Shiny pennies

Keywords: alkaline, coins, metal oxides, oxidation, reaction, vinegar

Meta Description

Pennies lose their shine after a while. This experiment explains what causes the dull colour on coins and how to make your pennies bright again.

Learning Objectives

To illustrate what an oxidation reaction is and how metal and oxygen react to form an oxide.
To understand the influence of an acid on an oxide layer.
To explore the concept of acids, bases and pH.

Key Terms

Oxidation

A reaction where oxygen interacts with other substances. Oxidation also involves the loss of at least one electron when two or more substances interact.

Acid

The presence of high concentration of hydrogen ions (H+) in a solution. The amount of hydrogen ions present is greater than the amount present in pure water.

Alkaline/base

A solution that has a pH higher than 7, due to a high concentration hydroxide ions, OH -. The amount of hydroxide ions present is greater than the amount present in pure water. A base is a substance with the properties of an alkaline but will not dissolve in water.

pH

A scale that determines how acidic or alkaline a substance is (from 1- strongly acidic, 7-neutral, 14- strongly alkaline). pH is determined by the concentration of hydrogen ion in moles per litre, which is then applied to the pH scale.

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Method

Step 1

Fill a glass cup with vinegar and pour it in a non-metallic bowl.

Step 2

Pour about two teaspoons of salt into the bowl with the vinegar.

Step 3

Mix it together with a plastic spoon until the salt is completely dissolved.

Step 4

Put some dirty pennies in the bowl and leave them for 2 minutes.

Step 5

Observe the difference in the colour of the pennies.

Step 6

Remove the pennies from the vinegar and put them in a bowl filled with water. What do you observe?

Step 7

Place two steel nails in the bowl containing the vinegar-salt solution which has been previously used to clean the coins, wait for 2 minutes. What do you observe?

Alternative Method

Instead of putting the entire coin in vinegar, dip only half of the coin in. This gives a contrast of the brightness of the coin before and after coming being treated with the vinegar solution.

Try the experiment with other metal (non valuable) objects- ideally made of other types of metal.

Precautions

Vinegar; Causes severe skin burns and eye damage. Avoid direct contact, if you do, wash immediately with warm running water.

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Use in a well-ventilated area as it is a flammable liquid and may cause respiratory irritation.

Narrative

Have you ever taken a walk off-road just after it rained and ended up with your boots covered with mud? In order to clean them, you submerge them in the water and you observe that the water gets dirty with the mud coming off of the shoes. This is a very much simplified representation of the removal of the copper oxide and the copper ions from the surface of the coin into the acid solution. However the copper oxide is not soluble in water and will not be removed from the coin as easily, that is why we need the acid solution.

Now, if you were to remove the boots and put a white shirt into this muddy water, the shirt would become stained with patches of mud. What happens is that some of the mud gets transferred from the water onto the t-shirt. This is similar to the transfer of copper ions on the surface of the steel nails.

Questions

Why is salt added?
Salt is added to react with the vinegar and produce a stronger acid to clean the pennies.

What is an acid?
An acid is a substance that is able to dissociate into hydrogen ions.

Why is vinegar and salt mixture suitable to clean pennies?
Copper oxide dissolves in the presence of an acid.

What causes the pennies to become dull?

Due to the formation of a black layer of copper oxide.

Why is water on its own not suitable for cleaning pennies?

Copper (II) oxide is not soluble in water

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It is important to wash the pennies with water after cleaning them. Why?

To stop the coins from reacting with the acid further and prevent the coins from turning a blue/green colour.

Brief Explanation

New pennies are very shiny because they are made up of copper. As time passes, the outer surface of the copper coin is exposed to the air and the copper reacts with the oxygen present to form a copper oxygen compound, known as a copper oxide. It is this compound that gives the dull brown colour to the pennies. http://sciencewithkids.com/Experiments/Chemistry-experiments/penny-cola-cleaner-experiment.html

The addition of vinegar and salt together creates an acid. This acid has the ability to remove the layer that gives a dark colour to the pennies. Therefore, upon its removal, the pennies become bright again.

