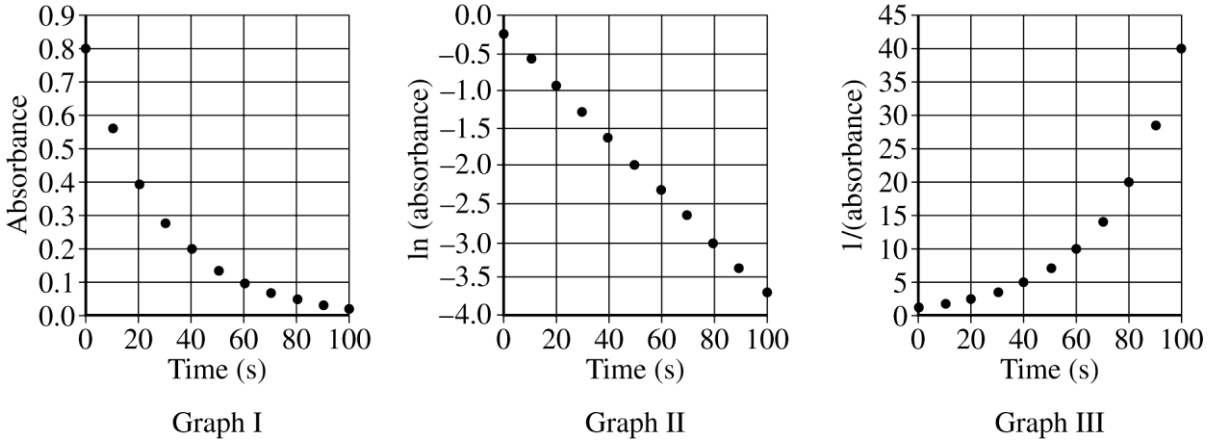
AP® CHEMISTRY
2015 SCORING GUIDELINES

Question 5

$$\underset{\textit{blue}}{Na_2C_{37}H_{34}N_2S_3O_9} + OCl^- \rightarrow \underset{\textit{colorless}}{\text{products}}$$

Blue food coloring can be oxidized by household bleach (which contains OCl^-) to form colorless products, as represented by the equation above. A student used a spectrophotometer set at a wavelength of 635 nm to study the absorbance of the food coloring over time during the bleaching process. In the study, bleach is present in large excess so that the concentration of OCl^- is essentially constant throughout the reaction. The student used data from the study to generate the graphs below.



Graph I Graph II Graph III

(a) Based on the graphs above, what is the order of the reaction with respect to the blue food coloring?

First order	1 point is earned for the correct order.

(b) The reaction is known to be first order with respect to bleach. In a second experiment, the student prepares solutions of food coloring and bleach with concentrations that differ from those used in the first experiment. When the solutions are combined, the student observes that the reaction mixture reaches an absorbance near zero too rapidly. In order to correct the problem, the student proposes the following three possible modifications to the experiment.

- Increasing the temperature
- Increasing the concentration of the food coloring
- Increasing the concentration of the bleach

Circle the one proposed modification above that could correct the problem and explain how that modification increases the time for the reaction mixture to reach an absorbance near zero.

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Question 5 (continued)

["Increasing the concentration of the food coloring" should be circled.] If the initial concentration of blue food coloring is increased, then more time is required (regardless of the reaction order indicated in part (a)) for the bleach to oxidize the additional blue food coloring.	1 point is earned for the correct choice. 1 point is earned for a correct explanation.

(c) In another experiment, a student wishes to study the oxidation of red food coloring with bleach. How would the student need to modify the original experimental procedure to determine the order of the reaction with respect to the red food coloring?

The spectrophotometer should be set to a different wavelength.	1 point is earned for a correct answer.

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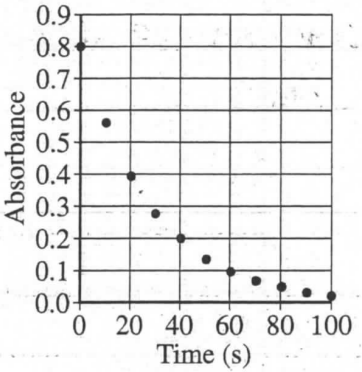
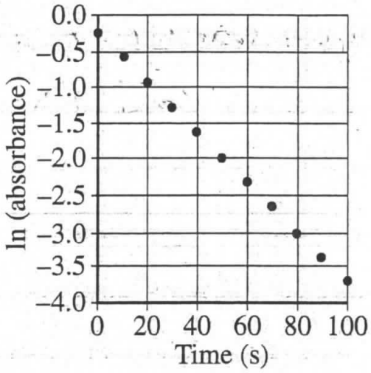
$$\underset{\textit{blue}}{Na_2C_{37}H_{34}N_2S_3O_9} + OCl^- \rightarrow \underset{\textit{colorless}}{\text{products}}$$

5A 1 of 2

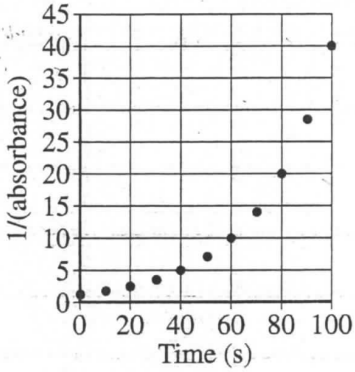
5. Blue food coloring can be oxidized by household bleach (which contains OCl^-) to form colorless products, as represented by the equation above. A student used a spectrophotometer set at a wavelength of 635 nm to study the absorbance of the food coloring over time during the bleaching process. In the study, bleach is present in large excess so that the concentration of OCl^- is essentially constant throughout the reaction. The student used data from the study to generate the graphs below.



