

Chemistry 12
Worksheet 4-4
Ka and Kb Calculations

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Name KEY

Due Date _____

Correct and Hand In by _____

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)

| | | | | |
|---|--|--|----|----|
| I | $H_2S + H_2O \rightleftharpoons H_3O^+ + HS^-$ | | | |
| C | 0.45 | | 0 | 0 |
| E | -x | | +x | +x |
| | 0.45-x | | x | x |

(3)

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

assume $0.45-x \approx 0.45$

$$K_a \approx \frac{x^2}{0.45} \Rightarrow x^2 = 0.45 K_a \Rightarrow [H_3O^+] = x = \sqrt{0.45(9.1 \times 10^{-8})} = 2.0236 \times 10^{-4} M$$

| |
|--|
| Answer $[H_3O^+] = 2.0 \times 10^{-4} M$ |
|--|

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

| | | | | |
|---|--|--|----|----|
| I | $NH_4^+ + H_2O \rightleftharpoons H_3O^+ + NH_3$ | | | |
| C | 0.60 | | 0 | 0 |
| E | -x | | +x | +x |
| | 0.60-x | | x | x |

(4)

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

assume $0.60-x \approx 0.60$

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

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

$$[H_3O^+] = 1.833 \times 10^{-5} M$$

$$pH = 4.74$$

| |
|--------------------|
| Answer $pH = 4.74$ |
|--------------------|

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KEY

3. The pH in a 0.25 M solution of the acid HBrO is 4.65. Using this, calculate the value of K_a for the acid HBrO. (4 marks) $\text{pH} = 4.65$ so $[\text{H}_3\text{O}^+] = \text{antilog}(-4.65) = 2.239 \times 10^{-5} \text{ M}$

$$\text{HBrO} + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{BrO}^-$$

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

(4)

$$K_a = \frac{[\text{H}_3\text{O}^+][\text{BrO}^-]}{[\text{HBrO}]}$$

$$= \frac{(2.239 \times 10^{-5})^2}{(0.25 - 2.239 \times 10^{-5})} = 2.0 \times 10^{-9}$$

Answer $K_a = 2.0 \times 10^{-9}$

4. The pH in a solution of benzoic acid is 2.355. Determine the molar concentration of the benzoic acid. (4 marks) $\text{pH} = 2.355$ $[\text{H}_3\text{O}^+] = \text{antilog}(-2.355) = 0.004416 \text{ M}$

$$\text{C}_6\text{H}_5\text{COOH} + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{C}_6\text{H}_5\text{COO}^-$$

| | | | | |
|-----|------------------|--|-------------|-------------|
| [I] | C_0 | | 0 | 0 |
| [C] | -0.004416 | | $+0.004416$ | $+0.004416$ |
| [E] | $C_0 - 0.004416$ | | 0.004416 | 0.004416 |

(4)

$$K_a = \frac{[\text{H}_3\text{O}^+][\text{C}_6\text{H}_5\text{COO}^-]}{[\text{C}_6\text{H}_5\text{COOH}]}$$

$$K_a = \frac{(0.004416)^2}{(C_0 - 0.004416)}$$

$$C_0 - 0.004416 = \frac{(0.004416)^2}{6.5 \times 10^{-5}} = 0.299976$$

$$C_0 = 0.299976 + 0.004416 = 0.30439 \text{ M}$$

Answer $C_0 = 0.30 \text{ M}$

5. Find the value of K_b for the oxalate ion ($\text{C}_2\text{O}_4^{2-}$). (1 mark)

$$K_b(\text{C}_2\text{O}_4^{2-}) = \frac{K_w}{K_a(\text{HC}_2\text{O}_4^-)} = \frac{1.00 \times 10^{-14}}{6.4 \times 10^{-5}} = 1.56 \times 10^{-10}$$

(1)

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

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

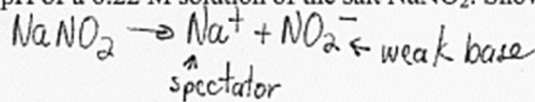
$$K_a(\text{CH}_3\text{NH}_3^+) = \frac{K_w}{K_b(\text{CH}_3\text{NH}_2)} = \frac{1.00 \times 10^{-14}}{4.4 \times 10^{-4}} = 2.27 \times 10^{-11}$$

(1)

