Exam III General Chemistry II (CHEM 102) Summer I Dr. Hahn Exam # _____

Name Kly (print) Name _____ (sign)

Please show work for partial credit and full credit on the Long Answers and in some of the Short Answer Questions. Multip choice questions have no partial credit. Please write anything you want graded legibly. If I cannot read your work, I obviously cannot grade it. (1 pts print and sign exam) If you run out of space, please continue on the back page of the exam and clearly tell me where the remaining answer can be found.

NA = not attempted NW = no work

$pH + pOH = 14$ $pKa + pKb = 14$ $K_a \times K_b = 1.0 \times 10^{-14}$ $[H_3O^+][OH^-] = 1.0 \times 10^{-14} = k_W$

p (anything) = - log (anything) $pH = pK_a + \log \{ [base] / [acid] \}$ M = molarity = moles / liter

Part I MULTIPLE CHOICE. Choose the one alternative that best completes the statement or answers the question. (2 pts per question, 24 pts total)

1) Identify the triprotic acid. 1) A

(A) H_3PO_4 B) H_2SO_3 C) H_2SO_4 D) HNO_3 E) $HClO_4$

2) Determine the value of K_c for the following reaction if the equilibrium concentrations are as follows: $[N_2]_{eq} = 1.5$ M, $[H_2]_{eq} = 1.1$ M, $[NH_3]_{eq} = 0.47$ M. 2) A

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

0.221 $\dfrac{[NH_3]^2}{[N_2][H_2]^3}$

(A) 0.11 B) 9.1 C) 0.28 D) 3.5 E) 0.78

$\dfrac{(0.47)^2}{(1.5)(1.1)^3} = 0.11$

1.33

3) Give the expression for the solubility product constant for $PbCl_2$. 3) B

A) $[Pb^{2+}]^2[Cl^-]$

(B) $[Pb^{2+}][Cl^-]^2$

C) $\dfrac{[Pb^{2+}]^2[Cl^-]}{[PbCl_2]}$

D) $\dfrac{[PbCl_2]}{[Pb^{2+}][Cl^-]^2}$

E) $\dfrac{[Pb^{2+}][Cl^-]^2}{[PbCl_2]}$

$PbCl_2(s) \rightarrow Pb^{+2}_{(aq)} + 2Cl^-_{(aq)}$

$K_{sp} = [Pb^{+2}][Cl^-]^2$

4) What is the conjugate base of H_2CO_3? 4) A

$H_2CO_3 \rightleftharpoons HCO_3^- + H^+ \rightleftharpoons CO_3^- + H^+$

(A) HCO_3^- B) CO_3^{2-} C) H_2O D) OH^- E) H_3O^+

5) Determine the pH of a 0.023 M HNO_3 solution. 5) D

A) 2.49 B) 12.36 C) 3.68 (D) 1.64 E) 2.30

$-\log(0.023) = 1.64$

6) Which of the following statements is FALSE? K equilibrium has nothing to do w rate 6) D

A) When $K >> 1$, the forward reaction is favored and essentially goes to completion.
B) When $K \approx 1$, neither the forward or reverse reaction is strongly favored, and about the same amount of reactants and products exist at equilibrium.
C) When $K << 1$, the reverse reaction is favored and the forward reaction does not proceed to a great extent.
D) $K >> 1$ implies that the reaction is very fast at producing products.
E) None of the above.

7) Which of the following statements is TRUE? 7) D

A) The equilibrium constant for the forward reaction is equal to the equilibrium constant for the reverse reaction. (nope)
B) Dynamic equilibrium indicates that the amount of reactants and products are equal.
C) If K (equilibrium constant) is a large number, the dynamic equilibrium favors the reactant. (product)
D) Dynamic equilibrium occurs when the reaction is at equilibrium. Reactant is going to product and the product is going to reantant so that overall the equilibrium concentrations are not changing.
E) All of the above are true.

8) Consider the following reaction at equilibrium. What effect will removing NO_2 have on the system? 8) C

$$SO_2(g) + NO_2(g) \rightleftharpoons SO_3(g) + NO(g)$$

A) No change will occur since SO_3 is not included in the equilibrium expression.
B) The equilibrium constant will decrease.
C) The reaction will shift in the direction of reactants.
D) The reaction will shift to decrease the pressure.
E) The reaction will shift in the direction of products.

