Fritz Haber at one hundred fifty: Evolving views of and on a German Jewish patriot*

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Prelude

Only few scientists have conferred benefits to humankind – both intellectual and practical – that are on a par with those we owe Fritz Haber. And yet, Haber has been a controversial figure – for about the last third of those one hundred fifty years that elapsed since his birth in 1868. It was Haber's role in World War One – most notably his initiative to usher in chemical warfare to the battlefield – that cast a long shadow over his legacy. The moral outrage elicited by the German chlorine cloud attack at Ypres on 22 April 1915 was immediate, but not long lasting: Within a few months of Ypres, the *Entente* deployed its own potent chemical arsenal and eventually declared, alongside with Germany, poison gas a "humane weapon" [Friedrich et al. 2017]. In the 1920s and early 1930s, Haber could even act, together with Albert Einstein and others, as ambassador of German science in Europe and America and actively participate in repairing the damage done to international cooperation by the "war of the intellects" [Wolff 2001, Wolff 2003, Berg und Thiel 2018] in general and the "chemists' war" [Friedrich 2015] in particular.

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Only during a commemoration of Haber’s centennial in 1968 at the *Technische Hochschule Karlsruhe* did a wave of enduring criticism of Haber’s leading role in chemical warfare surge up that has not quite subsided since. This upsurge, fifty years after the end of World War One, reflected the concerns of the 1960s anti-establishment and anti-war movements that fueled in part the student protests of 1968 in the U.S. and Western Europe [Judt 2010, pp. 418-421]. Chemical weapons had by then been reassessed as weapons of mass destruction that preceded – and complemented – nuclear weapons as instruments of mass murder. At the same time, the concurrent revisions of World War One’s historiography, cf. the Fischer Thesis [Fischer 1961], implied – rightly or wrongly [Clark 2012] – not only connections but also similarities between Germany’s roles in the two world wars. All of the above cast a stigma on Fritz Haber as someone who contributed to arming, with a weapon of mass destruction, a regime that was on the wrong side of history.

During the fifty years since 1968, two major scholarly biographies [Stoltzenberg 1994, 2004; Szöllösi-Janze 1998] as well as countless monographs and historical articles have been written dealing with aspects of Haber’s life, work, and legacy. As a result, much more is known about Haber today than in 1968. However, in the public eye, the scholarly literature on Haber has been largely eclipsed by the publication, in 1993, of Gerit von Leitner’s book about Fritz Haber’s first wife Clara, nee Immerwahr [Leitner, 1993]. This book created an appealing image of Clara but portrayed Haber as a warmonger contemptuous of human life and an oppressive husband to boot. Although largely “belletristic” [Friedrich and Hoffmann 2016 and 2017], von Leitner’s book resonated with the *Zeitgeist* and inspired a number of dramatizations, some of high artistic quality, cf. [Hoffmann and Laszlo 2001] for a review of some English-language works.

These dramatized accounts set off an additional wave of public disgrace that further eroded Haber's standing – and legacy.

But, as Dietrich Stoltzenberg, one of Haber's scholarly biographers, noted [Stoltzenberg 2004, p. 153]: "It is easy to condemn Haber; it is much harder to make a sound judgment on him."

Herein, I will not attempt to pass judgment on Haber. Instead, I will try to present a "sound selection" of what I think one should consider when forming a "sound opinion" on Fritz Haber.

Family background

Fritz Jacob Haber was born on December 9, 1868 in the then sprawling city of Breslau, Prussia (today Polish Wroclaw), into a well-to-do Jewish family. His father was a wealthy merchant – a leading indigo importer.[1] His mother died from complications of childbirth three weeks into his life. The parents were first cousins – descendents of brothers on the paternal side – so had the same family name, Haber, even before marriage.

The father remarried and the female element in Haber's childhood was mainly represented by his affectionate stepmother and three stepsisters. Fritz, the only son, ended up attending a traditional humanistic high school closely affiliated with St. Elisabeth's, the largest protestant church in Breslau. Half of its pupils were Jewish. Fritz was a good student, but not an outstanding one [Stoltzenberg 2004, p. 16].

Fritz's strongest early influence was his mother's brother, Hermann Haber, the leader of the *Liberal People's Party* in Silesia (of which Breslau was the

[1] Much of the biographical information summarized below draws on [Szöllösi-Janze 1998] and [Stoltzenberg 2004].

capital). Hermann ran a local newspaper, *Die Breslauer Zeitung*, to which Fritz would later contribute. Uncle Hermann also provided space, in his apartment, for Fritz's early chemical experiments. Haber's interest in chemistry may have been awoken by his father, who possessed some chemical expertise. When Fritz made it known that he wanted to become a chemist, his father disagreed: he wanted Fritz to be a merchant and to work for, and eventually take over, the Breslau-based family business.

Breslau, characterized by Goethe as a "noisy, dirty and stinking" town [Goethe 1949, p. 378], transformed itself during the second half of the 19th century into a prosperous metropolis teeming with business and industrial enterprise. This was accompanied by an enormous increase in population, which doubled between 1875 and 1905, reaching almost half a million then [Rahden 2008, p. 32]. At the same time, Breslau developed into a major center of science and culture with a large educated middle-class. There was the *Schlesische Friedrich-Wilhelms-Universität*, founded in 1811, a number of colleges, as well as an opera house, several orchestras, and a city theater – all of national significance.

