The catalytic decomposition of hydrogen peroxide essay sample

Science, Chemistry

Aim- The purpose of this investigation is to investigate how certain factors affect the catalytic decomposition of Hydrogen peroxide. I will investigate the effect of altering the mass of catalyst used on the rate of the decomposition of Hydrogen peroxide.

Introduction-

The decomposition of Hydrogen peroxide is a process by which Hydrogen peroxide decomposes into water and Oxygen. It has the following equation:

$2H_2O_2$ (l) —-> $2H_2O$ (l) + O_2 (g)

This reaction does occur spontaneously at room temperature with the presence of Ultraviolet light; however only very slowly. It occurs far faster when a catalyst is used. Catalysts are substances that speed the rate of a reaction without getting involved in the reaction therefore remaining unchanged at the end of it. They do this by lowering by lowering the activation energy of the substrate without being consumed. A peroxide ion collides with a catalyst ion producing an intermediate which is lower in energy than if two molecules of Hydrogen peroxide collided with each other which lowers the activation energy required for Hydrogen peroxide to decompose. If the Hydrogen peroxide is at a higher concentration, the molecules are more tightly packed together. Therefore there will be more collisions with an entity such as a catalyst. The same is true if more catalyst is present: if more catalyst molecules are present (and open to collision; it is the surface area that matters) then there is an increased chance of a

Hydrogen peroxide molecule colliding with a catalyst molecule because there are more catalyst molecules to collide with.

Therefore both increasing the concentration of the Hydrogen peroxide and increasing the surface area of the catalyst open to collision may increase the number of collisions between Hydrogen peroxide molecules and the catalyst therefore increasing the rate of catalytic decomposition. Collision theory states that for a reaction to take place the reactants must collide and the activation energy must be reached. More collisions through a higher concentration therefore means there are more reactions, and the catalyst, through lowering the activation energy through the presence of the intermediate, also increases the rate of reaction consequently.

Hypothesis- I predict that the higher the concentration of the Hydrogen peroxide; the rate of reaction will increase thereby producing products of the decomposition at a faster rate. Hydrogen peroxide only decomposes at a noticeable rate in the presence of a catalyst for the reasons described in the Introduction. Increasing the concentration of a given volume of Hydrogen peroxide means that more Hydrogen peroxide molecules are present which may react. If the Hydrogen peroxide is at a higher concentration, the molecules are also more tightly packed together and are therefore denser, and if the volume is the same, there are more Hydrogen peroxide molecules present. Therefore there are more likely to be more collisions as there are more particles in a given area which can collide with the catalyst. Therefore there will be more collisions with an entity such as a catalyst; and it is this collision with the catalyst that allows the reaction to take place. This increased number of collisions means more particles may react as the number of particles that are able to react where they were not before (due to the deduction in the amount of activation energy required via the catalyst) is also increased.

Doubling the concentration will double the chance for a certain number of molecules to collide with a catalyst as there is a double opportunity for it. Therefore increasing the concentration of Hydrogen peroxide increases the rate of reaction.

I believe that a graph will be obtained looking somewhat like this:

In all cases a high initial rate of reaction is obtained which gradually levels off as the reaction proceeds, until the rate of reaction is 0. As Oxygen and water are produced the water lowers the concentration of the Hydrogen peroxide present. This lowers the rate of reaction due to the lower concentration (as explained in the variables section). Once a Hydrogen peroxide molecule has decomposed it is no longer a consideration and cannot decompose again as it is no longer a Hydrogen peroxide molecule. This lowers the numbers of Hydrogen peroxide molecules present lowering the concentration thus lowering the rate of reaction, eventually lowering the rate of reaction to nil where all (or virtually all) Hydrogen peroxide molecules have decomposed. At this point no more products are produced as no more Hydrogen peroxide is reacting, as no more Hydrogen peroxide is colliding with catalyst particles, because it has all decomposed.

In this graph a higher concentration results in a higher rate of reaction whilst the reaction is proceeding (until the rate of reaction for all concentrations reaches 0) and a higher mass of product produced. This is because the increased chance of collisions with the catalyst, due to the increased number and density of the Hydrogen peroxide, means at the start of the reaction there are more collisions with the catalyst leading to a higher initial rate of reaction. I believe this rate of reaction will be proportional to the concentration as by increasing the concentration a certain amount you increase the number of molecules present by a proportional amount. You therefore also increase the chance of collision with the catalyst due to increased molecule density by a proportional amount.

Less total product is obtained by the smaller concentrations: I believe that this will be proportional to the concentration. The concentration is a measure of how many molecules are present in a given volume of Hydrogen peroxide. Therefore a lower concentration of Hydrogen peroxide means fewer molecules are present in the solution and therefore fewer molecules can decompose to produce a measurable product. The number of particles present in a certain volume of liquid is dictated by, and therefore proportional to, the concentration of that liquid as the concentration is a measure of the density of the solution and the number of molecules present in a certain volume. Since the amount of total product that can be produced by that number of particles is proportional to the number of molecules present the total product produced should be proportional to the concentration of the Hydrogen peroxide.

