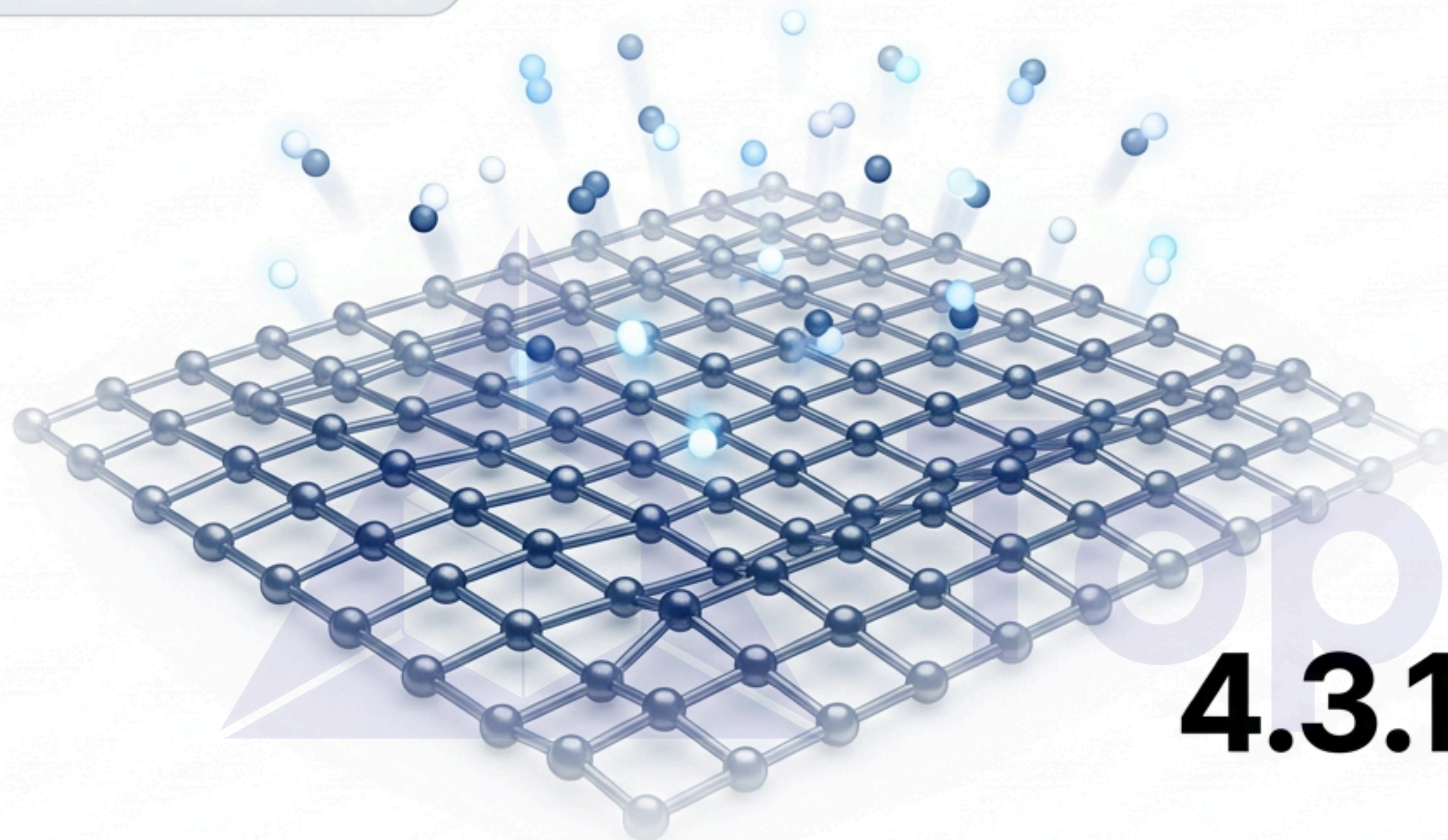




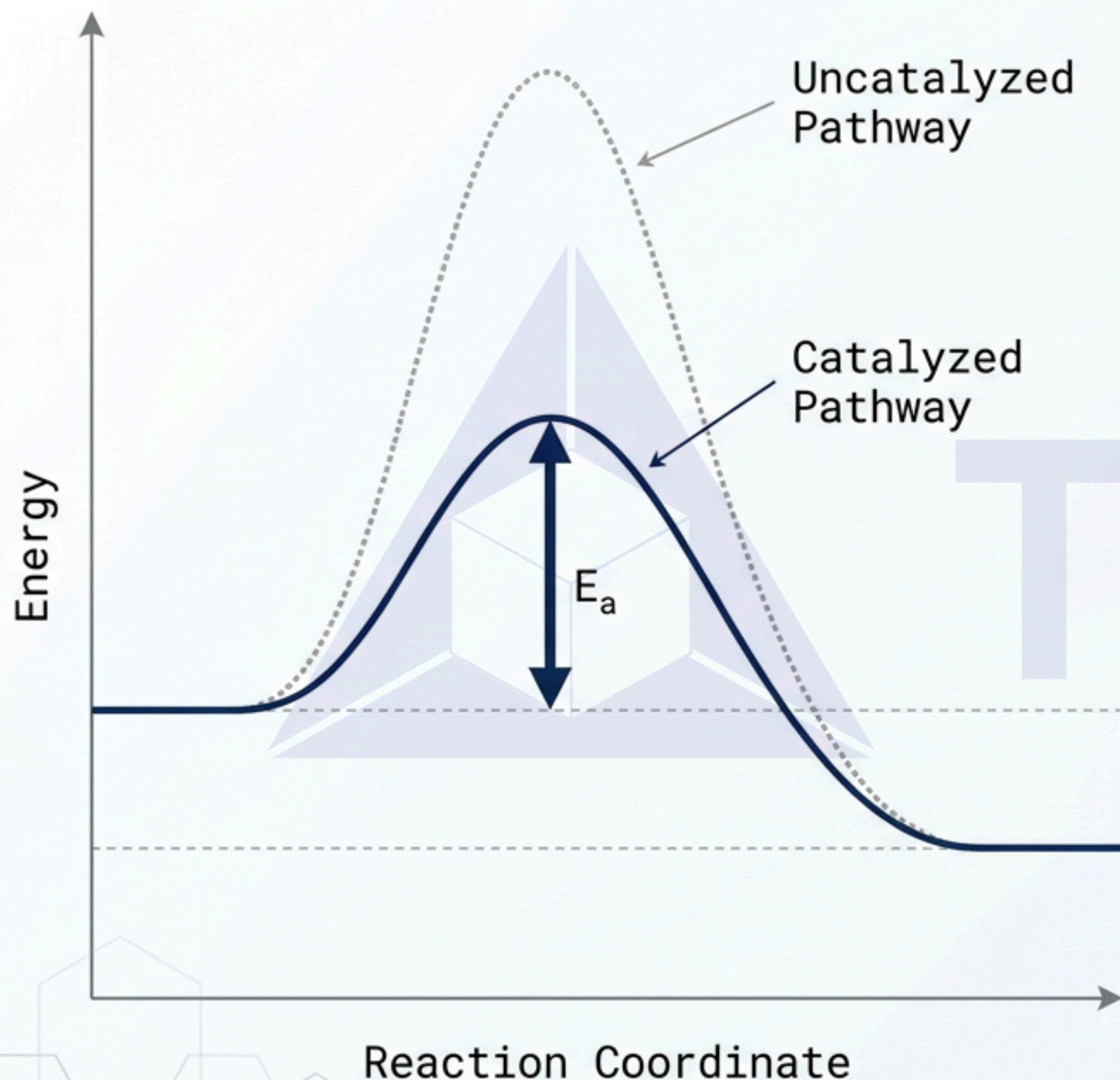
4.3.12 Catalytic Properties

How Transition Metals Drive Industrial Chemistry



TopAll

The Role of a Catalyst



The Goal

To increase the rate of a chemical reaction without being consumed in the process.

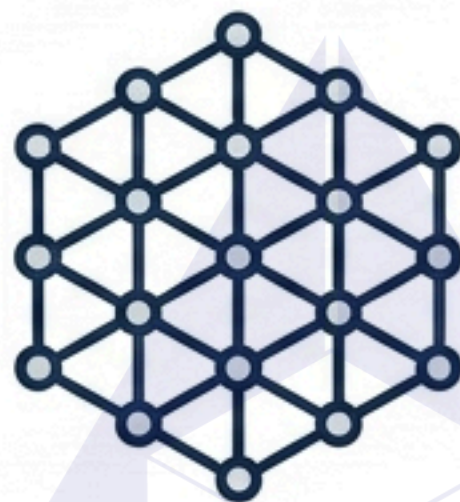
The Method

Lowers the Activation Energy (E_a) required for reactant molecules to transform into products.

Why Transition Metals?

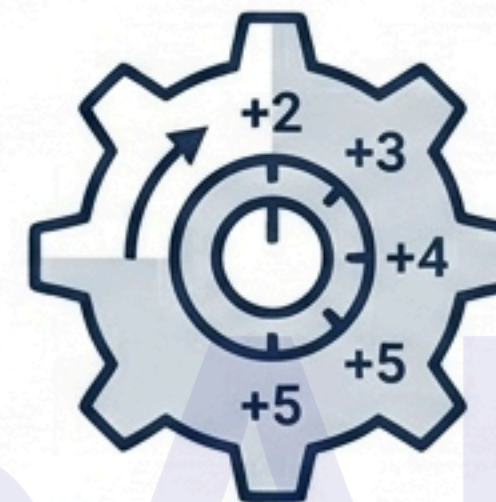
They are the undisputed kings of industrial catalysis due to their unique atomic structure.

Why are d-block elements superior catalysts?



1. Surface Adsorption (Physical)

Transition metals utilize 3d and 4s electrons to form transient bonds with reactant molecules. This provides a solid surface that dramatically concentrates reactants and weakens their internal bonds.

