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CHEMISTRY

Finding the Effects of Acids on Carbonates

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Abstract

Around the world, it is observed that lots of buildings, historical places are harmed. The damaged buildings have in common the features of the rainfall in their places. Effect of acid rain in these types of locations had been observed. Damages of the buildings have emerged because of the acid rains. The purpose of this project is observing the effects of different acids on the material of these types of buildings.

The experimental design was prepared with the acids which we have got high probability to experience in our daily lives and with the building materials that can be characterized as carbonates. And also as carbonates, marbles has been preferred since they are more similar to the structures of buildings, where the carbonate as the dense. Used acids can be sorted into coke, vinegar, lemon juice, nitric acid and sulfuric acid.

By comparing the observations, the most effective acid on carbonates and also the most powerful acid in the combination of acid rain can be found. This extended essay contains the background information about the subject, the collected data and analysis of these data. In addition, it includes the prevention and protection ways for the buildings and any other materials that can be affected by acids.

(231 words)

TABLE OF CONTENTS

1. INTRODUCTION

From the beginning of the industrial revolution, acid rain is one of the important factors that threat the nature. It can damage lots of material, including the human beings. On the other hand, so far, it was observed that the acid rain has been shown to have adverse impacts on mainly the carbonate containing buildings (They are mostly historical places because of the fact that as the effects of the acid rain was understood, most of the buildings constructed with keeping in mind the impact of acid rain.), forests, freshwaters and soils, killing insect and aquatic life-forms as well as having impacts on human health. The main factors of this process are kinds of acids containing. SO_2 and NO_X (mainly NO and NO_2), play a significant role in acid rain, these gases have direct relationship with their own acids which would be formed the acid rain. These acids would be formed from the series of reactions.

Acids can be considered as a pollutant and causes a lot of environmental problems. As a result, scientists are searching for ways of reducing the effects of acid rain as well as lots of organizations which struggle for having better environment, try to make people conscious of stopping the production of harmful gases.

2. RESEARCH QUESTION

Is there any effect of acids on the carbonates? If so, what kind of effects are they and which one among five different acids containing; coke, vinegar, lemon juice, nitric acid, sulfuric acid, is most effective?

2.1 Approaches to the Research Question

For analyzing data and understanding the result; acid behaviors towards carbonates, the characteristic properties of chosen acids must be clearly understood and also the basic mechanism of acid rain, the process of acid deposition must be researched on.

3. BACKGROUND INFORMATION

3.1 General Information about Acids

An acid (from the Latin acidus meaning sour) is traditionally considered any chemical compound that, when dissolved in water, gives a solution with a hydrogen ion activity greater than in pure water, i.e. a pH less than 7.0. That approximates the modern definition of Johannes Nicolaus Brønsted and Martin Lowry, who independently defined an acid as a compound which donates a hydrogen ion (H^+) to another compound (called a base). Common examples include acetic acid (in vinegar) and sulfuric acid (used in car batteries). Acid/base systems are different from redox reactions in that there is no change in oxidation state. Acids can occur in solid, liquid or gaseous form, depending on the temperature. They can exist as pure substances or in solution. The strength of an acid refers to its ability or tendency to lose a proton. A strong acid is one that completely dissociates in water; in other words, one mole of a strong acid HA dissolves in water yielding one mole of H^+ and one mole of the conjugate base, X^-, and none of the protonated acid HA. In contrast a weak acid only partially dissociates and at equilibrium both the acid and the conjugate base are in solution. Examples of strong acids are hydrochloric acid (HCl), hydroiodic acid (HI), hydrobromic acid (HBr), perchloric acid ($HClO_4$), nitric acid (HNO_3) and sulfuric acid (H_2SO_4). In water each of these essentially ionizes 100%. The stronger an acid is, the more easily it loses a proton, H^+. Two key factors that contribute to the ease of deprotonation are the polarity of the H—A bond and the size of atom A, which determines the strength of the H—A bond. Acid strengths are also often discussed in terms of the stability of the conjugate base.Stronger acids have a higher K_a and a lower pK_a than weaker acids. Sulfonic acids, which are organic oxyacids, are a class of strong acids. A common example is toluenesulfonic acid (tosylic acid). Unlike sulfuric acid itself, sulfonic acids can be solids. In fact, polystyrene functionalized into polystyrene sulfonate is a solid strongly acidic plastic that is filterable. Super acids are acids stronger than 100% sulfuric acid. Examples of superacids are fluoroantimonic acid, magic acid and perchloric acid. Superacids can permanently protonate water to give ionic, crystalline hydronium "salts". They can also quantitatively stabilize carbocations.

