Introduction

Through chemical kinetics it can be determined how a reaction is occurring by using the speed at which a reaction occurs and the factors that affect the reactions speed. During this lab, Chemical Kinetics, the rate at which a reaction occurs is determined, as well as the order of the reaction, with a pH solution.

This laboratory was set up with a hotplate boiling water in a 250mL beaker and a SpectroVis for LabQuest 2. Three trials were performed with different pH solutions each time – 4.0pH, 4.5pH, pH – for each trial the pH was submitted into the SpectroVis for 40min and the rest of the pH was submitted into the boiling water for 10 minutes and then cooled for the rest of the time. Once the original pH was in the SpectroVis for 40min we replaced it with the pH that was heated and then cooled.

The rate of a chemical reaction is shown by the equation; $Rate = k\ [A]^n[B]^m$ (A+B → P) where k is the rate constant. The rate of a chemical reaction is proportional to the product of the concentrations. The rate can also be determined by using a graph, generally finding the instantaneous rate when plotting the concentration as a function of time. The instantaneous rate can be determined through finding the slope of the tangent at that certain time.

Pseudo first order reactions are determined if the concentration of a reactant stays constant and its concentration can be absorbed through the rate constant, which proves that the concentration is only dependant on one reactant. According to the equation

$$Rate = -\frac{d[Cr(III)]}{dt} = \frac{d[Cr(III) - EDTA]}{dt} = k[Cr(III)]^a[H^+]^b$$

the rate of the reaction in this experiment should be dependent on both [Cr(III)] and $[H^+]$ but, if the concentrations of these are both changed at the same time it would be possible to determine if the change in rate was due to the change in [Cr(III)], $[H^+]$ or both.

A spectrophotometer is a method that can be used to measure the amount of a chemical substance that absorbs light, through which the intensity of a light as a beam of light passing through a solution is measured. Two very common terms when using a spectrophotometer are transmittance and absorbance. Transmittance is the ratio of the intensity of the light after it passes through the medium, to the intensity of the light before it passes through the medium. Absorbance shown through a logarithm and transmittance is shown through a line.

The Beer-Lambert law is the relation between absorbance and concentration and it is shown by the equation: $A = \varepsilon bc$, where A represents the absorbance, ε represents the molar absorptivity coefficient, b represents the path length and c represents the concentration of the absorbing species in the solution. The equation shows that the absorbance is directly proportional to the concentration because the path length is constant due to the fact that the same cuvette is being used for all measurements.

Reference: Chemical Kinetics: Pages 45-49.

Purpose

Refer to Lab handout: Chemical Kinetics. Page 43.

Materials

Refer to Lab handout: Chemical Kinetics. Page 50.

Procedure

Refer to Lab handout: Chemical Kinetics. Pages 50-54.

Observations

Table 1. Trial 1, 2 and 3. Reactions of different pH levels.

	Trial 1	**Trial 2**	**Trial 3**
pH Level	4.0 EDTA	4.5 EDTA	5.0 EDTA
Concentration	0.1M	0.1M	0.1M
Volume of pH	10mL	10mL	10mL
Amount of Cr(III)	2 drops	2 drops	2 drops

Concentration of Cr(III)	1.0M	1.0M	1.0M

Trial 1: For the first ten minutes of the SpectroVis and LabQuest 2 the absorbance of the 4.0pH was steady at 0.055nm – 0.127nm. When the Cr(III) drops were added to the test tube, there was not a big change in colour, from clear to greyish clear. The solution that was not used in the SpectroVis was inserted into the boiling water on the hotplate in a test tube. The solution immediately turned from the greyish clear colour to a dark purple. After the solution sat in the boiling water for ten minutes it was removed and placed in a water bath at room temperature. At 20 minutes the percent absorbance has slightly increased to 0.135nm - 0.168nm. At 30 minutes the percent absorbance was still slightly increasing from 0.168nm – 0.213nm and between 30 and 40 minutes it increased from 0.213nm – 0.260nm. At the 40 minute mark we transferred the heated and cooled solution from the room temperature water bath to the cuvette in the SpectroVis. Between 40 minutes and 42 minutes there was a significant increase from 0.260nm to 1.935nm.

Trial 2: For the first ten minutes of the second trial the percent absorbance has a slight increase that was a little bit more than the 4.0pH. The 4.5pH increased from 0.055nm – 0.138nm for the first ten minutes. From 10 to 20 minutes there was an increase of 0.138nm – 0.231nm and 20-30 minutes the increase was from 0.231nm – 0.304nm. This trial was stopped at 32 minutes due to the time constraints. The same thing happened with the remainder of the solution that was put into the boiling water. At 30 minutes the heated and cool solution replaced the other solution in the cuvette and between 30-32 minutes there was a larger increase from 0.304nm – 2.031nm.

Trial 3: For the final trail the first ten minutes had an increase of 0.054nm – 0.266nm for the 5.0pH solution. Between 10-20 minutes the percent absorbance increase from 0.266nm – 0.437nm and from 20-30 minutes the percent absorbance increased from 0.437nm – 0.553nm. This trial was also stopped at 30 minutes instead of 40 so, at the 30 minute mark the heated and cooled solution replaced the normal pH solution in the cuvette and there was a large increase in the percent absorbance at 30-32 minutes increase from 0.553nm – 2.096nm. It was noticed that the higher the pH the faster the reaction.

