

Vinegar as a rust remover | experiment



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Abstract

Despite the vast research regarding rusting, still many people do not recognize the harmful effect it can to environment and to take precaution measure to avoid or prevent rusting. Results of study show U. S. had to spend total \$276 billion, approximately 3. 1% of the nation's Gross Domestic Product (GDP) for corrosion direct cost. Therefore, these study is to find optional of artificial way to remove rusting from any other metal.

For my research, I choose vinegar as a substance that has the potential to remove the rust stain from metal due to presence of acid in its content. Vinegar is easy to be obtained and usually use as households. I choose three different types of vinegar brands and analyzed its percentage by mass of acetic acid using acid-base titration technique. Then, I test the strength of each vinegar on rate of removing rust on rusted iron nail by removing the rust form. After that, I compare which vinegar has the highest rate of removing rust compared to its percentage by mass of acetic acid.

As the result, I found out that different type of vinegar has different percentage by mass of acetic acid. But my experiment shows that, the higher percentage of acetic mass in the vinegar content, does not always lead to high rate of rust stain removal. These maybe due to my limitation of the research because I assumed that only acetic acid in vinegar reacts with the iron(III) oxide.

Still, my research able to prove that vinegar can act as a potential rust stain remover but in low degree because acetic acid is weak acid. My research

could help and provide people an easy way to remove rust from their accessories as vinegar could be easily obtained.

1. Introduction

Vinegar can be define as “ a sour liquid obtained by result through acetic fermentation of dilute alcoholic liquids and used as a condiment or preservative.” Aside from utilized widely, vinegar also can accommodate more than one purpose which usually used to enhance food taste. Vinegar is made through two stage of biological processes. These distinct process resulted from the action of innocuous microorganisms. In these process, yeast and “ Acetobacter” is used to convert sugars (carbohydrates) into acetic acid. The first stage of process is called alcoholic fermentation. It occurs when yeasts convert natural sugars to alcohol under controlled conditions. In the second stage of process, “ Acetobacter” which is a group of bacteria, changes the alcohol resulted from alcoholic fermentation to acid. This is the acid fermentation that forms vinegar. Since vinegar can be made from anything with sugar, there are probably too many variants to count made in countries throughout the world.[1](Kellen, 2005, Vinegar Institute Site)

Rust is define as the red or orange coating that forms on the surface of iron when exposed to air and moisture surroundings, consisting mass of ferric hydroxide. These ferric oxide is formed through oxidation. Rust forms due to the reaction of oxygen dissolved in dihydrogen monoxide(water) with iron. Rust also can be known or called as corrosion of metal.[2] (Holleman, Wiberg, 2001 “ Inorganic Chemistry” Academic Press: San Diego)

Rust is a general term to describe several different oxides that formed when an iron undergo corrosion. Some of the oxides are $\text{Fe}(\text{OH})_2$, $\text{Fe}(\text{OH})_3$, $\text{FeO}(\text{OH})$, and $\text{Fe}_2\text{O}_3 \cdot \text{H}_2\text{O}$. The prevalent rust that can be found is a reddish-brown, $\text{Fe}_2\text{O}_3 \cdot \text{H}_2\text{O}$. The oxygen in the air dissolve in water and promote the rust to start to compose. The rust also can be determine as an electrochemical process. The process of exchange of electrons (electricity) is conducted by chemical reactions in part of the electrical circuit. The surface of metal that exposed to electrolyte will undergo series of chemical reactions. Oxidation reactions (corrosion) occur at the surface of the anode while reduction reactions occur at the surface of the cathode.[3] (Jones, Denny (1996) Principles and Prevention of Corrosion.)

By observation, we could described that rust occurs very easily because the presence of air and water or wet condition virtually presence anywhere. We could see around ourselves rusting is occur greatly. Rust changes steel into a different material, one that is impuissant or weaker than the original steel. Rusting is a immensely colossal problem because so many things people use every day are made out of steel, like cars, bicycles, trucks, bridges, roofs, holding tanks, machinery, nuts, and bolts. When these objects are unprotected and exposed to water, they rust, and this damage can costs a lot of money. Rust also dangerous to human because a rusting iron nail can cause health issue such as tetanus if the iron nail pierce to human skin. Yet steel perpetuates to be widely used because it has an excellent strength-to-weight ratio. Also known as the best of all the common building materials. In addition, it is non-flammable, resistant to mold and termites, does not expand or contract under temperature changes, and can be made with a

consistent quality.[4] (Miller, L. (2003, July 31). Corrosion). Therefore, we must take alert and precaution about rusting of these iron metal.

