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AP® CollegeBoard

AP® Chemistry

Sample Student Responses and Scoring Commentary

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Question 7

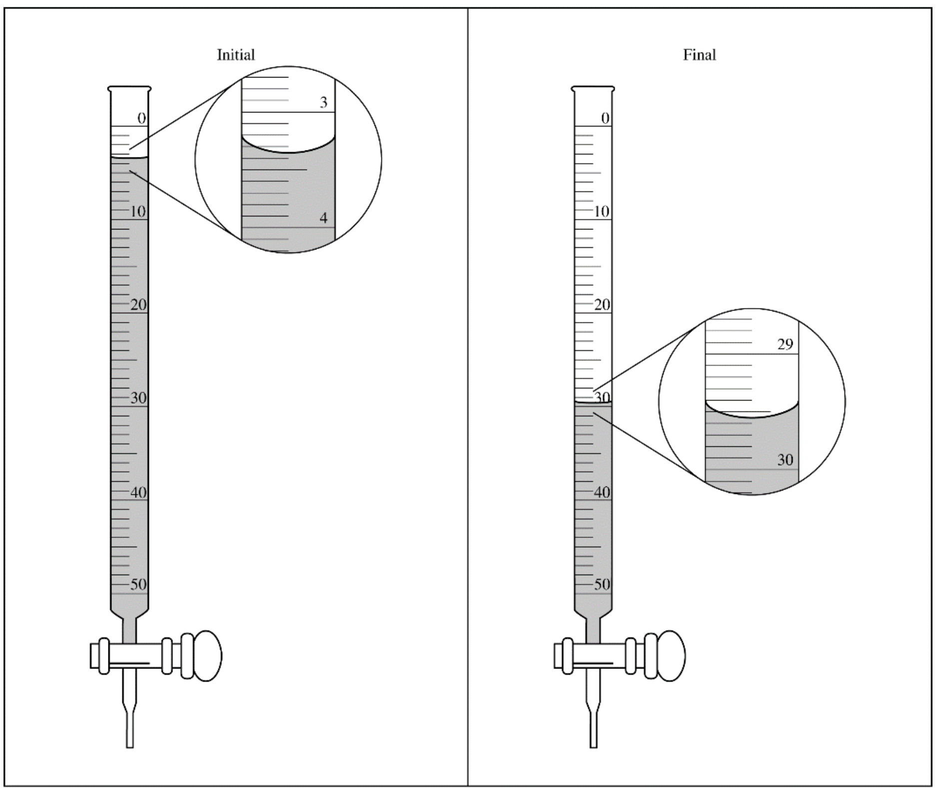
$$6\ H^+(aq) + 2\ MnO_4^-(aq) + 5\ H_2C_2O_4(aq) \rightarrow 10\ CO_2(g) + 8\ H_2O(l) + 2\ Mn^{2+}(aq)$$

A student dissolved a 0.139 g sample of oxalic acid, $H_2C_2O_4$, in water in an Erlenmeyer flask. Then the student titrated the $H_2C_2O_4$ solution in the flask with a solution of $KMnO_4$, which has a dark purple color. The balanced chemical equation for the reaction that occurred during the titration is shown above.

(a) Identify the species that was reduced in the titration reaction. Justify your answer in terms of oxidation numbers.

MnO_4^- is reduced to Mn^{2+} as the oxidation number of Mn changes from +7 to +2, indicating a gain of 5 electrons.	1 point is earned for the correct answer with justification.

(b) The student used a 50.0 mL buret to add the $KMnO_4(aq)$ to the $H_2C_2O_4(aq)$ until a faint lavender color was observed in the flask, an indication that the end point of the titration had been reached. The initial and final volume readings of the solution in the buret are shown below. Write down the initial reading and the final reading and use them to determine the volume of $KMnO_4(aq)$ that was added during the titration.



29.55 mL – 3.35 mL = 26.20 mL	1 point is earned for the correct answer.

Question 7 (continued)

(c) Given that the concentration of $KMnO_4(aq)$ was 0.0235 *M*, calculate the number of moles of MnO_4^- ions that completely reacted with the $H_2C_2O_4$.

(0.02620 L)(0.0235 mol/L) = 0.000616 mol	1 point is earned for the correct answer.

(d) The student proposes to perform another titration using a 0.139 g sample of $H_2C_2O_4$, but this time using 0.00143 *M* $KMnO_4(aq)$ in the buret. Would this titrant concentration be a reasonable choice to use if the student followed the same procedure and used the same equipment as before? Justify your response.

No. The 0.00143 *M* titrant solution is so diluted that the volume of titrant needed to reach the end point would be much greater than the 50 mL capacity of the buret.	1 point is earned for the correct answer with appropriate justification.

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a) Mn^{7+} (in MnO_4^-) was reduced to Mn^{2+} because its oxidation number decreased ~~went~~ from 7+ to 2+.

b) initial ≈ 3.35

final ≈ 29.55

volume added ≈ 26.20 mL

c) $\frac{26.20 \text{ mL} \mid 0.0235 \text{ mols } MnO_4^-}{\mid 1000 \text{ mL}} = 6.16 \times 10^{-4} \text{ mols } MnO_4^-$

d) This titrant concentration would not be a reasonable choice because it would require more titrant than the student's equipment (the buret) can hold without refilling.

