KWANTLEN POLYTECHNIC UNIVERSITY

CHEMISTRY 1210 – SPRING 2017

EXAM 1

February 9th 2017

Name: ANSKEY

Student #: _____

_____ / 40

Time allowed: 1h50

Only approved calculators are permitted
Cell phones and other electronics must be turned off
"What is 'HIJKLMNO'? – H_2O"
Good Luck – Bonne chance – Suerte

$T_k = T_c + 273.15$
$K_w = 1.0 \times 10^{-14}$ (at 25°C)

Assume all acid-base questions are at 25°C unless specified

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

$$\ln\left(\frac{K_{eq1}}{K_{eq2}}\right) = \frac{\Delta H^o}{R}\left(\frac{T_1 - T_2}{T_1 T_2}\right)$$

$$k_p = k_c(RT)^{\Delta n}$$

1) ***(1 pt)*** What is a chemical equilibrium? It is a chemical reaction... *(circle one)*

a) ...that is balanced precariously on the edge of a lab bench, but somehow manages to not fall off

b) ...where the concentration of the products is equal to the concentrations of the reactants which is defined by a constant

c) ...where both the forward and reverse reaction are taking place at the same rate

d) ...where the concentration of the products is a constant when conditions are changed

2) **(1 pt)** Which of the following is the strongest acid: *(circle one)*

a) H_3PO_4, phosphoric acid, ka = 7.1×10^{-3}

b) H_2CO_3, carbonic acid, ka = 4.3×10^{-7}

c) NH_3, ammonia, kb = 1.7×10^{-5}

d) $C_7H_6O_2$, benzoic acid, ka = 6.3×10^{-5}

3) ***(1 pt)*** Which of the following salts would be acidic? (NH_3, kb = 1.7×10^{-5}; H_2CO_3 ka1 = 4.3×10^{-7}, ka2 = 5.6×10^{-11}) *(circle one)*

a) NaCl

b) NH_4Cl

c) $CaCO_3$

d) $KClO_4$

4) ***(2 pts)*** What is a weak diprotic base, give one example and show its reactions with water.

$CO_3^{2-} + H_2O \rightleftharpoons HCO_3^- + OH^-$

$HCO_3^- + H_2O \rightleftharpoons H_2CO_3 + OH$

A BASE THAT CAN ACCEPT TWO H^+

5) ***(3 pts)*** The Haber reaction is used to produce ammonia

$$3H_2(g) + N_2(g) \rightleftharpoons 2NH_3(g) \quad \Delta H° = -92.4 \text{ kJ}$$

A mixture of $H_2(g)$, $N_2(g)$ and $NH_3(g)$ is brought to equilibrium at 3000°C. Describe how the reaction conditions, a-b-c, could be modified to increase the yield of $NH_3(g)$.

a) Concentration (reactants): increase the concentrations

b) Pressure: increase the pressure

c) Temperature: decrease the temperature

6) ***(2 pts)*** Based on the following two reactions and equilibrium constants, determine the value of K_3.

$\times 2$ $2NO(g) + \frac{1}{2}O_2(g) \rightleftharpoons NO_2(g)$ $\quad K_1 = 1.1\times10^{-3}$

$2NO(g) \rightleftharpoons N_2(g) + O_2(g)$ $\quad K_2 = 5.5\times10^{-1}$

$N_2(g) + 2O_2(g) \rightleftharpoons 2NO_2(g)$ $\quad K_3 = ?$

$2NO + O_2 \rightleftharpoons 2NO_2 \quad K = (1.1\times10^{-3})^2$

$N_2 + O_2 \rightleftharpoons 2NO \quad K = 1/5.5\times10^{-1}$

$N_2 + 2O_2 \rightleftharpoons 2NO_2 \quad K = (1.1\times10^{-3})^2 \times \frac{1}{5.5\times10^{-1}}$

