

ORGANIC CHEMISTRY 8.7.5 • REACTION MECHANISMS

The Inductive Effect

Understanding electron displacement
through sigma (σ) bonds.

The Polarization of Sigma Bonds

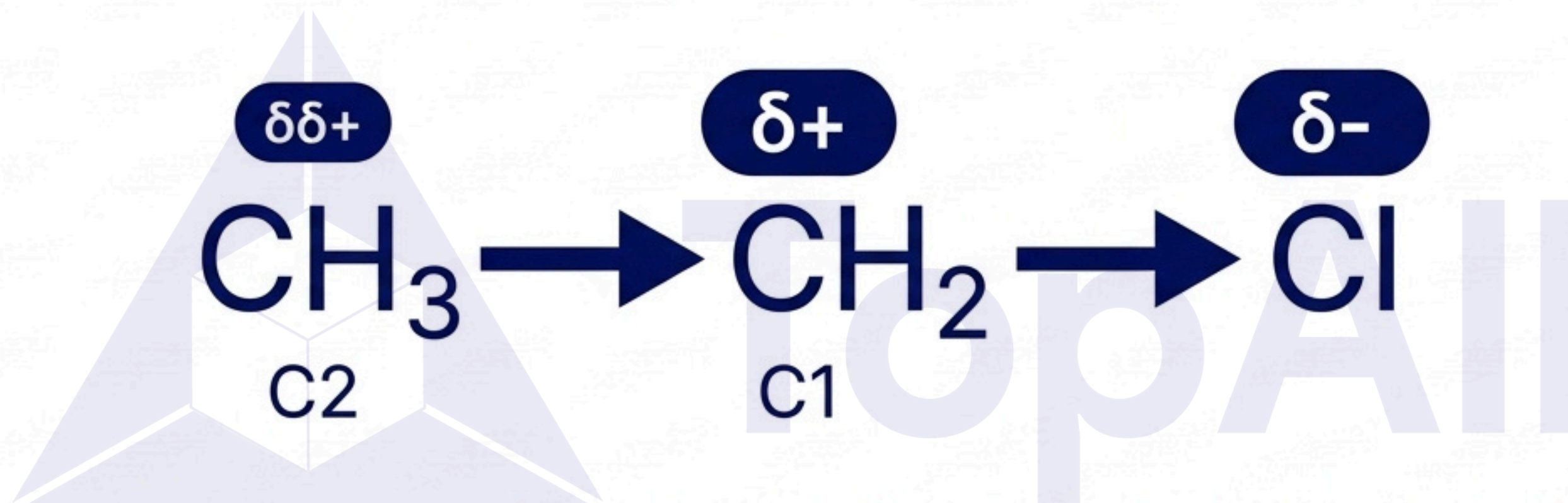
The Catalyst: Electronegativity

When a covalent bond forms between atoms of different electronegativities, electron density permanently shifts toward the more electronegative atom.

Note: This creates a permanent state of polarization with fractional charges, independent of any attacking reagent.



Propagation Through the Carbon Chain



1. Because Chlorine is more electronegative, it acquires a fractional negative charge ($\delta-$), leaving Carbon-1 with a fractional positive charge ($\delta+$).
2. Carbon-1, now electron-deficient, pulls electron density from Carbon-2, creating a smaller fractional positive charge ($\delta\delta+$).



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$$E=mc^2$$



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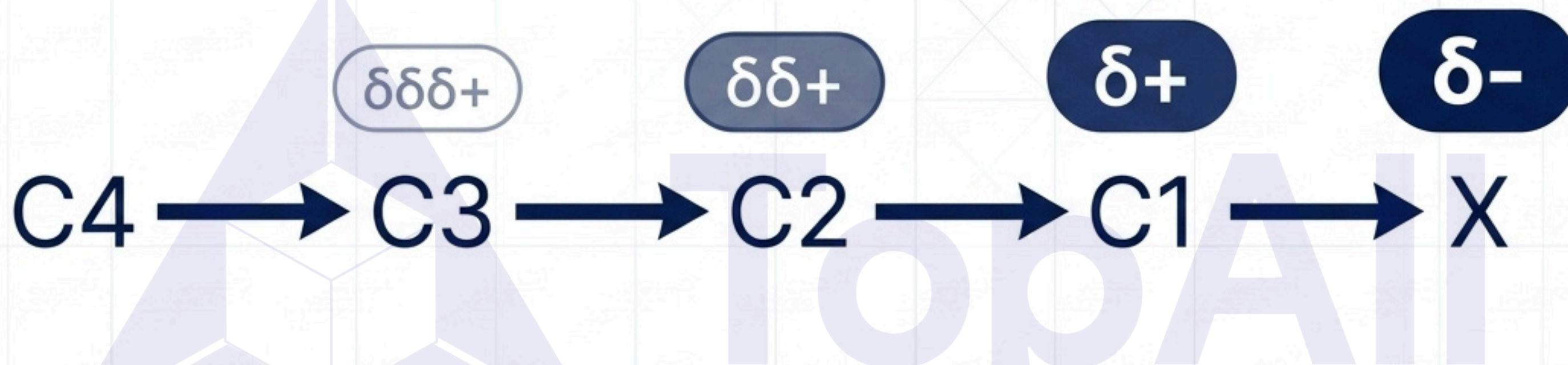
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LIMITATIONS OF THE EFFECT

Weakening with Distance



Transmission

The effect passes exclusively through adjacent sigma (σ) bonds. It does not travel through empty space or pi (π) bonds.

Attenuation

The magnitude of the fractional charge decreases rapidly as the number of intervening bonds increases.

The Limit

The inductive effect becomes effectively negligible after three carbon bonds (C3).

Electron-Withdrawing vs. Donating Groups

-I Effect (Withdrawing)

Definition: Atoms or groups that are more electronegative than hydrogen.

Action: They pull σ -electron density away from the carbon chain.



+I Effect (Donating)

Definition: Atoms or groups that are less electron-attracting than hydrogen.

Action: They push or release σ -electron density toward the carbon chain.



The Inductive Series

Electron-Withdrawing (-I) Series

Groups that exhibit the -I effect, ordered by common textbook priority relative to hydrogen:

Halogens (X)

>

-NO₂

>

-CN

>

-COOH

>

-COOR

>

-OAr

Electron-Donating (+I) Series

Alkyl groups typically exhibit the +I effect. As branching increases, the donating effect increases:

-CH₃ (Methyl)

<

-CH₂CH₃ (Ethyl)

<

Branched Alkyls

Key Takeaways: Inductive Effect

[Permanent & Polar]

The Inductive Effect is a permanent state of polarization resulting from electronegativity differences in a covalent bond.

[Sigma Transmission]

Electron displacement occurs strictly along the continuous framework of adjacent sigma (σ) bonds.

[Distance Dependent]

The effect creates a chain of fractional charges ($\delta+$, $\delta\delta+$) that diminishes rapidly, becoming negligible beyond three carbon bonds.

[-I vs +I]

Substituents either withdraw (-I, e.g., Halogens, $-\text{NO}_2$) or donate (+I, e.g., Alkyl groups) electron density relative to a standard Hydrogen atom.



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