Graph I



Graph II



Graph III

(a) Based on the graphs above, what is the order of the reaction with respect to the blue food coloring?

(b) The reaction is known to be first order with respect to bleach. In a second experiment, the student prepares solutions of food coloring and bleach with concentrations that differ from those used in the first experiment. When the solutions are combined, the student observes that the reaction mixture reaches an absorbance near zero too rapidly. In order to correct the problem, the student proposes the following three possible modifications to the experiment.

- Increasing the temperature
- Increasing the concentration of the food coloring
- Increasing the concentration of the bleach

Circle the one proposed modification above that could correct the problem, and explain how that modification increases the time for the reaction mixture to reach an absorbance near zero.

(c) In another experiment, a student wishes to study the oxidation of red food coloring with bleach. How would the student need to modify the original experimental procedure to determine the order of the reaction with respect to the red food coloring?

5. (a) The reaction is a first order as the graph with ln(absorbance) v. time is linear. As absorbance is directly proportional to concentration, the graph could also be ln (concentration) v. time. A linear graph of ln (concentration) v. time indicates a first order reaction.

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ADDITIONAL PAGE FOR ANSWERING QUESTION 5

(b) All these modifications will increase the rate of the reaction. However, by increasing the concentration of the food coloring, the absorbance of the solution will increase. The increased concentration will decay more rapidly initially, but should take longer for the absorbance to reach zero.

(c) The only change needing to take place would be to change the wavelength being studied. The wavelength would need to be shortened (to arrive at a wavelength that would be absorbed by the red dye.

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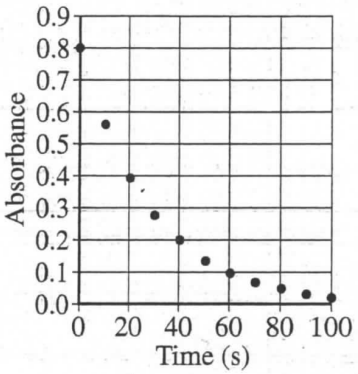
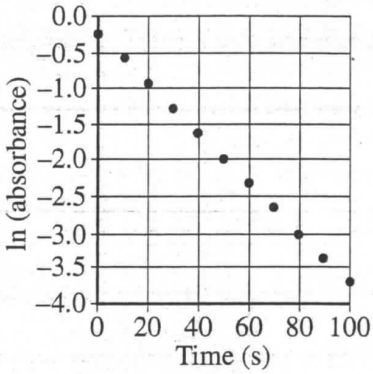
$$\underset{\textit{blue}}{Na_2C_{37}H_{34}N_2S_3O_9} + OCl^- \rightarrow \underset{\textit{colorless}}{\text{products}}$$

5B 1 of 2

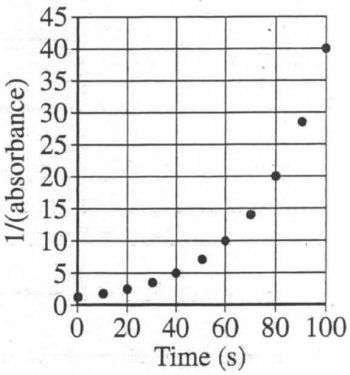
5. Blue food coloring can be oxidized by household bleach (which contains OCl^-) to form colorless products, as represented by the equation above. A student used a spectrophotometer set at a wavelength of 635 nm to study the absorbance of the food coloring over time during the bleaching process. In the study, bleach is present in large excess so that the concentration of OCl^- is essentially constant throughout the reaction. The student used data from the study to generate the graphs below.



Graph I



Graph II



Graph III

(a) Based on the graphs above, what is the order of the reaction with respect to the blue food coloring?

(b) The reaction is known to be first order with respect to bleach. In a second experiment, the student prepares solutions of food coloring and bleach with concentrations that differ from those used in the first experiment. When the solutions are combined, the student observes that the reaction mixture reaches an absorbance near zero too rapidly. In order to correct the problem, the student proposes the following three possible modifications to the experiment.

- Increasing the temperature
- Increasing the concentration of the food coloring
- Increasing the concentration of the bleach

Circle the one proposed modification above that could correct the problem, and explain how that modification increases the time for the reaction mixture to reach an absorbance near zero.

(c) In another experiment, a student wishes to study the oxidation of red food coloring with bleach. How would the student need to modify the original experimental procedure to determine the order of the reaction with respect to the red food coloring?

a) first order

b) if there is a greater concentration of food coloring it will take longer for the reaction to proceed to completion.

