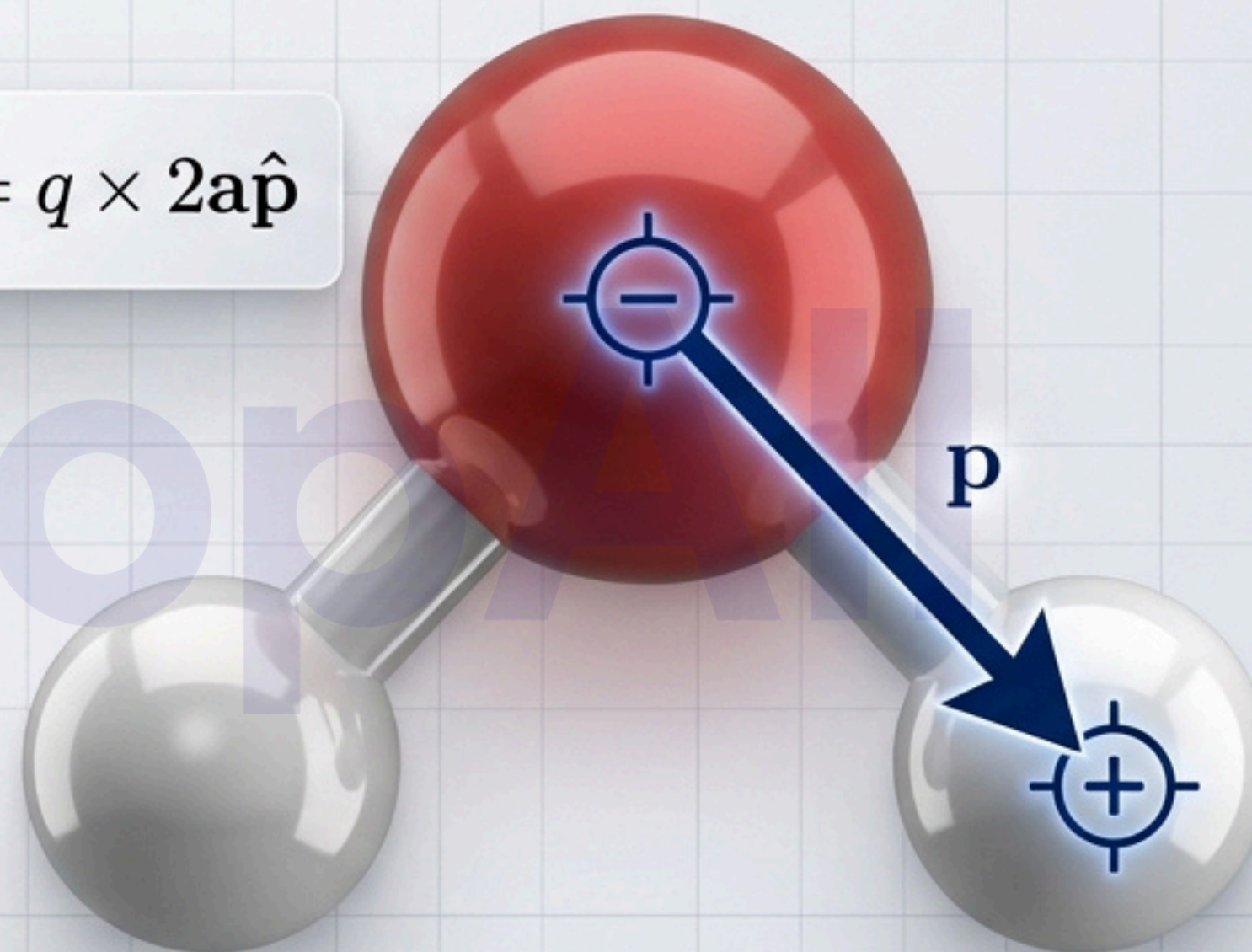


Electrostatics | Section 1.10.2

Physical Significance of Dipoles

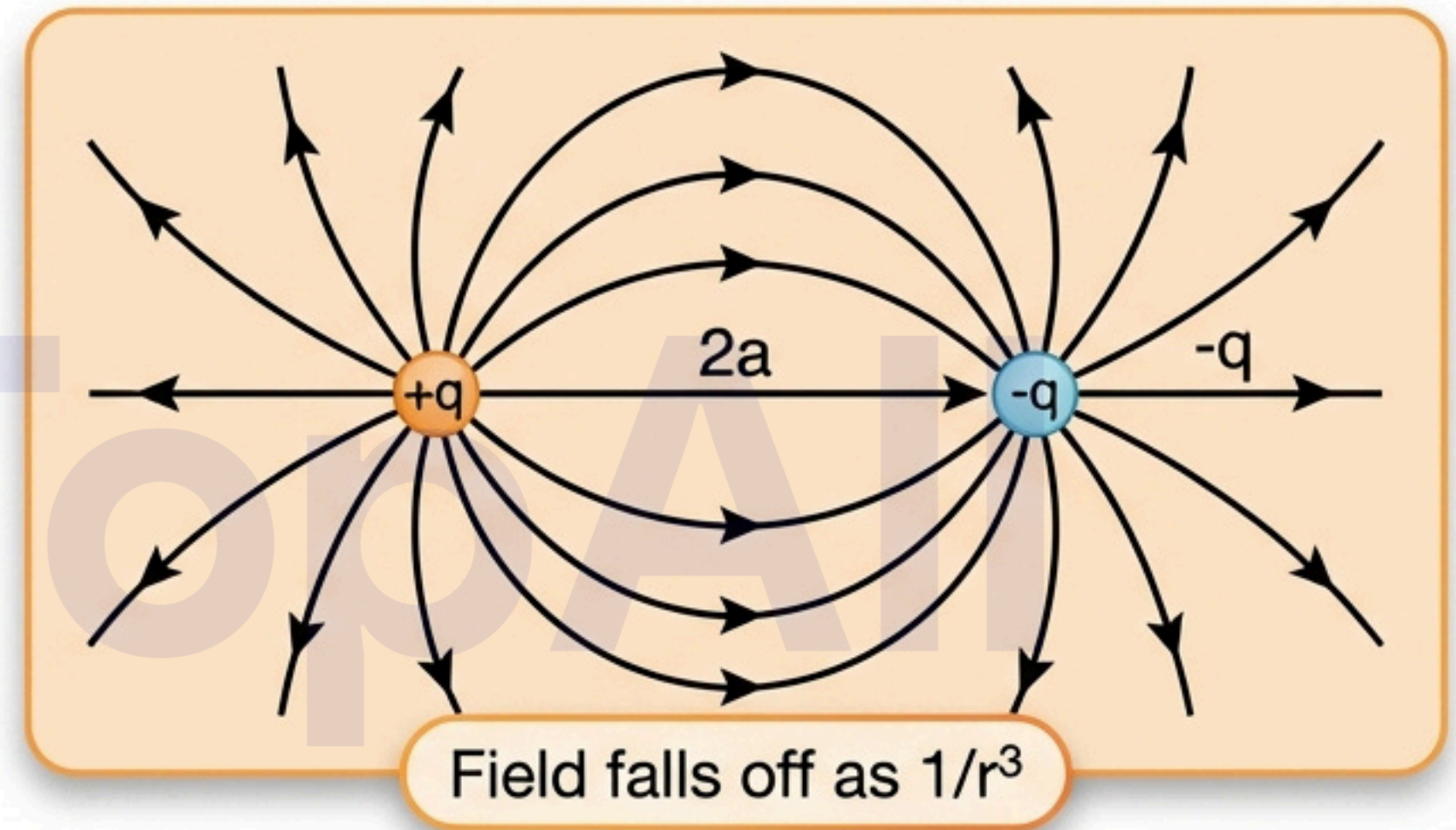
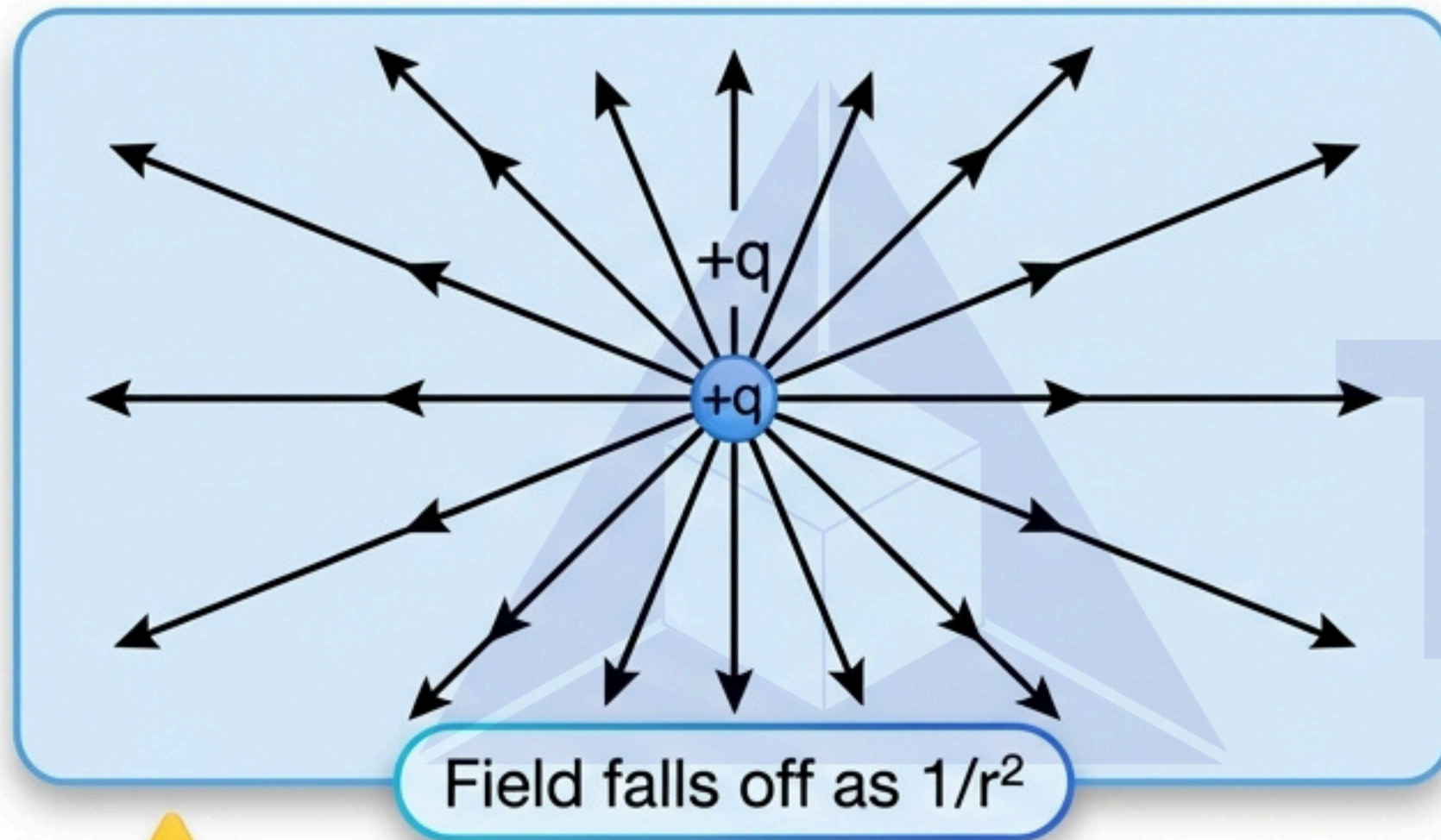
Bridging mathematical electrostatics and molecular reality.

$$\mathbf{p} = q \times 2a\hat{\mathbf{p}}$$



The Core Paradox: Net Charge is Zero, Field is Not

Total charge of a dipole is exactly zero: $q + (-q) = 0$. Why isn't the field zero? Because the charges are separated by a spatial distance ($2a$). The individual fields do not perfectly cancel out.

