Concentration of sulfuric acid

Abstract

My research question, as the topic states, is ‘ How would the concentration of sulfuric acid affect the rate of hydrogen gas produced when it reacts with iron?’ The reason that I want to do this experiment is to prove whether the collision theory in Chapter6. 2 of the Chemistry textbook1 is true about the concentration will affect the rate of a reaction. And I also did another extend experiment about whether the temperature will affect the rate of a reaction. After a lot of calculations, and analysis of the experiment’s data I got, my conclusion is the collision theory is not very suitable on this particular experiment.

Introduction

In Chapter 6 of IB chemistry textbook about Kinetics, the factors that will affect the rate of a reaction are Concentration, pressure, temperature, surface area and catalyst. I want to choose one of these factors and prove if it will actually affect the reaction rate and I choose the concentration.

Then I started to think about the experiment that can show whether the concentration of the reactants will affect the reaction rate. Because my school’s laboratory is very limited, so I can only do the experiments that are easy to operate and will not use very sophisticated apparatus. So, after serious consideration, I decided to use the iron react with sulfuric acid, the formula is elaborated below:

Fe + H2SO4 –> FeSO4 + H2

The reason that I choose to do this experiment is that this experiment can generate gas and the tools to do this experiment are easy to obtain. In

Chapter 6 of the Chemistry textbook, one of the techniques for measuring rate is a collection of an evolved gas. Because the rate that the gas generated can represent the rate of the whole reaction, so I just need to measure how fast does the hydrogen gas evolve.

Development of the Experiment

This experiment is not as simple as it looks like. The first way I use is let iron react with different concentration sulfuric acid, and use a stopwatch to measure the time for each different reaction to finish. But after I give a try of this method, I found out that for a reaction to completely stop will take hours or more, which means this way wastes too much time, so this method is not very practical.

The second way that came out of my mind is let the hydrogen gas been evolved to fill a balloon, and see how much time it will take to let the balloon to explode. But as everyone knows, Hydrogen gas can burn, so when the balloon explodes, it may also set off the hydrogen gas, so this method is way too dangerous to operate.

The final method I developed is close to perfect (I think), and it is better to be shown by a photograph:

In the left part of this photo, the iron and sulfuric acid will generate hydrogen gas; the hydrogen gas will go into the beaker in the middle of this photo through the rubber tube. Because the beaker in the middle has been filled with water, the hydrogen gas go into the beaker will begin to push the water out of the beaker. Because there is another glass tube in the beaker (you can see it in the photograph), water will be push into the graduated flask in the right part of the photo through the glass tube and the rubber tube. I just need to measure the time for a certain amount of water that has been push into the graduated flask, and compare the time taken of every different reaction, I will know whether the concentration will affect the rate of the reaction.

Although this method is perfect for me, I still made a mistake when I was assembling the apparatus together:

As the photograph above shows, this is the beaker used to let the reaction took place. The mistake I made is: The glass tube is too deep. Because the glass tube is so deep that the mouth of the glass tube is totally immersed by the sulfuric acid, thus the hydrogen gas evolved cannot go through the glass tube, as a result, the hydrogen gas push the sulfuric acid into the glass tube!

Luckily, this mistake is not very hard to correct, I just need to pull the glass tube out a little bit, as the photograph shows below:

Experimental Procedure

Material and instruments: pure iron powder, very concentrated sulfuric acid, gas collecting bottle, conical flask, balance, stop watch, grad cylinder, glass tubes and soft rubber tubes.

Because the sulfuric acid I got is very concentrated (98%), so the first thing I need to do is preparing sulfuric acid which has different concentration.

1. Use the grad cylinder to measure certain amount of 98% sulfuric acid.
2. Use the grad cylinder to measure certain amount of water.

3. Add the sulfuric acid very slowly into the water and use a glass stirs keep whisking the mixture. I have repeated these procedures for nine times because I raised the concentration of sulfuric acid by 10% each time, finally I got 9 solutions have different concentration: 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80% and 90%.
4. Use the balance to measure exactly 5g of iron powder.
5. Add the iron powder into the beaker on the left of the photograph.
6. Add the 10% sulfuric acid into the beaker on the left of the photograph.
7. The hydrogen gas will " press" the water in the bottle into the grad cylinder and use the stop watch to measure the time taken for the hydrogen gas to press out certain volume of water.
8. Add the 5g of iron powder and 20% sulfuric acid into the left beaker then repeat step 6 and 7.
9. Add the 5g of iron powder and 30% sulfuric acid into the left beaker then repeat step 6 and 7.
10. Add the 5g of iron powder and 40% sulfuric acid into the left beaker, then repeat step 6 and 7.
11. Add the 5g of iron powder and 50% sulfuric acid into the left beaker then repeat step 6 and 7.
12. Add the 5g of iron powder and 60% sulfuric acid into the left beaker then repeat step 6 and 7.
13. Add the 5g of iron powder and 70% sulfuric acid into the left beaker then repeat step 6 and 7.
14. Add the 5g of iron powder and 80% sulfuric acid into the left beaker then repeat step 6 and 7.

15. Add the 5g of iron powder and 90% sulfuric acid into the left beaker then repeat step 6 and 7.
16. Add the 5g of iron powder and 98% sulfuric acid into the left beaker then repeat step 6 and 7.

Data and Analysis

From the table above, we can see a very strange trend: When the concentration of sulfuric acid increase from 10% to 60%, the time is decreasing, in other words, the rate of the reaction keeps speeding up; but when the concentration of sulfuric acid reaches 70%, there's no reaction between iron and sulfuric acid at all! At first, I cannot even believe what I saw, so I repeat the reaction between iron and 70% sulfuric acid for several times but eventually lead to the same result: Nothing happened. Then I search this strange thing among a lot of books and websites, and this is called passivation2.

