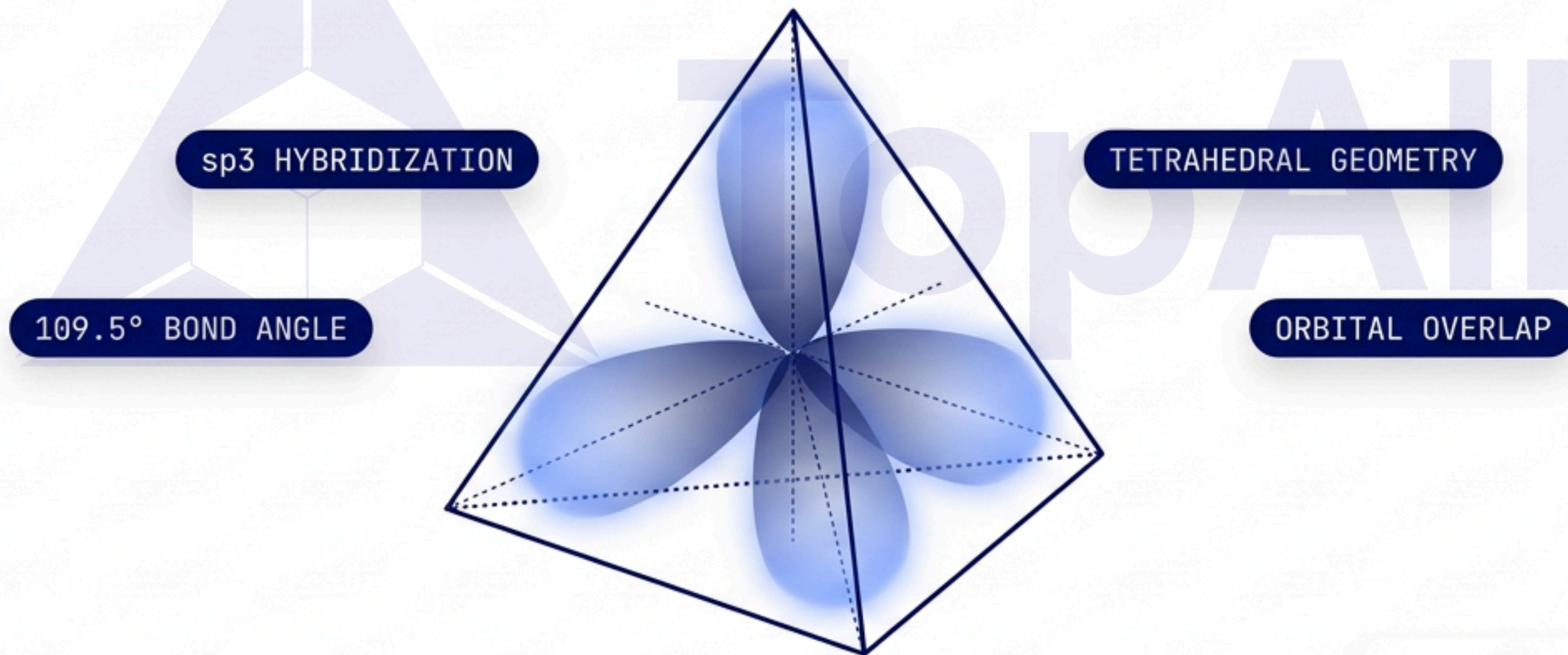


4.5.2 Directional Properties of Bonds

From atomic orbital overlap to 3D molecular architecture.

