Laboratory Report Cover Page

Experiment 4: Chemical Kinetics

Checklist:
Raw Data Sheet written in pen, signed by TA and attached
Report Form typed and attached

Introduction

"Chemical kinetics is the study and discussion of chemical reactions with respect to reaction rates, effect of various variables, re-arrangement of atoms, formation of intermediates etc" [1]. The purpose this experiment serves is to investigate the rate of chemical reactions, and enhance our knowledge of chemical kinetics. There are many factors that can affect the rate at which a reaction takes place, a relevant example being the effect concentration has on a chemical reaction. The Chemical Kinetics experiment helps us investigate this relationship. It should be noted that the concentration of the reactants is often referred to as the order of the reaction. One of the main goals of this experiment is to determine the partial order of the reaction between chromium (III) and EDTA solution. Prior to being able to understand the results of the experiment however; there are a couple key concepts that must first be understood:

- Rate of reaction

The rate of reaction is expressed as:

$$\text{Rate} = k\,[A]^n\,[B]^m$$

Where '[A]' and '[B]' are the concentrations of the reactants (mol/L), raised to a power 'n' and 'm', and 'k' being the rate constant. During the experiment we are asked to determine the instantaneous rate. This can be determined using the graph of concentration vs. time, by determining the slope of a tangent line at the desired point.

- Order

The order of the reaction refers to the exponent values ‘n’ or ‘m’ in the above equation. The total order of reaction refers to the sum of the individual orders (n+m). It is important to know that the order of reaction can only be determined experimentally, in this experiment it will be calculated using the graph of absorbance over time.

Procedure

As described in the lab manual[2]
No changes were made.

Observations

- Chromium nitrate solution was a dark blue/purple colour
- Initial solution is a light grey-ish purple transparent colour. This is the same for all pH values.
- The solutions appeared to be odourless
- The heated solutions rapidly changed to a dark purple/blue colour at 100 degrees.

Results

Chromium (III) complex at pH 4

Time (min)	% Trans	A (t)	A (CrIII)	Log A Cr(III)	Rate	Log Rate
0	83.504	0.07829	1.887709537	0.27593517	0.027369021 25	-1.562740733
2	70.213	0.15358	1.812416531	0.258258014 6	0.015590697 83	-1.807134446
4	70.035	0.15469	1.811314109	0.25799377	0.005147896 746	-2.288370173
6	69.702	0.15675	1.809248113	0.257498128 4	0.002080075 652	-2.68192087
8	69.336	0.15904	1.806959073	0.256948316 2	0.001227912 849	-2.910832456
10	68.941	0.16152	1.804475022	0.256350874 7	0.001445335 742	-2.840031258
12	68.385	0.16504	1.800963936	0.255505016 3	0.001565469 748	-2.805355321

14	67.923	0.16798	1.798015149	0.2547933465	0.001607662874	-2.793805017
16	67.438	0.17109	1.794905065	0.2540414832	0.001790192555	-2.747100253
18	66.809	0.17516	1.790835172	0.2530556154	0.001962551544	-2.707178928
20	66.169	0.17934	1.786656732	0.2520411201	0.001975905137	-2.70423391
22	65.633	0.18288	1.783122559	0.2511811945	0.002057512716	-2.686657472
24	64.949	0.18743	1.778572995	0.2500716938	0.002184921487	-2.660564164
26	64.292	0.19184	1.77415971	0.2489927124	0.002227787111	-2.652126313
28	63.613	0.19646	1.769544174	0.2478614085	0.002221780931	-2.653298765
30	63.027	0.20048	1.765524143	0.2468736609	0.002303115694	-2.637684245
32	62.275	0.20569	1.760310695	0.2455893276	0.002378913926	-2.623621271
34	61.611	0.21034	1.755661328	0.2444407431	0.002319450606	-2.634614872
36	61.002	0.21465	1.751345118	0.2433717361	0.026500479 48	-1.576746268
38	60.289	0.21976	1.74624041	0.2421040341	0.1037762146	-0.983902175
40	59.578	0.22491	1.741085119	0.2408200036	0.352162421	-0.453256989 2
42	1.081	0.1966	-4.54E-05		0.6294561802	-0.201034498

