1931

NOBEL LAUREATE

Carl Bosch

1874–1940

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Carl Bosch was born in Cologne, Germany, on August 27, 1874, and died in Heidelberg on April 26, 1940. He received the Nobel Prize in 1931 for the invention and development of chemical high-pressure methods. His father, Carl Friedrich, owned a wholesale firm with a workshop for gas and water installations. His uncle, Robert Bosch, was the founder of one of the leading companies in the German electrical industry.

Carl was the eldest of six children, and owing to his father's educational principles he grew up in an open-minded atmosphere. In contrast to what was common at that time, Carl's father would never punish the children; instead he would discuss interesting problems and explain his point of view. Carl's father was a great lover of nature and was able to explain to his children a great number of phenomena they saw in the garden or out in the fields. At an early age Carl started to collect minerals and animals, which became a passion he never lost. His father also introduced him to his craftsmanship. He bought Carl tools and the material needed to build the things he liked, such as bird cages, a terrarium, and even a boat. When Carl was 16, his interest gradually shifted to chemistry. Already a skillful craftsman, he was able to construct his own equipment, sometimes together with a foreman from his father's workshop.

In 1893 Bosch finished *Gymnasium,* and although he was mainly interested in chemistry, he started an apprenticeship in a metallurgical plant and after one year became a journeyman. With this practical back-

ground Bosch started to study metallurgy and mechanical engineering at the Technische Hochschule in Berlin. In pursuit of his special interest he went to chemistry lectures, worked in a chemistry laboratory, and practiced spectral analysis.

In 1896 Bosch finally decided to switch from engineering, a field which was mainly based on practical applications, to pure science. He went to the University of Leipzig, at that time one of the leading German centers of chemistry. As in Berlin, Bosch not only worked in one subject but also went to lectures on physics, mineralogy, and the natural history of animals. In chemistry he worked under Johannes Wislicenus, and in 1898 received his doctoral degree with a thesis in organic chemistry. After that he became a laboratory assistant.

Bosch actually wanted to start a university career, but his father persuaded him to look for a position in the chemical industry. He applied for a position at the Badische Anilin und Soda Fabrik (BASF) in Ludwigshafen, one of the leading chemical companies, and was accepted. He was assigned to the main laboratory and at first worked on azo dyes and phthalic acid anhydride, a compound needed for the synthesis of artificial indigo.

In 1900, after one year at Ludwigshafen, Bosch was confronted with a new problem. He was asked to redo some of Wilhelm Ostwald's experiments on the catalytic synthesis of ammonia from its elements. Ostwald was one of the most prominent physical chemists at that time, and he wanted to sell his ideas to BASF. Bosch could not verify Ostwald's results. Certainly it was not easy for a young laboratory chemist like Bosch to speak up against such an authority as Ostwald, but his excellent experiments and his clear way to prove where and how Ostwald had obtained incorrect results convinced Ostwald and the BASF directors of Bosch's ability to solve difficult problems. This was the first time Bosch was confronted with the nitrogen problem, the problem of how to convert molecular nitrogen into a nitrogen compound that could be used as fertilizer. Later he would become famous for the solution of this problem. His excellent work in disproving Ostwald's findings had won Bosch the favor of his superiors and of his own laboratory group at BASF. Therefore, they never hesitated to support him when he was working on the nitrogen conversion besides his work at the phthalic acid plant.

At the end of the 19th century the natural sources of nitrogen compounds, including Chilean saltpeter (sodium nitrate), were diminishing, and the chemical industry was desperately searching for a process to replace saltpeter as a base of fertilizer. Several methods of fixing nitrogen had been developed, and Bosch tried all of them. He even tried a large-scale method, to produce 90 tons of ammonia, but finally he discarded all the methods as being too expensive. Nevertheless, by testing those methods he had accumulated a huge amount of knowledge and experience as far as the solving of technical and chemical problems was concerned.

In 1909 the successful partnership between Bosch and Fritz Haber began. Haber had worked on the direct formation of ammonia, but contrary to Ostwald he used high pressure and found promising amounts of ammonia. The directors of BASF agreed to finance Haber's research. When Haber was able to find a good catalyst, osmium, and got a yield of 6–10% ammonia at a pressure of 200 atm and 600 °C, Bosch was convinced that the system could be adjusted to technical dimensions. At that time it was absolutely unthinkable to work on a technical level at 200 atm and at a temperature at which steel just started to glow, but Bosch had enough courage and confidence in the engineering capacity of modern technology to trust the impossible.

