How does acid rain affect buildings

Abstract: In this Extended Essay I am investigating the pH of the acid rain in Munich by titrating the collected rain water in Munich. I am also investigating the effects of the acid rain on the buildings in Munich which are made out of limestone and I am also working out how long it would take for the building to disintegrate with a certain pH value. Judging on the results the pH value in the Munich area is not low enough to destroy the buildings made out of limestone even in the long run. The pH is still around 5. 5 which would mean that it would take around xxxx (didn’t test that yet) years for the building to take significant damage.

Table of Contents

Contents Page Number

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Introduction: If the pH in the Munich area is too low then this would affect the buildings in Munich significantly. This is because most buildings are made out of limestone because around 100 years ago limestone was a good material to build with but it was still unknown that acid rain would affect limestone to this extent. Therefore many important buildings in Munich have been made out of limestone for example the Munich Town hall. There is however a way to save these buildings like the people did in cologne where the Koelner Dom was coated in a plastic material so that the acid rain wouldn’t affect the building because plastic doesn’t react with the acid rain so that the acid rain does not reach the limestone underneath the plastic coating.

Variables: Time between the different samples of rain that have been taken and the amount of rain collected.

Hypothesis: I think that the pH of the rain in Munich should be around 5-7 because of the industrial regions in Munich and the Automobiles using fossil fuel producing gases responsible for the formation of acid rain (i. e. NO_2, SO_2). The gases released form 2 kinds of acid rain: H_2SO_4 and HNO_3. Here are some equations to show how the acid rain is formed in the atmosphere:

To form H_2SO_4 we need SO_3 but in the industry and in automobiles the sulphur oxides are in the form of SO_2. The reaction that takes place in the atmosphere oxidizes SO_2 to become SO_3 but because SO_2 does not spontaneously react with O_2 it is being oxidized with NO_2:

$SO_2(g) + NO_2(g) \rightarrow NO(g) + SO_3(g)$

NO does react spontaneously with O_2 so the following reaction occurs:

$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$

Therefore the NO_2 which is needed in the first reaction regenerates every time it gets used up as seen in the second reaction and so therefore it acts as a catalyst for the first reaction. With SO_3 in the atmosphere it can now form H_2SO_4 in the following equation:

$SO_3(g) + H_2O(l) \rightarrow H_2SO_4(aq)$

The other known form of acid rain which contains nitric acid is formed by the reaction between nitrogen dioxide and water:

$2NO_2(g) + H_2O(l) \rightarrow HNO_3(aq) + HNO_2(aq)$

Or it is oxidized directly to nitric acid by oxygen in the presence of water:

$4NO_2(g) + O_2(g) + 2H_2O(l) \rightarrow 4HNO_3(aq)$

These are the main gases that produce acid rain. In nature however rain is naturally acidic due to the carbon dioxide in the air which has been dissolved in the rain water therefore the natural pH of the rain are 5. 65 but with a pH of 5. 65 it is not considered acid rain, if the rain has a pH of lower than 5. 6 it is considered acid rain. Of course the acidity of the rainwater also reflects in other precipitations like snow, hail, dew and fog. The short term effects of acid rain on buildings are not that significant where as the long term effects can be devastating. Acid rain can destroy buildings over a long period of

time if the pH is low enough. Of course the only buildings affected are those which are made out of stone which reacts with acid rain for example marble are very easily eroded by acid rain. The sulfuric acid in the rain reacts with the marble to form calcium sulphate which can be washed off by the rain water thus exposing more of the marble to erosion. Also salts could form inside the stone causing it to crack and disintegrate slowly from the inside.

Aim: To test the rainwater in Munich and to find out the pH level of the rain and the affect on buildings made out of limestone in Munich.

Method:

1. Set up a safe rain water collector where the rain will fall directly into the container so that contamination is kept to a minimum. For each sample collect at least 300 mL of rainwater.

2. Keep the rainwater which is not yet being used for experiments in a safe glass container which is sealed to prevent evaporation.

3. Set up the apparatus as shown in diagram 1-a

4. Fill up the burette with 1*10-4 mol L-1 NaOH.

5. Fill a beaker up with 150 mL of the collected rain water.

6. Put 1-2 drops of methyl orange indicator in the beaker containing the rainwater.

7. Titrate the rainwater with the NaOH.

8. Titrate until the indicator changes color then note the burette reading at which the color changed.

9. Repeat the steps 1-7 every time you collect a new sample of rain.

Results: All the results are listed as the pH of the rainwater deduced from the titration. The results were each taken whenever it was raining in the Munich area. All the results of a month have been recorded and also have been averaged.

Conclusion: My hypothesis was right the pH of the rainwater is just below 6 in the Munich area where I live. This pH level is not affecting the buildings in Munich like the Town Hall significantly. Even over a long time period this pH will not dissolve the buildings noticeably. There are worse regions for example at the east coast of the United States and Canada where the pH is as low as 4 (diagram 2-a).

Also the pH of the fog in Los Angeles was measured for its pH and that was as low as 2 (diagram 2-b)

in those regions the acid rain affects the buildings a lot and also the flora and fauna of the region is endangered. To reduce the rate at which the pH of the rain decreases we have to reduce the pollution which is the main reason for acid rain. NO_2 and SO_3/SO_2 are responsible for acid rain and from acids in a reaction in the atmosphere where these two gases combine with water as shown in the equations in the hypothesis. These gases are released by smelting sulphur, car exhausts, engine exhausts, power plants which use fossil fuel and various other industrial factories. These gases can be reduced

by using a different energy source apart from fossil fuel in cars and power plants, an example for this would be solar power, wind or water power which are all being ventured already but have not yet been standardized due to the early stages of these methods of gaining energy.

Also a better engine design and the use of catalytic converters could reduce the formation of the gases, reducing the amount of private transport and increasing public transport can also help the environment. Another method to reduce the formation of the acid rain causing gases is to pass environmental laws limiting the amount of the gases being formed in industries. From this we can deduce that in regions where industry is very concentrated and where environmental laws have not been passed or are ignored and not being followed the pH is respectively low. However even regions which do not have a concentrated industrial region and a polluting environment acid rain can still form. This is because winds can carry the pollution over a significant distance thus causing acid rain occurring even in regions where pollution is low or not at all present.

Evaluation: The experiment had a few errors like every experiment. Due to the fact that all the data was from titration there are some factors that could have affected the data collected so that it could be different from the actual data. For example the burette has its own error range due to the reading which ranges from +0. 075 and -0. 075. Because I had to standardize the chemicals first the burette error could have affected the whole experiment so that the results are not displaying the actual pH of the rainwater. However the possibility of that occurring is low. Of course the readings of any other equipment could have been faulty too for example pipetting the solutions

could have lead to a wrong result due to misreading the pipette. These errors however only affect the results minimally so are of no major concern. Another source of error could be from the collection of the rainwater.

Since the rainwater was collected outdoors in an open container, contamination can not be excluded. Any substance could have gone into the container and alter the pH of the rainwater thus leading to false results. To reduce the error due to readings to a minimum I repeated my experiments several times with the same sample of rainwater to ensure that the possibility of a false reading is kept low. For the problem with the contamination the most practical method was just to keep the container inside when it didn’t rain and just leave it out in the rain long enough to get the wanted amount of rainwater needed for testing so that the container is not exposed to influences that could cause a false result for too long if there are any.