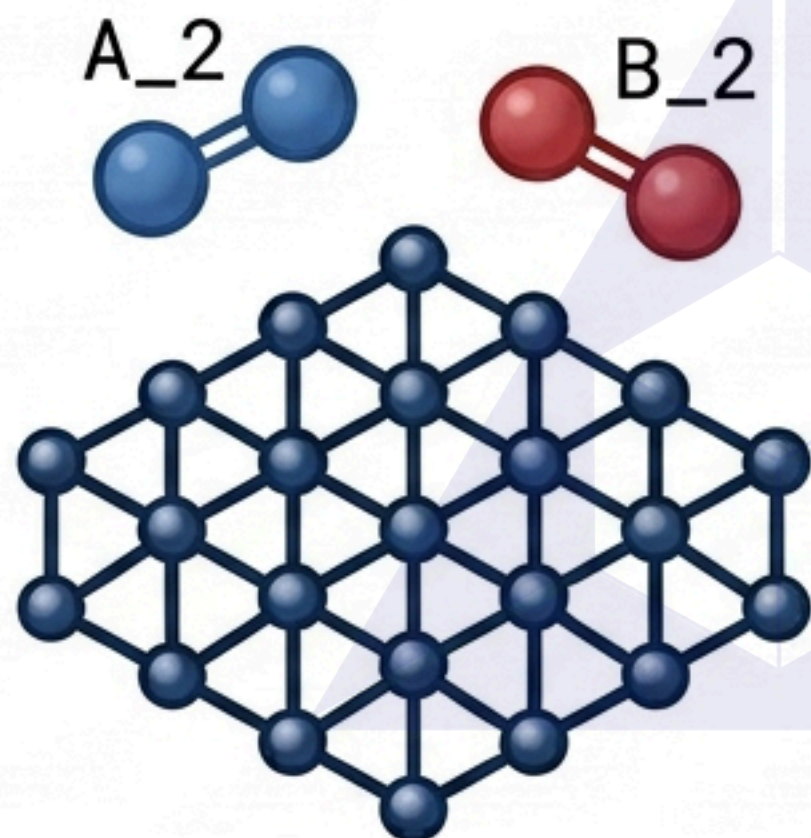


2. Variable Oxidation States (Chemical)

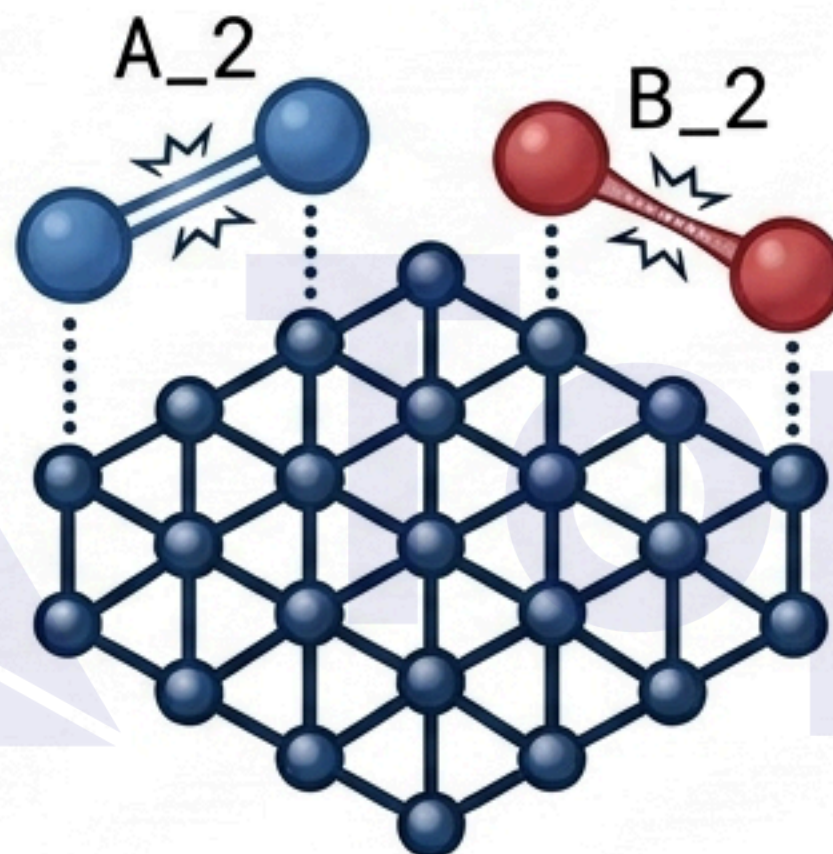
Incomplete d-orbitals allow them to easily lose or gain electrons. They act as an electron bridge, forming unstable intermediate compounds that readily decompose into the final product.

