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## BERLIN, JERUSALEM, AND KARLSRUHE MARK FRITZ HABER'S 150<sup>th</sup> BIRTHDAY

The German physical chemist Fritz Haber (1868-1934) ranks among the most significant scientists of the 20<sup>th</sup> century. In 1909, through his discovery of a method for synthesizing ammonia from its elements, he laid the scientific foundations for what was soon to be known as the Haber-Bosch process. This technology would overcome the overwhelming reliance of industrial countries on naturally occurring, and ever-more depleted, Chilean nitrate as fertilizer. By the mid-1920s, the Haber-Bosch process had become the dominant means of nitrogen fixation – and thus a cornerstone of food production for the growing world population.

The importance of Haber's work on the ammonia synthesis was recognized early on by the 1918 Nobel Prize in Chemistry (Carl Bosch, who scaled up Haber's method, shared the 1931 Nobel Prize in Chemistry with Friedrich Bergius for the invention of high-pressure methods in industrial chemistry).

The scope of Haber's work was unusually wide-ranging, from physical organic chemistry through electrochemistry to thermodynamics. In 1911, Haber became the founding director of Berlin's Kaiser Wilhelm Institute for Physical Chemistry and Electrochemistry (KWI; it was renamed after Haber in 1952). Haber's patriotic fervor during World War One led to his involvement in the development of chemical warfare (soon duplicated by the Allied nations) as well as in securing war materials for the German military, most especially nitrogen compounds for the production of strategic chemicals and explosives. During 1915-1918, Haber's KWI served as the German center for the development of chemical weapons – and of protective measures against them.

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After the war, Haber embraced the Weimar Republic and supported its democratic institutions. He co-founded, in 1920, the first research funding agency run by academics, and, in 1926, the Japan Institute, to foster cultural and economic relations with Japan. Jointly with Albert Einstein, he sought to restore relations with the academic communities of the former enemy countries.

In 1933, Haber's faith in and loyalty to Germany changed after the National Socialists acceded to power. The Law for the Restoration of the Civil Service, of April 7, required that Haber dismiss coworkers of Jewish descent from his institute. Haber refused. Then Herbert Freundlich and Michael Polanyi resigned, whereupon Haber formally dismissed Ladislaus Farkas and Leopold Frommer, under the threat that a Nazi commissioner would take over not just Haber's institute but the whole Kaiser Wilhelm Society. Finally, on April 30, Haber handed in his own resignation in protest against the Nazi law. Haber received several offers of support, including from his former KWI assistant Setsuro Tamaru in Tokyo. In the autumn of 1933, Haber left Germany and joined William Pope at Cambridge. Chaim Weizmann, a distinguished chemist and principal Zionist leader, who had modeled the Daniel Sieff Research Institute (later core of the Weizmann Institute) in Rehovot, in mandate Palestine, on Haber's KWI, entered into negotiations with Haber over the possibility of an appointment as chair of physical chemistry at The Hebrew University of Jerusalem. Haber apparently intended to visit Palestine, but was impaired by his heart problems, which made the long journey difficult. He died in Basel, Switzerland, on 29 January 1934.

The sesquicentenary of Haber's birth on 9 December 1868 provided an opportunity to reexamine aspects of his life, work, and legacy – controversial as well as beneficial – at three recently held symposia.

The first symposium (organized by Bretislav Friedrich and Gerard Meijer) was held by the **Fritz Haber Institute of the Max Planck Society** on 10 December 2018 at Harnack Haus, the Society's conference center in Berlin-Dahlem.

Bretislav Friedrich opened the symposium with a biographical summary of Fritz Haber (*Who was Fritz Haber?*). Haber was born in Breslau, Prussia, into an acculturated, bourgeois Jewish family. He studied in Berlin, Heidelberg, Zurich, and Jena, before receiving a post, in 1894, at the Technische Hochschule Karlsruhe. During his seventeen-year stint at Karlsruhe, Haber developed a wide-ranging research program in electrochemistry and physical chemistry that included his seminal work on the catalytic synthesis of ammonia. What followed, in 1911,

was Haber's appointment as founding director of the KWI for Physical Chemistry and Electrochemistry in Berlin and, from late 1914, his intense engagement in the German war effort. He would stay on at the KWI for 22 years, until his formal resignation, as of October 1, 1933. During his second heyday period, which coincided with the Weimar Republic, Haber and his coworkers, among them star-scientists such as Karl Friedrich Bonhoeffer, Ladislaus Farkas, Herbert Freundlich, Hartmut Kallmann, and Michael Polanyi, carried out pace-setting fundamental research at the intersection of chemistry and physics that foreshadowed many key post-World War Two developments in physical chemistry and chemical physics – and beyond.

Haber was married twice. His first wife Clara, nee Immerwahr, a PhD chemist, was among the first women to enter, at the turn of the twentieth century, the then exclusively male domain of scientific research. Her tragic suicide in 1915 ended an unfulfilled and unhappy life marked by indifference from both the scientific community – and from her husband. Haber's second wife, Charlotte, nee Nathan, was a secretary of the club "Deutsche Gesellschaft 1914." Haber had three children, Hermann, with Clara, and Ludwig and Eva, with Charlotte.

