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Extra credit paper

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Johannes Diderik van der Waals

Johannes Diderik van der Waals won the Nobel prize in 1910 due to his stunning work on the equation of states for liquids and gases. Waals work made a great breakthrough in the world in physics.

Johannes Diderik van der Waals was a Dutch theoretical physicist and thermodynamics that was born on November 23, 1837 in Leyden, The Netherlands. He was the son of Jacobus van der Waals and Elisabeth van den Burg. After van der Waals had finished elementary education at his birthplace he became a schoolteacher. At the time van der Waals had no knowledge of classical languages, and thus was not permitted to take academic examinations, however curious about science, he also attended night and summer school at the University of Leiden in 1862-1865. As years past he earned teaching certificates in mathematics and physics. He continued his studies and in 1873 at the age of 35 he earned his doctorate. In September of 1877 van der Waals was appointed the first professor of physics at the newly founded Municipal University of Amsterdam. Until the age of 70 van der waals remained teaching at the Amsterdam University until he was succeeded by his son Johannes Diderik van der Waals Jr, who was also a theoretical physicist. In 1910 at the age of 72, van der Waals was awarded the Nobel Prize in physics. He died at the age of 85 on March 8, 1923.

During Johannes Diderik van der Waals life time he studied many different things but what caught the attention of many was his work on the equation of states for liquids and gases. In

1873, van der Waals obtained his doctor's degree for a thesis entitled *Over de Coninuiteit van den Gas-en Vloeistoftoestand (on the continuity of the gas and the liquid state)*. This thesis put him at once on the foremost rank of physicists. In his thesis, he put forward and "Equation of State" embracing both the gaseous and liquid state; he could demonstrate that the two states of aggregation not only merge into each other in a continuous manner, but that they were actually of the same nature. This equation of state was a dramatic improvement over the ideal gas law. Van der Waals saw the necessity of taking into account the volumes of molecules and the intermolecular forces ("van der Waals forces" as they are now commonly called) in establishing the relationship between the pressure, volume and temperature of gases and liquids. In the copy of *Over de Coninuiteit* van der Waals equation of state is printed, (P + a/V2) (V - b) = RT. Van der Waals won the Nobel Prize or this work in 1910.

Van der Waals studied the behavior of gases, and showed that the liquid and gases of a substance are of the same nature and that the substance's behavior and transition between states could be accurately predicted. His work was predicated on the existence of molecules, still a disputed concept at the time, and the right assumption that molecules are of finite size and attract each other. The van der Waals equation describes the relation between pressure, volume, temperature and gas. His theorem of Corresponding States concludes that after scaling temperature, pressure and volume according to their critical values, all fluids have generally the same compressibility factor and show about the same variation from ideal gas behavior. These works caught the attention of James Clerk Maxwell, who recognized its importance and wrote in his book *Nature* that van der Waals work belongs "among the foremost in science". Gaining huge respect two years later he was elected to the Royal Netherlands Academy of Science, and two years later he was named the full professor of the University of Amsterdam.

Van der Waals’ discovery of this equation was strongly motivated by his attempt to understand the essential continuity between gaseous and liquid states of matter that was established a few years earlier by T. H. Andrews discovery in 1869 of the gas-liquid critical point. The Van der Waals equation and associated molecular viewpoint that underlies its derivation marked a pivotal advance in the molecular theory of gases and liquids.

During Van der Waals Nobel prize lecture he gives insight into his lifelong struggle to understand and extend his discovery. He acknowledges the huge influence of Clausius’ 1857 paper on the kinetic theory of heat, which provided the first correct proof of Maxwell’s velocity distribution law and led to his idea that there is no essential difference between the gaseous and the liquid state of matter, whereas the crystalline state definitely behaves in a slightly different way. He recognized the two factors that prevent exact agreement with Boyle’s law, as well as the remaining discrepancy with experiment that continually bothers him. Van der Waals emphasizes his conviction that the “constant b” actually carries significant V dependence, and his astonishment to learn that such dependence does not detract from essential consistency with the law of corresponding states. He recognizes the essential need to incorporate the addition effect of the “pseudo-association”. He also recognizes the compelling evidence that the “attraction of the molecules decreases extremely quickly with distance, that the attraction only has an appreciable value at distances close to the size of molecules and he recalls Debye’s explanation of a prescient remark by Boltzmann. He makes further remarks that one can see a pioneering suggestion of a cluster mixture theory of liquids with short-range forces. His last acknowledges the unexpected difficulty in extending his equation to binary mixtures and association complexes. Van der Waals lastly offers an impassioned testimony to his belief in atoms and molecules and addresses those who are skeptical of his ideals.

In conclusion Van der Waals was the recipient of numerous honours and distinctions. He received an honorary doctorate of the University of Cambridge; was made honorary member of the Imperial Society of Naturalists of Moscow, the Royal Irish Academy and the American Philosophical Society; corresponding member of the Institut de France and the Royal Academy of Sciences of Berlin; associate member of the Royal Academy of Sciences of Belgium; a foreign member of the Chemical Society of London, the National Academy of Sciences of the U.S.A., and of the Accademia dei Lincei of Rome, leaving his legacy in the world of science.

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