He started by choosing Alwin Mittasch as head of the chemical research and Franz Lappe as chief engineer. The problem was to find a suitable catalyst. Osmium, the catalyst Haber had used, was too scarce, so the chemists started to study practically every element's catalytic activity. After half a year of research with more than 20,000 experiments, they found a catalyst that gave results as good as osmium: iron contaminated with alumina (aluminum oxide). Engineers at BASF had to construct a reaction tube able to withstand 200 atm and 600 °C. The worst problem they found was that after a few hours of contact with hydrogen steel became very brittle, lost its ductility, and caused the reaction tube to explode under the high pressure. Bosch's solution was to separate the two functions of the tube, a tight seal for the gas and a great strength for pressure resistance: The inner lining of the reaction tube was soft iron, gas-tight except for the diffusing hydrogen. The outer part functioned to withstand the high pressure. The outer tube continued to be made of steel, but now it was punctured with thousands of holes so that the diffusing hydrogen could escape without reacting with the steel and thus destroy it. On March 5, 1911, the first specimen of the newly constructed tube worked, and the most important step in solving the nitrogen problem was taken. The commercial production of ammonia, however, did not start until

September 1913, when 20 metric tons of ammonia could be produced per day.

Bosch did not relax when the big plant worked at last. He knew that agriculture needed different types of fertilizer and that ammonium sulfate was not the best of them. Therefore he immediately started to work on the synthesis of urea and the oxidation of ammonia to nitric acid. At that time he did not know how important his research on nitric acid would be for his country. At the beginning of the century, nitric acid, produced until then from saltpeter, was an important ingredient for gunpowder manufacture. Before World War I nearly all saltpeter was imported, but when Germany's international connections were cut by the British fleet at the beginning of the war, the country needed new sources of nitric acid for the production of gunpowder. When Bosch heard about this problem he promised the German military that BASF would find a way to start the large-scale production of nitric acid. Based on his experiments on the oxidation of ammonia he worked out a procedure for the industrial production of nitric acid using atmospheric oxygen to oxidize NH_3. In May 1915 BASF was able to produce 150 metric tons of nitric acid per day.

When Bosch started to work on the production of ammonia he was an excellent chemist. However, the way he solved the arising problems and the way he coordinated all the steps needed to make the plant work showed that he was not only a very good scientist but also an outstanding organizer. The BASF board of directors appreciated that and always supported him and his often-unusual ways of handling things. His knowledge and capability soon made him one of the leading figures at BASF, and in 1916 he became one of its directors. Bosch's reputation for being an excellent organizer grew when he built a second ammonia plant, the famous "Leuna Werke", in 1916. He had to deal with all parts of German industry and the military to get the material he needed despite the war's needs. Nevertheless, it took him only 11 months from the beginning of construction to the first running ammonia reactor.

In 1916 the *Interessengemeinschaft der deutschen Teerfarbenfabriken* (Interest Group of the German Coal Tar Dye Industry) was founded. Bosch, already a member of many advisory boards and committees and one of the founders of the employers' association of the German chemical industry, took part in most of the meetings and thus from the beginning knew what was going on in the largest congregation of power within German industry.

His influence kept growing, and he was chosen to become one of the consultants for the German diplomats who had to conclude the treaties of Spa and Versailles after the end of World War I. The Versailles treaty forced the Germans to hand over the whole chemical industry with all its patents to the victors. Besides that, all war factories were to be destroyed, among them, of course, the ammonia production, important in the manufacture of explosives. Yet Bosch was able to persuade the French industrialists and generals that cooperation among the industries could be more valuable than confiscated patents without practical know-how. In addition they finally agreed to Bosch's suggestion of the Germans' helping to build an ammonia plant in Toulouse and sending all the machinery and even trained people who would help to run it. In exchange the German ammonia plant would not be destroyed. Despite the German public's resentment of this agreement, these transactions were the beginning of Bosch's career as a captain of industry. In those days he became acquainted with the leaders of foreign industries; he already knew the leaders of German industry, was a member of many of their boards and committees, and also knew quite a few politicians.

In the meantime Bosch had been promoted to head of the board of directors of BASF, and from that position he was able to increase his influence in the center of the coordinating committee of the German chemical industry. In 1925 he reached his next goal, the fusion of the eight big dyestuff companies of Germany to form IG Farben, whose head Carl Bosch became. It was by far the biggest joint-stock company in Germany and one of the leading chemical companies worldwide. Contracts between IG Farben and foreign chemical companies consolidated the international chemical market.