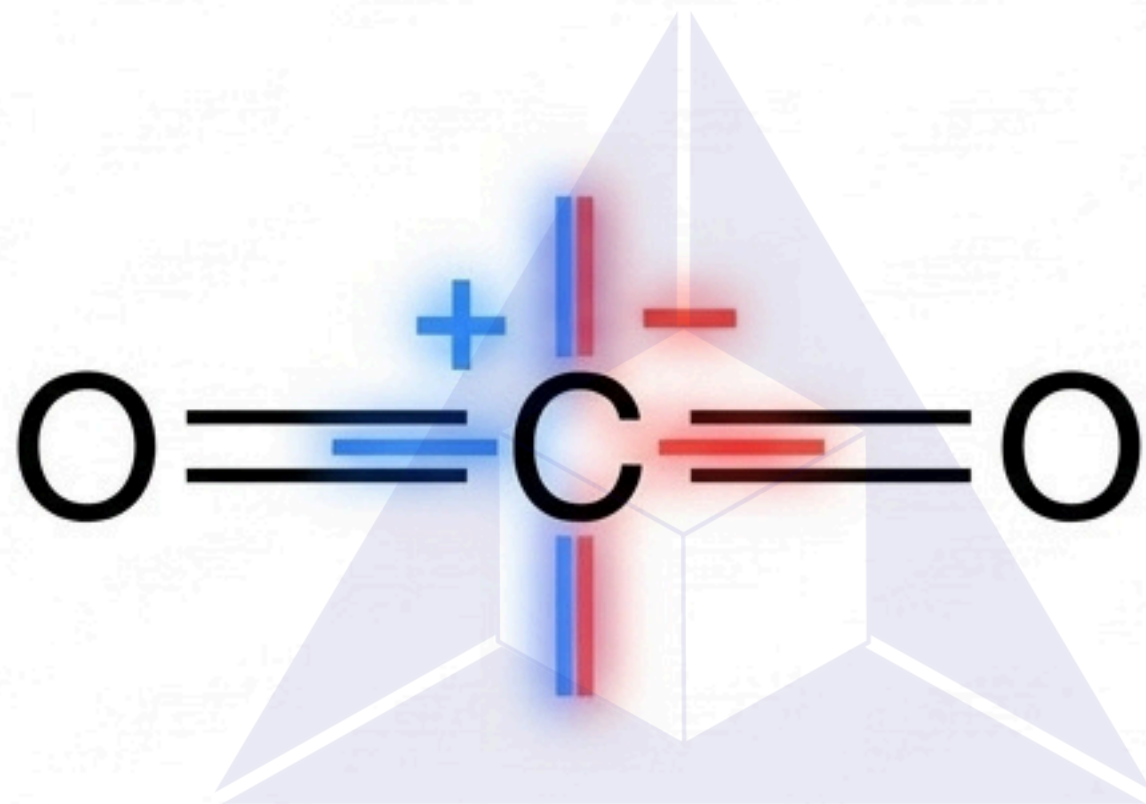


Misconception: Zero net charge means zero electric field.

Reality: Dipole fields exist because charge centers are spatially separated. They just weaken faster ($1/r^3$) than point charges ($1/r^2$).

