



## Introduction

How fast a chemical reaction react with one another varies from the rate of the reaction. The study of chemical kinetics by controlling factors that will control the rate of the reaction and when it will occur such as pH and concentrations. In this specific experiment the solution depends on the concentration in the reactants which is the order of reaction.

The rate of the reaction is proportional to the concentration of the products in a reaction the equation can be express as  $\text{Rate} = k [\text{A}]^n [\text{B}]^m$  where K is the rate constant. Another way to determine the rate of the reaction is graphically, where the slope of the graph at any time; then the instantaneous rate of the reaction can be determined by the tangent line; however, this a approximate approach.

The order in a reaction refers to the exponent's n and m in the rate of reaction. The order is proportional to the reactants and can only be found experimentally. Order is the power of concentration within the reaction, and the sum of order will equal the total order of the reaction.

In this experiment chromium (III) salt will be added to an excess amount of EDTA to create a reaction. To see what happened to the rate, the rate must have two variables while changing one. The concentration of Cr (III) was the same as well as the EDTA however the pH of the reaction changed. Due to the changing pH in the different solutions of EDTA there concentration of the  $\text{H}^+$  this will also affect the concentration of EDTA as well. Due to the little amount of Cr (III) put into the EDTA the EDTA is affect by very little. So the all the Cr (III) is used up in the reaction however the EDTA will also change, but because the change is so little the concentration of the EDTA stays constant.

This experiment is an example of spectrophotometry, which is the study of matter and electromagnetic radiation interacting with another. The measurement can be expressed as absorbance or transmittance. Transmittance (T) is intensity of the light after it has passed through an object (I) from when the light first passes through the object ( $I_0$ ) which can be expressed as  $T = I/I_0$ . However on the device used to measure the transmittance (spectrometer) it's more appropriate to use percent transmittance where T is multiplied by 100. While the absorbance can be found by  $A = -\log T$ .

In this reaction there will be a rater determining step, where a reaction contains multiple steps before reacting very quickly. For example during the experiment the colour will not react for quite a bit, but as time goes by it will start to change from colourless to grey to purple. That long period of time where it did not change colour is the rate determining step, after that slow step occurs the reactions starts to speed up.

## Material

- Refer to experiment 3 lab manual

## Procedure

- Refer to experiment 3 lab manual

## Observation:

Solution	Before reaction with $\text{Cr}(\text{NO}_3)_3$	After Reaction With $\text{Cr}(\text{NO}_3)_3$	Volume / Moles
ETDA pH = 4	-Transparent - Liquid form - Colourless	-Translucent - Liquid Form - Purple	Mol: 0.1M Volume: 10mL
ETDA pH = 4.5	-Transparent - Liquid form - Colourless	-Translucent - Liquid Form - Purple	Mol: 0.1M Volume: 10mL
ETDA pH = 5	-Transparent - Liquid form - Colourless	-Translucent - Liquid Form - Purple	Mol: 0.1M Volume: 10mL
$\text{Cr}(\text{NO}_3)_3$	-Translucent -Liquid form - Black colour	N/A	2 drops