$K = 2.2\times10^{-6}$

7) ***(4 pts)*** Consider the reaction: $2NO(g) \rightleftharpoons N_2(g) + O_2(g)$, for which $k_c = 10.0$ at 200 °C. A 5.00 L vessel if filled with 10.0 mol of $N_2(g)$ and 10.0 mol of $O_2(g)$

a) Determine the equilibrium concentration of NO

$2NO \rightleftharpoons N_2 + O_2$

I	0	2M	2M
C	+2x	−x	−x
E	2x	2M − x	2M − x

$K = \frac{[N_2][O_2]}{[NO]^2} = \frac{(2-x)^2}{(2x)^2} = 10.0$

$\frac{2-x}{2x} = 3.162$

$7.32x = 2$

$x = 0.27$

$[NO] = 0.54M$

b) Determine the k_p for this reaction at 200°C? (use R=0.08314 L bar/mol K)

$K_p = K_c(RT)^{\Delta n}$ $\Delta n = 0$

$K_p = K_c = \boxed{10.0}$

10) ***(4 pts)*** $H_3PO_4(aq)$ is an acid, with $K_{a1} = 6.9 \times 10^{-3}$; $K_{a2} = 6.3 \times 10^{-8}$; $K_{a3} = 4.8 \times 10^{-13}$.

Consider a 7.0 M solution of H_3PO_4.

a) Determine the pH of this solution

$H_3PO_4 + H_2O \rightleftharpoons H_2PO_4^- + H_3O^+$

I	7.0	0	0
C	$-x$	$+x$	$+x$
E	$7.0 - x$	x	x

ASSUME ≈ 7.0

$$\frac{x^2}{7.0} = 6.9 \times 10^{-3}$$

$$x = 0.22\,M$$

$$\boxed{pH = 0.66}$$

b) Determine the equilibrium concentration of PO_4^{3-} in this solution

$H_2PO_4^- + H_2O \rightleftharpoons HPO_4^{2-} + H_3O^+$

I	0.22	0	0.22
C	$-x$	$+x$	$+x$
E	$0.22 - x$	x	$0.22 + x$

ASSUME ≈ 0.22 ASSUME ≈ 0.22

$$\frac{x(0.22)}{(0.22)} = 6.3 \times 10^{-8}$$

$$x = 6.3 \times 10^{-8}$$

$HPO_4^{2-} + H_2O \rightleftharpoons PO_4^{3-} + H_3O^+$

I	6.3×10^{-8}	0	0.22
C	$-x$	$+x$	$+x$
E	6.3×10^{-8}	x	0.22

$$\frac{x(0.22)}{6.3 \times 10^{-8}} = 4.8 \times 10^{-13}$$

$$\boxed{x = 1.4 \times 10^{-19}\,M}$$

8) ***(2 pts)*** A solution is prepared as follows: 24.5 g of NaOH (40.0 g/mol) is dissolved in a 250.0 mL volumetric flask. A 15.00 mL sample of the first solution is diluted to 100.0 mL in a second volumetric flask. Determine the pH of the final solution.

$$24.5\,g\ NaOH \times \frac{1\,mol}{40.0\,g} = \frac{0.6125\,mol}{0.250\,L} = 2.45\,M \text{ initial}$$

$$2.45\,M \times \frac{15.00\,mL}{100.0\,mL} = 0.3675\,M\ NaOH \times \frac{1\,OH}{1\,NaOH} = 0.3675\,M\ OH$$

$$pOH = 0.435$$

$$pH + pOH = 14$$

$$\boxed{pH = 13.56}$$

9) ***(2 pts)*** Determine the pOH of a 0.45 M solution of HCl at 50.0°C. K_w = 1.0 x 10^{-14} at 25°C, and the autohydrolysis of water reaction has $\Delta H° = +55.8$ kJ/mol. (use R=8.314 J/mol K)

$$\ln\left(\frac{K_1}{1.0\times10^{-14}}\right) = \frac{55.8\times10^{3}\,J/mol}{8.314\,J/mol\,K}\left(\frac{323-298}{323\cdot298}\right)$$

