Ch. 14 Chemical Equilibrium

14.1 Characteristics

① not completely on product or reactant side - have some of each
"product favored" - mostly product
"reactant favored" - reactant

② "Dynamic Equilibrium"
- forward rate = reverse rate
- reactions happen, but cancel, so that no overall change
"steady state"

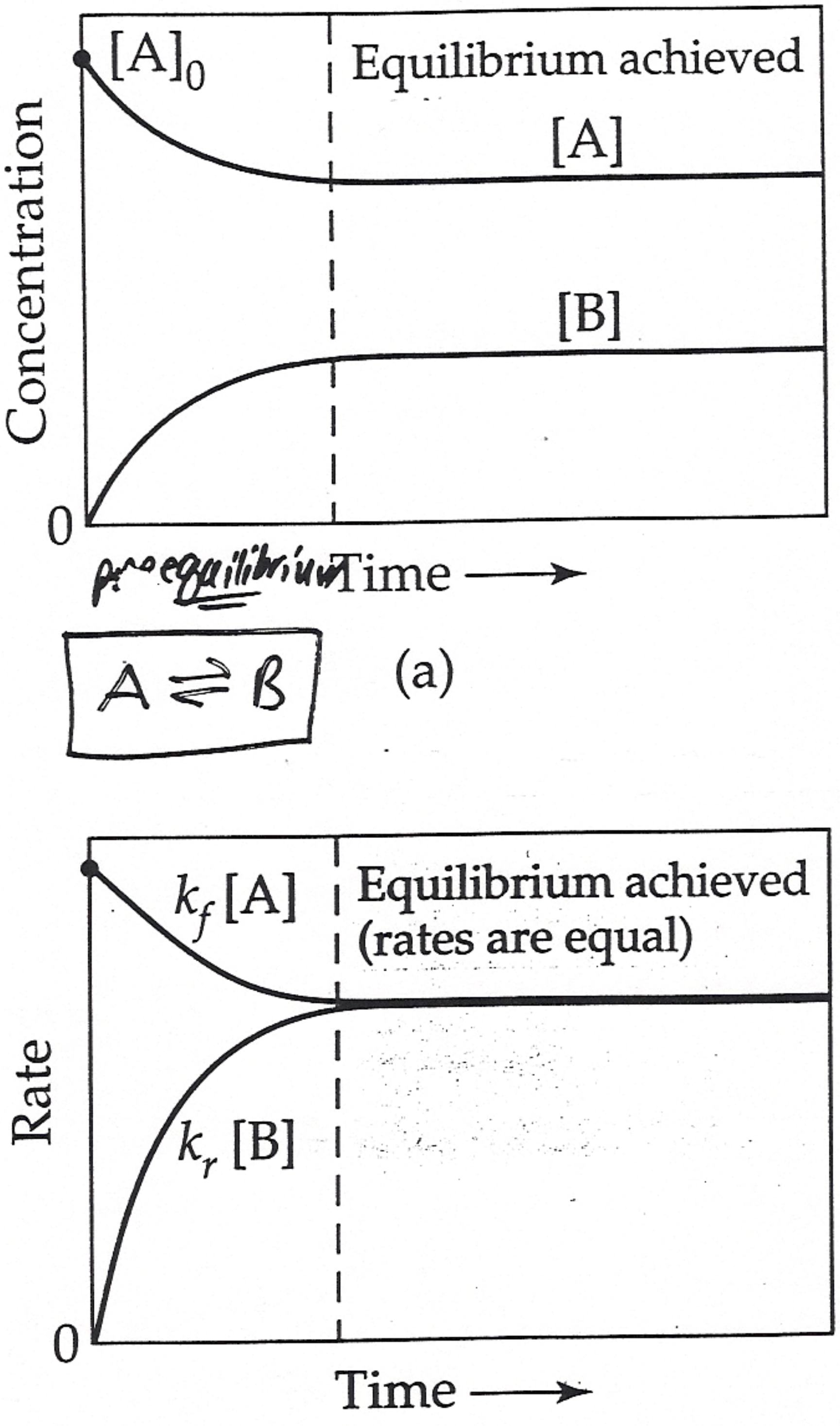
③ Previous Examples
1. Vapor Pressure (closed container)
liq $\rightleftharpoons$ vapor
2. Saturated soln solid $\rightleftharpoons$ dissolved
3. Weak acid/weak electrolyte $HF \rightleftharpoons H^{\oplus} + F^{\ominus}$

④ Doesn't matter whether you start from left side or right side
Fig T-117,118, Brown   Fig 14.1 Moore

⑤ Catalysts Don't Change (just faster)

