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LAB DAY/WEEK: WEDNESDAY/WEEK 1

TIME: 10:00 AM

LABORATORY REPORT ON
EXPERIMENT 4
CHEMICAL KINETICS

Student Initials: DL

INTRODUCTION

Chemical Kinetics is the study of the factors controlling the rates of reactions and the mechanism by which the reactions occur. A factor is the concentration of the reactants. This experiment is designed to find the way in which the rate of a chemical reaction depends on the concentration of the reactions. This characteristic is known as the '**order**' of the reaction.

Rate of a reaction

The rate of a reaction is proportional to the product of the concentrations of the reactants, raised to a power which indicates the order of the reaction with respect to each individual reactant. For example,



The rate is

$$\text{Rate} = k[A]^n[B]^m \quad (1)$$

K is the rate constant and the concentration is expressed in mol/L

Order

From the equation 1, the exponents, n and m are the order of the reaction with respect to reactants A and B. The sum, n + m is the total order of the reaction. This order must be determined experimentally, not theoretically.

In this experiment, we are finding the order of a reaction using the concept of **Spectrophotometry** with respect to the terms absorbance and transmittance.

Concept of the experiment

At a pH of 4, Cr(III) salt is added to an EDTA [ethylene (dinitrilo) tetraacetate] solution and boiled. The addition of the chromium salt produces a green-grey solution, during boiling, a purple colour is formed which is characteristic of the Cr(III)-EDTA complex. The formation of the complex involves slow steps, the first being first order with respect to the Cr(III) and inversely to the concentration of hydrogen ion.

In this experiment, we are using different pH EDTA [ethylene (dinitrilo) tetraacetate] solution at 4.0, 4.5 and 5.0 to determine the partial order of the reaction with respect to the Cr(III) ion

The rate of this reaction can be expressed as

$$\text{Rate} = k[\text{Cr(III)}]^a[\text{H}^+]^b$$

A solution of Cr(III) ions will be added to solutions of 0.1 mol/L EDTA at the different pHs and the increase in the concentration of the complex will be monitored using a spectrophotometer.

Spectrophotometry

Spectrophotometry is the study of the interaction of electromagnetic radiation with matter. It is a simple technique used to measure absorbance and percent transmittance of solutions.

In a spectrophotometry analysis,

The Transmittance (the amount of light reaching the detector) is

$$T = I/I_0$$

Where I is the intensity of light hitting the detector after passing through the measured sample.

I_0 is the intensity of light hitting the detector after passing through a blank solution.

From the transmittance, the Absorbance is calculated as

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

Beer-Lambert's Law demonstrates the relationship between the absorbance and the concentration of a solution

$$A = \epsilon b c$$

A is the absorbance, ϵ is the molar absorptivity co-efficient, b represents the path-length and c represents the concentration of the absorbing species in the solution.

'What in the world isn't Chemistry', General CHM1311 lab manual, Dr Rashmi, pgs. 45-47

'Creative Commons Attribution Non-Commercial Share Alike', Dr Jenny A. Koenig

Data Tables and Calculations

	Run 3		Run 1		Run 2	
	Time (min)	Trans @ 536.6 nm (%)	Time (min)	Trans @ 536.6 nm (%)	Time (min)	Trans @ 536.6 nm (%)
1	0	87.402	0	87.778	0	87.531
2	2	87.056	2	83.544	2	81.755
3	4	86.494	4	83.529	4	81.633
4	6	85.265	6	83.333	6	81.371
5	8	83.769	8	83.205	8	80.975
6	10	82.116	10	83.093	10	80.499
7	12	80.186	12	82.924	12	79.989
8	14	78.162	14	82.764	14	79.363
9	16	76.177	16	82.534	16	78.616
10	18	74.055	18	82.305	18	77.740
11	20	72.063	20	82.160	20	77.065
12	22	70.028	22	81.738	22	76.208
13	24	68.164	24	81.501	24	75.367
14	26	67.485	26	81.275	26	74.502
15	28	65.750	28	80.902	28	73.573
16	30	19.501	30	80.659	30	20.535
17			32	80.295		
18			34	80.000		
19			36	79.650		
20			38	79.424		
21			40	79.055		
22			42	14.633		
23						
24						
25						
26						
27						
28						
29						

Raw data from experiment showing percentage transmittance with respect to time of chromium (III)-EDTA complex