Calculations

$A_{Cr(III)} = A_\infty - A_t$

Trial 1 (pH 4.0 EDTA):

1. $A_{Cr(III)}$ = 1.935 – 0.055 = 1.88
2. $A_{Cr(III)}$ = 1.935 – 0.114 = 1.821
3. $A_{Cr(III)}$ = 1.935 – 0.114 = 1.821
4. $A_{Cr(III)}$ = 1.935 – 0.117 = 1.818
5. $A_{Cr(III)}$ = 1.935 – 0.122 = 1.813
6. $A_{Cr(III)}$ = 1.935 – 0.127 = 1.808
7. $A_{Cr(III)}$ = 1.935 – 0.135 = 1.8
8. $A_{Cr(III)}$ = 1.935 – 0.141 = 1.794
9. $A_{Cr(III)}$ = 1.935 – 0.149 = 1.786
10. $A_{Cr(III)}$ = 1.935 – 0.156 = 1.779
11. $A_{Cr(III)}$ = 1.935 – 0.168 = 1.767
12. $A_{Cr(III)}$ = 1.935 – 0.177 = 1.758
13. $A_{Cr(III)}$ = 1.935 – 0.186 = 1.749
14. $A_{Cr(III)}$ = 1.935 – 0.195 = 1.74
15. $A_{Cr(III)}$ = 1.935 – 0.204 = 1.731
16. $A_{Cr(III)}$ = 1.935 – 0.213 = 1.722
17. $A_{Cr(III)}$ = 1.935 – 0.223 = 1.712
18. $A_{Cr(III)}$ = 1.935 – 0.231 = 1.704
19. $A_{Cr(III)}$ = 1.935 – 0.242 = 1.693
20. $A_{Cr(III)}$ = 1.935 – 0.250 = 1.685
21. $A_{Cr(III)}$ = 1.935 – 0.260 = 1.675
22. $A_{Cr(III)}$ = 1.935 – 1.935 = 0

Trial 2 (pH 4.5 EDTA):

1. $A_{Cr(III)}$ = 2.031 – 0.055 = 1.976
2. $A_{Cr(III)}$ = 2.031 – 0.077 = 1.954
3. $A_{Cr(III)}$ = 2.031 – 0.087 = 1.944

4. $A_{Cr(III)}$ = 2.031 – 0.102 = 1.929
5. $A_{Cr(III)}$ = 2.031 – 0.118 = 1.913
6. $A_{Cr(III)}$ = 2.031 – 0.138 = 1.893
7. $A_{Cr(III)}$ = 2.031 – 0.157 = 1.874
8. $A_{Cr(III)}$ = 2.031 – 0.176 = 1.855
9. $A_{Cr(III)}$ = 2.031 – 0.196 = 1.835
10. $A_{Cr(III)}$ = 2.031 – 0.214 = 1.817
11. $A_{Cr(III)}$ = 2.031 – 0.231 = 1.800
12. $A_{Cr(III)}$ = 2.031 – 0.247 = 1.784
13. $A_{Cr(III)}$ = 2.031 – 0.263 = 1.768
14. $A_{Cr(III)}$ = 2.031 – 0.277 = 1.754
15. $A_{Cr(III)}$ = 2.031 – 0.291 = 1.740
16. $A_{Cr(III)}$ = 2.031 – 0.304 = 1.727
17. $A_{Cr(III)}$ = 2.031 – 2.031 = 0

Trial 3 (pH 5.0 EDTA):

1. $A_{Cr(III)}$ = 2.096 – 0.054 = 2.042
2. $A_{Cr(III)}$ = 2.096 – 0.106 = 1.990
3. $A_{Cr(III)}$ = 2.096 – 0.140 = 1.956
4. $A_{Cr(III)}$ = 2.096 – 0.182 = 1.941
5. $A_{Cr(III)}$ = 2.096 – 0.225 = 1.871
6. $A_{Cr(III)}$ = 2.096 – 0.266 = 1.829
7. $A_{Cr(III)}$ = 2.096 – 0.306 =1.790
8. $A_{Cr(III)}$ = 2.096 – 0.342 = 1.754
9. $A_{Cr(III)}$ = 2.096 – 0.376 = 1.720
10. $A_{Cr(III)}$ = 2.096 – 0.407 = 1.689
11. $A_{Cr(III)}$ = 2.096 – 0.437 = 1.659
12. $A_{Cr(III)}$ = 2.096 – 0.463 =1.633
13. $A_{Cr(III)}$ = 2.096 – 0.488 = 1.608
14. $A_{Cr(III)}$ = 2.096 – 0.512 = 1.584
15. $A_{Cr(III)}$ = 2.096 – 0.533 = 1.563

16. $A_{Cr(III)}$ = 2.096 – 0.553 = 1.543
17. $A_{Cr(III)}$ = 2.096 – 2.096 = 0

Discussion

In this laboratory experiment the levels of three different pH levels – 4.0pH, 4.5pH and 5.0pH – are compared through a reaction with Cr(III) in the SpectroVis. For the first trial of this experiment 4.0 EDTA was used with two drops of Cr(III). During the first 40 minutes of that solution in the cuvette in the SpectorVis there was not a big change in the percent absorbance, 0.055nm – 0.260nm. While the first solution was in the SpectroVis the remainder of that solution was emerged into a boiling water bath in a test tube for ten minutes and then is was placed in a water bath at room temperature. The solution that was placed in the boiling water immediately changed from the greyish clear colour to a dark purple. When this solution replaced the first solution in the cuvette the percent absorbance rapidly increased from 0.260nm – 1.935nm. The second and third trials were reduced to 30 minutes instead of 40 minutes due to the time constraints. The second and third trials had the same process and reactions as the first. As the pH got higher the reactions were faster. The second trials percent absorbance rapidly increased from 0.304nm – 2.031nm when the heated and cooled solution was added to the cuvette and for the third trial the percent absorbance increased from 0.553nm – 2.096nm with the heated and cooled solution.

Our data is in accordance with chemical kinetics, the absorbance percent becomes higher as the reaction unfolds and the trend becomes steady. Two factors that are not of great importance to the reaction were temperature and volume. The volume of solution made and put into the cuvette are not important because the EDTA is reacting with the Chromium (III) in major excess. Secondly, as long as the temperature remained stable (± 1°C) it would have little to no effect on the rate of the reaction. Overall, we were just focusing on the trend of the reaction and the absorbance and volume and temperature are not important.

The absorbance calculations above are showing the Chromium (III) being absorbed into the pH solutions. Through the trials the Cr(III) is slowly decreasing as the reaction is occurring. The higher the pH level the slower the Cr (III) is being absorbed. When the Cr(III) was heated and cooled and then added to the cuvette, the Cr(III) was completely absorbed in each trial. The rest of the solution that was not initially added to the cuvette was heated and then cooled to get it to the next step. If the remainder of the solution was not heated in boiling water it would take a very long time for the Cr(III) to completely absorb. The instantaneous rate of change was also graphed for each trial. The instantaneous rate of change is the slope of the tangent line and shows that the slope is constant which forms a straight line. For all three trials the slope was constant which proves that each trial was a first-order reaction.

