2022

AP® CollegeBoard

AP® Chemistry

Sample Student Responses and Scoring Commentary

Inside:

Free-Response Question 6

- ☑ **Scoring Guidelines**
- ☑ **Student Samples**
- ☑ **Scoring Commentary**

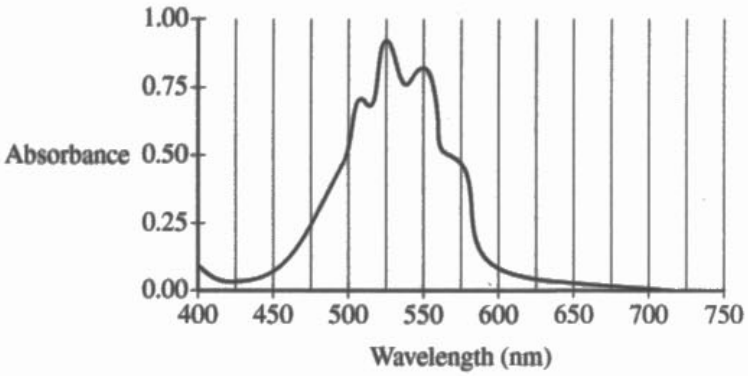
Question 6: Short Answer — 4 points

(a)	For the correct answer: 525 nm	**1 point**
(b)(i)	For the correct answer: 92.0 mL	**1 point**
(ii)	For the correct calculated value: $V_1 = \frac{M_2 V_2}{M_1} = \frac{\left(1.68 \times 10^{-3}\ M\right)(100.0\ \text{mL})}{\left(2.40 \times 10^{-3}\ M\right)} = 70.0\ \text{mL}$	**1 point**
	Total for part (b)	**2 points**
(c)	For the correct answer and a valid justification: *The student could have improperly executed step 3. If the cuvette was not rinsed with the standard solution prior to being filled for the measurement of absorbance, the standard solution would be diluted by the remaining distilled water, and the absorbance would be lower than what it should be.*	**1 point**
	Total for question 6	**4 points**

Question 6

Begin your response to **QUESTION 6** on this page.

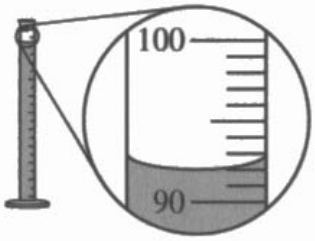
6. A student wants to determine the concentration of permanganate, $MnO_4^-(aq)$, in a solution. The student plans to use colorimetric analysis because solutions containing $MnO_4^-(aq)$ have a purple color.



(a) To determine the optimum wavelength for an experiment that measures the concentration of $MnO_4^-(aq)$, the student takes a sample of the solution and measures the amount of light absorbed by the sample over a range of wavelengths. The data are plotted in the graph shown. Identify the optimum wavelength that the student should use for the experimental procedure.

525 nm

(b) The student uses a stock solution of 2.40×10^{-3} M $KMnO_4(aq)$ to prepare the standard solutions of $MnO_4^-(aq)$ that are needed to construct a calibration curve.



(i) The student uses a 100.0 mL graduated cylinder to measure a certain volume of $KMnO_4(aq)$ stock solution, as shown in the diagram given. What volume should the student record?

92.0 mL

(ii) Calculate the volume, in mL, of 2.40×10^{-3} M $KMnO_4(aq)$ that is required to produce 100.0 mL of a standard 1.68×10^{-3} M $MnO_4^-(aq)$ solution.

$(2.40 \times 10^{-3}\ M)(x\ mL) = (1.68 \times 10^{-3}\ M)(100.0\ mL)$

$x = \boxed{70.0\ mL}$

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0078806

Q5119/16

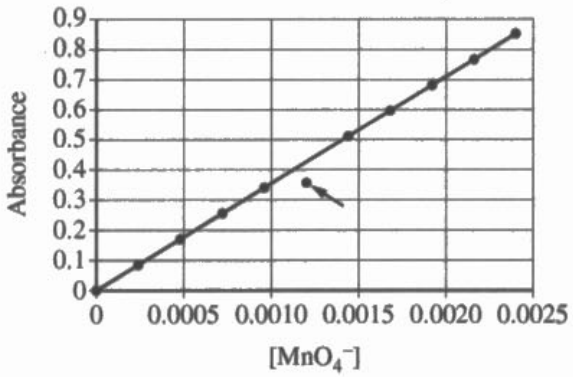
Question 6

Continue your response to **QUESTION 6** on this page.

