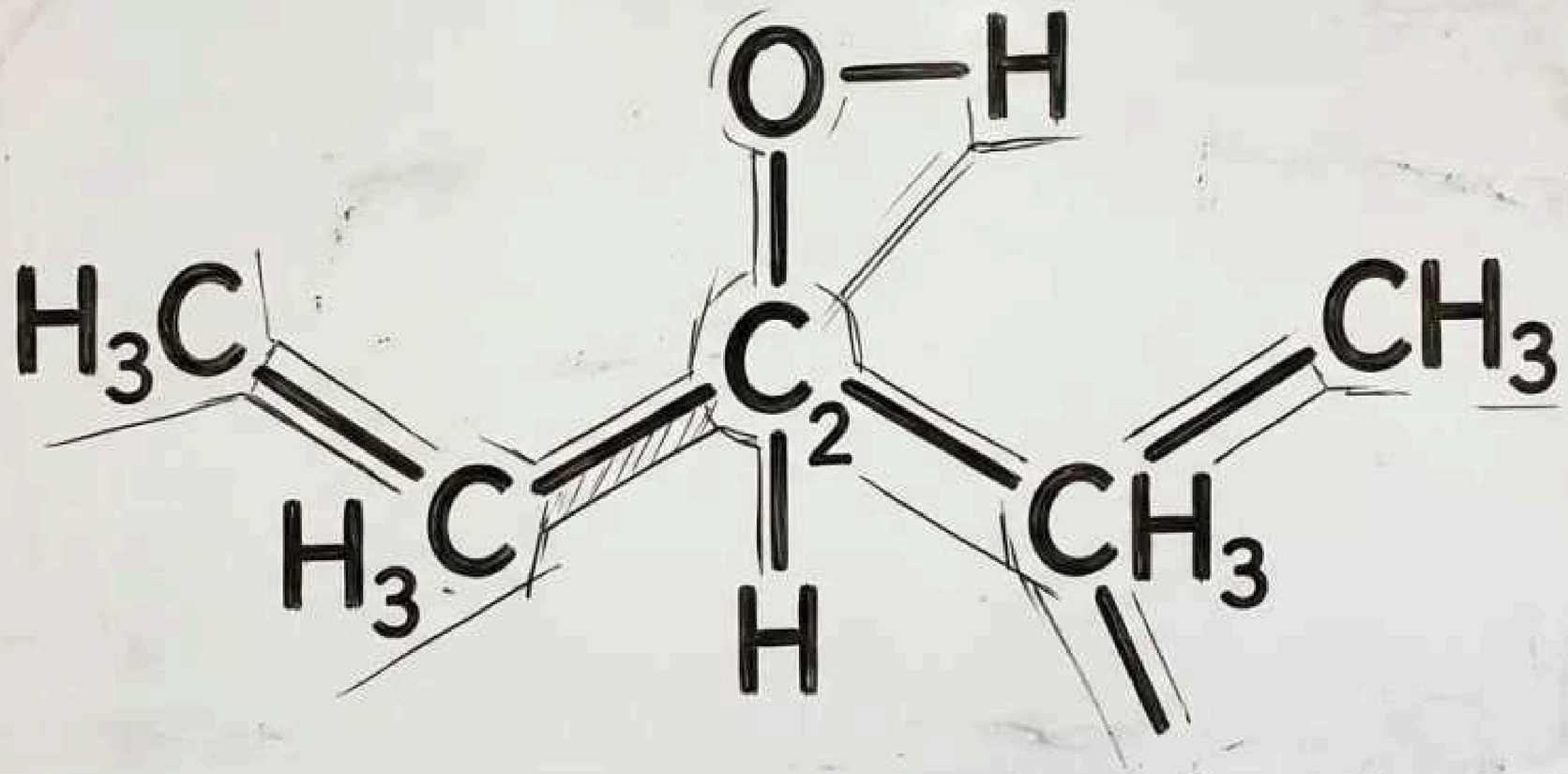
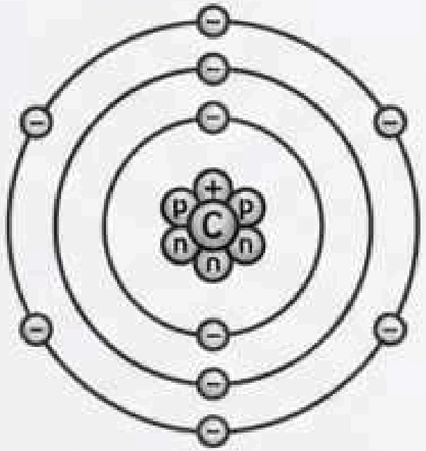
Structure and Bonding in Organic Molecules

A foundation for molecular geometry, electron behavior, and macroscopic properties.



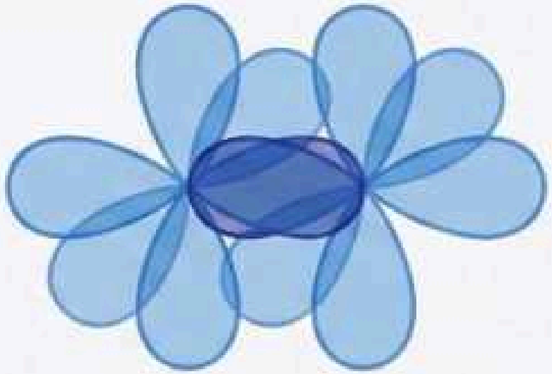
Three core questions govern organic chemistry

¶ 1.1



Suitability

Why is carbon uniquely suited to build molecules?



Connections

How do we describe bonds via drawings and orbitals?



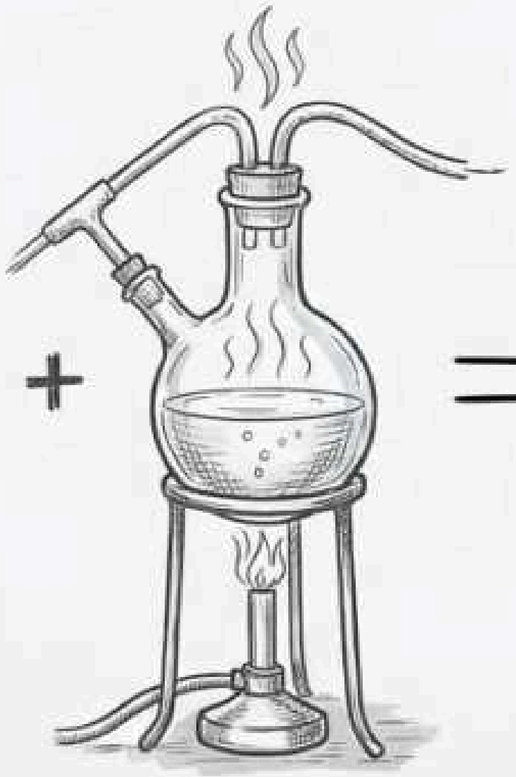
Consequences

How do shape and charge determine physical properties?

