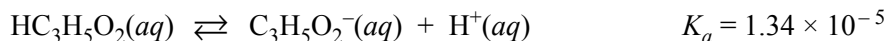


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Question 1



Propanoic acid, $\text{HC}_3\text{H}_5\text{O}_2$, ionizes in water according to the equation above.

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

| | |
|---|--|
| $K_a = \frac{[\text{H}^+][\text{C}_3\text{H}_5\text{O}_2^-]}{[\text{HC}_3\text{H}_5\text{O}_2]}$ <p><u>Notes:</u> Correct expression without K_a earns 1 point. Entering the value of K_a is acceptable. Charges must be correct to earn 1 point.</p> | <p>One point is earned for the correct equilibrium expression.</p> |
|---|--|

(b) Calculate the pH of a 0.265 M solution of propanoic acid.

| | | | | | | | | | | | | | |
|---|-----------|-------|----|----|---|----|----|----|---|-----------|----|----|---|
| $\text{HC}_3\text{H}_5\text{O}_2(aq) \rightleftharpoons \text{C}_3\text{H}_5\text{O}_2^-(aq) + \text{H}^+(aq)$ <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="padding: 2px 10px;">I</td> <td style="padding: 2px 10px;">0.265</td> <td style="padding: 2px 10px;">0</td> <td style="padding: 2px 10px;">~0</td> </tr> <tr> <td style="padding: 2px 10px;">C</td> <td style="padding: 2px 10px;">-x</td> <td style="padding: 2px 10px;">+x</td> <td style="padding: 2px 10px;">+x</td> </tr> <tr> <td style="padding: 2px 10px;">E</td> <td style="padding: 2px 10px;">0.265 - x</td> <td style="padding: 2px 10px;">+x</td> <td style="padding: 2px 10px;">+x</td> </tr> </table> $K_a = \frac{[\text{H}^+][\text{C}_3\text{H}_5\text{O}_2^-]}{[\text{HC}_3\text{H}_5\text{O}_2]} = \frac{(x)(x)}{(0.265 - x)}$ <p>Assume that $0.265 - x \approx 0.265$,</p> <p>then $1.34 \times 10^{-5} = \frac{x^2}{0.265}$</p> $(1.34 \times 10^{-5})(0.265) = x^2$ $3.55 \times 10^{-6} = x^2$ $x = [\text{H}^+] = 1.88 \times 10^{-3} \text{ M}$ $\text{pH} = -\log [\text{H}^+] = -\log (1.88 \times 10^{-3})$ $\text{pH} = 2.725$ | I | 0.265 | 0 | ~0 | C | -x | +x | +x | E | 0.265 - x | +x | +x | <p>One point is earned for recognizing that $[\text{H}^+]$ and $[\text{C}_3\text{H}_5\text{O}_2^-]$ have the same value in the equilibrium expression.</p> <p>One point is earned for calculating $[\text{H}^+]$.</p> <p>One point is earned for calculating the correct pH.</p> |
| I | 0.265 | 0 | ~0 | | | | | | | | | | |
| C | -x | +x | +x | | | | | | | | | | |
| E | 0.265 - x | +x | +x | | | | | | | | | | |

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Question 1 (continued)

(c) A 0.496 g sample of sodium propanoate, $\text{NaC}_3\text{H}_5\text{O}_2$, is added to a 50.0 mL sample of a 0.265 M solution of propanoic acid. Assuming that no change in the volume of the solution occurs, calculate each of the following.

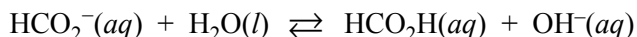
(i) The concentration of the propanoate ion, $\text{C}_3\text{H}_5\text{O}_2^-(aq)$ in the solution

| | |
|--|---|
| $\text{mol NaC}_3\text{H}_5\text{O}_2 = 0.496 \text{ g NaC}_3\text{H}_5\text{O}_2 \times \frac{1 \text{ mol NaC}_3\text{H}_5\text{O}_2}{96.0 \text{ g NaC}_3\text{H}_5\text{O}_2}$ $\text{mol NaC}_3\text{H}_5\text{O}_2 = 5.17 \times 10^{-3} \text{ mol NaC}_3\text{H}_5\text{O}_2 = \text{mol C}_3\text{H}_5\text{O}_2^-$ $[\text{C}_3\text{H}_5\text{O}_2^-] = \frac{\text{mol C}_3\text{H}_5\text{O}_2^-}{\text{volume of solution}} = \frac{5.17 \times 10^{-3} \text{ mol C}_3\text{H}_5\text{O}_2^-}{0.050 \text{ L}} = 0.103 \text{ M}$ | <p>One point is earned for calculating the number of moles of $\text{NaC}_3\text{H}_5\text{O}_2$.</p> <p>One point is earned for the molarity of the solution.</p> |
|--|---|