Run 1- pH 4.0 EDTA, Run 2- pH 4.5 EDTA, Run 3- pH 5.0 EDTA

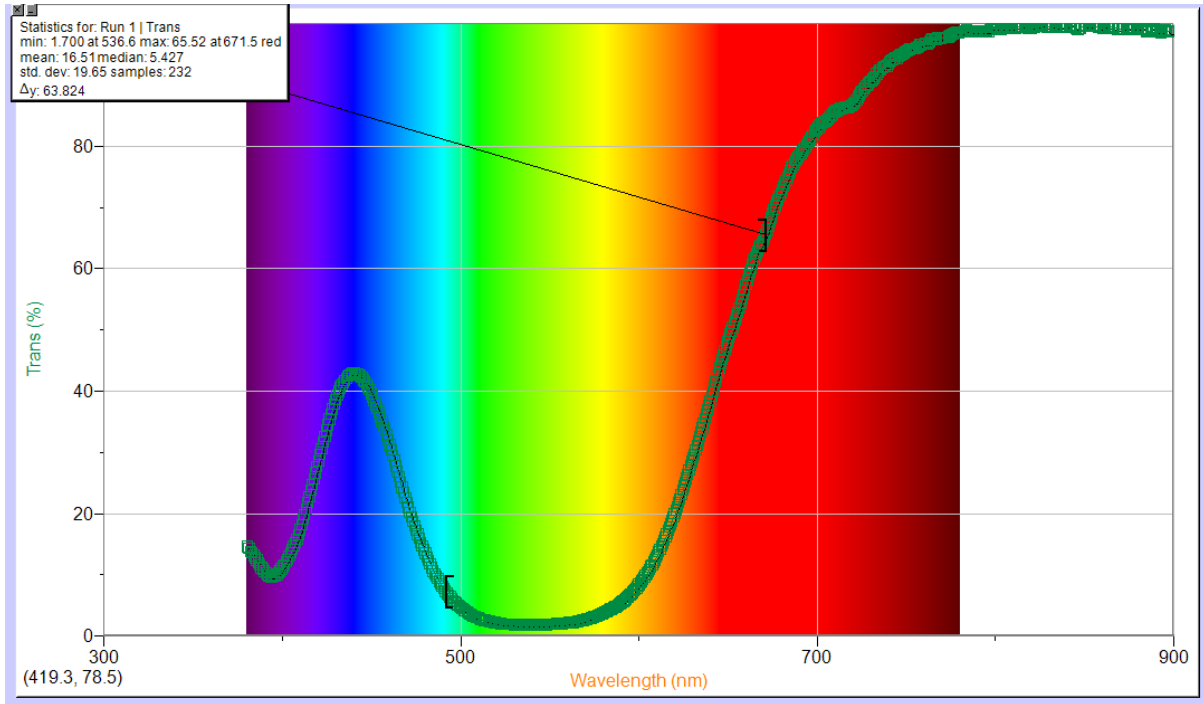
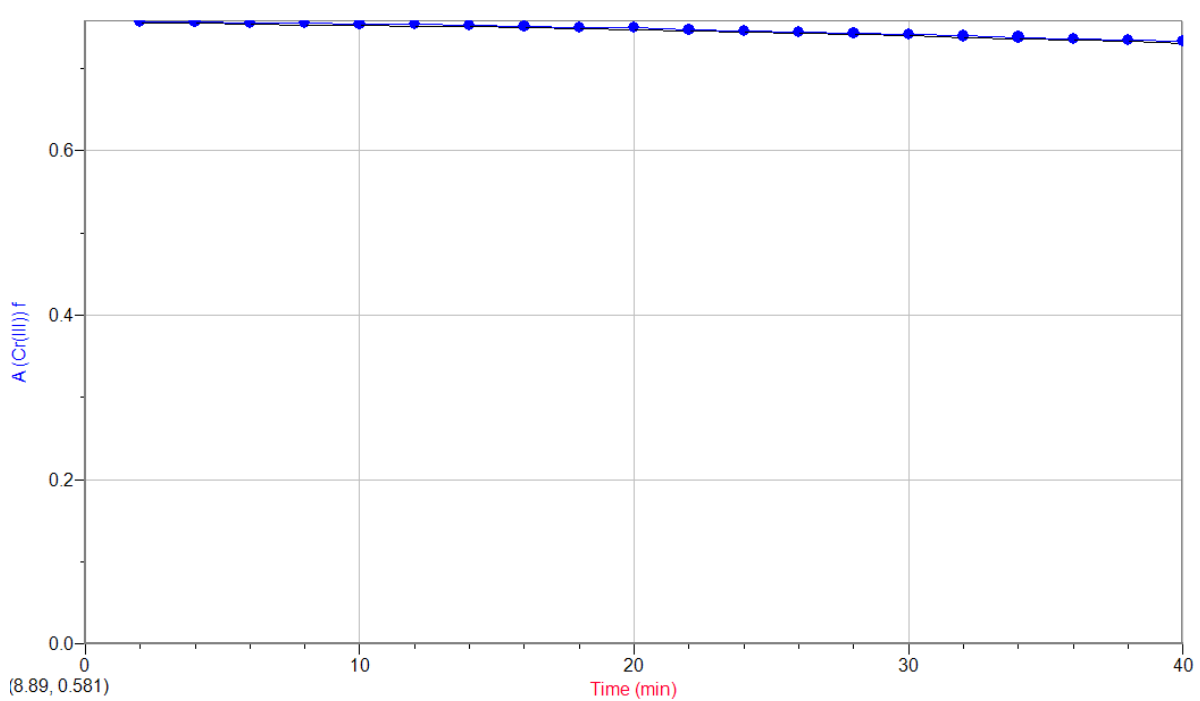


