Fritz Haber

"We congratulate you on this triumph in the service of ... humanity. Please accept ...." So introduced, Fritz Haber accepted the 1918 Nobel Prize in Chemistry for his method of synthesizing ammonia from its elements, nitrogen and hydrogen. This marked the culmination of his epic experiments on the thermodynamics of the ammonia equilibrium. This was also the harbinger of a technological revolution that dispelled the Malthusian threat of shortage. In ammonia synthesis, as elsewhere, Haber epitomized a rare fusion of the two faces of science: pure and applied.

Fritz was born on December 9, 1868 in the respected Haber family of Breslau, Germany (now Worclaw, Poland). His father was a prosperous chemical merchant and an alderman of the town. Fritz received an excellent school education and developed a keen interest in chemistry. Later he worked in his father's business but only briefly. The son's "lively adventurous spirit ... seemed a danger to the business".

Following brief stints at the Universities of Berlin and Hidelberg and at the Federal Technical College at Zurich, Haber had his first serious exposure to chemical research under Karl Libermann at the Charlottenberg Technical College in Berlin. The work was on the chemistry of piperonal and indigo derivatives and it formed the basis of his doctoral thesis (1891). Later, he worked under Ludwig Knorr on the constitution of diacetosuccinic ester at the University of Jena. In the end, however, organic chemical methods seemed too well established to young Haber who was left "uninspired".

The turning point came soon. In 1894 Haber joined the Department of Chemical and Fuel Technology at the Fredericiana Technical College in Karlsruhe as an assistant to Hans Bunte. He was given responsibilities and duties in both teaching and research and this was the start Haber was looking for. He engrossed himself with work. Haber had finally found himself. At Bunte's suggestion Haber examined the ill-understood phenomenon of hydrocarbon pyrolysis. His immense capacity for work quickly brought new insight into the relative stabilities of C-C and C-H bonds. On the strength of the dissertation, *Experimental Studies on the Decomposition of Hydrocarbons*, Haber became a Privat-dozent in 1896 – the first step to becoming a faculty. The hydrocarbon work had induced in him a liking for thermodynamics, which soon expanded into a liking for the then emerging area of physical chemistry. Haber's colleague and friend Hans Luggin, a former student of Svante Arrhenius, acted as catalyst. Haber rapidly metamorphosed into an extraordinary physical chemist who dominated and shaped the subject for the rest of his life.

It began with electrochemistry. The organic chemist in him was still alive and one of his first electrochemical studies concerned the origin of the many products formed in the cathodic reduction of nitrobenzene. By systematic control of the cathode potential, he demonstrated how the underlying complex electrochemistry could be neatly understood as a stepwise process. He made seminal contributions to many other areas such as the quinone-quinol redox equilibrium and the phase boundary potential. His findings later led to the development of the quinhydrone electrode and the glass electrode by others. In 1898 Haber became an extraordinary professor (associate professor).

Haber's first important book, *Technical Electrochemistry* was published in the same year. Seven years later, *The Thermodynamics of Technical Gas Reactions* appeared. This book which was hailed as "a model of accuracy and critical insight", stands tall in the annals of thermodynamics. In 1906 Haber was appointed professor and director of the Institute of Physical Chemistry and Electrochemistry at Karlsruhe. He had already ventured into his ammonia work in 1904, starting with the measurement of equilibrium constants.

Nitrogen was then generally believed to be too inert to combine with hydrogen. This myth died soon and by 1908 Haber and Le Rossignol established conditions (200 atmosphere, 550°C and uranium catalyst) at which the equilibrium concentration of ammonia was high enough to yield liquid ammonia under moderate cooling. In July 1909, a BASF engineer Carl Bosch visited Karlsruhe to see this demonstration. Translation to industrial scale became possible following some brilliant inventions in high pressure chemical engineering for which Bosch (along with F Bergius of coal hydrogenation fame) received the Chemistry Nobel Prize in 1931. The saga of ammonia thus came to be decorated by two Nobel Prizes.