Detailed Explanation

Pennies are made up of a mixture of copper, zinc and tin. The colour of the copper pennies darken over time as the positively charged copper atom attracts negatively charged oxygen atoms from the air to form copper oxide. It is the copper oxide that gives the dull colour. The oxidation reaction that happens is detailed below;

Image not found or type unknown

The vinegar and the table salt combine together to produce a strong hydrochloric acid.

Image not found or type unknown

In the salt and vinegar mixture, the copper oxide as well as some of the copper in the coin dissolve in the water. The latter forms positively charged copper ions in the liquid. These positive copper ions are formed when the copper is dissolved in the solution it leaves some of their negatively charged electrons in the pennies.

The copper oxide on the surface of the coin is basic and reacts with hydrochloric acid. This reaction is represented by the following equation;

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Once the pennies are removed from the vinegar solution, it is important to wash them with water. If the pennies are not rinsed, a blue-greenish layer forms on the surface of the pennies. This is formed because the copper on the pennies ends up reacting with oxygen from the air and with the chlorine from the table salt. This causes the formation of the blue-green malachite.

When steel nails are added to this solution, some of the iron from the nails dissolved into the vinegar-salt solution. Just like copper, the iron atoms leave two of their electrons in the nail, and form iron ions in the liquid. The positively charged copper ions that are already dissolved in the water from cleaning the pennies are attracted to the negatively charged nail. This results in a layer of copper on the steel, giving the steel a dull colour.
https://www.exploratorium.edu/science_explorer/copper_caper.html

Applications and Research

Applications

The described experiment is able to be conducted due to the presence of an appropriate pH, where acidic conditions are required for the copper oxide to dissolve. The importance of using appropriate pH is encountered in many practises in our daily life, such as for sewage treatment, water purification, food processing and as cleaning agents. A particular pH is required for the biological reactions to operate at their optimum rate, as any alteration in the pH can result in a disruption of the system.
http://sciencing.com/can-affected-change-ph-levels-6165622.html

Furthermore, the above reaction also involves the oxidation reaction of copper. The formation of an oxide layer occurs naturally as the metal comes in contact with the oxygen in the atmosphere. An example of which is aluminium oxide layer which serves as a barrier against corrosion and may also act against further oxidation. http://news.stanford.edu/pr/00/aluminum511.html

Research

Recently research is focusing more and more on developing green energy. The properties of metal oxides at the atomic level give rise to the possibility of using these reactions to generate energy. What makes them suitable for this is the fact that metal oxides are cheap to create, are relatively abundant and ‘green’. Metal oxides provide a possibility to produce artificial photosynthesis, with different oxides and methods being tested to determine how to increase the efficiency of this type of energy production. https://phys.org/news/2012-04-metal-oxides-key-cheap-green.html

Investigation

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- Try other acids instead of vinegar. Such as lemon juice, orange juice, water with baking powder or soft drinks.
- After removing the coins from the vinegar, place the coins on a paper towel instead of putting them in water. Observe the green colour of malachite coating forming.
- In the remaining vinegar solution, put some nuts and bolts and leave them for some minutes. Observe the colour changes. The copper removed from the previously cleaned coins will quickly get stuck on the nuts and bolts to give them a dark, copper colour.



Subject

Chemistry

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Education

Primary
Secondary
Informal

Time Required

~10 minutes
Preparation: 2 mins
Conducting: 5 mins
Clean Up: 2 mins

Cost

0 – 10 €

Recommended Age

6 – 9
10 – 12

Number of People

1 participant

Supervision

Required

Location

Indoors
Laboratory

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Sources

Penny Chemistry Experiment

Can Ketchup Clean a Penny?

Anodizing (Or the beauty of corrosion)

Artificial Photosynthesis System as efficient as plants and can reduce CO2 levels

Artificial Photosynthesis

Additional Content

Acids, alkalis and salts
(Beginner)

What Happens When You Clean Pennies With Lemon Juice?
(Intermediate)

The Effects of Oxidation on Copper (Advanced)

Cite this Experiment

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