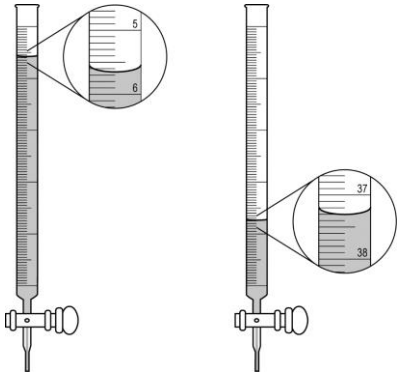
AP® CHEMISTRY
2016 SCORING GUIDELINES

Question 7

A student is given a 25.0 mL sample of a solution of an unknown monoprotic acid and asked to determine the concentration of the acid by titration. The student uses a standardized solution of 0.110 *M* NaOH(*aq*), a buret, a flask, an appropriate indicator, and other laboratory equipment necessary for the titration.

(a) The images below show the buret before the titration begins (below left) and at the end point (below right). What should the student record as the volume of NaOH(*aq*) delivered to the flask?



37.30 mL – 5.65 mL = 31.65 mL	1 point is earned for the correct volume.

(b) Based on the given information and your answer to part (a), determine the value of the concentration of the acid that should be recorded in the student's lab report.

At the equivalence point, moles OH^- added = moles of H^+ consumed. Because HA is monoprotic: $(0.110\ M)(0.03165\ \text{L}) \times \frac{1\ \text{mol HA}}{1\ \text{mol NaOH}} \times \frac{1}{0.0250\ \text{L}} = 0.139\ M$ OR moles of H^+ consumed = $M_a V_a$ $M_a V_a = M_b V_b$ Therefore, $M_a = \frac{M_b V_b}{V_a} = \frac{(0.110\ M)(0.03165\ \text{L})}{0.0250\ \text{L}} = 0.139\ M$	1 point is earned for the correct setup and molarity.

(c) In a second trial, the student accidentally added more NaOH(*aq*) to the flask than was needed to reach the end point, and then recorded the final volume. Would this error increase, decrease, or have no effect on the calculated acid concentration for the second trial? Justify your answer.

The error would increase the calculated acid concentration. A volume of NaOH(*aq*) larger than the actual volume needed to reach the equivalence point, would lead to a calculation of moles of base that would be greater than the moles of acid actually present in the solution. The assumption that the moles of acid are the same as the moles of base would lead to a calculated concentration of acid that would be higher than the actual concentration.	1 point is earned for indicating an increase. 1 point is earned for a valid justification.

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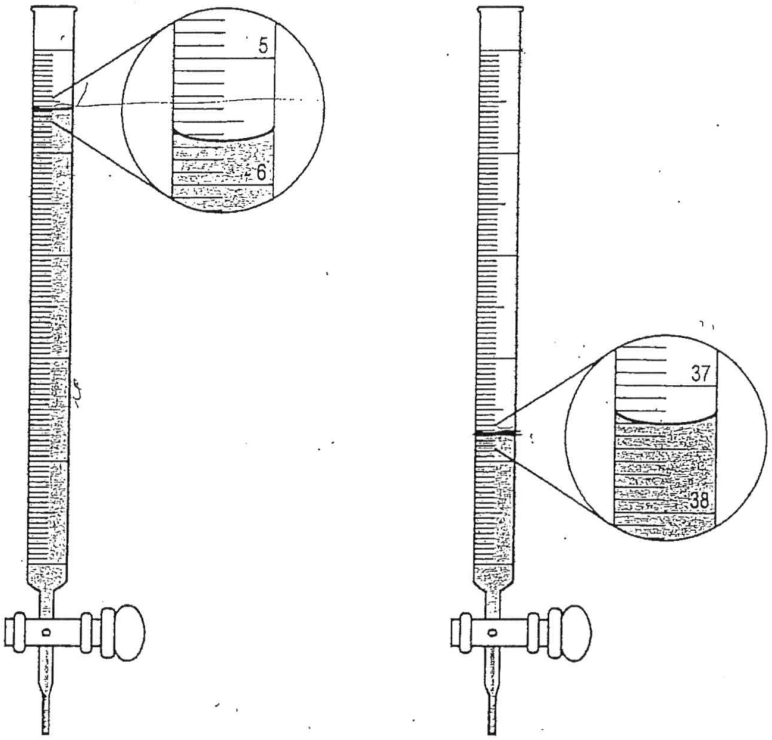

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(b) Based on the given information and your answer to part (a), determine the value of the concentration of the acid that should be recorded in the student's lab report.

