Kanazawa Izumigaoka High School 02

# Optimal Alloy Activation for Hydrogen Storage

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**Abstract**

We did research related to hydrogen storage alloy, which is a metal which can store and release 1,000 times larger volume of hydrogen than that of conventional metal. We set a goal to find the most effective conditions to store hydrogen. We used calcium nickel and conducted experiments to change the temperatures. When the temperature is over 200℃, the amount of hydrogen which alloy can store increases. However, the amount does not change when the temperature is between 100℃ and room temperature, 25℃. The results confirmed that alloy can store more hydrogen if the temperature is over 100℃.

## 1. Introduction

In the past 20 years, the use of renewable energy, such as solar energy, has attracted much attention around the world. However, the amount of electricity that renewable energy supplies tends to be inefficient. For example, solar energy can be collected during the day time, whereas, not at night. Therefore, we need to create methods to store the surplus energy when it is generated more than the demand, to make the supply balanced. (Fig.1)

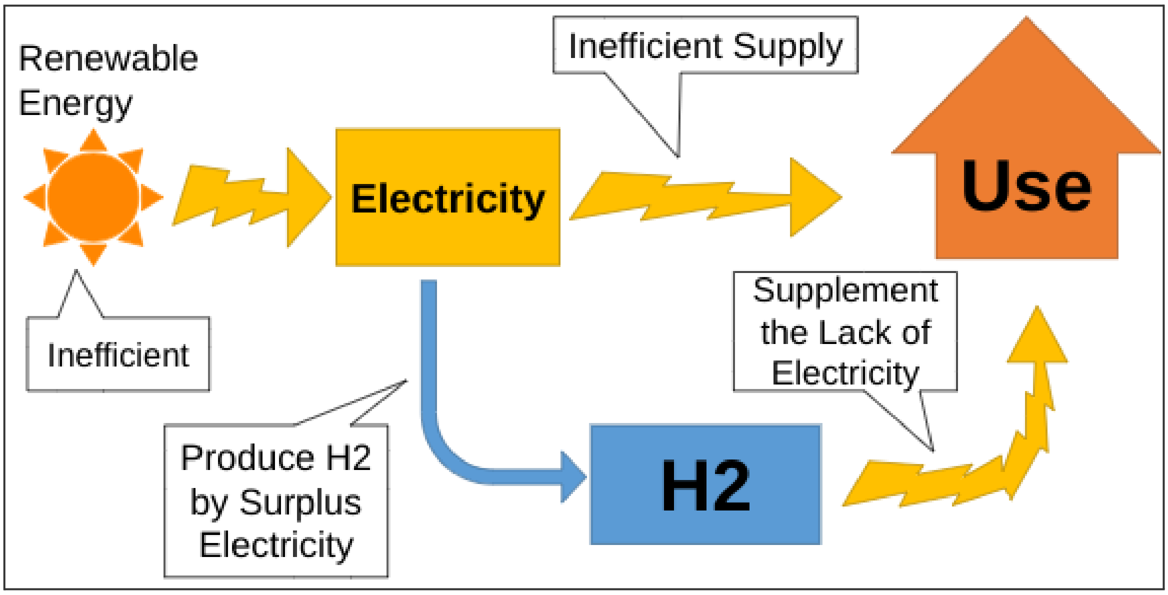



Fig.1 The Example of Utilization of Hydrogen Energy

"Hydrogen energy" allows us to store and release energy efficiently and safely. There are various ways to make use of the methods, like direct storage of hydrogen gas or liquid, and storing as ammonia. Among them, using "Hydrogen Storage Alloy" is one of the most effective and safe ways to store and release hydrogen. Nevertheless, this material is not used widely enough around the world. If we succeed in finding better ways to use alloy, we may be able to contribute to the development of a hydrogen-based society and supply consistent electricity generated by renewable energy.

Hydrogen storage alloy, which is also known as MH alloy, is a special alloy which can contain and can release about 1000 times larger volume of hydrogen gas than its volume. Thereby using MH alloy is often said to be one of the most effective ways to store hydrogen energy. There are various types of MH alloy. We purchased $CaNi_5$ alloy for our experiments because this type is relatively cheaper than other types and we couldn't find other types of alloy. $CaNi_5$ looks like a silver-colored powder.

