Introduction

When scientists study how fast or slow a reaction occurs, that is called *chemical kinetics*. Chemists also watch for factors that affect the rates of reactions. The rate of a reaction depends on the initial concentrations of the reactants (Refer to "If It Were Done…Then 'Twere Well It Were Done Quickly" Page 45). This is known otherwise as *order of reaction*. The order of reaction can be calculated using the following formula:

Rate= $k[A]^n[B]^m$

or it can be calculated by taking the slope of a graph that shows the concentration of the reactants over time.

In this experiment, we prepared reactions at different pH levels and observed the formation of a colored complex over time. We are trying to see how concentration affects the rate of reaction. We used different pH levels because the pH is known to affect the kinetics of aqueous reactions. A few drops of the Chromium (III) ion are added to the EDTA solution in excess, then over time, we observe the product being formed. At the start, no visible changed is observed. However, after a while, a solution with a deep purple color is formed. Transmittance is the ratio of intensity of light after it goes through the medium over the intensity of light before it goes through the medium $T=I/I_0$. We prefer to have the spectrophotometer read percent transmittance because it is linear, while absorbance is more of a logarithmic scale. The absorbance is related to transmittance through this equation:

$$A=-\log T=-\log(I/I_0)$$

However, none of these equations relate concentration to absorbance. The equation that shows us this relationship is called the *Beer-Lambert Law:*

$A=\varepsilon bc$, where ε is the molar absorptivity coefficient and b is the path length and c is the concentration. Since ε and b don't change, A=c. To find the $A_{Cr(III)}$, which is the amount of unreacted Cr(III), we use the following equation:

$\mathbf{A_{Cr(III)}=A_{Infinity}-A_t}$ **,** where $A_{infinity}$ is the absorbance at the very end after the solution is heated, and A_t is the absorbance at any time. Therefore, at time zero, that means only Cr(III) is present in solution.

Procedure: Refer to the lab manual (“If It Were Done…Then ‘Twere Well It Were Done Quickly”, Dr. Rashmi Venkateswaran, Experiment 4, pages 50-52).

Data Tables

Raw Data

*Don't unplug spectro. until saving data.

Experiment 4 Raw Data

minimum: 574.50 λ (Run 1).

calibration.

Step 24 (Starting ex.).

- pH = 4 volume = 10.00 mL.

- pH = 4.5 volume = 10.00 mL

- pH = 5 volume = 10.00 mL.

formal lab report

- include title pg.
- intro: provide theory + all you need to know to understand the lab.
- measurements don't belong in observations.
- graphs should have captions.
  ↳ should tell what graph represents.
- discussion: presenting results.
- units in calculations

Raw Data Tables

Run 1			Run 2			Run 3		
Time (min)	Trans @ (%)	A(t)	Time (min)	Trans @ (%)	A(t)	Time (min)	Trans @ (%)	A(t)
0	81.536	0.088649	0	81.529	0.088690	0	1.974	1.7047
2	73.397	0.13432	2	80.303	0.095269	2	69.621	0.15726
4	73.386	0.13438	4	79.513	0.099565	4	68.052	0.16716
6	73.390	0.13436	6	78.889	0.10298	6	66.136	0.17956
8	72.745	0.13820	8	78.020	0.10780	8	63.770	0.19539
10	72.238	0.14124	10	76.872	0.11423	10	61.355	0.21215
12	71.490	0.14575	12	75.794	0.12037	12	58.843	0.23031
14	70.547	0.15152	14	74.548	0.12756	14	56.320	0.24934
16	69.773	0.15632	16	73.229	0.13532	16	53.731	0.26978
18	68.957	0.16142	18	71.772	0.14404	18	51.527	0.28796
20	67.901	0.16812	20	70.406	0.15239	20	49.253	0.30756
22	67.068	0.17348	22	69.028	0.16098	22	47.044	0.32749
24	66.103	0.17978	24	67.567	0.17026	24	45.138	0.34546
26	65.212	0.18567	26	66.125	0.17964	26	43.283	0.36368
28	64.272	0.19198	28	64.678	0.18924	28	41.514	0.38180
30	63.337	0.19834	30	63.466	0.19746	30	39.879	0.39926
32	62.388	0.20490	32	62.093	0.20696	32	38.301	0.41679
34	61.534	0.21089	34	60.799	0.21610	34	36.830	0.43380
36	60.760	0.21639	36	59.499	0.22549	36	35.637	0.44810
38	59.926	0.22238	38	58.416	0.23347	38	34.346	0.46413
40	59.070	0.22863	40	57.206	0.24256	40	1.144	1.9417
42	1.219	1.9140	42	1.919	1.7169			

Observations: Upon first adding the drops of Cr(III), the color didn't immediately change to purple. It was a green-ish gray at the beginning. The percent transmittance decreased steadily throughout the forty minutes. The solution in the boiling water bath turned into a dark purple color after approximately five minutes. A(t) is increasing with time because it's the product.

