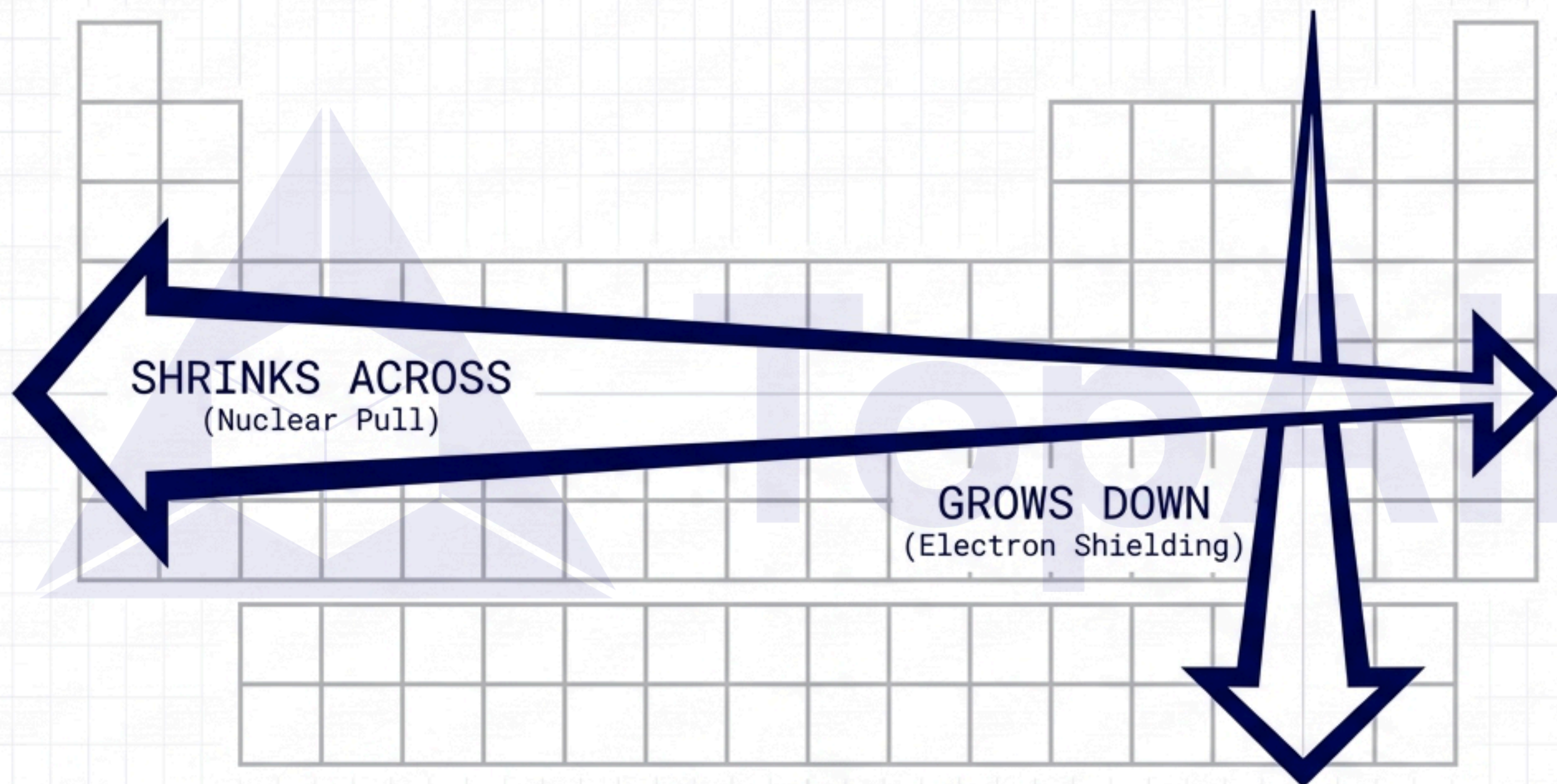
Causal Force Map

Down a Group (The Growth)



Principal quantum number (n) increases. Filled inner energy levels shield outer electrons, overpowering the nuclear pull.

The Master Rule of Atomic Size



Atomic radius is a delicate balance of opposing quantum forces: the inward pull of the nucleus against the outward expansion of shielded electron shells.



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