3.2 Acid Rains

As general, acid rain is rain or any other form of precipitation that is unusually acidic. It has harmful effects on plants, aquatic animals, and infrastructure. Acid rain is mostly caused by human emissions of sulfur and nitrogen compounds which react in the atmosphere to produce acids. In recent years, many governments have introduced laws to reduce these emissions. As more detailed, acid rain is a popular term referring to the deposition of wet (rain, snow, sleet, fog and cloud water, dew) and dry (acidifying particles and gases) acidic components. A more accurate term is “acid deposition”.

Since the Industrial Revolution, emissions of sulfur dioxide and nitrogen oxides to the atmosphere have increased. In 1852, Robert Angus Smith was the first to show the relationship between acid rain and atmospheric pollution in Manchester, England. Though acidic rain was discovered in 1852, it was not until the late 1960s that scientists began widely observing and studying the phenomenon. The term "acid rain" was generated in 1972. Occasional pH readings in rain and fog water of well below 2.4 (the acidity of vinegar) have been reported in industrialized areas. Industrial acid rain is a substantial problem in Europe, China, Russia and areas down-wind from them. These areas all burn sulfur-containing coal to generate heat and electricity. The problem of acid rain not only has increased with population and industrial growth, but has become more widespread. The use of tall smokestacks to reduce local pollution has contributed to the spread of acid rain by releasing gases into regional atmospheric circulation. Often deposition occurs a considerable distance downwind of the emissions, with mountainous regions tending to receive the greatest deposition (simply because of their higher rainfall).

The most important gas which leads to acidification is sulfur dioxide. Emissions of nitrogen oxides which are oxidized to form nitric acid are of increasing importance due to stricter controls on emissions of sulfur containing compounds. The principal natural phenomena that contribute acid-producing gases to the atmosphere are emissions from volcanoes and those from biological processes that occur on the land, in wetlands, and in the oceans. The major biological source of sulfur containing compounds is dimethyl sulfide. Acidic deposits have been detected in glacial ice thousands of years old in remote parts of the globe.

The principal cause of acid rain is sulfur and nitrogen compounds from human sources, such as electricity generation, factories, and motor vehicles. Coal power plants are one of the most polluting. The gases can be carried hundreds of kilometers in the atmosphere before they are converted to acids and deposited. In the past, factories had short funnels to let out smoke, but this caused many problems locally; thus, factories now have taller smoke funnels. However, dispersal from these taller stacks causes pollutants to be carried farther, causing widespread ecological damage.

Figure 1 :

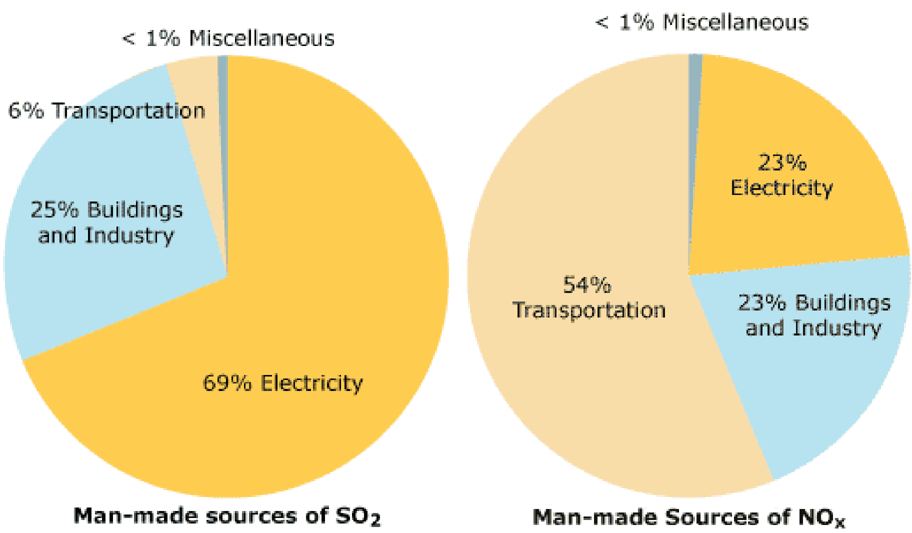

Figure 1 : sources of the production of gases, SO_2, NO_X.