⑥ Temp Does Change

Fig. 15.3 Achieving Equilibrium, General



preequilibrium

$\boxed{A \rightleftharpoons B}$

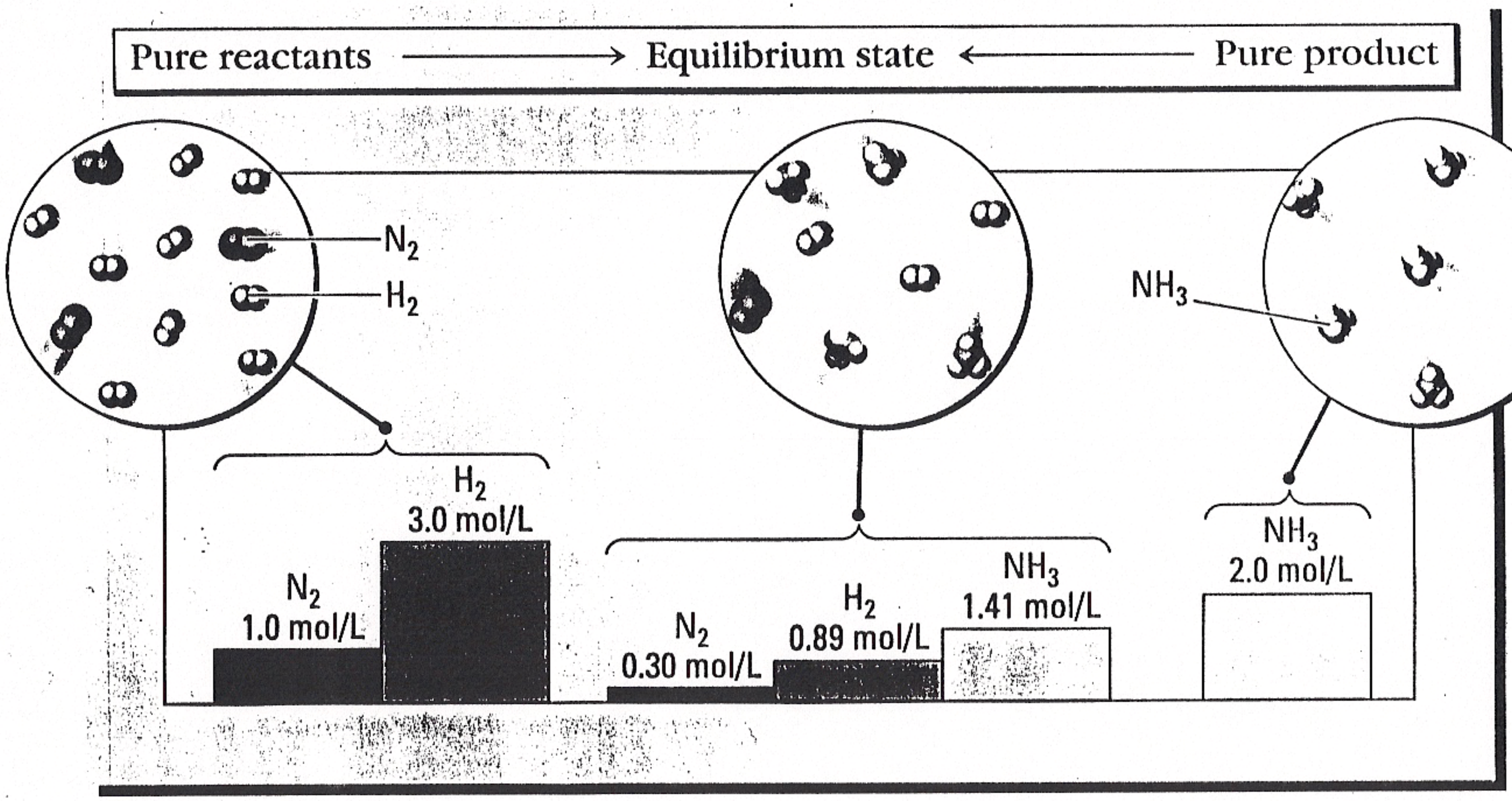


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Figure 14.1

14.2 The Equilibrium "Constant"

A. Intro

$$A \underset{k_r}{\overset{k_f}{\rightleftarrows}} B$$ at eq, $rate_{forward} = rate_{reverse}$

$$k_f[A] = k_r[B]$$

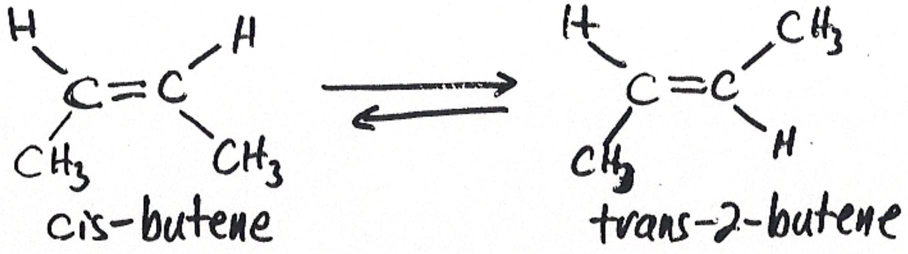
$$\frac{[B]}{[A]} = \frac{k_f}{k_r} = K_c$$

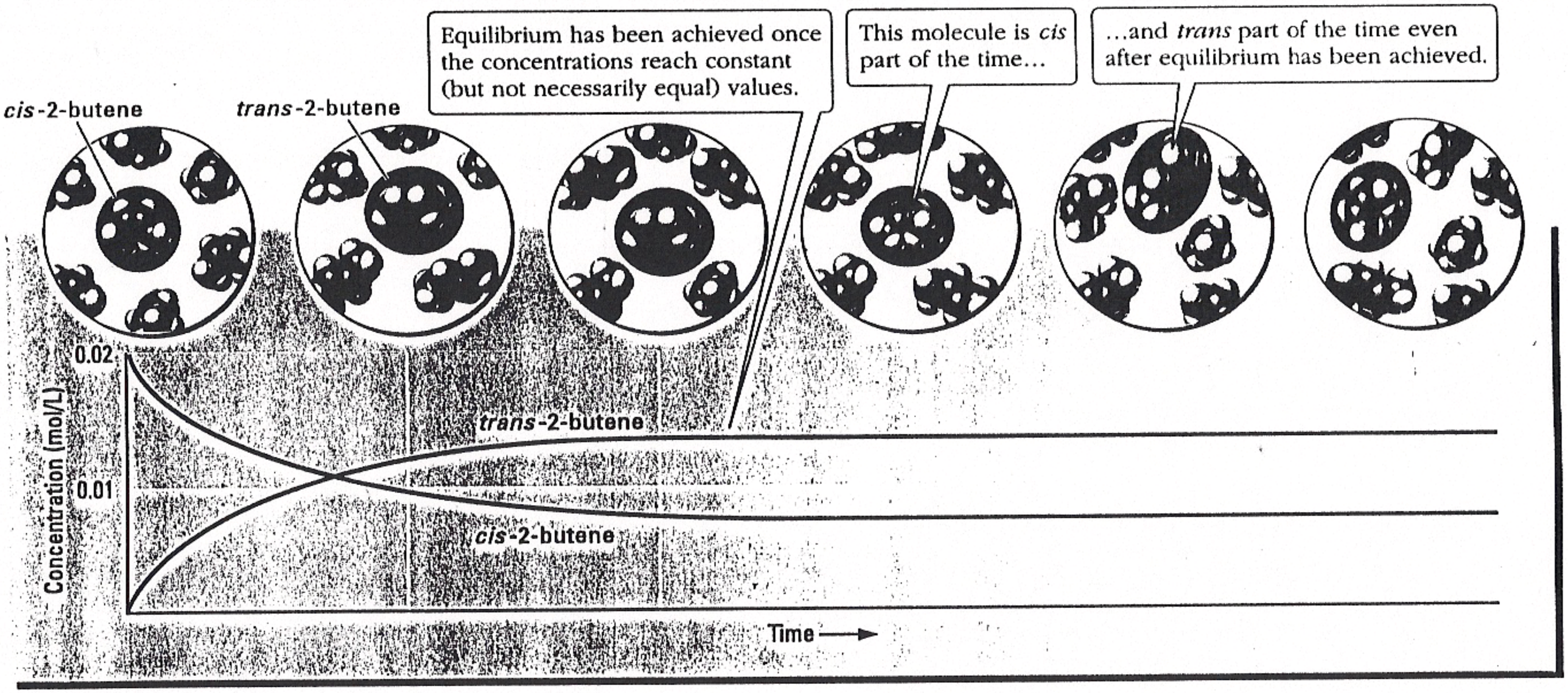
① K_c is a constant
② Each eq. has own "K"
③ Ratio of product/reactant concentration
④ Things K tells us
  a. at eq, product favored ($K \gg 1$)
    or reactants favored? ($K \ll 1$)
  b. if initial ratio ≠ K, in which direction will reaction go to achieve eq?
  c. what will specific concentrations be at eq?