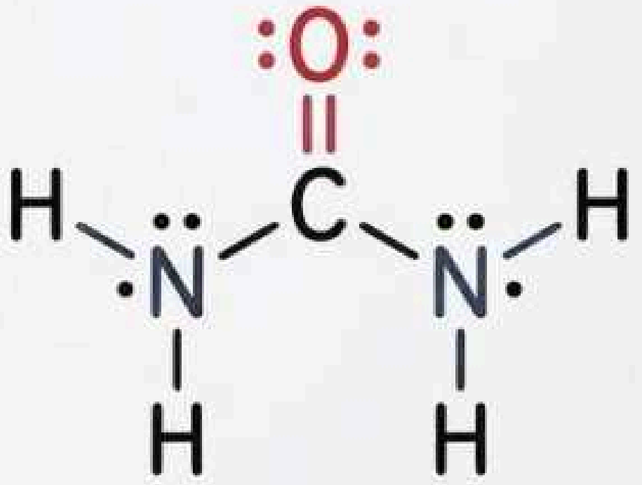
Answering these questions provides the mechanical foundation for all subsequent chemical reactions.

The synthesis of urea dissolved the boundary of vitalism

$[NH_4]^+ [OCN]^-$ +



$\xrightarrow{\Delta}$ 1828



Inorganic salt

Organic compound

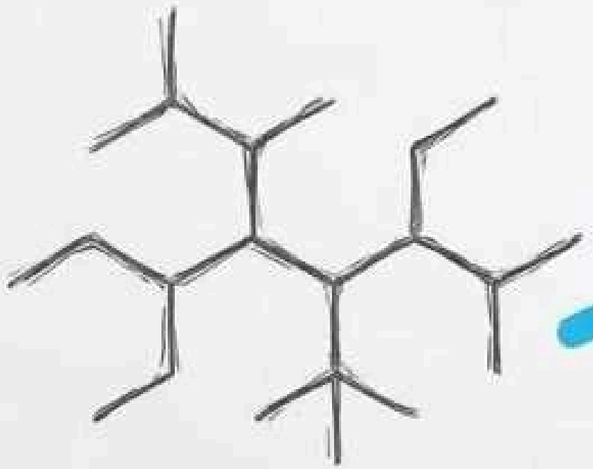
Prior to 1828, chemists believed living things contained an unreplicable vital force.

Wöhler's experiment proved organic compounds could be synthesized from nonliving, inorganic salts.

Carbon's valency allows infinite structural combinations

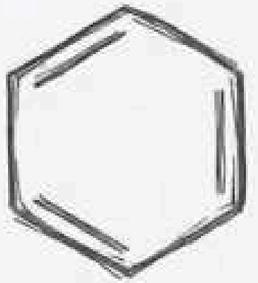


Linear chain

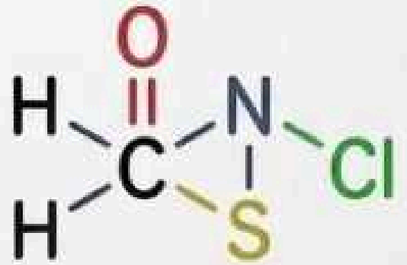


Branched structure

C



Cyclic ring

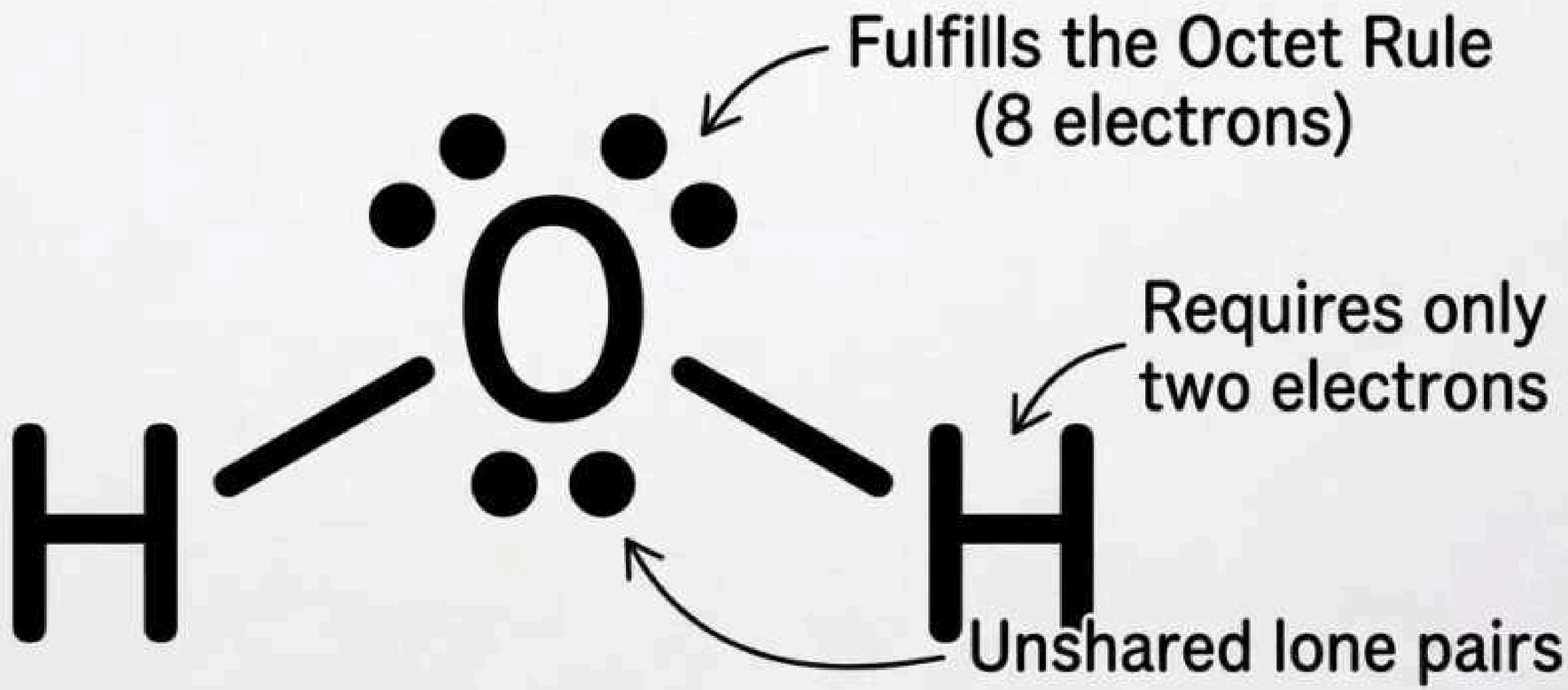


Heteroatom bonds

Most organic molecules rely on just a few elements, but carbon's four valence electrons enable tens of millions of known variations.