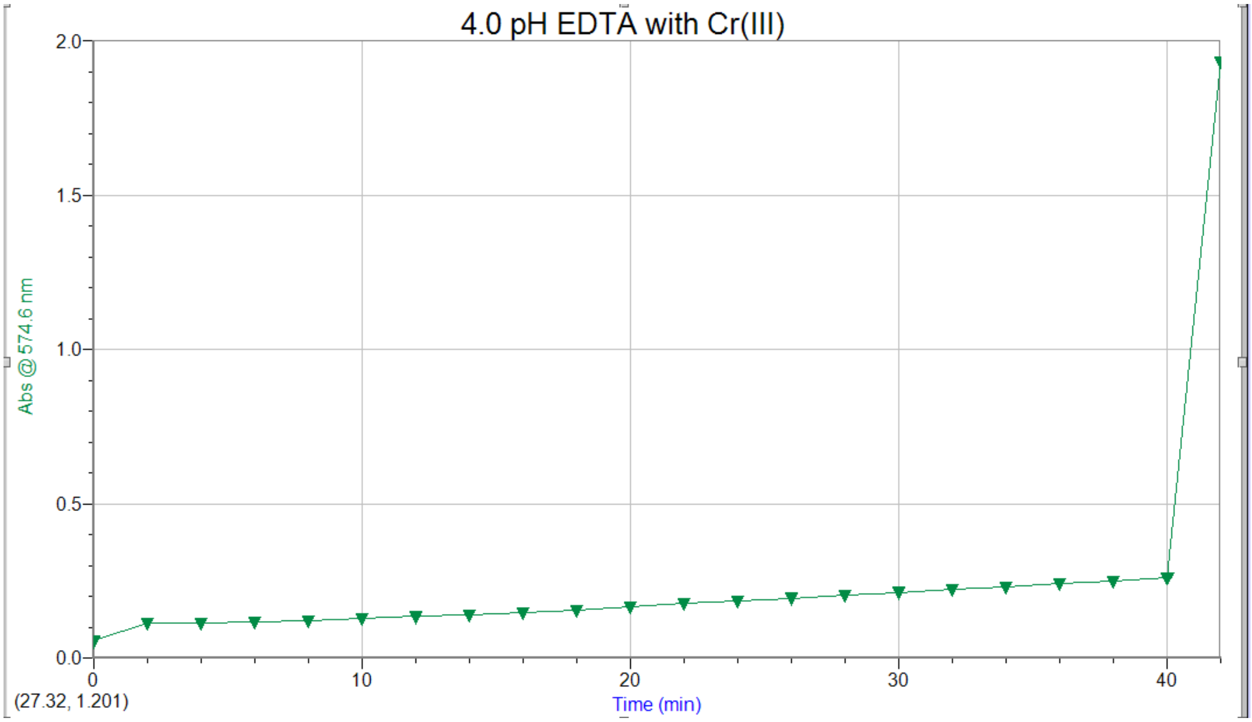
The sources of error in this lab could include excess water or solution when transferring solutions in and out of the cuvette and into the SpectroVis. The amount of water or solution that would be left over would be very small and would not affect the experiment in a drastic way. During this experiment there were no human errors and therefore with this data the experiment should be able to be reproduced.

Conclusion

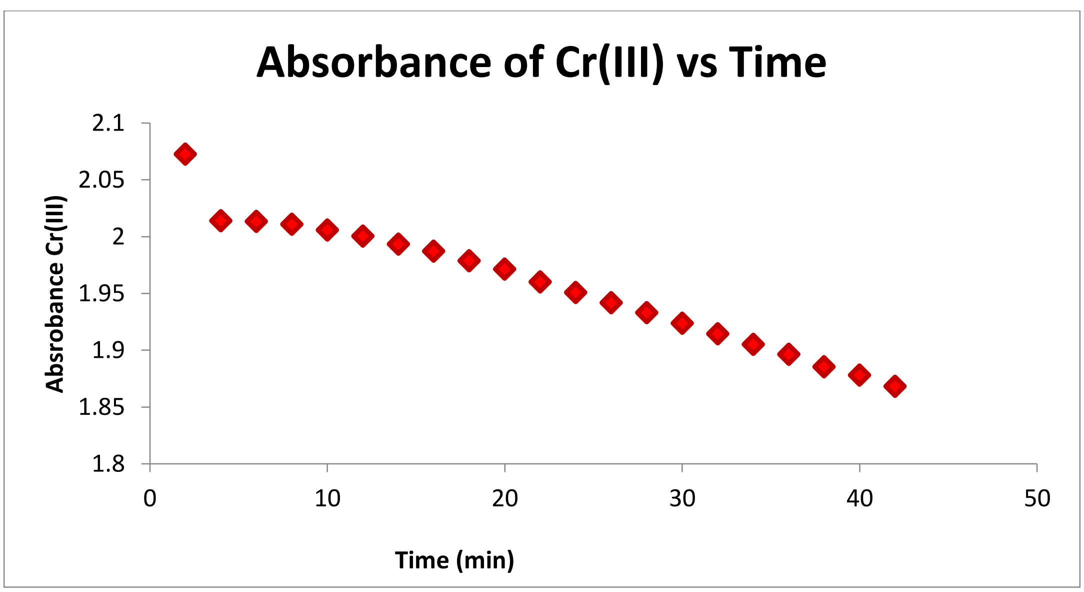
During this experiment three different levels of pH were observed in the same conditions. The absorbance of Cr(III) was calculated for each two minutes time interval. When the Cr(III) and pH solution was heated in a boiling water bath and then transferred to the cuvette, the Cr(III) was completely absorbed. The solution must be heated in order to get it to the next step, or it would have taken a very long time for the Cr(III) to be absorbed. The instantaneous rate of change was also showed on a graph proving that the slope was constant and that all three reactions are first-order reactions. Throughout this experiment it was determined that the higher the pH, the more acidic the reactant, the darker the colour and the faster the reaction occurred over the same amount of time.