The second presentation, by Deri Sheppard (University of South Wales), 'An ideal partnership,' Haber, Le Rossignol and the

*ammonia synthesis*, highlighted the important role played by Haber's English assistant Robert Le Rossignol (1884-1976) in designing and constructing the iconic steel laboratory apparatus for the high-pressure catalytic ammonia synthesis. It included recycling of the unreacted reagent gases, nitrogen and hydrogen. The apparatus – and hence the feasibility of ammonia synthesis – was demonstrated on 2 July 1909. Le Rossignol had previously refined his skills in engineering and chemistry at University College London, where he worked with high-pressure systems in the laboratory of William Ramsay. A major contribution to the success of the ammonia synthesis was Le Rossignol's design of a novel needle valve for the control of gas flow.

Jan Willem Erisman (Louis Bolk Institute/Vrije Universiteit Amsterdam), in *How 110 years of ammonia synthesis changed the world food production and environment*, drew attention to the fact that more than a half of the world population has enough to eat only thanks to the Haber-Bosch technology. However, many eat more than enough and a large part of the population is obese. Moreover, almost a half of the food produced is wasted. Given the low efficiency of the fertilization process, the release into the environment of much nitrogen contained in fertilizers unduly burdens the biosphere. This "fertilization of the biosphere" leads to the loss of biodiversity as well as to other deleterious effects, including those on human health. In



addition, the mass production of meat releases green-house gases into the atmosphere.

Margit Szöllösi-Janze (Ludwig-Maximilians-Universität München), under the heading *Science at war: Fritz Haber and the chemical industry, 1914-1918*, dealt with Haber's role as an expert war-time administrator and mediator who brought together, for the first time in history, key figures from science, chemical industry, the military, and the government. The German government recognized soon after the outset of the war that the country must rely on its own production of war chemicals – such as nitric acid, for manufacture of nitrates and nitro compounds. This need transformed the chemical industry and propelled Haber into a uniquely influential national role. The construction of the Leuna-Werke (Merseburg), financed largely by state loans, is but one example. Opened in April 1917, the factory supplied synthetic ammonia to sites in Germany where it was oxidized to nitric acid. The talk inspired reflections on the Janus-face of modern science and technology.

Stefan L. Wolff (Forschungsinstitut, Deutsches Museum München) in *Haber as a Jewish German patriot: from Baptism to Zionism* examined the circumstances of Fritz Haber's conversion to Protestantism and his further relation to Judaism. His family had been involved in several religious and social projects of Breslau's Jewish community. However, it was during his stint in Jena that the 22-year-old Fritz Haber converted to Protestantism. Wolff argued that this step might have been motivated mostly by spirituality and an interest in philosophy and less by Haber's academic ambitions. Moreover, according to Wolff, Haber's conversion did not cut-off his social ties to Judaism or preclude his concerns about anti-Semitism. Under the political circumstances of 1933 he felt isolated from the German scientific community and noted: "I was never in my life so Jewish as now." Through his contacts with Chaim Weizmann he became enthusiastic about Zionism and it was only his death that stopped short his plan to participate in establishing physical chemistry in mandate Palestine.

The symposium at Harnack Haus was enriched by two exhibitions displayed at the same venue. Firstly, about sixty works by the Belgian artist David Vandermeulen that are a part of a lavish six-volume graphic novel, *Fritz Haber*, were exhibited, in the presence of the artist. The volumes consist of hundreds of captioned sepia-colored comic-like aquarelles, each reminiscent of a camera still, that reflect the artist's astute vision of Fritz Haber's life and times. So far, the first four volumes of *Fritz Haber* have been published, between 2005 and 2015, by the Delcourt publishing house. The legend of Siegfried (Siegfried was also the name of Haber's father) is a metaphor that lurks behind Vandermeulen's view of Haber's life: like the legendary Siegfried, Haber had to take on several disguises in order to meet his fate.

Secondly, Hanoch Gutfreund (The Hebrew University of Jerusalem) presented a display of facsimiles of a selection of letters exchanged between Haber and Albert Einstein. The full collection is held at the Hebrew University's Albert Einstein Archives. The letters reveal a strong personal bond that transcends the correspondents' deep disagreements on a number of issues, including war, patriotism, and Zionism. It was Haber's extreme

loyalty to Germany that delayed his recognition of his Jewish roots and made his exile a torturous personal tragedy. The collection of the facsimiles is now on permanent loan to the Fritz Haber Institute.

Attending the Berlin symposium were members of Haber's family from Britain, Germany, and Israel, as well as members of the Tamaru family from Japan.

The event concluded with a concert of baroque music performed by Thomas Pietsch (baroque violin) and Dagmar Lübking (organ and chest organ) at the Jesus-Christus-Kirche, just across the street from Haber's former residence ("Haber Villa") on the campus of the Fritz Haber Institute.