Calculations:

<u>Run 1:</u>

Calculating $A_{Cr(III)}$ using $A_{Cr(III)}=A_{infinity}-A_t$

$A_{infinity}$: final absorbance value from logger pro.

A_t= absorbance at time zero.

$A_{Cr(III)}=1.9140-0.088649$

$\mathbf{A_{Cr(III)}=1.8254}$

<u>Run 2:</u>

$A_{Cr(III)}=1.7169-0.088690$

$\mathbf{A_{Cr(III)}=1.6282}$

<u>Run 3:</u>

$A_{Cr(III)}=1.9417-0.15726$

$\mathbf{A_{Cr(III)}=1.7844}$

Run 1 (pH 4)

	Run 1						
	Time (min)	Trans @ (%)	A(t)	A(CrIII)	Log A(CrIII)	Rate	Log Rate
1	0	81.536	0.088649	1.825	0.261	0.017	-1.783
2	2	73.397	0.13432	1.780	0.250	0.009	-2.032
3	4	73.386	0.13438	1.780	0.250	0.003	-2.531
4	6	73.390	0.13436	1.780	0.250	0.002	-2.807
5	8	72.745	0.13820	1.776	0.249	0.002	-2.804
6	10	72.238	0.14124	1.773	0.249	0.002	-2.707
7	12	71.490	0.14575	1.768	0.248	0.002	-2.617
8	14	70.547	0.15152	1.762	0.246	0.003	-2.589
9	16	69.773	0.15632	1.758	0.245	0.003	-2.582
10	18	68.957	0.16142	1.753	0.244	0.003	-2.543
11	20	67.901	0.16812	1.746	0.242	0.003	-2.529
12	22	67.068	0.17348	1.741	0.241	0.003	-2.528
13	24	66.103	0.17978	1.734	0.239	0.003	-2.519
14	26	65.212	0.18567	1.728	0.238	0.003	-2.513
15	28	64.272	0.19198	1.722	0.236	0.003	-2.502
16	30	63.337	0.19834	1.716	0.234	0.003	-2.498
17	32	62.388	0.20490	1.709	0.233	0.003	-2.509
18	34	61.534	0.21089	1.703	0.231	0.003	-2.531
19	36	60.760	0.21639	1.698	0.230	0.026	-1.581
20	38	59.926	0.22238	1.692	0.228	0.101	-0.996
21	40	59.070	0.22863	1.685	0.227	0.341	-0.467
22	42	1.219	1.9140	0.000		0.609	-0.215
23							
24							

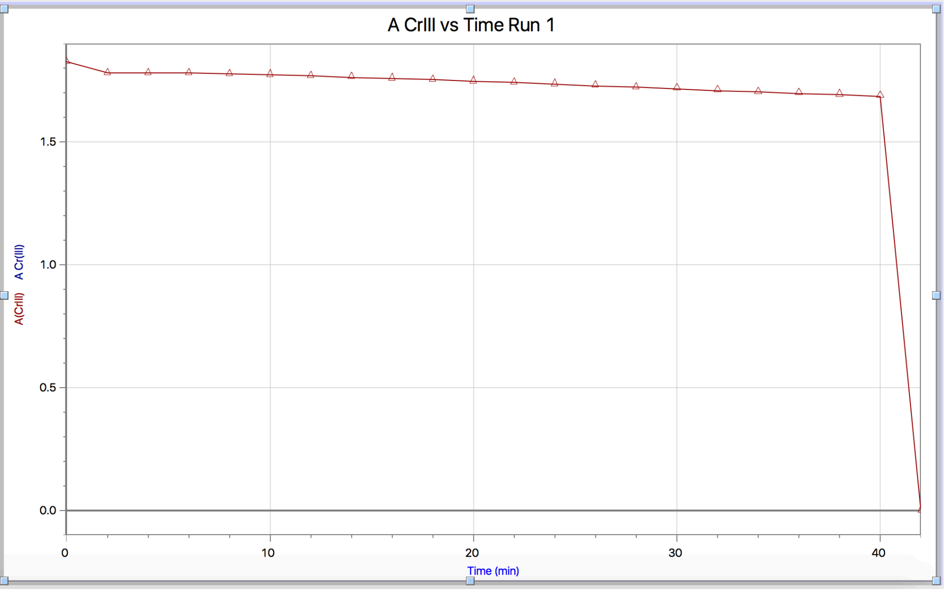
Run 1 (pH 4)