(c) In a second trial, the student accidentally added more NaOH(*aq*) to the flask than was needed to reach the end point, and then recorded the final volume. Would this error increase, decrease, or have no effect on the calculated acid concentration for the second trial? Justify your answer.

a) Volume of NaOH = 37.30 - 5.65

= 31.65 mL NaOH

= 0.03165 L NaOH

b) $\frac{0.110\ M\ NaOH}{1} \left| \frac{0.03165\ L\ NaOH}{} \right. = 3.48 \times 10^{-3}$ mol NaOH

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$H^+ + OH^- \rightarrow H_2O$

$$\frac{3.48 \times 10^{-3} \text{ mol NaOH}}{} \left| \frac{1 \text{ mol acid}}{1 \text{ mol NaOH}} \right. = 3.48 \times 10^{-3} \text{ mol acid}$$

$$\frac{3.48 \times 10^{-3} \text{ mol acid}}{0.0250 \text{ L acid}} = \boxed{0.139 \text{ M acid}}.$$

c) This error would increase the acid concentration for the second trial. As the volume of NaOH increases, the number of moles of NaOH increases. Therefore, the number of moles of acid also increases, causing the acid concentration increases.

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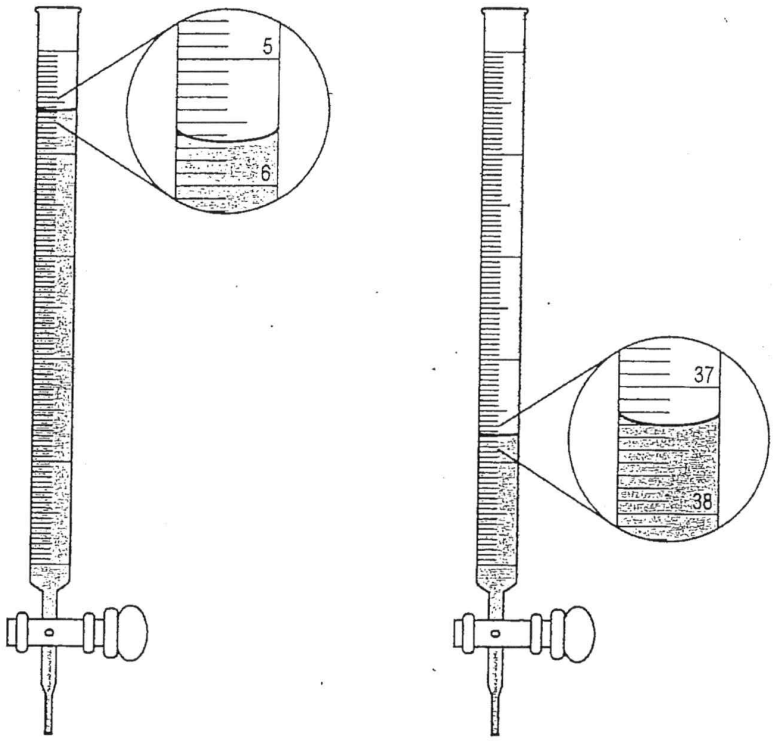

(b) Based on the given information and your answer to part (a), determine the value of the concentration of the acid that should be recorded in the student's lab report.

(c) In a second trial, the student accidentally added more NaOH(*aq*) to the flask than was needed to reach the end point, and then recorded the final volume. Would this error increase, decrease, or have no effect on the calculated acid concentration for the second trial? Justify your answer.

a) 37.30 mL − 5.65 mL = 31.65 mL

b) $\frac{.110\ mol}{L} \cdot .3165\ L = .035\ mol\ OH^-$

$[OH^-] = [H^+]$ $\frac{.035\ mol}{.025\ L}$ [acid] = 1.39 mol/L

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c) This error would increase the calculated acid concentration. By using the larger volume, a larger number of moles, of OH^- is assumed to be needed to reach the equivalence point. Therefore, a larger number of moles of the acid will be calculated in the same original 25 mL volume, increasing concentration.

7. A student is given a 25.0 mL sample of a solution of an unknown monoprotic acid and asked to determine the concentration of the acid by titration. The student uses a standardized solution of 0.110 *M* NaOH(*aq*), a buret, a flask, an appropriate indicator, and other laboratory equipment necessary for the titration.

