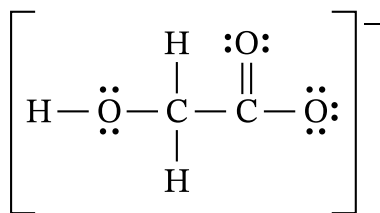
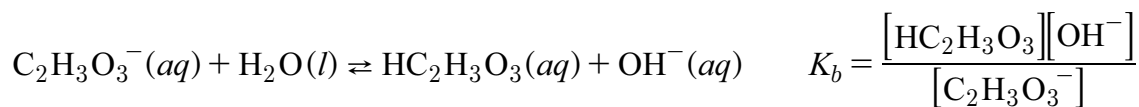


7. Answer the following questions about the glycolate ion,  $\text{C}_2\text{H}_3\text{O}_3^-$ , which acts as a base in aqueous solution. A Lewis diagram for the ion is provided.



A. On the Lewis diagram in part A, circle the atom that accepts the proton when the glycolate ion reacts with water.

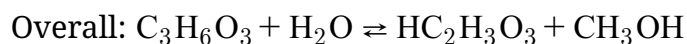
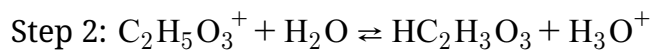
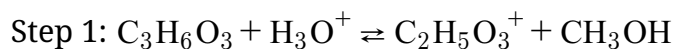
When the glycolate ion reacts with water, it forms glycolic acid,  $\text{HC}_2\text{H}_3\text{O}_3$ , according to the following equation. The  $K_b$  expression for the reaction is provided.



B. At  $25^\circ\text{C}$ , a  $2.5\text{ M}$  solution of glycolate is found to have  $[\text{OH}^-] = 1.3 \times 10^{-5}\text{ M}$ .

- Calculate the value of  $K_b$  for the glycolate ion.
- Using your answer to part B (i), calculate the value of  $K_a$  for glycolic acid at  $25^\circ\text{C}$ .

Glycolic acid can be produced from the hydrolysis of methyl glycolate,  $\text{C}_3\text{H}_6\text{O}_3$ . A proposed mechanism for the reaction is given.



C. A student claims that  $\text{H}_3\text{O}^+$  is a catalyst for the reaction. Do you agree or disagree? Justify your answer based on the mechanism given.

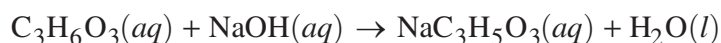
**STOP**

**END OF EXAM**

Begin your response to **QUESTION 1** on this page.**CHEMISTRY****SECTION II****Time—1 hour and 45 minutes****7 Questions**

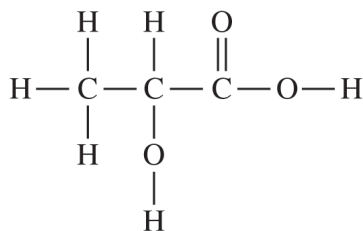
**Directions:** Questions 1–3 are long free-response questions that require about 23 minutes each to answer and are worth 10 points each. Questions 4–7 are short free-response questions that require about 9 minutes each to answer and are worth 4 points each.

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.



1. A student is studying the reaction between lactic acid,  $\text{C}_3\text{H}_6\text{O}_3$ , and sodium hydroxide,  $\text{NaOH}$ , as represented in the balanced equation above.

- (a) The structural formula of lactic acid is shown in the following diagram. Circle the hydrogen atom that most readily participates in the chemical reaction with sodium hydroxide.

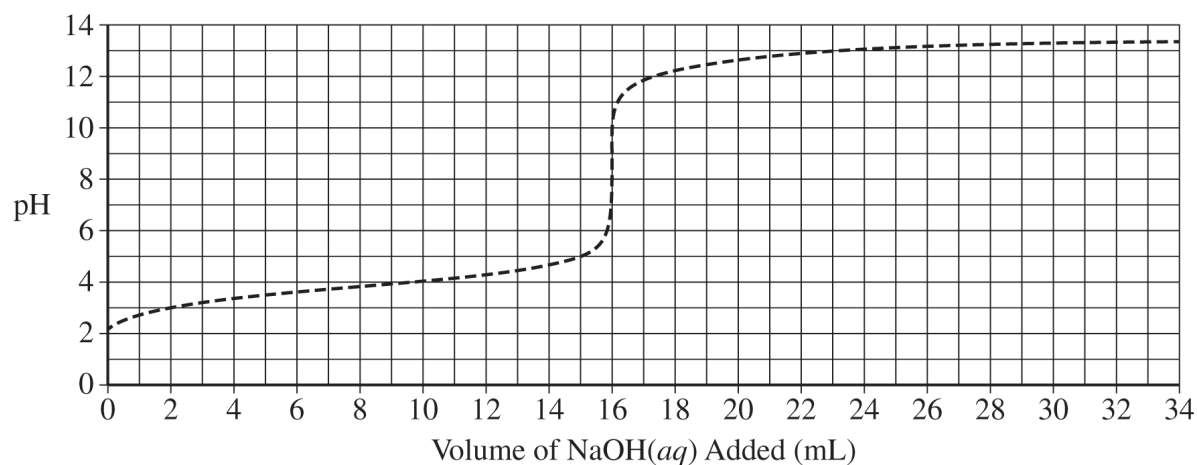


- (b) The student begins the experiment by dissolving 10.22 g of sodium hydroxide (molar mass 40.00 g / mol) in enough water to produce 500. mL of solution. Calculate the molarity of the sodium hydroxide solution.