Fig.2 $CaNi_5$, one of the MH Alloy

In our research, we defined "Activation" as the method to remove $CO_2$ or $H_2O$ by vacuuming and heating the alloy to 200℃. The alloy stores hydrogen by putting hydrogen atoms into the gap in its crystal grid. However, there are other molecules such as $CO_2$ and $H_2O$ already, resulting in the ineffective storage of hydrogen. To make the most of MH alloys, it needs to be "activated", because by conducting activation, we can get rid of those molecules before storing hydrogen, and thus the alloy can store the hydrogen more efficiently.

In the former research of our experiment, one of the MH alloys called "Zr-Mn" (Zirconium-Manganese) was tested. A teacher and students from the high school attached to Aichi Educational University conducted this research. They put the alloy into test tubes, and they vacuumed and heated the alloy to 200℃ for an hour. Afterwards, they made the alloy store hydrogen gas for two hours. The result showed that the more the alloy was activated to store hydrogen, the more hydrogen the alloy was able to store.

In the former research, they did not test whether the effectiveness of MH alloy would change if the conditions of activation, such as the temperature, the time, and so on were changed. For this reason, we set the goal of our research to detect the most optimal conditions of activation for MH alloy to store hydrogen most effectively.

## 2. Method

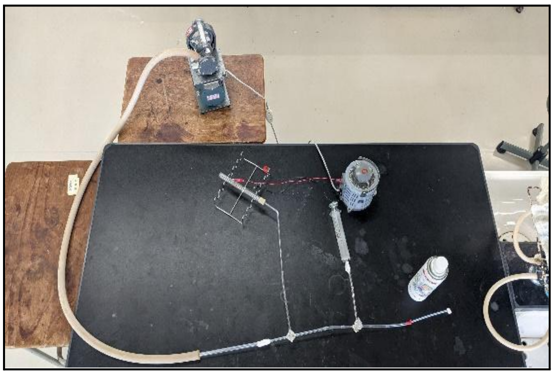
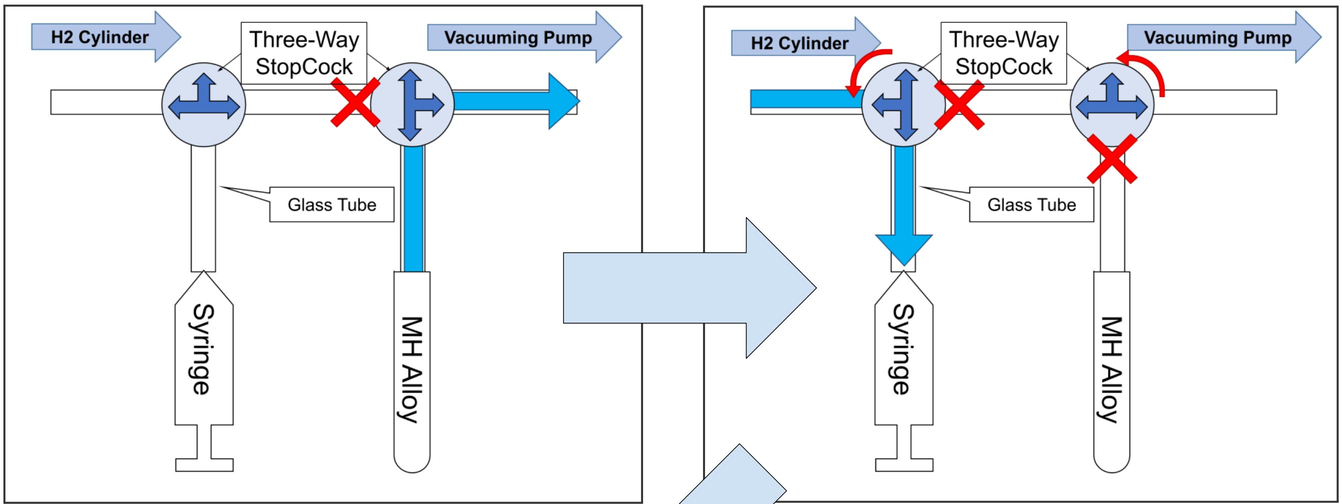


Fig.3 Experimental device laboratory

Firstly, we wanted to change the degrees of activation, the time it absorbs hydrogen, and the fineness of alloy. However, the experiment we conducted took about one and a half hours for each test. (We would like to explain the result, focusing on the data we were able to get.)