Variables- There are various variables in this experiment affecting the catalytic decomposition of Hydrogen peroxide; these are:

Refer to additional files.

Temperature- The temperature of the medium where the reaction occurs affects the rate of reaction. This is because increasing the temperature of the medium gives the particles in that medium a higher (average) energy. This means that they move and vibrate faster. This means that they have a higher chance at a certain time to collide with each other and to collide with a catalyst molecule in this case. This increase the number of collisions with a catalyst molecule, increasing the rate of reaction. Therefore the temperature of the reaction must be kept constant to ensure a fair test. This experiment will be carried out at room temperature; which cannot easily be controlled. However there are only small variations in room temperature of a specific room so the temperature will not change much therefore not affecting the rate of reaction to any significant degree.

Concentration of Hydrogen peroxide- The concentration of a reactant typically increases the rate of reaction. Altering the concentration of a liquid changes the number of molecules present in a given volume allowing for more production of products. As explained in the introduction, if there is a higher concentration there will be more collisions with the catalyst thus giving a faster reaction as explained in the hypothesis. This will be my independent variable; I will alter it to see the effect on the rate of reaction.

Type of catalyst- A catalyst (as stated in the introduction) is a substance that speeds up a reaction but remains unchanged at the end of it. Different catalysts differ in how effectively they do this and in how effectively they lower the activation energy required. Therefore changing the type of catalyst used will alter the rate of this reaction so the same catalyst will be used throughout the experiment.

Volume of Hydrogen peroxide- Increasing the volume of Hydrogen peroxide used (at a given concentration) will increase the number of particles present therefore resulting in more decomposition and more Water and Oxygen produced. Since these products are the only way of measuring the rate of decomposition, the volume of Hydrogen peroxide will be controlled throughout the experiment to ensure a fair test.

Surface area of catalyst grains- It is the contact surface area of a catalyst with a reactant that counts to catalyse a reaction. Using larger grains of catalyst will reduce the contact surface area for a given mass; so the catalyst cannot catalyse the reaction as well as if it was in smaller grains. Therefore I will need to keep the size of catalyst granules and therefore the surface area of each granule the same throughout the experiment. I will control the total surface area through controlling the mass of the catalyst.

Amount of catalyst used- Using more catalyst will mean that the catalyst meets the Hydrogen peroxide over a larger surface area to work on. Whilst it is the surface area of the catalyst (and not the mass that is used) that matters; it is extremely hard to accurately control the surface area of a given mass of catalyst as this cannot be easily measured. If equal size grains are used the contact surface area of the catalyst will be dictated by mass making it possible to control the variable. I will therefore keep the mass of catalyst used the same.

Speed of decomposition- This will be the dependent variable as how fast the reaction takes place depends on all the variables listed above. I will be changing the mass of catalyst used to see what effect it has on the decomposition of Hydrogen peroxide.

Preliminary work

Through preliminary work I will decide on:

– To decide on the best equipment and method of measuring the rate of reaction

– To see any major unseen problems that need to be solved before the main experiment.

– To ensure that the experiment is a fair test.

For preliminary work a simple experiment was set-up to measure the volume of gas produced over time during the reaction. A boiling tube was clamped and connected to a delivery tube which ran into a bowl of water with a udometer over the top of the end of the delivery tube. This udometer was used to measure the total volume of Oxygen gas produced. As Oxygen is produced from the decomposition of Hydrogen peroxide it displaces water in the udometer so that the volume of gas can be read by seeing how much water it has displaced. This is a diagram of the equipment:

(This was hand-drawn).

Here are the results for this experiment using this method and various catalysts:

Ten cm3 of “ 10” Hydrogen peroxide solution was used in each case with 0. 25grams of catalyst.

Manganese Oxide was also tested; but it was so effective that it was neither possible nor feasible to measure the effect of it in this experiment as so much Oxygen was produced so quickly.

Therefore we can conclude that Manganese Dioxide is the most effective catalyst out of the available catalysts. For the main experiment; it is needed to measure the reaction over a time period of at least a few minutes and to have an easily measurable amount of Oxygen produced in order to be able to see how the reaction has progressed easily. Therefore I will use Manganese Dioxide for the main experiment.

Another experiment was set up as shown:

(This was hand-drawn).

This is designed to measure the mass of Oxygen gas produced and lost from the system. As the reaction takes place, the Oxygen escapes and therefore there is a net mass loss which can be seen on the scales. This experiment was done using 50 cm3 of " 20" Hydrogen peroxide solution with varying masses of catalyst.

I have decided to use 0. 5g of catalyst: this is because it produces a reaction which lasts a few minutes: exactly what is needed. If a reaction is less than a few minutes it becomes hard to see how it progresses over a certain time-span and if a reaction is more than few minutes it is time wasting.

I have decided to use the second weighing method for the main experiment. This is because a great deal of Oxygen gas (at the start of the experiment when the rate of reaction is highest) is lost in the second method whilst the bung is being put in just after the catalyst is added.

