Quiz: Ch 15 – 16 **Name:** KEY
AP Chem (30 pts) **I have neither given nor received aid on this quiz.**
Version A **Period:** 6 7 **Date:** _____

Complete in pencil. Erase mistakes completely. If you need more space, use the back of this sheet or attach further sheets as is necessary. For problems involving calculations, no credit will be given if work is not shown.

ZUMDAHL CH 13 #67

1. (14 pts) An initial mixture of nitrogen gas and hydrogen gas reacts endothermically in a rigid container at a certain temperature by the reaction: 25°C

$$\text{heat} + 3\,H_2(g) + N_2(g) \leftrightarrow 2\,NH_3(g)$$

a. (3 pts) At equilibrium, the concentrations are $[H_2] = 5.0$ M, $[N_2] = 8.0$ M, and $[NH_3] = 4.0$ M. Write the expression for K_p and calculate its numerical value.

$K_c = \frac{[NH_3]^2}{[N_2][H_2]^3} \Rightarrow$ $K_p = \frac{P_{NH_3}^2}{P_{N_2} \cdot P_{H_2}^3}$ ①

$K_c = 0.016$

$= K_c (RT)^{\Delta n} = \left(\frac{4.0^2}{8.0 \cdot 5.0^3}\right)(.0821 \cdot 298)^{(2-4)}$ ①

$= 0.016 \cdot .00167$

$K_p = 2.7 \times 10^{-5}$ ①

b. (3 pts) Calculate the concentrations of nitrogen gas and hydrogen gas that were reacted initially to achieve the stated equilibrium concentrations.

	H_2	N_2	NH_3
I	$[H_2]_0$	$[N_2]_0$	0
C	$-3x$	$-x$	$+2x$
E	5.0	8.0	4.0

$4.0 = 2x$
$x = 2.0$ ①

$[H_2]_0 - 3x = 5.0 \Rightarrow [H_2]_0 = 11.0\text{ M} = [H_2]_0$ ①
$[N_2]_0 - x = 8.0 \Rightarrow [N_2]_0 = 10.0\text{ M} = [N_2]_0$ ①

c. (4 pts) Explain in which direction (forward, backward, or ~~not at all~~) the above reaction will shift, and why it shifts that way, if:

i. Ammonia is removed. shifts forward ① to replace NH_3 removed ①

ii. The temperature is decreased. shifts backward ① since heat is reactant; replace removed heat ①

d. (4 pts) Explain how the equilibrium constant of the above reaction will be affected, and why it will be (or will not be) affected, if:

i. The pressure is increased. K_{eq} not affected ①; ΔP does not change K_{eq} ①

ii. A catalyst is added. K_{eq} not affected ①; catalyst speeds up f and b rxn rate ①

0

2. (8 pts) The overall dissociation of oxalic acid, $H_2C_2O_4$, is represented below. The overall dissociation constant is also indicated.

$H_2C_2O_4 \leftrightarrow 2\ H^+ + C_2O_4^{2-} \qquad K = 3.78 \times 10^{-6} = \dfrac{[C_2O_4^{2-}]\,[H^+]^2}{[H_2C_2O_4]} = Ka_1 \cdot Ka_2$

a. (5 pts) Give the chemical equations and equilibrium constant expressions representing the first and second dissociations of oxalic acid. Calculate the value of the first dissociation constant, Ka_1, for oxalic acid if the value of the second dissociation constant, Ka_2, is 6.40×10^{-5}.

$H_2C_2O_4 \leftrightarrow HC_2O_4^- + H^+$ (1) $\qquad Ka_1 = \dfrac{[HC_2O_4^-]\,[H^+]}{[H_2C_2O_4]}$ (1)

$HC_2O_4^- \leftrightarrow C_2O_4^{2-} + H^+$ (1) $\qquad Ka_2 = \dfrac{[C_2O_4^{2-}]\,[H^+]}{[HC_2O_4^-]}$ (1)

$K = Ka_1 \cdot Ka_2$

$3.78\times10^{-6} = Ka_1 \cdot 6.40\times10^{-5} \Rightarrow \boxed{Ka_1 = 0.0591}$ (1)

b. (3 pts) 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.)

$pH = 0.5 \qquad [H^+] = 10^{-0.5} = 0.32\ M$ (1)

$[H_2C_2O_4] = 0.015 - x$

$x = [C_2O_4^{2-}]$

$K = \dfrac{[C_2O_4^{2-}]\,[H^+]^2}{[H_2C_2O_4]} = 3.78\times10^{-6} = \dfrac{x \cdot 0.32^2}{0.015 - x}$ (1)

$\approx \dfrac{x \cdot .10}{0.015}$ (1)

$x = \boxed{5.7\times10^{-7}\ M = [C_2O_4^{2-}]}$

3. (4 pts) Predict whether an aqueous solution of the following compound will be acidic, basic, or neutral. Explain briefly.

$NH_4NO_2 \qquad K_b(NH_3) = 1.8 \times 10^{-4};\ K_a(HNO_2) = 4.5 \times 10^{-4}$

$NH_4^+ + H_2O \leftrightarrow NH_3 + H_3O^+ \qquad K_a = \dfrac{K_w}{K_b} = \dfrac{1.0\times10^{-14}}{1.8\times10^{-4}} = 5.6\times10^{-11}$ (2)

$NO_2^- + H_2O \leftrightarrow HNO_2 + OH^- \qquad K_b = \dfrac{K_w}{K_a} = \dfrac{1.0\times10^{-14}}{4.5\times10^{-4}} = 2.2\times10^{-11}$ (2)

- since larger, more likely rxn so solution is acidic. (2)

4. (4 pts) Give the formula for an acid that is very similar to HNO_2, but that is stronger.