Definition of passivation: Passivation is the process of making a material " passive" in relation to another material prior to using the materials together. For example, prior to storing hydrogen peroxide in an aluminium container, the container can be passivated by rinsing it with a dilute solution of nitric acid and peroxide alternating with deionized water. The nitric acid and peroxide oxidizes and dissolves any impurities on the inner surface of the container, and the deionized water rinses away the acid and oxidized impurities. Another typical passivation process of cleaning stainless steel tanks involves cleaning with sodium hydroxide and citric acid followed by nitric acid (up to 20% at 120 °F) and a complete water rinse. This process will restore the film; remove metal particles, dirt, and welding-generated compounds (e. g. oxides).

In the context of corrosion, passivation is the spontaneous formation of a hard non-reactive surface film that inhibits further corrosion. This layer is usually an oxide or nitride that is a few atoms thick.

Mechanisms of passivation: Under normal conditions of pH and oxygen concentration, passivation is seen in such materials as aluminum, iron, zinc, magnesium, copper, stainless steel, titanium, and silicon.

Ordinary steel can form a passivating layer in alkali environments, as rebar does in concrete. The conditions necessary for passivation are recorded in Roubaix diagrams.

Some corrosion inhibitors help the formation of a passivation layer on the surface of the metals to which they are applied.

Passivation of specific materials: Aluminum may be protected from oxidation by anodizing and/or valorizing (sometimes called Anodizing), or any of an assortment of similar processes. In addition, stacked passivation techniques are often used for protecting aluminum. For example, chromating is often used as a sealant to a previously-anodized surface, to increase resistance to salt-water exposure of aluminum parts by nearly a factor of 2 versus simply relying on anodizing.

Ferrous materials, including steel, may be somewhat protected by promoting oxidation (“ rust”) and then converting the oxidation to a metalophosphate by using phosphoric acid and further protected by surface coating. As the uncoated surface is water-soluble a preferred method is to form manganese or zinc compounds by a process commonly known as Parkerizing or phosphate conversion. Older, less-effective but chemically-similar electrochemical conversion coatings included bluing, also known as black oxide.

Nickel can be used for handling elemental fluorine, thanks to a passivation layer of nickel fluoride.

After we read the above explanation of passivation, the reason why iron does not react with concentrated sulfuric acid is pretty clear: Because concentrated sulfuric acid is extremely oxidizing, so as long the sulfuric touches the surface of iron, it will form an oxidized layer on the iron and this layer will stop iron and sulfuric acid being “ touch”, thus there is no reaction would occur.

An Extend of the Topic

It seems that this experiment could be end here, but there’s another idea came out of my mind: Since concentration cannot always affect the rate of the reaction, what about the other factors? Will other factors be suitable on this very particular case? Then I decided to do another experiment to see whether the temperature will affect the rate of this reaction.

Procedure:

1. Use the balance to measure 5 gram iron powder.
2. Add the iron powder into a clean test tube.
3. Add some 98% sulfuric acid into the same test tube.

4. Use an alcohol burner to heat the test tube and observe what will happen.

Not everything goes like we expected, and this experiment is not an exception.

As you can see, in the photograph on page 15, there's a lot of gas evolved from the test tube, but I can definitely tell you that this gas is not hydrogen gas, there are two evidence I can found to prove that this is not hydrogen gas:

1. We all know that hydrogen gas can burn, right? But when I put the mouth of the test tube very closely to the fire, I can't see any combustion.
2. We all know that hydrogen gas doesn't have any odor, but when this gas evolved, I can smell a very strong pungent and smelly odor.

This evidence can prove this gas is not hydrogen gas, but this evidence also leads to another question: What gas is it?

I search on the internet and I found an equation that may be relevant to this experiment:

2Fe+6H2SO4(Hot, concentrated)= Fe2(SO4)3+3SO2+6H2O

I also found out the reason for why would the experiment react like the equation above in a Chinese website, here is the translation: When the temperature is rising, the oxidized layer on the iron will be destroyed and prevent this layer regenerate. Thus, the concentrated sulfuric acid can react with the iron. Also, the rising temperature cause the sulfuric acid be more oxidizing than when it's cold, so this directly cause the oxidation number of iron to increase, and this is the reason that when iron react with hot, concentrated sulfuric acid will generate sulfur dioxide(Which is the pungent and smelly odor I mentioned in the second evidence on page 16).

Conclusion

1. The Collision Theory in Chapter 6. 2 of the Chemistry textbook, which states " The rate at which particles collide is increased by increasing the concentration of the reactants", is not suitable on every reaction. In this case, increase the concentration of sulfuric acid can only increase the reaction rate in a certain range.
2. Increase the temperature of the reactants will not always leads to the increase of reaction rate; instead, increase the temperature may leads to a totally different reaction. In this case, raise the temperature will cause the iron and sulfuric acid to react and generate sulfur dioxide, rather than hydrogen gas.

Some limitation of the experiment:

1. After I know iron will not react with 70% sulfuric acid, I decided to do more experiments to obtain the accurate " Reaction-Stop Concentration", which must be in the range of 60%-70%, but because the experiments tools I have are very limited, so I cannot raise the concentration by1% at a time as I wanted, which leaves a little bit " flaw" to this experiment.
2. Normally students should do experiments in the school's laboratory, but because of " some reason", the lab can't give us the opportunity to do the experiment, so I have to buy the tools and materials and do the

experiments at home, so this cause a lot of inconveniences to my experiments.

Bibliography and References

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