Lewis structures reveal the shared electrons of covalent bonds

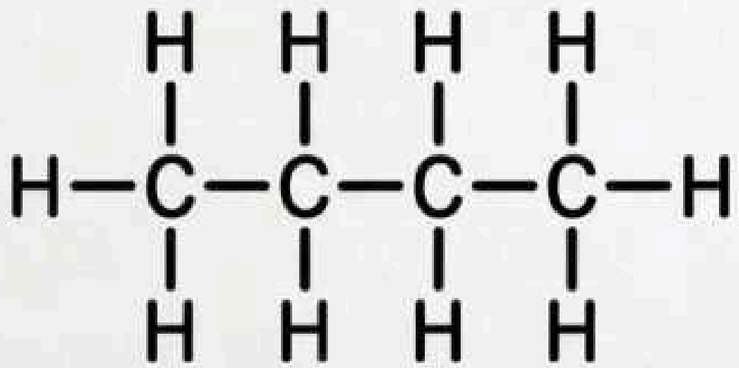
Shared pair of electrons = Covalent bond



Chemists use skeletal structures for rapid communication

¶ 1.5

Full Lewis Structure ⇒ Condensed Formula ⇒ Skeletal / Line-Angle Structure



$CH_3\text{-}CH_2\text{-}CH_2\text{-}CH_3$

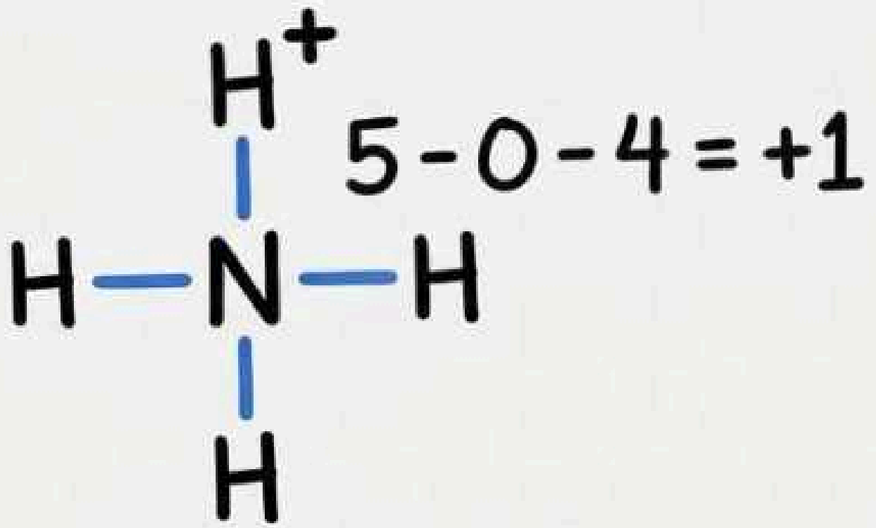


Each corner is a carbon

Missing bonds are understood to be hydrogens

Formal charge accounts for every electron in a molecule

$$FC = \text{Valence } e^- - \text{Nonbonding } e^- - \frac{1}{2}(\text{Bonding } e^-)$$



5 - 0 - 4 = +1



6 - 6 - 1 = -1

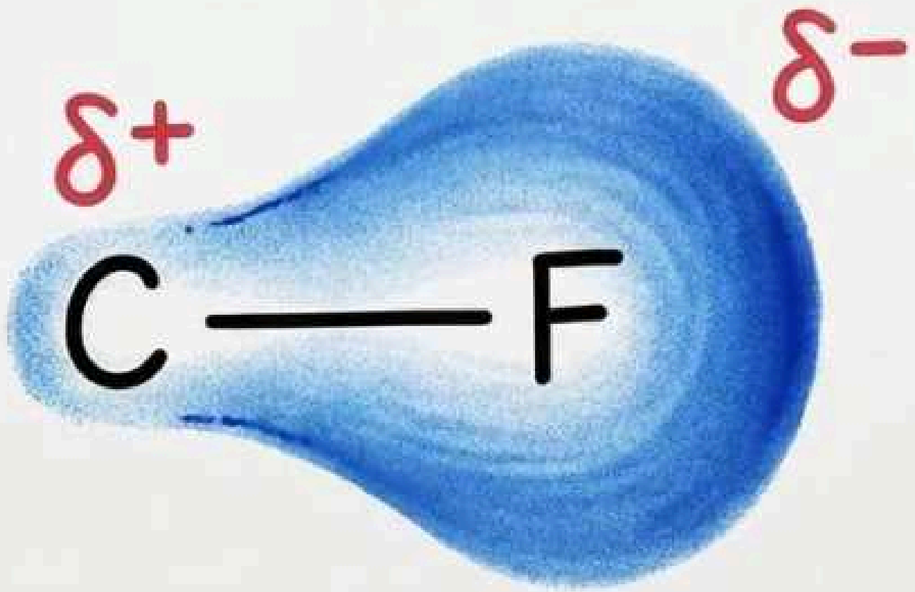
Rule: Individual formal charges within a structure must sum to the overall charge of the molecule or ion.