9) Express the equilibrium constant for the following reaction. 9) B

$$2\ Na(s) + 2\ H_2O(l) \rightleftharpoons 2\ NaOH(aq) + H_2(g)$$

solid liquid leave out

A) $K = [H_2][NaOH]^{-2}$
B) $K = [H_2][NaOH]^2$
C) $K = \dfrac{[NaOH]^2[H_2]}{[Na]^2[H_2O]^2}$
D) $K = \dfrac{[NaOH]^{1/2}[H_2]}{[Na]^{1/2}[H_2O]^{1/2}}$
E) $K = \dfrac{[Na]^2[H_2O]^2}{[NaOH]^2[H_2]}$

10) Give the equation for an unsaturated solution in comparing Q with K_{sp}. 10) C

A) $Q = K_{sp}$
B) $Q \neq K_{sp}$
C) $Q < K_{sp}$
D) $Q > K_{sp}$
E) none of the above

(more solid can dissolve in solution - no precipitate formed so $Q < K_{sp}$

11) Calculate the concentration of OH^- in a solution that contains 3.9×10^{-4} M H_3O^+ at 25°C. Identify the solution as acidic, basic or neutral. 11) B

$[[H_3O^+][OH^-] = 1.0 \times 10^{-14}]$

A) 3.9×10^{-4} M, neutral
B) 2.6×10^{-11} M, acidic
C) 2.6×10^{-11} M, basic
D) 2.7×10^{-2} M, acidic
E) 2.7×10^{-2} M, basic

$$[OH^-] = \frac{1.0 \times 10^{-14}}{3.9 \times 10^{-4}}$$

$$[OH^-] = 2.56 \times 10^{-11}$$

$[H_3O^+] > [OH^-]$

acidic

12) Identify the weak acid. 12) D

A) H_2SO_4
B) HNO_3
C) HBr
D) HF
E) not enough information is available

Part II Short Answer: Write the word or phrase or circle the choice that best completes each statement or answers the question. Some questions may require that you show work. If you do not show work, you may lose points. (46 pts)

1) $2\,NH_3(g) \rightleftarrows N_2(g) + 2\,H_2(g)$ $\quad K_{eq} = 7.3 \times 10^{-5}$ (I made up these numbers.)

Initially you have $[NH_3(g)] = 0.189$ M. What is the equilibrium concentration of the $N_2(g)$ and the concentration of $H_2(g)$ in molarity ? (I am not looking for the final answer. Just set up the problem because you do not have enough time to actually complete the algebra.) (10 pts)

a. Fill out the table shown below. (6 pts, 1 pt per table block)

$2\,NH_3(g) \rightarrow N_2(g) + 2\,H_2(g)$

	$[NH_3]$	$[N_2(g)]$	$[H_2(g)]$
initial	(1) 0.189 M	zero	zero
change	(2) $-2x$	$+x$	(3) $+2x$
equilibrium	(4) $0.189 - 2x$	(5) x	(6) $2x$

b. Write out the equilibrium constant expression for the equation using your equilibrium values. (2 pts)

$$K = \frac{[N_2][H_2]^2}{[NH_3]^2} = \frac{(x)(2x)^2}{[0.189-2x]^2}$$

graded consistent w your

did not need to show but incorrect formula -1

c. Write out the equilibrium constant expression for the reaction using your equilibrium values with your simplifying approximation. (2 pts)

$0.189 << 2x$

$$\frac{(x)(2x)^2}{(0.189)^2} = 7.3 \times 10^{-5}$$

not simplifying -2

2 For a weak acid HCN with a $K_a = 4.9 \times 10^{-10}$ the initial concentration of the HCN is 0.100 M. The equilibrium equation is shown below and an ICE table has been started.