No Device Connected

	Time (min)	A(CrIII)	Log Rate	Log
1	0	1.825	-1.783	0.26
2	2	1.780	-2.032	0.25
3	4	1.780	-2.531	0.25
4	6	1.780	-2.807	0.25
5	8	1.776	-2.804	0.24
6	10	1.773	-2.707	0.24
7	12	1.768	-2.617	0.24
8	14	1.762	-2.589	0.24
9	16	1.758	-2.582	0.24
10	18	1.753	-2.543	0.24
11	20	1.746	-2.529	0.24
12	22	1.741	-2.528	0.24
13	24	1.734	-2.519	0.23
14	26	1.728	-2.513	0.23
15	28	1.722	-2.502	0.23
16	30	1.716	-2.498	0.23
17	32	1.709	-2.509	0.23
18	34	1.703	-2.531	0.23
19	36	1.698	-1.581	0.23
20	38	1.692	-0.996	0.22
21	40	1.685	-0.467	0.22
22	42	0.000	-0.215	
23				
24				

Trans @ 574.5 nm

%

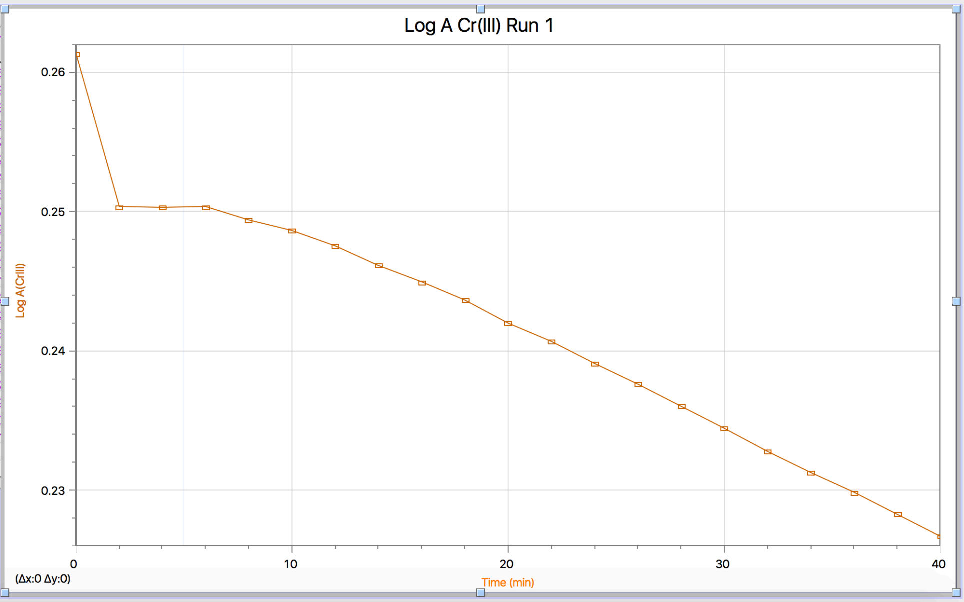


No Device Connected

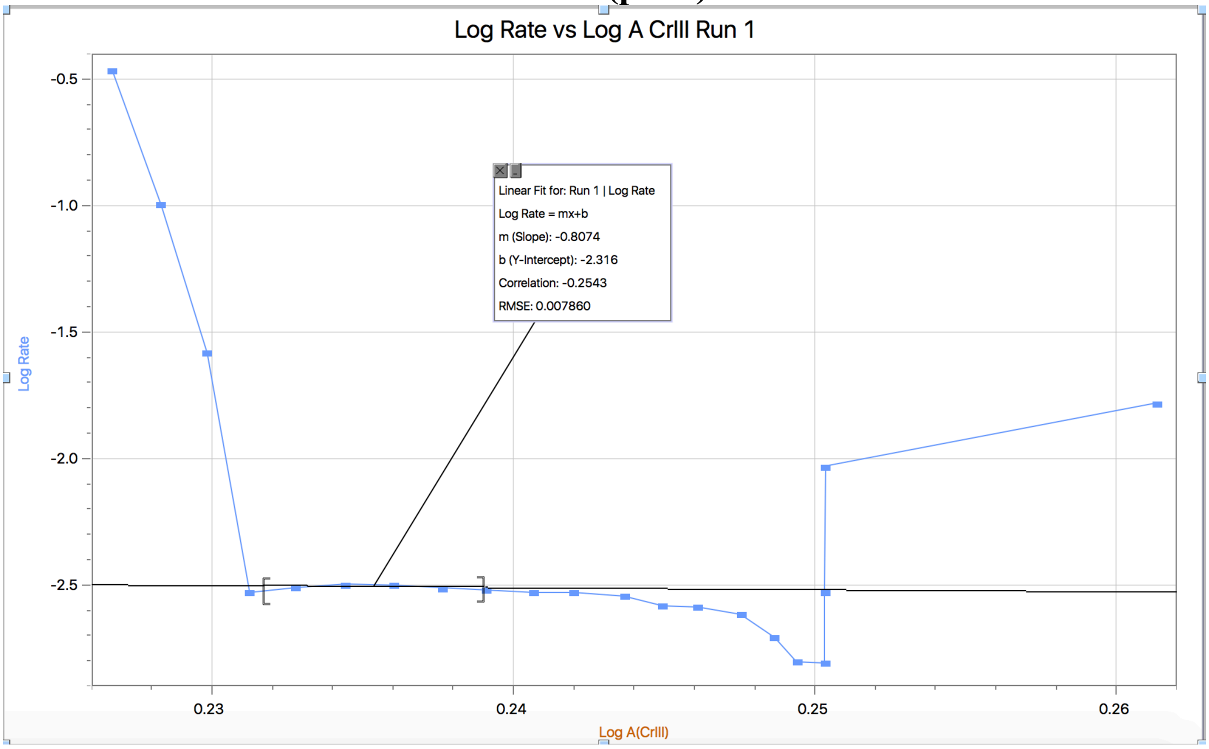
	Run 1			
	Time (min)	Log A(CrIII)	A(CrIII)	Tr
1	0	0.261	1.825	81.5
2	2	0.250	1.780	73.3
3	4	0.250	1.780	73.3
4	6	0.250	1.780	73.3
5	8	0.249	1.776	72.7
6	10	0.249	1.773	72.2
7	12	0.248	1.768	71.4
8	14	0.246	1.762	70.5
9	16	0.245	1.758	69.7
10	18	0.244	1.753	68.9
11	20	0.242	1.746	67.9
12	22	0.241	1.741	67.0
13	24	0.239	1.734	66.1
14	26	0.238	1.728	65.2
15	28	0.236	1.722	64.2
16	30	0.234	1.716	63.3
17	32	0.233	1.709	62.3
18	34	0.231	1.703	61.5
19	36	0.230	1.698	60.7
20	38	0.228	1.692	59.9
21	40	0.227	1.685	59.0
22	42		0.000	1.21
23				
24				