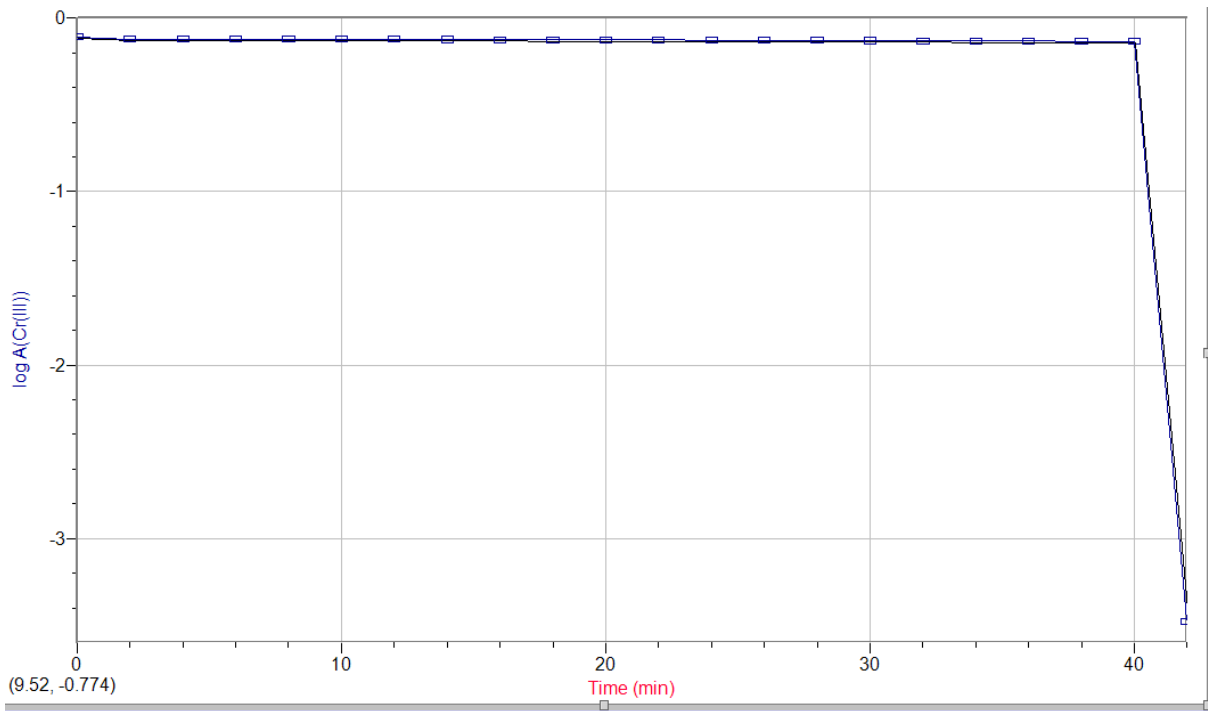
Diagram showing the percent transmittance and wavelength in the calibration of the SpectroVis

Manipulated data tables for chromium (III)-EDTA complex with pH of 4.0

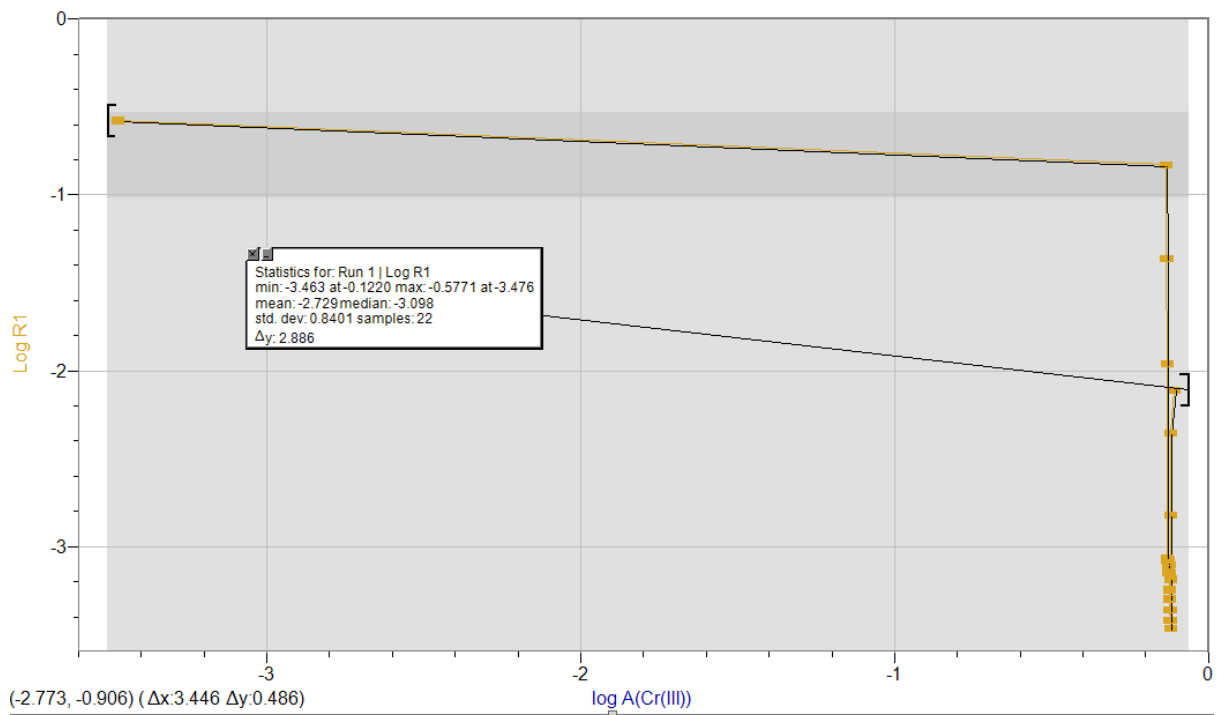
Time(mins)	Trans@536.6nm(%)	A(t)	A(Cr(III))	Log Ar(Cr(III))	Rate 1	Log R1	A(Cr(III)) f
0	87.77794036	0.056615	0.778385	-0.108805326	0.007791	-2.10843	
2	83.5435631	0.078087	0.756913	-0.120954039	0.004431	-2.35348	0.756913
4	83.52936552	0.078161	0.756839	-0.120996392	0.001502	-2.82326	0.7568392
6	83.33286341	0.079184	0.755816	-0.121583743	0.000652	-3.18571	0.7558163
8	83.20510113	0.07985	0.75515	-0.1219668	0.000344	-3.4629	0.75515
10	83.09318434	0.080435	0.754565	-0.122303111	0.00038	-3.42062	0.7545654
12	82.92445699	0.081317	0.753683	-0.12281149	0.000437	-3.35973	0.7536826
14	82.76407816	0.082158	0.752842	-0.123296228	0.000505	-3.29693	0.7528419
16	82.53417778	0.083366	0.751634	-0.123993682	0.000569	-3.24524	0.7516338
18	82.30520968	0.084573	0.750427	-0.12469136	0.000577	-3.23906	0.7504273
20	82.16032115	0.085338	0.749662	-0.125134429	0.000713	-3.1469	0.7496621
22	81.73779343	0.087577	0.747423	-0.126433595	0.000786	-3.10469	0.7474229
24	81.5011241	0.088836	0.746164	-0.127165942	0.00071	-3.14899	0.7461636
26	81.27460136	0.090045	0.744955	-0.127870049	0.000779	-3.1083	0.7449548
28	80.90231705	0.092039	0.742961	-0.129034006	0.000812	-3.09033	0.742961
30	80.65890257	0.093348	0.741652	-0.129799647	0.000834	-3.07903	0.7416523
32	80.29511373	0.095311	0.739689	-0.130950771	0.000867	-3.06217	0.7396891
34	79.99986437	0.096911	0.738089	-0.13189112	0.000856	-3.06731	0.7380893
36	79.65011838	0.098814	0.736186	-0.133012195	0.01097	-1.95979	0.7361864
38	79.42358176	0.100051	0.734949	-0.13374252	0.043469	-1.36182	0.7349495
40	79.05528993	0.102069	0.732931	-0.134936947	0.148077	-0.82951	0.7329309
42	14.63303944	0.834665	0.000335	-3.47554786	0.264807	-0.57707	