Table 1: What the solution looked like before and after reaction

## Calculations

### Finding A<sub>Cr(III)</sub> For EDTA pH = 4.0

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

$$A_{Cr(III)} \text{ Time } 0 = 1.830854 - 0.66557 = \mathbf{1.764296}$$

$$A_{Cr(III)} \text{ Time } 2 = 1.830854 - 0.358024 = \mathbf{1.47283}$$

$$A_{Cr(III)} \text{ Time } 4 = 1.830854 - 0.363398 = \mathbf{1.467456}$$

$$A_{Cr(III)} \text{ Time } 6 = 1.830854 - 0.368729 = \mathbf{1.462124}$$

$$A_{Cr(III)} \text{ Time } 8 = 1.830854 - 0.377745 = \mathbf{1.453109}$$

$$A_{Cr(III)} \text{ Time } 10 = 1.830854 - 0.386734 = \mathbf{1.44412}$$

$$A_{Cr(III)} \text{ Time } 12 = 1.830854 - 0.395122 = \mathbf{1.435732}$$

$$A_{Cr(III)} \text{ Time } 14 = 1.830854 - 0.407961 = \mathbf{1.422892}$$

$$A_{Cr(III)} \text{ Time } 16 = 1.830854 - 0.415239 = \mathbf{1.415615}$$

$$A_{Cr(III)} \text{ Time } 18 = 1.830854 - 0.425654 = \mathbf{1.4052}$$

$$A_{Cr(III)} \text{ Time } 20 = 1.830854 - 0.436549 = \mathbf{1.394305}$$

$$A_{Cr(III)} \text{ Time } 22 = 1.830854 - 0.447341 = \mathbf{1.383512}$$

$$A_{Cr(III)} \text{ Time } 24 = 1.830854 - 0.458768 = \mathbf{1.372086}$$

$$A_{Cr(III)} \text{ Time } 26 = 1.830854 - 0.473474 = \mathbf{1.35738}$$

$$A_{Cr(III)} \text{ Time } 28 = 1.830854 - 1.830854 = \mathbf{0}$$

Partial order = 2 however partial order should be first order.