Besides all this political and economic work, Bosch worked hard on the hydrogenation of coal. IG Farben bought the patents of Friedrich Bergius, whose knowledge of high-pressure reactions enabled that company to start the commercial hydrogenation of tar oil and coal in less than a year and to produce about 100,000 metric tons of gasoline per year. Unfortunately, the world depression was very harmful to international trade, which diminished considerably and was no longer thought of as a guarantee of peace.

In 1931, at the peak of the depression, when Carl Bosch was overburdened with economic problems, the Swedish Academy decided to honor him with the Nobel Prize for chemistry. It was the first time that industrial achievement rather than pure science was honored.

Together with Bergius he received the prize for "their contribution to the invention and development of chemical high-pressure methods". Thus, in the middle of the economic depression, Bosch's mind was turned back to the beginning of his career, to his love of scientific research and its technical application. The Swedish Academy especially honored the start of high-pressure chemistry, because that was the revolutionary beginning of a new age in chemical production methods. After the production of synthetic ammonia, Bosch had started the high pressure synthesis of methanol from carbon monoxide and water, soon to be followed by the high-pressure production of urea and gasoline. A consistent use of the theory of thermodynamic equilibrium, together with the use of an adequate catalyst and of high pressure to move the equilibrium in the right direction, and the application of all that on a large scale, constituted Bosch's prominent achievement. Most of the processes developed by Bosch and his co-workers are still used today without having been substantially changed. Some of his methods might even be of increased importance these days: for example, the production of gasoline from coal and tar.

When the Nazis came to power in Germany, Bosch's relation to them was very ambivalent and difficult to judge: On the one hand IG Farben donated large sums to the Nazi party; on the other hand Bosch resented their interference with free world trade and the freedom of scientific research, and he voiced that resentment. Soon after he had met Hitler in person, it became clear that they both deeply resented each other. Nevertheless, Bosch could not give up his position in German industry; IG Farben was his personal achievement, and, even when the Nazis took away most of his freedom of action, he stayed with IG Farben and tried to guide it through its difficulties. Very often, however, he could not find a solution to a particular problem and therefore suffered considerably from all the compromises he had to make with the regime. He was often depressed and acquired various diseases of the intestinal organs. During the years from 1935 to 1939 his health gradually deteriorated. After the beginning of World War II, Bosch's depressions became worse until he died in Heidelberg on April 26, 1940, full of dark visions about the future of his country and the future of his ideas.

During his lifetime Bosch was most famous as a captain of industry. To chemists, the work for which he received the Nobel Prize, namely, the techniques of high-pressure catalytic processes, is most important, but to most people Bosch is better known for another of his achievements. His name cannot be separated from Haber's, because their "Haber–Bosch process" solved the nitrogen problem, the artificial generation of nitrogen compounds to be used as fertilizer, which became more and more important to the rapidly increasing human population.

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1932

NOBEL LAUREATE

Irving Langmuir

1881–1957

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Irving Langmuir, who received the Nobel Prize in chemistry in 1932, was only the second American to be so honored. He was the first American employed by an industrial laboratory to receive the prize. It was awarded "for his outstanding discoveries and inventions within the field of surface chemistry". Langmuir was born on January 31, 1881, in Brooklyn, New York. His parents were Charles Langmuir, a prosperous insurance man, and Sadie Comings Langmuir; Irving was the third of their four sons. He died suddenly on August 16, 1957, at Woods Hole, Massachusetts, where he was visiting his nephew's family. Langmuir received his undergraduate degree in metallurgical engineering from Columbia University in 1903. He chose that course because of its strong combination of mathematics, physics, and chemistry. He then went to Germany for graduate study and completed his Ph.D. dissertation at Göttingen in 1906; his advisor, Walther Nernst (Nobel Prize in chemistry, 1920), has been called "the father of modern physical chemistry". Langmuir's thesis research concerned the dissociation of gases on hot filaments.[1]

After receiving his Ph.D., Langmuir took a teaching position in the chemistry department at Stevens Institute of Technology, a fledgling institution in Hoboken, New Jersey. He remained there three years, apparently with little opportunity for research (he published only

[1]Langmuir, I. "The Dissociation of Water and Carbon Dioxide at High Temperatures"; *J. Am. Chem. Soc.* **1906**, *28*, 1357–1379.