

COLLISION THEORY OF CHEMICAL REACTIONS

The Anatomy of a
Perfect Collision



$$Rate = k[A][B]$$



Collision Frequency (Z)

Number of collisions per second per unit volume



Threshold Energy

Minimum energy required (Activation Energy + reactant energy)



Effective Collisions

The specific collisions that successfully result in product formation

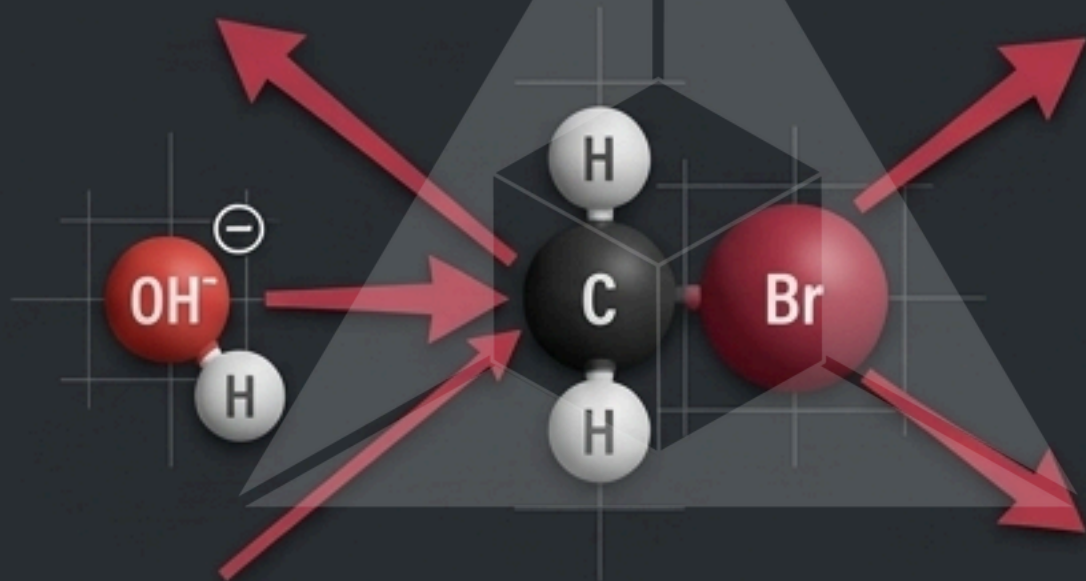


Steric Factor (P)

The probability factor accounting for strict molecular orientation

Improper Orientation

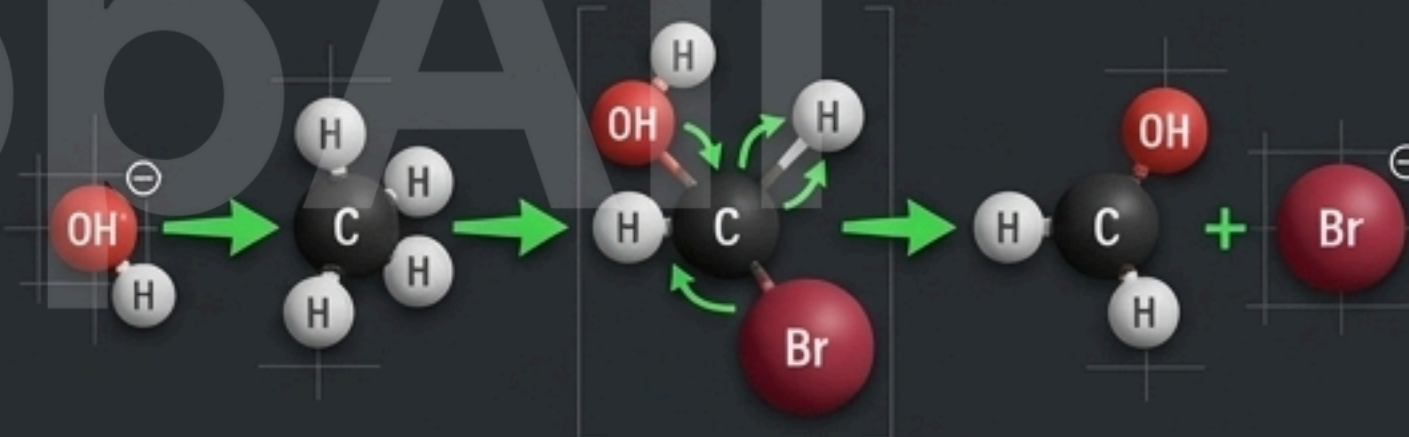
↓
No Products



Molecules simply bounce back.

Proper Orientation

↓
Intermediate
↓
Products



Bonds break and form.



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$$E=mc^2$$



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For simple, ideal bimolecular reactions:

$$\text{Rate} = Z_{AB} e^{-E_a/RT}$$

Modified for complex molecules (accounting for geometry):

$$\text{Rate} = P \cdot Z_{AB} \cdot e^{-E_a/RT}$$

$$\text{Rate} = P \cdot Z_{AB} \cdot e^{-E_a/RT}$$

 Z_{AB}

Raw Collision
Frequency

The raw volume of
crashes between
reactants A and B.

 $e^{-E_a/RT}$

Activation
Energy Fraction

The fraction of
molecules actually
possessing kinetic
energy $\geq E_a$.

 P

Steric
Factor

The strict probability
filter ensuring molecules
have the correct
spatial alignment.



ENERGY ALONE DOESN'T GUARANTEE REACTION — ORIENTATION MATTERS TOO.

Assuming $E \geq E_a$ is the only requirement is a classic exam trap. For complex molecules, if P (proper orientation) is missing, the collision is ineffective. They will just bounce back, no matter how fast they hit.

According to collision theory, which of the following is responsible for modifying the Arrhenius equation to account for the fact that not all collisions with sufficient energy lead to a reaction?

A) Collision frequency (Z)

B) Steric factor (P)



C) Activation energy (E_a)

D) Gas constant (R)

Explanation: P accounts for the specific spatial orientation required by complex molecules to successfully form transition states.

Key Takeaways

1. Reactions strictly require **Effective Collisions** (sufficient energy + exact alignment).
2. The **Collision Theory** (Trautz & Lewis) assumes reactant molecules are **hard spheres**.
3. The baseline **Arrhenius formula** ($Rate = Z_{AB}e^{-E_a/RT}$) fails for complex molecules because it assumes **energy is the only barrier**.
4. The **Steric Factor (P)** completes the equation, acting as a mathematical **geometry filter** for 3D chemical reality.



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