Question 1

$$HC_3H_5O_2(aq) \rightleftarrows C_3H_5O_2^-(aq) + H^+(aq) \qquad K_a = 1.34 \times 10^{-5}$$

Propanoic acid, $HC_3H_5O_2$, ionizes in water according to the equation above.

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

$K_a = \dfrac{[H^+][C_3H_5O_2^-]}{[HC_3H_5O_2]}$ Notes: Correct expression without K_a earns 1 point. Entering the value of K_a is acceptable. Charges must be correct to earn 1 point.	One point is earned for the correct equilibrium expression.

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

$HC_3H_5O_2(aq) \rightleftarrows C_3H_5O_2^-(aq) + H^+(aq)$ I 0.265 0 ~0 C $-x$ $+x$ $+x$ E $0.265 - x$ $+x$ $+x$ $K_a = \dfrac{[H^+][C_3H_5O_2^-]}{[HC_3H_5O_2]} = \dfrac{(x)(x)}{(0.265-x)}$ Assume that $0.265 - x \approx 0.265$, then $1.34 \times 10^{-5} = \dfrac{x^2}{0.265}$ $(1.34 \times 10^{-5})(0.265) = x^2$ $3.55 \times 10^{-6} = x^2$ $x = [H^+] = 1.88 \times 10^{-3}\ M$ $pH = -\log[H^+] = -\log(1.88 \times 10^{-3})$ $pH = 2.725$	One point is earned for recognizing that $[H^+]$ and $[C_3H_5O_2^-]$ have the same value in the equilibrium expression. One point is earned for calculating $[H^+]$. One point is earned for calculating the correct pH.

Question 1 (continued)

(c) A 0.496 g sample of sodium propanoate, $NaC_3H_5O_2$, 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, $C_3H_5O_2^-(aq)$ in the solution

$\text{mol } NaC_3H_5O_2 = 0.496 \text{ g } NaC_3H_5O_2 \times \frac{1 \text{ mol } NaC_3H_5O_2}{96.0 \text{ g } NaC_3H_5O_2}$ $\text{mol } NaC_3H_5O_2 = 5.17 \times 10^{-3} \text{ mol } NaC_3H_5O_2 = \text{mol } C_3H_5O_2^-$ $[C_3H_5O_2^-] = \frac{\text{mol } C_3H_5O_2^-}{\text{volume of solution}} = \frac{5.17 \times 10^{-3} \text{ mol } C_3H_5O_2^-}{0.050 \text{ L}} = 0.103 \ M$	One point is earned for calculating the number of moles of $NaC_3H_5O_2$. One point is earned for the molarity of the solution.

(ii) The concentration of the $H^+(aq)$ ion in the solution

$HC_3H_5O_2(aq) \rightleftarrows C_3H_5O_2^-(aq) + H^+(aq)$ I 0.265 0.103 ~0 C $-x$ $+x$ $+x$ E $0.265 - x$ $0.103 + x$ $+x$ $K_a = \frac{[H^+][C_3H_5O_2^-]}{[HC_3H_5O_2]} = \frac{(x)(0.103+x)}{(0.265-x)}$ Assume that $0.103 + x \approx 0.103$ and $0.265 - x \approx 0.265$ $K_a = 1.34 \times 10^{-5} = \frac{(x)(0.103)}{0.265}$ $x = [H^+] = (1.34 \times 10^{-5}) \times \frac{0.265}{0.103} = 3.45 \times 10^{-5} \ M$	One point is earned for calculating the value of $[H^+]$.

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

$$HCO_2^-(aq) + H_2O(l) \rightleftarrows HCO_2H(aq) + OH^-(aq)$$

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

Question 1 (continued)

(i) The value of K_b for the methanoate ion, $HCO_2^-(aq)$

	$HCO_2^-(aq)$	+ $H_2O(l)$	$\rightleftarrows$ HCO_2H	+ $OH^-(aq)$
I	0.309	-	0	~0
C	$-x$	-	$+x$	$+x$
E	$0.309 - x$	-	$+x$	$+x$

$x = [OH^-] = 4.18 \times 10^{-6}\ M$

$$K_b = \frac{[OH^-][HCO_2H]}{[HCO_2^-]} = \frac{(x)(x)}{(0.309-x)} = \frac{(4.18\times10^{-6})^2}{(0.309-x)}$$

x is very small ($4.18 \times 10^{-6}\ M$), therefore $0.309 - x \approx 0.309$

$$K_b = \frac{(4.18\times10^{-6})^2}{0.309} = 5.65 \times 10^{-11}$$

One point is earned for substituting 4.18×10^{-6} for both $[OH^-]$ and $[HCO_2H]$, and for calculating the value of K_b.

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

$$K_w = K_a \times K_b$$

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

$$K_a = 1.77 \times 10^{-4}$$

One point is earned for calculating a value of K_a from the value of K_b determined in part (d)(i).

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

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 $1.77 \times 10^{-4} > 1.34 \times 10^{-5}$.

One point is earned for the correct choice and explanation based on the K_a calculated for methanoic acid in part (d)(ii).