Although we wanted to do activation in an industrial manufacturing method, we could not do the same experiment in that way at the school, because we do not have facilities to change pressure or temperature easily. Therefore, we conducted similar experiments to previous studies that high school students had done in the past. The different point is that we changed the temperature of an activation.

Here is what we did in the experiments. First, we put the alloy powder in the test tube and heated it with nichrome wire under vacuumed condition for 30 minutes. Secondly, we stopped vacuuming and heating. After that, we put 50 mL of hydrogen gas into the syringe and connected the test tube which is in a vacuum with the syringe. Then, we kept them for 60 minutes at room temperature and atmospheric pressure while recording the scale on the syringe every 5 minutes for an hour. We regarded the decreasing amount on the syringe as decreased amount of the experiment.



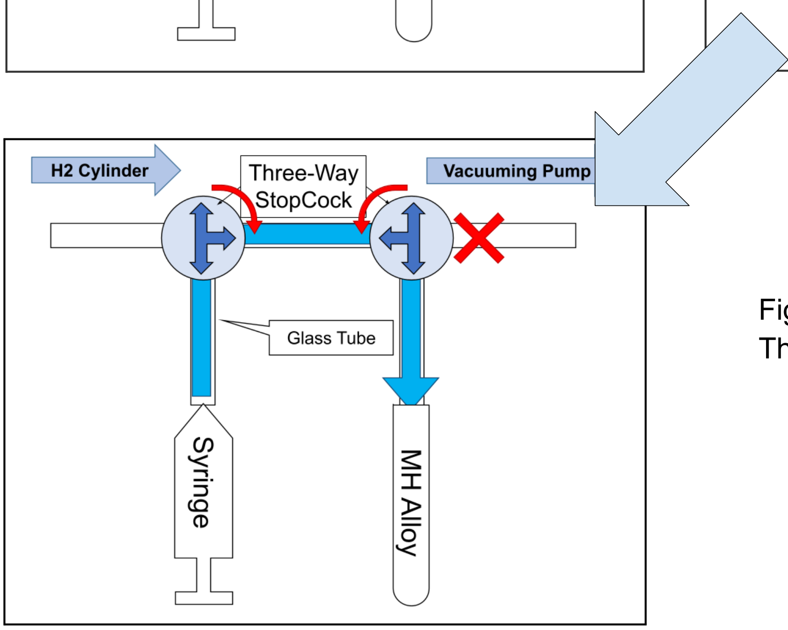




Fig.4,5,and 6
The Three Phases of the experiment

In our experiments, we changed only the temperature to heat up the alloy when we conducted activation. We conducted experiments with temperature at 250℃, 200℃, 100℃, and 25℃, which is at room temperature.

We defined hydrogen storage amount as differences between decreased amount of experiments and that of control experiment. In the control experiment, we did not put alloy into the test tube and followed the same method.

## 3. Experiment 1

**[Purpose]**

To learn how the alloy behaved when we heated it at 200℃.

**[Hypothesis]**

The more experiments we conduct, the more hydrogen gas the alloy absorbs.