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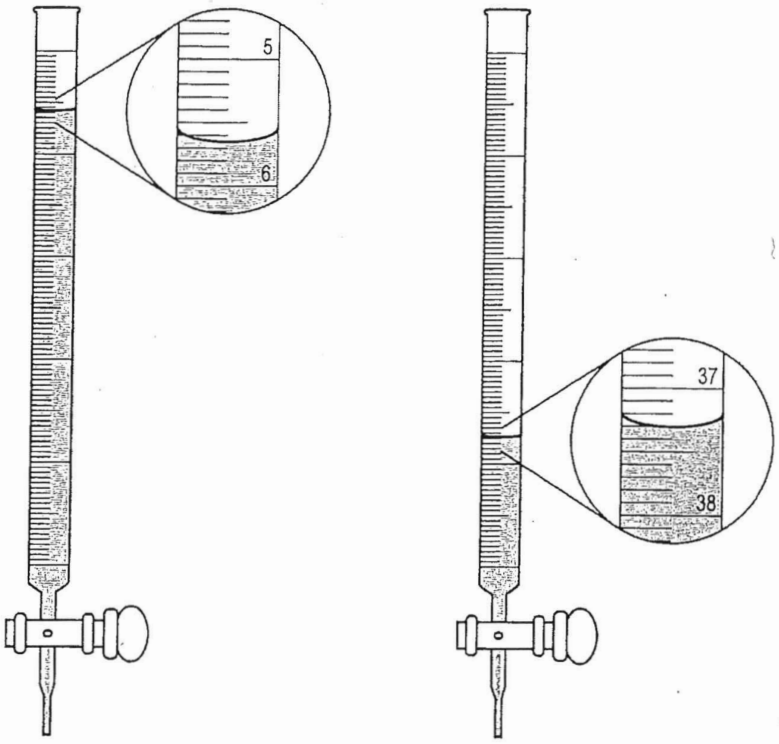

   (b) Based on the given information and your answer to part (a), determine the value of the concentration of the acid that should be recorded in the student's lab report.

   (c) In a second trial, the student accidentally added more NaOH(*aq*) to the flask than was needed to reach the end point, and then recorded the final volume. Would this error increase, decrease, or have no effect on the calculated acid concentration for the second trial? Justify your answer.

a.) The student should record a volume of about 31.7 mL at the end point
37.3 − 5.6 = 31.7 mL
b.) concentration of the unknown monoprotic acid:

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$\frac{25\,ml \cdot M_1}{25\,ml} = \frac{0.110\,M \cdot 31.7\,ml}{25\,ml}$

$M = .163$ of the unknown monoprotic acid

c.) This error made by the student would increase the concentration

hypothetical situation: student adds 40 ml

$\frac{25\,ml \cdot M}{25\,ml} = \frac{0.110\,M \cdot 40\,ml}{25\,ml} = .176\,M$

This concentration would be higher than the previous concentration of 31.7 ml

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AP® CHEMISTRY
2016 SCORING COMMENTARY

Question 7

Overview

Question 7 evaluated students' ability to collect data and utilize that data in a common laboratory calculation. In part (a) students were asked to determine the volume of the sodium hydroxide solution that was delivered to the flask, given two images showing the same buret at initial and final levels, during a titration experiment. The solution levels in the buret were enlarged to aid data collection by the student. In part (b) students were asked to use the volume from part (a) to determine the molarity of the unknown acid solution. In part (c) an error was described in which too much base was accidentally delivered into the flask. The students were asked to determine if this error would increase, decrease, or have no effect on the calculated molarity of the acid, and to justify their choice.

Sample: 7A
Score: 4

In part (a) the student correctly reads the burets and calculates the volume correctly for 1 point. In part (b) the student uses the values for the molarity and volumes to correctly calculate the molarity of the acid solution for 1 point. In part (c) 1 point was earned for the conceptual understanding that the volume error would increase the calculated acid concentration. The justification point was earned for explaining how the volume error would increase the calculated number of moles of NaOH, then connecting this to the number of moles of acid and the calculated acid concentration.

Sample: 7B
Score: 3

In part (a) the student correctly reads the burets and calculates the volume correctly for 1 point. In part (b) an error was made in converting milliliters to liters, and the calculated molarity of the acid solution is incorrect, so no point was earned. In part (c) 1 point was earned for the conceptual understanding that the volume error would increase the calculated acid concentration. The justification point was earned for explaining how the volume error would increase the calculated number of moles of OH^-, then connecting this to the number of moles of acid and the calculated acid concentration.

Sample: 7C
Score: 2

In part (a) no point was earned because the volume is not given to four significant figures or two decimal places. In part (b) no point was earned because a math error was made and the calculated acid molarity is incorrect and inconsistent with the substituted values. In part (c) 1 point was earned for the conceptual understanding that the volume error would increase the calculated acid concentration. The student earned the justification point by showing how a hypothetical volume of the base, larger than the value given in part (a), leads to a calculated acid molarity greater than the answer to part (b).