Chemistry 12
Worksheet 4-4
Ka and Kb Calculations

Name KEY

Due Date _____

Correct and Hand In by _____

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NOTE: For this worksheet, you must show all of your steps in each calculation. State any assumptions clearly. Make sure your answer is in the correct number of significant digits as justified by the data and make sure your answer has the correct unit. You are allowed one set of corrections.

1. Calculate the $[H_3O^+]$ in a 0.45 M solution of hydrogen sulphide (H_2S). (3 marks)

$H_2S + H_2O \rightleftharpoons H_3O^+ + HS^-$

	H_2S	H_2O	H_3O^+	HS^-
I	0.45		0	0
C	−x		+x	+x
E	0.45−x		x	x

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$K_a = \frac{[H_3O^+][HS^-]}{[H_2S]} = \frac{x^2}{0.45-x}$ assume $0.45-x \cong 0.45$

$K_a \cong \frac{x^2}{0.45} \Rightarrow x^2 = 0.45\,K_a \Rightarrow [H_3O^+] = x = \sqrt{0.45(9.1\times10^{-8})} = 2.0236\times10^{-4}\,M$

Answer $[H_3O^+] = 2.0\times10^{-4}\,M$

2. Calculate the pH in a 0.60 M solution of ammonium chloride (NH_4Cl). (4 marks)

NH_4^+ Cl^- spectator

$NH_4^+ + H_2O \rightleftharpoons H_3O^+ + NH_3$

	NH_4^+	H_2O	H_3O^+	NH_3
I	0.60		0	0
C	−x		+x	+x
E	0.60−x		x	x

4

$K_a = \frac{[H_3O^+][NH_3]}{[NH_4^+]} = \frac{x^2}{0.60-x}$ assume $0.60-x \cong 0.60$

$K_a \cong \frac{x^2}{0.60} \Rightarrow x^2 = 0.60\,K_a$

$[H_3O^+] = x = \sqrt{0.60(5.6\times10^{-10})}$

$[H_3O^+] = 1.833\times10^{-5}\,M$

$pH = 4.74$

Answer $pH = 4.74$

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3. The pH in a 0.25 M solution of the acid HBrO is 4.65 . Using this, calculate the value of Ka for the acid HBrO. (4 marks) pH = 4.65 so $[H_3O^+]$ = antilog (-4.65) = 2.239×10^{-5} M

$HBrO + H_2O \rightleftharpoons H_3O^+ + BrO^-$

[I]	0.25		0	0
[C]	-2.239×10^{-5}		$+2.239\times10^{-5}$	$+2.239\times10^{-5}$
[E]	$0.25 - 2.239\times10^{-5}$		2.239×10^{-5}	2.239×10^{-5}

(4)

$K_a = \frac{[H_3O^+][BrO^-]}{[HBrO]}$

$= \frac{(2.239\times10^{-5})^2}{(0.25 - 2.239\times10^{-5})} = 2.0\times10^{-9}$

Answer $K_a = 2.0\times10^{-9}$

4. The pH in a solution of benzoic acid is 2.355. Determine the molar concentration of the benzoic acid. (4 marks) pH = 2.355 $[H_3O^+]$ = antilog (-2.355) = 0.004416 M

$C_6H_5COOH + H_2O \rightleftharpoons H_3O^+ + C_6H_5COO^-$

[I]	C_o		0	0
[C]	-0.004416		+0.004416	+0.004416
[E]	$C_o - 0.004416$		0.004416	0.004416

(4)

$K_a = \frac{[H_3O^+][C_6H_5COO^-]}{[C_6H_5COOH]}$

$K_a = \frac{(0.004416)^2}{(C_o - 0.004416)}$

$C_o - 0.004416 = \frac{(0.004416)^2}{6.5\times10^{-5}} = 0.299976$

$C_o = 0.299976 + 0.004416$

$= 0.30439$ M

Answer $C_o = 0.30$ M

5. Find the value of Kb for the oxalate ion ($C_2O_4^{2-}$). (1 mark)

$K_{b(C_2O_4^{2-})} = \frac{K_w}{K_{a(HC_2O_4^-)}} = \frac{1.00\times10^{-14}}{6.4\times10^{-5}} = 1.56\times10^{-10}$

(1)

Answer $K_b = 1.6\times10^{-10}$

6. The value of Kb for the weak base methylamine (CH_3NH_2) is 4.4×10^{-4}. Calculate the value of Ka for the acid $CH_3NH_3^+$. (1 mark)

(1) $K_{a(CH_3NH_3^+)} = \frac{K_w}{K_{b(CH_3NH_2)}} = \frac{1.00\times10^{-14}}{4.4\times10^{-4}} = 2.27\times10^{-11}$

Answer $K_a = 2.3\times10^{-11}$

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7. Calculate the pH of a 0.22 M solution of the salt $NaNO_2$. Show all of your steps clearly. (6 marks)