### Finding A<sub>Cr(III)</sub> for EDTA pH = 4.5

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

$$A_{Cr(III)} \text{ Time } 0 = 1.13829 - 0.064166 = \mathbf{1.071124}$$

$$A_{Cr(III)} \text{ Time } 2 = 1.13829 - 0.064279 = \mathbf{1.07101}$$

$$A_{Cr(III)} \text{ Time } 4 = 1.13829 - 0.068297 = \mathbf{1.069993}$$

$$A_{Cr(III)} \text{ Time } 6 = 1.13829 - 0.076907 = \mathbf{1.061383}$$

$$A_{Cr(III)} \text{ Time } 8 = 1.13829 - 0.085743 = \mathbf{1.052546}$$

$$A_{Cr(III)} \text{ Time } 10 = 1.13829 - 0.093755 = \mathbf{1.044534}$$

$$A_{Cr(III)} \text{ Time } 12 = 1.13829 - 0.103551 = \mathbf{1.034739}$$

$$A_{Cr(III)} \text{ Time } 14 = 1.13829 - 0.114464 = \mathbf{1.023826}$$

$$A_{Cr(III)} \text{ Time } 16 = 1.13829 - 0.126422 = \mathbf{1.011868}$$

$$A_{Cr(III)} \text{ Time } 18 = 1.13829 - 0.138162 = \mathbf{1.000128}$$

$$A_{Cr(III)} \text{ Time } 20 = 1.13829 - 0.150099 = \mathbf{0.988191}$$

$$A_{Cr(III)} \text{ Time } 22 = 1.13829 - 0.160412 = \mathbf{0.977878}$$

$$A_{Cr(III)} \text{ Time } 24 = 1.13829 - 0.171407 = \mathbf{0.966883}$$

$$A_{Cr(III)} \text{ Time } 26 = 1.13829 - 0.180686 = \mathbf{0.957604}$$

$$A_{Cr(III)} \text{ Time } 28 = 1.13829 - 1.13829 = \mathbf{0}$$

Partial order = 1

### Finding A<sub>Cr(III)</sub> for EDTA pH = 5.0

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

$$\text{ACr(III) Time 0} = 1.360312 - 0.070322 = \mathbf{1.28999}$$

$$\text{ACr(III) Time 2} = 1.360312 - 0.07761 = \mathbf{1.282702}$$

$$\text{ACr(III) Time 4} = 1.360312 - 0.107016 = \mathbf{1.253296}$$

$$\text{ACr(III) Time 6} = 1.360312 - 0.132626 = \mathbf{1.227686}$$

$$\text{ACr(III) Time 8} = 1.360312 - 0.162304 = \mathbf{1.198008}$$

$$\text{ACr(III) Time 10} = 1.360312 - 0.190903 = \mathbf{1.169409}$$

$$\text{ACr(III) Time 12} = 1.360312 - 0.217251 = \mathbf{1.143061}$$

$$\text{ACr(III) Time 14} = 1.360312 - 0.244169 = \mathbf{1.116143}$$

$$\text{ACr(III) Time 16} = 1.360312 - 0.267613 = \mathbf{1.092699}$$

$$\text{ACr(III) Time 18} = 1.360312 - 0.28963 = \mathbf{1.070682}$$

$$\text{ACr(III) Time 20} = 1.360312 - 0.310936 = \mathbf{1.049376}$$

$$\text{ACr(III) Time 22} = 1.360312 - 0.330095 = \mathbf{1.030217}$$

$$\text{ACr(III) Time 24} = 1.360312 - 0.347674 = \mathbf{1.012638}$$

$$\text{ACr(III) Time 26} = 1.360312 - 0.362915 = \mathbf{0.997397}$$

$$\text{ACr(III) Time 28} = 1.360312 - 1.360312 = \mathbf{0}$$

Partial order = 1

## Results

Time (Mins)Trans @ 598.1nm (%)	Trans@ 598.1nm(%)	A	A Cr	A Cr(III)	Time (f)	Log A Cr(III)	Rate	Log Rate
0	85.79116	0.066557	1.764297	1.47283	2	0.168153	0.002783	-2.55541
2	43.85068	0.358024	1.47283	1.467456	4	0.166565	0.003032	-2.51828
4	43.31139	0.363398	1.467456	1.462125	6	0.164984	0.003608	-2.44275
6	42.78295	0.368729	1.462125	1.453109	8	0.162298	0.004266	-2.36998
8	41.904	0.377745	1.453109	1.44412	10	0.159603	0.004527	-2.3442
10	41.04557	0.386734	1.44412	1.435732	12	0.157073	0.005006	-2.30048
12	40.2604	0.395122	1.435732	1.422893	14	0.153172	0.004953	-2.30513
14	39.08757	0.407961	1.422893	1.415615	16	0.150945	0.004779	-2.32062
16	38.43806	0.415239	1.415615	1.4052	18	0.147738	0.005189	-2.28495
18	37.52721	0.425654	1.4052	1.394305	20	0.144358	0.005435	-2.26483
20	36.59746	0.436549	1.394305	1.383513	22	0.140983	0.00574	-2.24105
22	35.69921	0.447341	1.383513	1.372086	24	0.137381	0.006314	-2.19969
24	34.77218	0.458768	1.372086	1.35738	26	0.132702	0.00688	-2.16243
26	33.61448	0.473474	1.35738					
28	1.476204	1.830854	0					

Table 1: Data results for pH=4.0

Time (Min)	Trans@ 598.1nm(%)	A	A Cr	A Cr(III)	Time (f)	Log A Cr(III)	Rate	Log Rate
0	85.67106	0.067166	1.071134	1.071021	2	0.029798	0.00157	-2.80422
2	85.64865	0.067279	1.071021	1.070003	4	0.029385	0.002781	-2.55584
4	85.44819	0.068297	1.070003	1.061393	6	0.025876	0.003888	-2.41022
6	83.77096	0.076907	1.061393	1.052557	8	0.022245	0.00423	-2.37362
8	82.08363	0.085743	1.052557	1.044545	10	0.018927	0.004598	-2.33742
10	80.5832	0.093755	1.044545	1.034749	12	0.014835	0.005134	-2.28952
12	78.78596	0.103551	1.034749	1.023836	14	0.01023	0.005603	-2.25158
14	76.83091	0.114464	1.023836	1.011878	16	0.005128	0.005827	-2.23452
16	74.74427	0.126422	1.011878	1.000138	18	6.01E-05	0.005816	-2.23534
18	72.75091	0.138162	1.000138	0.988201	20	-0.00515	0.005575	-2.25372
20	70.77852	0.150099	0.988201	0.977888	22	-0.00971	0.00534	-2.27248
22	69.11752	0.160412	0.977888	0.966893	24	-0.01462	0.005119	-2.29078
24	67.38967	0.171407	0.966893	0.957614	26	-0.01881	0.004859	-2.31346
26	65.96511	0.180686	0.957614					
28	7.272942	1.13829	0					

Table 2: Data results for pH = 4.5

Time (mins)	Trans@ 598.1nm(%)	A	A Cr	A Cr(III)	Time (f)	Log A Cr(III)	Rate	Log Rate
0	85.05073	0.070322	1.289978	1.28269	2	0.108122	0.014289	-1.845
2	83.63542	0.07761	1.28269	1.253284	4	0.098049	0.013943	-1.85566
4	78.1599	0.107016	1.253284	1.227674	6	0.089083	0.013959	-1.85515
6	73.68405	0.132626	1.227674	1.197996	8	0.078455	0.014191	-1.84799
8	68.81709	0.162304	1.197996	1.169397	10	0.067962	0.013747	-1.86181
10	64.43137	0.190903	1.169397	1.143049	12	0.058065	0.013227	-1.87854
12	60.63861	0.217251	1.143049	1.116131	14	0.047715	0.012473	-1.90402
14	56.99418	0.244169	1.116131	1.092687	16	0.038496	0.011519	-1.93857
16	53.99916	0.267613	1.092687	1.07067	18	2.97E-02	0.010807	-1.96629
18	51.32983	0.28963	1.07067	1.049364	20	0.020926	0.010043	-1.99813
20	48.87243	0.310936	1.049364	1.030205	22	0.012924	0.009234	-2.0346
22	46.76333	0.330095	1.030205	1.012626	24	0.005449	0.008517	-2.06971
24	44.90824	0.347674	1.012626	0.997385	26	-0.00114	0.007989	-2.0975
26	43.35955	0.362915	0.997385					
28	4.362023	1.360312	0					