Graph of $A(\text{Cr(III)}) f$ against time for pH 4.0 Cr(III)-EDTA complex



Graph of $\log A(\text{Cr(III)})$ against time for pH 4.0 Cr(III)-EDTA complex



Graph of $\text{Log R}(1)$ against $\log A(\text{Cr(III)})$ for pH 4.0 Cr(III)-EDTA complex

Calculations for pH 4 chromium (III)-EDTA complex

At time=8 min, [Trans@536.6nm=83.205%](#)

$$\text{Absorbance} = A(t) = \log (100/\% \text{ trans}) = \log (100/83.205)$$

$$A(t) = 0.07985 \approx 0.0799$$

$$A(\text{Cr(III)}) = A_{\infty} - A_t = 0.83467 - 0.07985$$

$$A(\text{Cr(III)}) = 0.75482 \approx 0.755$$

$$\text{Log } A(\text{Cr(III)}) = \log (0.75482)$$

$$\text{Log } A(\text{Cr(III)}) = -0.12215 \approx -0.122$$

$$\text{Log } R (1) = \log (0.000344)$$

$$\text{Log } R (1) = -3.46344 \approx -3.463$$

Slope of the Log R (1) against Log A(Cr(III))

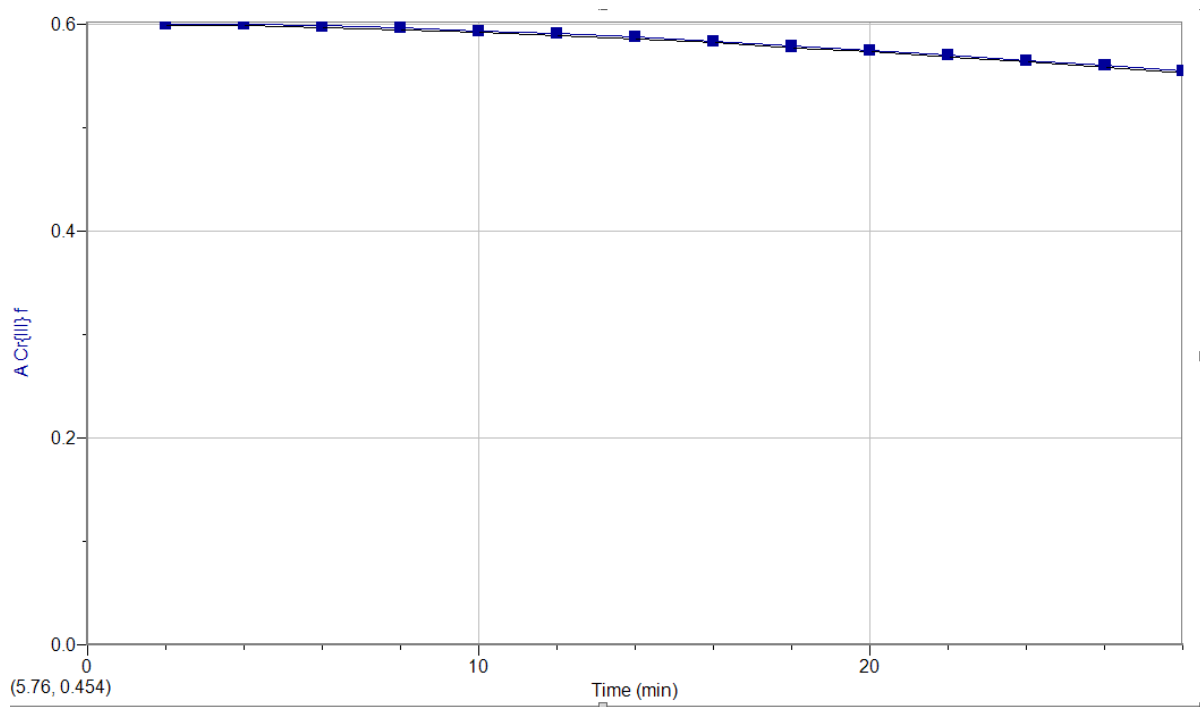
$$= \frac{\text{Change in Log } R (1)}{\text{Change in Log } A(\text{Cr(III)})} = \frac{-0.57707 - (-2.1084)}{-3.47555 - (-0.10881)}$$