Physical Mechanism: Surface Adsorption

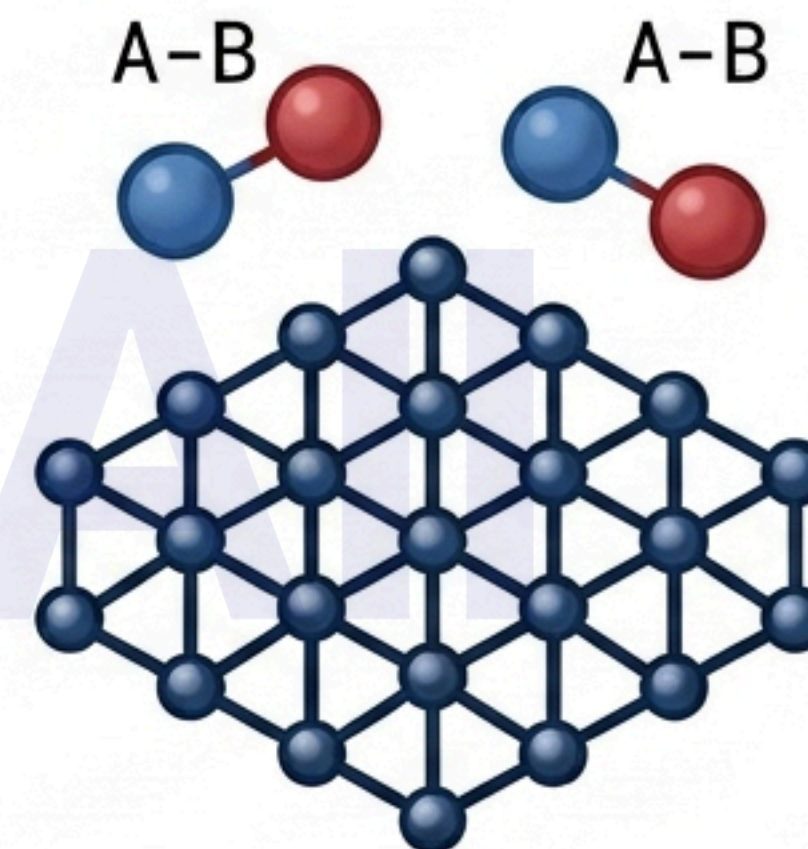
Key Concept: Concentration & Activation



1. Reactants adsorb onto the solid catalyst surface.



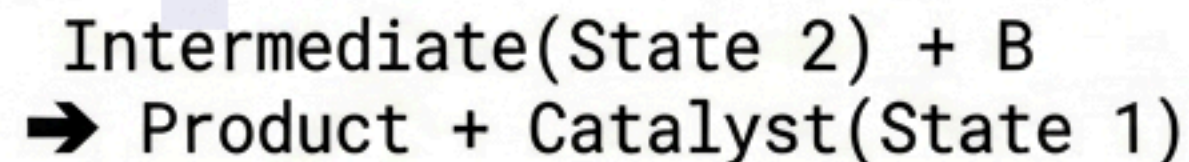
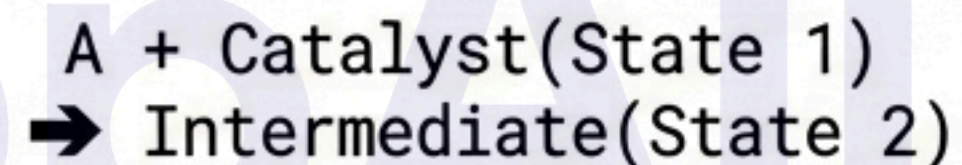
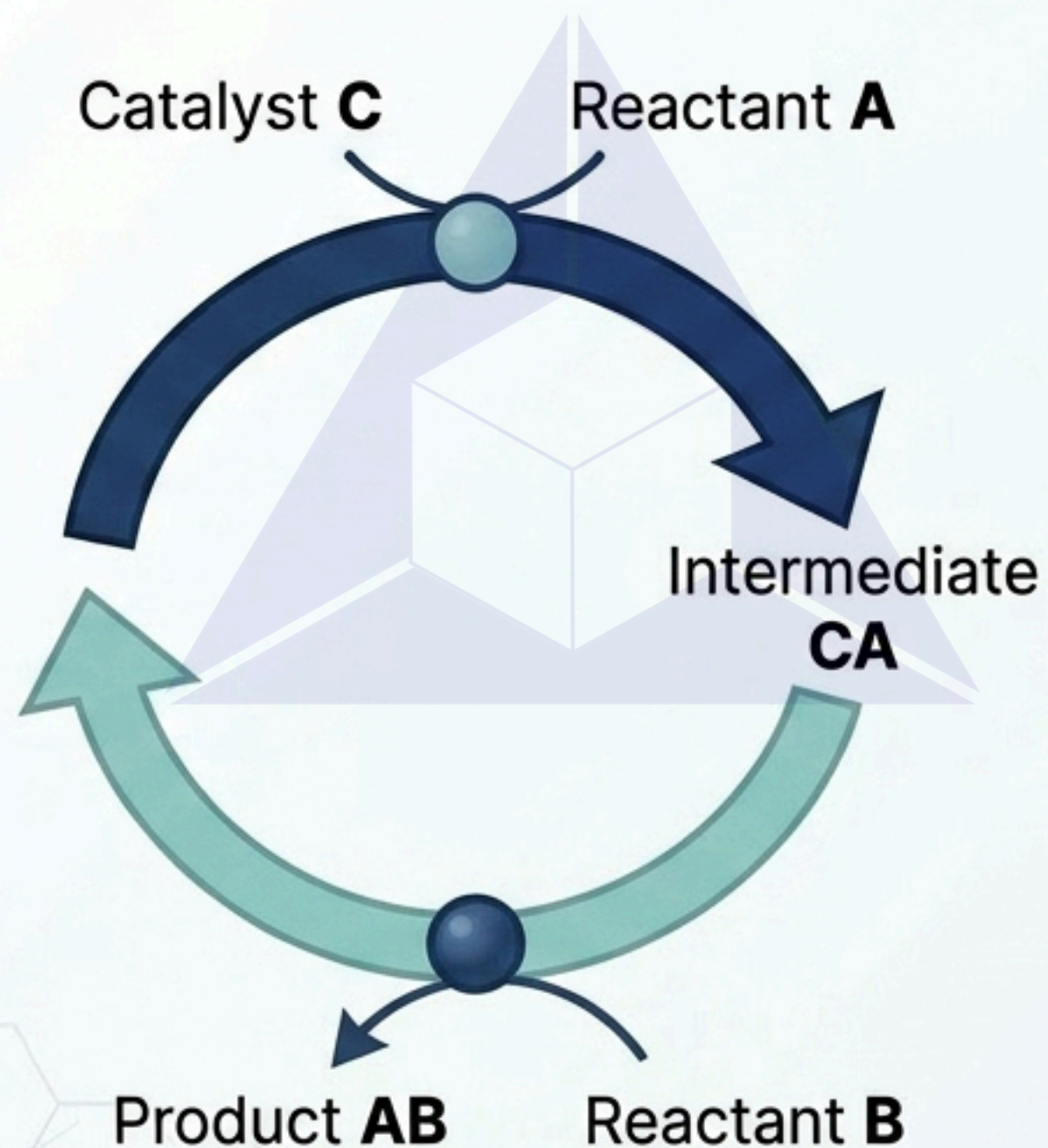
2. Local concentration spikes; metal pulls electron density to weaken reactant bonds.



