Ch16 Chemical Equilibrium Exercises

21c) $K = \frac{[CS_2][H_2]^4}{[CH_4][H_2S]^2}$ d) $K = \frac{[CO_2]^2}{[CO]^2[O_2]}$

23) The K_{eq} is much smaller than 1 so reactants will be favored. (independent of initial concs)

24)

a	8	2	2	Cl_2
b	6	4	4	Br_2
c	3	7	7	I_2
	P	R		

$K_{Cl_2} > K_{Br_2} > K_{I_2}$

25 data

	H_2	I_2	HI
(i)	10	10	0
(ii)	7	7	6
(iii)	5	5	10
(iv)	4	4	12
(v)	3	3	14
(vi)	3	3	14

25) a) eq by step V since conc same at v1

b) reach eq faster

c) same amt catalyst ↑ speed but does not change eq conditions

26) The K_{eq} gives the ratio of products to reactants at eq it does not say how long it takes to reach eq so the rxn w/ the smaller K_{eq} must have faster kinetics

27) a) $K = \frac{1}{2.26 \times 10^4} = 4.42 \times 10^{-5}$ R favored b) ½ conc $K = (2.26 \times 10^4)^{1/2} = 1.50 \times 10^2$ P favored

c) ~~$K = \frac{1}{(2.26 \times 10^4)^2} = 1.95 \times 10^{-9}$ R favored~~

29) $N_2 + O_2 \rightleftharpoons 2NO$ $\frac{1}{2.1 \times 10^{30}}$

$2NO + Br_2 \rightleftharpoons 2NOBr$ $(5.3)^2$

$N_2 + O_2 + Br_2 \rightleftharpoons 2NOBr$ $K = \frac{(5.3)^2}{2.1 \times 10^{30}} = 1.3 \times 10^{-29}$

31) b) $K_p = K_c (RT)^{\Delta n}$ $K_c = \frac{K_p}{(RT)^{\Delta n}}$

$K_c = \frac{7.7 \times 10^{24}}{(0.08206 \times 298)^{4-2}} = 1.3 \times 10^{22}$

c) ~~$K_c = \frac{81.9}{(0.08206 \times 298)^{2-2}} = 81.9$~~

32 b) $K_p = (3.7 \times 10^8)(0.08206 \times 298)^{2-4} = 6.2 \times 10^5$

33 a) $K_{eq} = \frac{[HCO_3^-][OH^-]}{[CO_3^{-2}]}$ b) $K_{eq} = [O_2]^3$

35) $K_c = \frac{[CH_3OH]}{[CO][H_2]^2} = \frac{(0.185)}{(0.105)(0.114)^2} = 136$

37) $K_c = \frac{[NH_3]^2}{[N_2][H_2]^3} = \frac{(0.439)^2}{(0.115)(0.105)^3} = 1.45 \times 10^3$

~~$9.6 = \frac{(0.128)^2}{(0.110)\,x^3}$ $x = 0.249$~~

~~$0.0584 = \frac{x^2}{(0.120)(0.140)^3}$~~

~~$x = 0.00439$~~

39) $P_{NO} = 108 \text{ torr} \times \frac{1 \text{ atm}}{760} = 0.1421 \text{ atm}$

$P_{Br_2} = 126 \text{ torr} \times \frac{1}{760} = 0.1658 \text{ atm}$

$K_p = \frac{(P_{NOBr})^2}{(P_{NO})^2(P_{Br_2})}$ ↵ must be in atm

$28.4 = \frac{x^2}{(0.1421)^2(0.1658)}$

$x = 0.308 \text{ atm} = 234 \text{ torr}$

41)

	A	⇌	2B
I	1.32		0
C	−x		+2x
E	0.25		2x

$x = 1.07 \quad 2x = 2.14$

$K_p = \frac{(P_B)^2}{(P_A)} = \frac{(2.14)^2}{(0.25)} = 18$

43) $Fe^{+3} + SCN^- \rightleftharpoons FeSCN^{+2}$

$K_c = \frac{[FeSCN^{+2}]}{[Fe^{+3}][SCN^-]}$

	Fe^{+3}	SCN^-	$FeSCN^{+2}$
I	1.0×10^{-3}	8.0×10^{-4}	0
C	-1.7×10^{-4}	-1.7×10^{-4}	$+1.7\times10^{-4}$
E	8.3×10^{-4}	6.3×10^{-4}	1.7×10^{-4}