Table 3: Data results for pH = 5.0

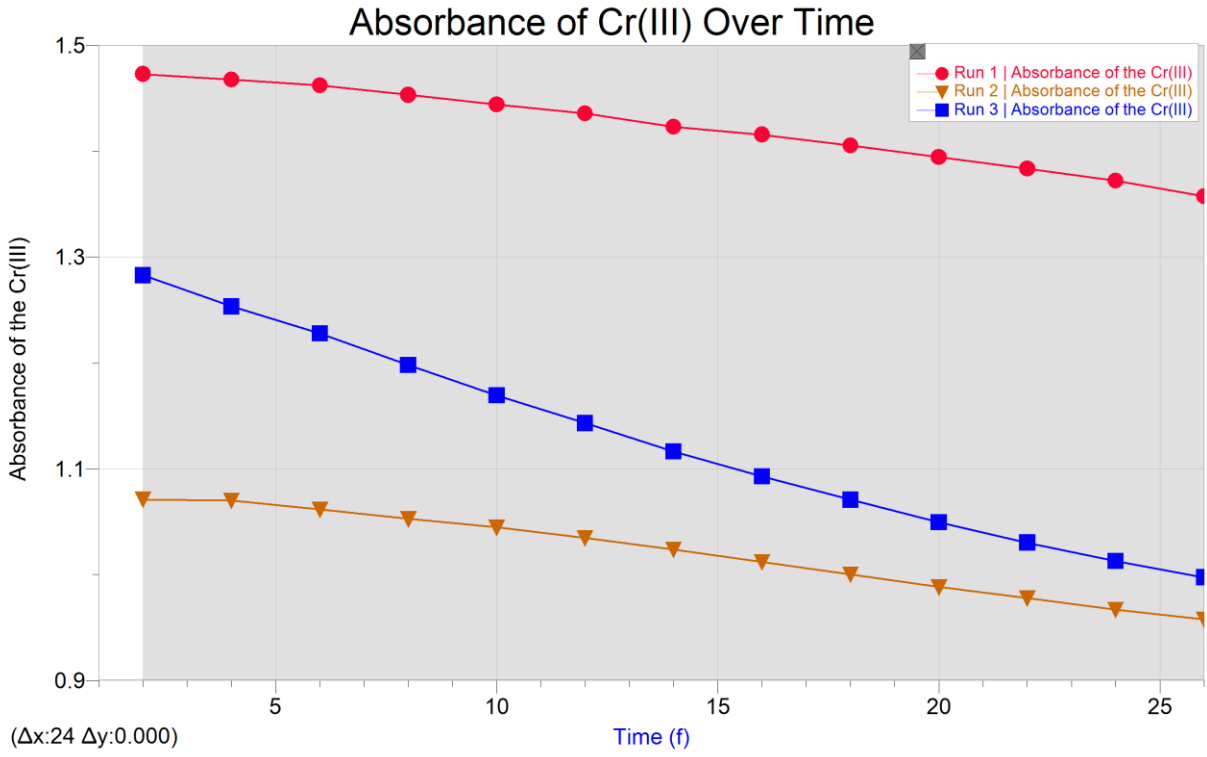


Figure 1: Amount of light going past the solution containing Cr (III).