Electronegativity dictates the polarity of chemical bonds

¶ 1.7

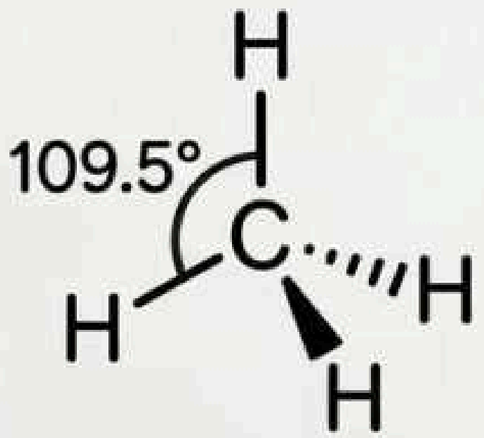
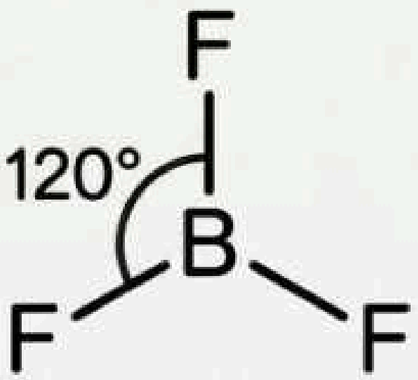
Linus Pauling's 1932 metric

Hydrogen	Carbon	Nitrogen	Oxygen	Fluorine
(2.1)	(2.5)	(3.0)	(3.5)	(4.0)



VSEPR theory translates electron repulsion into 3D geometry

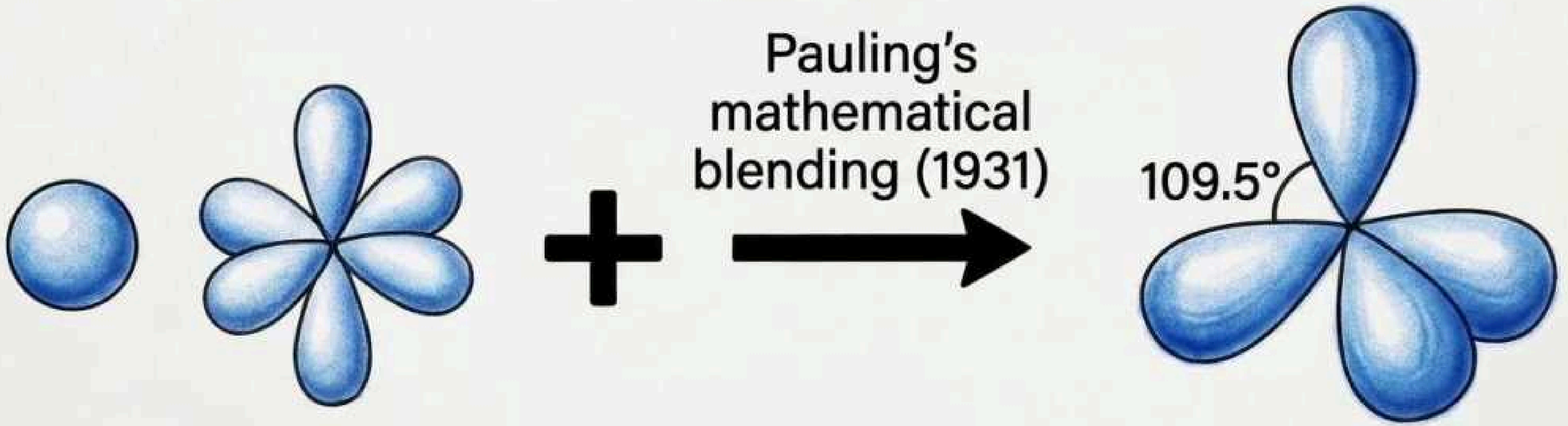
¶ 1.8

4 Groups	3 Groups	2 Groups
Tetrahedral (109.5°)	Trigonal Planar (120°)	Linear (180°)
		

Diagnostic Note: Lone pairs occupy physical space and repel other bonds. This is why water is bent and ammonia forms a pyramid rather than lying flat.

Hybrid orbitals solve the geometric puzzle of methane

¶1.9



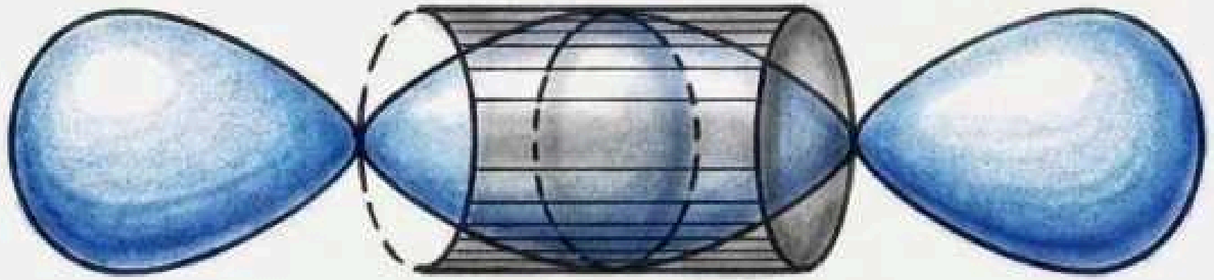
Ground-state orbitals

sp^3 Hybrid orbitals (tetrahedral)

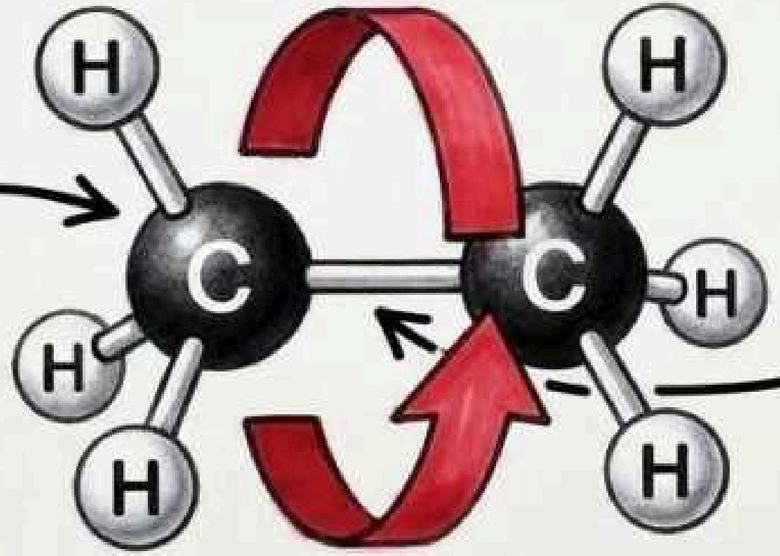
Carbon's ground-state electrons suggest right-angle bonds. Methane's perfect tetrahedral geometry cannot be explained without this hybridized model.