3.3 The Properties of Chosen Acids

In this experiment, chosen acids are vinegar, coke, lemon juice, nitric acid and sulfuric acid. Especially, vinegar, coke and lemon juice have chosen for their effects on carbonates. In our daily lives, we face with acids via mostly vinegar, coke and lemon juice. For comparing their effects on our daily lives, they have chosen. Nitric acid and sulfuric acid have chosen for mostly scientific comparison.

Vinegar

Vinegar is the most common application of the acetic acid.In the form of vinegar, acetic acid solutions (typically 5% to 18% acetic acid, with the percentage usually calculated by mass) are used directly as a condiment, and also in the pickling of vegetables and other foodstuffs. Table vinegar tends to be more diluted (5% to 8% acetic acid), while commercial food pickling generally employs more concentrated solutions. The vinegar used in this experimental study is table vinegar, because table vinegar is commonly used in our daily lives. The amount of acetic acid used as vinegar on a worldwide scale is not large, but historically this is by far the oldest and most well-known application.

Acetic acid, CH_3COOH, also known as ethanoic acid, is an organic acid which gives vinegar its sour taste and pungent smell. Pure, water-free acetic acid (*glacial acetic acid*) is a colourless liquid that absorbs water from the environment (hygroscopy), and freezes at 16.7 °C (62 °F) to a colourless crystalline solid. It is a weak acid, in that it is only partially dissociated acid in aqueous solution

Acetic acid is one of the simplest carboxylic acids. It is an important chemical reagent and industrial chemical, used in the production of polyethylene terephthalate mainly used in soft drink bottles; cellulose acetate, mainly for photographic film; and polyvinyl acetate for wood glue, as well as synthetic fibres and fabrics. In households, diluted acetic acid is often used in descaling agents. In the food industry acetic acid is used under the food additive code E260 as an acidity regulator.

Coke

Coke is the most common drink in the world with it's caramel colouring and containig caffeine.The acidity of coke is often provided by phosphoric acid, sometimes accompanied by citric or other isolated acids. Being carbonated, colas are acidic (carbonic acid is formed when carbon dioxide dissolves in water), and so can react violently with basic chemicals, such as baking soda. Many types of cola also contain phosphoric acid and/or citric acid, which further increase the acidity. Colas containing phosphoric acid have been linked to chronic kidney disease. It simply shows the effect of phosphoric acid on human health. Drinking two or more of these colas per day more than doubled the incidence of kidney disease, while it is said that colas containing citric acid did not have an effect.

Carbonic acid, (ancient name acid of air or aerial acid) has the formula H_2CO_3. It is also a name sometimes given to solutions of carbon dioxide in water, which contain small amounts of H_2CO_3. The salts of carbonic acids are called bicarbonates (or hydrogen carbonates) and carbonates. It is a weak acid.

Phosphoric acid, also known as orthophosphoric acid or phosphoric(V) acid, is a mineral (inorganic) acid having the chemical formula H_3PO_4. Orthophosphoric acid molecules can combine with themselves to form a variety of compounds which are also referred to as phosphoric acids, but in a more general way.

Citric acid, is a weak organic acid, and it is a natural preservative and is also used to add an acidic, or sour, taste to foods and soft drinks. In biochemistry, it is important as an intermediate in the citric acid cycle and therefore occurs in the metabolism of virtually all living things. It can also be used as an environmentally benign cleaning agent. It is weak acid because of being carbonic acid.

The carbonic acid has the highest concentration in most of the cokes so in this experiment, comparisons, analyses are done according to the carbonic acid.

Lemon Juice

Basically, lemon juice is a kind of juice which is made from lemons and it contains vitamin C, in other words, ascorbic acid.

Ascorbic acid is a sugar acid with antioxidant properties. Its appearance is white to light-yellow crystals or powder, and it is water-soluble. One form of ascorbic acid is commonly known as vitamin C. Ascorbic acid, the formula of which is $C_6H_8O_6$, behaves as a vinylogous carboxylic acid. As ascorbic acid is an organic acid, it classifies in weak acids.

