Practice Quiz Equilibrium
AP Chemistry
1. 1995 A

$$CO_2(g) + H_2(g) \rightleftarrows H_2O(g) + CO(g)$$
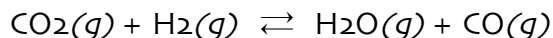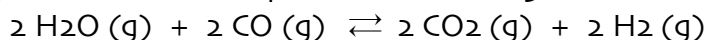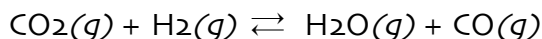
When $H_2(g)$ is mixed with $CO_2(g)$ at 2,000 K, equilibrium is achieved according to the equation above. In one experiment, the following equilibrium concentrations were measured.
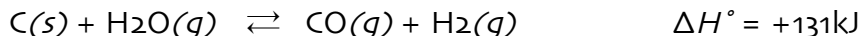
[H2] = 0.20 mol/L   [CO2] = 0.30 mol/L   [H2O] = [CO] = 0.55 mol/L

(a)   What is the mole fraction of $CO(g)$ in the equilibrium mixture?
(b)   Using the equilibrium concentrations given above, calculate the value of K_c, the equilibrium constant for the reaction.
(c)   i) Determine K_p in terms of K_c for this system.
        ii) Using Kp from (i), what would be Kp' for the following rxn?

$$2 H_2O (g) + 2 CO (g) \rightleftarrows 2 CO_2 (g) + 2 H_2 (g)$$

(d)   When the system is cooled from 2,000 K to a lower temperature, 30.0 percent of the $CO(g)$ is converted back to $CO_2(g)$. Calculate the value of K_c at this lower temperature.
(e)   In a different experiment, 0.50 mole of $H_2(g)$ is mixed with 0.50 mole of $CO_2(g)$ in a 3.0-liter reaction vessel at 2,000 K. Calculate the equilibrium concentration, in moles per liter, of $CO(g)$ at this temperature.

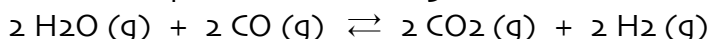2. 1998 D $C(s) + H_2O(g) \rightleftarrows CO(g) + H_2(g)$ $\Delta H° = +131kJ$
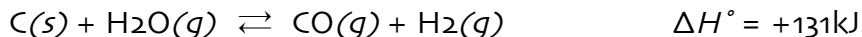
A rigid container holds a mixture of graphite pellets ($C(s)$), $H_2O(g)$, $CO(g)$, and $H_2(g)$ at equilibrium. State whether the number of moles of $CO(g)$ in the container will increase, decrease, or remain the same after each of the following disturbances is applied to the original mixture. Explain each answer with a short statement.

(a)   Additional $H_2(g)$ is added to the equilibrium mixture at constant volume.
(b)   The temperature of the equilibrium mixture is increased at constant volume.
(c)   The volume of the container is decreased at constant temperature.
(d)   The graphite pellets are pulverized.

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The overall dissociation of oxalic acid, $H_2C_2O_4$, is represented below. The overall dissociation constant is also indicated.

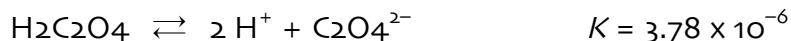$$H_2C_2O_4 \rightleftharpoons 2\,H^+ + C_2O_4^{2-} \qquad\qquad K = 3.78 \times 10^{-6}$$
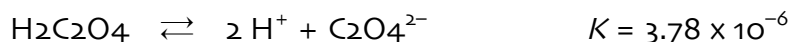
(a)   What volume of 0.400-molar NaOH is required to neutralize completely a 5.00×10^{-3}-mole sample of pure oxalic acid?
(b)   Give the equations representing the first and second dissociations of oxalic acid. Calculate the value of the first dissociation constant, K_1, for oxalic acid if the value of the second dissociation constant, K_2, is 6.40×10^{-5}.
[acid/base equilibrium chemistry starts here↓]
(c)   To a 0.015 molar solution of oxalic acid, a strong acid is added until the pH is 0.5. Calculate the $[C_2O_4^{2-}]$ in the resulting solution. (Assume the change in volume is negligible.)
(d)   i) Calculate the value of the equilibrium constant, K_b, for the reaction that occurs when solid $Na_2C_2O_4$ is dissolved in water.
        ii) Write a HYDROLYSIS reaction for the salt, $Na_2C_2O_4$.