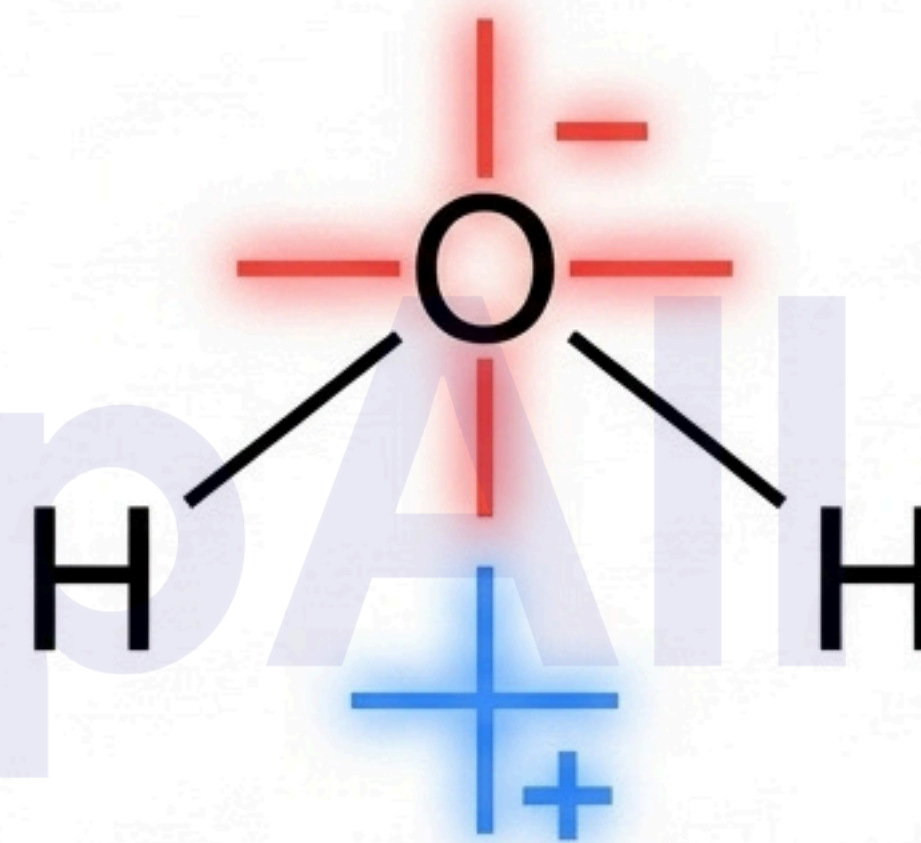
The Molecular Divide: Polar vs. Non-Polar

Non-Polar Molecules



- Centers of positive and negative charge coincide.
- Net dipole moment: $\mathbf{p} = 0$
- Examples: CO_2 , CH_4

Polar Molecules



- Centers of positive and negative charge do not coincide.
- Net dipole moment: $\mathbf{p} \neq 0$ (Permanent)
- Example: H_2O