Trans @ 574.5 nm

%



Run 1 (pH 4)



Log Rate vs Log A CrIII Run 1
Linear Fit for: Run 1 | Log Rate
Log Rate = mx+b
m (Slope): -0.8074
b (Y-Intercept): -2.316
Correlation: -0.2543
RMSE: 0.007860
Log Rate
-0.5
-1.0
-1.5
-2.0
-2.5
0.23
0.24
0.25
0.26
Log A(CrIII)

Run 2 (pH 4.5)

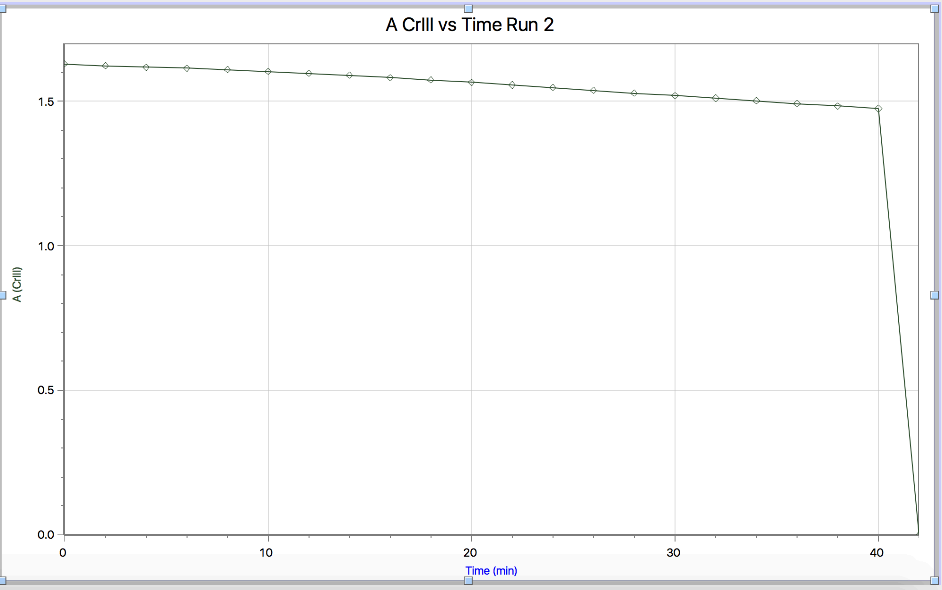
	Run 2						
	Time (min)	Trans @ (%)	A(t)	A (CrIII)	Log A (CrIII)	Rate	Log Rate
1	0	81.529	0.088690	1.628	0.212	0.003	-2.530
2	2	80.303	0.095269	1.622	0.210	0.003	-2.593
3	4	79.513	0.099565	1.617	0.209	0.002	-2.660
4	6	78.889	0.10298	1.614	0.208	0.002	-2.646
5	8	78.020	0.10780	1.609	0.207	0.003	-2.565
6	10	76.872	0.11423	1.603	0.205	0.003	-2.510
7	12	75.794	0.12037	1.597	0.203	0.003	-2.471
8	14	74.548	0.12756	1.589	0.201	0.004	-2.428
9	16	73.229	0.13532	1.582	0.199	0.004	-2.393
10	18	71.772	0.14404	1.573	0.197	0.004	-2.375
11	20	70.406	0.15239	1.565	0.194	0.004	-2.367
12	22	69.028	0.16098	1.556	0.192	0.004	-2.350
13	24	67.567	0.17026	1.547	0.189	0.005	-2.336
14	26	66.125	0.17964	1.537	0.187	0.005	-2.332
15	28	64.678	0.18924	1.528	0.184	0.005	-2.345
16	30	63.466	0.19746	1.519	0.182	0.005	-2.347
17	32	62.093	0.20696	1.510	0.179	0.005	-2.338
18	34	60.799	0.21610	1.501	0.176	0.005	-2.341
19	36	59.499	0.22549	1.491	0.174	0.025	-1.606
20	38	58.416	0.23347	1.483	0.171	0.090	-1.047
21	40	57.206	0.24256	1.474	0.169	0.300	-0.524
22	42	1.919	1.7169	0.000	-4.337	0.534	-0.273
23							
24							

