

Chemistry III, Assessable Prac II

“The Clock Reaction”

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Aim: To use the clock reaction to quantitatively demonstrate the factors affecting rates of reaction.

Conclusion: The factors that affect the rates of reaction are the concentration of the reactants, the temperature of the reactants and the addition of a catalyst into the reaction solution. The factors were demonstrated quantitatively in this experiment using the reaction between persulfate ions and iodide ions in solution.

Potassium iodide / starch / sodium thiosulfate solution + persulfate solution: 5m 40s.

- With catalyst ferrous ammonium sulfate: 2m 5s
- Suspended in a beaker full of boiling water: 3m 20s.
- Using 0.5 M persulfate instead of 0.05 M persulfate: 35s

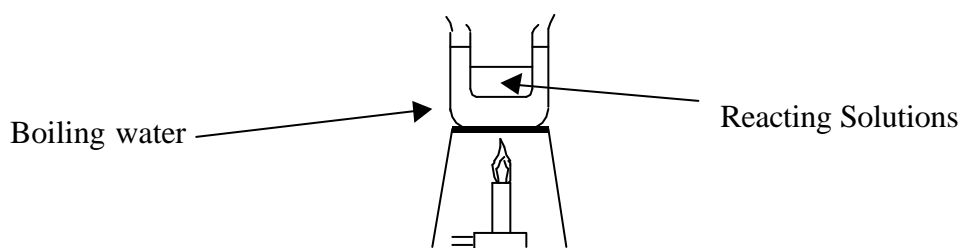
Background: The rate of a reaction is the rate at which the reactants react to form the products. The rate of a reaction is written as moles per litre per second, or the concentration difference between two times divided by the time difference. The rate of reaction decreases as the reaction proceeds. Many things influence the rate of reaction. The rate of reaction increases when the concentration of a reactant is increased, as the reaction proceeds the concentrations of the reactants decrease and therefore the rate of reaction decreases. The rate of a reaction will also increase when the temperature of the reactants is increased. Another way to increase the rate of a reaction is to add the presence of a substance which is not even involved in the stoichiometric equation for the reaction. A substance that increases the rate of a reaction without undergoing a permanent chemical change in the reaction is called a catalyst. Catalysts can be either homogeneous or heterogeneous. A homogeneous catalyst works throughout the bulk of the reaction mixture. A heterogeneous catalyst provides a surface on which the reaction occurs more rapidly.

- Method:**
1. 10.0 mL of 0.1 M potassium iodide solution was placed in each of two 100mL beakers and 0.5mL starch solution was added from a pipette to each.
 2. To one beaker 10.0 mL of 0.05 M sodium persulfate was added and observations were recorded.
 3. To the other beaker 2 mL sodium thiosulfate was added and observations recorded.
 4. To the second beaker, 10.0 mL of 0.05 M sodium persulfate solution was then added and observed.
 5. Into one 100 mL beaker, 20 mL potassium iodide/starch/sodium thiosulfate solution was added and into another, 20 mL of the 0.05 M persulfate solution was added.
 6. The time was recorded and the two solutions were mixed by pouring them back and forth from one beaker to another several times.
 7. After the reaction occurred, the time was recorded.
 8. Steps 5, 6 & 7 were repeated and 5 drops of ferrous ammonium sulfate were added, and the mixture was stirred.

Methods for predicted ways to increase or decrease rate of the reaction.

Method 1 – Add heat to the reaction.

1. Into one 100 mL beaker, 20 mL potassium iodide/starch/sodium thiosulfate solution was added and into another, 20 mL of the 0.05 M persulfate solution was added.
2. The time was recorded and the two solutions were mixed by pouring them back and forth from one beaker to another several times.
3. The beaker containing the solutions was placed in a beaker of boiling water.



4. After the reaction occurred, the time was recorded.

Method 2 – Increase the concentration of the persulfate solution.

1. Into one 100 mL beaker, 20 mL potassium iodide/starch/sodium thiosulfate solution was added and into another, 20 mL of 0.5 M persulfate solution was added.
2. The time was recorded and the two solutions were mixed by pouring them back and forth from one beaker to another several times.
3. After the reaction occurred, the time was recorded.

Data: Original method:

1. When the starch was added to the potassium iodide, the solution turned from yellow to dark purple.
2. A dark precipitate immediately formed in a light green translucent liquid.
3. The liquid very quickly changed from dark purple to clear.
4. After approximately 11 minutes and 25 seconds a dark precipitate formed in a green translucent solution.
7. The reaction took 5 minutes and 40 seconds to change to a dark precipitate in a translucent, green solution.
8. The reaction took 2 minutes and 5 seconds to change to a dark precipitate in a translucent, green solution.

Method 1:

4. The reaction took 3 minutes and 20 seconds to change to a dark precipitate in a translucent green solution.

Method 2:

3. The reaction took 35 seconds to change to a dark precipitate in a translucent green solution.

Analysis:

Reactions

Persulfate reacts with iodide producing iodine: $S_3O_8^- + I^- \Leftrightarrow I_2$

Thiosulfate reacts with iodine producing iodide: $S_2O_3^{2-} + I_2 \Leftrightarrow I^-$

Original Method:

- Reaction 1 - 10.0 mL of 0.05 M sodium thiosulfate reacts with 10.0 mL, 0.1 M of potassium iodide / starch solution, time taken <1s
- Reaction 2 - 10.0 mL of 0.05 M sodium thiosulfate reacts with 10.0 mL, 0.1 M potassium iodide / starch / sodium thiosulfate solution, time taken = 11m25s.

