Nano Camp
Kinetics and Catalysis

Presented by
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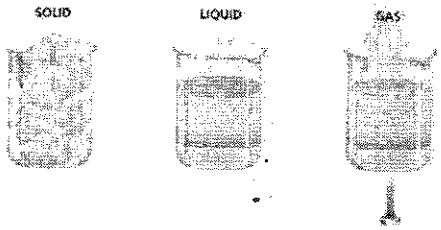
Background

Kinetics is the study of how fast a reaction proceeds, or its RATE. Some reactions occur very quickly, like adding baking soda reacting with vinegar. Other reactions cannot be seen instantly for example, a nail rusting is a chemical reaction but it takes years to occur. There are many factors that influence the rate of a reaction such as the physical STATE, CONCENTRATION of the reactants, TEMPERATURE, SURFACE AREA, and the addition of a CATALYST.

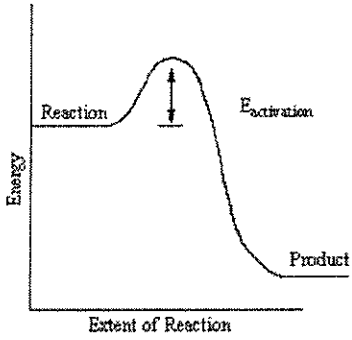


The physical state of a reactant (solid, liquid, or gas) effects how quickly it will react. A reaction can occur between reactants in the same or different phases. An example of a reaction between two gases is when hydrogen and oxygen gas react to form water:

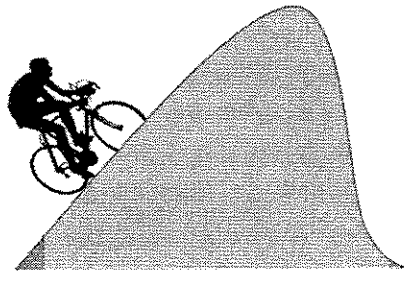
$$2H_{2(g)} + O_{2(g)} \rightarrow H_2O_{(l)}$$

This reaction is very quick. A slightly slower reaction occurs when two liquids react. For example, the chemical sodium hydroxide and hydrochloric acid react when added together. These two chemicals can be dangerous separately, but after they are added together the result is salt water! The slowest class of reactions occurs between two solids. In the medicine Alka Seltzer, two solid chemicals citric acid and sodium hydrogen carbonate react over time. If the tablet is left in the packaging too long the chemicals react with each other, making the once hard tablet soft. If a fresh Alka Seltzer tablet is added to water, the reaction of the sodium hydrogen carbonate solid with liquid water results in bubbles of Carbon Dioxide gas.

For a reaction to occur the reactants must have enough energy to get over a barrier called ACTIVATION ENERGY. This is similar to riding a bicycle over a hill. In order for you to ride down a hill you have pedal the bike to the top. If you never reach the top of the hill, you can't ride down the other side. In a reaction if the reactants cannot pass the activation energy barrier (reach the top of the hill) they cannot react (ride down). A catalyst speeds up a reaction by providing an alternate pathway, such as making the hill shorter and easier to get over or letting the reaction go around the hill, without being used up.



Be very careful if you are asked about this in an exam. The correct form of words is "A catalyst provides an alternative route for the reaction with a lower activation energy." It does



not "lower the activation energy of the reaction". There is a subtle difference between the two statements that is easily illustrated. Suppose you have a mountain between two valleys so that the only way for people to get from one valley to the other is over the mountain. Only the most active people will manage to get from one valley to the other. Now suppose a tunnel is cut through the mountain. Many more people will now manage to get from one valley to the other by this easier route. You could say that the tunnel route has lower activation energy than going over the mountain. But you haven't lowered the mountain! The tunnel has provided an alternative route but hasn't lowered the original one. The original mountain is still there, and some people will still choose to climb it.

Your job is to discover what can be done to change the rate of reaction, and to hopefully have fun while discovering.

Effect of Surface Area on Reaction Kinetics

Background

The more finely divided the solid is, the faster the reaction happens. A powdered solid will normally produce a faster reaction than if the same mass is present as a single lump. The powdered solid has a greater surface area than the single lump.

My Predictions:

1) Using powdered zinc will be _____ times faster than using lump zinc.
2) Using Mentos will be _____ times faster than using marbles.

