

NUMERICAL ANSWERS TO ASSIGNED TUTORIAL PROBLEM SETS FOR CHEM206  
 FROM KOTZ & TREICHEL'S CHEMISTRY & CHEMICAL REACTIVITY, 6<sup>th</sup> Ed.

**NOTE: the answers from Ch.16 have not been verified. Please report any errors.**

Ch.	Q#	Answer	Units	SFs	Comments
16	2a				$K = \frac{[O_3]^2}{[O_2]^3}$ and $K_p = \frac{(P_{O_3})^2}{(P_{O_2})^3}$
	2b				$K = \frac{[Fe(CO)_5]}{[CO]^5}$ and $K_p = \frac{(P_{Fe(CO)_5})}{(P_{CO})^5}$
	2c				$K = [NH_3]^2[CO_2][H_2O]$ and $K_p = (P_{NH_3})^2(P_{CO_2})(P_{H_2O})$
	2d				$K = [Ag^+]^2[SO_4^{2-}]$ and no $K_p$ since no gases involved
16	4	3800	unitless	2	= Q, rxn quotient. $Q > K$ , so rxn not yet at eqm. $[NO_2]$ will increase as system proceeds toward equilibrium
16	6	$5.0 \times 10^{-4}$	unitless	2	= Q. $Q < K$ , not yet at eqm. Rxn will proceed to RIGHT to form more products
16	8	279	unitless	3	= K, based on concentrations (i.e., $K_c$ ).
16	10a	1.6		2	= $K_c$
	10b	0.028	mol	2	moles of CO present at eqm; moles of water is same; in 2L... use eqm expression and ICE table to solve for x ( $x = 0.014$ mol/L)
16	14	$1.7 \times 10^{-3}$	mol	2	= $[C_5H_9CH_3]$ at eqm; $[C_6H_{12}] = 0.014$
16	16a	0.0636	moles	3	= moles $NO_2$ at eqm K expression & ICE table...solve for x using quadratic equation
	16b	18.8	%	3	percent of $N_2O_4$ dissociated at eqm
16	18	$4 \times 10^{-4}$	g	1	amount of $I_2$ remaining in water layer at eqm
16	20				second equation has been reversed and multiplied by $\frac{1}{2}$ so: $K_2 = \frac{1}{(K_1)^{1/2}}$
16	24	2.4	unitless	2	= eqm constant for net rxn: add rxns $\Rightarrow$ multiply K's to find net K
16	26a	Adding more $Br_2$ will cause eqm to shift left (rxn proceeds left to reach eqm...more reactants at new eqm)			
	26b	removing some $NOBr$ will shift eqm to left			
	26c	decreasing temperature will shift eqm to left			
	26d	increasing container volume $\Rightarrow$ decreases P $\Rightarrow$ shifts to right			

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16	28	When T raised: rxn consumes reactants more quickly (endothermic fwd rxn) thus eqm "shifts right". Adding solid $\text{NH}_4\text{SH}$ has no effect (as long as IS present...). Adding $\text{NH}_3$ (a product) causes eqm to shift left. Removing $\text{H}_2\text{S}$ , a product, causes shift to right, increasing $P_{\text{NH}_3}$			
16	30a	0.041	unitless	2	$= K_{\text{new}} = (K_{\text{original}})^{1/2}$ ....original equation multiplied by $1/2$
	30b	590	unitless	2	$= K_{\text{new}} = 1/K_{\text{original}}$ ....original equation reversed
16	32	0.0273	M	3	$= [\text{CCl}_4]_{\text{eqm}}$
16	34	54	unitless	2	= eqm constant
16	36ab	$2.8 \times 10^{-4}$	unitless	2	= Q; $Q < K$ , so system is not at equilibrium; rxn will proceed right.
	36c	Use ICE table...take square root of both sides of K expression, & solve for x (= conc. decrease for $\text{N}_2$ ...)			
		0.25	M	2	$= [\text{N}_2]_{\text{eqm}} = [\text{O}_2]_{\text{eqm}}$
		0.102	M	3	$= [\text{NO}]_{\text{eqm}}$ ...note 3 SF because of SF rules for adding...
16	40a	The addition of a product, CO, will shift the equilibrium to the left.			
	40b	Use ICE table & K expression solve for x (= conc. decrease for $\text{COBr}_2$ ...) with quadratic formula			
		0.211	M	3	$= [\text{COBr}_2]_{\text{eqm}}$ (using SF rules for adding...)
		1.039	M	4	$= [\text{CO}]_{\text{eqm}}$
		0.039	M	2	$= [\text{Br}_2]_{\text{eqm}}$
	40c	57.1	%	3	= % $\text{COBr}_2$ decomposed BEFORE adding CO...
		16	%	2	= new % $\text{COBr}_2$ decomposed... Thus, adding CO decreased the amount of $\text{COBr}_2$ decomposed.
16	44	0.116	atm	3	$= P_{\text{tot}} = P_{\text{NH}_3} + P_{\text{CO}_2}$ ...assume container was initially evacuated
		0.0387	atm	3	$= P_{\text{CO}_2} = 1/3 P_{\text{tot}}$ because of stoichiometry
		0.0774	atm	3	$= P_{\text{NH}_3} = 2 P_{\text{CO}_2}$ because of stoichiometry
		$2.31 \times 10^{-4}$	unitless	3	$= K_p$
16	46a	$2.3 \times 10^{-4}$	M	2	= x = amount of dimer formed
		$4.6 \times 10^{-4}$	M	2	= 2x = amount of acetic acid converted to dimer...
		84	%	2	= % acetic acid converted to dimer
	46b	Formation of hydrogen bonds (to make dimer) is exothermic $\therefore$ $\uparrow$ temperature will shift eqm to left.			
16	48	Use $P_{\text{N}_2\text{O}_4} = P_{\text{tot}} - P_{\text{NO}_2}$ in K expression & solve for $P_{\text{NO}_2}$ ...			
		0.40	atm	2	$= P_{\text{NO}_2}$
		1.1	atm	2	$= P_{\text{N}_2\text{O}_4}$
16	50a	$2.1 \times 10^5$	unitless	2	= Q; $Q < K$ so rxn will proceed forward to reach equilibrium
	50b	-199.9	kJ	4	= $\Delta H^\circ$ ; exothermic forward rxn. Increasing T will shift eqm to left. The product concentrations will decrease.