$HClO_2$ (2)

Give the formula for an acid that is very similar to HNO_2, but that is weaker, but for a different reason than that used in the above question.

HNO (2)

Quiz: Ch 15 – 16 **Name:**
AP Chem (30 pts) **I have neither given nor received aid on this quiz.**
Version B **Period: 6 7 Date: _____**

Complete in pencil. Erase mistakes completely. If you need more space, use the back of this sheet or attach further sheets as is necessary. For problems involving calculations, no credit will be given if work is not shown.

1. (14 pts) An initial mixture of nitrogen gas and hydrogen gas reacts endothermically in a rigid container at a certain temperature by the reaction:

   $heat + 3\,H_2(g) + N_2(g) \leftrightarrow 2\,NH_3(g)$ 25°C

   a. (3 pts) At equilibrium, the concentrations are $[H_2] = 2.0$ M, $[N_2] = 4.0$ M, and $[NH_3] = 0.72$ M. Write the expression for K_p and calculate its numerical value.

   $K_c = \frac{[NH_3]^2}{[H_2]^3[N_2]}$ if R=8.31 (-1)

   $K_p = \frac{(P_{NH_3})^2}{(P_{H_2})^3(P_{N_2})} = K_c(RT)^{\Delta n} = \frac{0.72^2}{2.0^3 \cdot 4.0} \cdot (0.0821 \cdot 298)^{-2}$ (1)

   $= 0.0162 \cdot 0.00167 = 2.7 \times 10^{-5} = K_p$ (1)

   b. (3 pts) Calculate the concentrations of nitrogen gas and hydrogen gas that were reacted initially to achieve the stated equilibrium concentrations.

	$[H_2]$	$[N_2]$	$[NH_3]$
I	$[H_2]_0$	$[N_2]_0$	0
C	$-3x$	$-x$	$+2x$
E	2.0	4.0	0.72

   $0.72 = 2x$ (1)
   $x = 0.36$

   $[H_2]_0 - 3x = 2.0$ $[N_2]_0 - x = 4.0$

   $[H_2]_0 = 3.1$ M (1) $[N_2]_0 = 4.4$ M (1)

   c. (4 pts) Explain in which direction (forward, backward, or not at all) the above reaction will shift, and why it shifts that way, if:

      i. The pressure is increased. shifts forward (1) b/c forms side w/ fewer (1) mols of gas

      ii. A catalyst is added. does not shift (1) b/c catalyst speeds both (1) → and ←

   d. (4 pts) Explain how the equilibrium constant of the above reaction will be affected, and why it will be (or will not be) affected, if:

      i. Ammonia is removed. not affected (1)

      ii. The temperature is decreased. $K_c = \frac{k_f}{k_r}$ (1) by T ↓, inc K_r (1) ∴ K_c decreases (1)

2. (8 pts) The overall dissociation of chromic acid, H_2CrO_4, is represented below. The overall dissociation constant is also indicated.

$$H_2CrO_4 \leftrightarrow 2\ H^+ + CrO_4^{2-} \qquad K = 5.83 \times 10^{-8}$$

a. (5 pts) Give the chemical equations and equilibrium constant expressions representing the first and second dissociations of chromic acid. Calculate the value of the first dissociation constant, Ka_1, for chromic acid if the value of the second dissociation constant, Ka_2, is 3.24×10^{-7}.

$K = Ka_1 \cdot Ka_2$

$5.83\times10^{-8} = Ka_1 \cdot 3.24\times10^{-7}$

$Ka_1 = 0.180$ (1)

$H_2CrO_4 \leftrightarrow H^+ + HCrO_4^-$ (1)

$Ka_1 = \frac{[H^+][HCrO_4^-]}{[H_2CrO_4]}$ (1)

$HCrO_4^- \leftrightarrow H^+ + CrO_4^{2-}$ (1)

$Ka_2 = \frac{[H^+][CrO_4^{2-}]}{[HCrO_4^-]}$ (1)

b. (3 pts) To a 0.010-molar solution of chromic acid, a strong acid is added until the pH is 0.8. Calculate the $[CrO_4^{2-}]$ in the resulting solution. (Assume the change in volume is negligible.)

$pH = 0.8$

$[H^+] = 10^{-0.8} = 0.16$ (1)

$[H_2CrO_4] = 0.010$

$K = 5.83\times10^{-8} = \frac{[H^+]^2[CrO_4^{2-}]}{[H_2CrO_4]}$ (1)

$= \frac{0.16^2 \cdot x}{0.010 - x}$

$\approx 2.6x$

$x = 2.2\times10^{-8}\ M$ (1)

3. (4 pts) Predict whether an aqueous solution of the following compound will be acidic, basic, or neutral. Explain briefly.

NH_4AsO_4 $\quad K_b(NH_3) = 1.8 \times 10^{-4}$; $K_a(HAsO_4) = 5.6 \times 10^{-3}$

$NH_4^+ + H_2O \leftrightarrow NH_3 + H_3O^+$ (1) $K_a = \frac{K_w}{K_b} = \frac{1.0\times10^{-14}}{1.8\times10^{-4}} = 5.6\times10^{-11}$ ← greater so soln is acidic (2)

$AsO_4^- + H_2O \leftrightarrow HAsO_4 + OH^-$ (1) $K_b = \frac{K_w}{K_a} = \frac{1.0\times10^{-14}}{5.6\times10^{-3}} = 1.8\times10^{-12}$

4. (4 pts) Give the formula for an acid that is very similar to $HAsO_4$, but that is stronger.

$HClO_4$ (2)

Give the formula for an acid that is very similar to $HAsO_4$, but that is weaker, but for a different reason than that used in the above question.

$HAsO_3$ (2)