The topic that be investigated in this extended essay is about rusting or corrosion and the way to prevent rust. Thus, my research question is to analyse the percentage by mass of acetic acid in different type of vinegar brands by using titration method and to investigate the potential of vinegar as rust stain remover. Therefore, my extended essay required two experimental procedures. My hypothesis for first experiment is that different types of vinegars have different percentage by mass of acetic acid. If the result of experiment one parallel with my hypothesis, second experiment could be carried out which is to investigate the potential of vinegar as rust stain remover. My hypothesis for second experiment is that the higher the percentage by mass of acetic acid in vinegar, the more efficient the vinegar to act as rust stain remover.

The significant of my research is to investigate a cheapest and easiest way to remove rust. In this research, I choose vinegar as the potential method to remove stain rust because vinegar contain acetic acid . Vinegar could be easily found and present almost in every living house. Because acid is corrosive, it occur to me that the acid could corrode the rust stain from metal. To test the validity of my statement, a research and experimental procedure is carried out to justify the validity of my research question. The chosen area of study is rusting since my experiment focus more on rusting.

These experiments included several methods such as acid - base titration. Vinegar is acidic. Therefore, it will be titrated with base solutions, sodium

hydroxide. The titration method is carried out to find the volume of base needed to neutralize the acid solution of vinegar. These method is essential for the experiment to find the percentage by mass of acetic acid in vinegar. Second method is rusting of iron nail. I could not choose any random iron nail to conduct my experiment because the result will not be accurate and precise as they could have different degree of rusting. Therefore, I buy iron nails that not rusted yet and undergo experimental procedure for the iron nails to rust under constant condition. These method needed to carry out so that the iron nails undergo rusting in constant activity. Then, the iron nails could be tested with the vinegar.

In my experiment, I used some instrument from the chemistry laboratory. The instruments I used is pH meter. The pH meter is used to find the pH of different type of vinegar. I also use burette which is necessary for the titration method. The burette is used to find the volume of base needed to neutralise the acidic solution. I also used electronic balance to weigh the iron nails initial mass before in undergo rusting and the final mass after the iron nails undergo rusting. Stopwatch is used to record the time taken for the acid to remove the rust stain.

*Due to some error, all the pictures for the experiment have loss.

2. Methodology:

2.1 Variables and method of controlling variables

Variable type: Independent

Variable: Different type of vinegar brands

Method of controlling: By using vinegar of different brands for the experiment.

Variable type: Dependent

Variable: Volume of sodium hydroxide needed to neutralize acid solution

Method of controlling: By measured the volume of sodium hydroxide needed to neutralize acid solution using burette.

Variable type: Controlled

Variable: Volume of vinegar used

Method of controlling: Fixed the amount of vinegar is used for the experiment which is 2.0 ml.

Variable: temperature

Method of controlling: The experiment is conducted in same room

Variable: Volume of distilled water added

Method of controlling: Fixed the amount of volume distilled water added in the vinegar.

Add phenolphthalein

Method of controlling: By adding 3 drops phenolphthalein to every vinegar solution in conical flask during experiment.

Variable: Concentration of sodium hydroxide

Method of controlling: By fixed the concentration of sodium hydroxide used which is 1.0 M.

Table 1 : Variables for experiment to determine the percentage by mass of acetic acid in vinegars

Variable type

Variable

Method of controlling

Independent

Type of vinegar used

By using vinegar of different brands for the experiment.

Dependent

Time taken to remove the rust stain

By recorded the time taken for different type of vinegars to remove the rust stain on the iron nail using stop watch.

Controlled

Type of metal

By using the same metal throughout the experiment which is iron nail.

Temperature

The experiment is conducted in same room

Using same electronic balance

By using the same electronic balance to weigh the mass of iron nail.

Time for iron to rust

Fixed the time for the iron to rust which is 7 days or 1 week

Using same stopwatch

By fixed the type of stopwatch used to record the time taken.