Appendix

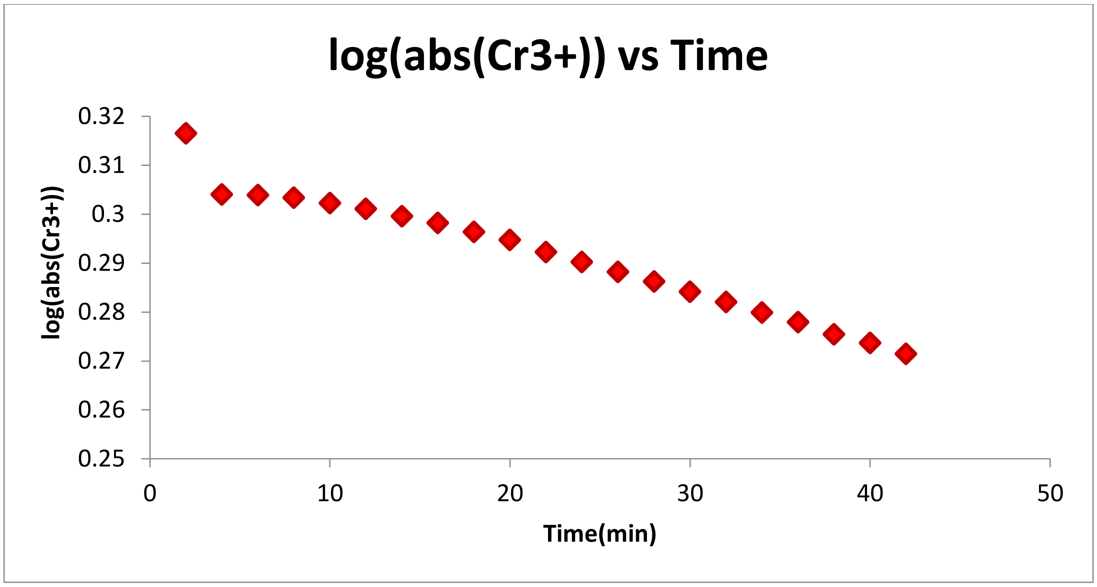
Trial 1: pH 4.0 EDTA → Logger Pro



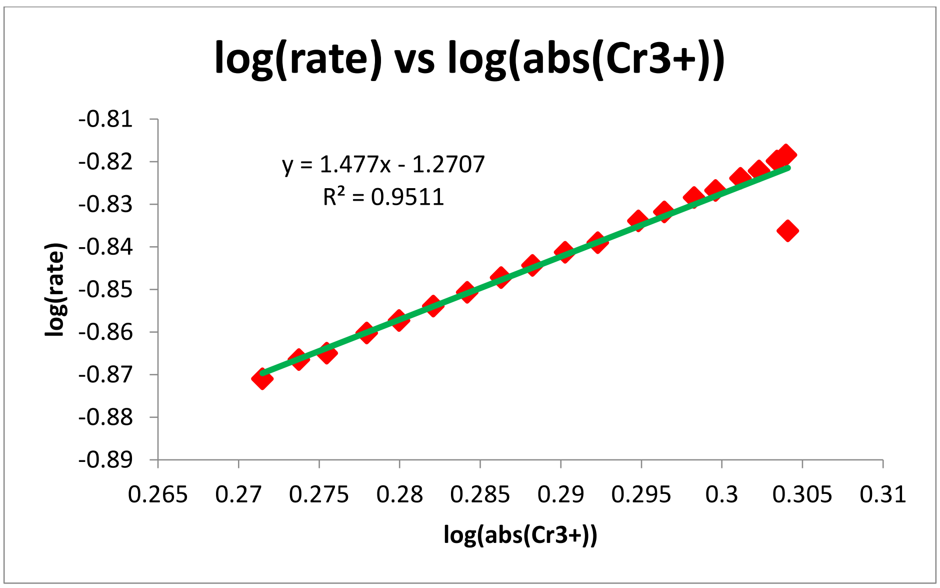
Trial 1: Absorbance of Cr(III) vs Time



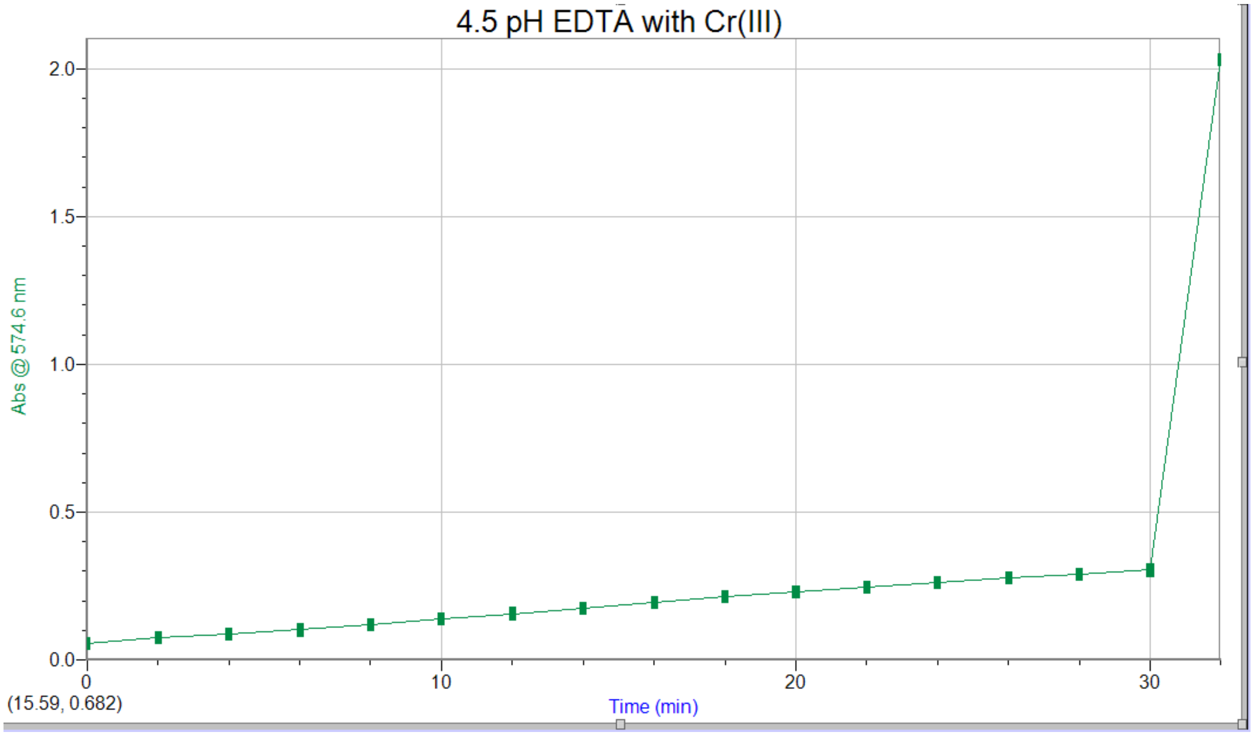