Materials:

1 Package Mentos
12 marbles
1 bottle Diet Coke
Mossy Zinc
Powdered Zinc
1 M hydrochloric acid (HCl) (very dilute)
Liquid soap
Wood splint
Matches
Graph paper (last page of packet)

Procedure:

A) Mentos vs. Marbles in Diet Coke

1.) Carefully remove the cap from a bottle of diet Coke.
2.) Dump all 12 marbles rapidly into the bottle of diet Coke. Record the reaction on your data sheet
3.) Open one end of the tube of Mentos being careful not to bend or crush the tube.
4.) Dump the entire tube of mentos rapidly into the bottle of diet coke. (The faster the **entire tube** is dumped into the bottle of coke the more effective the reaction will be.)
5.) Record the results of the reaction on your data sheet

B) Powdered zinc vs. mossy lump zinc

6.) Pour 5 mL of HCl in each of 3 test tubes
7.) Mix in 1 drop of liquid soap to each test tube
8.) Add 1 small lump of mossy zinc to first test tube
9.) Time how long the bubbles take to reach the top of the test tube. Record the results in your data table
10.) Add a small spatula tip-full of powdered zinc to the second test tube
11.) Time how long the bubbles take to reach the top of the test tube. Record the results in your data table
12.) Make notes about the 3rd test tube. This is your control it is what we compare the other reaction rates to.

C) What is the gas inside the soap bubbles?

13.) Carefully light one end of a wooden splint

14.) Touch the end of the burning wooden splint to the bubbles. Record your observations in your data sheet.

Data Sheet:

Sample	Time (seconds)	Observations
Marbles		
Mentos		

Sample	Time (seconds)	Time (seconds)
Powdered Zinc		
Lump Zinc		
No Zinc		

Sample	Observations
Soap Bubbles	

Questions:

Effect of Concentration on Reaction Kinetics

Background

A RATE expresses how fast a chemical reaction occurs. The CONCENTRATION of a solution, how much of a specific reactant is in the liquid, can affect the reaction rate. The rate of most chemical reactions can be increased by increasing the concentration of the solutions.

My Predictions:

The reactants at a concentration ½ the original will react _____ times (circle one: slower or faster) than the original.

The reactants at a concentration ¼ the original will react _____ times (circle one: slower or faster) than the original.

Materials:

2 – Test tubes
Test Tube rack
Hydrogen Peroxide
Malonic Acid with Starch (various concentrations)
Potassium Iodate in Sulfuric Acid
Distilled Water
Stop Watch
Graph paper (last page of packet)

Procedure:

1.) Get a labeled test tube with 1mL of Malonic Acid with Starch. Record your number
2.) Get a second test tube with 1mL of Hydrogen Peroxide solution and 1mL of Potassium Iodate solution.
3.) Get out the stop watch and prepare to time the reaction.
4.) Pour the second solution into the numbered test tube. Do NOT shake.
5.) When the solution turns blue, start the timer.
6.) The color will disappear. When the solution turns blue again stop the timer.
7.) Record the time. Gather all of the data for the people at the station.
8.) Plot the number vs. time data on your graph paper.

Data Sheet:

Test Tube Number	Time (seconds)
1	
2	
3	
4	
5	
6	

Questions:

1) As the concentration of Malonic Acid with starch decreases the rate of reaction _____?
2) Which test tube number was the least concentrated?
3) At double the original concentration, it would take about _____ seconds for the reaction to occur.

Effect of Catalysts on Reaction Kinetics

Background

A catalyst is a substance which speeds up a reaction, but chemically appears unchanged at the end of the reaction. When a reaction has finished, you have exactly the same mass of catalyst as you had at the beginning. Normally a catalyst works by providing an alternate path for the reaction. Rather than the reaction going over the hill it lets the reaction go around the hill.

In this reaction we are going to look at the decomposition of hydrogen peroxide $2H_2O_2 \rightarrow 2H_2O + O_2$. This is a reaction that occurs naturally. If you leave a bottle of hydrogen peroxide on a shelf for a few months you will only have a bottle of water left. We are going to add two different catalysts to the H_2O_2 and compare the results. We are going to add a homogeneous catalyst, and a heterogeneous catalyst. Homogeneous means that the catalyst and the reactants are in the same phase, in this case liquid. Hetergeneous catalysts are in a different phase than the reactants, in this case a solid and a liquid.