$\frac{6.16\times10^{-4} \text{ mols} \mid L \text{ dilute solution}}{\mid 0.00143 \text{ mols}} = 0.431 \text{ L} = 431 \text{ mL}$ of 0.00143 M solution

~~431>50m~~ 431 mL > 50 mL

a) Mn was reduced, as its Oxidation number went from +3 to +2

b) Initial reading: 3.35 mL → Volume of $KMnO_4$ added = 29.55 − 3.35 = **26.20 mL**
Final reading: 29.55 mL

c) $\frac{0.0235\text{ mol}}{\text{L}} \cdot \left(\frac{1\text{ L}}{1000\text{ mL}}\right) \cdot \left(26.20\text{ mL}\right) = \boxed{6.16 \cdot 10^{-4}\text{ mol } MnO_4^-}$

d) $0.139\text{ g } H_2C_2O_4 \cdot \left(\frac{1\text{ mol}}{90.04\text{ g}}\right) = 0.00154\text{ mol } H_2C_2O_4 \cdot \left(\frac{2\text{ mol } MnO_4^-}{5\text{ mol } H_2C_2O_4}\right) \cdot \left(\frac{1\text{ L}}{0.00143\text{ mol}}\right) \cdot \left(\frac{1000\text{ mL}}{1\text{ L}}\right) = 432\text{ mL } KMnO_4$ needed

No, this would not be reasonable, as you need 432 mL of $KMnO_4$ to run the experiment, and the buret only holds 50.0 mL.

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7.) a.) Mn is oxidized. Its oxidation # goes from +7 to 0.

b) 29.4 - 3.6 = 25.8 mL $KMnO_4$

c.) $\frac{0.0235 \text{ mol}}{1 \text{ L}} \times \frac{0.0258 \text{ L}}{1} = 6.06 \times 10^{-4} \text{ mol}$

d.) No, the molarity of $KMnO_4$ is too low, so it would take too much $KMnO_4$ to make a difference, and indicate anything.

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Question 7

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

Overview

This question deals with the theory and practice of a redox titration in which MnO_4^- reacts with oxalic acid, $H_2C_2O_4$. In part (a) students are required to determine the species that is reduced in the titration reaction and use oxidation numbers to justify their selection (LO 3.12; SP 2.2, 2.3, 6.4). Part (b) assesses their ability to read a buret, both at the beginning and at the end point of the titration, and to use those readings to determine the volume of MnO_4^- solution that was delivered during the experiment. In part (c) students use that volume of titrant to determine the number of moles of MnO_4^- that reacted during the titration. Part (d) requires students to demonstrate their understanding of titration procedure and the limitations of the available equipment. Using a much more dilute solution of titrant (by a factor of ~16) would require a large amount of titrant (431 mL) that would exceed the capacity of the buret. Parts (b) through (d) all address LO 1.20; SP 4.2, 5.1, and 6.4.

Sample: 7A
Score: 4

In part (a) the statement "Mn^{7+} (in MnO_4^-) was reduced to Mn^{2+}" correctly identifies the reactant that is reduced. Also "its oxidation number decreased from 7+ to 2+" shows the correct assignment of oxidation numbers. Thus, 1 point was earned in part (a). The response earned 1 point in part (b) for the two correct buret readings and the correct subtraction of the readings. In part (c) the response earned 1 point for the correct calculation of the moles of permanganate and reporting of the answer to three significant figures. In part (d) the student earned 1 point for stating that "it would require more titrant than the student's equipment (the buret) can hold without refilling."

Sample: 7B
Score: 3

In part (a) the statement "Mn was reduced" correctly identifies the species that was reduced; however, the oxidation numbers "from +3 to +2" are incorrect. Therefore, no point was earned. The response earned 1 point in part (b) for correct buret readings and the correct subtraction of these values to determine the volume of the potassium permanganate solution. In part (c) the calculated value of the moles of permanganate is correct, and it is reported to three significant figures, so 1 point was earned. In part (d) the statement "[n]o, this would not be reasonable, as you need 432 mL of $KMnO_4$ to run the experiment, and the buret only holds 50.0 mL" indicates that the volume of titrant needed will exceed the capacity of the buret, so 1 point was earned.

Sample: 7C
Score: 1

In part (a) the statement "Mn is oxidized" does not correctly identify the species that was reduced, also the oxidation number for Mn^{2+} is incorrect. Thus, no point was earned. In part (b) no point was earned because the two buret readings are incorrect. In part (c) the correct number of moles are calculated based on the volume determined in (b), and the answer is reported to three significant figures, so 1 point was earned. In part (d) the statement "the molarity of $KMnO_4$ is too low, so it would take too much $KMnO_4$ to make a difference" does not indicate that the required volume of titrant would exceed the volume of the buret. No point was earned in part (d).