$$= \frac{-0.57707 - (-2.1084)}{-3.47555 - (-0.10881)}$$

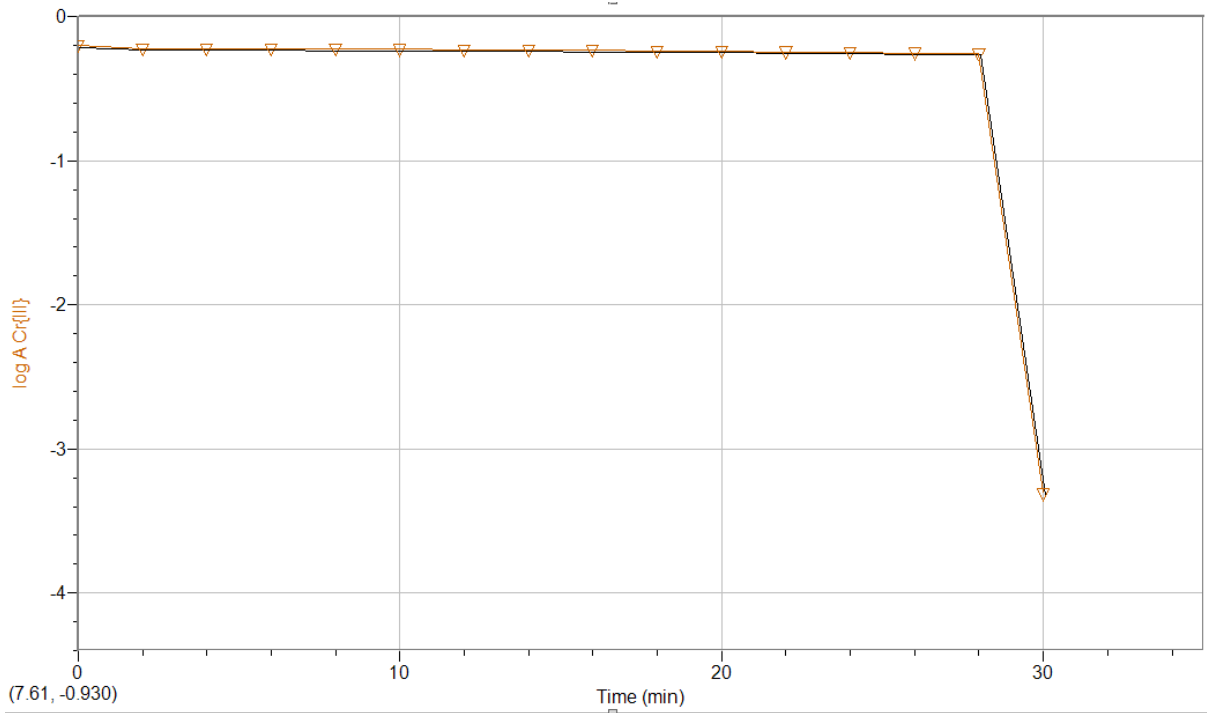
$$= -0.454849 \approx -0.45485$$

Manipulated data tables for chromium (III)-EDTA complex with pH of 4.5

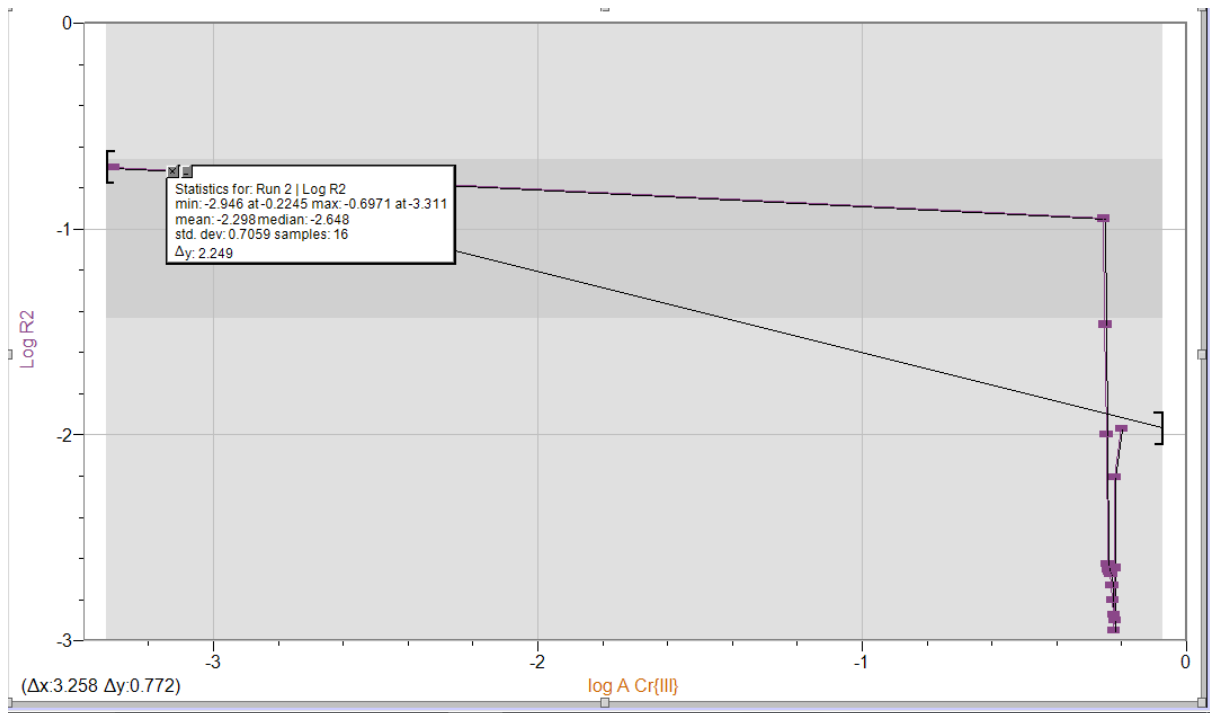
Time(min)	Trans@536.6nm(%)	A(t)	A Cr{III}	Log A Cr{III}	Rate 2	Log R2	A Cr{III} f
0	87.53137031	0.0578363	0.63016373	-0.2005466	0.010817	-1.96589	
2	81.75542978	0.0874834	0.60051661	-0.221475	0.006252	-2.20395	0.6005166
4	81.63298803	0.0881343	0.59986569	-0.221946	0.002271	-2.64381	0.5998657
6	81.37126384	0.0895289	0.59847106	-0.2229568	0.001263	-2.89848	0.5984711
8	80.9745012	0.0916517	0.59634828	-0.2245	0.001132	-2.94614	0.5963483
10	80.49942287	0.0942072	0.59379277	-0.2263651	0.001344	-2.87161	0.5937928
12	79.98921306	0.0969686	0.59103142	-0.2283894	0.001582	-2.80077	0.5910314
14	79.36302099	0.1003818	0.58761819	-0.2309048	0.00187	-2.72822	0.5876182
16	78.6157876	0.1044902	0.58350977	-0.2339519	0.002126	-2.6725	0.5835098
18	77.74042059	0.1093531	0.57864689	-0.2375864	0.002174	-2.66267	0.5786469
20	77.06530262	0.1131411	0.57485889	-0.2404387	0.002225	-2.65258	0.5748589
22	76.2083222	0.1179976	0.5700024	-0.2441233	0.002379	-2.62353	0.5700024
24	75.36722977	0.1228174	0.56518255	-0.2478113	0.010099	-1.99574	0.5651826
26	74.5020563	0.1278317	0.56016826	-0.2516815	0.034611	-1.46079	0.5601683
28	73.57253677	0.1332843	0.55471573	-0.2559295	0.113197	-0.94617	0.5547157
30	20.53472566	0.6875111	0.00048891	-3.3107755	0.200883	-0.69706	



