ISSN:2249-5347

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International Journal of Science Innovations and Discoveries

An International peer Review Journal for Science

Nobel Prize in Physics 1946

Percy Williams Bridgman

The Nobel Prize in Physics 1946 was awarded to Percy W. Bridgman *"for the invention of an apparatus to produce extremely high pressures, and for the discoveries he made therewith in the field of high pressure physics"*.

RESEARCH INFORMATION:

The earliest known attempts to attain high pressures and to study various properties of matter under the influence of these pressures date from the beginning and middle of the 17th century. The experiments, which were carried out by extremely primitive methods, aimed in the first place at throwing light on the compressibility of liquids. These investigations did not become of a more scientific and systematic nature until the beginning of the last century, although at first they had the same limited aims as before. However, they were gradually extended to other fields. As an example may be mentioned attempts to compress a number of gases at high pressure, when great divergencies from Boyle's law revealed themselves, and further, investigations of the effect of pressure on the refractivity of water, the effect of pressure on the resistance of an electric conductor. Most important of all was in 1861 Andrews' discovery of the critical phenomena in gases.

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A period of intensive research began after this last discovery, a period which lasted until the beginning of the 1890's. During this period the leading research workers in this field were the two French physicists, Cailletet and Amagat, of whom the former was active during an earlier phase of the period mentioned. These two scientists, especially the latter, made important contributions towards improving the technique for attaining high pressures and worked out reliable methods for measuring them. Amagat developed a special technique for ensuring effective scalings or packings, a fundamental problem when working on high pressures. Thanks to this technique, Amagat succeeded in obtaining constant pressures of 3,000 kg/cm^2 and more. His contributions were of the greatest importance for further work, and subsequently a large number of research workers in different countries devoted themselves to the study of high pressures. Although very comprehensive work in this field was done, no considerable progress was made in the matter of an improved technique. The limit remained at 3,000 kg/cm^2, and it was not until after 1905 that it began to make gigantic leaps upwards. The credit for this is due in the first place to Professor P. W. Bridgman, who is today to receive the 1946 Nobel Prize for Physics for his invention of an apparatus for obtaining extremely high pressures, and for the discoveries he has made with it within that field of physics.

According to Professor Bridgman himself, it was by a mere chance that he came to devote his activities to high pressures. At about the year 1905, he began to study certain optical phenomena under the influence of pressure. During his experiments the apparatus, parts of which were made of glass, exploded, and an essential part of it was destroyed and had to be replaced. In the interval, Bridgman tried to find another use for the actual pressure apparatus, and while working out a sealing device for the pressure chamber, he found that the sealing device he had constructed functioned far better than he had at first imagined, for the efficiency of the sealing proved to increase as the pressure increased, and there was no perceptible leakage. A new pressure range had presented itself, a range which was not, as in Amagat's experiments, limited by leakage, but only by the strength of the

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material of which the pressure apparatus was made. After the problem of leakage had been solved, an advance towards higher pressures came to be essentially a question of materials.

Even in his earliest experiments Bridgman succeeded in arriving at pressures of 20,000 kg/cm2. In the earlier investigations, however, the pressure was kept at a lower value, in order to avoid deformation of the material then used. Considerable time was devoted both to investigating the material and to different methods of making accurate determinations of the pressures. From his first successful attempts to pass Amagat's pressure limit of 3,000 kg/cm^2, Bridgman has step by step, by means of his brilliant apparatus and skilful use of the resources of modern technics, extended the pressure range, and has made pressures up to 100,000 kg/cm^2 available for research work. In certain cases pressures of between 400,000 and 500,000 kg/cm^2 have been attained.

The essential features of the Bridgman pressure apparatus are two containers, communicating with each other by means of strong connecting channels. The whole system is filled with an appropriate fluid. In one of the containers (the pressure chamber itself) the pressure fluid is subjected, by means of a movable piston, to a great pressure, which is transmitted by the fluid to the other container, the actual experimental chamber. This last-mentioned part varies in accordance with the nature of the projected investigations.

Working on the principle that the resistance of a vessel which is subjected to internal pressure is increased if at the same time it is subjected to external pressure, Bridgman used double high-pressure vessels for ranges from cat 30,000 to 100,000 kg/cm^2. The internal pressure vessel with an external conical surface is fitted into a corresponding bore in a reinforcement cylinder and equipped with a cylindrical channel, where the material which is to be subjected to pressure is placed between two pistons working from opposite ends. As material for the high-pressure vessel in the range from 50,000 to 100,000 kg/cm^2, Bridgman used the extremely hard tungsten carbide, or, as it is called, carboloy, which is subject to the least possible deformation.

The investigations with the highest pressures, between 400,000 and 500,000 kg/cm^2, have been made with the help of carboloy pistons, the effective surface being 3 mm

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in diameter. This small size is a necessary result of the expansion of the pressure area under these high pressures, and therefore the amount of matter which can be compressed is extremely small. With a pressure of 425,000 kg/cm^2 Bridgman obtained compressed material in the form of small thin flakes. An X-ray analysis of these showed that, under the influence of the pressure, the structure had passed from crystalline to noncrystalline form, i.e. the substance had become amorphous.

Bridgman's research work has not been directed only towards attaining record high pressures. The gradual advance towards higher and ever higher pressures was immediately taken advantage of for investigations in fields where the impossibility of attaining higher pressures had previously put a stop to research work. Bridgman's important discoveries in the course of this work are so many that here it is only possible to touch upon them briefly.

The majority of Bridgman's earlier investigations were carried out within the range up to 12,000 kg/cm^2. The first more comprehensive investigations had to do with the solid and fluid conditions, and these investigations were subsequently extended to ranges up to 50,000 kg/cm^2, new modifications of different substances being discovered, *inter alia*, of both ordinary and heavy water in solid form, and altogether seven different mod)fications of ice are known. Further, two new modifications of phosphorus have been discovered, one stable form- the so-called black phosphorus - and one unstable form. By means of investigations of compressibility at pressures right up to 100,000 kg/cm^2, a large number of polymorphous substances have been discovered. A great deal of work has been devoted to meticulous investigations of the pressure effect on electric resistance, and here, *inter alia*, the existence of a resistance minimum for certain metals at very high pressures has been established. Bridgman's interest has also been directed towards other spheres. Thus, investigations have been made into the pressure effect on thermoelectric phenomena, on the conduction of heat in gases, on the viscosity of fluids, which have led to discoveries, significant both scientifically and technically. This applies also to his work on the effect of pressure on the elastic properties of solid bodies. These contributions were all made in

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fields which had previously not attracted much interest. Attention should also be called to the extensive and difficult investigations of materials, which were a necessary precondition for the successful advances towards higher pressures, investigations which are of the greatest importance for further work in the field of high pressures.

Finally, attention should be called to the immense scientific value of the impressive collection of data regarding the properties of matter at high pressures which Bridgman has assembled during his long and important research activities in the field of high pressure physics

Professor Bridgman. In awarding you this year's Nobel Prize for Physics, The Royal Swedish Academy of Sciences desires to express its unreserved acknowledgement of your outstanding pioneer work in the field of high-pressure physics. By means of your ingenious apparatus, combined with a brilliant experimental technique, you have, by your intense research work and the resulting manifold and remarkable discoveries, very greatly enriched our knowledge of the properties of matter at high pressures.

On behalf of The Royal Swedish Academy of Sciences, I congratulate you on your important and successful work in the service of science, and I now ask you to receive your Nobel Prize from the hands of His Majesty the King.

For more details please visit:

http://www.nobelprize.org/nobel_prizes/physics/laureates/1946/press.html

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