3. New products detach, leaving the catalyst intact.

Chemical Mechanism: Variable Oxidation States

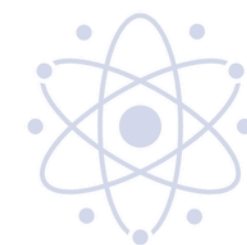
Transition metals easily shift between oxidation states, providing an alternate reaction pathway with a lower energy barrier.





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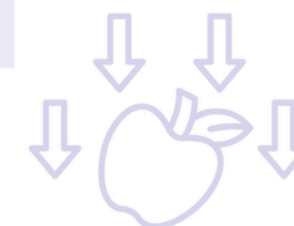
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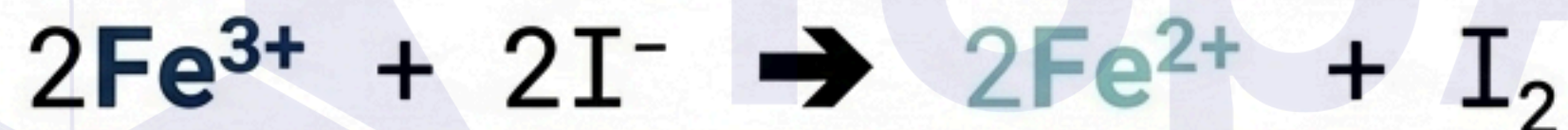


Proof of Concept: Iron(III) Catalysis

Iron shifts between +3 and +2 oxidation states to drive the reaction between iodide and persulphate ions.