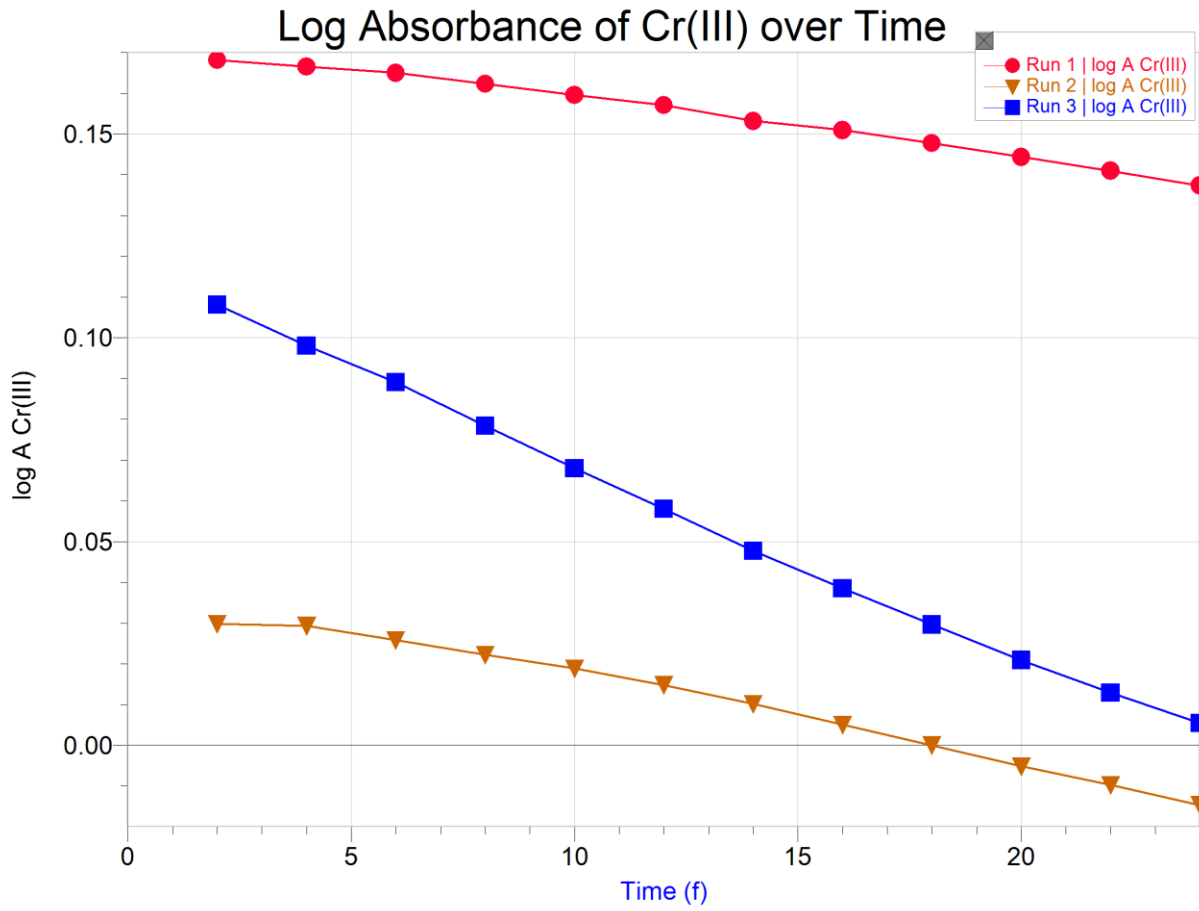


Figure 2: intensity of light going through Cr (III)

