Begin your response to **QUESTION 1** on this page.

CHEMISTRY

SECTION II

Time—1 hour and 45 minutes

7 Questions

YOU MAY USE YOUR CALCULATOR FOR THIS SECTION.

Directions: Questions 1–3 are long free-response questions that require about 23 minutes each to answer and are worth 10 points each. Questions 4–7 are short free-response questions that require about 9 minutes each to answer and are worth 4 points each.

For each question, show your work for each part in the space provided after that part. Examples and equations may be included in your responses where appropriate. For calculations, clearly show the method used and the steps involved in arriving at your answers. You must show your work to receive credit for your answer. Pay attention to significant figures.

$$\mathrm{HCOOH}(aq) + \mathrm{H_2O}(l) \rightleftarrows \mathrm{H_3O^+}(aq) + \mathrm{HCOO^-}(aq) \qquad K_a = 1.8 \times 10^{-4}$$

1. Methanoic acid, HCOOH, ionizes according to the equation above.

   (a) Write the expression for the equilibrium constant, K_a, for the reaction.

   (b) Calculate the pH of a 0.25 M solution of HCOOH.

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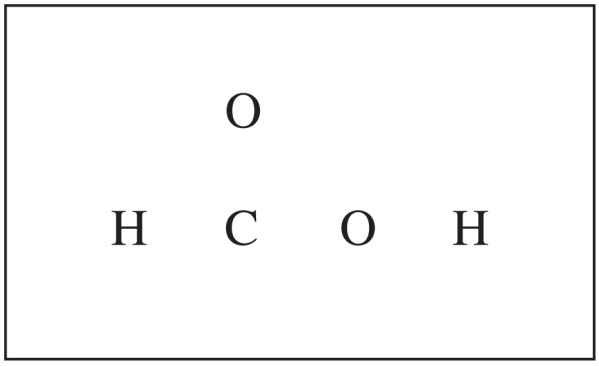
Continue your response to **QUESTION 1** on this page.

(c) In the box below, complete the Lewis electron-dot diagram for HCOOH. Show all bonding and nonbonding valence electrons.



$$H_2NNH_2(aq) + H_2O(l) \rightleftarrows H_2NNH_3^+(aq) + OH^-(aq) \qquad K_b = 1.3 \times 10^{-6}$$

(d) In aqueous solution, the compound H_2NNH_2 reacts according to the equation above. A 50.0 mL sample of 0.25 *M* $H_2NNH_2(aq)$ is combined with a 50.0 mL sample of 0.25 *M* $HCOOH(aq)$.

(i) Write the balanced net ionic equation for the reaction that occurs when H_2NNH_2 is combined with HCOOH.

(ii) Is the resulting solution acidic, basic, or neutral? Justify your answer.

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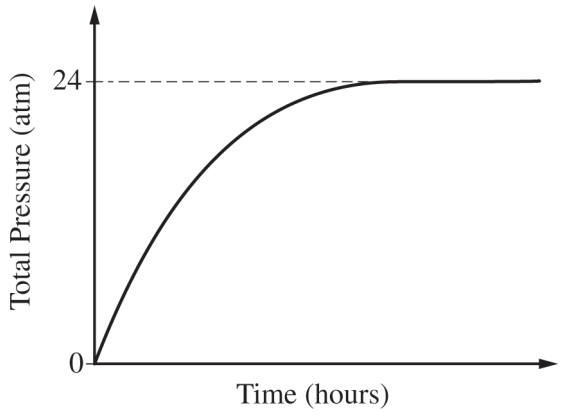
Continue your response to **QUESTION 1** on this page.

When a catalyst is added to a solution of $HCOOH(aq)$, the reaction represented by the following equation occurs.

$$HCOOH(aq) \rightarrow H_2(g) + CO_2(g)$$

(e) Is the reaction a redox reaction? Justify your answer.



(f) The reaction occurs in a rigid 4.3 L vessel at 25°C, and the total pressure is monitored, as shown in the graph above. The vessel originally did not contain any gas. Calculate the number of moles of $CO_2(g)$ produced in the reaction. (Assume that the amount of $CO_2(g)$ dissolved in the solution is negligible.)

(g) After the reaction has proceeded for several minutes, does the amount of catalyst increase, decrease, or remain the same? Justify your answer.

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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	⇄ H_3O^+	+ $HCOO^-$
I	0.25		0	0
C	$-x$		$+x$	$+x$
E	$0.25 - x$		x	x

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

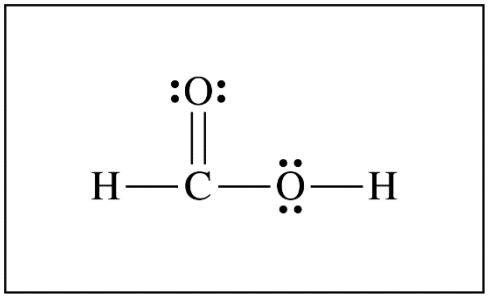
Assume $x << 0.25$, *then* $1.8\times10^{-4} = \dfrac{x^2}{0.25} \Rightarrow x = 0.0067\ M$

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): *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: $PV = nRT$ $n = \frac{PV}{RT} = \frac{(12\text{ atm})(4.3\text{ L})}{(0.08206\text{ L atm mol}^{-1}\text{ K}^{-1})(298\text{ K})} = 2.1\text{ mol CO}_2$	**1 point**
	Total for part (f)	**2 points**
(g)	For the correct answer and a valid justification: *It would remain the same. In a catalyzed reaction the net amount of catalyst is constant.*	**1 point**
	Total for question 1	**10 points**