I will use a range of " 5" to " 20" concentration for the main experiment. This provides a large enough range to collect results over and is possible to use. It is not possible, in this instance, to use a concentration of Hydrogen peroxide of more than 20. This is because 20 concentration is the highest concentration typically available from chemical companies, and whilst it is possible to dilute it down, it is not possible to easily increase the concentration. Therefore 20 is the highest concentration I can test for this experiment. I will not go below 5 concentration simply because the reaction below this concentration will be too slow and insignificant to be worth measuring, and any small inaccuracies would amount to huge percentage errors. I will take readings in between and including these values at intervals of 2. 5 concentration. This number of readings (meaning 7 reactions will be tested) means that a large range is being covered fully and a large enough number of readings are tested to ensure that a meaningful conclusion can be reached. Taking more data is unnecessary. I will do two check readings, three readings in all, for each concentration. This will make any anomalous data apparent and will make it possible to take an average reading for mass loss.

Method for the main experiment

Apparatus list-

Weighing scales- This is used to measure out the mass of catalyst required and the weight (over time) of the equipment and solution to determine weight loss.

A 150cm3 conical flask- this is used to house the Hydrogen peroxide and catalyst whilst the reaction takes place. A 150cm3 flask is large enough to house the liquid without risk of it spilling when effervescence occurs; but larger flasks (such as a 250cm3 one) have a lot of air in them above the solution where the reaction is occurring. This air is displaced and a lot of Oxygen actually remains therefore in the flask, not escaping and counting towards weight loss giving a false indication of the mass of Oxygen produced and lost from the flask.

A measuring cylinder- Used to measure out the Hydrogen peroxide.

“ 20” concentration Hydrogen peroxide- This is what decomposes for the experiment.

Distilled water- This is used to dilute the Hydrogen peroxide.

Cotton wool- This is used to “ plug” the top of the flask.

Manganese Dioxide catalyst- This is used as the catalyst for this reaction.

A plastic boat- This is used to measure out the catalyst into.

A spatula- This makes it possible to move the catalyst from a container so that it may be measured out.

A stop-clock- This is to keep track of the time so that appropriate readings may be taken at appropriate times.

Experimental method-

This is a diagram of the apparatus:

(This was hand drawn.)

A plastic boat will be placed on the weighing scales; which are then tared. This makes it possible to see how much mass has been added since the scales were tared. 0. 25grams of Manganese Oxide catalyst will then measured out into the boat.

The measuring cylinder will then be used to measure out 50 cm3 of the Hydrogen peroxide. This will then be transferred into the conical flask.

The total weight of the Flask (with its contents), the plastic boat (with its contents) and the cotton wool will then be taken. This is the total weight on the scale. The catalyst is then put into the Hydrogen peroxide and the top of the flask “ bunged” with the cotton wool. At the same time the stop-clock will be started. Every following ten seconds the mass of all the said contents on the scales (nothing will be removed; the plastic boat will be left on the scales) will be taken. From that it will be possible to work out the mass lost from the starting mass. Readings will continue to be taken every ten seconds until the reaction has completed (that is no more noticeable mass changes are occurring).

The experiment will then be repeated but by using different concentrations of Hydrogen peroxide: namely, “ 20”, “ 15”, “ 10” and “ 5” (these numbers refer to the volume in cm3 of Oxygen produced by the decomposition of 1 cm3 of the solution) level concentrations. This will be achieved by diluting the Hydrogen peroxide (at a “ 20” concentration as supplied), whilst keeping the same volume of solution, 50 cm3, by using a mixture of distilled water and Hydrogen peroxide. This is a table of the relative amounts of Hydrogen peroxide and distilled water required:

Precautions-

-When using the measuring cylinder the liquid volume must be read off at eye-level to avoid parallax error in order to ensure that the volumes read using the measuring cylinder are precise and reliable.

-The scales should be zeroed before weighing the equipment to check that the scales are in good working order and that they are not giving a reading with no equipment on it: this would affect the mass reading obtained for the equipment producing imprecise and unreliable data.

-Care must be taken when handling Hydrogen peroxide; and goggles must be worn during the experiment to protect the eyes.

-Care must be taken not to plug the Cotton wool too tightly so that it does not allow gas to escape leading to a build up of pressure and an untrue reading of the mass lost as Oxygen in this case is not being allowed to escape and builds up pressure inside the flask which can be dangerous and will not have its mass taken into account as mass lost.

Fair test-The experiment needs to be a fair test. This is important, as it is not possible to see the effect of only one factor (here, the concentration of Hydrogen peroxide if other factors are altered). This means that the experiment has to be easily reproducible; i. e. it must be easy to carry it out exactly the same way each time it is done. The experiment is easy to carry out in the same fashion each time with the given equipment. In addition t controlling the factors discussed above: The cotton wool used must be kept the same throughout the experiment to ensure a fair test: using a different clump of cotton wool may mean that clump blocks the Oxygen escaping more or less, particularly at the beginning of the experiment. The same scales ought to be used throughout the experiment, as different scales can be calibrated slightly differently and therefore have different sensitivities to different masses which may affect the results obtained.