Can Hot Water Freeze Faster Than Cold Water?

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I. Introduction

In 1969, a man named Mpemba claimed that hot water can freeze faster than cold water. This statement seems impossible, however, There are numerous experiments supporting this effect, but never mentioned precise data. On the other hand, the papers[1] which provided precise data all reported Mpemba effect is impossible. Therefore, this topic truly intrigued our curiosity. There are four main reason which can effect measurement of Mpemba effect, gas dissolve, over cooling, convection, and evaporation. Over cooling can't manipulate so we reduced the effect of convection and evaporation. Eventually, we observed Mpemba effect in a limited range of temperature and with the specific definition of Mpemba effect. We also found out an interesting phenomenon, which the temperature of water suddenly decreases faster during cooling process.

II. Apparatus for Experiment

The devices of our experiment are divided into three parts, temperature controlling system, cooling system, and data acquiring system. First of all, we heat the water in by using temperature controlling system. Each test tube contains 5 ml water and cooled down in the cold reservoir which is cooled down by cold nitrogen air. Nitrogen air goes through the liquid nitrogen then goes into cold reservoir. The temperature of water inside test tube was measured by thermocouples and recorded by LabVIEW program.

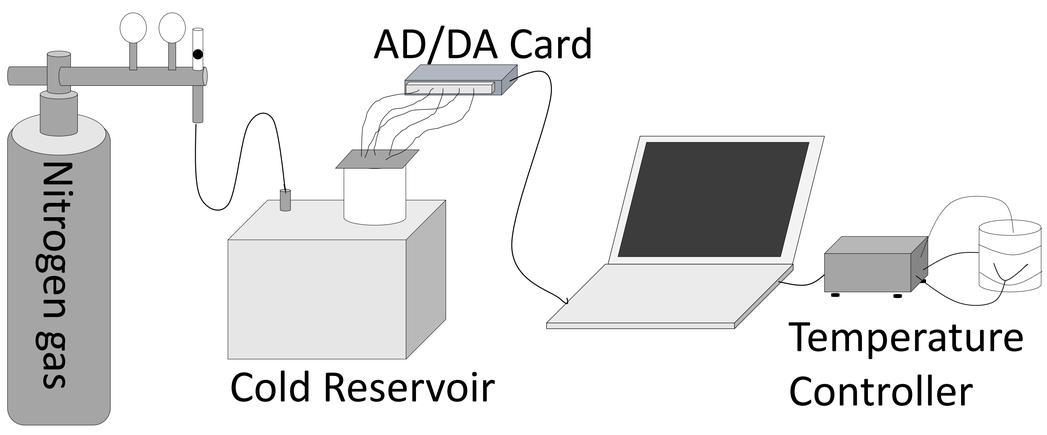

Fig. 1 Schematic diagram of apparatus

III. Experimental Results

Fig. 2 (top channel) shows that the cooling rate changing suddenly at about 4℃, that is due to the temperature distribution of water inside test tube is not uniform. When the water at the bottom cooled lower than 4℃, the density[2] starting to decrease rather than increase. Therefore, it causes the system to form convection.

To exclude the convection effect, we used very little amount of water (0.5 ml) to ignore the effect of temperature gradient. The result is shown in Fig. 3, without a doubt, the rate changing point disappeared. Therefore, we used these samples to study Mpemba effect.

We used 13℃ as a reference temperature, and detected the cooling time of every sample from the reference temperature to 0℃. These samples were prepared at several different temperatures. Fig. 4 shows that the cooling time as a function of sample prepared temperature.

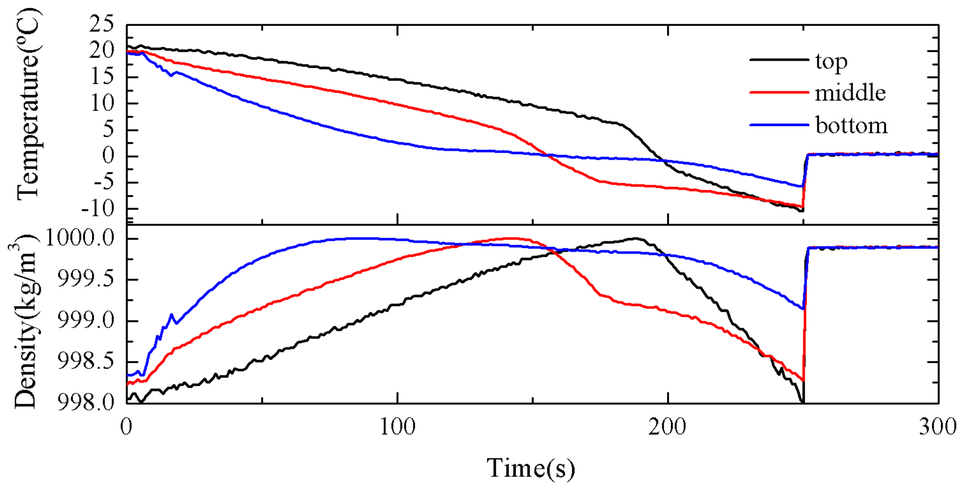

Fig. 2 temperature and density of sample water as a function of time in three different vertical position of test tube.

