AP CHEMISTRY

TOPIC 7: ACIDS & BASES, Day 82:

CLEARY SHOW THE METHOD USED AND THE STEPS INVOLVED IN ARRIVING AT YOUR ANSWERS.

$$HC_7H_5O_{2\,(aq)} \rightleftharpoons C_7H_5O_2^{-1}{}_{(aq)} + H^{+1}{}_{(aq)} \qquad K_a = 6.4 \times 10^{-5}$$

1. Benzoic acid, $HC_7H_5O_2$, ionizes in water according to the equation above.

(a) Write the equilibrium-constant expression for the reaction.

$$K_a = \frac{\left[C_7H_5O_2^{-1} \right]\left[H^{+1} \right]}{\left[HC_7H_5O_2 \right]}$$

(b) Calculate the pH of 0.567 *M* solution of benzoic acid.

	$[HC_7H_5O_2]$	$\rightleftharpoons$	$[C_7H_5O_2^{-1}]$	+	$[H^{+1}]$
I	0.567 *M*		0		0
C	$-x$		$+x$		$+x$
E	0.567 *M* - x		x		x

$$K_a = \frac{\left[C_7H_5O_2^{-1} \right]\left[H^{+1} \right]}{\left[HC_7H_5O_2 \right]} = \frac{x^2}{0.567 - x} = \frac{x^2}{0.567} = 6.4 \times 10^{-5}$$

$$x^2 = (0.567)(6.4 \times 10^{-5}), \qquad x = \sqrt{3.63 \times 10^{-5}} = 6.02 \times 10^{-3}$$

$$[H^{+1}] = 6.02 \times 10^{-3}\ M$$

$$\mathbf{pH} = -\log(6.02 \times 10^{-3}) = \mathbf{2.22}$$

(c) A 0.763 g sample of lithium benzonate, $LiC_7H_5O_2$, is added to a 75.0 mL sample of a 0.567 *M* solution of benzoic acid. Assuming that no change in the volume of the solution occurs, calculate each of the following.

(i) The concentration of the benzonate ion, $C_7H_5O_2^{-1}{}_{(aq)}$, in the solution.

$$\#\text{ mol } LiC_7H_5O_2 = \frac{0.763\ g\ LiC_7H_5O_2}{} \times \frac{1\ mol\ LiC_7H_5O_2}{128.05\ g} = 5.96 \times 10^{-3}\ mol$$

$$\boldsymbol{LiC_7H_5O_2 \rightarrow Li^{+1} + C_7H_5O_2^{-1}}$$

(Li^{+1} is a conjugate of a strong base, $C_7H_5O_2^{-1}$ is a conjugate of weak acid)

$$[C_7H_5O_2^{-1}] = \frac{5.96 \times 10^{-3}\ mol}{0.075\ L} = 0.0794\ M$$

(ii) The concentration of the $H^{+}_{(aq)}$ ion in the solution.

	$[\ C_7H_5O_2^{-1}\ ]$	+	HOH	$\rightleftharpoons$	$[\ HC_7H_5O_2\ ]$	+	$[\ OH^{-1}\ ]$
I	0.0794 *M*		-		0.567 *M*		~ 0
C	- *x*		-		+ *x*		+ *x*
E	0.0794 - *x*		-		0.567 - *x*		$[\ OH^{-1}\ ]$

$$K_b = \frac{K_w}{K_a} = \frac{1.00\times10^{-14}}{6.40\times10^{-5}} = 1.56\times10^{-10}$$

$$K_b = \frac{\left[\ HC_7H_5O_2\ \right]\left[\ OH^{-1}\ \right]}{\left[\ C_7H_5O_2^{-1}\ \right]} = \frac{\left(\ 0.567+x\ \right)\left[\ OH^{-1}\ \right]}{\left(\ 0.0794-x\ \right)} = \frac{\left(\ 0.567\ \right)\left[\ OH^{-1}\ \right]}{\left(\ 0.0794\ \right)} = 1.56\times10^{-10}$$

$$\left[\ OH^{-1}\ \right] = \frac{\left(\ 1.56\times10^{-10}\ \right)\left(\ 0.0794\ \right)}{\left(\ 0.567\ \right)} = 2.19\times10^{-11}$$

$$\left[\ H^{+1}\ \right] = \frac{K_w}{\left[OH^{-1}\right]} = \frac{1.00\times10^{-14}}{2.19\times10^{-11}} = 4.57\times10^{-4}$$

The methanoate ion, $HCO_2^{-1}{}_{(aq)}$, reacts with water to form methanoic acid and hydroxide, as shown in the following equation.

$$HCO_2^{-1}{}_{(aq)} + H_2O_{(l)} \rightleftharpoons H_2CO_{2\,(aq)} + OH^{-1}{}_{(aq)}$$

(d) Given that $[\ OH^{-}\ ]$ is 4.18×10^{-6} *M* in a 0.309 *M* solution of sodium methanoate, calculate each of the following.

(i) The value of K_b for the methanoate ion, $HCO_2^{-1}{}_{(aq)}$.

$$NaHCO_2 \rightarrow Na^{+1} + HCO_2^{-1}$$

(Na^{+1} is a conjugate of a strong base, HCO_2^{-1} is a conjugate of weak acid)

	$[\ HCO_2^{-1}\ ]$	+	HOH	$\rightleftharpoons$	$[H_2CO_2\ ]$	+	$[\ OH^{-1}\ ]$
I	0.309 *M*		-		0		0
C	- *x*		-		+ *x* = 4.18×10^{-6}		+ *x* = 4.18×10^{-6}
E	0.309 - 4.18×10^{-6}		-		4.18×10^{-6}		4.18×10^{-6}

$$K_b = \frac{\left[\ H_2CO_2\ \right]\left[\ OH^{-1}\ \right]}{\left[\ HCO_2^{-1}\ \right]} = \frac{\left(\ 4.18\times10^{-6}\ \right)^2}{\left(0.309\ -\ 4.18\times10^{-6}\right)} = 5.65\times10^{-11}$$

(ii) The value of K_a for methanoic acid, $H_2CO_{2\,(aq)}$

$$K_a = \frac{K_w}{K_b} = \frac{1.00\times10^{-14}}{5.65\times10^{-11}} = 1.77\times10^{-4}$$

(e) Which acid is stronger, benzoic acid or methanoic acid? Justify your answer.

K_a = 6.40×10^{-5} = benzoic acid (see given K_a at the beginning of the question)

K_a = 1.77×10^{-4} = methanoic acid (calculated value from above)

Methanoic acid. For acids, the larger the K_a, the greater the strength (dissociation).