Year 9 Acid Rain PDR

Spyridon Manolidis

Jan. & Feb. 2024

1 Introduction

This is a paper as part of the Corpus Christi High School Year 9 P.D.R.[1] on acid rain.

The aim/brief is to:

Investigate if magnesium erodes in a shorter time when the concentration of Acid is increased.

2 Research

2.1 Definition & Formation of Acid Rain

Acid rain is a term that includes any form of precipitation with acidic components, for example, sulphuric/nitric that falls to the ground from the atmosphere in wet or dry form.[1] More scientifcally, it is also defined as any rainfall that has an acidity level beyond what is expected in non-polluted rainfall (referred to in the next subsection). This can include rain, snow, fog, hail, or even dust that is acidic.

Acid rain is a consequence of sulphur dioxide & nitrogen oxide being emitted into the atmosphere and transported by wind by wind & air currents. Although a small portion of sulphur dioxide & nitrogen oxide is produced naturally, occuring from volcanoes, the majority is from the burning of fossil fuels, vehicle exhaustion, manufacturing & oil refineries. They react with water, oxygen and other chemicals, forming sulphuric & nitric acid. These acids then mix with water and fall to the ground. These reactions can be described as the following word equations:
Firstly,

$$2\,\mathrm{SO_2} + \mathrm{O_2} \longrightarrow 2\,\mathrm{SO_3}$$

Then,

$$SO3 + H2O - > H_2SO_4$$

Finally, the acid rain can then react with the metal in what is called a **redox** reaction.

2.2 Acid Rain pH Range & its Effect on Metalic Objects

Generally, pH 5.6 is used as the base line for acid rain, with precipitation of less than 5.6 considered to be acidic precipitation.[4] Acid rain generally has a pH between 4.2 - 4.4, although this can and does vary over the years and is heavily dependent on the geographical location (this can be proven in the graph below, showing how acid rain pH levels can flactuate over the years).

Additionally, the acid particles corrode metal and cause paint & stone to deteriorate quickly. The consequences of such damages can be costly. Damaged vehicles need to be replaced/repaired and there are increased maintenence costs.

[1] Policy, Development & Research

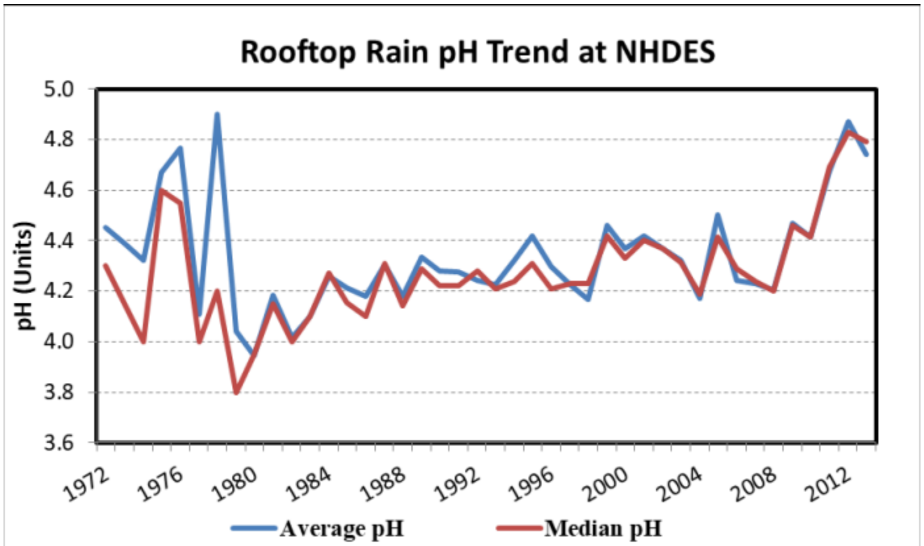


Figure 1: Trend in pH values of precipitation collected at NHDES through the Rooftop Rain Program, 1972 – 2013. [5]

2.3 Collision Theory

[3] Collision theory dictates that reactions occur through colliding particles, and that the rate of the reaction depends on the frequency of collisions.[2] It also suggests that even when particles do collide, they might not react as they have not met the following criterea needed for a reaction to take place:

1. The particles must collide.

2. The particles must have sufficient energy.

3. The particles must be in the proper orientation.

Collision theory also suggets that the following can affect the rate of reaction:

1. Temperature - an increase of temperature will cause the particles to move faster, and thus, collide faster and with more energy (this increases the probability of the particles colliding with at least activation energy).

2. Concentration - an increase of concentration increases the probability of the particles colliding, as they are confined to a smaller space and have less free space to move to.

[2]Although far too advanced for this paper, it is worth mentioning that the plot of the number of particles with each particular energy is known as the *Maxwell-Boltzmann Distribution*. More can be found at the referenced website.

3. Surface Area - an increase in surface area will result in more particles being exposed to the reaction, and thus the reaction occurring faster.
4. Catalysts - Catalysts are substances that can speed up a chemical reaction by lowering the activation energy needed and thus, increase the probability of the reaction occurring.[2]
(With reactions involving gasses, an increase in pressure can also result in an increase in the rate of reaction).