$= \frac{1.7\times10^{-4}}{(8.3\times10^{-4})(6.3\times10^{-4})}$

$= 330$

45) $\frac{0.763\,g\,H_2}{3.67\,L} \times \frac{1\,mol\,H_2}{2.016\,g} = 0.103\,M$ $\quad \frac{96.9\,g\,I_2}{3.67\,L} \times \frac{1\,mol\,I_2}{253.8\,g} = 0.104\,M$

$\frac{90.4\,g\,HI}{3.67\,L} \times \frac{1\,mol\,HI}{127.9\,g\,HI} = 0.193\,M$

	H_2	+	I_2	⇌	2 HI
I	0.103		0.104		0
C	−0.0965		−0.0965		+0.193
E	0.0065		0.0075		0.193

$K_c = \frac{[HI]^2}{[H_2][I_2]} = \frac{(0.193)^2}{(0.0065)(0.0075)}$

$= 764$

47) $Q = [NH_3][H_2S] = (0.166)(0.166) = 0.0276 = 2.76\times10^{-2}$ $\quad K_c = 8.5\times10^{-3}$

$Q > K_c$ so the rxn will shift left so more solid will form

49) $\frac{6.55\,g\,Ag_2SO_4}{1.5\,L\,soln} \times \frac{1\,mol}{311.81\,g} = 0.0140\,M\ Ag_2SO_4$ dissolved so $[Ag^+] = 2(0.0140\,M)$

$[SO_4^{-2}] = 0.0140\,M$

$Q = [Ag^+]^2[SO_4^{-2}]$

$= (0.0280)^2(0.0140) = 1.1\times10^{-5}$

$Q = K$ so system is at eq + soln is sat No more solid will dissolve

50) ~~$K_c = \frac{K_p}{(RT)^{\Delta n}} = \frac{(6.7)}{(0.08206)(298)} = 164$~~ $\quad Q = \frac{[N_2O_4]}{[NO]^2} = \frac{\left(\frac{0.082\,mol}{2.25\,L}\right)}{\left(\frac{0.055\,mol}{2.25\,L}\right)^2} = 61$

~~$Q < K_c$ so rxn will shift to right~~

53)

	N_2O_4	⇌	$2NO_2$
I	0.0500		0
C	−x		+2x
E	0.0500−x		2x
	0.0115 M		0.0770 M

$Q = \frac{[NO_2]^2}{[N_2O_4]} = \frac{0}{0.0500} = 0$ $\quad Q < K$ rxn $\rightarrow$

$K_c = \frac{[2x]^2}{(0.500-x)} = 0.513$ $\quad 4x^2 + 0.513x - 0.02565 = 0$ (a, b, c)

$x = -0.1667$ or 0.0385

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

54) $CO + Cl_2 \rightleftharpoons COCl_2$

$Q = \frac{[COCl_2]}{[CO][Cl_2]} = \frac{0}{(0.1500)(0.175)} = 0$ $Q < K$ rxn →

	CO	Cl_2	$COCl_2$
I	0.1500	0.175	0
C	−x	−x	+x
E	0.1500 − x	0.175 − x	x
	0.01378	0.03878	0.13622

$K_c = \frac{x}{(0.1500-x)(0.175-x)} = 255$

$255x^2 - 83.875x + 6.69375 = 0$

$x = 0.1927$ or 0.13622

55) $NiO + CO \rightleftharpoons Ni + CO_2$ $Q = \frac{[CO_2]}{[CO]} = 0$ $Q < K$ rxn →