The second Haber symposium (organized by Roi Baer and Igor Shapiro) was held at the **Fritz Haber Center for Molecular Dynamics of the Institute of Chemistry**, The Hebrew University of Jerusalem, Israel, on 17-18 December 2018. Following a short historical introduction, presentations by the center's researchers emphasized the continuation of the tradition laid down by Haber in the 1920s for pace-setting research at the intersection of physics and chemistry. The Jerusalem center has a strong focus on theoretical and computational research aimed at understanding processes occurring in the fields of chemistry, physics and biology. Significantly, among Haber's assistants in Berlin was Ladislaus Farkas, who in the mid-1930s founded physical chemistry at The Hebrew University of Jerusalem. The main historical talk was given by Tony Travis (Edelstein Center for the History and Philosophy of Science, Technology and Medicine, The Hebrew University). In *Fritz Haber and the pursuit of nitrogen* he described the steps leading to the development of the Haber-Bosch process.

Haber's work on ammonia was sponsored by BASF, a leading dye manufacturing firm that was interested in diversification into nitrogen fixation. When BASF chemist Carl Bosch and his team scaled up Haber's laboratory process they confronted several novel technical challenges, including the need for a suitable catalyst, one that had to be much cheaper than, and at least as efficient as, Haber's osmium. Following 2,500 screening experiments Alwin Mittasch decided on a suitable catalyst based on iron containing small amounts of promoters. No less problematic were the metallurgical and engineering challenges. At the working pressure of 200 atmospheres, hydrogen reacted with the carbon of the steel causing it to become brittle, resulting in explosions. Bosch designed a double-wall high-pressure converter. The inner wall, of low carbon steel, withstood the great stress, allowing hydrogen to diffuse through it. As a result of the loss of pressure, the outer wall, made of ordinary steel, did not become brittle. In 1911 BASF decided to erect a full-scale plant, at Oppau, near the main Ludwigshafen works. Extremely pure nitrogen and hydrogen gases required scale up of existing coal-based processes. The gas mixture, adjusted to give seventy-five percent hydrogen and twenty-five percent nitrogen, was compressed in massive reciprocating compressors. The process went on line in September 1913, initially for production of ammonium sulphate fertilizer.

After 1918, BASF refused to license the process. This became a spur to inventors and entrepreneurs to devise similar synthetic ammonia processes. Among the most successful variations on the Haber-Bosch process were those of Luigi Casale and Giacomo Fauser, in Italy, and Georges Claude, in France. Casale and Claude worked with extreme pressures, 800 and 1000 atmospheres, respectively, what Claude called “hyperpressures.” In the late 1920s, both processes were adopted by Du Pont in the United States. By 1930, synthetic ammonia had become a global industry, its several novel high-pressure processes all closely based on Haber’s innovations at Karlsruhe.

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**The Karlsruhe Institute of Technology** (KIT) held on 15 January 2019 a third Haber symposium (organized by Marcus Poppow, Caroline Robertson-von Trotha, and Doris Wedlich). In his opening remarks, Alexander Wanner, KIT’s Vice President for Higher Education and Academic Affairs, recalled the achievements of Haber, “one of the most outstanding scientists who ever worked in Karlsruhe,” as well as Haber’s denomination as “the Father of Chemical Warfare.” In light of such diverging assessments that, in recent years, have also been discussed at KIT, Wanner highlighted the aim of the colloquium, to provide “a solid basis of information as well as a discussion from different perspectives and perceptions.” There followed a brief address by Caroline Robertson-von Trotha, director of KIT’s Centre for Cultural and General Studies, in which she characterized Fritz Haber as a personification of the dilemmas presented by the dual use of science. In 2014, the centennial of the beginning of World War I, in which the then new Haber-Bosch process

(1913) was to play a prominent role, her center held a three-day international symposium entitled “Still at War. From Poison Gas to Drones” as a public science event within the Festival of European Culture in Karlsruhe. The symposium’s panel discussion addressed, with a focus on Haber, the conflict between the freedom of research as guaranteed by the German constitution and the demand for civil clauses prohibiting military research at German universities. As part of the public science event, the play “Colours” by Mathieu Bertholet was performed at the Badisches Staatstheater Karlsruhe. The play depicts the suicide of Clara Haber, who took her life after Germany used poison gas at Ypres, in violation of the spirit of the Hague Conventions of 1899 and 1907. The panel discussion aimed at providing a critically reflected representation of Haber that distinguishes between his scientific merits and his involvement in chemical warfare in World War One.

In the keynote address on 15 January 2019, Bretislav Friedrich (*Fritz Haber at 150: The unfolding views of and on a German Jewish Patriot*) provided a “sound selection” of what one should consider when forming a “sound opinion” on Fritz Haber. There followed a discussion among the panelists (Marcus Poppow, Thomas Potthast, Caroline Robertson-von Trotha, Doris Wedlich, and Bretislav Friedrich), and subsequently with the audience, that raised issues as diverse as the relationship between Haber and Einstein, forms of commemorating Haber on KIT’s campus, and initiatives for an extended integration of ethical issues into engineering curricula. Participants agreed that students – and others – should be properly informed about all aspects of Fritz Haber’s life and work in order to be able to critically engage in discussions on this most outstanding scientist.