Nitric Acid

Nitric acid (HNO3), also known as aqua fortis and spirit of nitre, is a highly corrosive and toxic strong acid that can cause severe burns. Colorless when pure, older samples tend to acquire a yellow cast due to the accumulation of oxides of nitrogen. Being a typical acid, nitric acid reacts with alkalis, basic oxides, and carbonates to form salts, such as ammonium nitrate. Due to its oxidizing nature, nitric acid generally does not donate its proton (that is, it does not liberate hydrogen) on reaction with metals and the resulting salts are usually in the higher oxidized states. For this reason, heavy corrosion can be expected and should be guarded against by the appropriate use of corrosion resistant metals or alloys. Nitric acid is made by reacting nitrogen dioxide (NO_2) with water.

Sulfuric Acid

Sulfuric (or sulphuric) acid, H_2SO4, is a strong mineral acid. It is soluble in water at all concentrations. Sulfuric acid has many applications, and is one of the top products of the chemical industry. World production in 2001 was 165 million tones, with an approximate value of US$8 billion. Principal uses include lead-acid batteries for cars and other vehicles, ore processing, fertilizer manufacturing, oil refining, wastewater processing, and chemical synthesis.

3.4 Carbonates / Marbles

In chemistry, a carbonate is a salt or ester of carbonic acid. The term "carbonate" is also commonly used to refer to one of these salts or carbonate minerals. Most common is calcite, or calcium carbonate, $CaCO_3$, the chief constituent of limestone. The process of removing carbon dioxide from these salts by heating is called calcination. In this process, marbles are used and they are formed from the most common carbonate, calcium carbonate. **Calcium carbonate** is a chemical compound with the chemical formula $CaCO_3$. It is a common substance found in rock in all parts of the world, and is the main component of shells of marine organisms, snails, pearls, and eggshells. Calcium carbonate is the active ingredient in agricultural lime , and is usually the principal cause of hard water. It is commonly used medicinally as a calcium supplement or as an antacid, but high consumption can be hazardous. **Marble** is a no foliated metamorphic rock resulting from the metamorphism of limestone, composed mostly of calcite (a crystalline form of calcium carbonate, $CaCO_3$). It is extensively used for sculpture, as a building material, and in many other applications. In this experiment, the aim is to find the effect of different acids on marbles. The research question is mainly formed by the damage of the buildings and sculptures after the acid rains.

3.5 The Reaction between Carbonates and Acids

Acid- carbonate reactions are one of the most main reactions as a chemical reaction in chemistry. Acid- carbonate reaction is the reaction between an acid a carbonate forming a salt, carbon dioxide and water as products. Some examples are given below;

1. Nitric acid and sodium carbonate ---> sodium nitrate and carbon dioxide and water $2HNO_3 + Na_2CO_3 \text{ ---> } 2NaNO_3 + CO_2 + H_2O$

2. Sulphuric acid and calcium carbonate --->calcium sulphate and carbon dioxide and water $H_2SO_4 + CaCO_3 \text{ ---> } CaSO_4 + CO_2 + H_2O$

4. HYPOTHESIS

In this research work, the aim is to investigate the effect of the different acids on the marbles, in other words on carbonates. Marbles are chosen from the same place for providing the same structure. As it is searched before starting the experiment, there must be a hypothesis to determine the target of the experiment. In this experiment, hypothesis deals with the mass change of the used carbonate. The total mass of the reaction mixture will only vary if a gas is evolved. To be really effective, the gas being evolved should have a high molar mass, so there is a significant change in mass, also the gas should not be significantly soluble in the solvent used. As the carbon dioxide is one of the products in acid-carbonate reactions, there must be a significant mass change on the carbonate which turns to carbon dioxide. For example, if the evolved gas is hydrogen, it is difficult to obtain a significant change in mass. The chosen metal carbonate (such as calcium carbonate, marble chips) and the chosen acids will provide an abundant experiment.

5. EXPERIMENTAL SET UP AND PROCEDURE

Experimental set up and procedure is one of the most important factors in an experiment. As the experiment works on a comparison between the effects of chosen acids, it must be a controlled experiment. The marble chips in the laboratory are got from the same place for providing same structure. There must be a little difference between them which will discuss in conclusion.