The booming of Breslau was a reflection of what was going on throughout Germany at the time: the whole country was booming. It was for the first time in history that an economic transformation of a major country was driven by scientific and technological advances [Smil 2001, p. 66] – rather than by conquest.

The era of academic and cultural prosperity that Breslau had enjoyed coincided with the childhood and youth of Fritz Haber. But he wanted to "get out of there," as he put it [Willstätter 1928], to study in Berlin and other places.

Fritz Haber as a Student

At loggerheads with his father and with some support from uncle Hermann, Haber entered, at age eighteen, Berlin's *Friedrich-Wilhelms-Universität* (now Humboldt University) to study chemistry and physics.

He was drawn to these subjects by the towering figures of August von Hofmann (1818-1892) and Hermann von Helmholtz (1821-1894). However, Haber would be disappointed by both: Hofmann's lectures amounted, in Haber's view, to easy, unchallenging entertainment. And Helmholtz was just mumbling to himself while doing incomprehensible calculations on the blackboard [Willstätter 1928].

The next three semesters Haber spent with Robert Bunsen (1811-1899) in Heidelberg, who was already seventy-six when he'd arrived – and another disappointment. The silver lining on Haber's time in Heidelberg was the calculus course that he took from Leo Königsberger (1837-1921), from which he benefited for the rest of his career [Szöllösi-Janze 1998, p. 43].

The subsequent year Haber performed the legally required military service – in Breslau, with an artillery regiment. In order to save himself from "death by boredom," as he put it [Szöllösi-Janze 1998, p. 47], he took a course in Kantian philosophy at the university.

Back in Berlin, this time at the *Technische Hochschule Charlottenburg* (today the Technical University Berlin), Haber, under the tutelage of Carl Liebermann (1842-1914), of alizarin fame, fell under the spell of organic chemistry. He wrote a doctoral thesis on the synthesis of an indigo precursor – but was far from being proud about it: In Haber's view, it entailed too much of routine cookery [Szöllösi-Janze 1998, p. 51]. The rumor that Haber synthesized “ecstasy” – at this or any other juncture – proved to be unfounded [Benzenhöfer und Passie, 2006].

Since the *Technische Hochschule Charlottenburg* did not award doctoral degrees at the time, Haber graduated, in May 1891, from the *Friedrich-Wilhelms-Universität*, **Figure 1**. The thesis defense took place before a committee that included von Hofmann and the Kantian philosopher Wilhelm Dilthey (1833-1911). Apparently, Haber did well in philosophy but not so well in physics, which spoiled his grade: he earned just a *cum laude*.

Subsequently, on his father’s urging, he took several “apprentice jobs” in chemical industry, which brought him eventually to the *ETH Zürich* – as a student of Georg Lunge (1839-1923), his father’s acquaintance – to improve his skills.

After a brief stint at his father’s company in Breslau – during which he proved himself to be a “danger to the business” [Coates 1939] – he moved on to do organic chemistry again, this time in Jena with Ludwig Knorr (1859-1921), of antipyrine fame. Antipyrine was a predecessor of aspirin.

Apparently, in Jena, Haber developed an interest in a fledgling science, namely in physical chemistry. Likely instigated by his friend from Breslau and *Kommilitone* from Berlin, Richard Abegg (1869-1910), Haber took a course, nominally in physical chemistry, from the mathematical physicist Rudolf Straubel. However, Haber’s attempt to gain admission to the circle of Wilhelm Ostwald (1853-1932) – one of the founders of physical chemistry – remained unsuccessful.

Haber's best friend, Richard Willstätter (1872-1942), would later characterize what Haber did up to this point as a "complete failure" [Willstätter 1928]. However, it was a failure from which Haber was able to learn.

Right at the outset of his time in Jena, Haber, at age twenty-three, converted to Christianity, or, more accurately, to Protestantism, to which he was exposed since high school. Haber's conversion happened against the background of the memorable exchange, in 1880, between Heinrich von Treitschke (1834-1896), an overt anti-Semite, and Theodore Mommsen (1817-1903), a liberal. According to Mommsen, Germans were to abandon "those loyalties and affiliations that divided them" [Mommsen 1880].

According to Stefan Wolff, a stronger influence yet may have been Greek philosophy, especially Plato and Plato's emphasis on the spirit [Wolff 2018b]. As emphasized by Rudolf Stern [Stern 1963, p. 88],

> one has no right to throw doubt on the integrity of [Haber's] motives [for conversion]. It would be ridiculous to interpret his conversion as caused by ambition and opportunism, for it was performed at a period when Haber did not dream of an academic career but was firmly resolved to take over and enlarge the family business.

Haber's father was dismayed by his son's conversion. And, as Fritz Stern (1926-2016) speculated, Haber's closest Jewish friends, Albert Einstein (1879-1955) and Willstätter,[2] both unconverted, would not hear much from Haber about it [Stern 1999, p. 75]. However, Haber's conversion did not sever his social ties to Judaism or diminish his concerns about anti-Semitism [Wolff 2018b].