- Reaction 3 - 20 mL potassium iodide / starch / sodium thiosulfate solution reacts with 20 mL 0.05 M persulfate solution, time taken = 5m40s.
- Reaction 4 - 20 mL potassium iodide / starch / sodium thiosulfate solution reacts with 20 mL 0.05 M persulfate / catalyst (five drops of ferrous ammonium sulfate) solution, time taken = 2m5s.

Reaction	Time taken	Substance added
1	Less than 1s	
2	11 m 25 s	Sodium Thiosulfate
3	5 m 40 s	
4	2 m 5 s	Ferrous Ammonium sulfate

The sodium thiosulfate in reaction 2 slows down the rate of reaction between the sodium persulfate and the potassium iodide / starch solution. It acts as an anti catalyst.

In reaction 4, the ferrous ammonium sulfate speeds up the rate of reaction and is therefore a homogenous catalyst to the reaction between the potassium iodide / starch / sodium thiosulfate solution and the persulfate solution.

Method 1:

- Reaction 3 in original method - 20 mL potassium iodide / starch / sodium thiosulfate solution reacts with 20 mL 0.05 M persulfate solution, time taken = 5m40s.
- Reaction 1 - 20 mL potassium iodide / starch / sodium thiosulfate solution reacts with 20 mL 0.05 M persulfate solution in a beaker of boiling water, time taken = 3m20s.

Reaction	Time taken	Catalyst
3 in Original	5m40s	
1	3m20s	Heat from boiling water

The heat provided by the boiling water, speeds up the rate of reaction. It is a catalyst to the reaction even though it is not a chemical one.

Method 2:

- Reaction 3 in original - 20 mL potassium iodide / starch / sodium thiosulfate solution reacts with 20 mL 0.05 M persulfate solution, time taken = 5m40s.
- Reaction 1 - 20 mL potassium iodide / starch / sodium thiosulfate solution reacts with 20 mL 0.5 M persulfate solution, time taken = 35s.

Reaction	Time taken	Difference
3 in Original	5m40s	
1	35s	Increased persulfate conc.

In reaction 1, there is a greatly increased concentration of persulfate ions in the reacted solution. This means that there were a lot more persulfate molecules bouncing around in a

smaller space and therefore there was a much higher probability of reaction between persulfate ions and iodide ions.

Questions

1. a) Not every collision between an ethanol molecule and an acetic acid molecule will lead to the formation of an ethyl acetate molecule, because if they don't have enough energy to react, then they will just deflect off each other.

b) The probability of reactions occurring when molecules collide increases when the temperature increases because, when the heat is added, the average energy of the molecules is higher, and the probability of two molecules colliding with each other with sufficient energy increases.

2. a) The reactant molecules can be pushed over the activation energy "barrier", allowing the reactants to form products, by adding heat energy.

b) The activation energy "barrier" can be lowered by adding a chemical catalyst to the reaction i.e. Ferrous Ammonium Sulfate.

3. a) A catalyst is a substance or energy that alters the rate of a chemical reaction, but is itself unchanged at the conclusion of the reaction. Catalyst is from the Greek Katalysis, meaning breaking down or loosening.

b) The rate of a reaction changes in the presence of a catalyst, because the catalyst provides a pathway of lower activation energy, or increases the molecules' individual energy, increasing the possibility of collisions.

c) Catalysts are important in industry because they lower the activation energy "barrier" for a reaction, which increases the speed of the reaction, therefore decreasing the amount of energy required and saving time and money, whilst increasing output/production. This increases the profits for the industry, making it a favorable venture.

d) i) Industrial synthesis of ammonium for fertilizers and explosives

$$N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$$
 Catalyst: Vanadium Pentoxide | Heterogeneous.

ii) Industrial synthesis of sulfur trioxide to make sulfuric acid

$$2SO_{2(g)} + O_{2(g)} \rightleftharpoons 2SO_{3(g)}$$
 Catalyst: Free Iron Ions (Fe^{2+}) | Homogeneous.

iii) Industrial synthesis of nitric acid

$$2NH_{3(g)} + 3O_{2(g)} \rightleftharpoons 2HNO_{3(s)} + 2H_{2(g)}$$
 Catalyst: Platinum & Platinum-Rhodium gauze | Heterogeneous.

Errors: If you put too much of a reactant into a reaction, the rate of the reaction will be affected and the time that the reaction takes to complete will be incorrect to the data taken down when the method is being followed.

If one accidentally takes a chemical such as the persulfate solution, of the wrong concentration, then the rate of reaction will again be disturbed from the expected results and the observations will be useless.

If you use the same measuring cylinder for getting all of your chemicals and you don't wash it, or don't wash it thoroughly enough, then some of the reactants may accidentally react before the reaction is meant to take place. This may lead to the wrong amounts of reactants being reacted and again, the rate of reaction will be affected.

If you are waiting for one of the reactions to complete it self and you look away from the beaker, you may miss the actual moment of the reaction completing and the time that you record for the reaction rate will be incorrect.

Adding too little catalyst may only speed up the rate of reaction a small amount and the differences in time may be too small to observe and so that data will be useless.

To minimize errors, always make sure that you get the right chemicals and if you are using the same measuring cylinder for all chemicals, then make sure that you wash it thoroughly before using it for another chemical. Watch the experiment at all times to make sure that you do not miss an important observation, or the completion of the reaction.