Chromium (III) complex at pH 4.5

Time (min)	% Trans	A (t)	A (CrIII)	Log A Cr(III)	Rate	Log Rate
0	83.36909674	0.07899490381	1.484105096	0.1714646564	0.005054658 45	-2.296308185
2	75.09430644	0.12439298894	1.438707011	0.1579723599	0.003116649 09	-2.506312093
4	74.35073816	0.12871471544	1.434385285	0.1566658211	0.001399517 221	-2.854021753
6	73.59711362	0.13313921778	1.429960782	0.1553241268	0.000928071 8619	-3.032418394
8	72.69807467	0.13847709088	1.424622909	0.1536999239	0.000866455 6113	-3.062253681
10	71.6468431	0.14480294007	1.418297059	0.1517672024	0.000937048 0173	-3.028238154

12	70.67755714	0.1507184696	1.41238153	0.1499520297	0.001005305457	-2.99770196
14	69.52004696	0.1578899432	1.405210057	0.1477412493	0.001069533386	-2.970805654
16	68.46208955	0.1645498498	1.39855015	0.1456780442	0.001132474993	-2.945971379
18	67.23962555	0.1723747138	1.390725286	0.1432413511	0.001204251469	-2.919282815
20	66.01286655	0.180371408	1.382728592	0.1407369433	0.001220093146	-2.913607013
22	64.88192004	0.1878763066	1.375223693	0.1383733461	0.001237319752	-2.907518054
24	63.68844216	0.1959393739	1.367160626	0.1358195423	0.001262864212	-2.898643344
26	62.53109267	0.2039039823	1.359196018	0.1332820934	0.001273229095	-2.895093446
28	61.39287095	0.211882057	1.351217943	0.1307254037	0.001281611461	-2.892243618
30	60.28285781	0.2198061674	1.343293833	0.1281710208	0.001287406972	-2.890284143
32	59.15820528	0.2279850099	1.33511499	0.125518672	0.00127133244	-2.895740871
34	58.11566215	0.2357068096	1.32739319	0.1229995854	0.001220505173	-2.913460376
36	57.23896287	0.242308244	1.320791756	0.1208343495	0.001250463716	-2.902928906
38	56.10296464	0.2510141888	1.312085811	0.1179622391	0.001265117453	-2.897869153
40	55.20411073	0.2580285817	1.305071418	0.1156342785	0.00121992125	-2.913668204
42	2.734597527	1.563106583	-6.58E-06			

Chromium (III) complex at pH 5.0

Time (min)	% Trans	A (t)	A (CrIII)	Log A Cr(III)	Rate	Log Rate
0	83.35356425	0.07907582471	1.619624175	0.2094142506	0.01603376815	-1.796496401
2	75.55343706	0.121745774	1.576954226	0.1978190873	0.01007387661	-1.996803373
4	74.87430062	0.1256672212	1.573032779	0.1967377725	0.005100164815	-2.292415789
6	73.70759741	0.1324877449	1.566212255	0.1948506178	0.004212786165	-2.375430584
8	72.33662866	0.140641736	1.558058264	0.1925836942	0.004450188515	-2.351621591
10	70.69583794	0.1506061536	1.548093846	0.1897972843	0.005045658901	-2.297082112