Sigma bonds allow free rotation along the bonding axis

¶1.10



Length:
154 picometers

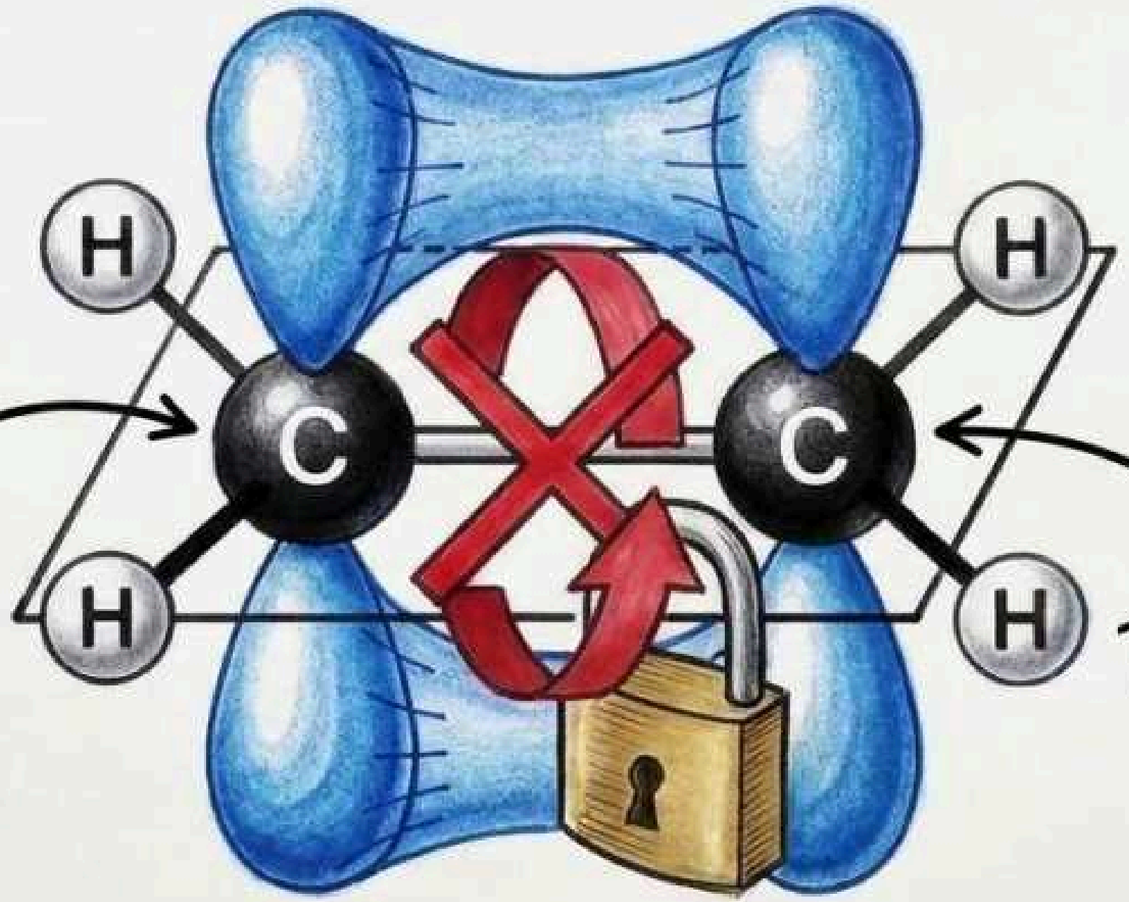


Every bond in an alkane is a cylindrical sigma bond.

Pi bonds lock atoms in place and prevent rotation

¶1.11

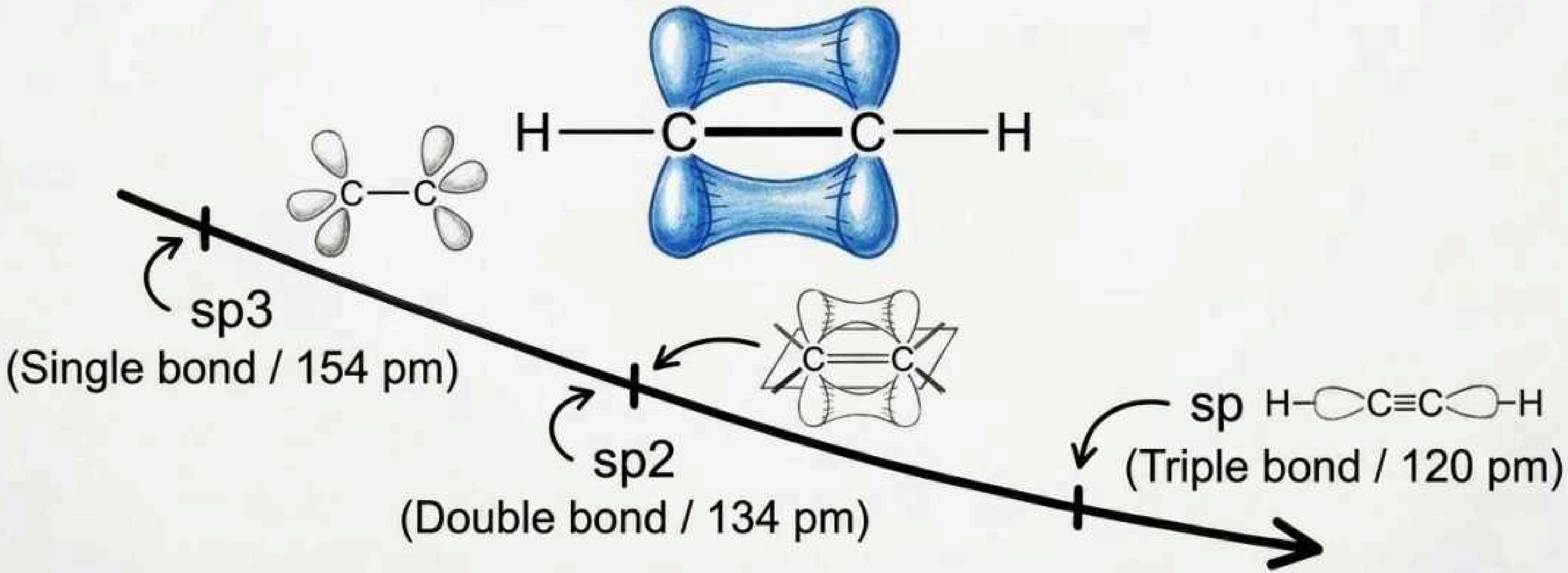
Architecture:
1 Sigma Bond
+ 1 Pi Bond



Length:
134 picometers
(Shorter and
restricted)