2.4 Sources

References

[1] United States Environmental Protection Agency. `https://www.epa.gov/acidrain/what-acid-rain`. Accessed on the 23rd of January, 2024.

[2] BBC Bitesize. `https://www.bbc.co.uk/bitesize/guides/z3nbqhv/revision/5`. Accessed on the 7th of February, 2024.

[3] LibreTexts Chemistry. `https://chem.libretexts.org/Bookshelves/Physical_and_Theoretical_Chemistry_Textbook_Maps/Supplemental_Modules_(Physical_and_Theoretical_Chemistry)/Kinetics/06%3A_Modeling_Reaction_Kinetics/6.01%3A_Collision_Theory/6.1.06%3A_The_Collision_Theory`. Accessed on the 5th of February, 2024.

[4] Department for Environment Food & Rural Affairs. `https://uk-air.defra.gov.uk/air-pollution/glossary`. Accessed on the 25th of January, 2024.

[5] New Hampshire Department of Environmental Services. `https://www.des.nh.gov/sites/g/files/ehbemt341/files/documents/2020-01/bb-8.pdf`. Accessed on the 25th of January, 2024.

2.4.1 Diamond Diagram of Sources

	Bitesize	
LibreTexts	DEFRA	EPA
	NHDES	

I believe that the best source I used was BBC Bitesize because it included the most relevant information for this experiment. Furthermore, BBC Bitesize is a nationwide trusted & accepted source for retriving scientific information, as well as being specifically designed with the intent that it will be used in situations such as these.

On the other hand, I believe the worst source I used was the New Hampshire Department of Environmental Studies' article. Although it is government-funded, and thus, is reliable and likely accurate, it has far too irrelevant data as its geographically distant, and thus has low validity in accordance with my aim/brief.

3 Prediciton

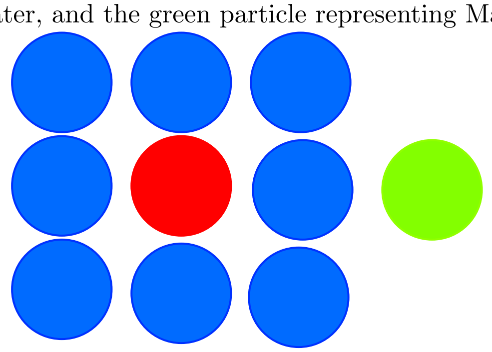
3.1 Hypothesis

I believe that as the concentration of acid (ρ) increases, the time taken for the Magnesium strip to erode (t) will decrease.

In other words, I hypothesize that $t = -f(\rho)$, where $f(\rho)$ is a function of ρ (as explained below, our research suggests that $\frac{df}{d\rho} \neq c$, where c is a constant). [3]

3.2 Justification

As we dilute an acid, and it's density, ρ, decreases, there are less acidic particles to react with the stips of Magnesium. Furthermore, a lower concentration means that the acidic particles are more spread out. This means that when reacting with strips of Magnesium, not only is there less acid for the Magnesium to react with, but the dilution of the acid means that many acidic particles are blocked from reacting with Magnesium by water (as shown in the diagram below, with the red particle representing Hydrochloric Acid, the blue particles representing water, and the green particle representing Magnesium).



Consequently, diluted acids commonly have to be mixed with their metal to collide and react, and very low-concentrated acids cannot fully erode the Magnesium.

In the more theoretical world, we could imagine that as the concentration approaches 0, and Hydrochloric acid particles get surrounded by water, unless there is external force that shifts the particles so that the Hydrochloric Acid and the Magnesium react, the Magnesium will never react and thus never erode. In other words,

[3] Of course, the function to calculate the time taken to erode would be *multi-variable*, but considering our brief is to study the relationship between the concentration of an acid (ρ), and the time it takes for a strip of Magnesium to erode (t), we will spare any minutia as they are irrelevant to this paper.

$\lim_{\rho \to 0} f(\rho) = \infty$ (in a closed system)

As mentioned above, very low amounts of acid are insufficient in mass to fully react with Magnesium. This is determined by the balenced chemical equation for the reaction. We can start with:

$$\mathrm{Mg} + \mathrm{HCl} \longrightarrow \mathrm{MgCl} + \mathrm{H}$$

Of course, we can immediately notice that this equation is incorrect, as Hydrogen, except for a few extreme cases, will only exist in pairs. Therefore, we double the components to create a balenced equation:

$$\mathrm{Mg} + 2\,\mathrm{HCl} \longrightarrow \mathrm{MgCl_2} + \mathrm{H_2}$$

From the equation, we can identify that for the reaction to take place, we need twice the amount of Hydrochloric acid compared to Magnesium. We know that for 10g of a strip of Magnesium, the amount of moles will be 0.411 moles (10g is the estimated weight weight). [4] The formula tells us that we would need twice the amount of Hydrochloric acid compared to Magnesium for the reaction to take place, therefore, we would need at least 0.822 moles. This is highly dependent on the conctration of the acid, given in mol/ml, and even with high amounts of dilouted acid, a low concentration would not be able to fully erode the Magnesium.

[4] We can conclude this the formula from $\text{Moles} = \frac{\text{mass}}{\text{Molar Mass}}$, which in this case would be $\frac{10}{24.31}$