Reaction Rates

Equation - What happens?

Rate - How fast? - almost instantaneous to years

What changes the Reaction Rate?

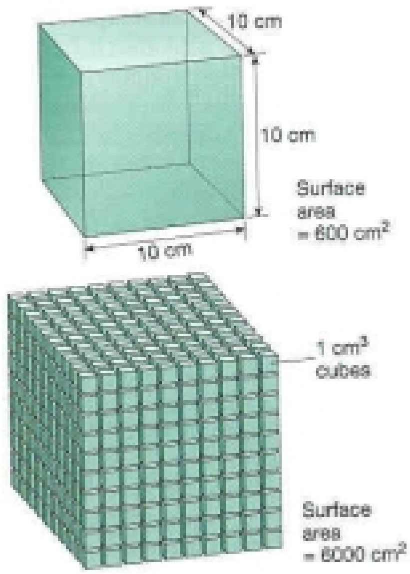
1. Nature of the Reactants

How easy is it
for different reactants
to "touch"?

gas - easy

liquid - stirring helps

solids
increasing surface area
grind or powder
increases rate



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2. Temperature: increasing T $\Rightarrow$ increases rate

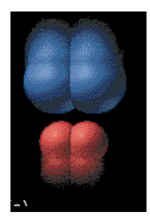
example: $H_2 + O_2$

at 20°C: stable for years

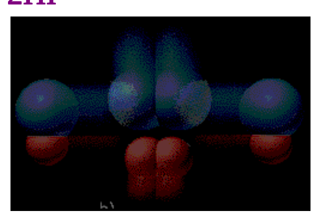
at 700°C: explodes

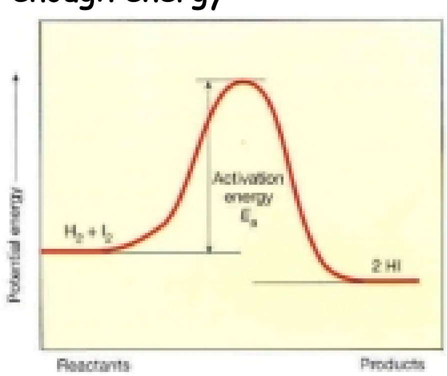
Collision Theory: reactions only possible with certain collisions

must exceed **Energy Barrier**
or **Activation Energy**
for reactants to get
close enough
most collision do not have
enough energy



$H_2 + I_2 \Rightarrow$ 2HI





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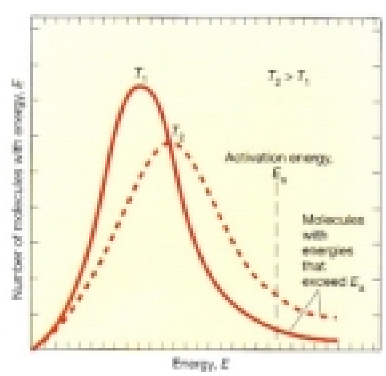

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increase T by 10°C at room temperature
changes average E by 3%
but almost doubles high E collisions

3. Concentration: number of atoms/molecules in a given volume

Law of Mass Action

for reaction $A + B \rightarrow C$ rate = k[A][B]

k = constant

[A] = concentration of A

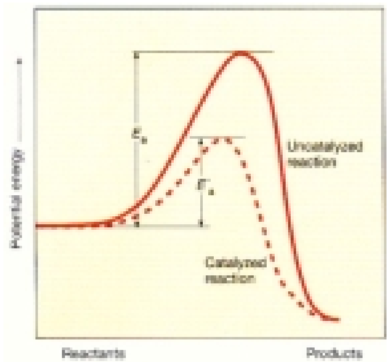
[B] = concentration of B

increasing [A] or [B] increases rate

4. Catalyst

increases rate by providing new path with lower E_a

left unchanged after reaction



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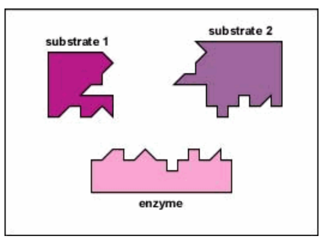
Enzyme

large protein molecule

catalyst in biological reactions



Chemical Equilibrium

Reversible Reaction: $A + B \Leftrightarrow C + D$

start with A & B

no C & D

only forward reaction

$A + B \rightarrow C + D$

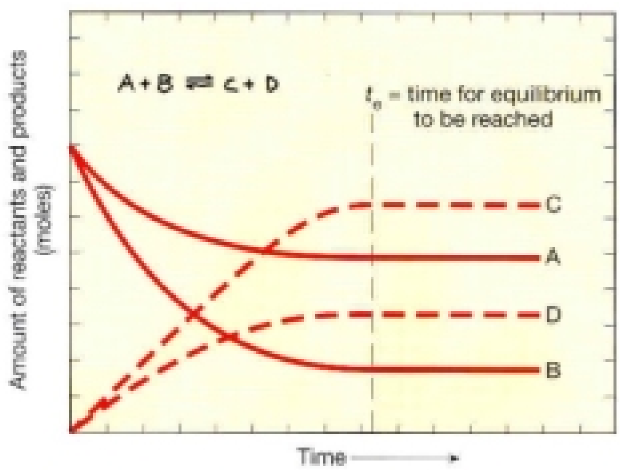
as A & B decrease

C & D increases

reverse reaction starts

$C + D \rightarrow A + B$

final state:



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Dynamic Equilibrium

forward AND **reverse** reactions both occur but concentrations do not change in time.

Rates?

rate forward = $r_f = k_f[A][B]$

rate backward = $r_b = k_b[C][D]$

Equilibrium Constant, K determined by $r_f = r_b$

$$K = \frac{k_f}{k_b} = \frac{[C]\,[D]}{[A]\,[B]}$$

when $aA + bB \Leftrightarrow cC + dD$, $K = \dfrac{[C]^c\,[D]^d}{[A]^a\,[B]^b}$

when K is very big $k_f \gg k_b$

reaction is mostly **forward**, little A,B much C,D

when K is very small $k_f \ll k_b$

reaction is mostly **reverse**, much A,B little C,D

Le Châtelier's Principle

when stress imposed on an equilibrium system,
equilibrium shifts to minimize effect of the stress

Effect of Concentration on Equilibrium

for $A + B \Leftrightarrow C + D$, $K = \dfrac{[C]\,[D]}{[A]\,[B]}$

increase [A] or [B] **(left side)**
increase **forward** reaction $\Rightarrow$ [C] and [D] increase
equilibrium **shifts to the right**

increase [C] or [D] **(right side)**
increase **reverse** reaction $\Rightarrow$ [A] and [B] increase
equilibrium **shifts to the left**

Effect of Temperature on Equilibrium

$$H_2 + I_2 \Leftrightarrow 2HI + \text{heat}$$

forward reaction generates heat - **exothermic**
reverse reaction absorbs heat - **endothermic**

What happens if heat is added?

increase **(right side)**
equilibrium **shifts to the left**
increase **reverse** reaction $\Rightarrow$ more H_2 and I_2