$$K_1 = 5.716\times10^{-14} = [H_3O^+][OH^-]$$

$$\uparrow$$

$$0.45\,M$$

$$[OH^-] = 1.27\times10^{-13}$$

$$\boxed{pOH = 12.90}$$

11) ***(4 pts)*** Benzoic acid has a $k_a = 6.3\times10^{-5}$. Determine the pH of:

a) A 0.100 M benzoic acid solution

$HA + H_2O \rightleftharpoons A^- + H_3O^+$

I	0.1	0	0
C	$-x$	$+x$	$+x$
E	$0.1-x$	x	x

ASSUME ≈ 0.1

$$\frac{x^2}{0.1} = 6.3\times10^{-5}$$

$$x = [H_3O^+] = 2.51\times10^{-3}$$

$$\boxed{pH = 2.60}$$

b) A 0.500 M sodium benzoate solution *(benzoate is the conjugate base of benzoic acid)*

$A^- + H_2O \rightleftharpoons HA + OH$

$$K_b = \frac{K_w}{K_a} = \frac{1.0\times10^{-14}}{6.3\times10^{-5}} = 1.59\times10^{-10}$$

I	0.500	0	0
C	$-x$	$+x$	$+x$
E	$0.500-x$	x	x

ASSUME ≈ 0.500

$$\frac{x^2}{0.500} = 1.59\times10^{-10}$$

$$x = [OH^-] = 8.91\times10^{-6}$$

$$pOH = 5.05$$

$$\boxed{pH = 8.95}$$

12) ***(2 pts)*** Determine the mass of sodium fluoride NaF (42.0 g/mol) that needs to be added to 1.50 L of 0.100 M hydrofluoric acid HF ($k_a = 6.6\times10^{-4}$) to prepare a solution with a pH of 3.50.

$HF + H_2O \rightleftharpoons F^- + H_3O^+$

I	0.1 M	?	0
C	$-x$	$+x$	$+x$
E	$0.1-x$	$?+x$	x
	ASSUME 0.1M	ASSUME $\approx$?	$10^{-pH} = 3.16\times10^{-4}$

$$\frac{(3.16\times10^{-4})?}{0.1} = 6.6\times10^{-4}$$

$$? = 0.20g\ M \times 1.50L = 0.313\ moles \times 42.0\frac{g}{mol} = \boxed{13\ g\ NaF}$$

13) ***(2 pts)*** Consider the following reaction:

$CO(g) + 3H_2(g) \rightleftharpoons CH_4(g) + H_2O(g)$

When 2.00 ~~mol~~ 2.0 of CO(g) is mixed with 4.50 ~~mol~~ 2.0 of H_2(g) in a 2.0 L vessel at 250°C and the reaction is allowed to reach equilibrium, it is determined that 0.250 mol of H_2O(g) are present at equilibrium. Determine K_c at 250°C. 2.0

$CO + 3H_2 \rightleftharpoons CH_4 + H_2O$

I	1.0M	2.25M	0	0
C	$-x$	$-3x$	$+x$	$+x$
E	0.875	$2.25-3(0.125)$ = 1.875	0.125M	0.125 M

$$K = \frac{[CH_4][H_2O]}{[CO][H_2]^3} = \frac{(0.125)^2}{(0.875)(1.875)^3} = \boxed{2.21\times10^{-3}}$$

14) ***(2 pts)*** Consider the following equilibrium:

$15.09 \times \frac{1\ mol}{98.9\ g} = 0.152\ mol$

$COCl_2(g) \rightleftharpoons CO(g) + Cl_2(g)$ $K_c = 4.6 \times 10^{-3}$ at 800 K

If a sample of 15.0 g of $COCl_2(g)$ (98.9 g/mol) is placed in a 1.00 L flask at 800 K and the reaction is allowed to reach an equilibrium, determine the equilibrium concentration of $COCl_2(g)$.