Preparation of the Initial Set Up

First of all, five groups are constituted: vinegar, coke, lemon juice, nitric acid, sulfuric acid. Three trials are done for each group. Fifteen beakers are prepared and each one is classified. All of them are filled with its fluid and all of them are 100.0 (±0.1) mL. Each beaker is numbered because the numbers on the marbles can be wiped because of the chemical reaction between them. It is not possible to change the molarities of the coke, vinegar and lemon juice but to get more effective results, the molarities of the nitric acid and sulfuric acid are equalized and both of them are 0.1 molar. The initial pH values of the fluids are taken and noted down. Fifteen marble chips are chosen which are approximately having same sizes, numbered, weighed on weighing machine and put into the beakers with the help of a gantlet. The beakers are put at a safe place in the laboratory and changes are waited for one week.

Continuous Procedure

After one week, marbles are taken to outside from the beakers and waited for them to be dry for approximately four hours. Then each one is weighed and the data is noted down. And also pH values of the fluids are again noted down.

6. DATA COLLECTION

Table 1:

Groups (In each group, all the beakers filled with 100.0 (±0.1) mL fluids.)	**Number of Trials**	**Initial pH Values (±0.01)**	**Mass of the Initial Marble Chips (±0.001) (gram)**
Vinegar	1	3.11	33.725
	2	3.12	41.030
	3	3.16	39.111
Coke	1	2.78	43.148
	2	2.74	30.978
	3	2.78	55.728
Lemon Juice	1	2.43	26.374
	2	2.53	23.904
	3	2.48	64.171
Nitric Acid	1	1.52	59.582
	2	1.61	33.812
	3	1.54	33.835
Sulfuric Acid	1	1.58	29.906
	2	1.64	25.247
	3	1.59	33.065

Table 1: Collected initial pH data of the fluids and initial mass data of the marble chips.

Table 2:

Groups	Number of Trials	Collected pH Values After One Week (±0.01)	Mass of the Marble Chips After One Week (±0.001) (gram)	Volume of the Fluids in the Beaker After One Week (±0.1) (mL)
Vinegar	1	5.63	30.601	70.0
	2	5.62	38.242	60.0
	3	5.56	36.303	60.0
Coke	1	5.39	43.087	70.0
	2	5.42	30.808	75.0
	3	5.44	55.685	70.0
Lemon Juice	1	5.84	25.228	65.0
	2	6.05	22.547	65.0
	3	6.01	62.014	65.0
Nitric Acid	1	7.20	59.103	65.0
	2	7.63	33.328	65.0
	3	7.60	33.083	65.0
Sulfuric Acid	1	2.38	29.666	73.0
	2	2.42	25.129	75.0
	3	2.39	32.916	73.0

Table 2: Collected pH values of the fluids after one week and mass values of the marble chips after one week.

Qualitative Observations:

During this experimental study, there are qualitative changes on the marbles and also on the liquids. In this part, they will be presented.

Table 3:

Groups (All qualitative observations are same for same group members.)	**Qualitative Changes on the fluids and also on the marbles**
Vinegar	On the surface of the vinegar, there are grey materials like a thin lime layer. The numbers written on the marbles are cleaned.
Coke	On the surface of the coke, there are green-white circles like moldy. The numbers written on the marbles are not cleaned.
Lemon Juice	The lemon juice gets brighter and there are white materials at the surface of it. The numbers written on the marbles are cleaned.
Nitric Acid	There is not any big difference but the numbers written on the marbles are cleaned.
Sulfuric Acid	The numbers written on marbles are cleaned and also

Table 3: Observed qualitative changes for each group.