STUDY YOUR SYLLABUS!!

PRACTICE QUIZ/EQUILIBRIUM ANSWERS:

<u>1995 A</u>

A) $0.55 + 0.55 + 0.30 + .20 = 1.6 mol L^{-1}$ $CO = 0.55 mol L^{-1}$ $.55/1.6 = 0.34 = X_{CO}$

B) $Kc = \dfrac{[CO][H_2O]}{[CO_2][H_2]} = \dfrac{[.55][.55]}{[.30][.20]} = Kc = 5.0$

C) (i) $Kp = Kc(RT)^{\Delta n}$ $\Delta n = 0$ So, $Kp = Kc = 5.0$
   (ii) The reaction was reversed and all of the coefficients were doubled. $Kp' = 1/(Kp)^2$

D) $.55(.30) = 0.165 \rightarrow 0.17 mol L^{-1}$ lost

$0.55 - 0.17 = 0.38$ mol CO and H_2O/L
$\rightarrow$ Since all chemicals are in 1:1 ratio, 0.17 mol/L of CO_2 and H_2O will be gained.

$0.30 + 0.17 = 0.47 = [CO_2]$ $Kc = \dfrac{[CO][H_2O]}{[CO_2][H_2]} = \dfrac{[.38][.38]}{[.47][.37]} = 0.83$ shifts left!
$0.20 + 0.17 = 0.37 = [H_2]$

E)

	CO_2	+	H_2	$\rightleftarrows$	H_2O	+	CO
I	.5mol$\frac{}{3 L}$		.5mol$\frac{}{3L}$				
	= 0.17M		= 0.17M		0		0
C	-x		-x		+x		+x
E	0.17 – x		0.17 – x		x		x

$Kc = \dfrac{x^2}{(0.17 - x)^2} = 5.0$

$\sqrt{x^2/(0.17 - x)^2} = \sqrt{(5.0)}$

$x/(0.17 - x) = 2.2$

$[CO] = x = 0.38 - 2.2x \rightarrow 3.2x = 0.38 \rightarrow [CO] = x = 0.38/3.2 = 0.12$

<u>1998 D</u>

$$heat + C + H_2O \rightleftarrows CO + H_2$$

A) Q > K, the reaction will shift left $\propto$ [CO] $\downarrow$.

B) Endothermic reactions will shift right when heat is added $\propto$ [CO] $\uparrow$.

C) $\downarrow$ V $\propto$ $\uparrow$ P The reaction will shift to the side with the least moles (coefficients) of gas.
    The reaction will shift left $\propto$ [CO] $\downarrow$.

D) Pulverizing the carbon pellets will increase the surface area $\propto$ $\uparrow$ rate.
    This does not affect K (the equilibrium constant). No Δ in [CO].

<u>1997 A</u>

A) 5.00×10^{-3} mol acid $\times \dfrac{2 \text{ mol } OH^-}{1 \text{ mol oxalic}} = 0.400$ mol OH^-/L

0.0100 mol OH^- = $.400$ mol OH^-/L $\times$ Z liters

Z liters = $.0100/.400 = .0250$ L OR 25.0 mL.

B) $Ka_{total} = Ka_1 \times Ka_2$ $3.78 \times 10^{-6} = Ka_1 \times 6.40 \times 10^{-5}$ $Ka_1 = \dfrac{3.78 \times 10^{-6}}{6.40 \times 10^{-5}}$

$Ka_1 = 5.91 \times 10^{-2}$

C) $pH = 0.5$ So, $-\log[H^+] = 0.5$ $\rightarrow$ $10^{-0.5} = [H^+] = 0.32M$
Remember that strong acid was added until the pH was 0.5, or the molarity reached 0.32 for $[H^+]$ at equilibrium. Substitute 0.32 into the ice table.