Table 2 : Variables for experiment to determine the time taken for the vinegars to remove rust

2. 2 Methodology for neutralisation process

To find the percentage by of acetic acid in different types of vinegar brands, a neutralisation process follow the standard procedure is carries out. First , the apparatus is set up . The burette is clamped on the retort stand. Then, 2. 0 ml of vinegar is measured using measuring cylinder. An empty conical flask is weighed. Then 2. 0 ml vinegar which is Earth Brand is poured in the conical flask. The conical flask is weighed again. This procedure has to be carried out to find the mass of 2. 0 ml of vinegar assumed that different vinegars has different density. After that, 48. 0 ml of distilled water is measured using measuring cylinder. Then, the distilled water is mixed with the vinegar in the conical flask. This procedure has to be carried out because vinegar is very concentrated so dilution process has to be done. The pH mater is used to find the pH value of vinegars.

After mixed, the initial weight of vinegar with conical flask is measured using weighing balance. Then , sodium hydroxide is filled in the burette. The conical flask is placed under the burette. 3 drops of phenolphthalein is added into the diluted vinegar.

The neutralisation process is started as soon the alkali is added into the conical flask.

The sodium hydroxide is assumed to only react with the acetic acid presence in the vinegar. The conical flask is swirled gently. The initial colour for the acidic solution is colourless. As the acid solution undergo titration, the colour change from colourless to pale pink colour. The end of titration is indicated when the mixture remains in pale pink colour. The titration process is stopped.

The volume of sodium hydroxide needed to neutralise 2. 0 ml of vinegar is recorded and final weight of vinegar with conical flask is weighed. The experiment above is repeated twice to get the average reading of volume of sodium hydroxide needed to neutralise the acid solution. All the data is recorded in the table. The experiment procedure above is then repeated using different type of vinegar which is Yeo's and Jalen.

Burette, $\pm 0.05 \text{ cm}^3$

Different vinegar brands (Jalen, Yeo's, Earth Brand)

Beaker, ± 0.5

Conical flask , ± 0.5

Retort stand and clamp

Pipette and ph meter

Phenolphthalein

Weighing balance , ± 0.0001

Sodium hydroxide (1.0 molar)

Rod and distilled water

2.3 Methodology for rusting process and rust stain removal

This experimental procedure is carried out because it is hard to determine the degree of rusting of any random metal. Therefore, I fixed the type of metal use which is iron nails and the time left for iron to rust which is approximately 7 day (1 week) .

The materials is ready and apparatus needed is set up. The initial mass of each iron nail is weighed and the data is recorded. The 5 iron nails is marked such as iron nail A, iron nail B and consecutively by using a small piece of paper attached to each nail. Then , a mineral bottle is cut to get the bottom part of mineral bottle and form a cup like. Then, the cup is filled with small amount of tap water. All iron nails is dipped in the water and left to be exposed to air in the laboratory for seven days.

After seven days , all iron nails are take out from the bottle. Then, each iron nail which already rusted now is weighed again to get mass of rust with the iron nail. The mass of rust formed on each iron nail is found by subtracted the final weight of iron nail with its initial weigh. Then, the average mass of

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rust formed is calculated. All the data of the experiment is recorded in a table. The experiment above is repeated twice.

The process to remove rust stain is carried out. Vinegar is inserted into a transparent cup. The rusted iron nail is immersed into the cup contained vinegar. The reaction is observed. The time taken for the iron rust to be remove completely by the vinegar from the iron nail is recorded by using stopwatch. The same procedure done to all 5 iron nails . The average time taken needed to remove the rust is calculated. The data and result is tabulated. The experiment above is repeated using different type of vinegars.

Apparatus and materials

- Burette, $\pm 0.05 \text{ cm}^3$
- Beaker, ± 0.5
- Bottle cup
- Different vinegar brands (Jalen, Yeo's, Earth Brand)
- Conical flask , ± 0.5
- Measuring cylinder, ± 0.05
- Weighing balance , ± 0.0001
- 5 Iron nails
- Distilled water

3. Data collection and processing

3.1 Data collection and processing for experiment

Quantitative data

Type of vinegar brand

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Weight of empty conical flask (g)

± 0.0001

Weight of 2.0 ml of vinegar with conical flask (g) ± 0.0001

Mass of vinegar ± 0.0002 (g)

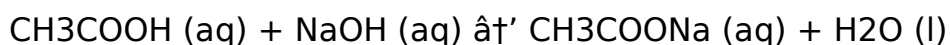
Earth Brand

Qualitative data

The initial colour of vinegar and sodium hydroxide is colourless. The colour of vinegar solution remains colourless even after phenolphthalein is added.