$HCN\ (aq) + H_2O\ (l) \rightarrow H_3O^+\ (aq) + CN^-\ (aq)$

a. complete the following ICE table using the variable x = change in $[H_3O^+]$ (6 pts, 1 pt each block)

1 pt per block

	[H CN]	$[H_3O^+]$	$[CN^-]$
initial	(1) 0.100	zero	zero
change	(2) $-x$	$+ X$	(3) $+x$
equilibrium	(4) $0.100 - x$	(5) x	(6) x

b. Complete the following K_a expression with the equilibrium values from **your** completed chart above. (2 pts)

$$K_a = \frac{[H_3O^+]\,[CN^-]}{[H\,CN]} = \frac{(x)(x)}{(0.100-x)} = 4.9 \times 10^{-10}$$

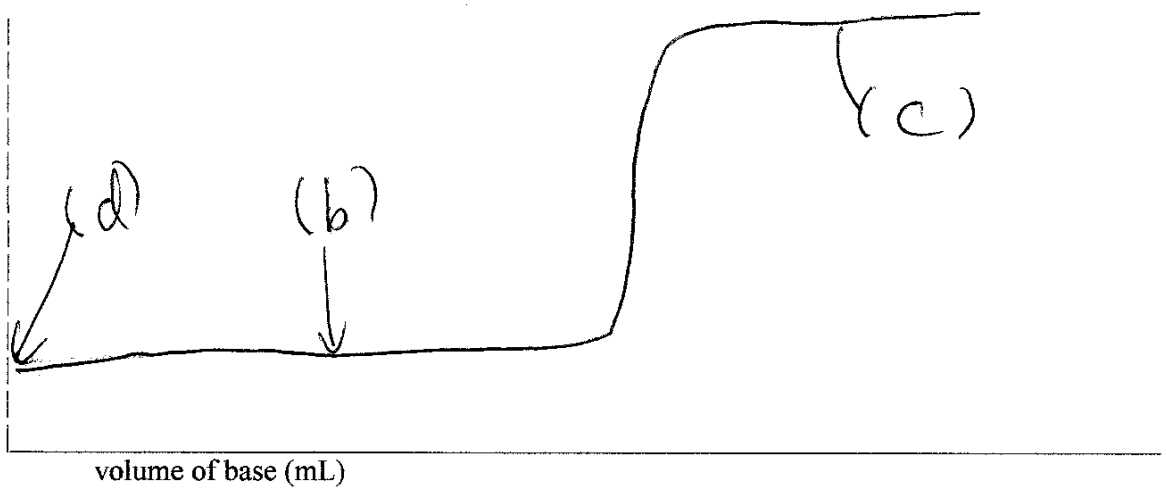
3 If the K_a of CH_3 C OOH is 1.8×10^{-5}, what is the K_b of the CH_3COO^- ($K_a \times K_b = K_w = 1.0 \times 10^{-14}$). (show work) (6 pts)

$$K_b = \frac{1.0 \times 10^{-14}}{1.8 \times 10^{-5}} = 5.56 \times 10^{-10}$$

$K_b = 5.56 \times 10^{-10}$

4 In the following titration graph for a strong acid to which is added a strong base, match the letter with the appropriate parenthesis. The equations below are absolutely correct except for you not knowing which of the equations goes with which part of the graph until you fill in the parenthesis with the correct letter. (12 pts, 4 pts each)

(a) $[H^+] = 1.0 \times 10^{-7}$
(b) $[H^+]$ = (# moles acid - # moles base) / {(mL volume acid + mL volume base) x (1 Liter /1000 mL)}
(c) $[OH^-]$ = (# moles base - # moles acid)/ {(mL volume acid + mL volume base) x (1 Liter/1000 mL) }
(d) $[H^+]$ = concentration of the strong acid



5. If the K_{sp} of $PbCl_2$ is 1.17×10^{-5} , what is the solubility (S) ? Towards answering this question complete only the following. Fill in the ICE table below by putting in (a) the variable, S or a (b) a number or (c) a combination of a number and the variable, S or (d) the words "no value in this box". **Do not continue on to actually answer the actual value of S. (If you do, you will run out of time.)** (2 pts per block, 10 pts total)

$PbCl_2$ (s) $\rightleftarrows$ Pb^{+2} (aq) + 2 Cl^- (aq)

2 pt per block

$K_{sp} = [Pb^{+2}]\,[Cl^-]^2$

	$[PbCl_2]$	$[Pb^{+2}]$	$[Cl^-]$
initial	no value this box	zero	zero
change	(1) no value this box	(2) +S	+ 2 S
equilibrium	(3) no value this box	(4) S	(5) 2S