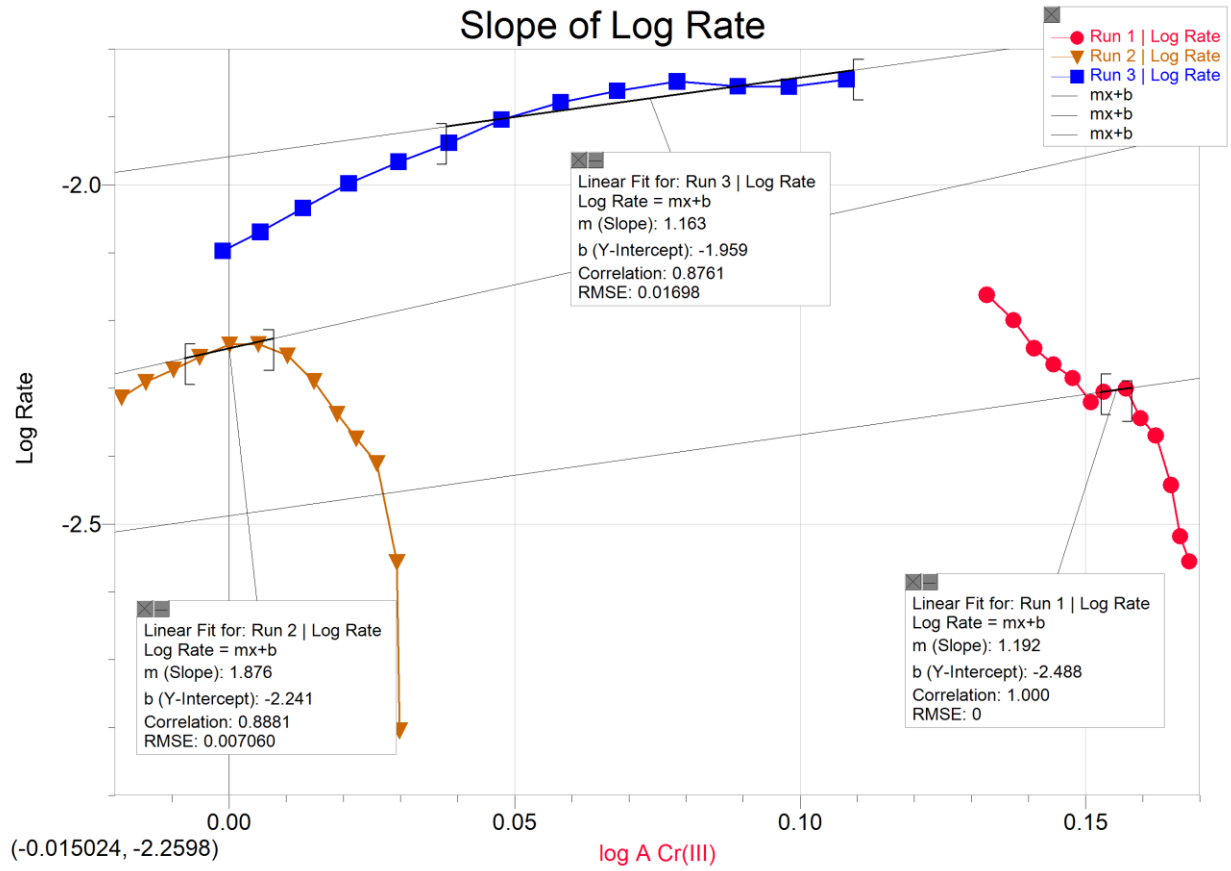


Figure 3: The instantaneous rate of change is the order of the reaction.

## Discussion

During the reaction it took a fair bit of time before the solution went from colourless to purple. This could be because of the rate determining step for the Cr (III) to react with itself then react with the solution to change colour, however after the rate determining step the reaction from colourless to colour was very rapid. As the solution was changing colour the amount of absorbance of Cr (III) decreased because the solution was getting darker. For example a clear glass window can let 100% of light through but as you put a tint onto the window the amount of light allowed to go through decreases, this is the case as seen in figure 1, and tables 1, 2, and 3. Due to the solution getting darker and the absorbance decreasing this means that the amount of light going through the solution decreases therefore the light intensity decreases which can be seen in figure 2 as well as in tables 1, 2, and 3.