Answer $K_a = 2.3 \times 10^{-11}$

KEY

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



$$\text{NO}_2^- + \text{H}_2\text{O} \rightleftharpoons \text{HNO}_2 + \text{OH}^-$$

| | | | |
|-----|--------|----|----|
| [I] | 0.22 | 0 | 0 |
| [C] | -x | +x | +x |
| [E] | 0.22-x | x | x |

$$K_b = \frac{[\text{HNO}_2][\text{OH}^-]}{[\text{NO}_2^-]} = \frac{x^2}{(0.22-x)}$$

$$K_b \approx \frac{x^2}{0.22} \Rightarrow x^2 = 0.22K_b$$

Assume
 $0.22-x \approx 0.22$

$$\Rightarrow [\text{OH}^-] = x = \sqrt{0.22(2.174 \times 10^{-11})} = 2.187 \times 10^{-6} \text{ M}$$

$\text{pOH} = 5.660$

Answer $\text{pH} = 8.34$

$$K_b \text{ NO}_2^- = \frac{K_w}{K_a \text{ HNO}_2}$$

$$= \frac{1.00 \times 10^{-14}}{4.6 \times 10^{-4}}$$

$$= 2.174 \times 10^{-11}$$

8. A 0.40 M solution of the lactate ion ($\text{C}_3\text{H}_5\text{O}_3^-$) (a weak base), has a pH of 8.728.

- a) Calculate the K_b of the lactate ion ($\text{C}_3\text{H}_5\text{O}_3^-$). (4 marks)

$$\text{pH} = 8.728 \quad \text{pOH} = 5.272 \quad [\text{OH}^-] = \text{antilog}(-5.272) = 5.346 \times 10^{-6} \text{ M}$$

$$\text{C}_3\text{H}_5\text{O}_3^- + \text{H}_2\text{O} \rightleftharpoons \text{C}_3\text{H}_6\text{O}_3 + \text{OH}^-$$

| | | |
|-------------------------------|-------------------------|-------------------------|
| 0.40 | 0 | 0 |
| -5.346×10^{-6} | $+5.346 \times 10^{-6}$ | $+5.346 \times 10^{-6}$ |
| $0.40 - 5.346 \times 10^{-6}$ | 5.346×10^{-6} | 5.346×10^{-6} |

④

$$K_b = \frac{[\text{C}_3\text{H}_6\text{O}_3][\text{OH}^-]}{[\text{C}_3\text{H}_5\text{O}_3^-]}$$

$$= \frac{(5.346 \times 10^{-6})^2}{(0.40 - 5.346 \times 10^{-6})}$$

$$= 7.144 \times 10^{-11}$$

Answer $K_b = 7.1 \times 10^{-11}$

- b) Using the information from (a), calculate the K_a for lactic acid ($\text{HC}_3\text{H}_5\text{O}_3$). (1 mark)

$$K_a(\text{HC}_3\text{H}_5\text{O}_3) = \frac{1.00 \times 10^{-14}}{K_b(\text{C}_3\text{H}_5\text{O}_3^-)} = \frac{1.00 \times 10^{-14}}{7.144 \times 10^{-11}} = 1.40 \times 10^{-4}$$

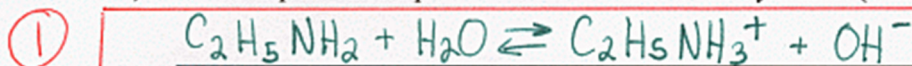
①

Answer $K_a = 1.4 \times 10^{-4}$

KEY

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

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

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_0 | | 0 | 0 |
| -0.01265 | | +0.01265 | +0.01265 |
| $C_0 - 0.01265$ | | 0.01265 | 0.01265 |

$$C_0 - 0.01265 = \frac{(0.01265)^2}{6.4 \times 10^{-4}}$$

④ $K_b = \frac{[C_2H_5NH_3^+][OH^-]}{[C_2H_5NH_2]} \Rightarrow 6.4 \times 10^{-4} = \frac{(0.01265)^2}{(C_0 - 0.01265)} \Rightarrow C_0 - 0.01265 = 0.24993$
 $C_0 = 0.24993 + 0.01265 = 0.2626 M$

Answer $C_0 = 0.26 M$

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

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

② $pH = -\log(2.5) = -0.39794$

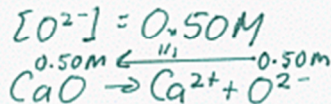
Answer $pH = -0.40$

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

$$CaO + H_2O \rightleftharpoons Ca^{2+} + 2OH^-$$



Answer $[CaO] = 0.50 M$

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