Trial 1: log(abs(Cr3+)) vs Time



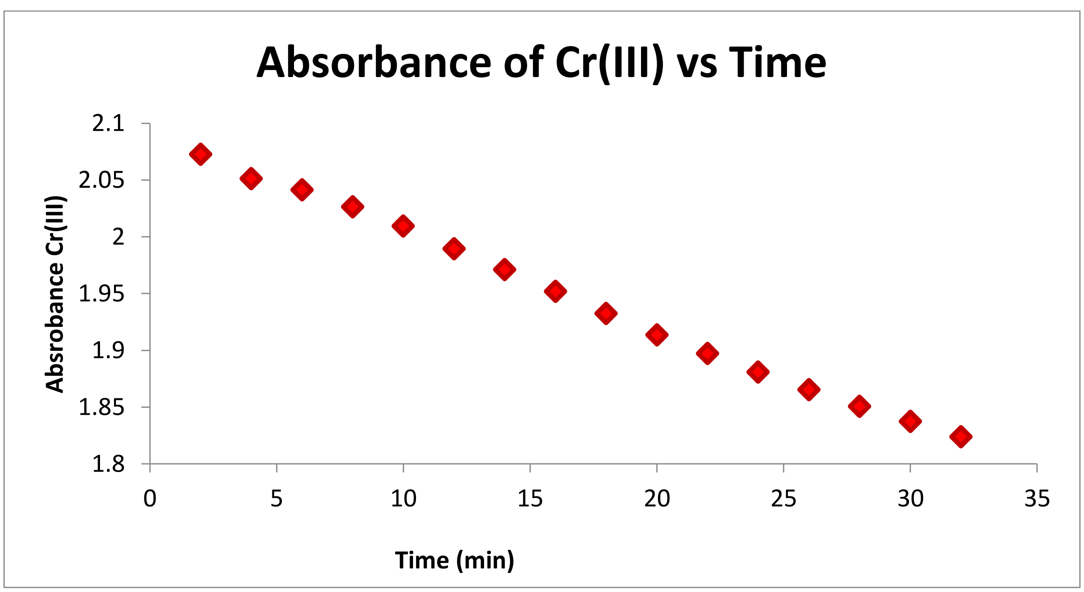
Trial 1: log(rate) vs log(abs(Cr3+)) → Instantaneous Rate of Change



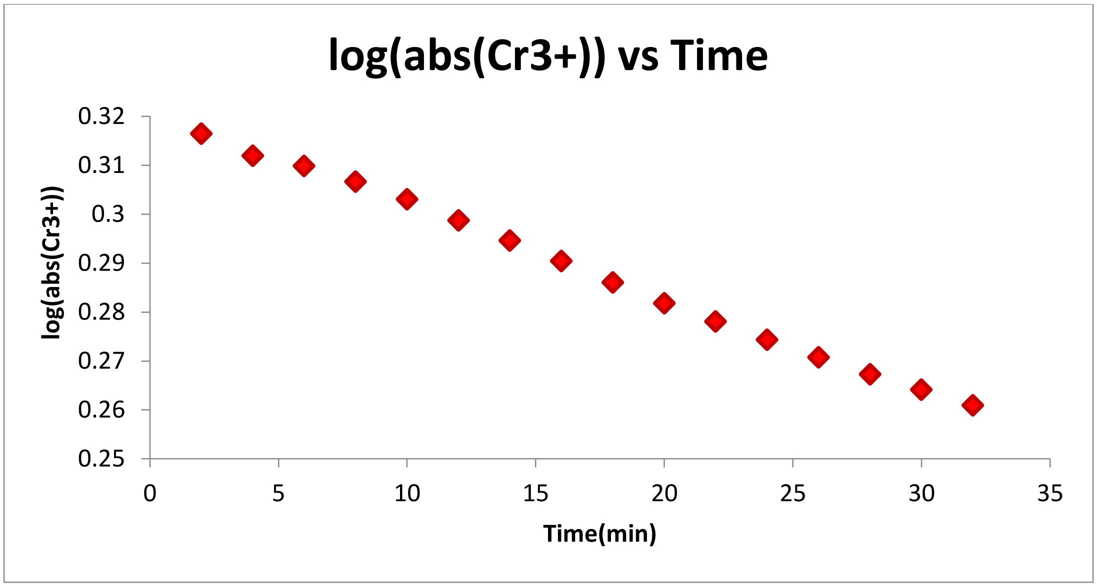
Trial 2: 4.5pH EDTA with Cr(III) → Logger Pro