**[Result]**

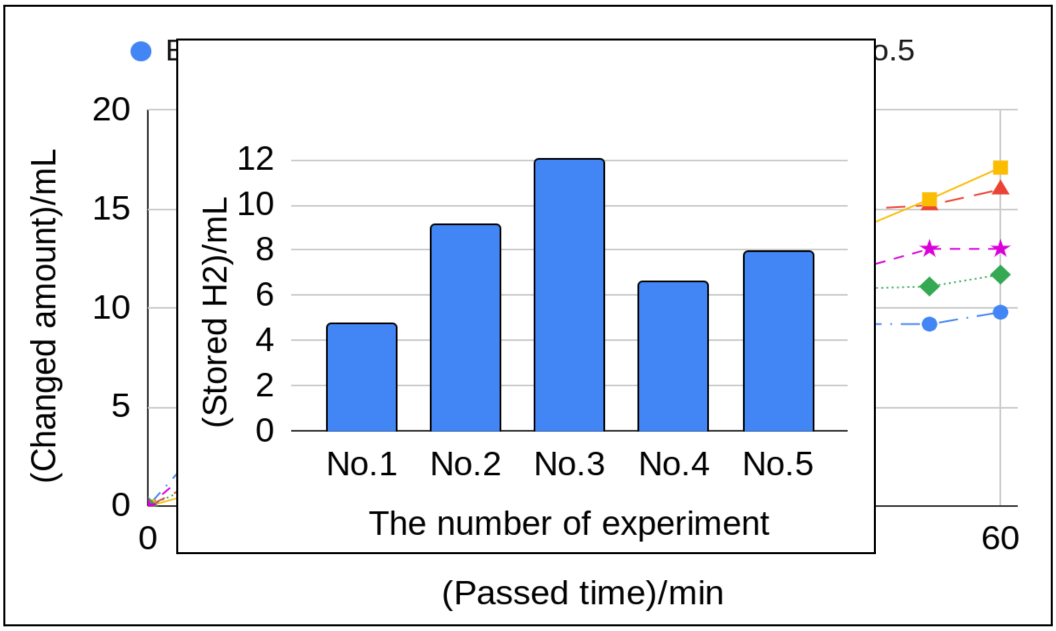



Fig.7 The Relationship between the time and the decreased amount of hydrogen gas when heated up by 200℃

Fig.8 The total amount of stored hydrogen in each experiment

As we put the alloy in the hydrogen gas longer, it absorbed more hydrogen gas. (Fig.7)

Moreover, we found out that the more times we activated the alloy, the more hydrogen gas it contained. On the other hand, the results show that the alloy contained less amount of hydrogen gas in experiment 4. (Fig.8)

**[Discussion]**

The results indicate that the alloy attains higher purity as we activate the alloy for many times. Thus, it has stored more amounts of hydrogen gas.

In experiment 4, the amount of stored hydrogen was less than Experiment 3. We consider that the alloy contained other substances between Experiment 3 and Experiment5 because the interval of those experiments was a week longer than usual.

## 4. Experiment 2

**[Purpose]**

To learn relation between the temperature and the amount of hydrogen that alloy can absorb.

**[Hypothesis]**

It allows hydrogen storage alloy to absorb more hydrogen gas by heating it to high temperature.