Graph of A Cr{III} f against time for pH 4.5 Cr(III)-EDTA solution



Graph of Log A Cr{III} against time for pH 4.5 Cr(III)-EDTA complex



Graph of Log R(2) against Log A Cr{III} for pH 4.5 Cr(III)-EDTA complex

Calculations for pH 4.5 chromium (III)-EDTA complex

At time= 8 mins, [Trans@536.6nm](#)= 80.975%

Absorbance, $A(t) = \log (100/\%trans) = \log (100/80.975)$

$$A(t) = 0.091649 \approx 0.09165$$

$$A_{Cr \{III\}} = A_{\infty} - A_t = 0.68751 - 0.091649$$

$$A_{Cr \{III\}} = 0.59586 \approx 0.5969$$

$$\log A_{Cr \{III\}} = \log (0.59586)$$

$$\log A_{Cr \{III\}} = -0.22485 \approx -0.2249$$

$$\log R (2) = \log (0.001132)$$

$$\log R (2) = -2.94615 \approx -2.9462$$

Slope of $\log R (2)$ against $\log A_{Cr\{III\}}$

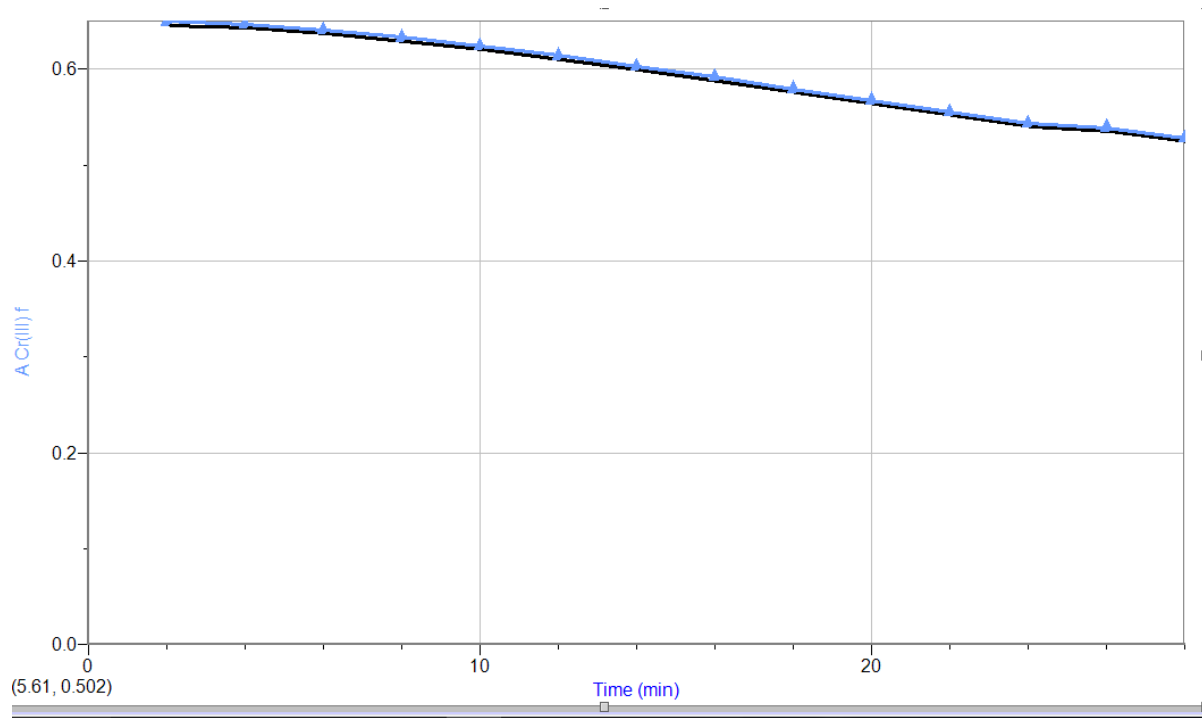
$$= \frac{\text{Change in } \log R (2)}{\text{Change in } \log A_{Cr \{III\}}} = \frac{-0.69706 - (-1.96589)}{-0.31078 - (-0.20055)}$$