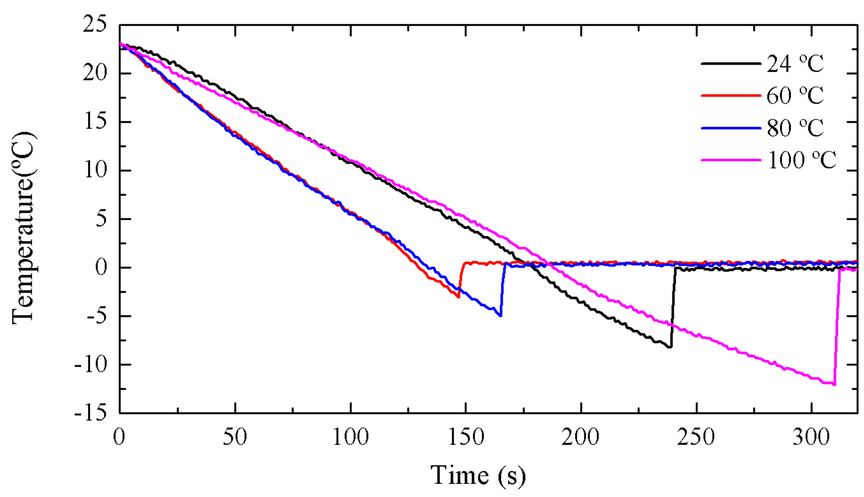

Fig. 3 The temperature as function of time of samples prepared at several different temperatures.

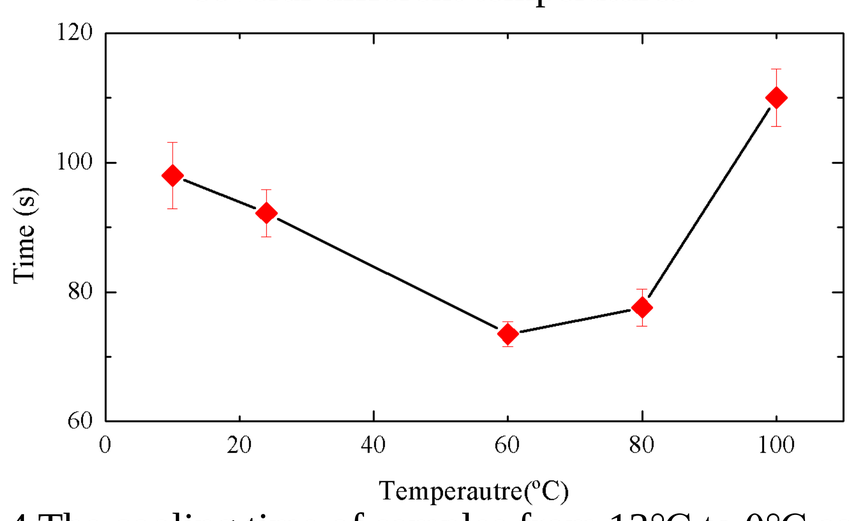

Fig. 4 The cooling time of samples from 13℃ to 0℃ as a function of sample prepared temperature.

IV. Discussion

If we use samples with different initial temperature and compare the time of samples cooling down from same reference temperature to 0℃[1], Mpemba effect could be observed in our system between 13℃ and 60℃, even though we had tried to perform the experiment without evaporation and convection. However, if we use others viewpoints, Mpemba effect couldn't be observed.

V. Conclusion

The argument of Mpemba effect is very foggy. According to our experimental results, our opinion on defining Mpemba effect is the time of different temperature samples cooling from certain temperature to 0℃. Because convection and evaporation can affect by the shape of container and the cooling system condition. Therefore, in the experiments we discussed, we excluded these two effects from the experiments in order to prove Mpemba effect.

Reference:

[1] Monwhea Jeng, Can hot water freeze faster than cold water?, University of California: California, available at: http://math.ucr.edu, accessed 5th May 2017, (1998)
[2] S. C. McCutcheon, J. L. Martin, and T. O. Jr. Barnwell, *Handbook of Hydrology*, New York: McGraw-Hill, (1993)