**You've Learned the Theory.
Let's Test Them Now.**

$$E=mc^2$$



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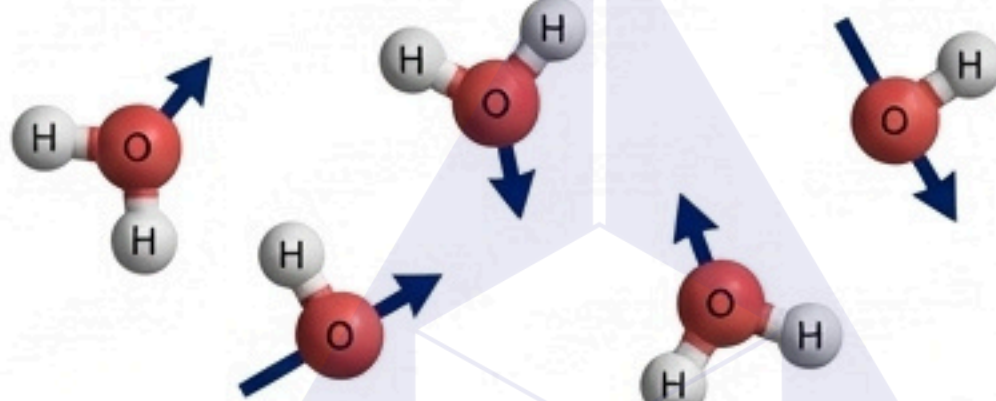
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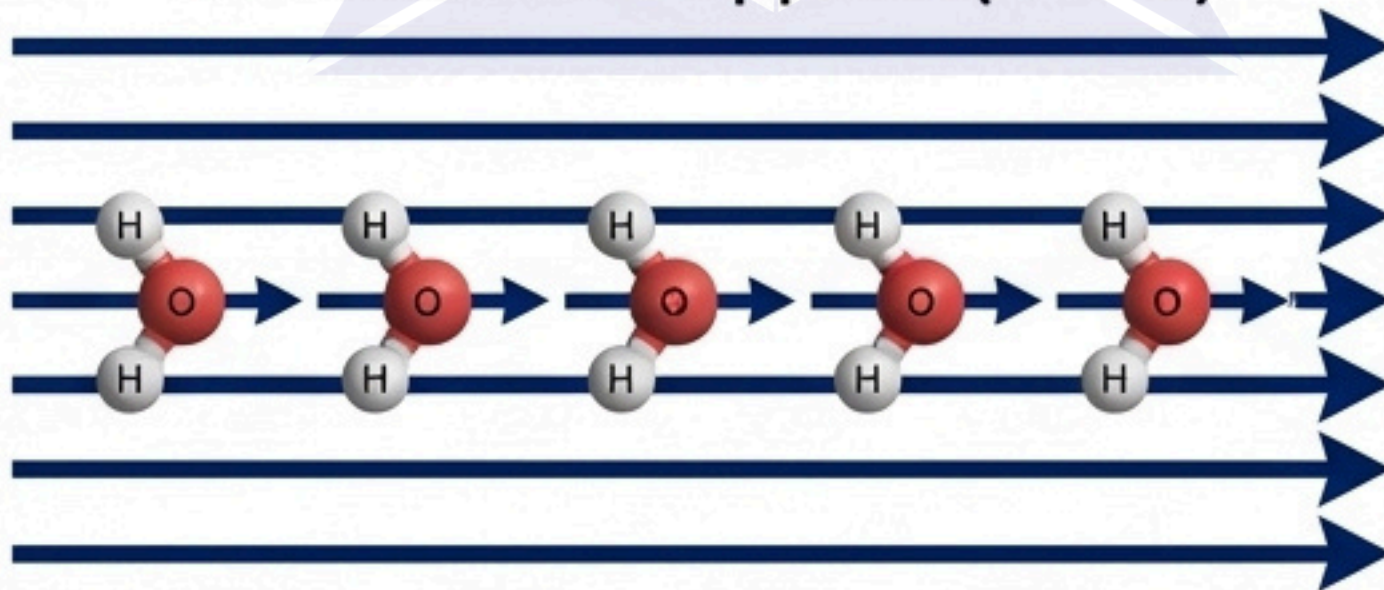


Permanent Dipoles: The Polar World

No External Field ($E = 0$)



External Field Applied ($E \neq 0$)