$NaNO_2 \rightarrow Na^+ + NO_2^-$ ← weak base

↑ spectator

$K_{b\ NO_2^-} = \frac{K_w}{K_{a\ HNO_2}} = \frac{1.00\times10^{-14}}{4.6\times10^{-4}} = 2.174\times10^{-11}$

$NO_2^- + H_2O \rightleftharpoons HNO_2 + OH^-$

	NO_2^-	H_2O	HNO_2	OH^-
[I]	0.22		0	0
[C]	$-x$		$+x$	$+x$
[E]	$0.22-x$		x	x

$K_b = \frac{[HNO_2][OH^-]}{[NO_2^-]} = \frac{x^2}{(0.22-x)}$ Assume $0.22-x \cong 0.22$

$K_b \cong \frac{x^2}{0.22} \Rightarrow x^2 = 0.22K_b \Rightarrow [OH^-] = x = \sqrt{0.22(2.174\times10^{-11})} = 2.187\times10^{-6}\ M$

$pOH = 5.660$

Answer $pH = 8.34$

8. A 0.40 M solution of the lactate ion ($C_3H_5O_3^-$) (a weak base), has a pH of 8.728.

a) Calculate the Kb of the lactate ion ($C_3H_5O_3^-$). (4 marks)

$pH = 8.728$ $pOH = 5.272$ $[OH^-] = \text{antilog}(-5.272) = 5.346\times10^{-6}\ M$

$C_3H_5O_3^- + H_2O \rightleftharpoons C_3H_6O_3 + OH^-$

	$C_3H_5O_3^-$	H_2O	$C_3H_6O_3$	OH^-
	0.40		0	0
	-5.346×10^{-6}		$+5.346\times10^{-6}$	$+5.346\times10^{-6}$
	$0.40-5.346\times10^{-6}$		5.346×10^{-6}	5.346×10^{-6}

(4)

$K_b = \frac{[C_3H_6O_3][OH^-]}{[C_3H_5O_3^-]} = \frac{(5.346\times10^{-6})^2}{(0.40-5.346\times10^{-6})} = 7.144\times10^{-11}$

Answer $K_b = 7.1\times10^{-11}$

b) Using the information from (a), calculate the Ka for lactic acid ($HC_3H_5O_3$). (1 mark)

$K_{a(HC_3H_5O_3)} = \frac{1.00\times10^{-14}}{K_{b(C_3H_5O_3^-)}} = \frac{1.00\times10^{-14}}{7.144\times10^{-11}} = 1.40\times10^{-4}$

(1)

Answer $K_a = 1.4\times10^{-4}$

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9. The weak base ethylamine ($C_2H_5NH_2$) has a Kb of 6.4×10^{-4}.

a) Write the equilibrium equation for the ionization of ethylamine. (1 mark)

(1) $C_2H_5NH_2 + H_2O \rightleftharpoons C_2H_5NH_3^+ + OH^-$

b) What $[C_2H_5NH_2]$ is required to produce an ethylamine solution with a pH = 12.102? (4 marks)

$pH = 12.102$ $pOH = 1.898$ $[OH^-] = \text{antilog}(-1.898) = 0.01265\ M$

$C_2H_5NH_2 + H_2O \rightleftharpoons C_2H_5NH_3^+ + OH^-$

C_o		0	0
-0.01265		$+0.01265$	$+0.01265$
$C_o - 0.01265$		0.01265	0.01265

(4) $K_b = \dfrac{[C_2H_5NH_3^+][OH^-]}{[C_2H_5NH_2]} \Rightarrow 6.4 \times 10^{-4} = \dfrac{(0.01265)^2}{(C_o - 0.01265)} \Rightarrow C_o - 0.01265 = 0.24993$

$C_o - 0.01265 = \dfrac{(0.01265)^2}{6.4 \times 10^{-4}}$

$C_o = 0.24993 + 0.01265 = 0.2626\ M$

Answer $C_o = 0.26\ M$

10. Calculate the pH of a 2.5 M solution of hydriodic acid (HI). (2 marks)

SA

SA: $[H_3O^+] = [HI] = 2.5\ M$

(2) $pH = -\log(2.5) = -0.39794$

Answer $pH = -0.40$

11. What concentration of the base CaO is needed to produce a solution with a pH = 14.00? (2 marks)

$pH = 14.00$ $pOH = 14.00 - 14.00 = 0.00$

(2) $[OH^-] = \text{antilog}(0.00) = 1.0\ M$

$0.50\ M \xleftarrow{1/2} 1.0\ M$

$O^{2-} + H_2O \rightarrow 2OH^-$

$[O^{2-}] = 0.50\ M$

$0.50\ M \xleftarrow{1/1} 0.50\ M$

$CaO \rightarrow Ca^{2+} + O^{2-}$

Answer $[CaO] = 0.50\ M$

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