When the mixture undergo titration process, the mixture remains colourless but when the end point of titration reach, the colour of mixture turns from colourless to pale pink.

Equation for the neutralization process =



Calculation of percentage by mass of acetic acid in vinegars.

1. Earth Brand

Calculate number of moles for NaOH

= MV

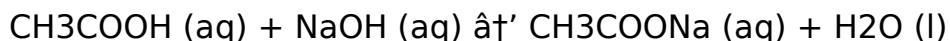
1000

(32.54 ml of NaOH solution added x 1.0 molar of NaOH)

1000

= 0.03254 moles of NaOH

uncertainties = $(0.05 / 32.54) \times 100\% = 0.15\%$



From the equation, the acetic acid in vinegar reacts with sodium hydroxide in a 1:1 ratio.

1 mole of acetic acid reacts with 1 mole of sodium hydroxide to form 1 mole of sodium acetate and 1 mole of water. Thus, 0.03254 mole of acetic acid reacts with 0.03254 mole of sodium hydroxide to form 0.03254 mole of sodium acetate and 0.03254 mole of water.

Calculate the amount of acetic acid in Earth Brand.

Therefore, Molecular mass calculation:

$$12.0107 + 1.00794 \times 3 + 12.0107 + 15.9994 + 15.9994 + 1.00794$$

$$= 60.05196 \text{ g/mol}$$

To find the mass of acetic acid in vinegar is given by the formula

number of mole \times molar mass of acetic acid

Thus, $0.03254 \text{ moles} \times 60.05196 \text{ g/mol} = 1.954 \text{ g of acetic acid} \pm 0.15\%$

To calculate the percentage by mass of acetic acid in vinegar (Earth Brand):

Mass of vinegar used = 2.2837 g

uncertainties = $(0.0001 / 2.2837) \times 100\% = 0.0044\%$

mass of acetic acid in vinegar = 1.9540 g

The percentage by mass of acetic acid

$$= (1.9540 / 2.2837) \times 100 = 85.56 \%$$

$$\text{uncertainties} = 0.0044 + 0.15 = 0.1544 \%$$

Therefore, the percentage by mass of acetic acid in Earth Brand is

$$= 85.56 \% \pm 0.15 \%$$

The method of calculation of percentage by mass of acetic acid for other vinegars is same with the calculation above. Therefore, the result for the calculation is tabulated.

Discussion

The 2.0 volume for vinegar used needed to be weighed to find the mass of vinegar as I assumed the density for vinegar is different from density of water. From the result, it shows that different vinegars has different density, therefore different vinegars will have different mass of 2.00 volume used.

I also assumed that during neutralisation process, the sodium hydroxide will only reacts with the acetic acid presence in the vinegar. Based on the result, it shows that different type of vinegar brands has different percentage by mass of acetic acid of vinegar of different brands. Jalen has the highest percentage by mass of acetic acid followed by Earth Brand and Yeo's. These explained that why different vinegars have different pH value. Acetic acid is weak acid. The higher the percentage by mass of acetic acid, the lower the pH value of the vinegar.

Hypothesis for experiment one is accepted. Different type of vinegar has different percentage of acetic acid of vinegar. Thus, experiment two can be conducted.

3. 2 Data collection and processing for experiment 2

Quantitative data

The iron nail pale brown in colour while the tap water and the vinegar is colourless.

When the iron nail is left in the bottle cup, there is no immediate reaction occurred.

After several hours, a reddish brown substance start to appear around the iron nail.

After several days more reddish brown substance deposited around the iron nail like coated it.

When the iron is immersed in vinegar inside a cup bottle, bubble formed and the reddish brown substance fall off from the iron nail.

The colour of vinegar turned slightly from colourless to pale reddish and the reddish substances settle at the bottom of the cup bottle. Later, it dissolve in the vinegar.

4. Processed result

Discussion

To put in a simple words, rusting is the corrosion of iron and readily occurs in the metal in the presence of water , oxygen and iron. The formation of a <https://assignbuster.com/vinegar-as-a-rust-remover-experiment/>

reddish brown substance like which appeared and adheres to the iron nail is called rust. Based on the research, it shows that vinegar could serve as one of the substance that can remove rust stain on metal due to the presence of acid. From the experiment, it clearly shows that different vinegar has different degree of removing the rust stain because due to different percentage by mass of acetic acid in the different type of vinegars.