The student designs the following procedure to produce a calibration curve.

Step 1: Prepare several standard solutions that have known $MnO_4^-(aq)$ concentrations by dilution of the stock solution.
Step 2: Rinse the cuvette with distilled water.
Step 3: Rinse the cuvette with the standard solution and fill the cuvette with the standard solution.
Step 4: Measure the absorbance of the standard solution with the colorimeter.
Step 5: Repeat steps 2-4 for each of the standard solutions.

The data are plotted in the calibration curve shown. One of the data points (indicated with an arrow) on the calibration curve is below the line of best fit.



(c) Assuming that all lab equipment is functioning properly, identify which one of the procedural steps the student could have executed incorrectly that would explain why the marked data point is below the line of best fit. Justify your answer.

Step 3. If the student does not rinse the cuvette with the standard solution, the standard solution would be slightly diluted by the distilled water, so it cannot absorb as much as predicted.

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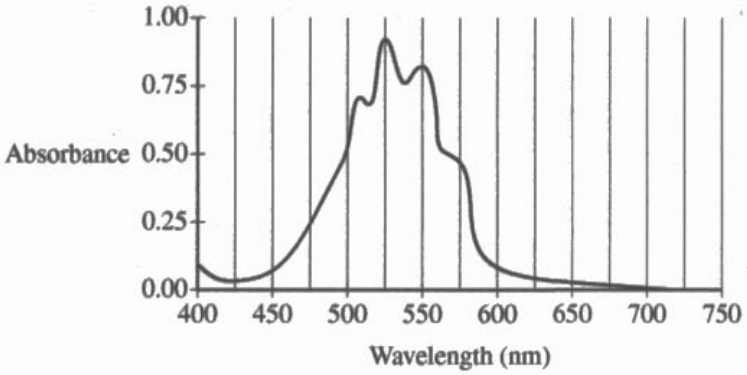
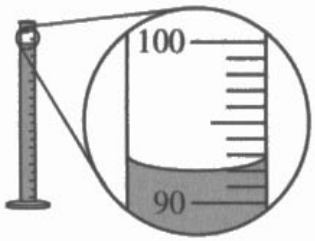


(a) To determine the optimum wavelength for an experiment that measures the concentration of $MnO_4^-(aq)$, the student takes a sample of the solution and measures the amount of light absorbed by the sample over a range of wavelengths. The data are plotted in the graph shown. Identify the optimum wavelength that the student should use for the experimental procedure. 525 nm

(b) The student uses a stock solution of 2.40×10^{-3} *M* $KMnO_4(aq)$ to prepare the standard solutions of $MnO_4^-(aq)$ that are needed to construct a calibration curve.



(i) The student uses a 100.0 mL graduated cylinder to measure a certain volume of $KMnO_4(aq)$ stock solution, as shown in the diagram given. What volume should the student record? 92 mL

(ii) Calculate the volume, in mL, of 2.40×10^{-3} *M* $KMnO_4(aq)$ that is required to produce 100.0 mL of a standard 1.68×10^{-3} *M* $MnO_4^-(aq)$ solution.

$M_1V_1 = M_2V_2$

$(2.40 \times 10^{-3}\,M)(V_1) = (1.68 \times 10^{-3}\,M)(100.0\,mL)$

$V_1 = \dfrac{(1.68 \times 10^{-3}\,M)(100.0\,mL)}{(2.40 \times 10^{-3}\,M)}$

$V_1 = 70.0\,mL$

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Use a pencil or a pen with black or dark blue ink. Do NOT write your name. Do NOT write outside the box.