7. DATA PROCESSING AND PRESENTATION

Table 4:

Groups	Number of Trials	Difference Between Initial and Final PH Value (±0.01)	Difference Between Initial and Final Mass of the Marble (±0.001) (gram)	Difference Between Initial and Final Volume of the Fluids in the Beaker (±0.1) (mL)
Vinegar	1	2.52	3.124	30.0
	2	2.50	2.788	40.0
	3	2.40	2.808	40.0
Coke	1	2.61	0.061	30.0
	2	2.68	0.170	25.0
	3	2.66	0.043	30.0
Lemon Juice	1	3.41	1.146	35.0
	2	3.52	1.357	35.0
	3	3.53	2.157	35.0
Nitric Acid	1	5.68	0.479	35.0
	2	6.02	0.484	35.0
	3	6.06	0.752	35.0
Sulfuric Acid	1	0.80	0.240	27.0
	2	0.78	0.118	25.0
	3	0.80	0.149	27.0

Table 4: Table of the differences between initial and final values and they are found with a simple subtraction method.

8. CONCLUSION AND EVALUATION

In this experimental study, aim is to investigate the effects of different acids on carbonates, marbles. Chosen acids are the most employed acids in our daily lives and also most known acids in science, in chemistry. Vinegar, coke, lemon juice are mostly used in kitchen. On the other hand, sulfuric acid and nitric acid are mostly known with their relationships with acid rains. In this experimental study, vinegar, coke and lemon juice will be analyzed in itself. And also sulfuric acid and nitric acid will be analyzed in itself too. This classification is done for obtaining efficient analysis.

To obtain and observe the effects of acids, they are reacted with carbonates. Results, analysis and problems that may occurred, will be discussed in this part.

First of all, vinegar, coke and lemon juice will dissect. Collected data shows that most powerful and also effective acid on carbonates is vinegar. Vinegar, in other words acetic acid, reacts with the carbonates mostly, because of the fact that the difference of the volume in beaker and the difference in mass change is most for vinegar. The least effective acid on carbonates is coke, carbonic acid. It can be easily predicted that coke is the weakest since it is known that carbonic acids are weak acids in chemistry. In this experiment it will be again proved that coke does not provide big mass changes on carbonates. Lemon juice provides the biggest Ph change in this group. Especially vinegar and lemon juice damages the workbenches in the kitchens. In recent years, the material of these workbenches is marble. So because of the vinegar and lemon juice which may split on the workbenches, they get damaged as time passes. With time, as the effect of vinegar and lemon juice is understood, the material of the workbenches in the kitchens is changed. For prevention, choosing any other material instead of marble for workbenches in the kitchens is the best way to prevent the damages.

Secondly, sulfuric acid and nitric acid are vital for analyzing the acid rains. In this experiment, nitric acid is the acid which provides the biggest difference in Ph values and mass changes. Nitric acid is more powerful than the other one. It also informs us about their effects in acid rains. It can be understood that, in acid deposition, nitric acid has a significant role so in other words, nitric acid is the most effective gas in acid rain structure. Acid rains can cause damages on buildings which are formed with marbles and carbonates. Nitric acid is more responsible for these types of damages on buildings, sculptures.

If all acids are compared, there is unexpected result that acetic acid is more effective than nitric acid or sulfuric acid on carbonates. On the other hand it is known that they are more strong acids than the other ones. This problem is mainly related with their molarities. The molarities of sulfuric and nitric acid are 0.1(± 0.1) M and this can be classified as low concentration. Low concentration of these acids can reduce the effects too, so these acids can not provide big mass changes. Adjusting same molarities for coke, vinegar and lemon juice is impossible in our laboratory conditions. This can be one of the sources of error. And also the structures of the chosen marbles are not same completely; this can be other sources of error. But it is not possible to find completely same structured marbles. For obtaining better results the molarities of nitric acid and sulfuric acid must be increased because in acid rains their concentrations are obviously higher.

The concentrations of the acidic gases in acid rains cause various damages. Some effects of acid rain in the city, especially the sculptures, monuments and works of art made of marble in the outer surface can be seen clearly. For example, the Taj Mahal in India, polluting in the surrounding environment occurs due to industry, was destroyed by acid gases. This 350-year work of art is faced with the threat of extinction. It is possible to reproduce similar examples. Today, it is not possible to avoid from formation of this kind of damages on arts in such large locations of the industrial zone, ancient cities, and historical works of art as a concentrated area near the residential areas. In this regard, the protection of works of art to draw attention to these issues is good. Moreover, comparison of the relative strength of the acid or base is necessary to investigate to what extent can change. Prevention from acid rains can be obtained by conscious building construction and by avoiding using marbles in construction, especially in the places where acid rains occurs.