B. Writing K Expressions

$$aA + bB \rightleftarrows cC + dD \qquad K_c = \frac{[C]^c[D]^d}{[A]^a[B]^b}$$

① products over reactants
② to the "coefficient" power
③ straight from balanced eqn. (don't need mech, etc.)





Equilibrium has been achieved once the concentrations reach constant (but not necessarily equal) values.

This molecule is *cis* part of the time…

…and *trans* part of the time even after equilibrium has been achieved.

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Figure 14.2

C. Heterogeneous Equilibria: Do not include solids or liquids (solvents) in K expressions ↳ (water!!)

- their conc. is constant, so just wrapped into K
- only gases and "aqueous things" appear

$A(g)$, $B(aq)$ Yes
$C(l)$, $D(s)$ NO

ex $CuOH(s) \xrightleftharpoons{H_2O} Cu^+(aq) + OH^-(aq)$

$K = \frac{[Cu^+][OH^-]}{\underset{\text{constant}}{[CuOH]}}$ so $\boxed{K_c = [Cu^+][OH^-]}$

ex $\underset{\nwarrow}{H_2O}(l) + HF(aq) \rightleftharpoons H_3O^+(aq) + F^{\ominus}(aq)$

$$\boxed{K_c = \frac{[H_3O^+][F^{\ominus}]}{[HF]}}$$

D. K's for Related Reactions

reverse direction: $1/K_c = K_c^{-1}$

$aA \rightleftharpoons bB$ $K_c = [B]^b/[A]^a$ $K_{reverse} = \frac{[A]^a}{[B]^b} = \frac{1}{K_c}$

x2

$2aA \rightleftharpoons 2bB$ $K_{x2} = K_c^2 = \frac{[B]^{2b}}{[A]^{2a}}$

①Write K_c Expressions

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

b. $A(g) + 2B(g) \rightleftharpoons 3C(g) + D$

c. $NaF(aq) + H_2O(l) \rightleftharpoons HF(aq) + NaOH(aq)$

d. $CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$

e. $HF(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + F^-(aq)$

② If $A+B \rightleftharpoons C$ $K_c = 10^4$

what is K for $C \rightleftharpoons A+B$?

③ $A \rightleftharpoons B$ Find [B]/[A] ratios

a. $K_c = 10^3$

b. $K_c = 10^{-3}$

Jasperse Chem 160 Ch.14 In Class Problems

① Write K_c Expressions

a. $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ $K_c = \frac{[NH_3]^2}{[N_2][H_2]^3}$

b. $A(g) + 2B(g) \rightleftharpoons 3C(g) + D$ $K = \frac{[C]^3[D]}{[A][B]^2}$

c. $NaF(aq) + H_2O(l) \rightleftharpoons HF(aq) + NaOH(aq)$

$K_c = \frac{[HF][NaOH]}{[NaF]}$

d. $CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$ $K_c = [CO_2]$

e. $HF(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + F^-(aq)$

$K_c = \frac{[H_3O^+][F^-]}{[HF]}$

② If $A + B \rightleftharpoons C$ $K_c = 10^4$

what is K for $C \rightleftharpoons A + B$? $K_c = 1/10^4 = 10^{-4}$

③ $A \rightleftharpoons B$ Find $[B]/[A]$ ratios

a. $K_c = 10^3$ 1000/1

b. $K_c = 10^{-3}$ 1/1000

14.3 Calculating K
- need all equilibrium concentrations, plug into K_c

A. Given eq. concs (easy) (14.6, p. 1,2)

B. Given initial concentrations and at least one final concentration (medium)

① Write balanced eqn, K_c
② Make "ICE" table, enter knowns
<u>I</u>nitial
<u>C</u>hange
<u>E</u>quilibrium
③ Find change for chemical whose final conc is known
④ Use stoich to determine changes of others
⑤ From initial concs and deduced changes, determine all ~~final~~ eq. concs.
⑥ Solve for K

(practice: 14.6 #3+4)

Note: "E" must be in molarity, moles/liter
If info. given in "moles" or "grams" plus volume, will need to convert.

Using the "ICE" Method to Calculate K, Given Initial Concentrations and One Final Concentration

1. Write balanced equation, and expression for K_c
2. Make an "ICE" table, and enter the knowns
    a. Initial
    b. Change
    c. Equilibrium
3. Find the Change for the chemical whose final concentration is known
4. Use stoichiometric relationship to determine the change in concentrations for the others
5. From the initial concentrations and the deduced changes, determine all equilibrium concentrations
6. With all equilibrium concentrations now known, plug into the K_c expression and solve for K
7. Check: Does Answer Make Any Sense?

- Note: equilibrium concentrations must be in Molarity, moles/liter. If information is given in grams or moles plus solvent volume, you will need to convert into molarity.