No Device Connected

	Time (min)	A (CrIII)	Log A (CrIII)
1	0	1.628	0.212
2	2	1.622	0.210
3	4	1.617	0.209
4	6	1.614	0.208
5	8	1.609	0.207
6	10	1.603	0.205
7	12	1.597	0.203
8	14	1.589	0.201
9	16	1.582	0.199
10	18	1.573	0.197
11	20	1.565	0.194
12	22	1.556	0.192
13	24	1.547	0.189
14	26	1.537	0.187
15	28	1.528	0.184
16	30	1.519	0.182
17	32	1.510	0.179
18	34	1.501	0.176
19	36	1.491	0.174
20	38	1.483	0.171
21	40	1.474	0.169
22	42	0.000	-4.337
23			
24			

Trans @ 574.5 nm

%



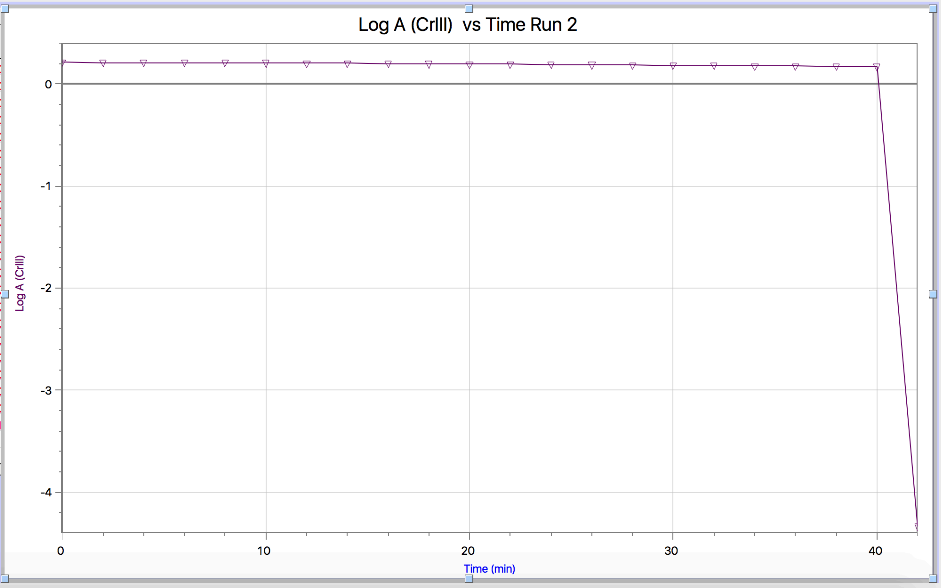
Run 2 (pH 4.5)