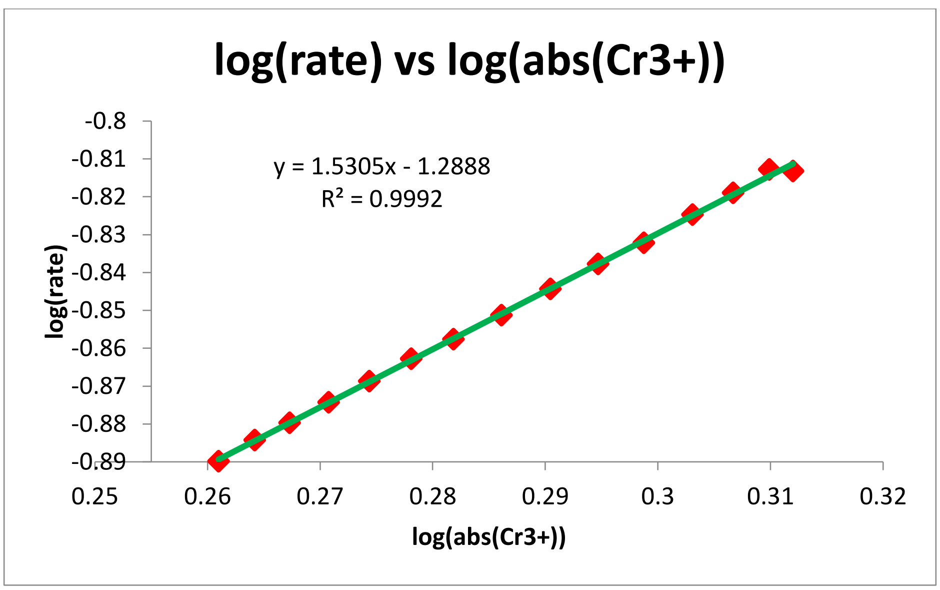
Trial 2: Absorbance of Cr(III) vs Time



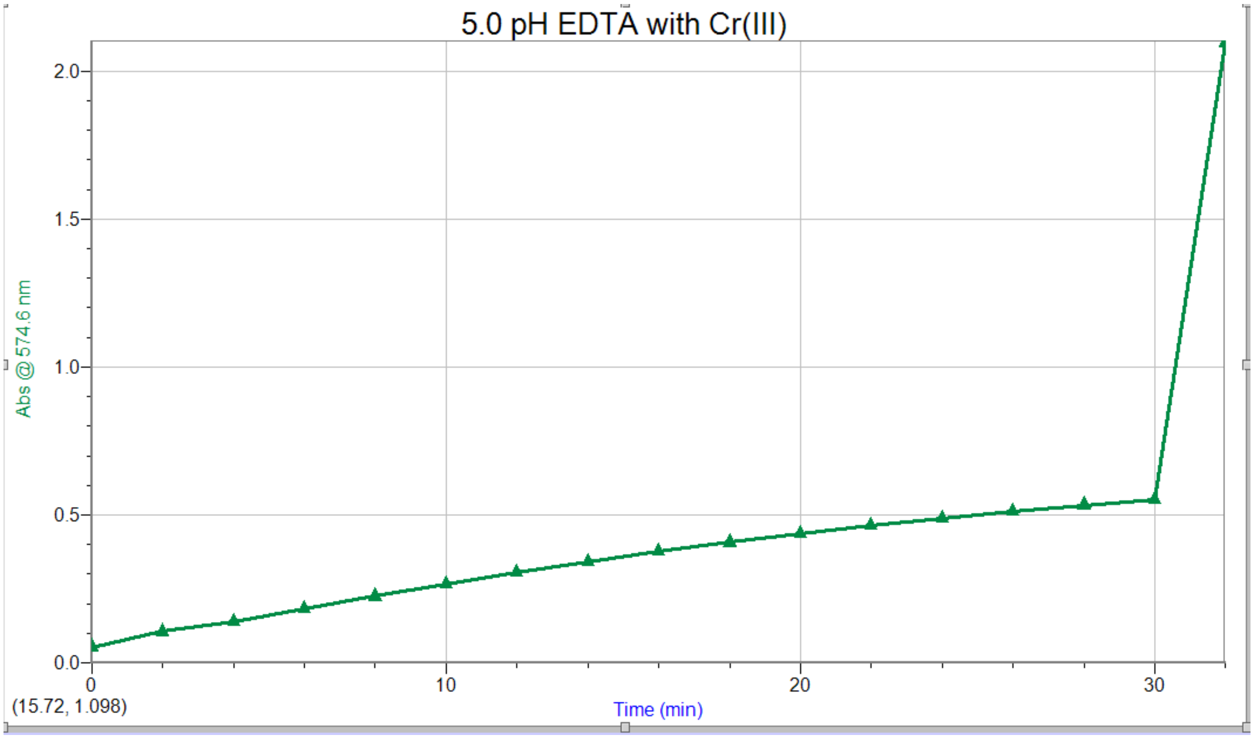
Trial 2: log(abs(Cr3+)) vs TIme



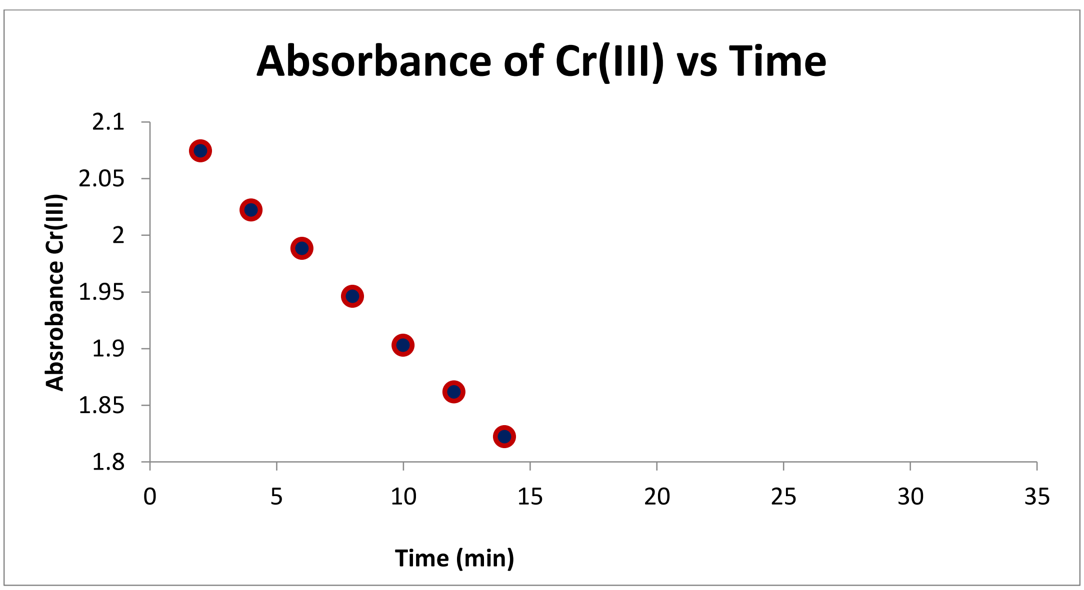
Trial 2: log(rate) vs log(abs(Cr3+)) → Instantaneous Rate of Change