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c) The student must re-calibrate the spectrometer when working with a new food color.

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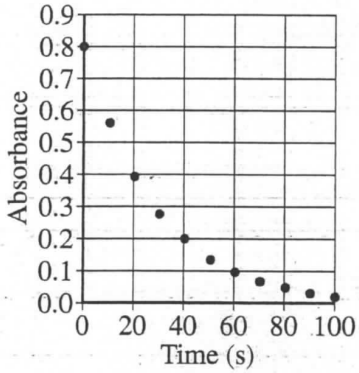
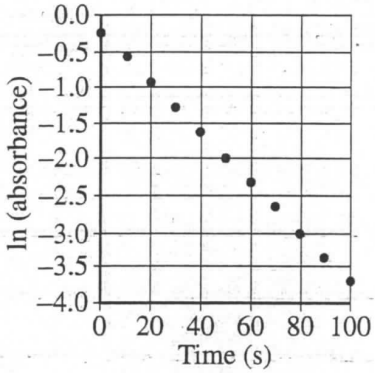
5C 1 of 2

$$Na_2C_{37}H_{34}N_2S_3O_9 + OCl^- \rightarrow \text{products}$$
blue *colorless*

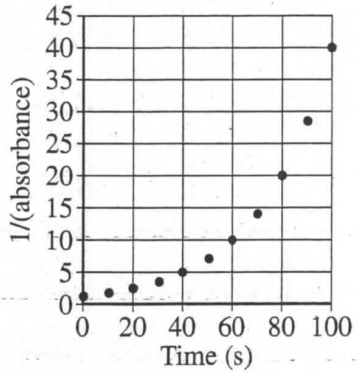
5. Blue food coloring can be oxidized by household bleach (which contains OCl^-) to form colorless products, as represented by the equation above. A student used a spectrophotometer set at a wavelength of 635 nm to study the absorbance of the food coloring over time during the bleaching process. In the study, bleach is present in large excess so that the concentration of OCl^- is essentially constant throughout the reaction. The student used data from the study to generate the graphs below.



Graph I



Graph II



Graph III

(a) Based on the graphs above, what is the order of the reaction with respect to the blue food coloring?

(b) The reaction is known to be first order with respect to bleach. In a second experiment, the student prepares solutions of food coloring and bleach with concentrations that differ from those used in the first experiment. When the solutions are combined, the student observes that the reaction mixture reaches an absorbance near zero too rapidly. In order to correct the problem, the student proposes the following three possible modifications to the experiment.

- Increasing the temperature
- Increasing the concentration of the food coloring
- Increasing the concentration of the bleach

Circle the one proposed modification above that could correct the problem, and explain how that modification increases the time for the reaction mixture to reach an absorbance near zero.

(c) In another experiment, a student wishes to study the oxidation of red food coloring with bleach. How would the student need to modify the original experimental procedure to determine the order of the reaction with respect to the red food coloring?

(a) The order of reaction is 1.

(b) With a higher bleach concentration, it will take more time for the food coloring to absorb because there is more bleaching occuring.

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(c) The student would have to change the wavelength of the spectrophotometer because it is originally set at a wavelength that only corresponds with the blue color.

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AP® CHEMISTRY
2015 SCORING COMMENTARY

Question 5

Overview

This question assessed the students' understanding of the spectrophotometric determination of reaction order for a pseudo-decomposition reaction, one of the common AP® Chemistry laboratory exercises included in the College Board lab manual. In part (a) students were challenged to determine the order of the oxidation reaction of blue food coloring from graphically presented data of absorbance versus time, ln (absorbance) versus time, and 1/absorbance versus time. Part (b) assessed the students' understanding of the experimental methodology by requiring them to select an appropriate modification to a poor experimental setup. Finally, part (c) tested the students' grasp of spectrophotometry and the relationship between absorbance, color, and wavelength.

Sample: 5A
Score: 4

This response earned all 4 possible points. One point was earned in part (a) for correctly determining the reaction order with respect to blue food coloring. Two points were earned in part (b) for correctly stating that increasing the concentration of the food coloring would cause the absorbance to take longer to reach zero. One point was earned in part (c) for indicating that the wavelength setting of the spectrophotometer would need to be shortened.

Sample: 5B
Score: 3

This response earned 3 out of 4 possible points. One point was earned in part (a) for correctly stating that the reaction is first order with respect to the blue food coloring. Two points were earned in part (b) for indicating that increasing the concentration of the food coloring would be an appropriate modification, and for stating that this modification would cause the reaction to take longer to proceed to completion. No point was earned in part (c); although the paper states that the spectrometer (sic) must be recalibrated, no mention is made of altering the wavelength.

Sample: 5C
Score: 2

This response earned 2 out of 4 possible points. One point was earned in part (a) for correctly stating that the reaction is first order with respect to the blue food coloring. The points were not earned in part (b) because the response indicates that an increase in the concentration of bleach would be a suitable modification to increase the time needed for the reaction mixture to reach a near-zero absorbance. One point was earned in part (c) for correctly identifying a change in wavelength as a necessary experimental modification.

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