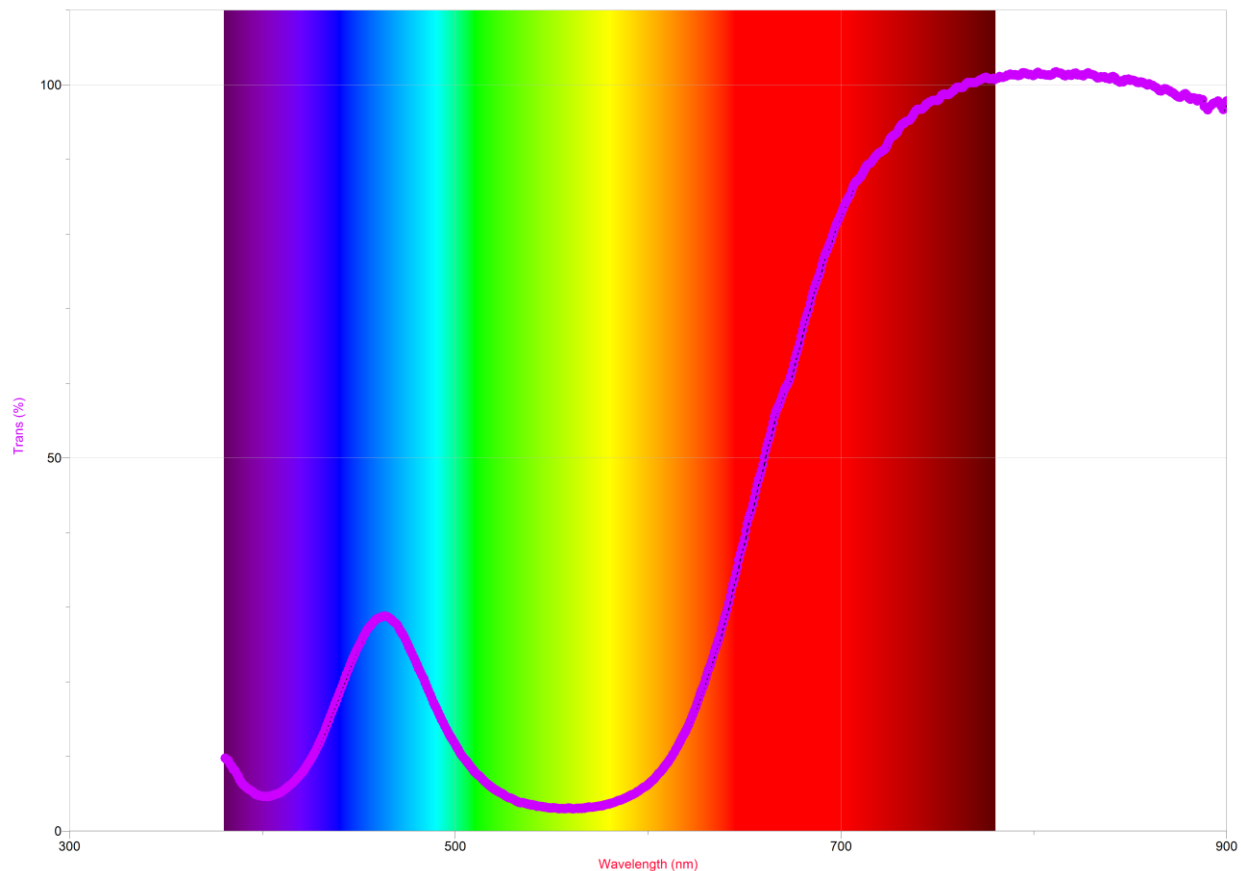
In this experiment was the rate order and partial order for the solution Cr (III) when mixed with different pH of EDTA can be determined. By using the spectrometer and the knowledge of rate of reaction, the partial order (which can only be figured out by experiment) should be one as can be seen in figure 3. However as we did get some of our slopes were close to one (run 1 and 3), run 2 was a bit off. This could be a source of error that occurred during the experiment The rate depends on the concentration because the more concentrated the solution, the more molecules that are in that solution thus giving us a rate of a reaction to be slow or quick depending on what it was mixed with. However in some experiments it is hard to judge if a reaction is occurring for example, and acid and base experiment where the reaction is dependent on heat, and bubbles forming to tell if a reaction is down, but in this experiment it can be visually determined by seeing the reaction go from colourless to purple; which helps determines if the reaction has occurred or not, thus allowing us to determine the rate of the reaction.

In the figure 1 the absorbance of the Cr (III) can be determined by  $A_{\infty}$  (which is the time where only the Cr (III) formed into the complex) and  $A_t$  (absorbance of Cr (III) at that specific time) and subtracting it which will give us the total amount of Cr (III) absorbance only at that time  $A_{Cr(III)} = A_{\infty} - A_t$ . This will help us find the partial order of Cr (III).

Some sources of error that can occur during this experiment are not equipment being contaminated, technology error, and setting up the experiment wrong. Contamination can lead to misleading data for example if there were a solution in the test tube that happened to be a catalyst to help the rate of the reaction then the rate determining step will be much shorter as well as the data will instead slowly measure the absorbance it will measure it very quickly, thus skewing our data to determine the rate of the reaction. The second error that could occur would be technology based, since we used logger pro and a spectrometer there are possibilities that the machines were defective and could skew with calibration of the spectrometer, or given false data. Preparing the experiment correctly is important if all the steps were met then an error could occur for example, not heating the solution in boiling water would ruin one of the graphs (figure 2) because it did not take the heat at time infinity and that was the purpose of heating up the solution to get  $A_{\infty}$ . This skewing our data for the experiment.

## Conclusion

The partial order of the reaction is one. By doing an experiment and plotting the data into a graph then finding the instantaneous rate of change of the slope, the partial order can be determine in this case it happens to be one.



