Award Ceremony Speech

Presentation Speech by Professor O. Klein, member of the **Swedish Academy of Sciences**

Your Majesty, Your Royal Highnesses, Ladies and Gentlemen.

This year's Nobel Prize in Physics - to professor Hans A. Bethe - concerns an old riddle. How has it been possible for the sun to emit light and heat without exhausting its source not only during the thousands of centuries the human race has existed but also during the enormously long time when living beings needing the sun for their nourishment have developed and flourished on our earth thanks to this source? The solution of this problem seemed even more hopeless when better knowledge of the age of the earth was gained. None of the energy sources known of old could come under consideration. Some quite unknown process must be at work in the interior of the sun. Only when radioactivity, its energy generation exceeding by far any known fuel, was discovered, it began to look as if the riddle might be solved. And, although the first guess that the sun might contain a sufficient amount of radioactive substances soon proved to be wrong, the closer study of radioactivity would by and by open up a new field of physical research in which the solution was to be found.

While ordinary physics and chemistry could be led back to the behaviour of the electrons which form the outer part of atoms, the new field is concerned with their innermost part, the atomic nucleus. Its discoverer, **Rutherford**, called it the newer alchemy because nuclear reactions, in contrast to chemical reactions, usually lead to transmutations of the chemical elements - what alchemists wished to produce but could not by their means-the reaction energy being there some million times greater than in chemical reactions.

It soon became clear that the proton, the nucleus of the hydrogen atom, is a common building stone of all atomic nuclei. It is electrically charged. The other building stone, the neutron, being electrically neutral as indicated by its name, was discovered in 1932, twenty-one years later than the nucleus itself. And, in spite of important progress during those years, it may be said that from then on nuclear physics had really started. At that time it was already apparent that Bethe belonged to the small group of young theoretical physicists who through skill and knowledge were particularly qualified for tackling the many theoretical problems turning up in close connection with the rapidly appearing experimental discoveries. The centre of these problems was to find the properties of the force that keeps the protons and neutrons together in the nucleus, the counterpart of the electric force which binds the atomic electrons to the nucleus. Bethe's contributions to the solution of these problems have been numerous and are still continuing. They put him clearly in the first row among the workers in this field - as in several other fields. Moreover, about the middle of the thirties he wrote, partly alone, partly together with some colleagues, what nuclear physicists at the time used to call the Bethe bible, a penetrating review of about all that was known of atomic nuclei, experimental as well as theoretical.

This extensive and profound knowledge of his regarding atomic nuclei together with a rare gift of rapidly grasping the essence of a physical problem and finding ways of solving it explains that Bethe could so swiftly do the work awarded by the Nobel Prize. He started his work after a conference taking place in Washington in March 1938 and the paper containing a thorough description of it was delivered for print at the beginning of September the same year. During that conference and afterwards he seems also to have acquired the necessary astrophysical knowledge. This knowledge depended mainly on a pioneer work by Eddington from the year 1926, according to which the innermost part of the sun is a hot gas mainly consisting of hydrogen and helium. Owing to the high temperature, about 20 million degrees, - these atoms being dissolved into electrons and nuclei - the mixture, despite the high density - about 80 times that of water - really behaves like a gas. The amount of energy generation necessary to maintain this state was known from measurements of the radiation falling on the earth. Taken as a whole it is enormous, but very slow as compared to the size of the sun. An ordinary 60-Watt electric bulb would correspond to about 300 tons average sun matter. This very slow burning together with the very high energy release from a given weight of fuel gives this source the high durability required by geology and the long existence of life on the earth.

Before coming to the nuclear processes, which according to Bethe's work are definitely the source of the energy generation of the sun and similar stars, a few words should be said about two questions which naturally present themselves in this connection. Why are these nuclear processes so slow in the sun when they are so fast in atomic reactors, not to mention atomic bombs? And why are they non-existent under ordinary conditions? The answer is that nuclei are protected against other nuclei by the repulsion due to their electric charges together with the extremely small range of the nuclear force - which is about as small relative to a midget as a midget is to the sun - implying that a proton must have an extremely high velocity in order to come so close to another nucleus as is necessary for a nuclear reaction to take place. If it were not for the quantum-mechanical tunnel effect studied very closely in this connection by Gamow - who must be considered the main forerunner of Bethe with respect to the application of nuclear physics to astronomy - even the velocities of the protons at the high temperature of the sun would not be able to produce any such processes. But through this effect the required slow reactions do occur. The case of the atomic reactors is different, because the reactions are there produced by neutrons, which having no charge are not stopped by the electric charge of the nuclei. Fortunately neutrons are short-lived and therefore extremely rare under ordinary circumstances and also in the sun.

Even when Bethe started his work on the energy generation in stars there were important gaps in the knowledge about nuclei which made the solution of the problem very difficult. And it was by a remarkable combination of underdeveloped theory and incomplete experimental evidence, under repeated comparison of his conclusions with their astronomical consequences, that he succeeded in establishing the mechanism of energy generation in the sun and similar stars so well that only minor corrections were needed when many years later the required experimental knowledge had made considerable progress and when, moreover, electronic computers had become available for the numerical calculations.

A very important part of his work resulted in eliminating a great number of thinkable nuclear processes under the conditions at the centre of the sun, after which only two possible processes remained. The simplest of them begins with two protons colliding and forming a nucleus of heavy hydrogen, the surplus of electric charge vanishing in the form of a positive electron. After capturing a few more protons the result of the process is the formation of a helium nucleus from four protons. Thereby the energy release from a given weight of hydrogen is nearly 20 million times greater than that produced by burning the same weight of carbon into carbon dioxide. The second process is more complicated. It requires the presence of carbon which, however, will practically not be consumed but acts as a catalyst, the result being the same as in the former process. It should be mentioned that the first process had been proposed a few years earlier by Atkinson and later discussed by von Weizsacker, who also considered the second process independently of and at about the same time as Bethel But none of them had attempted a thorough analysis of these and other thinkable processes necessary to make it reasonably certain that these processes, and only these, are responsible for the energy generation in the sun and similar stars.

Bethe's work constitutes since many years a main foundation for the great development which has taken place of the knowledge of the interior of the sun and the stars. During recent years it has obtained a new actuality through a promising attempt made by a group of astrophysicists to understand what happens when a star has used up its hydrogen, thereby throwing new light on another old riddle, that of the origin of the chemical elements.

Professor Bethe. You may have been astonished that among your many contributions to physics, several of which have been proposed for the Nobel Prize, we have chosen one which contains less fundamental physics than many of the others and which has taken only a short part of your long time in science. This, however, is quite in agreement with the rules of the Nobel Prize and does not imply that we are not highly impressed by the role you have played in so many parts of the development of physics ever since you started doing research some forty years ago. On the other hand your solution of the energy source of stars is one of the most important applications of fundamental physics in our days, having led to a deepgoing evolution of our knowledge of the universe around us. On behalf of the Royal Swedish Academy of Sciences I extend to you the most hearty congratulations. And now I have the privilege to ask you to receive the Nobel Prize for Physics from the hands of His Majesty the King.

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