$$= \frac{-0.69706 - (-1.96589)}{-0.31078 - (-0.20055)}$$

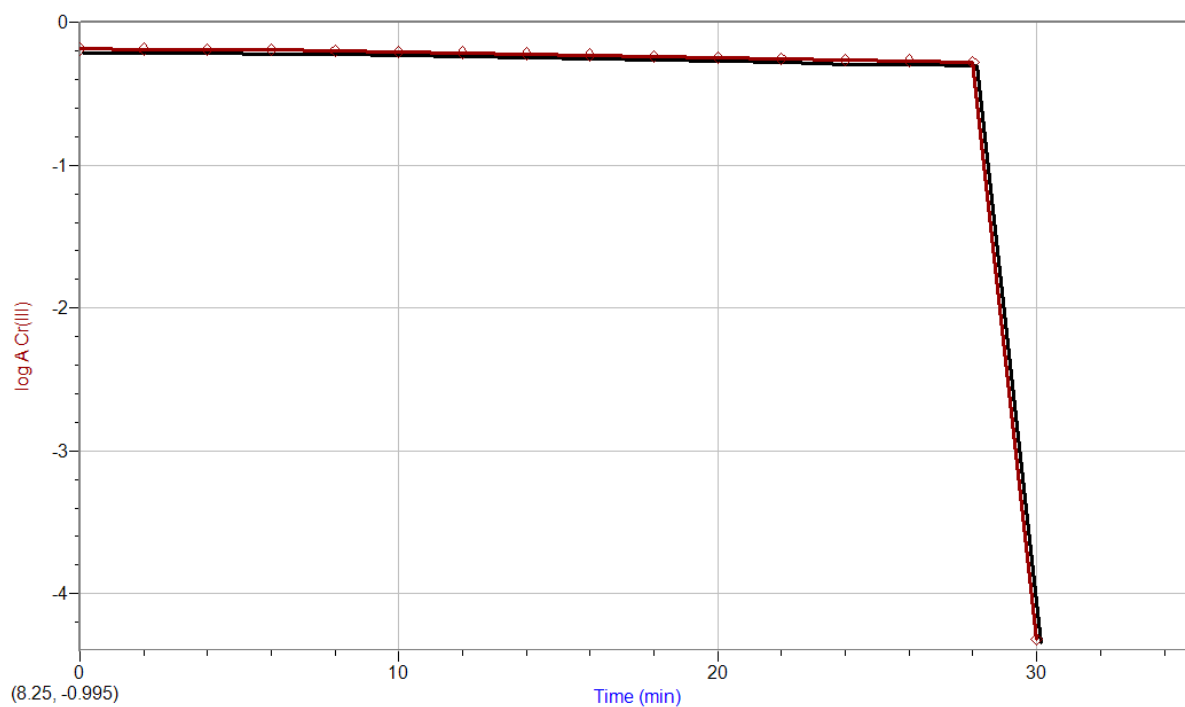
$$= -0.4079537 \approx -0.40795$$

Manipulated data tables for chromium (III)-EDTA complex with pH of 5.0

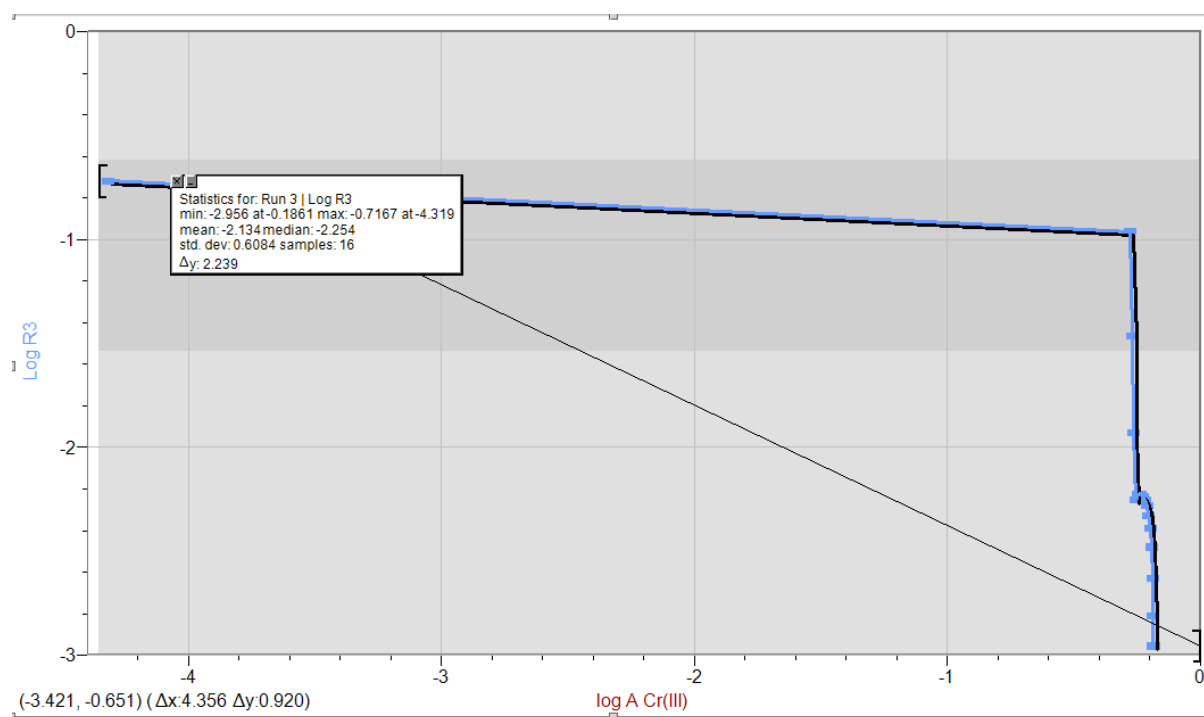
Time(mins)	Trans@536.6nm(%)	A(t)	A Cr(III)	Log A Cr(III)	Rate 3	Log R3	A Cr(III) f
0	87.40187268	0.058479	0.6515207	-0.1860718	0.0011069	-2.95587	
2	87.05596616	0.060201	0.6497985	-0.1872213	0.001548	-2.81022	0.6497985
4	86.49414936	0.063013	0.6469867	-0.1891046	0.0023481	-2.62929	0.6469867
6	85.26532448	0.069228	0.6407724	-0.1932962	0.003315	-2.47952	0.6407724
8	83.76860389	0.076919	0.6330813	-0.1985405	0.0040632	-2.39113	0.6330813
10	82.11645334	0.08557	0.6244302	-0.2045161	0.0047132	-2.32668	0.6244302
12	80.18553188	0.095904	0.614096	-0.2117637	0.0052483	-2.27998	0.614096
14	78.16227867	0.107003	0.6029972	-0.2196847	0.0055615	-2.25481	0.6029972
16	76.17737385	0.118174	0.591826	-0.227806	0.0058235	-2.23482	0.591826
18	74.05502666	0.130445	0.5795545	-0.2369057	0.0059823	-2.22313	0.5795545
20	72.06309262	0.142287	0.5677129	-0.2458712	0.0059323	-2.22677	0.5677129
22	70.0282866	0.154726	0.5552735	-0.2554931	0.0055886	-2.25269	0.5552735
24	68.16430453	0.166443	0.543557	-0.2647549	0.0117163	-1.93121	0.543557
26	67.4845936	0.170795	0.5392046	-0.2682464	0.0345529	-1.46152	0.5392046
28	65.75024497	0.182103	0.5278974	-0.2774505	0.1091567	-0.96195	0.5278974
30	19.50059871	0.709952	4.79E-05	-4.3192535	0.1919896	-0.71672	



Graph of A Cr(III) f against time for pH 5.0 Cr(III)-EDTA solution



Graph of Log A Cr(III) against time for pH 5.0 Cr(III)-EDTA complex



Graph of Log R(3) against log A Cr(III) for pH 5.0 Cr(III)-EDTA complex

Calculations for pH 5.0 chromium (III)-EDTA complex

At time = 8 mins, [trans@536.6nm](#) = 83.769%

Absorbance, $A(t) = \log(100/\%trans) = \log(100/83.769)$

$$A(t) = 0.0769166 \approx 0.07692$$

$$A_{Cr(III)} = A_{\infty} - A_t = 0.709952 - 0.0769166$$

$$A_{Cr(III)} = 0.6330334 \approx 0.6330$$

$$\log A_{Cr(III)} = \log(0.6330334)$$

$$\log A_{Cr(III)} = -0.198573 \approx -0.1986$$

$$\log R(3) = \log(0.0040632)$$

$$\log R(3) = -2.3911318 \approx -2.3911$$

Slope of R (3) against log A Cr(III)