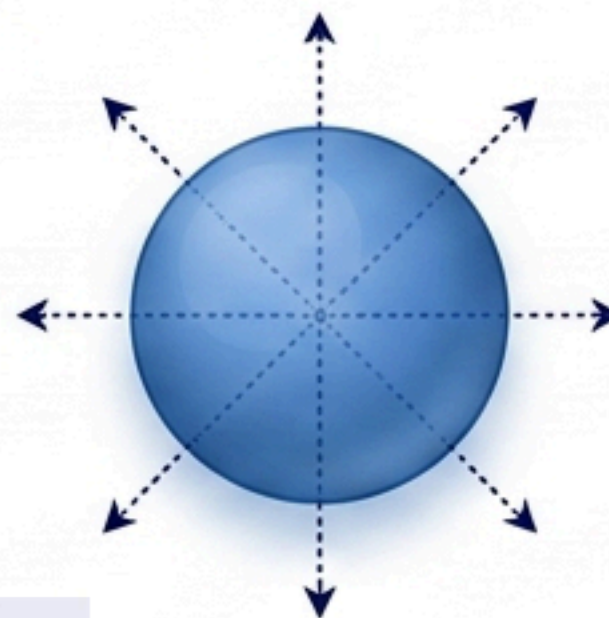


THE LIMITATION OF SIMPLE OVERLAP

Why Bonds Have Direction

A covalent bond requires the partial interpenetration (overlap) of atomic orbitals. But simple atomic orbitals cannot explain the observed 3D geometries of polyatomic molecules.

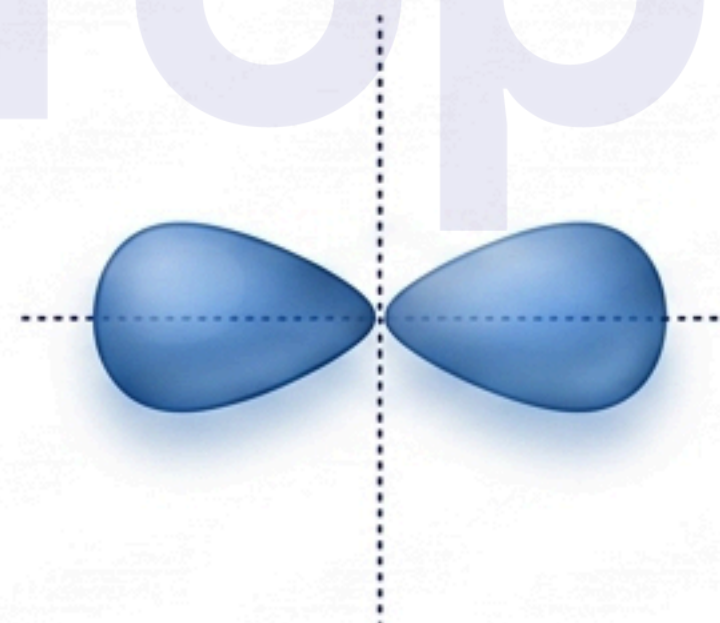
The Architectural Solution: To maximize bond strength and minimize repulsion, atoms create new directional blueprints called hybrid orbitals.



Non-Directional Orbitals

s orbitals are spherically symmetrical and can overlap equally in any direction.

H_2 (s-s overlap)



Directional Orbitals

p orbitals project along specific axes. If Carbon only used pure p orbitals, bonds would be forced into tight 90° angles.