Using the "ICE" Method to Calculate Equilibrium Concentrations, Given Only Initial Concentrations and K_c

1. Write balanced equation, and expression for K_c
2. Make an "ICE" table, and enter the known initial concentrations
    a. Initial
    b. Change
    c. Equilibrium
3. Use "x" to define the change of one substances. Use stoichiometric relationships to determine the changes in the concentrations for the others, in terms of "x".
4. Calculate the equilibrium concentrations of all chemicals in terms of initial concentrations and "x", and enter them in the table.
    - If K is small so that "x" is likely to be small, the simplifying assumption that $[A]_{initial}$ – "x" = $[A]_{initial}$ is often justified, and can greatly simplify the math.
5. Solve for "x" (This is the hard part!)
6. Once "x" is known, solve for the actual equilibrium concentrations
7. Check: Does Answer Make Any Sense? If you made the "simplifying assumption", was it justified?

14-6

① For $A \rightleftharpoons B + C$, *find* K_c *if* $[A] = 0.26$
$[B] = 0.26$
$[C] = 0.93$

② For $A + 2B \rightleftharpoons 2C + D$ find K_c if $[A] = 0.15$
$[B] = 0.18$
$[C] = 2.0 \times 10^{-4}$
$[D] = 3.0 \times 10^{-6}$

③ $2A + 2B \rightleftharpoons C + 2D$

	$2A$	$2B$	C	$2D$
I	0.20	0.30	0	0.10
C				
E	0.10			

$K_c =$ ______

$K_c =$

④ $A + 2B \rightleftharpoons C + D$ $K_c =$ ______

	A	$2B$	C	D
I	0.20	0.20	0	0
C				
E	0.15			

$K_c =$

① For $A \rightleftharpoons B + C$, find K_c if $[A] = 0.26$

$[B] = 0.26$

$[C] = 0.93$

$$K = \frac{B\,C}{A} = \frac{(0.26)(0.93)}{.26} = \boxed{0.93}$$

② For $A + 2B \rightleftharpoons 2C + D$ find K_c if $[A] = 0.15$

$[B] = 0.18$

$[C] = 2.0 \times 10^{-4}$

$[D] = 3.0 \times 10^{-6}$

$$K = \frac{C^2 D}{A\,B^2} = \frac{(2.0\times10^{-4})^2\,(3.0\times10^{-6})}{(0.15)\,(0.18)^2}$$

$$\boxed{K_c = 2.47 \times 10^{-11}}$$

③ $2A + 2B \rightleftharpoons C + 2D$

	2A	2B	C	2D
I	0.20	0.30	0	0.10
C	−0.10	−0.10	+0.05	+0.10
E	0.10	0.20	0.05	0.20

$$K_c = \frac{[C][D]^2}{[A]^2[B]^2}$$

$$K_c = \frac{(0.05)(0.20)^2}{(0.10)^2(0.20)^2}$$

$$\boxed{K_c = 5.0}$$

④ $A + 2B \rightleftharpoons C + D$

$$K_c = \frac{[C][D]}{[A][B]^2}$$

	A	2B	C	D
I	0.20	0.20	0	0
C	−0.05	−0.10	+0.05	+0.05
E	0.15	+0.10	+0.05	+0.05

$$K_c = \frac{(.05)(.05)}{(.15)(.10)^2}$$

$$\boxed{K_c = 1.67}$$

14.4 Meaning of K

① $K_c \gg 1$ Product favored
② $K_c \ll 1$ Reactants favored
③ $K_c \approx 1$ Significant quantities of both products + reactants
↳ calcs required

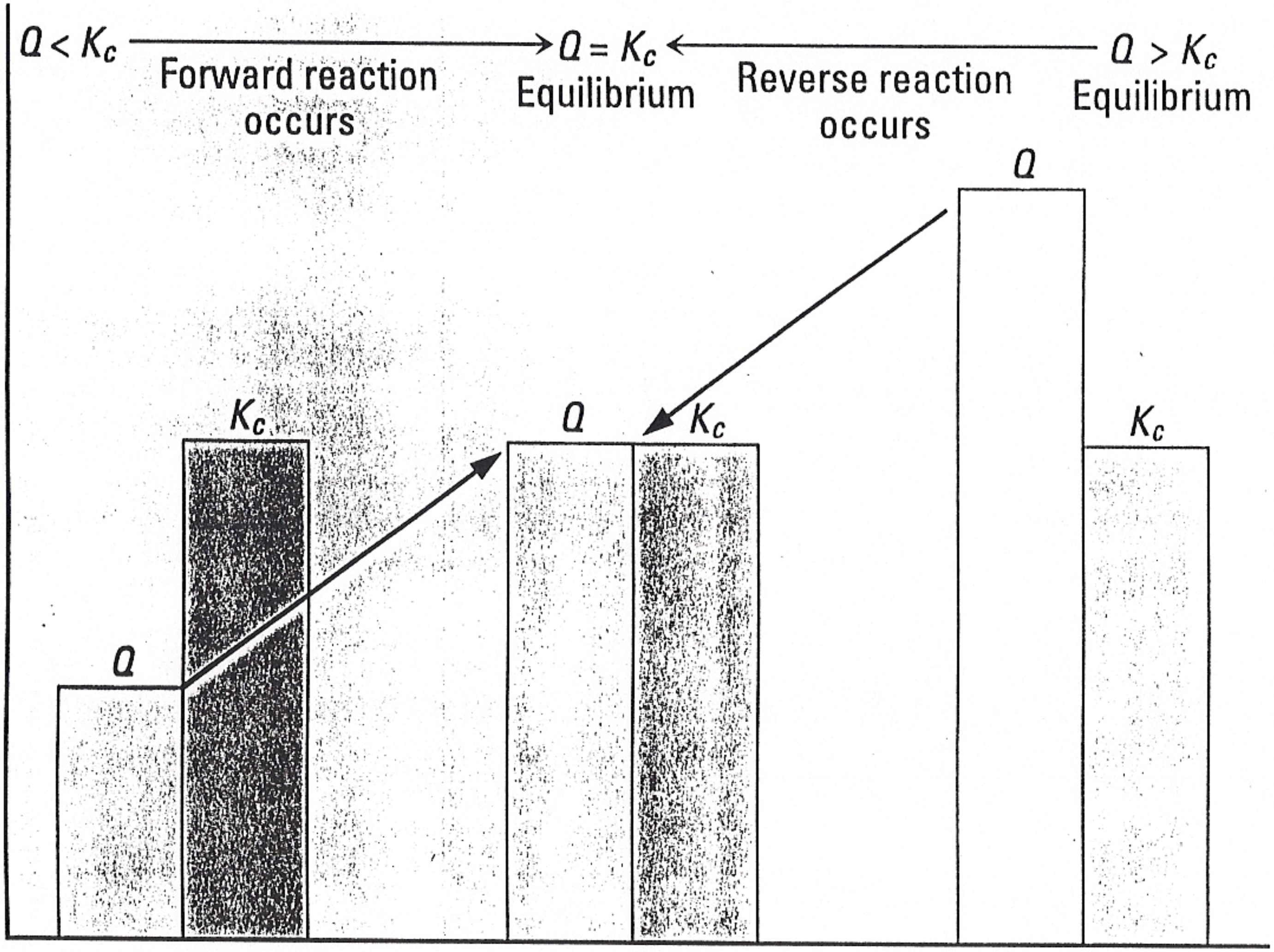
– many cases where $K_c \ll 1$, but small amount of product still very important

