

**CHEMISTRY**

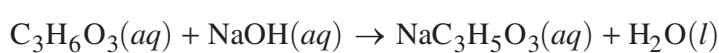
**SECTION II**

**Time—1 hour and 45 minutes**

**7 Questions**

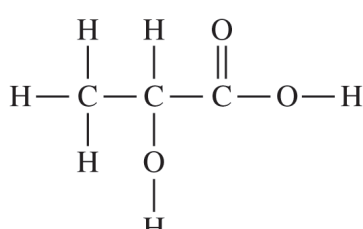
**Directions:** Questions 1–3 are long free-response questions that require about 23 minutes each to answer and are worth 10 points each. Questions 4–7 are short free-response questions that require about 9 minutes each to answer and are worth 4 points each.

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.

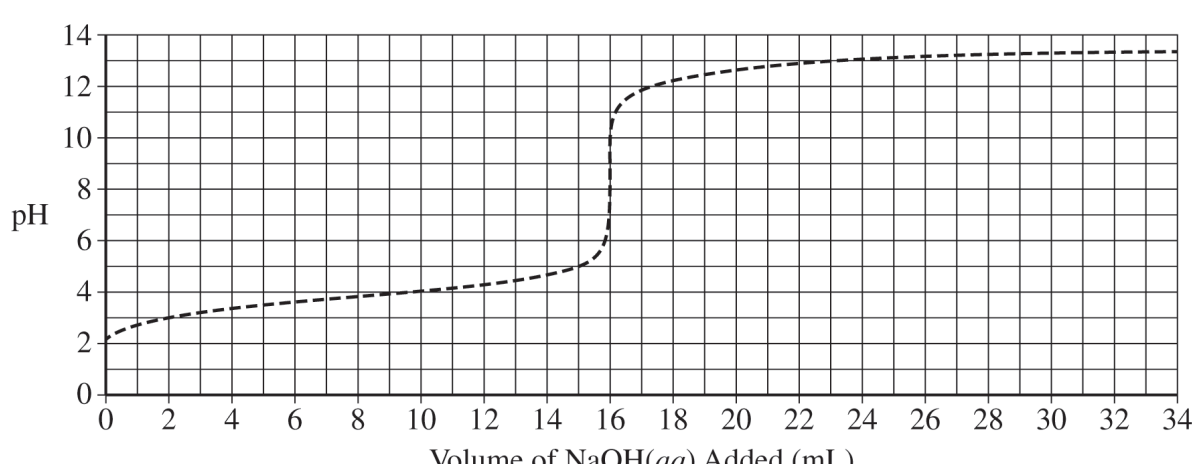


- (b) The student begins the experiment by dissolving 10.22 g of sodium hydroxide (molar mass 40.00 g / mol) in enough water to produce 500. mL of solution. Calculate the molarity of the sodium hydroxide solution.

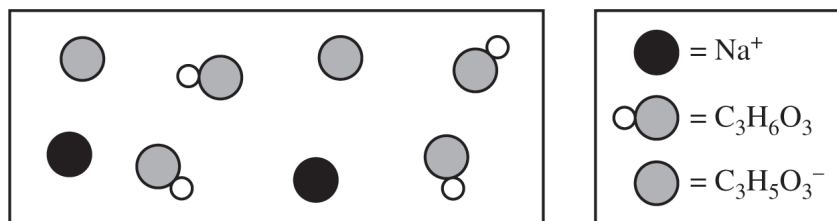
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Continue your response to **QUESTION 1** on this page.

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  $\text{p}K_a$  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.)

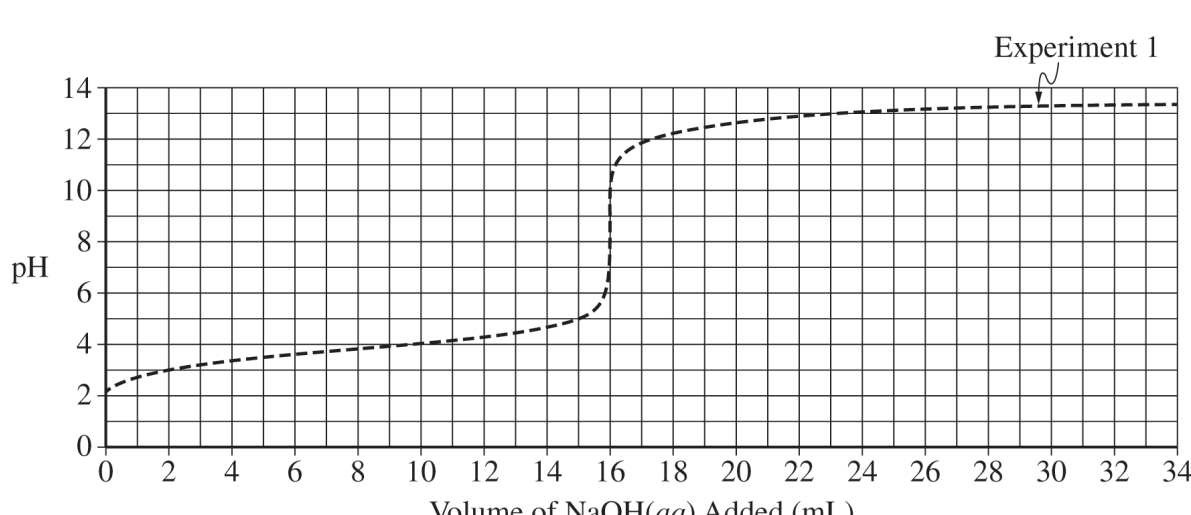
- (i) Draw an X on the preceding titration curve at a point in the titration where the reaction mixture would be represented by this diagram.
- (ii) Justify your answer.

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

| Experiment | Mass of $\text{NaOH}(s)$ (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  $\text{NaOH}(aq)$  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  $\text{NaOH}$  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.

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

- (ii) Calculate the molar enthalpy of reaction, in kJ / mol<sub>rxn</sub>. 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.

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