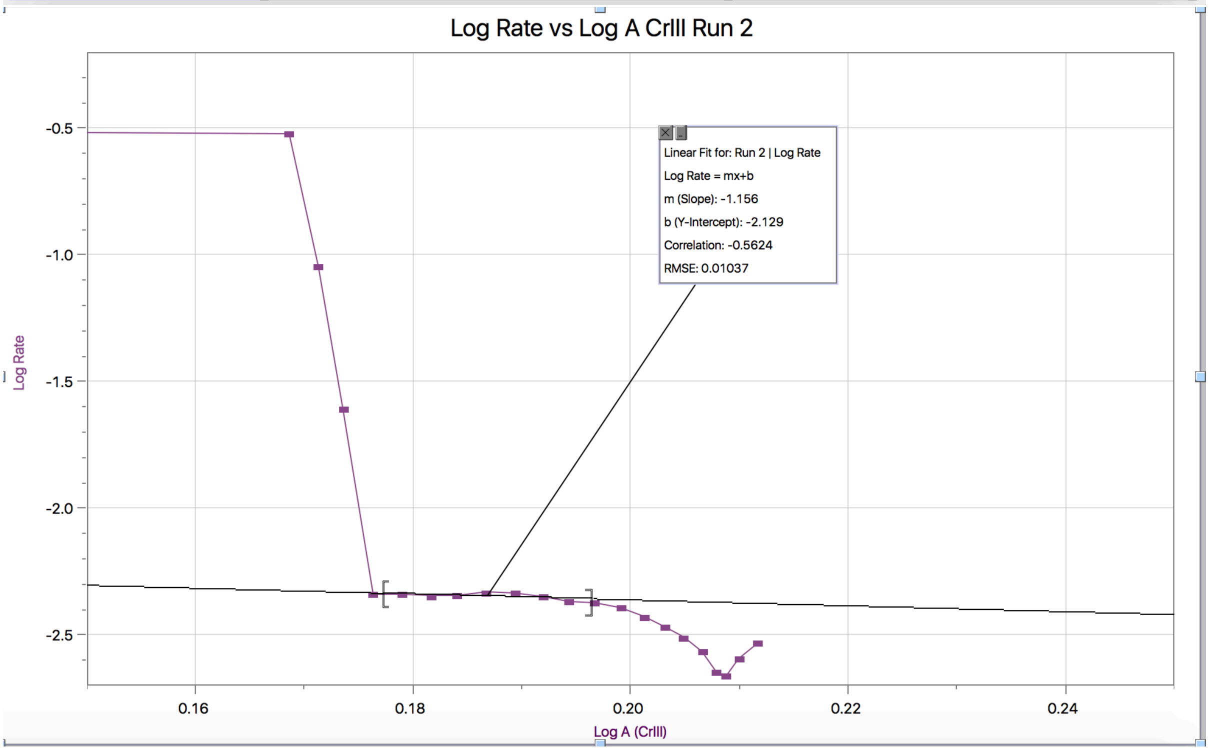
No Device Connected

	Time (min)	Log A (CrIII)	A (CrIII)
1	0	0.212	1.628
2	2	0.210	1.622
3	4	0.209	1.617
4	6	0.208	1.614
5	8	0.207	1.609
6	10	0.205	1.603
7	12	0.203	1.597
8	14	0.201	1.589
9	16	0.199	1.582
10	18	0.197	1.573
11	20	0.194	1.565
12	22	0.192	1.556
13	24	0.189	1.547
14	26	0.187	1.537
15	28	0.184	1.528
16	30	0.182	1.519
17	32	0.179	1.510
18	34	0.176	1.501
19	36	0.174	1.491
20	38	0.171	1.483
21	40	0.169	1.474
22	42	-4.337	0.000
23			
24			

Trans @ 574.5 nm

%





Run 3 (pH 5)

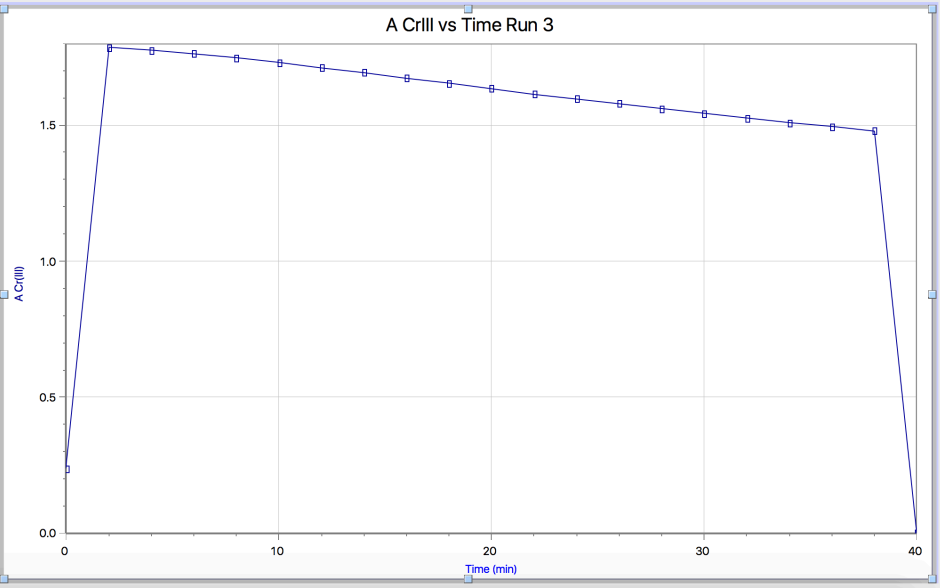
	Run 3						
	Time (min)	A Cr(III)	Log A Cr(III)	A(t)	Rate	Log Rate	Trans @ (%)
1	0	0.237	-0.625	1.7047	-0.557		1.974
2	2	1.784	0.252	0.15726	-0.308		69.621
3	4	1.775	0.249	0.16716	-0.085		68.052
4	6	1.762	0.246	0.17956	-0.015		66.136
5	8	1.746	0.242	0.19539	0.008	-2.098	63.770
6	10	1.730	0.238	0.21215	0.009	-2.061	61.355
7	12	1.711	0.233	0.23031	0.009	-2.034	58.843
8	14	1.692	0.228	0.24934	0.010	-2.015	56.320
9	16	1.672	0.223	0.26978	0.010	-2.016	53.731
10	18	1.654	0.218	0.28796	0.010	-2.019	51.527
11	20	1.634	0.213	0.30756	0.010	-2.014	49.253
12	22	1.614	0.208	0.32749	0.009	-2.025	47.044
13	24	1.596	0.203	0.34546	0.009	-2.038	45.138
14	26	1.578	0.198	0.36368	0.009	-2.043	43.283
15	28	1.560	0.193	0.38180	0.009	-2.051	41.514
16	30	1.542	0.188	0.39926	0.009	-2.059	39.879
17	32	1.525	0.183	0.41679	0.008	-2.072	38.301
18	34	1.508	0.178	0.43380	0.028	-1.549	36.830
19	36	1.494	0.174	0.44810	0.093	-1.031	35.637
20	38	1.478	0.170	0.46413	0.302	-0.520	34.346
21	40	0.000	-4.367	1.9417	0.536	-0.271	1.144
22							
23							
24							