Part III. Long Answer Please show work for full credit and to receive partial credit. (30 pts)
****** Please attempt every problem for partial credit. You will get no partial credit if you just rewrite the question with no change in anything.******

1. For a buffer of 0.110 M of H CN and 0.180 M of CN^-, what is the pH ? The H CN $pK_a = 9.30$ {Henderson Hasselbalch may be useful. $pH = pK_a + \log \{ [base] / [acid] \}$ (15 pts)

[base] = $[CN^-]$ = 0.180 M
[acid] = [HCN] = 0.110 M
pKa = 9.30

$$pH = 9.30 + \log\left\{\frac{(0.180\,M)}{(0.110\,M)}\right\}$$ (-5)

$$pH = 9.30 + \log(1.636)$$

$$pH = 9.30 + 0.213 = 9.51$$

2. **Titration of a strong acid to which you add a strong base: (This is an after equivalence point problem)**: For 30 mL of H Br of concentration 0.150 M and a KOH concentration of 0.200 M, what is the $[H_3O^+]$ concentration ~~after the addition~~ of 25 mL of the K OH ? You must show work for full credit. (15 pts)

attempt -1

$$[OH^-] = \frac{\#\text{moles base} - \#\text{moles acid}}{\left\{\left(\text{volume base} + \text{volume acid}\right) \times \frac{1\,l}{1000\,ml}\right\}}$$ (5 pt)

$$\#\text{moles base} = 25\,ml\ KOH \times \frac{0.200\,mol\ KOH}{1000\,ml\ KOH\ soln.} = 5.0 \times 10^{-3}\,mol\ KOH$$ (3 pt)

$$\#\text{moles acid} = 30\,ml\ HBr \times \frac{0.150\,mol\ HBr}{1000\,ml\ HBr} = 4.5 \times 10^{-3}\,mol\ HBr$$ (3 pt)

$$\text{volume total} = 25\,ml\ KOH + 30\,ml\ HBr = 55\,ml\ \text{total soln.}$$ (3 pt)

$$\#\text{moles base left} = 5.0 \times 10^{-3}\,mol\ KOH - 4.5 \times 10^{-3}\,mol\ HBr$$

$$[OH^-] = \frac{5.0 \times 10^{-3}\,mol\ KOH - 4.5 \times 10^{-3}\,mol\ HBr}{\left[55\,ml\ soln \times \frac{1\,l}{1000\,ml}\right]} = \frac{5.0 \times 10^{-4}}{0.055}$$ (1 pt)

$$[OH^-] = 9.1 \times 10^{-3}\,M$$

$$[H_3O^+] = \frac{1.0 \times 10^{-14}}{9.1 \times 10^{-3}}$$

$[H_3O^+] = 1.1 \times 10^{-12}$ ✓

Exam III General Chemistry II (CHEM 102) Summer I Dr. Hahn Exam # _____

Name_____ (print) Name _____(sign)

Please show work for partial credit and full credit on the Long Answers and in some of the Short Answer Questions. Multip choice questions have no partial credit. Please write anything you want graded legibly. If I cannot read your work, I obviously cannot grade it. (1 pts print and sign exam) If you run out of space , please continue on the back page of the exam and clearly tell me where the remaining answer can be found.

$pH + pOH = 14$ $pKa + pKb = 14$ $K_a \times K_b = 1.0 \times 10^{-14}$ $[H_3O^+][OH^-] = 1.0 \times 10^{-14} = k_W$

p (anything) = - log (anything) $pH = pK_a + \log \{ [base] / [acid] \}$ M = molarity = moles / liter

Part I MULTIPLE CHOICE. Choose the one alternative that best completes the statement or answers the question. (2 pts per question, 24 pts total)

1) Identify the triprotic acid. 1) _____

A) H_3PO_4 B) H_2SO_3 C) H_2SO_4 D) HNO_3 E) $HClO_4$

2) Determine the value of K_c for the following reaction if the equilibrium concentrations are as follows: $[N_2]_{eq} = 1.5$ M, $[H_2]_{eq} = 1.1$ M, $[NH_3]_{eq} = 0.47$ M. 2) _____