**[Result]**

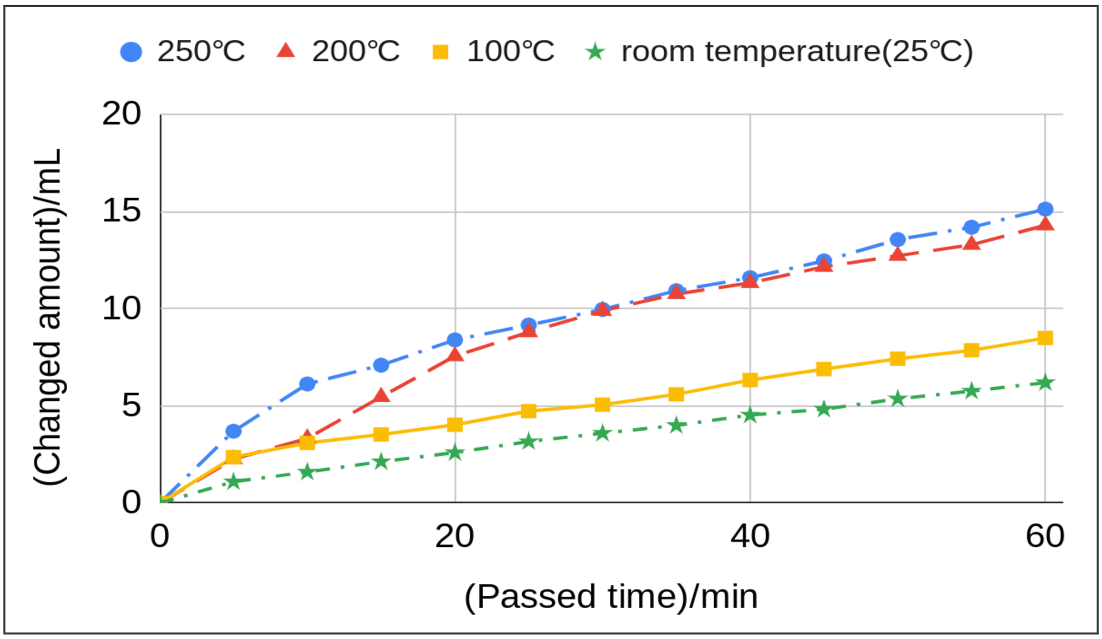



Fig.9 The relationship between the time and the decreased volume of hydrogen gas in each experiment (heated by 250℃, 200℃, and 100℃, and non-heated)

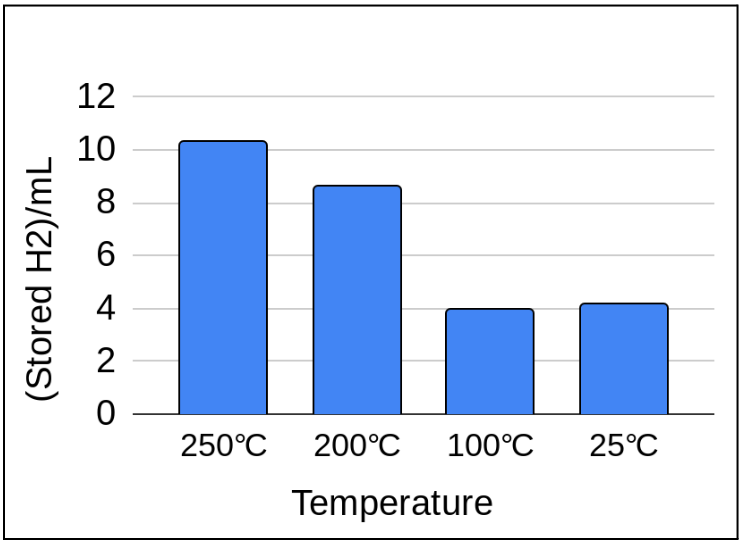



Fig.10 The average amount of absorbed hydrogen in each experiment (Heated by 250℃, 200℃, and 100℃, and non-heated)

The results of Fig.9 indicate that regardless of temperature, the amount of stored hydrogen monotonically increases as time passes.

Moreover, the results in Fig.10 show that there are almost no differences in the average amount of absorbed Hydrogen between 25℃ and 100℃. Furthermore, the average amount rises over 100℃.

**[Discussion]**

We consider that $CaNi_5$ can absorb more hydrogen effectively, because it takes away other substances, such as carbon dioxide or water molecules. In addition, the longer we activate the alloy, the more hydrogen gas it absorbs. The results also show that the alloy absorbs hydrogen gas constantly when we activate the alloy for at least 120 minutes. What is more, the results of the second experiment indicate that there seems to be a point that the alloy gets much more efficient to absorb hydrogen gas between 100℃ and 200℃.

## 5.Conclusion

We can conclude that MH alloy absorbs more hydrogen when we heat the alloy many times. However, this expectation does not work when it is heated over 250℃. In addition, according to Fig.7, we found out that between the temperature between 100℃ and 200℃, a lot of hydrogen is stored into MH alloy.

Therefore, we can estimate that MH alloy can absorb hydrogen effectively when heated by between 100℃ and 200℃, because the purity of the alloy increases by extracting other substances. Also, the more times we activate the alloy and make it contain hydrogen, the more hydrogen it absorbs constantly, at least 120 minutes.

## 6.Future Outlook

In this research, we measured the temperature with an infrared thermometer. Nevertheless, this measuring method might be affected by the temperature of Nichrome wire and we were not able to measure the temperature inside the syringe accurately. We need to improve that. Moreover, we want to change other conditions other than the temperature.

Furthermore, we had to arrange the way of preservation of MH alloy, because that in our experiment was so unstable that the amount of hydrogen stored by hydrogen storage alloy decreased.

In addition, we could not see MH alloy transformed into pieces of powder, yet it should be powdered when it is activated. Therefore, we had to assess why this phenomena had not occured.


## 7. Acknowledgements

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**9. Key words**

Hydrogen Storage Alloy, Activation, $CaNi_5$