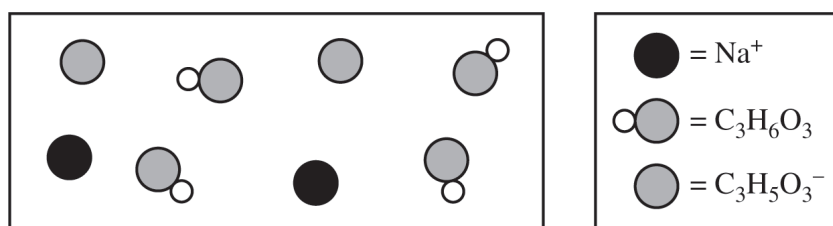
**GO ON TO THE NEXT PAGE.**

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

The student uses the sodium hydroxide solution from part (b), a buret, a pH meter, and a 100 mL Erlenmeyer flask to titrate a 25.0 mL sample of lactic acid solution. The student's data are shown in the following graph.



(c) Use the information in the graph to determine the approximate  $pK_a$  of lactic acid. \_\_\_\_\_



(d) The preceding diagram represents the relative amounts of major species in a sample of the solution in the flask at one point during the titration. (Note that water molecules are omitted.)

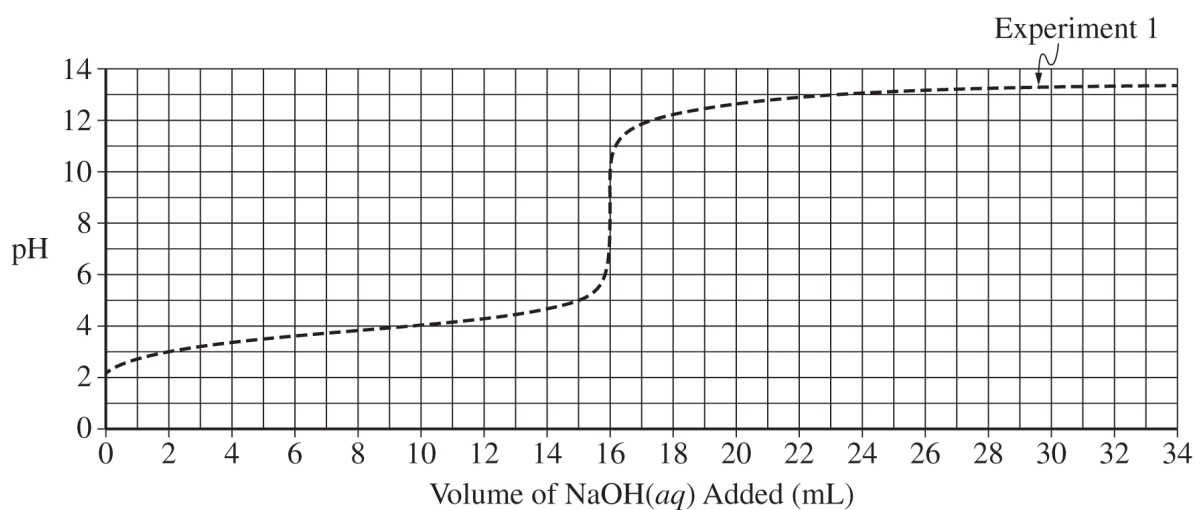
- (i) Draw an X on the preceding titration curve at a point in the titration where the reaction mixture would be represented by this diagram.
- (ii) Justify your answer.

**GO ON TO THE NEXT PAGE.**

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

| Experiment | Mass of NaOH( <i>s</i> ) (grams) | Volume of Solution (mL) | Titration Curve        |
|------------|----------------------------------|-------------------------|------------------------|
| 1          | 10.22                            | 500.                    | Already shown on graph |
| 2          | 20.44                            | 500.                    | ?                      |

- (iii) The student repeats the experiment but uses a solution of NaOH(*aq*) with twice the concentration, as shown in the preceding table. On the following graph, draw the titration curve that would be expected for experiment 2.



- (e) In a third experiment, the student investigates the enthalpy of the reaction between lactic acid and sodium hydroxide. The student combines 100.0 mL of a 0.500 *M* lactic acid solution at 20.0°C with 100.0 mL of a 0.500 *M* NaOH solution at 20.0°C in a calorimeter. The final temperature of the resulting combined solution is 23.2°C. Assume that the density of each solution before combining is 1.00 g / mL and that the specific heat capacity of the combined solution is 4.2 J / (g · °C).

- (i) Calculate the quantity of heat produced in the reaction, in J.

**GO ON TO THE NEXT PAGE.**

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

(ii) Calculate the molar enthalpy of reaction, in  $\text{kJ} / \text{mol}_{\text{rxn}}$ . Include the sign in your answer.

(iii) The student claims that if heat is lost from the calorimeter to the surrounding air during the reaction, then the experimental value of the molar enthalpy of reaction will be smaller in magnitude than the actual value. Do you agree or disagree with the student's claim? Justify your answer.

**GO ON TO THE NEXT PAGE.**