0014439

Q5119/16

Question 6

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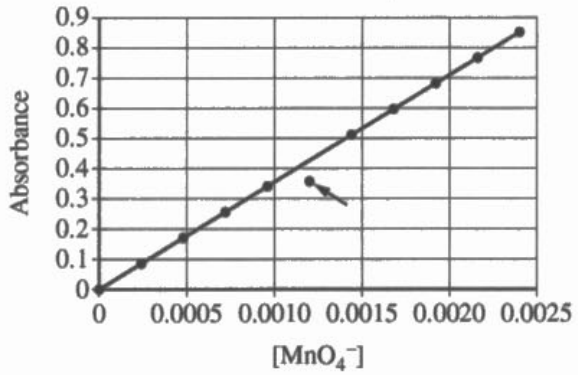
The student designs the following procedure to produce a calibration curve.

Step 1: Prepare several standard solutions that have known $MnO_4^-(aq)$ concentrations by dilution of the stock solution.
Step 2: Rinse the cuvette with distilled water.
Step 3: Rinse the cuvette with the standard solution and fill the cuvette with the standard solution.
Step 4: Measure the absorbance of the standard solution with the colorimeter.
Step 5: Repeat steps 2-4 for each of the standard solutions.

The data are plotted in the calibration curve shown. One of the data points (indicated with an arrow) on the calibration curve is below the line of best fit.



(c) Assuming that all lab equipment is functioning properly, identify which one of the procedural steps the student could have executed incorrectly that would explain why the marked data point is below the line of best fit. Justify your answer.

Step 3 could have been executed incorrectly. The student may have rinsed the cuvette in the sink with water instead of with the standard solution. This means that when the standard solution is added to the cuvette after rinsing, the solution will become diluted by the water, which would result in a lower absorbance value.

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Use a pencil or a pen with black or dark blue ink. Do NOT write your name. Do NOT write outside the box.

Question 6

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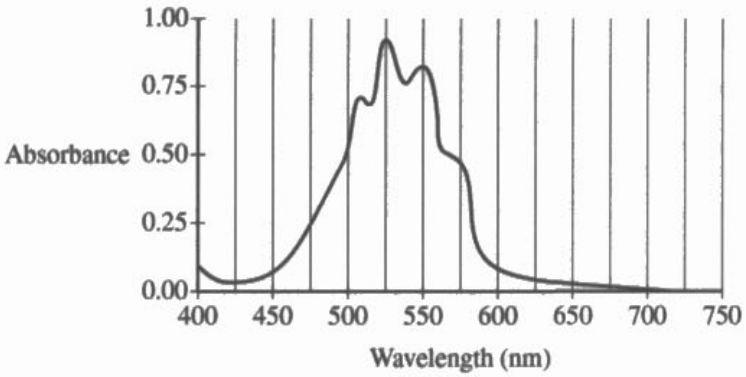
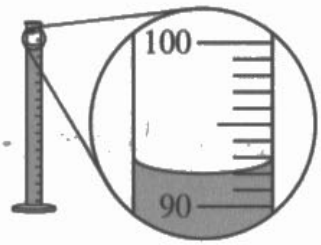


(a) To determine the optimum wavelength for an experiment that measures the concentration of $MnO_4^-(aq)$, the student takes a sample of the solution and measures the amount of light absorbed by the sample over a range of wavelengths. The data are plotted in the graph shown. Identify the optimum wavelength that the student should use for the experimental procedure.

525 nm

(b) The student uses a stock solution of 2.40×10^{-3} M $KMnO_4(aq)$ to prepare the standard solutions of $MnO_4^-(aq)$ that are needed to construct a calibration curve.



(i) The student uses a 100.0 mL graduated cylinder to measure a certain volume of $KMnO_4(aq)$ stock solution, as shown in the diagram given. What volume should the student record?

92.0 mL

(ii) Calculate the volume, in mL, of 2.40×10^{-3} M $KMnO_4(aq)$ that is required to produce 100.0 mL of a standard 1.68×10^{-3} M $MnO_4^-(aq)$ solution.

