CHEMISTRY 12 – HYDROLYSIS WORKSHEET

1) Which of the following 1.0 M salt solutions will be acidic? **(1 mark)**

$NaNO_3$ $NaHCO_3$ **$NaHSO_4$** Na_2HPO_4

$NaNO_3 \rightarrow Na^+ + NO_3^-$ neutral

$NaHCO_3^- \rightarrow Na^+ + HCO_3^-$ basic since HCO_3^- is a stronger base

$NaHSO_4 \rightarrow Na^+ + HSO_4^-$ acidic

$Na_2HPO_4 \rightarrow 2Na^+ + HPO_4^{2-}$ basic since HPO_4^{2-} is a stronger base

2) Which of the following 1.0 M solutions would have a pH greater than 7.00? **(1 mark)**

HCN **KNO_3** NH_4Cl **$NaCH_3COO$**

HCN acid ∴ pH < 7

$KNO_3 \rightarrow K^+ + NO_3^-$ neutral

$NH_4Cl \rightarrow NH_4^+ + Cl^-$ acidic

$NaCH_3COO \rightarrow Na^+ + CH_3COO^-$ basic

3) Which of the following solutions will have the lowest $[OH^-]$? **(1 mark)** most acidic

NaF **NaCl** $NaHCO_3$ Na_2HPO_4

$NaF \rightarrow Na^+ + F^-$ basic

$NaCl \rightarrow Na^+ + Cl^-$ neutral ∴ has lower $[OH^-]$ than others

$NaHCO_3 \rightarrow Na^+ + HCO_3^-$ basic

$Na_2HPO_4 \rightarrow 2Na^+ + HPO_4^{2-}$ basic

4) List the following 1.0 M solutions in order of decreasing pH. **(1 mark)** base to acid

$CaBr_2$ Li_2SO_3 $FeCl_3$ NaF

$CaBr_2 \rightarrow Ca^{2+} + 2Br^-$ neutral

$Li_2SO_3 \rightarrow 2Li^+ + SO_3^{2-}$ basic

$FeCl_3 \rightarrow Fe^{3+} + 3Cl^-$ acidic

$NaF \rightarrow Na^+ + F^-$ basic

Li_2SO_3, NaF, $CaBr_2$, $FeCl_3$ SO_3^{2-} is a stronger base than F^-

5) Which of the following represents a basic salt solution? **(1 mark)**

NH_3 NH_4I KNO_3 **Na_2CO_3**

NH_3 base but not a salt

$NH_4I \rightarrow NH_4^+ + I^-$ acidic

$KNO_3 \rightarrow K^+ + NO_3^-$ neutral

$Na_2CO_3 \rightarrow 2Na^+ + CO_3^{2-}$ basic

6) One of the products of the reaction between $HNO_{2\,(aq)}$ and $KOH_{\,(aq)}$ undergoes hydrolysis. Write the predominant equilibrium expression and the appropriate equilibrium constant expression for this hydrolysis reaction? **(3 marks)**

$HNO_2 + KOH \longrightarrow H_2O_{(l)} + KNO_2$ (1)

$KNO_2 \rightarrow K^+ + NO_2^-$

$NO_2^- + H_2O_{(l)} \rightleftharpoons HNO_2 + OH^-$ (1)

$K_b = \dfrac{[HNO_2][OH^-]}{[NO_2^-]}$ (1)

7) What is the equilibrium constant expression for the predominant reaction between the hydrogen oxalate ion, $HC_2O_4^-$, and water? **(1 mark)**

based on relative position on the table, $HC_2O_4^-$ is a stronger acid than base

$HC_2O_4^- + H_2O_{(l)} \rightleftharpoons C_2O_4^{2-} + H_3O^+$

$K_a = \dfrac{[C_2O_4^{2-}][H_3O^+]}{[HC_2O_4^-]}$ (1)

8) Consider the salt ammonium acetate, NH_4CH_3COO.

a) Write the equation for the dissociation of NH_4CH_3COO. **(1 mark)**

$NH_4CH_3COO \rightarrow NH_4^+ + CH_3COO^-$

b) Write equations for the hydrolysis reactions that occur. **(2 marks)**

$NH_4^+ + H_2O_{(l)} \rightleftharpoons NH_3 + H_3O^+$ (1)

$CH_3COO^- + H_2O_{(l)} \rightleftharpoons CH_3COOH + OH^-$ (1)

c) Explain why a solution of NH_4CH_3COO has a pH = 7.00. Support your answer with calculations. **(2 marks)**

K_a of $NH_4^+ = 5.6 \times 10^{-10}$

K_b of $CH_3COO^- = \frac{K_w}{K_a} = \frac{1.0 \times 10^{-14}}{1.8 \times 10^{-5}} = 5.6 \times 10^{-10}$ (1)

Since $K_a = K_b$, solution is neutral (1)

9) A chemist prepares a solution by dissolving the salt $NaIO_3$ in water.

a) Write the equation for the dissociation reaction that occurs. **(1 mark)**

$NaIO_3 \rightarrow Na^+ + IO_3^-$

b) Write the equation for the hydrolysis reaction that occurs. **(1 mark)**

$IO_3^- + H_2O_{(l)} \rightleftharpoons HIO_3 + OH^-$

c) Calculate the value of the equilibrium constant for the hydrolysis in part b). **(1 mark)**

$K_b = \frac{K_w}{K_a} = \frac{1.0 \times 10^{-14}}{1.7 \times 10^{-1}} = 5.9 \times 10^{-14}$