Methane (CH₄): The Ideal Tetrahedral

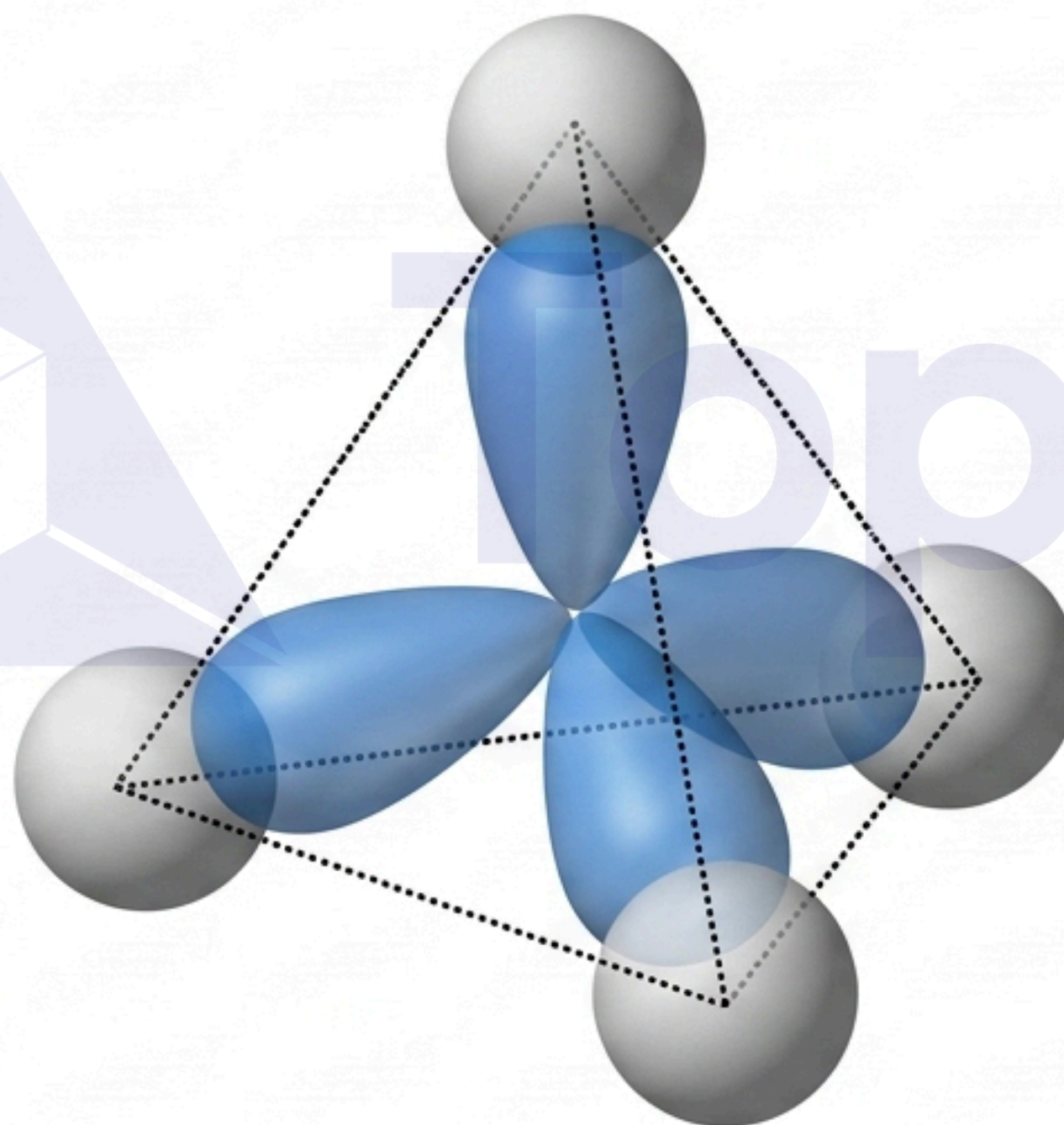
Nature solves the 90° problem by hybridizing orbitals, maximizing the distance between electron pairs for perfect stability.

The Mix

Carbon blends one 2s + three 2p orbitals → four identical sp³ hybrids (25% s, 75% p).

The Overlap

Each sp³ lobe aligns directly toward a tetrahedral corner, forming four strong σ (sigma) bonds via positive overlap.



The Geometry

- Geometry: Tetrahedral
- Bond Angle: 109.5°
- Repulsion: Equal (bp-bp) symmetrical forces.