After rusting process occurs on the iron nail, the iron nail weighed more. This is because rust forms when iron metal is oxidized by oxygen in the presence of water. Iron oxide is another term for rust. Iron oxide as a molecule and consist of three elements which is of iron with oxygen and water. From the result obtained based on the experiment, it shows that the rust form is originally mass from the iron but the mass of oxygen and water comes from the atmosphere. When the rust form on the iron nail, the mass of iron rust increased by the mass of oxygen and water that combined with the iron. Therefore, iron nail weight more after rusting process occurs due to addition of these elements from atmosphere.

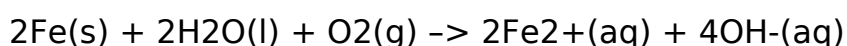
In the presence of oxygen and water,

Reduction half equation: $4e^- + 2H_2O(l) + O_2(g) \rightarrow 4OH^-(aq)$

The tip or the head component of iron nail is easily oxidised. The crystal lattice of iron is distorted and the iron atoms will be facilely oxidised.

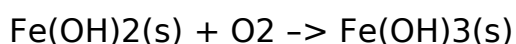
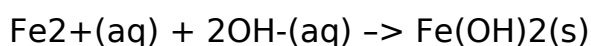
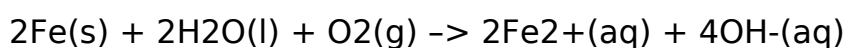
Oxidation half equation: $2Fe(s) \rightarrow 2Fe^{2+}(aq) + 4e^-$

Therefore the overall net equation for the chemical reaction is



The process continues. After that, the Fe^{2+} and OH^- ions will move and diffuse through the water. When both ions meet they will react to produce precipitate which is iron (II) hydroxide, Fe(OH)_2 . This iron (II) hydroxide then will be further oxidised to iron (III) hydroxide, Fe(OH)_3 and will be dehydrated to produce rust.

Chemical equation for rusting process :



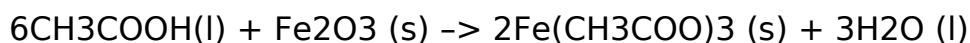
$\text{Fe(OH)}_3\text{(s)}$ - dehydrates $\rightarrow \text{Fe}_2\text{O}_3 \cdot n\text{H}_2\text{O(s)}$ or rust

Therefore, the chemical formula for rust is $\text{Fe}_2\text{O}_3 \cdot n\text{H}_2\text{O(s)}$ [5]

(Loh Wai Leng, Tan Yin Toon, Tan On Tin, 2011, oxidation and reduction)

Acetic acid is a weak acid that is present in vinegar. Vinegar works better than other strong acids because of the presence of weak acid. Therefore, it will not attack the iron nail itself. Strong acids will corrode both the rust stain and the iron nail. To prevent that, a substance with weak acid is preferable. When the iron nail with rust is soaked into the vinegar containing acid, the rust on the iron nail will dissolve and loosen. The crumbly hydrated iron oxide will form a soluble salt, in this reaction between acetic acid and iron(III) oxide, it will form iron acetate.

Equation of reaction between acetic acid and rust:



and ferric acetate, $\text{Fe}(\text{CH}_3\text{COO})_3$ is water soluble.

However, the hypothesis for my second experiment is rejected. Clearly from the experiment above, it shows there is no directly proportional relationship between percentage of mass of acetic acid in vinegar and rate of removing rust. Jalen has the highest percentage of mass of acetic acid followed by Earth Brand and Yeo's but Earth Brand shows the highest rate of removing rust followed by Jalen and Yeo's. There, my experiment has limitation which lead to these result.

After the experiment, I accidentally left the iron nail that already washed with vinegar in the cup bottle. I found out that the rusting on iron nail occur more faster by the day. I concluded myself that acid actually can remove the rust stain from the nail but in the same time it also promote rusting. The surface of iron nail will clean after the rust stain is remove and let the iron nail exposed to acid. Somehow, acid will react on the surface of iron nail. Further research could be done to investigate the after effect of acid after removing the rust stain.