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16	54a	0.0496	M	3	= $[\text{SO}_2\text{Cl}_2]_0$ ...sub into K expression; use quadratic formula...	
		0.030	M	2	= $x = [\text{SO}_2]_{\text{eqm}} = [\text{Cl}_2]_{\text{eqm}}$ ...	
		0.020	M	2	= $[\text{SO}_2\text{Cl}_2]_{\text{eqm}}$	
		0.60	unitless	2	= fraction $\text{SO}_2\text{Cl}_2$ dissociated	
	54b	0.0188	M	3	= $[\text{Cl}_2]_0$ ...sub into K expression; use quadratic formula...	
		0.025	M	2	= $x = [\text{SO}_2]_{\text{eqm}}$	
		0.030	M	2	= $[\text{Cl}_2]_{\text{eqm}}$	
		0.025	M	2	= $[\text{SO}_2\text{Cl}_2]_{\text{eqm}}$	
		0.50	unitless	2	= fraction $\text{SO}_2\text{Cl}_2$ dissociated	
	54c	Le Chatelier's principle predicts that the addition of $\text{Cl}_2(\text{g})$ , a product, would shift the equilibrium to the left. This prediction is confirmed by these calculations.				
	16	56	18.5	g	3	= mass of $\text{CaCO}_3$ . Found by finding $P_{\text{CO}_2} = 3.87$ atm & using ideal gas law to calculate moles $\text{CO}_2$ ... then rxn's stoichiometry to find moles $\text{CaCO}_3$
	16	57	$1.7 \times 10^{18}$	O atoms	2	<i>see solutions manual...</i> First: convert $K_p$ to $K_c$ (more convenient to work with) $K_c = 8.12 \times 10^{-13}$ Use K and ICE table, & use quadratic formula OR approximation To solve for $x = 1.4 \times 10^{-7}$ ...find $[\text{O}] = 2x$ ... use molarity to calc. moles of O atoms...convert to # atoms with Avogadro's #
	16	60a	0.013	unitless	2	= $K_c$
		60b	1.16	atm	3	= $P_{\text{CO}_2}$
60c		0.013	mol/L	2	= $K_c = [\text{CO}_2]$	
		12	g	2	= mass $\text{CaCO}_3$ decomposed...found via stoichiometry.	
		45	%	2	= % undecomposed	
16	63a	false: magnitude of eqm constant is always dependent on temp.				
	63b	true				
	63c	false: eqm constant (K) for a rxn is reciprocal of K for the reverse rxn				
	63d	true				
	63e	false: $K_p = K_c(\text{RT})^1$				
16	66	This is a dynamic equilibrium. Initially, the rate of evaporation is greater than the rate of condensation. At equilibrium, the two rates are equal.				
16	68	System not at eqm since continues to absorb heat from surr. T of ice/water mix remains at $0^\circ\text{C}$ until all ice melted, then T rises as more heat gained from surr (not at $0^\circ\text{C}$ ). Only if beaker was in perfectly isolated compartment would it stay at $0^\circ\text{C}$ , equilibrated. Eqm for this mixture: molecules moving from solid $\rightarrow$ liquid at same rate as molecules moving from liquid to solid; quantity of ice will not change. Expt: if add a $\text{D}_2\text{O}$ (heavy water) ice cube to some $\text{H}_2\text{O}(\text{l})$ , eqm would be attained...amount of $\text{D}_2\text{O}$ in liquid phase would continue to increase because of the dynamic nature of eqm... exchange of molecules liquid $\leftrightarrow$ solid. Could measure $\text{D}_2\text{O}$ content of the liquid to prove "dynamic" eqm.				

Ch.	Q#	Answer	Units	SFs	Comments
16	70a	[B] will immediately increase, and the blue colour will become darker.			
	70b	The reaction equilibrium will shift to the side with fewer molecules (because the flask size has been halved, causing a sudden increase in pressure). Thus, it will shift toward the blue molecules, and the blue colour will become even more pronounced.			
16	72a	142	unitless	3	= K ... [Fe <sup>3+</sup> ] does not go to zero...
	72b				[Fe <sup>3+</sup> ] = [SCN <sup>-</sup> ] at equilibrium, & these ions have highest conc.
	72c	2.64x10 <sup>-3</sup>	M	3	= [Fe <sup>3+</sup> ] <sub>eqm</sub>
		3.64x10 <sup>-3</sup>	M	3	= [SCN <sup>-</sup> ] <sub>eqm</sub>
		1.36x10 <sup>-3</sup>	M	3	= [FeSCN <sup>2+</sup> ] <sub>eqm</sub>