$$= \frac{\text{Change in Log R (3)}}{\text{Change in Log A Cr(III)}} = \frac{-0.71672 - (-2.95587)}{-0.31925 - (-0.18607)}$$

$$= 0.5417499 \approx -0.54175$$

Observations and Discussions

The initial addition of the Cr(III) ion to different pH EDTA solution turned the solution green grey. After boiling, this becomes dark purple. As the cuvette is in the SpectroVis, it is seen that as time goes by, the percent transmittance of the solution decreases and at a certain time when the cuvette solution is replaced, the percent transmittance drops greatly.

In the experiment, the volume and temperature are very important. The volume is related to the size of the cuvette, which must be low for more accurate result. The temperature must be relatively low (about 20-30°C) to maintain the intensity of the light particles.

The data got from the experiment can be reproduced if the conditions for the experiment are kept constant.

The graphs of $\log A$ Cr(III) were linear, meaning that the partial order with respect to Cr(III) is one, indicating that the reaction was undergoing pseudo first-order kinetics.

There are sources of error in this experiment. One is the amount of Cr(III) ion to the EDTA solution. Also, if the boiling and cooling of the formed complex is not done well, some errors could come in place.

The solution with the pH 4 EDTA solution had the highest percent transmittance while that of pH 5 had the lowest percent transmittance. This is because a pH of 4 indicates higher content of hydrogen ions and the formation of Cr(III) ion is inversely proportional to the concentration of hydrogen ions.

Conclusion

It was seen that absorbance of the reaction decreased over time. Also, the EDTA solution with pH4 had the highest percent transmittance while that of pH5 had the lowest percent transmittance.

Calibration

Using pH 4.5 EDTA Solution

Measured % Transmittance = 100% at 586.60 nm

1st Experiment

pH 4.5 EDTA Solution

Volume = 10ml

% Transmittance at 40 minutes = 77.88%

% Transmittance at 42 minutes = 74.83%

2nd Experiment

pH 4.5 EDTA Solution

Volume = 10ml

% Transmittance at 29 minutes = 48.57%

% Transmittance at 30 minutes = 20.54%

3rd Experiment

pH 5.0 EDTA Solution

Volume = 10ml

% Transmittance at 28 minutes = 65.75%

% Transmittance at 20 minutes = 19.96%