14.5 Using K_c

A. Predicting the Direction of a Reaction, Given Info About Actual Situation

K= equilibrium Q = actual ratios (same format)

if Q=K you're at eq, won't change
Q<K not " ", short on product, reactants will go to products to achieve eq
Q>K excess product, will proceed to left



Moore/Sta[illegible]tski/Jurs, Chemistry: The Molecular Science
Figure 14.5

(14-8)

① $A + B \rightleftharpoons C$ $K_c = 72$

Suppose [A], [B], + [C] all begin at 0.33 M:

a. what is Q?

b. Which direction will the reaction go to achieve equilibrium?

c. What will happen to the concentrations of: [A]

[B]

[C]

② $HF(aq) \rightleftharpoons H^+(aq) + F^-(aq)$ $K_c =$ ~~[illegible]~~ 6.8×10^{-4}

a. Find [H^+] if [HF] = 0.10 and [F^-] = 0.10

b. Find [F^-] if [HF] = 0.20 and [H^+] = 10^{-3}

(14-8)

① $A + B \rightleftharpoons C \qquad K_c = 72$

Suppose [A], [B], + [C] all begin at 0.33 M:

a. what is Q? $Q = \frac{[C]}{[A][B]} = \frac{.33}{(.33)(.33)} = \boxed{3.0}$

b. which direction will the reaction go to achieve equilibrium? $\boxed{\text{Forwards}}$

$Q < K$

c. what will happen to the concentrations of:

[A] ↓

[B] ↓

[C] ↑

② $HF(aq) \rightleftharpoons H^+(aq) + F^-(aq) \qquad K_c = 6.8 \times 10^{-4}$

a. Find [H⁺] if [HF] = 0.10 and [F⁻] = 0.10

$K = \frac{[H^+][F^-]}{[HF]} \qquad 6.8\times10^{-4} = \frac{[H^+]\ 0.10}{0.10} \qquad \boxed{H^+ = 6.8\times10^{-4}}$

b. Find [F⁻] if [HF] = 0.20 and [H⁺] = 10^{-3}

$6.8\times10^{-4} = \frac{(10^{-3})[F^-]}{0.20} = \boxed{0.136\,M}$

(14-9)

B. Calculating Eq. Conc.

1. If some eq. conc. are given (easy)
(14.8 p#2) Plug + chug

2. If only initial conditions are given:
Use ICE

① Write balanced eqn, K_c
② Make "ICE" table, enter knowns
③ Use "x" to define change of one substance. Use stoich to calculate other changes in terms of x
④ Calculate eq. concs. in terms of x, and enter them in table
rd part!! ⇒ ⑤ Solve for "x", then use "x" to calculate other things. (targets)
ometimes ⇒
me simplifications ⑥ Check: does answer make any sense?

Note: Some hard math! Quadratics are tough!

* Great simplifying assumption: changes "x" are often small, so something with nonzero original concentration can be approximated to be unchanged
ex $0.20 - x \approx 0.20$
-check at end. If $x > 5\%$ of number, the assumption causes trouble

Using the "ICE" Method to Calculate K, Given Initial Concentrations and One Final Concentration

1. Write balanced equation, and expression for K_c
2. Make an "ICE" table, and enter the knowns
    a. Initial
    b. Change
    c. Equilibrium
3. Find the Change for the chemical whose final concentration is known
4. Use stoichiometric relationship to determine the change in concentrations for the others
5. From the initial concentrations and the deduced changes, determine all equilibrium concentrations
6. With all equilibrium concentrations now known, plug into the K_c expression and solve for K
7. Check: Does Answer Make Any Sense?

- Note: equilibrium concentrations must be in Molarity, moles/liter. If information is given in grams or moles plus solvent volume, you will need to convert into molarity.

Using the "ICE" Method to Calculate Equilibrium Concentrations, Given Only Initial Concentrations and K_c

1. Write balanced equation, and expression for K_c
2. Make an "ICE" table, and enter the known initial concentrations
    a. Initial
    b. Change
    c. Equilibrium
3. Use "x" to define the change of one substances. Use stoichiometric relationships to determine the changes in the concentrations for the others, in terms of "x".
4. Calculate the equilibrium concentrations of all chemicals in terms of initial concentrations and "x", and enter them in the table.
    - If K is small so that "x" is likely to be small, the simplifying assumption that $[A]_{initial}$ – "x" = $[A]_{initial}$ is often justified, and can greatly simplify the math.
5. Solve for "x" (This is the hard part!)
6. Once "x" is known, solve for the actual equilibrium concentrations
7. Check: Does Answer Make Any Sense? If you made the "simplifying assumption", was it justified?

14-10

① $N_2O_4 \rightleftharpoons 2\,NO_2$ $K = 0.211$

If 0.10 mol of N_2O_4 is added to 1L flask, what will be concs at equilibrium?

I
C
E

② Find final concentrations given

$$HA \rightleftharpoons H^+ + A^- \qquad K_c = 1.6\times10^{-7}$$

	HA	H^+	A^-
I	0.20	0	0

③ $A \rightleftharpoons B + C$ $K_c = 2.4\times10^{-6}$

	A
I	0.30
C	
E	

① If 0.10 mol of N_2O_4 is added to 1L flask, what will be concs at equilibrium?