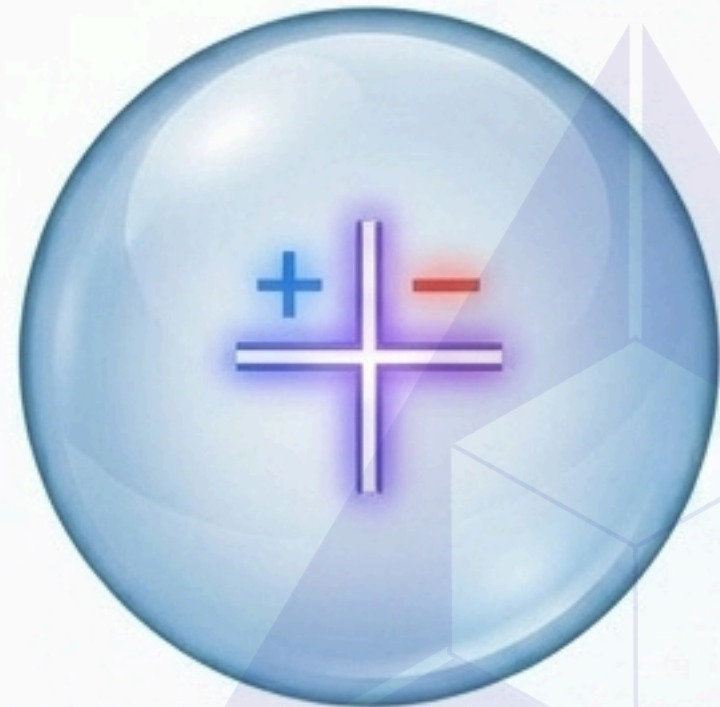
Because their charge centers are naturally separated, polar molecules possess a permanent dipole moment $\mathbf{p}$.

$$\boldsymbol{\tau} = \mathbf{p} \times \mathbf{E}$$

Mechanism: In a uniform external field, the dipole experiences no net force, but it does experience a torque. This physically rotates the molecule to align parallel to the external field.

Induced Dipoles: The Non-Polar World

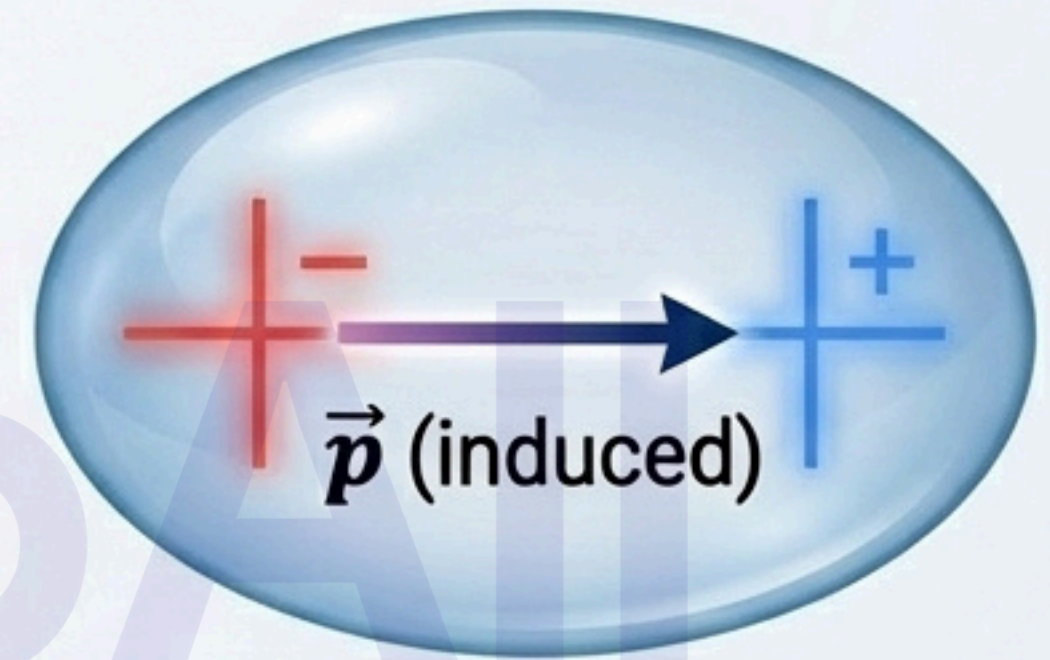
State 1 (Left Side)



