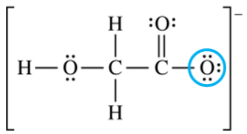
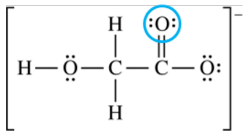
## Question 7: Short Answer — 4 points

**A** For a correct circled atom. **Point 01**

Accept one of the following:

- 
- 

*(Because of resonance, the two* C–O *bonds on the right are equivalent.)*

**B** (i) For the correct calculated value: **Point 02**

$$K_b = \frac{[HC_2H_3O_3][OH^-]}{[C_2H_3O_3^-]} = \frac{(1.3\times10^{-5})(1.3\times10^{-5})}{(2.5-1.3\times10^{-5})} \approx \frac{(1.3\times10^{-5})^2}{(2.5)} = 6.8\times10^{-11}$$

(ii) For the correct calculated value, consistent with part B (i): **Point 03**

$$K_a = \frac{K_w}{K_b} = \frac{1.0\times10^{-14}}{6.8\times10^{-11}} = 1.5\times10^{-4}$$

**C** For the correct answer and a valid justification: **Point 04**

*Agree.* $H_3O^+$ *is consumed in step 1 and regenerated in step 2, which is consistent with the behavior of a catalyst.*





## Question 1: Long Answer — 10 points

**(a)** For the correct expression: **1 point**

$$K_a = \frac{[H_3O^+][HCOO^-]}{[HCOOH]}$$

**(b)** For the correct calculated concentration of $H_3O^+$: **1 point**

| | $HCOOH$ | $+\ H_2O$ | $\rightleftarrows$ | $H_3O^+$ | $+\ HCOO^-$ |
|---|---|---|---|---|---|
| $I$ | $0.25$ | | | $0$ | $0$ |
| $C$ | $-x$ | | | $+x$ | $+x$ |
| $E$ | $0.25-x$ | | | $x$ | $x$ |

*Let* $[H_3O^+] = x$, *then* $1.8\times10^{-4} = \dfrac{x^2}{(0.25-x)}$

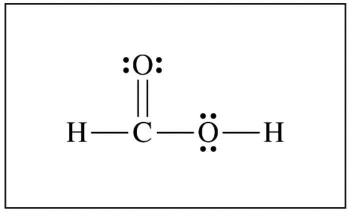
*Assume* $x << 0.25$, *then* $1.8\times10^{-4} = \dfrac{x^2}{0.25} \Rightarrow x = 0.0067\ M$

For the correct calculated value of pH: **1 point**

$$pH = -\log[H_3O^+] = -\log(0.0067) = 2.17$$

**Total for part (b) — 2 points**

**(c)** For the correct diagram: **1 point**



**(d)** **(i)** For the correct balanced equation (state symbols not required): **1 point**

$$H_2NNH_2(aq) + HCOOH(aq) \rightarrow H_2NNH_3^+(aq) + HCOO^-(aq)$$

**(ii)** For the correct answer and a valid justification: **1 point**

*Acidic. The* $K_a$ *of* $H_2NNH_3^+$ *is greater than the* $K_b$ *of* $HCOO^-$, *so the production of* $H_3O^+(aq)$ *occurs to a greater extent than the production of* $OH^-(aq)$.

**Total for part (d) — 2 points**

**(e)** For the correct answer and a valid justification: **1 point**

Accept one of the following:

- *Yes. The oxidation number of hydrogen changes from +1 in HCOOH to zero in* $H_2$.
- *Yes. The oxidation number of carbon changes from +2 in HCOOH to +4 in* $CO_2$.

| | | |
|---|---|---|
| **(f)** | For the correct calculated value of the pressure of $CO_2$ (may be implicit):<br>*24 atm total × 1 atm $CO_2$ / 2 atm of product = 12 atm $CO_2$* | **1 point** |
| | For the correct calculated number of moles of $CO_2$:<br>$PV = nRT$<br>$n = \frac{PV}{RT} = \frac{(12\text{ atm})(4.3\text{ L})}{(0.08206\text{ L atm mol}^{-1}\text{ K}^{-1})(298\text{ K})} = 2.1\text{ mol CO}_2$ | **1 point** |
| | **Total for part (f)** | **2 points** |
| **(g)** | For the correct answer and a valid justification:<br>*It would remain the same. In a catalyzed reaction the net amount of catalyst is constant.* | **1 point** |
| | **Total for question 1** | **10 points** |