Need quadratic

$N_2O_4 \rightleftharpoons 2NO_2$ $K = 0.211$

	N_2O_4	$2NO_2$
I	0.10	0
C	$-x$	$+2x$
E	$0.10-x$	$2x$

$$0.211 = \frac{[NO_2]^2}{[N_2O_4]}$$

$$0.211 = \frac{(2x)^2}{0.10-x}$$

$$0.0211 - .211x = 4x^2$$

so $4x^2 + .211x - 0.0211 = 0$

$$x = \frac{-b \pm \sqrt{b^2-4ac}}{2a}$$

$$= \frac{-.211 \pm \sqrt{(.211)^2 - 4(4)(-.0211)}}{8}$$

$$= \frac{-.211 \pm \sqrt{0.382}}{8}$$

$$= \frac{-.211 \pm .618}{8} = 0.0509$$

so $[N_2O_4] = .10 - .0509 = \boxed{.0491\ \bar{M}}$

$[NO_2] = 2x = 2x(.0509) = \boxed{0.102\ \bar{M}}$

② Find final concentrations given

Can bypass Quadratic

$HA \rightleftharpoons H^+ + A^-$ $K_c = 1.6 \times 10^{-7}$

	HA	H^+	A^-
I	0.20	0	0
C	$-x$	$+x$	$+x$
E	$.20-x$	x	x
simplify → E*	$.20$	x	x

$$K_c = \frac{[H^+][A^-]}{[HA]}$$

$$1.6 \times 10^{-7} = \frac{x^2}{.20}$$

$$x^2 = 3.2 \times 10^{-8}$$

$x = 1.78 \times 10^{-4}$

so $[HA] = 0.20$
$[H^+] = 1.78 \times 10^{-4}$
$[A^-] = 1.78 \times 10^{-4}$

③ $A \rightleftharpoons B + C$ $K_c = 2.4 \times 10^{-6}$

	A	B	C
I	0.30	0	0
C	$-x$	$+x$	$+x$
E	$.30-x$	x	x
simplify → E*	$.30$	x	x
$\boxed{E}$	0.30	8.48×10^{-4}	8.48×10^{-4}

$$2.4 \times 10^{-6} = \frac{x^2}{.30}$$

$\boxed{x = 8.48 \times 10^{-4}}$

④ $A \rightleftharpoons B + C$ $K_c = 0.018$

	A		B	C
I	0.30			
C				
E				

⑤ $A \rightleftharpoons 2B + C$ $K_c = 2.0 \times 10^{-8}$

	A		2B	C
I	0.20			
C				
E				

A "Square Root" Simplification

⑥ $A + B \rightleftharpoons C + D$ $K = 0.060$

	A	B		C	D
I	0.30	0.30		0	0
C					
E					

$K = 0.060 = \_\_\_\_$

take square root of everything

$\sqrt{0.060} = \sqrt{\_\_\_\_}$

④ $A \rightleftharpoons B + C$ $K_c = 0.018$

	A	B	C
I	0.30	0	0
C	$-x$	$+x$	$+x$
E	$.30-x$	x	x
E*	0.27	.0288	.0288

$.018 = \frac{x^2}{.30-x}$

$5.4\times10^{-3} - .018x = x^2$

$x^2 + .018x - 5.4e^{-3} = 0$

$x = \frac{-.018 \pm \sqrt{(.018)^2 - 4(-5.4e^{-3})}}{2}$

$= \frac{-.018 \pm \sqrt{.005724}}{2}$

$= \frac{-.018 \pm .0757}{2}$

$\boxed{x = 0.0288}$

In this case, K_c too big to justify simplifying assumption.
Need quadratic.

⑤ $A \rightleftharpoons 2B + C$ $K_c = 2.0 \times 10^{-8}$

	A	2B	C
I	0.20	0	0
C	$-x$	$+2x$	$+x$
E	$.20-x$	$2x$	x
E*	.20	$2x$	x
E*	0.20	2.0×10^{-3}	1.0×10^{-3}

$2.0\times10^{-8} = \frac{(2x)^2 x}{.20}$

$4.0\times10^{-9} = 4x^3$

$1.0\times10^{-9} = x^3$

$\boxed{x = 1.0\times10^{-3}}$

A "Square Root" Simplification

⑥ $A + B \rightleftharpoons C + D$ $K = 0.060$

	A	B	C	D
I	0.30	0.30	0	0
C	$-x$	$-x$	$+x$	$+x$
E	$.30-x$	$.30-x$	x	x
E*	0.241	0.241	0.059	0.059

$K = 0.060 = \frac{x^2}{(.30-x)^2}$

take square root of everything

$\sqrt{0.060} = \sqrt{\frac{x^2}{(.30-x)^2}}$

$0.245 = \frac{x}{.30-x}$

$.0735 - .245x = x$

$.0735 = 1.245x$ $\boxed{x = 0.059}$

Solution with + without Simplifying Assumption

$$A \rightleftharpoons 2B + C \qquad K_c = 2.0 \times 10^{-8}$$

<u>with</u>

	A	2B	C
I	0.20	0	0
C	$-x$	$2x$	x
E	$.20-x$	$2x$	x
E*	0.20	x	x

so $K = 2.0 \times 10^{-8} = \dfrac{(2x)^2 x}{0.20} = \dfrac{4x^3}{.20}$

$0.4 \times 10^{-8} = 4x^3$ $\boxed{\text{Easy}}$

$x^3 = 1.0 \times 10^{-9}$ $\boxed{x = 1.0 \times 10^{-3}}$

<u>without</u> (Using $.20-x$ for [A] at eq)

$K = 2.0 \times 10^{-8} = \dfrac{(2x)^2 x}{.20 - x}$

so $2.0 \times 10^{-8} (0.20 - x) = 4x^3$

so $4.0 \times 10^{-9} - 2.0 \times 10^{-8} x = 4x^3$

so $4x^3 + 2.0 \times 10^{-8} x - 4.0 \times 10^{-9} = 0$

$\boxed{\text{Not Easy !!}}$

14.6 Response when an Eq. is Disturbed

"Steady state at equilibrium. But what if something does change? If we want a conc. to change, can we cause that?" (acid rain, lake acidity ---)

Le Chatelier's Principle: when system is disturbed from eq, it responds so as to ① reach a new eq. (usually same K, but different concs) and ② partially counteract the change