	CO	CO_2
I	0.20	0
C	−x	+x
E	0.20 − x	x
		0.199 M

$K_c = \frac{x}{(0.20-x)} = 4.0 \times 10^3$ $x = 0.199$

large K means rxn essentially goes to completion

56) $CO + H_2O \rightleftharpoons CO_2 + H_2$ $Q = 0$ $Q < K$ rxn →

	CO	H_2O	CO_2	H_2
	0.110	0.110	0	0
	−x	−x	+x	+x
	0.110 − x	0.110 − x	x	x
	0.010	0.010	0.100	0.100

$K_c = \frac{x^2}{(0.110-x)^2} = 102$ $\frac{x}{0.110-x} = \sqrt{102}$

$x = 0.100$

57) $HC_2H_3O_2 + H_2O \rightleftharpoons H_3O^+ + C_2H_3O_2^-$

	$HC_2H_3O_2$	H_2O	H_3O^+	$C_2H_3O_2^-$
	0.210		0	0
	−x		+x	+x
	0.210 − x		x	x
	0.208		0.00194	0.00194

$K_c = \frac{[H_3O^+][C_2H_3O_2^-]}{[HC_2H_3O_2]} = \frac{x^2}{0.210-x} = 1.8 \times 10^{-5}$

WA so assume x is small compared to 0.210

$x = 0.00194$

Check $\frac{0.00194}{0.210} \times 100 = 0.92\%$ valid assumption

61) a) $A \rightleftharpoons B + C$

	A	B	C
I	1.0	0	0
C	−x	+x	+x
E	1.0 − x	x	x

$K = \frac{[B][C]}{[A]} = \frac{x^2}{1.0-x} = 1.0$

$x^2 + x - 1 = 0$

$x = 0.618$

$K_c = 1.0$

b) $x = 0.09512$

c) $\frac{x^2}{1.0-x} = 1.0 \times 10^{-5}$ x small compared to 1.0

$x = 0.00316$

63) a) shift L

b) shift R

c) shift R

65 a) L

b) No change

c) "

d) L

67) a) ↑V ↓P shift R to more moles (gas)

b) ↓V ↑P shift L

c) ↓V ↑P No change (equal moles)

(69) ↑ T adds heat since rxn is endo shift → Conc of products ↑
conc products ↓ value of K will ↑

71) a) No change b) Shift R ✓ c) rxn is exo shift L d) ↓V ↑P shift R ✓
e) catalyst speeds up rxn reaches eq faster f) No change

77) $P_1V_1 = P_2V_2$ $(0.0260\,atm)(10.0L) = P_2(0.100L)$ $P_2 = 2.60\,atm$

$MgCO_{3(s)} \rightleftharpoons MgO_{(s)} + CO_{2(g)}$

2.60
−x
2.60−x

$K_p = P_{CO_2} = 0.0260 = 2.60 - x$

$x = 2.579\,atm$

$0.0248\,mol\,MgO \times \frac{1\,mol\,MgCO_3}{1\,mol\,MgO} \times \frac{84.3\,g}{1\,mol}$

$= 2.09\,g\,MgCO_3$

$n = \frac{PV}{RT} \quad \frac{(2.579)(10.0)}{(0.08206)(650)} = 0.4835\,mol\,CO_2$ ER

$1.0\,g\,MgO \times \frac{1\,mol}{40.30\,g} = 0.0248\,mol\,MgO$ LR

79) a) ↑V ↓P Shift L b) Shift R ✓ c) ↓T removes heat rxn will shift R to produce heat ✓
d) shift R ✓

81) Rxn 1 $H_2 + I_2 \rightleftharpoons 2HI$

0.958 0.877 0.020

$K_p = \frac{(0.020)^2}{(0.958)(0.877)} = 4.76 \times 10^{-4}$

Rxn 2 0.621 0.621 0.101

+x +x −2x

0.621+x 0.621+x 0.101−2x

$Q = \frac{(0.101)^2}{(0.621)^2} = 0.0264$

Q > K shift L

$K_p = \frac{(0.101-2x)^2}{(0.621+x)^2} = 4.76 \times 10^{-4}$ $x = 0.0433$