Today tens of million tons of ammonia are made worldwide each year, all by the Haber process. In modern plants the temperature and pressure ranges used are 400-500°C and 100-1000 atmosphere, respectively. In large plants the amount of catalyst (usually iron mixed with basic oxide promoters) can be as large as hundred tons, which remains active for over 10 years of use.

Ammonia synthesis tends to overshadow the other important gas reactions that Haber studied at Karlsruhe, for example, his seminal work on flame and combustion. He demonstrated that in the luminous inner core of the Bunsen flame, the thermodynamic water gas equilibrium operates and the combustion of water gas occurs in the outer mantle. The Karlsruhe years were by far the most brilliant period in Haber's career – his *Glanzzeit* as his friend Willstätter called it.

Haber left Karlsruhe in 1911 to become the director of the newly built Kaiser Wilhelm Institute of Physical Chemistry and Electrochemistry at Dahlem near Berlin (renamed Fritz Haber Institute after Haber's death). He rounded off his ammonia work and immersed himself in planning the activities of the institute. Quantum theory and the era of the electron had arrived. And Haber began by discovering the phenomenon of emission of free electrons in the low pressure reactions between chlorine (or oxygen) and alkali metals. When such exciting happenings had just begun came the abrupt halt due to the first World War, 1914.

For Haber, Germany always came first. He placed himself and his laboratories at the service of the war ministry. Ammonia was oxidized to nitric acid for explosives. Poison gases were deployed. The war ended in 1918 with the German defeat. Haber was left diminished in both health and spirit. It was a shock from which he never recovered fully. Some quarters accused Haber of crime against humanity and some laureates boycotted the Nobel Prize award ceremony. Mankind will see a much more deadly world war. And time will heal it all. Today Haber is remembered as the genius that he was.

With the war finally behind him, Haber's indomitable spirit rose again to build his institute which soon became one of the major centres of research. He collected a group of greats like Herbert Freundlich, Rudolf Ladenburg, Michael Polanyi and James Franck. There was a shower of fundamental advances in atomic physics, spectroscopy, colloid science and reaction dynamics. Haber himself was busy with chemiluminescence, flame spectra, radicals, chain reactions, autooxidation and other fascinating problems. The *Born–Haber cycle* for lattice energy was formulated with his friend Max Born. He worked hard to find an economic method to extract gold from seawater in order to help Germany to make the large reparative payments to countries violated in the war. Unfortunately, the abundance of gold in seawater had been greatly overestimated by earlier workers and the project ended in failure – a bitter disappointment for Haber.

Haber had known disappointments. He married twice but divorce was the common end. He had lost his mother at birth. But the blow of fate came in 1933. His great institution was ruined by the anti-Jewish policy of the National Socialist Government that came to power in the same year. A galaxy of people led by Haber resigned. Haber, then sixty-five, suddenly found himself without home and country. The long years of perpetual overwork already had its toll and now he was very sick. He lived in Cambridge for sometime and died in Basel on January 29, 1934.

In his Nobel lecture, Haber had said, "It may be that this solution is not the final one. Nitrogen bacteria utilizes methods which we do not as yet know how to imitate". After nearly a century we still do not know, and Haber synthesis remains the only solution. And using the fruits of his discovery, the farmer continues "to change stones into bread in the good earth".

Sources

[1] J E Coates, The Haber Memorial Lecture, *J. Chem. Soc.*, pp. 642-1672, 1939.

[2] K F Bonhoeffer in *Great Chemists*, Ed., E Farber, Interscience Publishers, pp.1301-1311, 1961.

[3] W A E Mebryde, *Nobel Laureates in Chemistry 1901-1992*, Ed., L K James, American Chemical Society, pp. 114-123,1993.

[4] M Goran, The Story *of Fritz Haber*, University of Oklahoma Press, 1967.

Animesh Chakravorty
Indian Association for the Cultivation of Science, Kolkata 700 032, India.