Heike Kamerlingh Onnes

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I. INTRODUCTION

Heike Kamerlingh Onnes was a brilliant, experimental physicist who studied under some of the most famous scientists of his day. He was driven by his motto "To comprehend through measurement"[1, pp. 2]. He constantly delved further and further into the world of low temperatures. This drive would eventually lead him to be known as the "the gentleman of absolute zero" [2, pp. 4], being one of the greatest scientists of low temperature physics.

II. ONNES' BEGINNINGS

Onnes was born in 1953 in Groningen in the Netherlands. His father owned a roofing-tile factory. His mother was an artistic woman whose father was an architect. His brother and nephew would later go on to become famous artists, and his sister would go on to marry a famous artist Floris Verster [2, pp. 1].

Heike Kamerlingh Onnes [3].

Onnes first studied at Hoogere Burgerschool in his hometown of Groningen as a teenager. He then enrolled at the University of Groningen in 1870 when he was 17 and received his candidaats degree the following year. He then went on to University of Heidelberg where he studied under the famous chemist Robert Wilhelm Eberhard von Bunsen and physicist Gustav Robert Kirchhoff from 1871 to 1873 [3]. Onnes then

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returned to Groningen where he later received the doctor's degree in 1879 on the influence of the earth's rotation on a short pendulum [2, pp. 1].

Onnes' talent for problem solving was apparent from an early age. In 1871, at age 18 he won a gold medal for a competition held by the Natural Sciences Faculty of the University of Utrecht. The following year he won a silver medal for a similar event at the University of Groningen. While working at the University of Heidelberg, he won the "Seminarpreis", which won him an assistantship under Khirchhoff [3].

III. THE QUEST FOR LIQUID HELIUM

Towards the end of his doctoral work, Onnes became aquainted with Johannes Diderik van der Waals. In 1880, van der Waals published his Law of Corresponding States, a single statement describing the behavior of all real gases. It was through this aquantince that Onnes would become interested in the behavior of gases [2, pp. 2].

Before the end of the 19th century, scientists were beginning to believe that some gases, namely oxygen, nitrogen and hydrogen, were "permanent gases", they would never condense to a liquid phase. However, in 1877, Louis Paul Cailletet succeeded in liquefying oxygen at 90.2 K [4, pp. 1-2]. In 1883, Raoul P. Pictet succeeded in liquefying nitrogen at 77.4 K [2, pp. 3].

The race then became for liquid hydrogen. It was at this time that Onnes began his work in liquefying gases. He wanted to test van der Waals' Law of Corresponding States, and the only way to do this was by examining gases in extreme conditions. He concentrated all of his efforts on liquefying large quantities of hydrogen gas, as this was the next milestone in liquefying gases, always being directly involved with the experiment. At the same time, Sir James Dewer was working on the same goal of liquefying hydrogen.

However, word soon spread of Onnes' work in Leiden where he was working. Nearly 90 years before this, in 1807, an ammunitions ship anchored in a canal exploded in the middle of town, causing massive damaging and reducing part of the town to ruins. The lab where Onnes was working with large amounts of explosive hydrogen gas was built upon those ruins. This fact drove the town's council into a panic and put a halt on Onnes' work for two years before they allowed him to continue his work in 1896. But despite this major setback, Onnes continued with his work, ever diligent in his experiments [2, pp. 4].

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In 1898, however, Dewer succeeded in liquefying a small amount of hydrogen gas at ~~20~~ 20 K. Onnes continued his work, though, until he was able to liquefy large amounts of hydrogen gas in 1906 [2, pp. 3-4].

However, in 1869, helium was discovered in the spectrum of the solar corona. And in 1895, Sir William Ramsay found helium gas on earth when certain minerals are heated up. The new quest became to liquefy helium [4, pp. 2].

REDUNDANT

Now that Onnes was ~~now~~ able to produce relatively large quantities of hydrogen gas, he was able to begin work on a helium liquefier. Onnes used the same principles on his helium

he needed Hydrogen gas to begin work on helium?

liquefier as he did on his hydrogen liquefier. By using Joule-Thomson expansion, he would repeatedly cool a gas and then allow it to expand, cooling it even further [2, pp. 3-4].

Because of the complexity of the machine, Onnes enlisted the help of a Dr. Cornelius Dorsman, an expert at the time in electrical measuring. He also enlisted a technician named G.J. Flim and a graduate student Gilles Holst who actually measured the resistance. Onnes himself kept his eyes on the delicate cryogenic apparatus [1, pp. 2].