Raw data: Calibration of pH 4.0

Run 1								
Time (min)	Trans @ 598.1 nm (%)	A	A Cr	A Cr(III)	Time (f)	log A Cr(III)	Rate	Log Rate
0	85.791	0.066557	1.764	1.473	2	0.168	0.00278	-2.555
2	43.851	0.35802	1.473	1.467	4	0.167	0.00303	-2.518
4	43.311	0.36340	1.467	1.462	6	0.165	0.00361	-2.443
6	42.783	0.36873	1.462	1.453	8	0.162	0.00427	-2.370
8	41.904	0.37774	1.453	1.444	10	0.160	0.00453	-2.344
10	41.046	0.38673	1.444	1.436	12	0.157	0.00501	-2.300
12	40.260	0.39512	1.436	1.423	14	0.153	0.00495	-2.305
14	39.088	0.40796	1.423	1.416	16	0.151	0.00478	-2.321
16	38.438	0.41524	1.416	1.405	18	0.148	0.00519	-2.285
18	37.527	0.42565	1.405	1.394	20	0.144	0.00543	-2.265
20	36.597	0.43655	1.394	1.384	22	0.141	0.00574	-2.241
22	35.699	0.44734	1.384	1.372	24	0.137	0.00631	-2.200
24	34.772	0.45877	1.372	1.357	26	0.133	0.00688	-2.162
26	33.614	0.47347	1.357					
28	1.476	1.8309	0.000					

Run 1: EDTA pH = 4.0 raw data

Run 2								
Time (min)	ans @ 598.1 n (%)	A	A Cr	A Cr(III)	Time (f)	og A Cr(III)	Rate	Log Rate
0	85.671	0.067166	1.071	1.071	2	0.030	0.00157	-2.804
2	85.649	0.067279	1.071	1.070	4	0.029	0.00278	-2.556
4	85.448	0.068297	1.070	1.061	6	0.026	0.00389	-2.410
6	83.771	0.076907	1.061	1.053	8	0.022	0.00423	-2.374
8	82.084	0.085743	1.053	1.045	10	0.019	0.00460	-2.337
10	80.583	0.093755	1.045	1.035	12	0.015	0.00513	-2.290
12	78.786	0.10355	1.035	1.024	14	0.010	0.00560	-2.252
14	76.831	0.11446	1.024	1.012	16	0.005	0.00583	-2.235
16	74.744	0.12642	1.012	1.000	18	0.000	0.00582	-2.235
18	72.751	0.13816	1.000	0.988	20	-0.005	0.00558	-2.254
20	70.779	0.15010	0.988	0.978	22	-0.010	0.00534	-2.272
22	69.118	0.16041	0.978	0.967	24	-0.015	0.00512	-2.291
24	67.390	0.17141	0.967	0.958	26	-0.019	0.00486	-2.313
26	65.965	0.18069	0.958					
28	7.273	1.1383	0.000					

Run 2: EDTA pH = 4.5 raw data

Run 3								
Time (min)	ans @ 598.1 n (%)	A	A Cr	A Cr(III)	Time (f)	og A Cr(III)	Rate	Log Rate
0	85.051	0.070322	1.290	1.283	2	0.108	0.01429	-1.845
2	83.635	0.077610	1.283	1.253	4	0.098	0.01394	-1.856
4	78.160	0.10702	1.253	1.228	6	0.089	0.01396	-1.855
6	73.684	0.13263	1.228	1.198	8	0.078	0.01419	-1.848
8	68.817	0.16230	1.198	1.169	10	0.068	0.01375	-1.862
10	64.431	0.19090	1.169	1.143	12	0.058	0.01323	-1.879
12	60.639	0.21725	1.143	1.116	14	0.048	0.01247	-1.904
14	56.994	0.24417	1.116	1.093	16	0.038	0.01152	-1.939
16	53.999	0.26761	1.093	1.071	18	0.030	0.01081	-1.966
18	51.330	0.28963	1.071	1.049	20	0.021	0.01004	-1.998
20	48.872	0.31094	1.049	1.030	22	0.013	0.00923	-2.035
22	46.763	0.33009	1.030	1.013	24	0.005	0.00852	-2.070
24	44.908	0.34767	1.013	0.997	26	-0.001	0.00799	-2.097
26	43.360	0.36292	0.997					
28	4.362	1.3603	0.000					

Run 3: EDTA pH = 5.0 raw data