$M_1V_1 = M_2V_2$

$(2.40 \times 10^{-3})(V_1) = (1.68 \times 10^{-3})(.1)$

$V_1 = 14.285$ L

14285.7 mL

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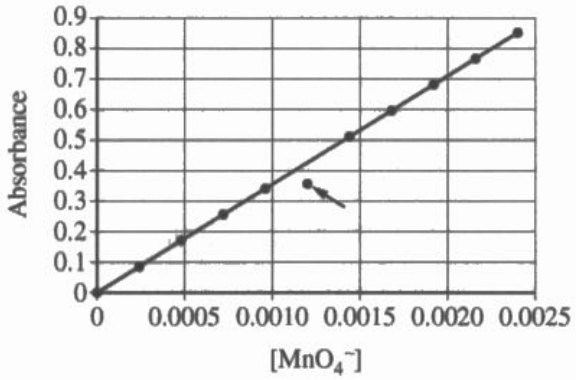
Question 6

Continue your response to **QUESTION 6** on this page.

The student designs the following procedure to produce a calibration curve.

Step 1: Prepare several standard solutions that have known $MnO_4^-(aq)$ concentrations by dilution of the stock solution.
Step 2: Rinse the cuvette with distilled water.
Step 3: Rinse the cuvette with the standard solution and fill the cuvette with the standard solution.
Step 4: Measure the absorbance of the standard solution with the colorimeter.
Step 5: Repeat steps 2-4 for each of the standard solutions.

The data are plotted in the calibration curve shown. One of the data points (indicated with an arrow) on the calibration curve is below the line of best fit.



(c) Assuming that all lab equipment is functioning properly, identify which one of the procedural steps the student could have executed incorrectly that would explain why the marked data point is below the line of best fit. Justify your answer.

Step 3 could have been executed incorrectly because the student might not have gotten all out of standard solution out before filling the cuvette with the solution concentration he was getting the data for.

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Question 6

Note: Student samples are quoted verbatim and may contain spelling and grammatical errors.

Overview

Question 6 presented students with a laboratory experiment to determine the permanganate concentration in a solution by colorimetry/spectrophotometry.

Part (a) asked students to identify the optimum wavelength for the experiment by analyzing a plot of absorbance versus wavelength (Learning Objective SAP-8.C, Science Practice 6.A from the *AP Chemistry Course and Exam Description*).

Part (b) was worth 2 points. Part (b)(i) asked students to determine the volume of stock solution in a graduated cylinder and estimate the volume reading appropriately to the nearest 0.1 mL (SPQ-3.A, 2.D). Part (b)(ii) asked students to calculate the volume of a stock solution required to perform a dilution resulting in the desired standard concentration (SPQ-3.A, 5.F).

Part (c) provided students with an experimental procedure to produce a calibration curve as well as an experimental calibration curve with a marked point below the line of best fit. The prompt then asked students to identify a step in the procedure that could have been executed incorrectly to produce the marked data point and to justify their answer (SAP-8.C, 2.E).

Sample: 6A
Score: 4

This response earned 4 points. In part (a) the point was earned for correctly identifying the optimum wavelength as 525 nm. In part (b)(i) the point was earned because the response indicates a volume of 92.0 mL, correctly estimating to one-tenth of the graduated cylinder increments. In part (b)(ii) the point was earned because the correct volume of $KMnO_4(aq)$ solution required is calculated. In part (c) the point was earned because the response correctly indicates that neglecting to rinse the cuvette with standard solution would result in a sample diluted by the distilled water in the cuvette, and the sample would absorb less.

Sample: 6B
Score: 3

This response earned 3 points. In part (a) the point was earned because the optimum wavelength is correctly identified as 525 nm. In part (b)(i) no point was earned because the volume indicated, 92 mL, is not estimated to one-tenth of the graduated cylinder increments. In part (b)(ii) the point was earned because the correct volume of $KMnO_4(aq)$ solution required is calculated. In part (c) the point was earned because the response indicates that incorrectly executing step 3 by rinsing with water instead of standard solution would result in a more dilute sample, causing a lower absorbance.

Question 6 (continued)

Sample: 6C
Score: 2

This response earned 2 points. In part (a) the point was earned for correctly identifying the optimum wavelength as 525 nm. In part (b)(i) the point was earned because the response indicates a volume of 92.0 mL, correctly estimating to one-tenth of the graduated cylinder increments. In part (b)(ii) no point was earned because, although the response sets up a $M_1V_1 = M_2V_2$ calculation, the calculation produces an incorrect volume of $KMnO_4(aq)$ solution required. In part (c) no point was earned because, although the response correctly selects step 3, it does not justify how the incorrect execution of the procedure could lead to the data point below the line of best fit.