Step 1: Reduction of Catalyst



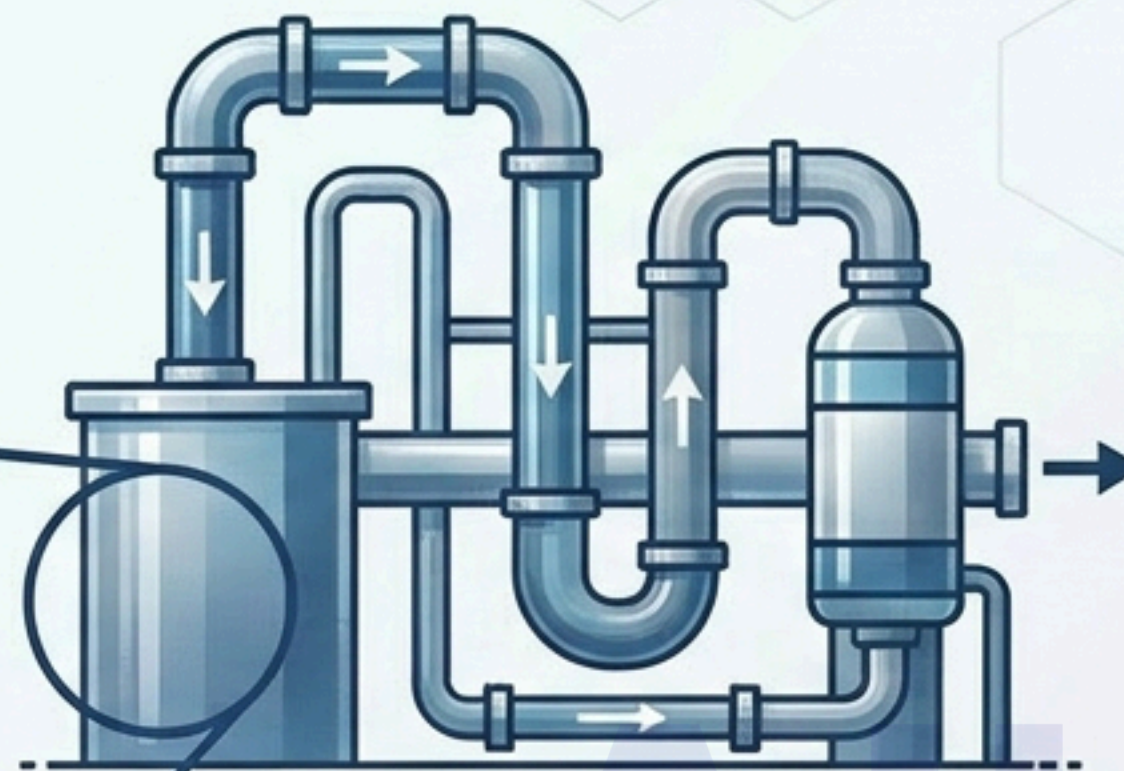
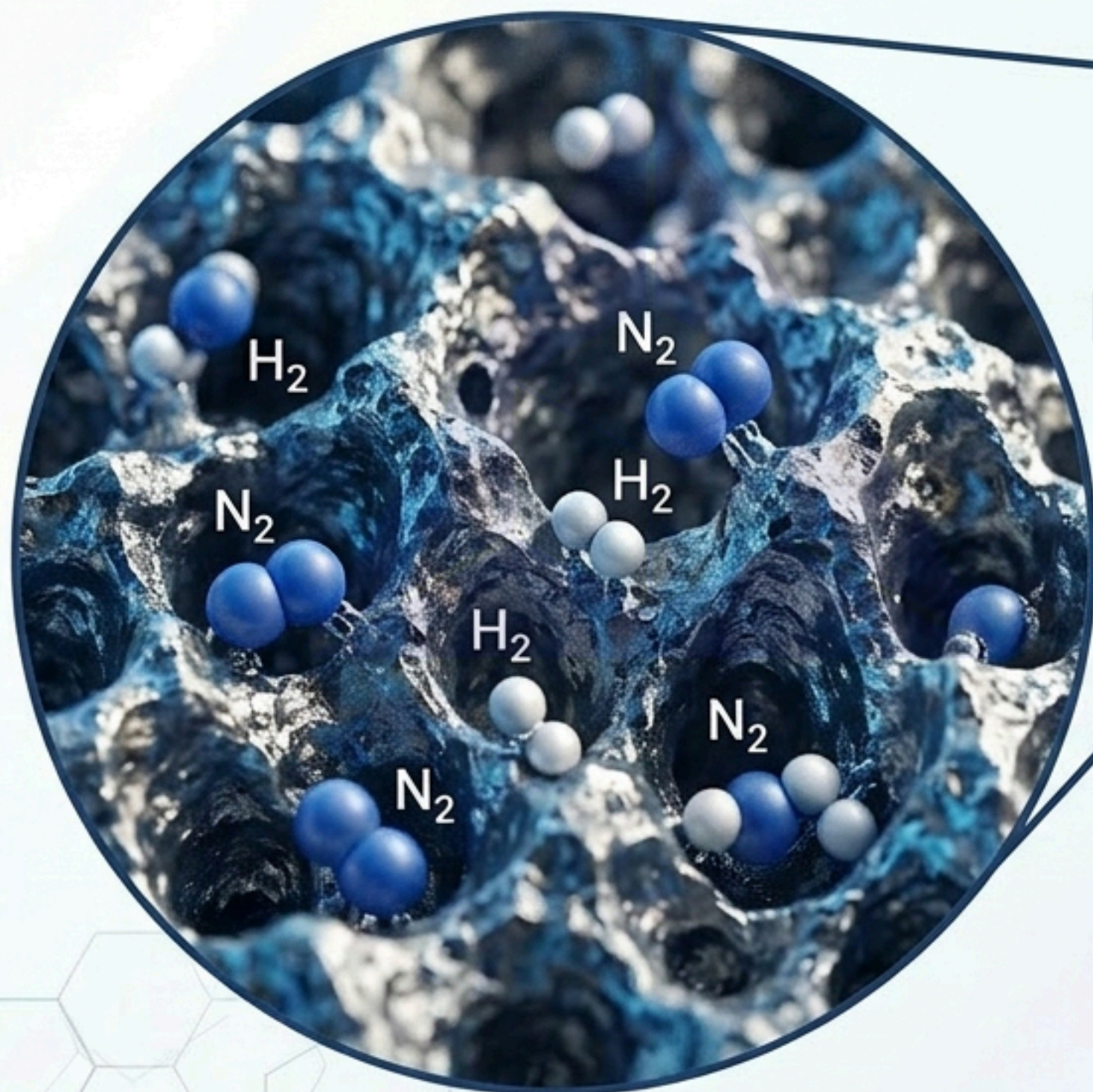
Step 2: Regeneration of Catalyst



Iron(III) acts as an electron carrier, breaking a difficult single reaction into two low-energy steps.