Uniform State: $E = 0$

Apply External Field E

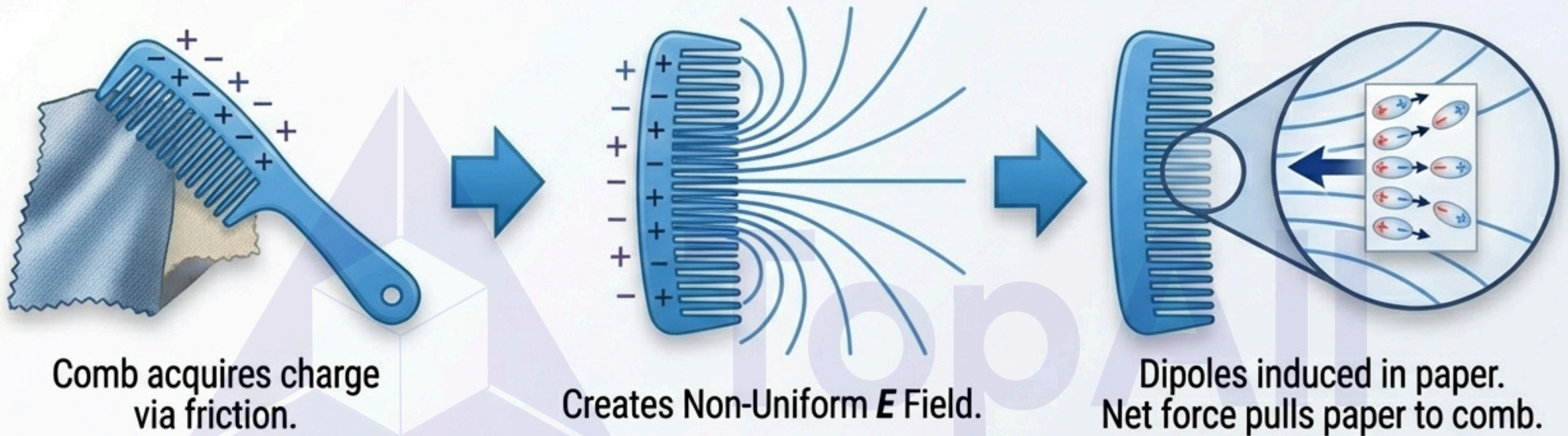
State 2 (Right Side)



Stretched State: $E \neq 0$

- Non-polar molecules have zero permanent dipole moment.
- Induction: An external electric field exerts opposite forces on the positive and negative charges.
- This 'stretches' the molecule, forcing the charge centers apart.
- Result: The molecule develops an induced dipole moment strictly for the duration the external field is present.

Real-World Synthesis: Why a comb attracts paper



A charged comb creates a non-uniform field. This polarizes the neutral bits of paper. Because the field is stronger closer to the comb, the attractive force is greater than the repulsive force, resulting in net attraction.

- ✓ • Dipoles dictate macroscopic polarization, bridging single charges to bulk material properties.
- Net charge is 0, but field is non-zero ($1/r^3$ dependence).
- Uniform field: Yields torque ($\tau = \mathbf{p} \times \mathbf{E}$), no net force.
- Non-uniform field: Yields torque AND a net translating force.

Check Your Understanding (JEE/NEET)

“A molecule has its center of positive charge coinciding exactly with its center of negative charge. When placed in a non-uniform external electric field, what is the sequence of events?”

A) It remains completely unaffected because its net charge is zero.

B) It experiences only a torque and rotates in place.

C) It develops an induced dipole moment, but experiences zero net force.

D) It develops an induced dipole moment, aligns, and experiences a net force.

Correct Answer: D

Centers coincide = Non-polar molecule.

Step 1: External field pulls the centers apart, creating an induced dipole.

Step 2: Because the field is non-uniform, forces on $+q$ and $-q$ do not cancel. It experiences a net force toward the stronger region of the field.



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