No Device Connected

	Time (min)	A Cr(III)	Log A Cr(III)
1	0	0.237	-0.625
2	2	1.784	0.252
3	4	1.775	0.249
4	6	1.762	0.246
5	8	1.746	0.242
6	10	1.730	0.238
7	12	1.711	0.233
8	14	1.692	0.228
9	16	1.672	0.223
10	18	1.654	0.218
11	20	1.634	0.213
12	22	1.614	0.208
13	24	1.596	0.203
14	26	1.578	0.198
15	28	1.560	0.193
16	30	1.542	0.188
17	32	1.525	0.183
18	34	1.508	0.178
19	36	1.494	0.174
20	38	1.478	0.170
21	40	0.000	-4.367
22			
23			
24			

Trans @ 574.5 nm

%



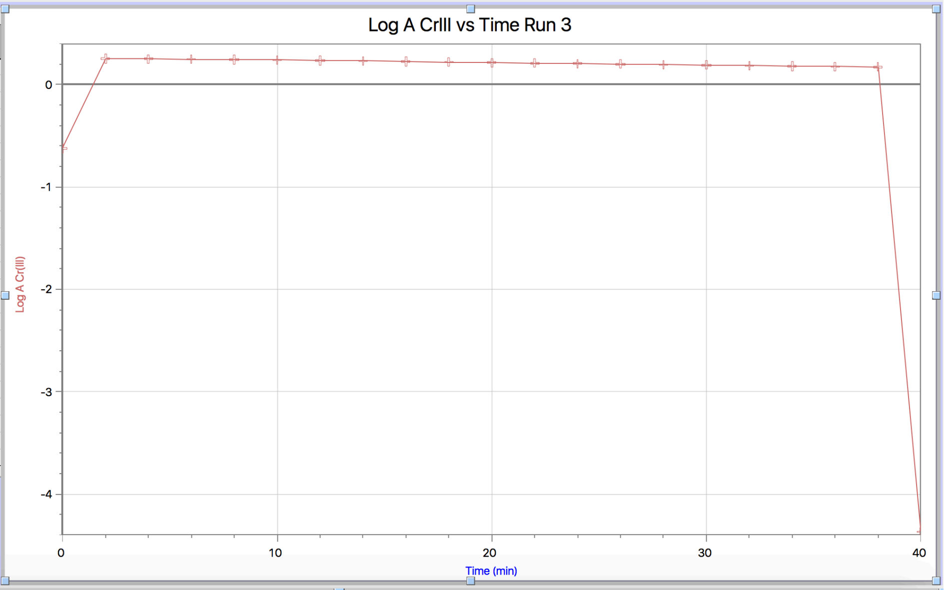
Run 3 (pH 5)