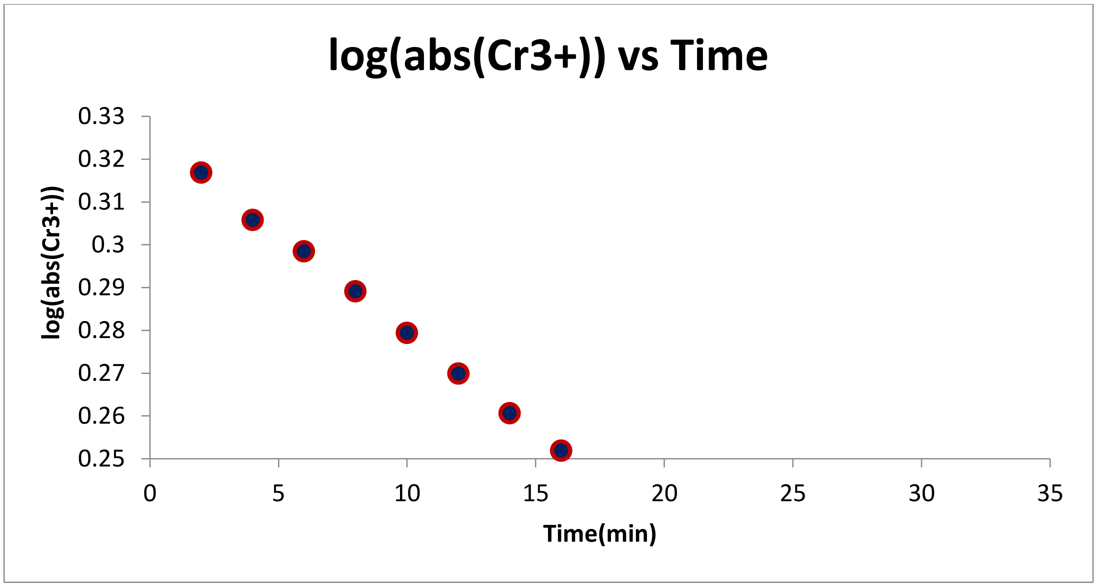
Trial 3: 5.0 pH EDTA → Logger Pro



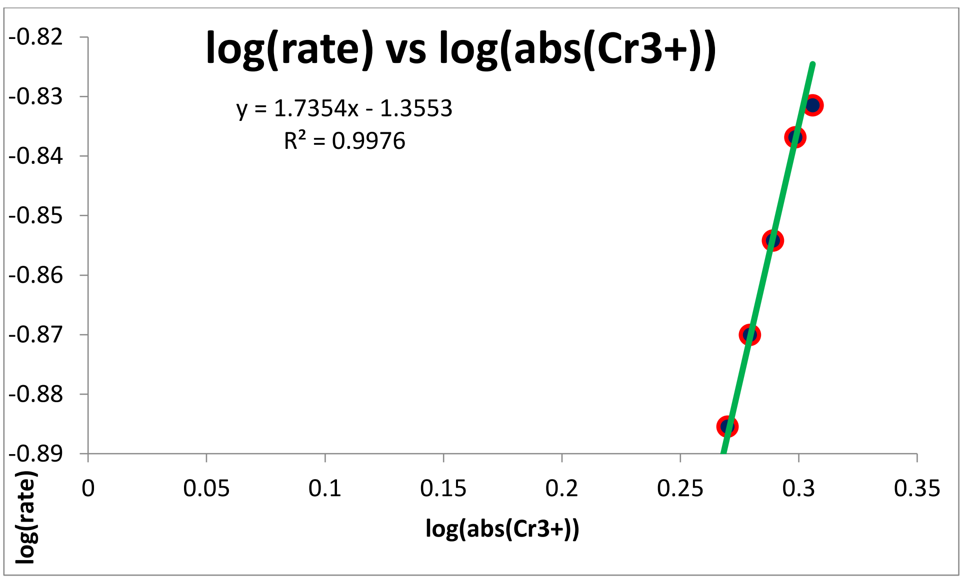
Trial 3: Absorbance of Cr(III) vs Time



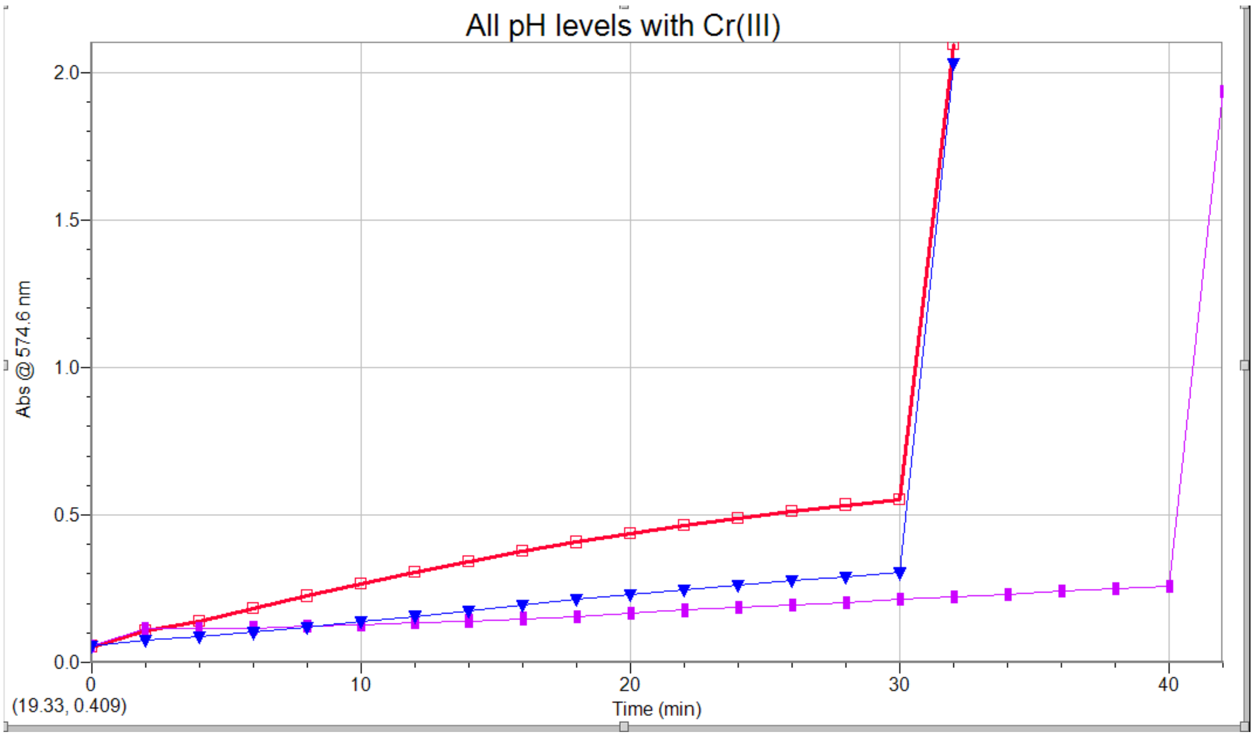
Trial 3: log(abs(Cr3+)) vs Time



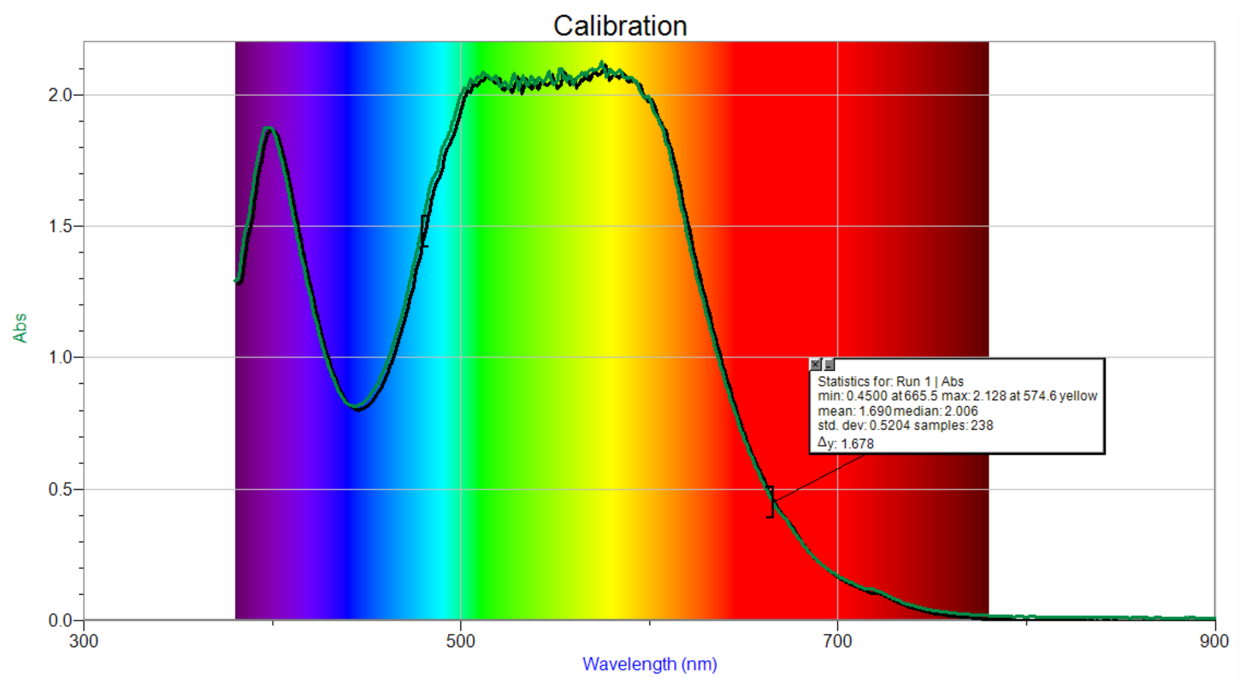
Trial 3: log(rate) vs log(abs(cr3+)) → Instantaneous Rate of Change



All Runs → Logger Pro



Calibration → Logger Pro



Raw Data 1:

Calibration = run 1 — added heat to increase reaction

Paige Dorey

Lab3 XEMONS.

pH 4.5 EDTA Mole concentration = 0.1M   Cr(III) = 1.0M

Calibration 5mL pH + 5 drops Cr(III).

min = 0.450 @ 665.50   wavelength = 667.00 nm

max = 2.128 @ 574.60

↳ absorbing more light ∴ its getting darker.

• when solution was added to the boiling water it turned to a dark eggplant purple within the first minute.

Trial 1

pH 4.0 EDTA, concentration = 0.1M.

Volume of 4.0 = 10mL

Labquest2 Data → % Transmittance every 2 min.

Observations

• for the 1st 10 minutes of the Spectrovis and LabQuest the percent ~~transmittance~~ absorbance. was steady at

• The solution that was not used in the spectrovis was inserted into the boiling water; (2 drops Cr(III) & 10mL 4.0pH), it immediately turned from the greyish clear ~~to~~ colour to a nice ~~bright~~ dark. purple.

• when the Cr(III) was added to the test tube it didn't change too much in color, greyish clear.

• at 20 minutes the % absorbance had a slight increase but nothing major.