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Key Highlights

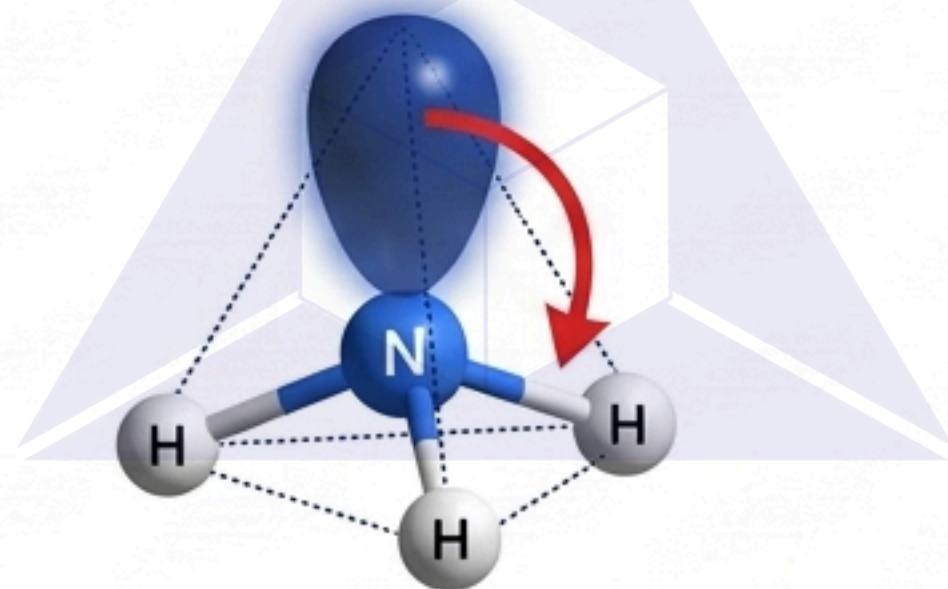
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Ammonia and Water Comparison

What happens when directional sp^3 orbitals hold unshared electrons? Lone pairs act as invisible weights, distorting the ideal architectural blueprint.

Ammonia (NH_3) 1 Lone Pair

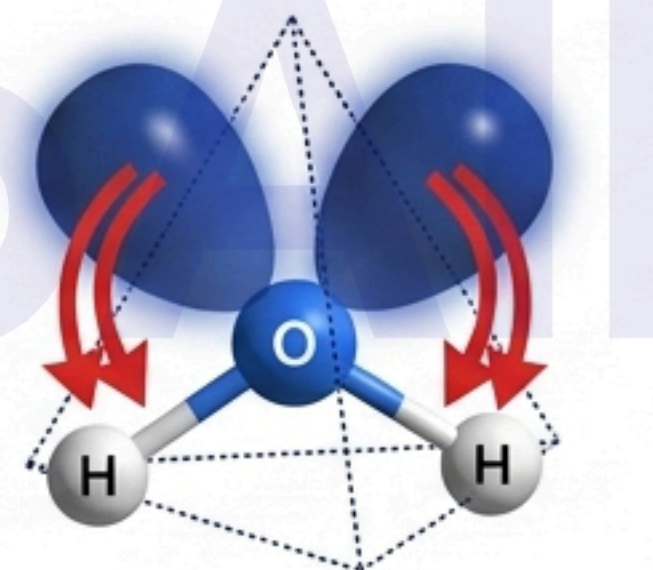


Repulsion Dynamic: $lp-bp > bp-bp$

Result: Trigonal Pyramidal geometry.

Angle Shift: $109.5^\circ \rightarrow 107^\circ$

Water (H_2O) 2 Lone Pairs



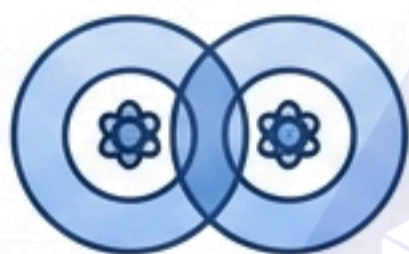
Repulsion Dynamic: $lp-lp > lp-bp > bp-bp$

Result: Bent / V-Shaped geometry.

Angle Shift: $109.5^\circ \rightarrow 104.5^\circ$

Covalent Bonds are Directional and Define Geometry

[Orbitals Mix] → [Create Directional Hybrids] → [Overlap to Form Bonds] → [Lone Pairs Dictate Final Angles]



Overlap Dictates Strength

A covalent bond is the physical interpenetration of wave functions. Maximum strength requires precise directional alignment.



Hybrids Create the Blueprint

Pure atomic orbitals (s, p) often fail to explain observed shapes. Hybridization (sp^3) constructs an optimized directional framework.



Repulsions Refine the Shape

VSEPR dynamics modify the basic framework. Lone pair repulsions fine-tune the final architectural angles.



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