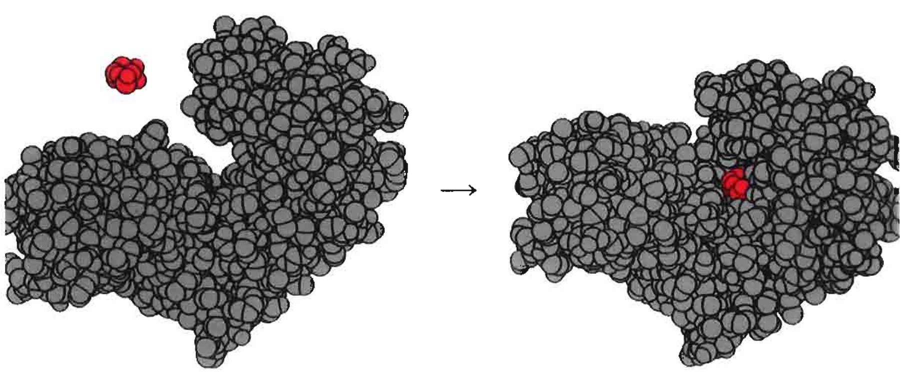
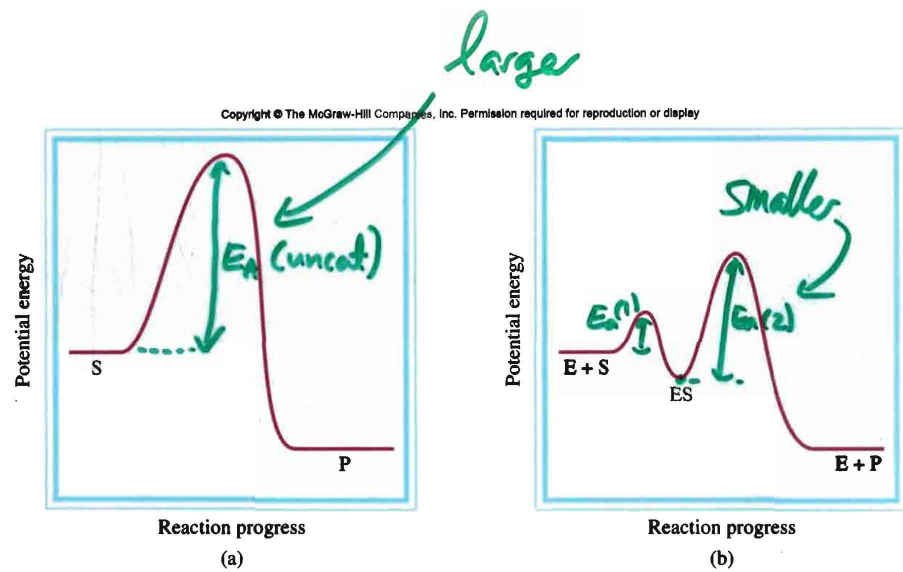



large
Potential energy
S
E_A (uncat)
P
Reaction progress
(a)
Smaller
Potential energy
E + S
$E_A(1)$
ES
$E_A(2)$
E + P
Reaction progress
(b)

2 types of catalysts:

(1) Homogeneous
- same phase as reactants.

ex: $H_2O_2(aq) \xrightarrow{\text{slow}} H_2O(l) + \frac{1}{2}O_2(g)\uparrow$

$H_2O_2(aq) \xrightarrow[\text{cat}]{I^-(aq)} H_2O(l) + \frac{1}{2}O_2(g)\uparrow$

homogeneous cat

FAST

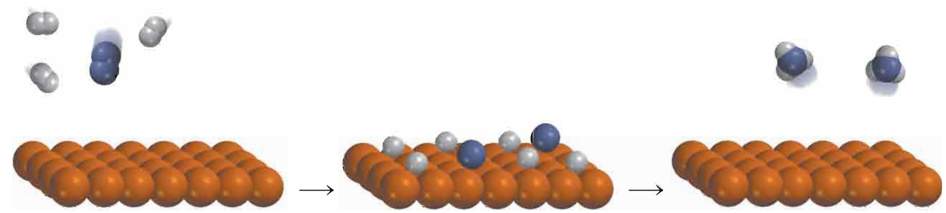
(2) Heterogeneous
- different phase as reactants.