5. Conclusion

This research show that each vinegar has it own percentage by mass of acetic acid in each and every different type of vinegar. From the experiment and calculation, it shows that the percentage by mass of acetic acid in vinegar brands of Earth Brand, yeo's and Jalen accordingly is 85. 56%, 83.

68% and 92.20%. The difference of percentage by mass of acetic acid in vinegar resulted the difference in the vinegar taste and the pH value. The experiment shows that there is not much significant difference of percentage by mass of acetic acid in different type of vinegar brands. The vinegars used in the experiment is the product of Malaysia. Different result may show if I test of the products of other country. These difference of percentage of acetic acid in different type of vinegar, effect the result obtained in experiment two. The hypothesis for experiment one is accepted.

These research also shows that vinegar could serve as a potentially rust stain remover but in low degree because acetic acid presence in vinegar is a weak acid. Still, it could be use safely because the acidic concentration is not harmful and vinegar is easy to obtain rather than any other applications. However, from the result obtain, it shows that the higher the percentage of acetic acid in vinegar, does not always cause higher rate of rust stain removal. Jalen has the highest percentage by mass of acetic acid in vinegar followed by Earth Brand and Yeo's which is 92.20%, 85.56% and 83.68% respectively. But the experiment shows that the vinegar that has the highest degree of rust stain removal is Earth Brand followed by Jalen and Yeo's which is 0.0049gs-1, 0.0044gs-1 and 0.0043gs-1 second respectively.

Therefore I could conclude that, Earth Brand is a better rust stain remover Yeo's and Jalen, but Jalen is better than yeo's. Even though there is no not much significant difference, but it effected the overall result. Therefore, the hypothesis for the second experiment is not accepted. There is several reason why these result obtained. Maybe there is another substance that presence in the vinegar, react with the rust stain on iron nail which can

affect the result because I assumed that the rust stain will only react with the acetic acid presence in vinegar. Further research could be conducted to explain and determine the problem. The other reason may cause due to limitation that will be discuss later.

However , these research able to prove that there is difference of percentage by mass of acetic acid in different type of vinegar and vinegar can act as a potentially rust stain remover . But due to weak acid presence in vinegar, vinegar could only remove rust stain that only form only on surface of metal . It cannot remove the rust that has been deeper into metal . Overall, I can conclude from the experiment that different vinegar has different percentage by mass of acetic acid and vinegar is a highly potential rust stain remover.

6. Evaluation

Throughout the experiment there are several limitations that can affect the result of the experiment. During the titration process, The colour of acidic solution which is vinegar, will change from colourless to pale pink at the end of titration process. The perception of colour change will affect the result. It is hard to determine what the exact pale pink colour that need to be achieve. In order to overcome this problem, a controlled conical flask containing acid solution when end point of titration which colour is pale pink should be put beside the set up apparatus so that the person would know what exactly pale pink colour they need to reach. pH meter also can be used to fixed the pH value needed.

Another problem that could effect the result is when weighing the weight of iron nail after the rust is formed. Rust that is formed for several days only

appear on the surface of the iron nail. Therefore, when removing the iron nail to be weighed, the rust from the surface of iron nail could drop. Even a slight drop of rust from the iron nail, could cause the result obtained will not be accurate. Therefore, to overcome these problem, during the formation of rust, the iron nails should be left on the electronic balance. So, the iron nail does not have to be removed and rust will not fall off. The result obtained will be more precise.

Another problem that could arise is when removing the rust from iron nail using vinegar. In these experiment, I assumed that, only acetic acid in vinegar will react with the rust on the iron nail. So that my hypothesis could be achieved. But it turn out my hypothesis is invalid. It could be that other substances presence in the vinegar, will react with the rust on the iron nail. After all, vinegar consist more than one substance. these problem can be overcome by doing some further research.

Lastly, the after effect of the experiment. Acid can remove rust stain but the chemical reaction between acid and the surface of iron nail, can increase the rate of rusting of iron nail. Corrosion in acid solutions is much more rapid than in neutral solutions, and the latter is more rapid than in alkaline solutions.[6](Frank N. Neller, 2004, Corrosion Facts). Therefore to solve the problem, after washed the iron nail to remove the rust, the iron nail need to place in boil water for a while. Therefore, no after chemical reaction will occur. Thus, rusting will not occur.