discussion * our graph will be increasing because we are calculating. the % absorbance, ~~so~~ where if we were to calculate the % transmittance the graph would be decreasing *

• at 30 minutes the % abs ~~is~~ was still slightly increasing.

• between 30-40 there is more of an increase.

• 40-42.; removed solution from cuvette and added the heated and cooled solution to the spectrovis → Increased significantly.

* The higher the pH the faster reaction *

↳ higher pH, darker the colour → over the same amount of time

conclusion   basic ⟶ acidic ↳ more reactive.

Raw Data 2:

XEMONE.

Trial 2

pH 4.5 = 10mL 2 drops Cr(III).

Observations

- first 10 minutes increase in % absorbance, slightly larger ↑ than 4.0pH.
- same thing happened for the heated and cooled solution, little bit darker.
- 20 minute mark increased again slightly
- 30 mins another slight increase
- removed solution from cuvette and added heated and cooled solution at 30 min.
- stopped at 32 minutes → 30-32 big increase again but it appears less of an increase than the 4.0 pH.

Trial 3

pH 5.0 = 10mL = 0.1M   2 drops Cr(III) = 1.0M → very dark.

- heated solution immediately changed to purple again
- at 10 minutes an increase in the % absorbance, much bigger increase than pH 4.0 and pH 4.5.
- at 20 minutes it is still increasing must faster than the 2 lower pH levels. (4.0 - 4.5)
- 30 minutes we remove the solution and add the heated and cooled pH 5.0 for the last two min
- rapid increase for the last 2 min
- stopped at 32 min.