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

A) 0.11 B) 9.1 C) 0.28 D) 3.5 E) 0.78

3) Give the expression for the solubility product constant for $PbCl_2$. 3) _____

A) $[Pb^{2+}]^2[Cl^-]$

B) $[Pb^{2+}][Cl^-]^2$

C) $\dfrac{[Pb^{2+}]^2[Cl^-]}{[PbCl_2]}$

D) $\dfrac{[PbCl_2]}{[Pb^{2+}][Cl^-]^2}$

E) $\dfrac{[Pb^{2+}][Cl^-]^2}{[PbCl_2]}$

4) What is the conjugate base of H_2CO_3 ? 4) _____

A) HCO_3^- B) CO_3^{2-} C) H_2O D) OH^- E) H_3O^+

5) Determine the pH of a 0.023 M HNO_3 solution. 5) _____

A) 2.49 B) 12.36 C) 3.68 D) 1.64 E) 2.30

6) Which of the following statements is FALSE? (K is equilibrium constant) 6) _____

A) When $K >> 1$, the forward reaction is favored and essentially goes to completion.
B) When $K \approx 1$, neither the forward or reverse reaction is strongly favored, and about the same amount of reactants and products exist at equilibrium.
C) When $K << 1$, the reverse reaction is favored and the forward reaction does not proceed to a great extent.
D) $K >> 1$ implies that the reaction is very fast at producing products.
E) None of the above.

7) Which of the following statements is TRUE? 7) _____

A) The equilibrium constant for the forward reaction is equal to the equilibrium constant for the reverse reaction.
B) Dynamic equilibrium indicates that the amount of reactants and products are equal.
C) If K (equilibrium constant) is a large number, the dynamic equilibrium favors the reactant.
D) Dynamic equilibrium occurs when the reaction is at equilibrium. Reactant is going to product and the product is going to reantant so that overall the equilibrium concentrations are not changing.
E) All of the above are true.

8) Consider the following reaction at equilibrium. What effect will removing NO_2 have on the system? 8) _____

$$SO_2(g) + NO_2(g) \rightleftharpoons SO_3(g) + NO(g)$$

A) No change will occur since SO_3 is not included in the equilibrium expression.
B) The equilibrium constant will decrease.
C) The reaction will shift in the direction of reactants.
D) The reaction will shift to decrease the pressure.
E) The reaction will shift in the direction of products.

9) Express the equilibrium constant for the following reaction. 9) _____

$$2\ Na(s) + 2\ H_2O(l) \rightleftharpoons 2\ NaOH(aq) + H_2(g)$$

A) $K = [H_2][NaOH]^{-2}$

B) $K = [H_2][NaOH]^2$

C) $K = \dfrac{[NaOH]^2[H_2]}{[Na]^2[H_2O]^2}$

D) $K = \dfrac{[NaOH]^{1/2}[H_2]}{[Na]^{1/2}[H_2O]^{1/2}}$

E) $K = \dfrac{[Na]^2[H_2O]^2}{[NaOH]^2[H_2]}$

10) Give the equation for an unsaturated solution in comparing Q with K_{sp}. 10) _____

A) $Q = K_{sp}$

B) $Q \neq K_{sp}$

C) $Q < K_{sp}$

D) $Q > K_{sp}$

E) none of the above

11) Calculate the concentration of OH^- in a solution that contains 3.9×10^{-4} M H_3O^+ at 25°C. Identify the solution as acidic, basic or neutral. $[H_3O^+][OH^-] = 1.0 \times 10^{-14}$ 11) _____

A) 3.9×10^{-4} M, neutral

B) 2.6×10^{-11} M, acidic

C) 2.6×10^{-11} M, basic

D) 2.7×10^{-2} M, acidic

E) 2.7×10^{-2} M, basic

12) Identify the weak acid. 12) _____

A) H_2SO_4

B) HNO_3

C) HBr

D) HF

E) not enough information is available

Part II Short Answer: Write the word or phrase or circle the choice that best completes each statement or answers the question. Some questions may require that you show work. If you do not show work, you may lose points. (46 pts)

1) $2\,NH_3(g) \rightleftarrows N_2(g) + 2\,H_2(g)$ $\quad K_{eq} = 7.3 \times 10^{-5}$ (I made up these numbers.)