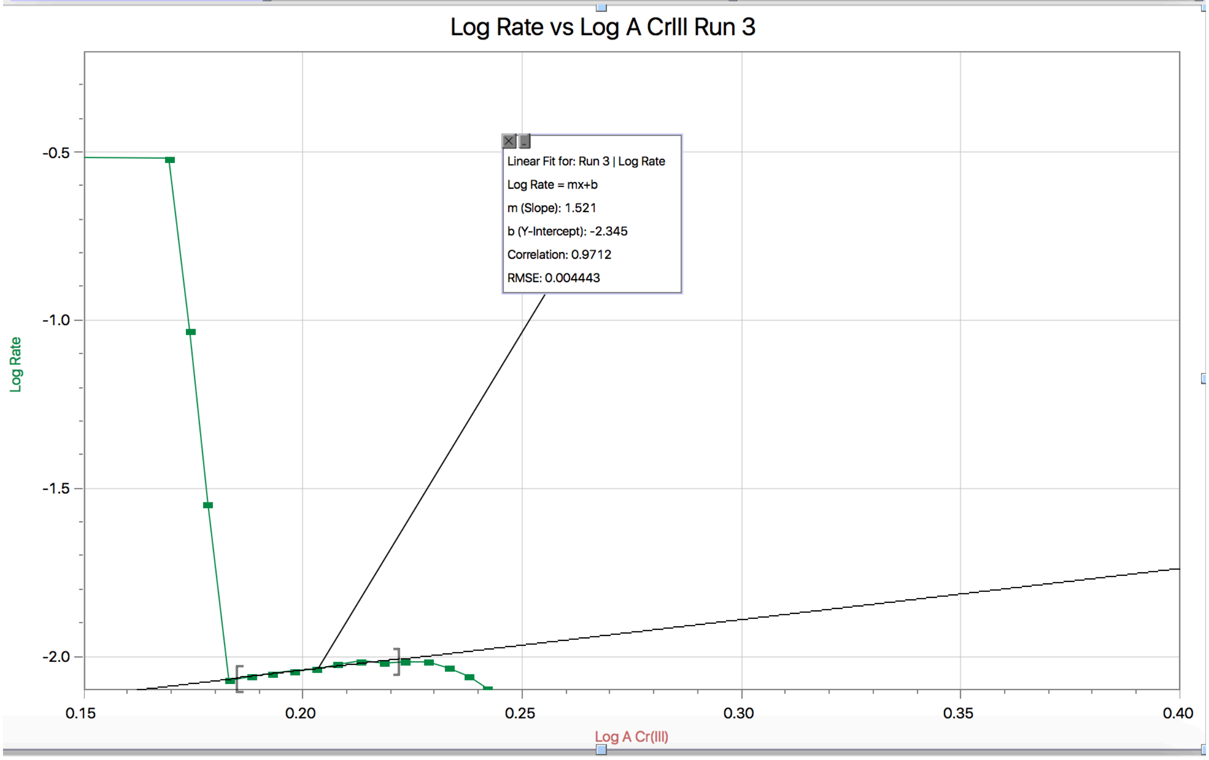
No Device Connected

	Time (min)	Log A Cr(III)	Log Rate
1	0	-0.625	
2	2	0.252	
3	4	0.249	
4	6	0.246	
5	8	0.242	-2.098
6	10	0.238	-2.061
7	12	0.233	-2.034
8	14	0.228	-2.015
9	16	0.223	-2.016
10	18	0.218	-2.019
11	20	0.213	-2.014
12	22	0.208	-2.025
13	24	0.203	-2.038
14	26	0.198	-2.043
15	28	0.193	-2.051
16	30	0.188	-2.059
17	32	0.183	-2.072
18	34	0.178	-1.549
19	36	0.174	-1.031
20	38	0.170	-0.520
21	40	-4.367	-0.271
22			
23			
24			

Trans @ 574.5 nm

%





Discussion:

The purpose of the experiment was to see how the different pH levels affect the rate of reaction with respect to the Cr(III) ion. The partial reaction order can be found by taking the slope of the Log Rate versus Log A Cr(III) graph. For the first run with pH 4, the partial reaction order was 0.8074. For the second run with pH 4.5, the partial reaction order was 1.156. For the third run with pH 5, the partial reaction order was 1.521. It is understandable that the partial reaction orders would not be exactly the same with each pH, since the absorbance differs for each trial. It makes sense that the order would increase as the pH increases. The reaction happens quicker because, with the higher pH, there are more hydrogen ions to react with the Cr(III).

There were some possible errors during this lab.

1) The amount of Cr(III) we were adding was crucial because the concentration of the reactant is what the reaction depends upon. The amount we were adding wasn't exact. We were approximating two drops of Cr(III), but that doesn't mean the same amount was added during every trial. Some drops could have been bigger than the others.
2) During the experiment, we were working under the assumption that the reaction was in the spectrophotometer at constant room temperature, but we weren't actually measuring the temperature. The temperature is crucial because an increase in temperature shifts the equilibrium towards the products side, and speeds up the rate of reaction. Any change in temperature could have had an effect on how quickly the solution turned purple.
3) At one point in our trials, we forgot to wipe down the cuvette. Because the spectrophotometer can pick up the dust or fingerprint or other marks, the data was probably slightly altered or skewed.
4) For one of our trials, we took longer than two minutes to get the cuvette in the spectrophotometer. By the time we got it in, the reaction had already started. Because of this, some of our data was lost and we didn't have all the information.
5) Concentration is dependent on the volume. That means the volume of EDTA we added was very important, because according to one of the equations, absorbance is equal to concentration. If a little more or a little less of EDTA was added in each trial, that could speed up or slow down the reaction, thus increasing or decreasing the reaction rate.

Conclusion:

The average of the three partial reaction order is 1.16. This means that the partial reaction order with respect to Cr(III) is approximately 1.