10) Consider a 1.0 M solution of $NaHSO_3$. $NaHSO_3 \rightarrow \cancel{Na^+} + HSO_3^-$

a) Write both hydrolysis reactions that occur when $NaHSO_3$ is dissolve in water. **(2 marks)**

acid $HSO_3^- + H_2O_{(l)} \rightleftharpoons SO_3^{2-} + H_3O^+$ (1)

base $HSO_3^- + H_2O_{(l)} \rightleftharpoons H_2SO_3 + OH^-$ (1)

b) Will the above NaHSO3 solution be acidic, basic or neutral? Support your answer with calculations. **(2 marks)**

K_a of $HSO_3^- = 1.0 \times 10^{-7}$

K_b of $HSO_3^- = \frac{K_w}{K_a} = \frac{1.0 \times 10^{-14}}{1.5 \times 10^{-2}} = 6.7 \times 10^{-13}$ (1)

$K_a > K_b \therefore$ acidic (1)

10) Consider a 1.0 M solution of NH_4F. $NH_4F \rightarrow NH_4^+ + F^-$

a) Write both hydrolysis reactions that occur when NH_4F is dissolved in water. **(2 marks)**

$NH_4^+ + H_2O_{(l)} \rightleftarrows NH_3 + H_3O^+$ (1)

$F^- + H_2O_{(l)} \rightleftarrows HF + OH^-$ (1)

b) Will the above NH_4F solution be acidic, basic or neutral? Support your answer with calculations. **(2 marks)**

K_a of $NH_4^+ = 5.6 \times 10^{-10}$

K_b of $F^- = \frac{K_w}{K_a} = \frac{1.0 \times 10^{-14}}{3.5 \times 10^{-4}} = 2.9 \times 10^{-11}$ (1)

$K_a > K_b \therefore$ acidic (1)

11) Which of the following is true as a result of the predominant hydrolysis of $NaHCO_3$? **(1 mark)**

	Solution	Reason
A.	basic	$K_a > K_b$
(B.)	basic	$K_b > K_a$
C.	acidic	$K_a > K_b$
D.	acidic	$K_b > K_a$

$NaHCO_3 \rightarrow \cancel{Na^+} + HCO_3^-$

based on relative position on the table, HCO_3^- is a stronger base than acid

12) Calculate the pH of 3.0 M Na_2CO_3. **(5 marks)**

$Na_2CO_3 \rightarrow 2\cancel{Na^+} + CO_3^{2-}$

$CO_3^{2-} + H_2O_{(l)} \rightleftarrows HCO_3^- + OH^-$ (1)

	CO_3^{2-}	HCO_3^-	OH^-
I	3.0	0	0
C	$-x$	$+x$	$+x$
E	$3.0-x$	x	x

(1)

assume $3.0 - x = 3.0$

$K_b = \frac{[HCO_3^-][OH^-]}{[CO_3^{2-}]}$

$K_b = \frac{K_w}{K_a} = \frac{1.0 \times 10^{-14}}{5.6 \times 10^{-11}}$

$= 1.8 \times 10^{-4}$ (1)

$1.8 \times 10^{-4} = \frac{x^2}{3.0}$

$x = 0.023\ M$ (1)

$pOH = -\log [OH^-]$

$= -\log (0.023)$

$= 1.64$ (0.5)

$pH + pOH = 14.00$

$x + 1.64 = 14.00$

$x = 12.36$ (0.5)

13) Calculate the pH of 0.50 M $NaHSO_4$. **(4 marks)**

HSO_4^- never acts as a base since it is a conjugate of a strong acid ∴ HSO_4^- undergoes cationic hydrolysis

$NaHSO_4 \rightarrow 2\,Na^+ + HSO_4^-$

$HSO_4^- + H_2O(l) \rightleftharpoons SO_4^{2-} + H_3O^+$ (1)

	HSO_4^-	SO_4^{2-}	H_3O^+
I	0.50	0	0
C	−x	+x	+x
E	0.50−x	x	x

(1)

assume $0.50 - x = 0.50$

$$K_a = \frac{[SO_4^{2-}][H_3O^+]}{[HSO_4^-]}$$

$$1.2\times10^{-2} = \frac{x^2}{0.50}$$

$x = 0.077\ M$ (1)

$$pH = -\log[H_3O^+]$$
$$= -\log(0.077)$$
$$= 1.11$$ (1)

14) Calculate the initial concentration of an NH_4Cl salt solution that has a pH = 4.80. Begin by writing the equation for the predominant equilibrium reaction. **(5 marks)**

$NH_4Cl \rightarrow NH_4^+ + Cl^-$

$NH_4^+ + H_2O(l) \rightleftharpoons NH_3 + H_3O^+$ (1)

	NH_4^+	NH_3	H_3O^+
I	x	0	0
C	-1.6×10^{-5}	$+1.6\times10^{-5}$	$+1.6\times10^{-5}$
E	$x - 1.6\times10^{-5}$	1.6×10^{-5}	1.6×10^{-5}

(1)

assume $x - 1.6\times10^{-5} = x$ (0.5)

$[H_3O^+] = 10^{-pH}$

$= 10^{-4.80}$

$= 1.6\times10^{-5}\ M$ (1)

$$K_a = \frac{[NH_3][H_3O^+]}{[NH_4^+]}$$ (0.5)

$$5.6\times10^{-10} = \frac{(1.6\times10^{-5})^2}{x}$$

$x = 0.45\ M$ (1)