Increased s-character creates shorter, stronger bonds

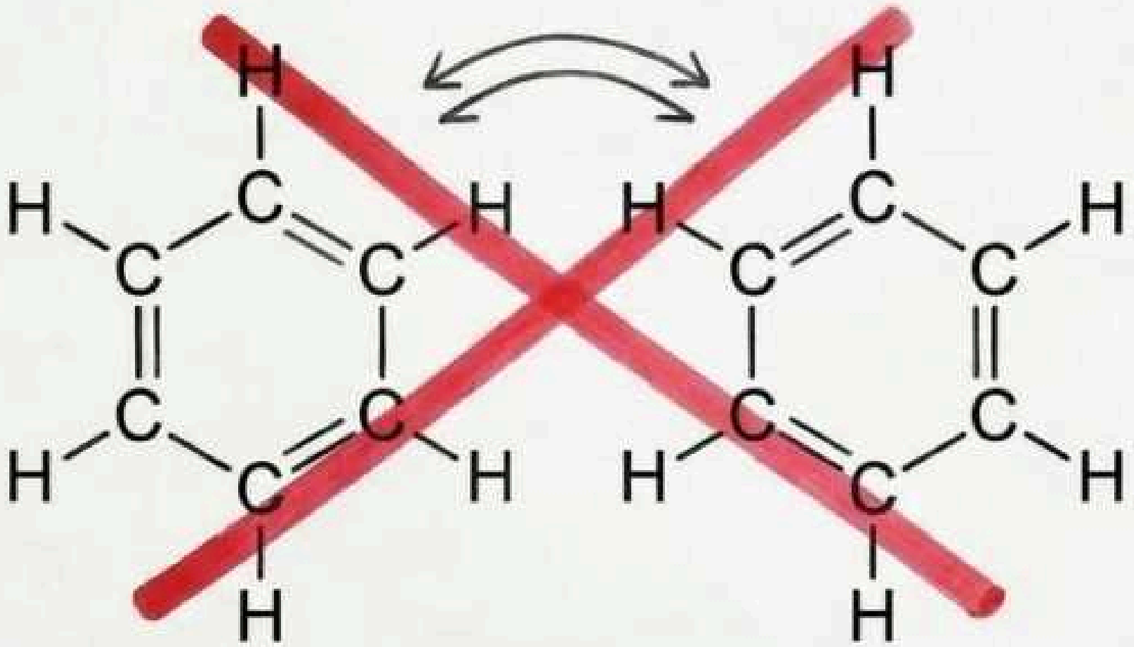
¶1.12

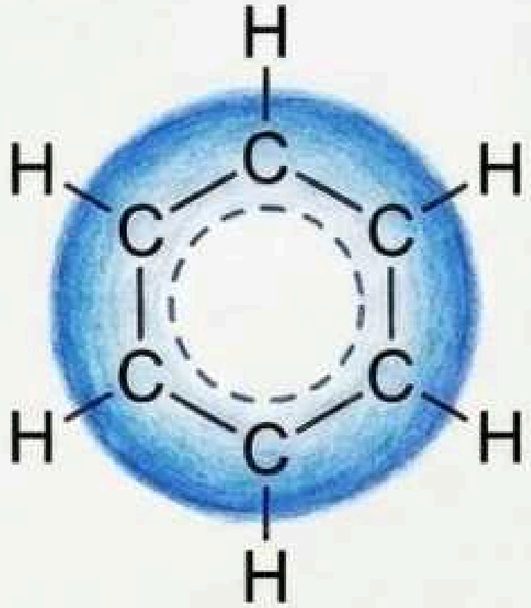


As s-character increases, electrons are held more tightly to the nucleus, resulting in progressively shorter and stronger molecular bonds.

Resonance stabilizes molecules by spreading electron density

¶1.13



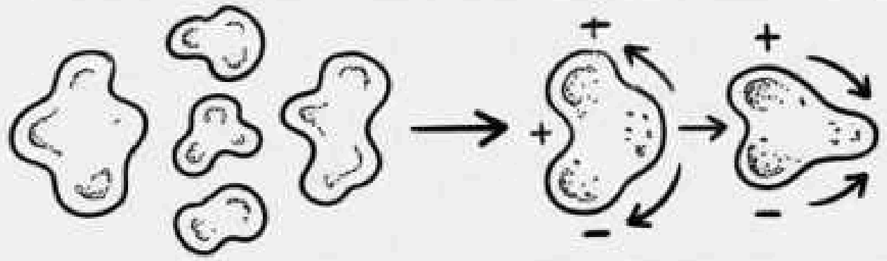
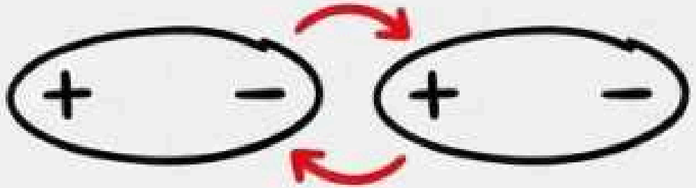


Myth: Molecules flipping back and forth. **Reality:** A stable, blended state.

Measurements prove all six bonds are identical at exactly 140 picometers. Resonance means the true electron distribution is spread out, which inherently stabilizes the molecule.

Intermolecular forces determine how separate molecules interact

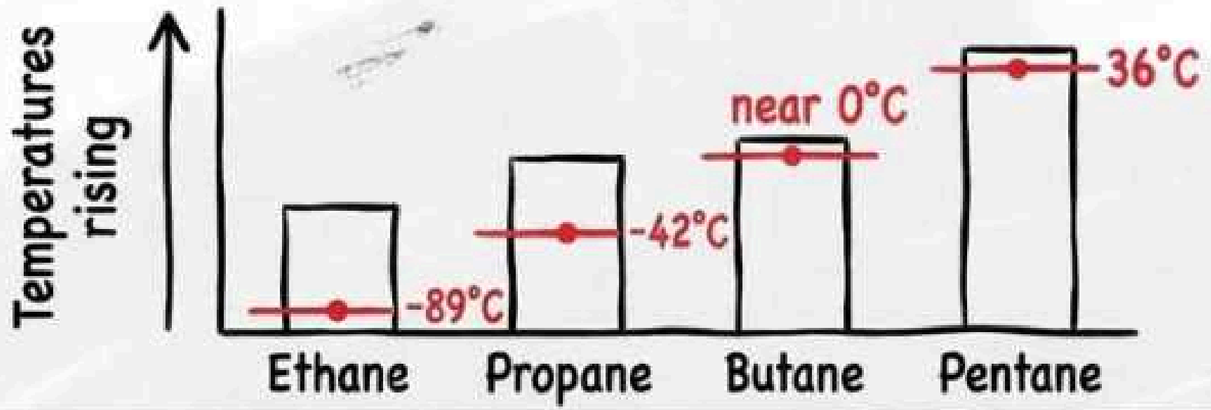
¶ 1.14

London Dispersion Forces (Fritz London, 1930)		Momentary shifts present in all molecules. Grows with surface area.
Dipole-Dipole Attractions		Permanent polar alignments between molecules.
Hydrogen Bonding		An exceptionally strong dipole attraction involving H attached to N, O, or F.