Qual: if something added, react to remove
" " removed, " " replace

3 Factors

① Concentrations
② Temp
③ volume

Goals

① restore $Q = K$
② offset change

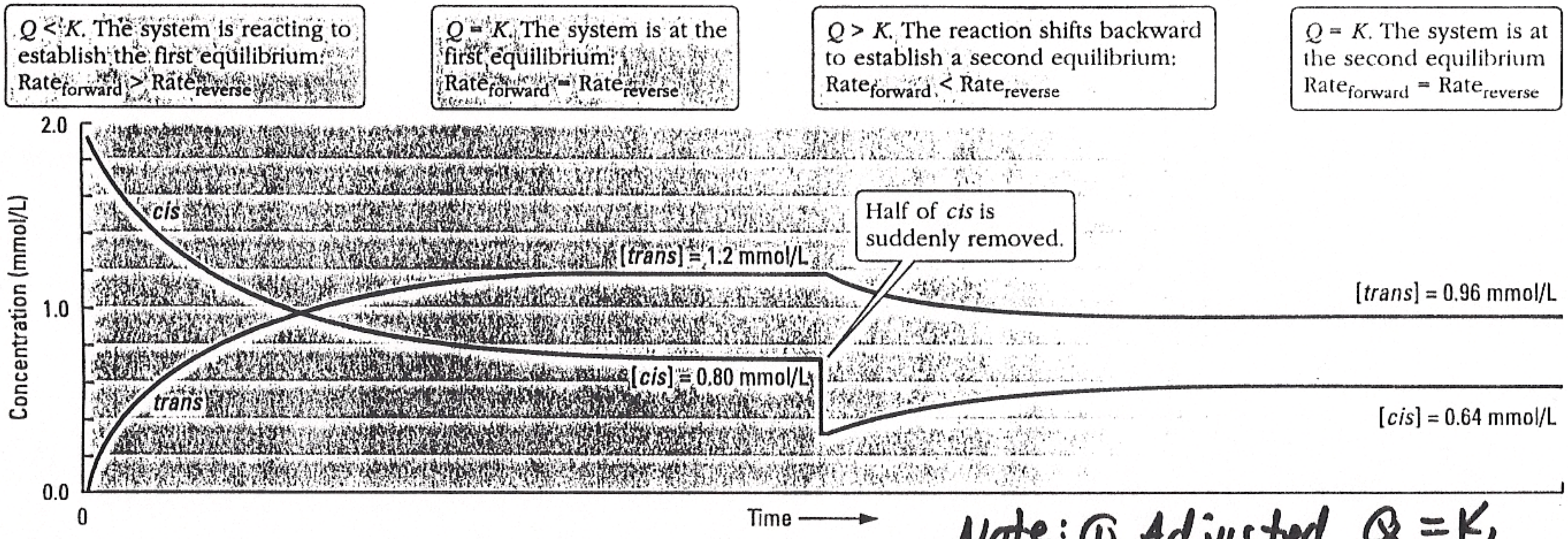
A. Concentration

- if you add (or remove) a chem, at that moment $Q \neq K$
- system (and concs) will shift forward or backward to adjust Q so $Q = K$
- Note: K value does not change
- many chemical ways to remove a chem (precipitation, acid-base, etc)

p. 1444

$Q = 1.5$
$K = 1.5$

$Q = 1.5$
$K = 1.5$



$Q < K$. The system is reacting to establish the first equilibrium: $\text{Rate}_{\text{forward}} > \text{Rate}_{\text{reverse}}$

$Q = K$. The system is at the first equilibrium: $\text{Rate}_{\text{forward}} = \text{Rate}_{\text{reverse}}$

$Q > K$. The reaction shifts backward to establish a second equilibrium: $\text{Rate}_{\text{forward}} < \text{Rate}_{\text{reverse}}$

$Q = K$. The system is at the second equilibrium $\text{Rate}_{\text{forward}} = \text{Rate}_{\text{reverse}}$

Half of *cis* is suddenly removed.

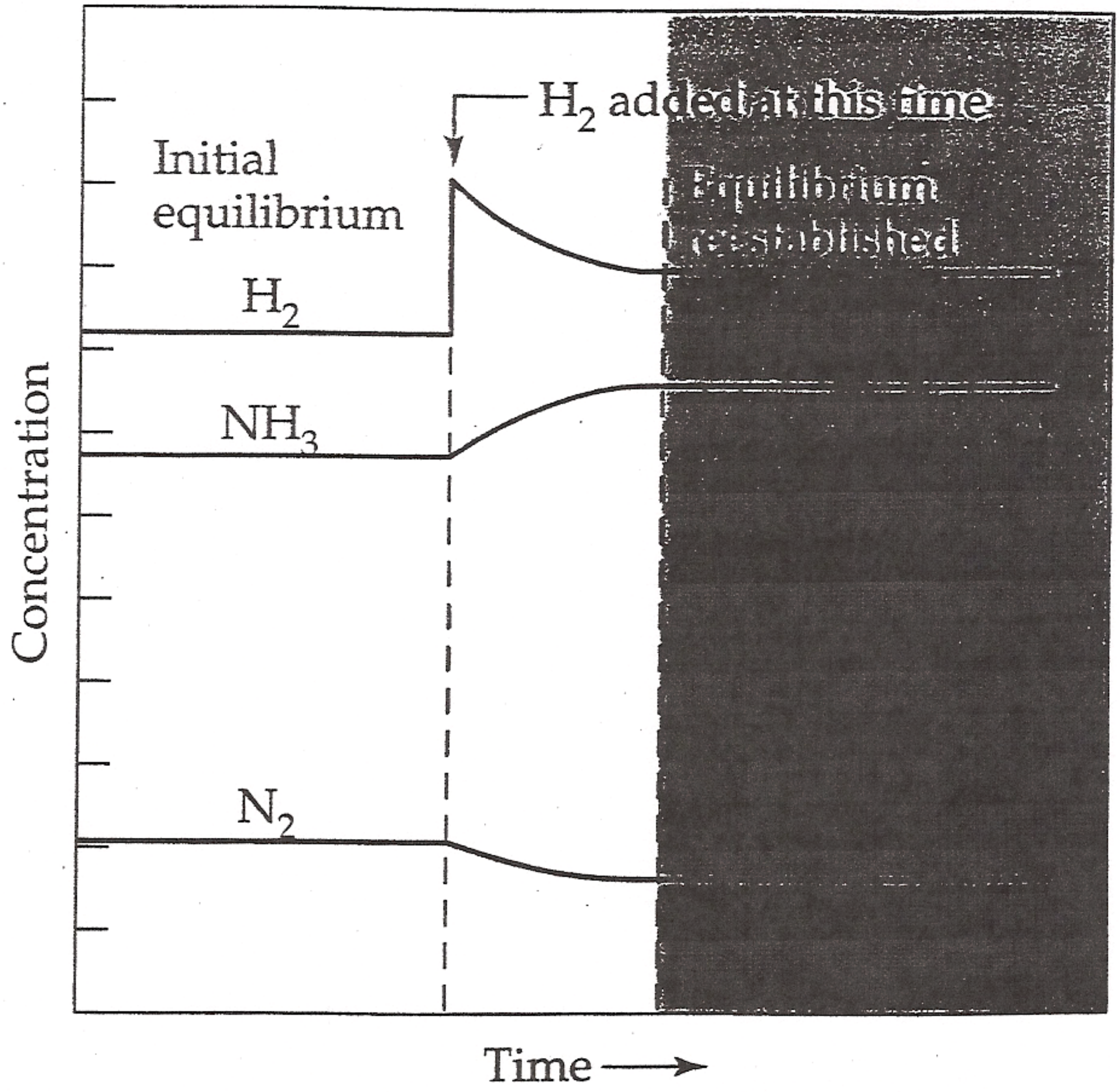
Moore/St[illegible]tski/Jurs, Chemistry: The Molecular Science
Figure 14.[illegible]