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

| | | | | | | | | | | | | | |
|---|-----------|-----------|-------|----|---|----|----|----|---|-----------|-----------|----|--|
| $\text{HC}_3\text{H}_5\text{O}_2(aq) \rightleftharpoons \text{C}_3\text{H}_5\text{O}_2^-(aq) + \text{H}^+(aq)$ <table style="margin-left: 20px; border-collapse: collapse;"> <tr> <td style="padding-right: 10px;">I</td> <td style="padding-right: 20px;">0.265</td> <td style="padding-right: 20px;">0.103</td> <td>~0</td> </tr> <tr> <td>C</td> <td>-x</td> <td>+x</td> <td>+x</td> </tr> <tr> <td>E</td> <td>0.265 - x</td> <td>0.103 + x</td> <td>+x</td> </tr> </table> $K_a = \frac{[\text{H}^+][\text{C}_3\text{H}_5\text{O}_2^-]}{[\text{HC}_3\text{H}_5\text{O}_2]} = \frac{(x)(0.103 + x)}{(0.265 - x)}$ <p>Assume that $0.103 + x \approx 0.103$ and $0.265 - x \approx 0.265$</p> $K_a = 1.34 \times 10^{-5} = \frac{(x)(0.103)}{0.265}$ $x = [\text{H}^+] = (1.34 \times 10^{-5}) \times \frac{0.265}{0.103} = 3.45 \times 10^{-5} \text{ M}$ | I | 0.265 | 0.103 | ~0 | C | -x | +x | +x | E | 0.265 - x | 0.103 + x | +x | <p>One point is earned for calculating the value of $[\text{H}^+]$.</p> |
| I | 0.265 | 0.103 | ~0 | | | | | | | | | | |
| C | -x | +x | +x | | | | | | | | | | |
| E | 0.265 - x | 0.103 + x | +x | | | | | | | | | | |

The methanoate ion, $\text{HCO}_2^-(aq)$, reacts with water to form methanoic acid and hydroxide ion, as shown in the following equation.



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

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Question 1 (continued)

(i) The value of K_b for the methanoate ion, $\text{HCO}_2^-(aq)$

| | | | | | | | | | | | | | | | | |
|--|-----------|-------|----|----|----|---|----|---|----|----|---|-----------|---|----|----|--|
| $\text{HCO}_2^-(aq) + \text{H}_2\text{O}(l) \rightleftharpoons \text{HCO}_2\text{H} + \text{OH}^-(aq)$ <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="padding: 2px 10px;">I</td> <td style="padding: 2px 10px;">0.309</td> <td style="padding: 2px 10px;">-</td> <td style="padding: 2px 10px;">0</td> <td style="padding: 2px 10px;">~0</td> </tr> <tr> <td style="padding: 2px 10px;">C</td> <td style="padding: 2px 10px;">-x</td> <td style="padding: 2px 10px;">-</td> <td style="padding: 2px 10px;">+x</td> <td style="padding: 2px 10px;">+x</td> </tr> <tr> <td style="padding: 2px 10px;">E</td> <td style="padding: 2px 10px;">0.309 - x</td> <td style="padding: 2px 10px;">-</td> <td style="padding: 2px 10px;">+x</td> <td style="padding: 2px 10px;">+x</td> </tr> </table> <p style="margin-top: 10px;">$x = [\text{OH}^-] = 4.18 \times 10^{-6} M$</p> $K_b = \frac{[\text{OH}^-][\text{HCO}_2\text{H}]}{[\text{HCO}_2^-]} = \frac{(x)(x)}{(0.309 - x)} = \frac{(4.18 \times 10^{-6})^2}{(0.309 - x)}$ <p style="margin-top: 10px;">x is very small ($4.18 \times 10^{-6} M$), therefore $0.309 - x \approx 0.309$</p> $K_b = \frac{(4.18 \times 10^{-6})^2}{0.309} = 5.65 \times 10^{-11}$ | I | 0.309 | - | 0 | ~0 | C | -x | - | +x | +x | E | 0.309 - x | - | +x | +x | <p>One point is earned for substituting 4.18×10^{-6} for both $[\text{OH}^-]$ and $[\text{HCO}_2\text{H}]$, and for calculating the value of K_b.</p> |
| I | 0.309 | - | 0 | ~0 | | | | | | | | | | | | |
| C | -x | - | +x | +x | | | | | | | | | | | | |
| E | 0.309 - x | - | +x | +x | | | | | | | | | | | | |

(ii) The value of K_a for methanoic acid, HCO_2H

| | |
|--|--|
| $K_w = K_a \times K_b$ $K_a = \frac{K_w}{K_b} = \frac{1.00 \times 10^{-14}}{5.65 \times 10^{-11}}$ $K_a = 1.77 \times 10^{-4}$ | <p>One point is earned for calculating a value of K_a from the value of K_b determined in part (d)(i).</p> |
|--|--|

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

| | |
|--|--|
| <p>K_a for propanoic acid is 1.34×10^{-5}, and K_a for methanoic acid is 1.77×10^{-4}. For acids, the larger the value of K_a, the greater the strength; therefore methanoic acid is the stronger acid because $1.77 \times 10^{-4} > 1.34 \times 10^{-5}$.</p> | <p>One point is earned for the correct choice and explanation based on the K_a calculated for methanoic acid in part (d)(ii).</p> |
|--|--|