Haber's Process

Manufacturing Ammonia (NH₃)



Catalyst: Finely Divided Iron (Fe)

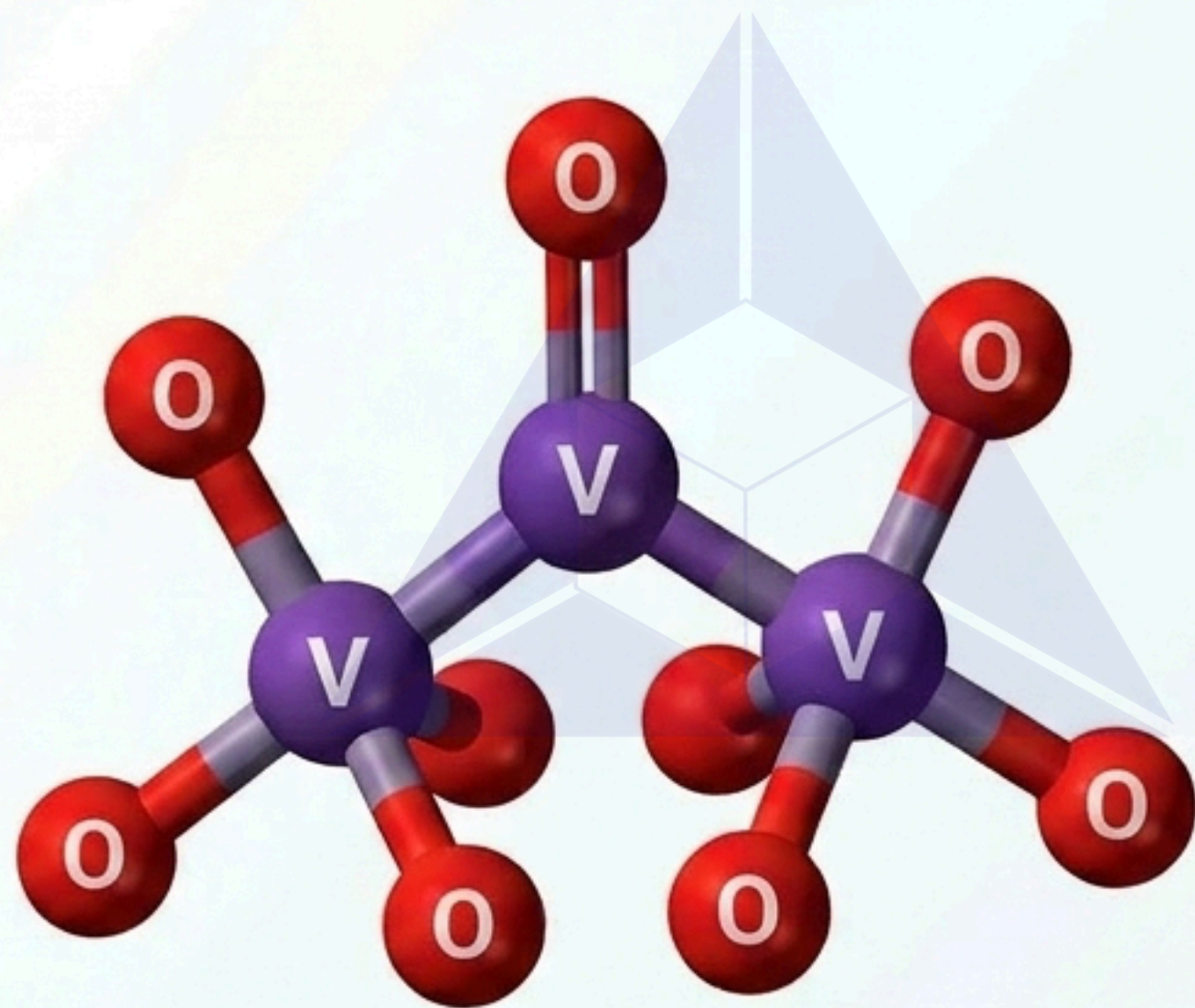


Mechanistic Focus: Surface Area

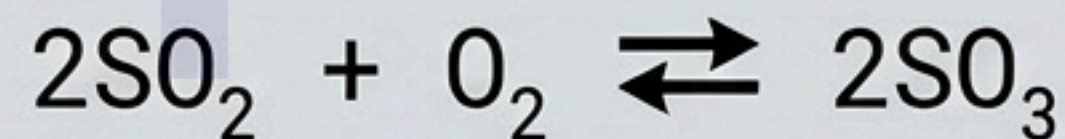
The iron is specifically finely divided to maximize the surface area available for the physical adsorption of Nitrogen and Hydrogen gases.

Contact Process

Manufacturing Sulphuric Acid (The Oxidation Step)



Catalyst: Vanadium(V) Oxide (V_2O_5)