My Predictions:

Using a homogeneous catalyst will make the reaction go _____ than using a heterogeneous catalyst.

Materials:

Graph paper (last page of packet)
10% (v/v) Hydrogen peroxide
Liquid soap
Manganese dioxide
Saturated potassium iodide solution
Wood splint
Matches
3 test tubes

Procedure:

A) Heterogeneous Catalyst

1.) Fill 3 test tubes ½ full of hydrogen peroxide
2.) Add 1 drop of liquid soap to each test tube swirl gently to mix but not hard enough to make bubbles
3.) Add a small spatula full of manganese dioxide to one test tube. Record how long it takes for the bubbles to reach the top of the test tube on your data sheet.

B) Homogeneous Catalyst

4) Add 1 drop of potassium iodide solution to one test tube. Record how long it takes for the bubbles to reach the top of the test tube on your data sheet.
5) Compare the heterogeneous and homogeneous catalyzed reaction test tubes to the test tube without a catalyst. Record the observations on your data sheet.

C) What is the gas inside the soap bubbles?

6) Carefully light one end of a wooden splint then blow it out
7) Touch the end of the glowing wooden splint to the bubbles. Record your observations in your data sheet.

Data Sheet:

Sample	Time (sec)	Observations
Heterogeneous Catalyst		
Homogeneous Catalyst		
No catalyst (control)		

Questions:

1) A catalyst speeds up a reaction by providing _____
2) Homogeneous catalyst and heterogeneous catalysts both _____ the rate of reaction
3) Homogeneous catalysts tend to make the reaction go _____ than the same amount of heterogeneous catalyst
4) Heterogeneous catalysts are used more often in industry because the catalyst can be _____ from the final product

Effect of Temperature on Reaction Kinetics

Background

In order for a chemical reaction to occur, the particles, atoms or ions, which are REACTANTS, must physically come into contact with one another. Anything that increases the frequency of these encounters will increase the rate at which PRODUCTS are formed. The rate of a chemical reaction can be increased by increasing the temperature of the reactants.

My Predictions:

Using hot water out of the tap, the rate of reaction will be _____ times faster than at 0 °C.
Using cold water out of the tap, the rate of reaction will be _____ times faster than at 0 °C.

Materials:

Stop watch
3 250 mL beakers
Thermometer
3 Alka-Seltzer tablets
Hot tap water
Cold tap water
Ice cubes
Graph paper (last page of packet)

Procedure:

A) Hot Tap Water

1.) Fill one beaker with 100 mL of hot tap water.
2.) Use the thermometer to take the temperature and record it on your data sheet
3.) Drop 1 Alka-Seltzer tablet into the water. Measure the time it takes for the tablet to fully dissolve. Record the time on your data sheet.
4.) Plot the time vs. temperature on your graph paper

B) Cold Tap Water

5.) Fill one beaker with 100 mL of cold tap water.
6.) Use the thermometer to take the temperature and record it on your data sheet
7.) Drop 1 Alka-Seltzer tablet into the water. Measure the time it takes for the tablet to fully dissolve. Record the time on your data sheet.
8.) Plot the time vs. temperature on your graph paper

C) Ice Cold Water

9.) Fill one beaker with 100 mL of water from the ice bath.
10.)Use the thermometer to take the temperature and record it on your data sheet
11.)Drop 1 Alka-Seltzer tablet into the water. Measure the time it takes for the tablet to fully dissolve. Record the time on your data sheet.
12.)Plot the time vs. temperature on your graph paper

Data Sheet:

Sample	Water Temperature (°C)	Time (seconds)
Hot Tap Water		
Cold Tap Water		
Ice Water		

Questions:

1) As the temperature of the water increases the rate of reaction _____?
2) At a temperature of 10 degrees C, it would take _____ seconds for 1 Alka-Seltzer tablet to react with 8 oz. of water.
3) If the temperature is doubled from 20 degrees C to 40 degrees C, the time for the rate of reaction _____by approximately _____.
4) Using hot tap water, the rate was _____ times faster than at 0 degrees C.