ex: $N_2(g) + 3H_2(g) \xrightarrow{\text{SLOW}} 2NH_3(g)$

$N_2(g) + 3H_2(g) \xrightarrow[\text{cat}]{Fe(s)} 2NH_3(g)$

heterogeneous

FAST

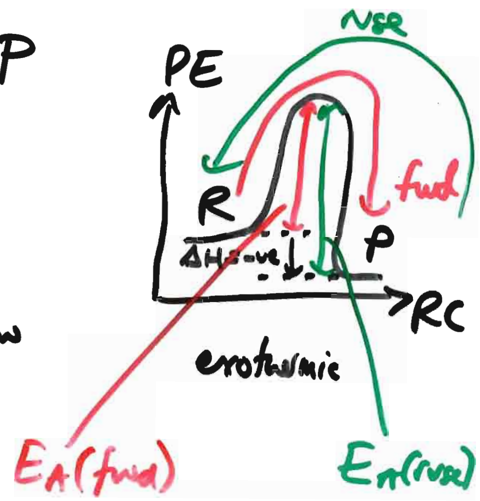


Ch 15 — Chemical Equilibrium (Eq^{m})

$R \rightleftarrows P$

$R \rightleftharpoons P$

↑ eQ^{m} arrow



$H_2O(l) \rightleftharpoons H_2O(g)$

physical eq^{m}.

rate of fwd rxn = rate of reverse rxn.
@ eQ^{m}.

Same idea for chem. rxns!

ex: $N_2O_4(g) \rightleftharpoons 2NO_2(g)$

@ eQ^{m}: rate: $N_2O_4 \longrightarrow 2NO_2$
||
rate: $2NO_2 \longrightarrow N_2O_4$

$\Rightarrow$ these concs (NO_2, N_2O_4) do not change @ eQ^{m}.

Amazing observation:

@ 25°C

$$\frac{[NO_2]^2}{[N_2O_4]} = 4.63 \times 10^{-3} \text{ always!}$$

We call this the Equilibrium Constant, K

In general:

$$aA + bB \rightleftharpoons cC + dD$$

$$K = \frac{[C]^c \cdot [D]^d}{[A]^a \cdot [B]^b}$$

where A, B, C, D are all either gases (g) or solutions (aq)

$$K \sim \frac{\text{Prods}}{\text{Reacts.}}$$

K is a constant @ a particular temp.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

$$K = \frac{[NH_3]^2_{eQ}}{[N_2]_{eQ} \times [H_2]^3_{eQ}}$$

or: $Pb^{2+}(aq) + 4Cl^-(aq) \rightleftharpoons PbCl_4^{2-}(aq)$

$$K = \frac{[PbCl_4^{2-}]_{eQ}}{[Pb^{2+}]_{eQ}[Cl^-]^4_{eQ}}$$

eQ = @ eqm

$$K \sim \frac{\text{Products}}{\text{Reactants.}}$$

$K > 1$, [Products] > [R]

$K = 1$, [Prods] ≈ [R]

$K < 1$, [P] < [R]

K > 1

Product rich @ eq^{m}

$R \rightharpoonup P$

can pretend $R \rightarrow P$

$K \approx 1$ $\quad R \rightleftharpoons P$

$K < 1$ $\quad R \leftharpoondown P$

$R \leftarrow P$

Two types of K

for ex: $aA \rightleftharpoons bB$

$$K_c = \frac{[B]^b}{[A]^a}$$

c = conc

- commonly use w/ (aq)

$$K_p = \frac{P_B^{\,b}}{P_A^{\,a}}$$

p = press.

- common w/ gas phase rxns.

$$N_2O_4(g) \rightleftharpoons 2\,NO_2(g)$$

$$K_c = \frac{[NO_2]^2}{[N_2O_4]}$$

$$K_p = \frac{P_{NO_2}^{\,2}}{P_{N_2O_4}}$$