Note: ① Adjusted $Q = K$,
but specific concentrations
have changed
② Final [cis] isn't as low
as right after disruption,
but change only parti[illegible]

T–120

Fig. 15.11 Reestablish Equilibrium

$N_2 + 3H_2 \rightleftharpoons 2NH_3$



① Note: Adjusted Q = K, but final concs different from original

② Disruption of $[H_2]$ is counteracted, partially

CHEMISTRY: The Central Science 7/e
by Brown/Lemay/Bursten

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$$A + B \rightleftharpoons C + D$$

Disruption	Immediate Impact on Q	Direction to Restore Eq	Response of			
			[A]	[B]	[C]	[D]
Add A	Q < K	forward	↓	↓	↑	↑
Add B						
Add C						
Add D						
Remove A						
Remove B						
Remove C						
Remove D						

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$$A + B \rightleftharpoons C + D$$

Disruption	Immediate Impact on Q	Direction to Restore Eq	Response of			
			[A]	[B]	[C]	[D]
Add A	$Q < K$	forward	↓	↓	↑	↑
Add B	$Q < K$	⟶	↓	↓	↑	↑
Add C	$Q > K$	⟵	↑	↑	↓	↓
Add D	$Q > K$	⟵	↑	↑	↓	↓
Remove A	$Q > K$	⟵	↑	↑	↓	↓
Remove B	$Q > K$	⟵	↑	↑	↓	↓
Remove C	$Q < K$	⟶	↓	↓	↑	↑
Remove D	$Q < K$	⟶	↓	↓	↑	↑

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B. Volume (when gases involved)

- volume changes change concs, at instant of change $Q \neq K$

offset change

Qual: when volume expands, want more gas to fill it

" " shrinks, want to get rid of gas

Disruption	Response
Volume Increase	Shift toward side with more gas
Volume Decrease	" " less

- if moles of gas equal, no impact
- note: K unchanged

C. Temp

- heat viewed as reactant (endo, $\Delta H > 0$) or product (exo, $\Delta H < 0$).

offset change

- with temp change, system responds to remove heat (after temp increase) or replace heat (after temp decreased)
- K changes!!

Temp Increase	$\Delta H > 0$	forward	K increases
	$\Delta H < 0$	reverse	K decreases

D. Catalyst: get to eq. faster, but otherwise no impact

14.7 Skim: Eq. favor more stable chems

kH6

① $2H_2(g) + O_2(g) \rightleftharpoons 2H_2O(g)$

Volume Change	Direction to Restore Eq	Response of $[H_2]$	$[O_2]$	$[H_2O]$
Increase				
Decrease				

② $A \rightleftharpoons B$ $\Delta H < 0$

-write in "heat" as reactant or product

Temp Change	Direction to Restore Eq	Response of $[A]$	$[B]$	K
Increase				
Decrease				

③ $A \rightleftharpoons B$ $\Delta H > 0$

Temp	Response	$[A]$	$[B]$	K
Increase				
Decrease				

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① $2H_2(g) + O_2(g) \rightleftharpoons 2H_2O(g)$

Volume Change	Direction to Restore Eq	Response of $[H_2]$	$[O_2]$	$[H_2O]$
Increase	←	↑	↑	↓
Decrease	→	↓	↓	↑

② $A \rightleftharpoons B + \text{heat} \quad \Delta H < 0$

-write in "heat" as reactant or product

Temp Change	Direction to Restore Eq	Response of $[A]$	$[B]$	K
Increase	←	↑	↓	↓
Decrease	→	↓	↑	↑

③ $\text{heat} + A \rightleftharpoons B \quad \Delta H > 0$

Temp	Response	$[A]$	$[B]$	K
Increase	→	↓	↑	↑
Decrease	←	↑	↓	↓

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$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H = -9$$

Disruption	Direction to Restore Eq	Response of $[N_2]$	$[H_2]$	$[NH_3]$	K
1. Raise temp					
2. Increase volume					
3. Add N_2					
4. Remove NH_3					
5. Lower temp					
6. Add NH_3					
7. Remove N_2					
8. Reduce Volume					

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$\text{heat} + N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ $\Delta H=$

Disruption	Direction to Restore Eq	Response of $[N_2]$	$[H_2]$	$[NH_3]$	K
1. Raise temp	→	↓	↓	↑	↑
2. Increase volume	←	↑	↑	↓	—
3. Add N_2	→	↓	↓	↑	—
4. Remove NH_3	→	↓	↓	↑	—
5. Lower temp	←	↑	↑	↓	↓
6. Add NH_3	←	↑	↑	↓	—
7. Remove N_2	←	↑	↑	↓	—
8. Reduce Volume	→	↓	↓	↑	—