On July 10, 1908, Onnes and his team began their experiment at six in the morning to try and liquefy helium. The experiment lasted 16 hours [1, pp. 2]. By early evening, the

HOW DOES THIS SUPPORT YOUR THESIS — THAT HE WAS DRIVEN TO MEASURE THINGS?

temperature of the helium gas remained stable at 4.2 K no matter what Onnes and his team did to try and lower the temperature further. Fransiscus Schreinemakers, a chemistry professor who dropped in on the experiment that evening suggested that maybe the thermometer wouldn't drop any further because the helium was liquefying, and Onnes and his team simply couldn't see it. Onnes proceeded to illuminate the collecting chamber of the apparatus and was then able to see for the first time liquid helium [2, pp. 5].

Always wanting to do more, Onnes would go on to improve his experiment. By decreasing the pressure of the liquid tank, he was able to drop the temperature down to a then astonishing 1.7 K. In 1911, he was able to develop a helium cryostat that enabled him to transport the liquid helium while maintaining liquid state [2, pp.5].

IV. NO MORE RESISTANCE

It was not enough for Onnes that he was able to reach his goal of liquid helium. At the time, no one was exactly sure what would happen to the resistance as the temperature approached 0 K. Always true to his motto, he wanted to see what would happen to the resistance of metals as the temperature via experiment. Onnes set out with his new liquid to experiment with low temperature resistivity.

There were two predominating theories of the time. The first was that as the temperature dropped the motion of the electrons would also drop, until the electrons stopped moving all together at 0 K. This would correspond to a minimum resistivity of metals near zero, but then approaching infinite resistivity at 0 K. Lord William Thomson Kelvin was the main person who upheld this view [2, pp. 6-7].

The second theory, which Onnes was inclined to, was that the resistivity of metals was due to both the scattering of electrons by thermal vibrations and the impurities in the metal. This would correspond to zero resistance in a pure metal at 0 K [5, pp. 1]. So Onnes began his experiment to see which was true, it there would be infinite or zero resistance. If

In order to really test the later, Onnes would need a very pure metal to test only the thermal effects of electrons (it would later turn out that the purity was unimportant). It was for this reason he chose to use mercury for the experiment, an element that could be sufficiently purified at the time [5, pp. 1].

Onnes used his helium liquefier to reach adequately low temperatures. He placed the purified liquid mercury in a U-shaped glass with two cathodes at both ends and then chilled the mercury until it solidified into a wire. Onnes then placed this in a circuit and began dropping the temperature even farther with liquid helium while monitoring the current, and subsequently the resistance [2, pp. 7-8].

Much to his surprise, as the temperature approached 4 K, the resistance suddenly dropped off. The sensitivity of his instruments was such that Onnes thought the resistance was only very small, not that it had disappeared altogether. He first thought that a short circuit had occurred in the circuit. But after repeated trials and frequently checking the apparatus, Onnes realized that indeed the resistance had completely disappeared. He would later call this newly found phase "Superconductivity" [2, pp. 7-8].

Onnes, again not merely satisfied with this result, went on to further test what happened near 0 K. He found that the purity of the sample did not affect the ability of the sample to achieve superconductivity. Onnes also discovered that even a small external magnetic field could disrupt superconductivity (Onnes would only ever know of "Type I" superconducting materials before his death [1, pp. 6]). He also found that other materials were able to reach superconductivity besides mercury [2, pp. 7-8].

V. CONCLUSION

Heike Kamerlingh Onnes was a brilliant physicist who helped to discover the world of low temperatures. For his work with liquid helium and superconductivity, he would be known as "the gentleman of absolute zero" [2, pp. 4]. Driven by his desire to always learn more through ~~experiment,~~ he changed our knowledge of low temperature physics forever.
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WORKS CITED

[1] J.D. Doss. Engineer's Guide to High-Temperature Superconductivity. New York: John Wiley & Sons, Inc., 1989.

[2] R. de Bruyn Ouboter. "Heike Kamerlingh Onnes's Discovery of Superconductivity." Scientific American Mar. 1997: 98

[3] The Nobel Prize in Physics 1913. 2004. Nobel Foundation. 28 September 2004. <http://nobelprize.org/physics/laureates/1913/onnes-bio.html>

[4] V.Z. Kresin, and S.A. Wolf. Fundamentals of Superconductivity. New York: Plenum Press, 1990.

[5] A Guide to Superconductivity. D. Fishlock. New York: American Elsevier Publishing Company, Inc., 1969.