Initially you have $[NH_3(g)] = 0.189$ M. What is the equilibrium concentration of the $N_2(g)$ and the concentration of $H_2(g)$ in molarity ? (I am not looking for the final answer. Just set up the problem because you do not have enough time to actually complete the algebra.) (10 pts)

a. Fill out the table shown below. (6 pts, 1 pt per table block)

$2\,NH_3(g) \rightarrow N_2(g) + 2\,H_2(g)$

	$[NH_3]$	$[N_2(g)]$	$[H_2(g)]$
initial	(1)	zero	zero
change	(2)	+ X	(3)
equilibrium	(4)	(5)	(6)

b. Write out the equilibrium constant expression for the equation using your equilibrium values. (2 pts)

c. Write out the equilibrium constant expression for the reaction using your equilibrium values with your simplifying approximation. (2 pts)

2 For a weak acid HCN with a $K_a = 4.9 \times 10^{-10}$ the initial concentration of the HCN is 0.100 M. The equilibrium equation is shown below and an ICE table has been started.

$HCN\ (aq) + H_2O\ (l) \rightarrow H_3O^+\ (aq) + CN^-\ (aq)$

a. complete the following ICE table using the variable x = change in $[H_3O^+]$ (6 pts, 1 pt each block)

	[H CN]	$[H_3O^+]$	$[CN^-]$
initial	(1)	zero	zero
change	(2)	+ X	(3)
equilibrium	(4)	(5)	(6)

b. Complete the following K_a expression with the equilibrium values from **your** completed chart above. (2 pts)

$$K_a = \frac{[H_3O^+]\ [CN^-]}{[H\ CN]}$$

3 If the K_a of CH_3 C OOH is 1.8×10^{-5}, what is the K_b of the CH_3COO^- ($K_a \times K_b = K_w = 1.0 \times 10^{-14}$). (show work) (6 pts)

$K_b =$ _____

4 In the following titration graph for a strong acid to which is added a strong base, match the letter with the appropriate parenthesis. The equations below are absolutely correct except for you not knowing which of the equations goes with which part of the graph until you fill in the parenthesis with the correct letter. (12 pts, 4 pts each)

(a) $[H^+] = 1.0 \times 10^{-7}$
(b) $[H^+]$ = (# moles acid - # moles base) / {(mL volume acid + mL volume base) x (1 Liter /1000 mL)}
(c) $[OH^-]$ = (# moles base - # moles acid)/ {(mL volume acid + mL volume base) x (1 Liter/1000 mL) }
(d) $[H^+]$ = concentration of the strong acid

5. If the K_{sp} of $PbCl_2$ is 1.17×10^{-5} , what is the solubility (S) ? Towards answering this question complete only the following. Fill in the ICE table below by putting in (a) the variable, S or a (b) a number or (c) a combination of a number and the variable, S or (d) the words "no value in this box". **Do not continue on to actually answer the actual value of S. (If you do, you will run out of time.)** (2 pts per block, 10 pts total)

$PbCl_2$ (s) $\rightleftarrows$ Pb^{+2} (aq) + 2 Cl^- (aq)

$K_{sp} = [Pb^{+2}]\,[Cl^-]^2$

	$[PbCl_2]$	$[Pb^{+2}]$	$[Cl^-]$
initial	no value this box	zero	zero
change	(1)	(2)	+ 2 S
equilibrium	(3)	(4)	(5)

Part III. Long Answer Please show work for full credit and to receive partial credit. (30 pts)
****** Please attempt every problem for partial credit. You will get no partial credit if you just rewrite the question with no change in anything.******

1. For a buffer of 0.110 M of H CN and 0.180 M of CN^-, what is the pH ? The H CN $pK_a = 9.30$ {Henderson Hasselbalch may be useful. $pH = pK_a + \log \{ [base] / [acid] \}$ (15 pts)

2. **Titration of a strong acid to which you add a strong base: (This is an after equivalence point problem)**: For 30 mL of H Br of concentration 0.150 M and a KOH concentration of 0.200 M, what is the $[H_3O^+]$ concentration after the addition of 25 mL of the K OH ? You must show work for full credit. (15 pts) $([H_3O^+][OH^-] = 1.0 \times 10^{-14})$