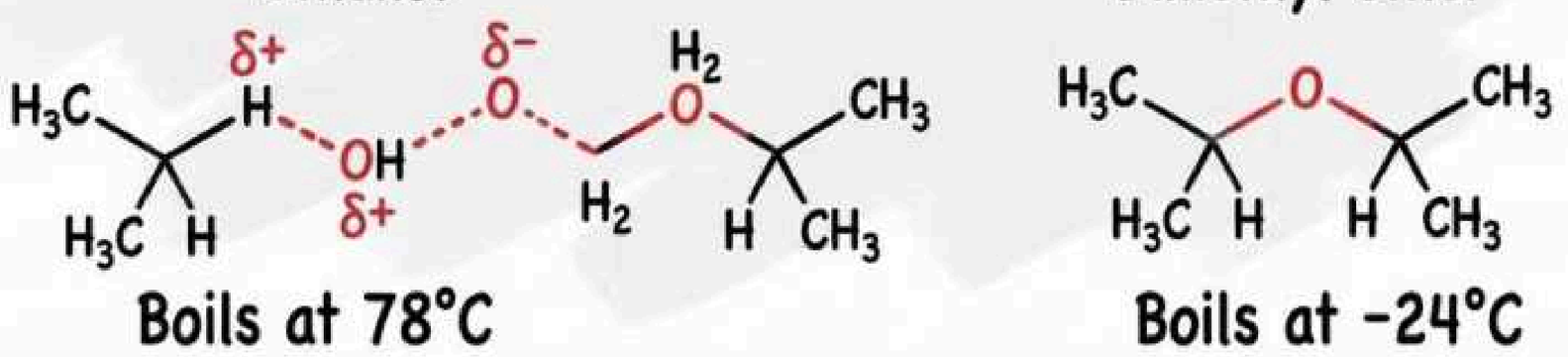
Microscopic forces dictate macroscopic physical properties

¶ 1.15

Top Panel



Bottom Panel

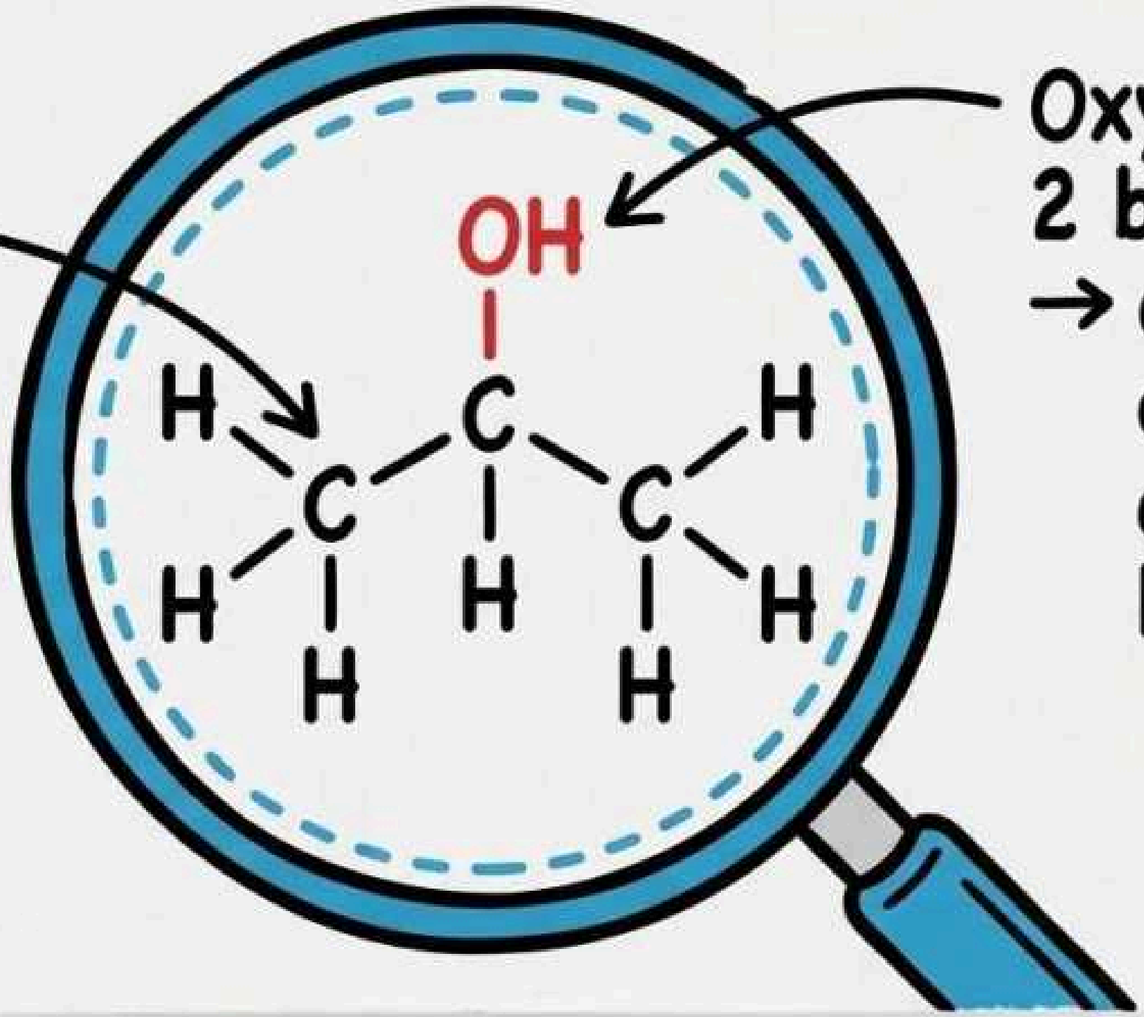


Intermolecular forces and surface area are the invisible architects of everyday physical realities.