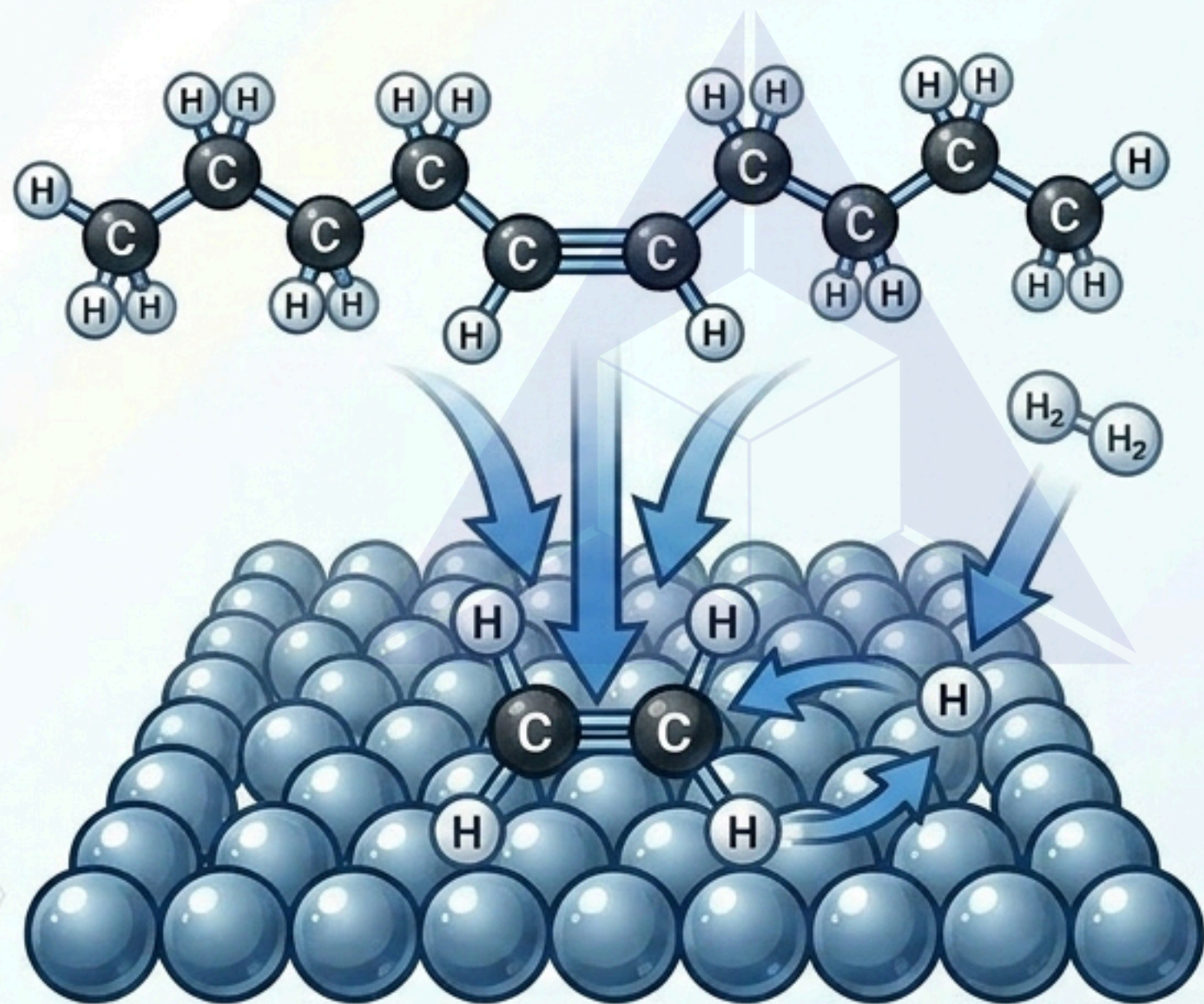


Mechanistic Focus: Oxidation State Shift

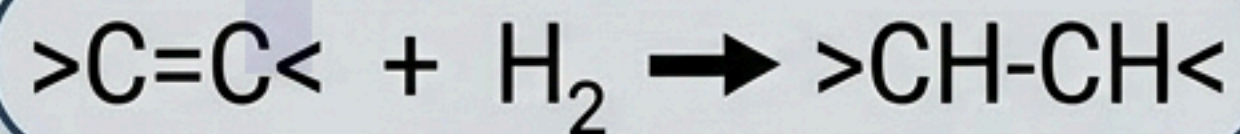
Vanadium chemically shifts from the +5 state to +4 (forming V_2O_4) and back again, acting as a direct bridge for the transfer of oxygen to SO_2 .

Catalytic Hydrogenation

Hardening of Oils and Fats



Catalyst: Nickel (Ni)



Mechanistic Focus: Adsorption & Activation

Nickel's atomic lattice provides the perfect spacing to adsorb H₂ gas, splitting the tough H-H bond and delivering highly active hydrogen atoms to the carbon double bond.

The Big Three: Industrial Catalysts Summary

Process	Reaction / Product	Catalyst	Primary Mechanism
Haber Process	$\text{N}_2 + \text{H}_2 \rightarrow \text{NH}_3$	Finely Divided Fe	Surface Adsorption
Contact Process	$\text{SO}_2 \rightarrow \text{SO}_3$	Vanadium(V) Oxide (V_2O_5)	Variable Oxidation States
Hydrogenation	Alkene $\rightarrow$ Alkane	Finely Divided Ni	Surface Adsorption

Exam Focus: How this is tested



Direct Matching

Expect Match the Following questions.

Instantly pair

Haber $\leftrightarrow$ Fe and

Contact $\leftrightarrow$ V_2O_5 .

Assertion-Reasoning

If an assertion praises transition metal catalysts, the correct reason must mention **BOTH** vacant d-orbitals/surface area **AND** variable oxidation states.

Intermediate States

Examiners frequently ask for the specific intermediate ion in the Iodide/Persulphate reaction. Remember

that it is  that gets oxidized back to Fe^{3+} to complete the cycle.



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