	$COCl_2$	$\rightleftharpoons$	CO	+	Cl_2
I	0.152 M		0		0
C	$-x$		$+x$		$+x$
E	$0.152 - x$		x		x

CANNOT MAKE ASSUMPTION

$\frac{0.152}{4.6 \times 10^{-3}} = 33$

$\frac{x^2}{0.152 - x} = 4.6 \times 10^{-3}$

$x^2 = 6.992 \times 10^{-4} - 4.6 \times 10^{-3} x$

$x^2 + 4.6 \times 10^{-3} x - 6.992 \times 10^{-4} = 0$

$x = \frac{-4.6 \times 10^{-3} \pm \sqrt{(4.6 \times 10^{-3})^2 - (4)(1)(-6.992 \times 10^{-4})}}{2}$

$x = 0.024$

$[COCl_2] = 0.128\ M$

15) ***(4 pts)*** A 0.14 M HNO_2 solution is 5.75% ionized.

a) Calculate the pH of this solution

	HNO_2	+	H_2O	$\rightleftharpoons$	NO_2^-	+	H_3O^+
I	0.14				0		0
C	$-x$				$+x$		$+x$
E	$0.14 - x$				x		x
	≈ 0.139						

$\frac{x}{0.14} \times 100\% = 5.75$

$x = 8.05 \times 10^{-3}\ M$

$pH = 2.09$

b) Determine the K_a of HNO_2

$K_a = \frac{[NO_2^-][H_3O^+]}{[HNO_2]} = \frac{(8.05 \times 10^{-3})^2}{0.1395} = 4.91 \times 10^{-4}$

16) **(4 pts)** Consider the titration of 50.00 mL of 0.125 M benzoic acid ($k_a = 6.3\times10^{-5}$) with 0.125 M NaOH.

6.25×10^{-3} moles

2.5×10^{-3} moles

a) Determine the pH after 20.00 mL of NaOH has been added to the acid

$HA + \bar{O}H \rightarrow A^- + H_2O$

moles: 6.25×10^{-3} 2.5×10^{-3} 0 0

-2.5×10^{-3} -2.5×10^{-3} $+2.5\times10^{-3}$

3.75×10^{-3} 0 2.5×10^{-3}

70 70

TOTAL VOLUME = 70 mL

$= 0.0536\ M$ $0.0357\ M$

	$HA + H_2O \rightleftharpoons A^- + H_3O^+$		
I	0.0536	0.0357	0
C	$-x$	$+x$	$+x$
E	$0.0536 - x$	$0.0357 + x$	x
	ASSUME ≈ 0.0536	ASSUME $0.0357\ M$	

$$\frac{x(0.0357)}{(0.0536)} = 6.3\times10^{-5}$$

$$x = 9.46\times10^{-5}$$

$$\boxed{pH = 4.02}$$

b) Determine the volume required to reach the equivalence point and the pH at the equivalence point.

EQUIVALENCE PT moles HA = moles OH^-

$(50\ mL)(0.125\ M) = (?\ mL)(0.125)$

VOLUME = 50.00 mL

AT EQUIVALENCE PT $HA \rightarrow A^-$

$$\frac{6.25\times10^{-3}\ \text{moles } A^-}{100\ mL} = 0.0625\ M\ A^-$$

$$K_b = \frac{K_w}{K_a} = \frac{1.0\times10^{-14}}{6.3\times10^{-5}} = 1.587\times10^{-10}$$

$A^- + H_2O \rightleftharpoons HA + \bar{O}H$

I	0.0625 M	0	0
C	$-x$	$+x$	$+x$
E	$0.0625 - x$	x	x
	ASSUME ≈ 0.0625		

$$\frac{x^2}{0.0625} = 1.587\times10^{-10}$$

$x = [OH^-] = 3.149\times10^{-6}$

$pOH = 5.50$

$$\boxed{pH = 8.50}$$