Reading skeletal structures requires only seconds of counting

¶ 1.16

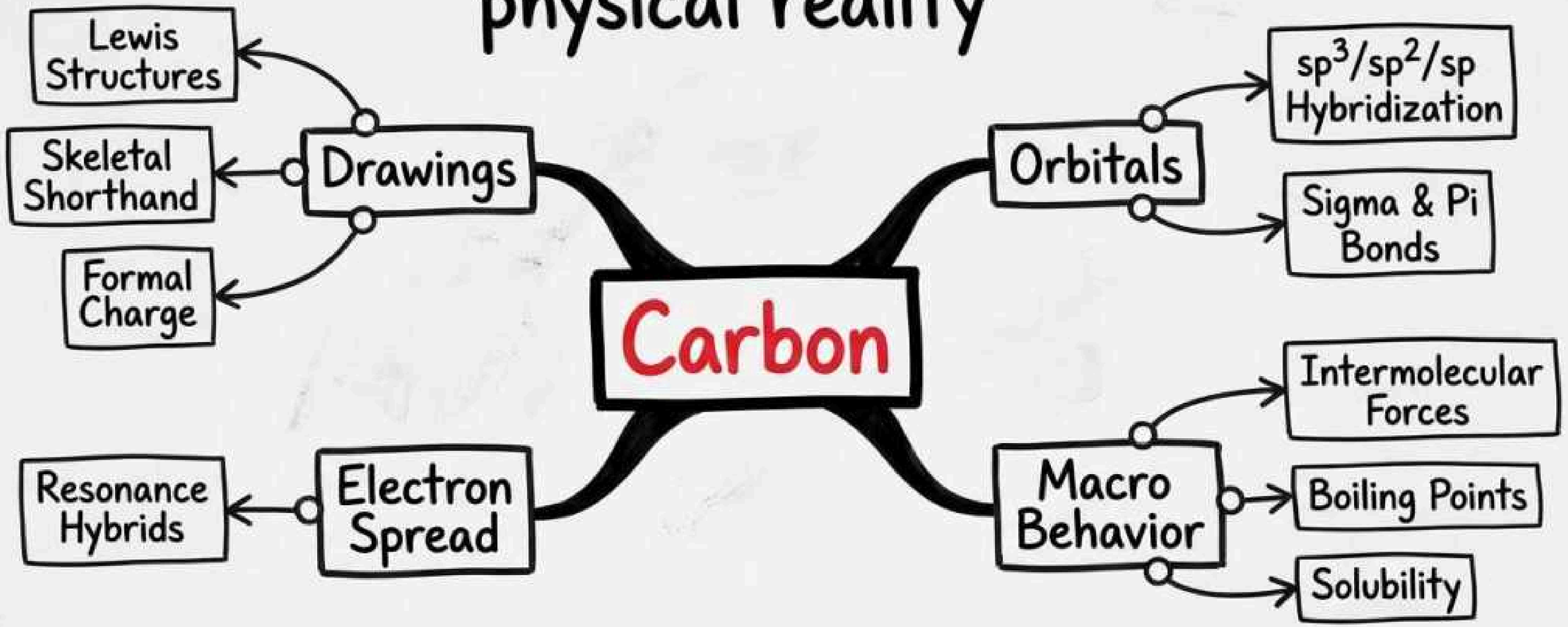
Carbon needs 4 bonds
→ count the drawn lines
→ missing bonds equal hidden hydrogens.



Oxygen needs 2 bonds
→ carries exactly 1 drawn hydrogen.

The architecture of carbon determines physical reality

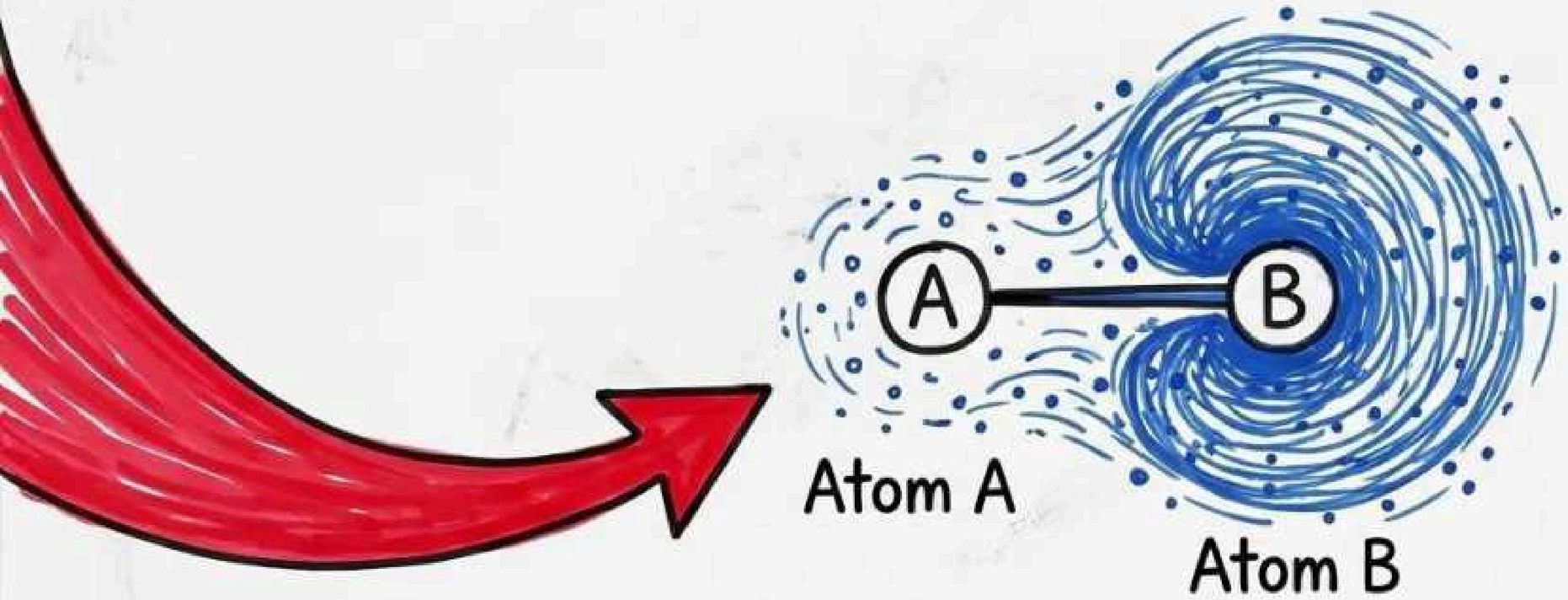
¶ 1.17



Geometry, charges, and intermolecular forces turn abstract molecular structure into tangible, macroscopic properties.

Uneven electron pull sets the stage for chemical reactivity

¶ 1.18



Bonds are made of electrons, and uneven pulling determines which molecules give up protons and which accept them. Next: Acids, bases, and the curved arrows that dictate every reaction.