12	69.01688326	0.1610446569	1.537655343	0.1868590017	0.005490295967	-2.260404243
14	67.14885907	0.172961362	1.525738638	0.1834801445	0.005733441235	-2.241584634
16	65.47755861	0.183907522	1.514792478	0.1803531399	0.005980740485	-2.223245042
18	63.56311607	0.1967948204	1.50190518	0.176642515	0.006243033 07	-2.204604365
20	61.78489051	0.2091177186	1.489582281	0.1730644977	0.006385735 28	-2.194789089
22	59.91020999	0.2224991582	1.476200842	0.1691454486	0.006434978 312	-2.191452913
24	58.20524473	0.2350378804	1.46366212	0.1654408332	0.006352415 531	-2.197061101
26	56.49315283	0.248004187	1.450695813	0.1615763576	0.025870581 91	-1.587193803
28	54.91406523	0.2603164048	1.438383595	0.1578747213	0.088467646 24	-1.053215527
30	53.5762829	0.2710274208	1.427672579	0.1546286182	0.290886755	-0.536276053
32	2.001206438	1.698708109	-8.11E-06		0.517083478 4	-0.286439338 4

**** In each of the below graphs:**
Pink represents a pH value of 4.0
Red represents a pH value of 4.5
Blue represents a pH value of 5.0

A Cr(III) as a function of time

Log A Cr(III) as a function of time

Log Rate and a function of Log A Cr(III)

Results

** The calculations are based off the data found in run 3 (pH 5.0) at time 22 (minutes) as shown below.

Time (min)	% Trans	A (t)	A (CrIII)	Log A Cr(III)	Rate	Log Rate
22	59.91020999	0.2224991582	1.476200842	0.1691454486	0.006434978312	-2.191452913

Transmittance:

The following is done for pH 5.0 at 22 minutes

Absorbance (A_T):

Absorbance (CrIII):

Log A Cr(III):

Rate: 0.00643497

Log Rate:

Partial Order:

First Order Reaction

Discussion

Based on the information and calculations above, the reaction is found to be first order reaction. During this experiment, three separate labs were performed, all with EDTA at a different pH level (4.0, 4.5, 5.0). Volume plays a large role in this experiment. In this experiment, the Hydrogen concentration is negligible. Due to a smaller sample size of 10 mL EDTA solution, and two drops of Cr(III), if any less solution was used then the hydrogen concentration may need to be taken into consideration. Temperature also plays a crucial role in the experiment, due to the reaction rate being heavily dependant on the temperature. When the solution of Cr(III) and EDTA (regardless of pH) was placed in a boiling water bath, the reaction (observed by a colour change from light grey/purple to dark purple) was almost immediate; whereas this reaction did not occur right away at room temperature. Therefore; as the temperature increases or decreases, the reaction rates responds accordingly.
Based on the fact that each of experiments with differing pH levels all produced almost identical graphs, we can conclude that the results are reproducible. As long as the same volumes and concentrations are used in the experiment the same results should be obtained each time.

The graph of log A Cr(III) with respect to time has a downward linear slope, which indicates that the reaction being observed is a first-order reaction. This slope was similar for each of the pH values, so from this we can conclude that regardless of pH, the reaction is going to be first-order. The reason this graph was plotted as a function of time is so the order of the reaction is visible.

The overall reaction rate is determined by the sum of the individual reactant orders. If we know based on our graphs that the Cr(III) will produce a first order reaction, and the sum of that and the hydrogen is what determines the overall reaction order (which we found to be 1) then it can be assumed that the Hydrogen component is a zeroth-order reaction.

Two sources of error throughout this experiment occurred with the boiling water bath and the Cr(III) drops. The water in the bath kept evaporating and we had to keep adding either turning down the temperature (while the solution was not inside) or adding more water. This changes the temperature of the water as the whole bath is not at 100 degrees celsius. Another source of error was in regards to the Cr(III). While each solution contained two drops, the drops were inevitably different sizes resulting in the concentration between the three varying slightly.

Conclusion:
In conclusion, the rate of reaction is directly proportional to the concentration of the reactants, and well as temperature and volume. The results from the graphs throughout the experiment proved the reaction to be first order.

References:

1. University of Waterloo. “Chemical Kinetics” [http://www.science.uwaterloo.ca/~cchieh/cact.html.]

2. Dr. R. Venkateswaran, “What In the World Isn’t Chemistry?”, General Chemistry Laboratory Manual, 2016, Experiment 4, p(49-53).

Raw Data: