CHM1311A – Exam 2A

Last name: CORRECTED

First name: _____

Student number: _____

Reminder:

- **Circle your final answer**
- **Calculators are permitted**
- **Circle your final answer**
- **Make sure there are 13 pages to this exam**

Question	Points	Points received
1	14	
2	10	
3	10	
4	4	
5	8	
6	14	
7	20	
Total	**80**	

Exam 2A

1. Given the following compounds classify each as either strong acid, strong base, weak acid, or weak base (indicate your answer to the right of the compound):
   a. HF WEAK ACID (2)
   b. H_2SO_4 STRONG ACID (2)
   c. $Ca(OH)_2$ STRONG BASE (2)
   d. NH_{4+} WEAK ACID (2)
   e. HBr STRONG ACID (2)
   f. HCN WEAK ACID (2)
   g. HClO WEAK ACID (2)

2. Given the following salts, determine whether each compound will generate an acidic, basic, or neutral solution. Be sure to provide the chemical equation with justification.

   a. $Cr(NO_3)_3$ ($pK_{a,HNO3} = -2.8$)

(1) $Cr(NO_3)_3\ (s) \longrightarrow Cr^{3+}\ (aq) + 3\ NO_3^-\ (aq)$

(1) $[Cr(H_2O)_6]^{3+}\ (aq) + H_2O\ (l) \longrightarrow [CrCH_2O)_5OH]^{2+}\ (aq) + H_3O^+\ (aq)$

ACIDIC (2)

   b. NH_4ClO ($pK_{a,\ NH4} = 9.25$; $pK_{a,HClO} = 7.54$)

$NH_4ClO\ (s) \longrightarrow \overset{+}{N}H_4\ (aq) + ClO^-\ (aq)$

(2) $\overset{+}{N}H_4\ (aq) + H_2O\ (l) \rightleftharpoons NH_3\ (aq) + H_3O^+\ (aq) \quad K_a = 5.62\times10^{-10}$

(2) $ClO^-\ (aq) + H_2O\ (l) \rightleftharpoons HClO\ (aq) + \bar{O}H\ (aq) \quad K_b = \frac{K_w}{K_a} = 3.47\times10^{-7}$

BASIC (2)

3. Codeine ($C_{18}H_{21}NO_3$) is a narcotic pain reliever that forms a salt with HCl. What is the pH of 0.075 mol/L codeine hydrochloride (pK_b of codeine = 5.80)

(3)

$C_{18}H_{21}NO_3 \cdot HCl\ (aq) + H_2O(l) \rightleftharpoons C_{18}H_{21}NO_3\ (aq) + H_3O^+\ (aq)$

I	0.075	0	0
C	$-x$	$+x$	$+x$
E	$0.075-x$	x	y

$pK_b = 5.80 \quad K_A = 6.309 \times 10^{-9}$ (2)

(2) $6.309 \times 10^{-9} = \dfrac{x^2}{0.075}$ $\quad x = 2.175 \times 10^{-5}$ (assumption valid)

$pH = -\log(2.175 \times 10^{-5}) = \boxed{4.66}$ (3)

4. Calculate the concentration of IO_3^- in a 5.03 mM $Pb(NO_3)_2$ solution saturated with $Pb(IO_3)_2$. The K_{sp} of $Pb(IO_3)_2$ is 2.5×10^{-13}. Assume that $Pb(IO_3)_2$ is negligible source of Pb^{2+} compared to $Pb(NO_3)_2$.

(1) $5.03\ mM\ Pb(NO_3)_2 \times \frac{1\ M}{1000\ mM} = 0.00503\ M$

(1) $Pb(IO_3)_2(s) \longrightarrow Pb^{2+}(aq) + 2\,IO_3^-(aq)$ (1) $K_{sp} = [Pb^{2+}][IO_3^-]^2$

$2.50 \times 10^{-13} = [0.00503]\,[IO_3^-]^2$

$[IO_3^-] = \frac{7.049 \times 10^{-6}}{2}\ M$ or $\boxed{3.5 \times 10^{-6}\ M}$ (1)

5. At 1000$_o$C, cyclobutene (C_4H_8) decomposes in a first-order reaction, with the very high rate constant of 83.5 s^{-1}, to two molecules of ethene (C_2H_4). The initial C_4H_8 concentration is 1.97 M. What is the concentration after 0.009 s?

1^{st} order: $\ln \frac{(A)_0}{(A)_t} = kt$

(6) $\ln \frac{[1.97]}{(A)_t} = (83.5\ s^{-1})(0.009\ s)$

$[A]_t = [C_4H_8]_{0.009\,s} = \boxed{0.929\ M}$ (2)

6. A hot lump of 35.7 g of copper at an initial temperature of 58.4 °C is placed in 55.0 mL of H_2O initially at 27.5 °C and allowed to reach thermal equilibrium. What is the final temperature of the copper and water given that the specific heat of copper is 0.385 J/(g·°C)? Assume no heat is lost to surroundings.

(1) $q_{H_2O} = -q_{metal}$

$m_{H_2O} \times C_{H_2O} \times \Delta T_{H_2O} = -m_{metal} \times C_{metal} \times \Delta T_{metal}$ (5) (5)

$(55.0\,g) \times \left(4.184 \frac{J}{g \cdot °C}\right) \times (T_F - 27.5) = -(35.7\,g) \times \left(0.385 \frac{J}{g \cdot °C}\right) \times (T_F - 58.4)$

$t_F - 27.5°C = -\left(\frac{(35.7\,g) \times \left(0.385 \frac{J}{g \cdot °C}\right)}{(55.0\,g) \times \left(4.184 \frac{J}{g \cdot °C}\right)}\right)(t_F - 58.4°C)$

$t_F - 27.5°C = -(0.059)(T_F - 58.4°C)$

$T_F = 29.2°C$ (3)

Exam 2A

BONUS

7. Find the pH during the titration of 30.00 mL of 0.1150 mol/L triethylamine $(CH_3CH_2)_3N$ ($K_b = 5.2 \times 10^{-4}$) with 0.1150 mol/L HCl solution after each addition of titrant: Et_3N

a. 0.00 mL

(3)

$(CH_3CH_2)_3N(aq) + H_2O(l) \rightleftharpoons (CH_3CH_2)_3\overset{+}{N}H(aq) + OH^-(aq)$

I	0.1150	0	0
C	$-x$	$+x$	$+x$
E			

$5.2 \times 10^{-4} = \frac{x^2}{0.1150}$ $\quad x = 0.00773$ $\quad pH = 14 - pOH = \boxed{11.89}$ (2)

b. 10.0 mL

$0.1150 \frac{mol}{L} \times 0.03000\,L = \frac{0.00345\ mol}{0.040\ L} = 0.08625\ M\ Et_3N$

$0.1150 \frac{Mol}{L} \times 0.0100\,L = \frac{0.00115\ mol}{0.040\,L} = 0.02875\ M\ HCl$

$K_b = \frac{[^-OH][Et_3\overset{+}{N}H]}{[Et_3N]}$

(3)

$Et_3N(aq) + HCl(aq) \rightleftharpoons Et_3\overset{+}{N}H + H_2O(l)$

I	0.08625	0.02875	0
C	-0.02875	-0.02875	$+0.02875$
E	0.0575	0	0.02875

$5.2 \times 10^{-4} = \frac{[^-OH](0.02875)}{(0.0575)}$ $\quad [^-OH] = 0.00104$

$pH = 14 - pOH = \boxed{11.02}$ (2)

c. 20.0 mL

$0.1150 \frac{mol}{L} \times 0.0300\ L = \frac{0.00345\ mol}{0.050\ L} = 0.069\ M\ Et_3N$

$0.1150 \frac{mol}{L} \times 0.0200\ L = \frac{0.0023\ mol}{0.050\ L} = 0.046\ M\ HCl$

(3)

$Et_3N(aq) + HCl(aq) \rightleftharpoons Et_3\overset{\oplus}{N}H + H_2O(l)$

	Et_3N	HCl	$Et_3\overset{\oplus}{N}H$	H_2O
I	0.069	0.046	0	
C	−0.046	−0.046	+0.046	
E	0.023	0	+0.046	

$5.2 \times 10^{-4} = \frac{(OH^-)(0.046)}{(0.023)}$ $\quad [OH^-) = 0.00026$ $\quad pH = 10.41$ (2)

d. 30.0 mL

$0.1150 \frac{mol}{L} \times 0.0300\ L = \frac{0.00345\ mol}{0.060}\ Et_3N = 0.0575\ M\ Et_3N$

$0.1150 \frac{mol}{L} \times 0.0300\ L = \frac{0.00345\ mol}{0.060}\ HCl = 0.0575\ M\ HCl$

(3)

$Et_3\overset{\oplus}{N}H(aq) + H_2O(l) \rightleftharpoons Et_3N(aq) + H_3O^{\oplus}(aq)$

	$Et_3\overset{\oplus}{N}H$		Et_3N	$H_3O^{\oplus}$
I	0.075		0	0
C	−x		+x	+x
E	0.075 − x		x	x

0.0575

$K_a = \frac{K_w}{K_b} = 1.92 \times 10^{-11} = \frac{x^2}{0.075}$

$x = 1.2 \times 10^{-6}$ $\quad 1.05 \times 10^{-6}$

$pH = 5.92$ (2)

5.98