$$H_2C_2O_4 \rightleftarrows 2H^+ + C_2O_4^{2-}$$

	$H_2C_2O_4$	$2H^+$	$C_2O_4^{2-}$
I	0.015	0	0
C	-x	+2x	+x
E	0.015 – x	0.32	x
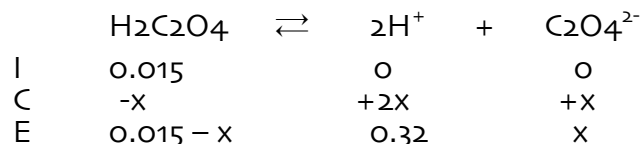
$Ka_{total} = \dfrac{[H^+]^2[C_2O_4^{2-}]}{[H_2C_2O_4]} = \dfrac{(0.32)^2x}{.015 - x} = 3.78 \times 10^{-6}$

$\dfrac{(0.32)^2x}{0.015 - x} = 3.78 \times 10^{-6} \rightarrow 0.10x = 5.7 \times 10^{-8} - 3.78 \times 10^{-6}x$

$\rightarrow 0.10x = 5.7 \times 10^{-8}$

$\rightarrow x = [C_2O_4^{2-}] = 5.7 \times 10^{-7}$

Check to see if it's correct:
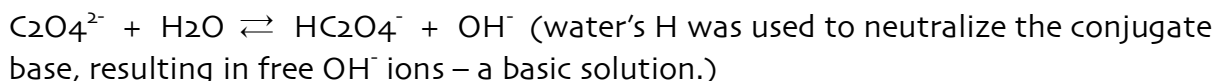$[H_2C_2O_4] = 0.015 - 5.7 \times 10^{-7} = 0.015$
$[H^+] = 0.32$ $\rightarrow$ $\dfrac{(.32)^2(5.7 \times 10^{-7})}{0.015} = 3.9 \times 10^{-6}$ [pretty close!]
$[C_2O_4^{2-}] = 5.7 \times 10^{-7}$

D) I'll do (ii) first:
$Na_2C_2O_4$ will dissociate into this $\rightarrow 2Na^+ + C_2O_4^{2-}$ It is the oxalate ion that is the conjugate base of the weak acid, oxalic acid. Therefore, the conjugate base will act as a base in an aqueous solution – leading to hydrolysis.

"Hydro" referring to water . . . . . "Lysis" referring to splitting.

$C_2O_4^{2-} + H_2O \rightleftarrows HC_2O_4^- + OH^-$ (water's H was used to neutralize the conjugate base, resulting in free OH^- ions – a basic solution.)

(i) the Kb for the hydrolysis reaction above is:

$Kb = \dfrac{[HC_2O_4^-][OH^-]}{[C_2O_4^{2-}]}$ notice that the H_2O is not present in the expression due to it being a pure (l)

$Kw = Ka \times Kb = [OH^-][H^+]$ $Kb = Kw/Ka_2$ $1.0 \times 10^{-14}/6.4 \times 10^{-5} * = Kb$
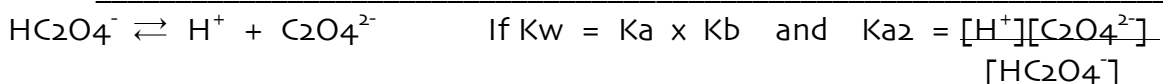
* This value was revealed in part B. $Kb = 1.6 \times 10^{-10}$
It must be based off of Ka_2 because
The expression contains both the acid and the base in question.

Proof:_____
$HC_2O_4^- \rightleftarrows H^+ + C_2O_4^{2-}$ If $Kw = Ka \times Kb$ and $Ka_2 = \dfrac{[H^+][C_2O_4^{2-}]}{[HC_2O_4^-]}$

and $Kb = \dfrac{[HC_2O_4^-][OH^-]}{[C_2O_4^{2-}]}$ Then $Kw = \dfrac{[H^+][C_2O_4^{2-}][HC_2O_4^-][OH^-]}{[HC_2O_4^-][C_2O_4^{2-}]} = [OH^-][H^+]$ proof!

Also: If $Kw = 1.0 \times 10^{-14} = Ka_2 \times Kb$. Then $(6.4 \times 10^{-5})(1.6 \times 10^{-10}) = 1.0 \times 10^{-14}$ double proof!