[2] In his autobiography, Willstätter noted that conversion was out of the question for him because it was connected with benefits [Willstätter 1973, p. 396].

First Heyday Period: **Karlsruhe 1894-1911**

In the Spring of 1894, when he was twenty-five, Haber moved to Karlsruhe, the capital of the liberal Duchy of Baden, to live through "the best seventeen years of [his] working life." After an uncertain start [Szöllösi-Janze 1998, p. 97] at the institute of the distinguished organic chemist, Carl Engler (1842-1925), at the *Technische Hochschule Karlsruhe*, Haber was appointed assistant to the professor of chemical technology, Hans Bunte (1848-1925). In two years, he habilitated as *Privatdozent* with work on pyrolisis of hydrocarbons, rose to the rank of *Extraordinarius* in four years, and was finally named full professor, of physical chemistry and electrochemistry, after twelve years. This was a fast rise – he was thirty-seven then. The average age for reaching the academic pinnacle in Germany at the time was forty-two [Szöllösi-Janze 1998, p. 153]. This did not prevent Haber from complaining about the sluggishness of the process and even invoking anti-Semitism as a possible cause [Charles 2005, p. 65].

Haber's textbooks on pyrolisis [Haber 1896], electrochemistry [Haber 1898], and gas-phase reactions [Haber 1905] were already well known by then. Haber never attended a single lecture on physical chemistry though, apart from his own, as he would later admit with glee [Stoltzenberg 2004, p. 69].[3]

Let me note that physical chemistry came about with a purpose, namely to save chemistry from becoming a collection of little disconnected facts, generated mainly by organic chemists. The success of physical chemistry

[3] Throughout this article, the easily available English-language Haber biographies [Stoltzenberg 2004, Charles 2005] are cited as sources of the quotes whose originals are deposited at the Archive of the Max Planck Society. The catalogue numbers of the originals at the Archive are referenced in these biographies.

in providing a common ground for chemistry was celebrated by Ostwald in his proclamation, “Physical chemistry is not just a branch on, but the blossom of, the tree of knowledge” [Ostwald 1887]. The fragrance of this blossom proved irresistible to scores of scientists who would lead chemistry through the quantum revolution and beyond, and find a new gratification in the premise that the road to general chemistry goes through physics and mathematics [Friedrich 2016].

In Karlsruhe, Haber developed a remarkably diverse research program, ranging from electrochemistry, to gas-phase chemistry, to chemical technology.

Haber’s crowning achievement at Karlsruhe was the catalytic synthesis of ammonia from its elements. The need to find new ways of replenishing agricultural soil with nitrogen in a form that can be metabolized by plants was articulated, in 1898, by William Crookes (1832-1919) and was widely perceived as a challenge. In Sir William’s words [Crookes 1898, p. 3]: “The fixation of atmospheric nitrogen is one of the great discoveries, awaiting the genius of chemists.” It was one of the most publicized speeches of its time.

Some of the most illustrious chemists had a go at fixing nitrogen to hydrogen, i.e., at the direct synthesis of ammonia from its elements. Among them were Ostwald, Henri Le Chatelier (1850-1936), William Ramsay (1852-1916), and Walther Nernst (1864-1941). All failed.

There were two basic questions to answer: a thermodynamic one and a kinetic one.

The thermodynamic question was: Where does the equilibrium lie? Imagine we mix nitrogen and hydrogen at a given pressure and temperature. What will the fraction of ammonia in the mixture be? Or the other way around, if we want on the order of, say, 10% of ammonia, what must the pressure and temperature be?

And the kinetic question was: How quickly will the equilibrium be reached – or the given fraction of ammonia produced?

The answer, found by Haber together with his young collaborator from England, Robert Le Rossignol (1884-1976), to both questions was: Work at as low a temperature as possible to save the ammonia from thermal decomposition, but use as high a pressure as you can to increase its yield. Separate out whatever ammonia you get and recycle the unused nitrogen and hydrogen. In order for the reaction to go quickly enough to sustain the cycle, use an osmium catalyst.

Figure 2 shows a schematic of the iconic Le Rossignol-Haber laboratory apparatus out of which the first synthetic ammonia had dripped. At a temperature of 550 degrees centigrade and a pressure of 175 atmospheres, the yield of ammonia was 8%. This would correspond to a single pass of the reagent gases. The multiple cycling enabled a yield of over 90%. The historic date of the demonstration of the apparatus in Karlsruhe to the representatives of the *Badische Anilin und Soda Fabrik* is July 2, 1909 [Travis 2018, p. 109].

In 1907, the yield of ammonia was a point of bitter contention between Haber and his senior colleague, Walther Nernst, who claimed at the annual meeting of the Bunsen Society and in writing that Haber's numbers were "far from the truth" [Nernst and Jost 1907; Sheppard 2017]. However, they weren't. Later, Nernst would testify in favor of awarding the ammonia patent to BASF and to Haber.[4] In turn, the agreement between the predictions of Nernst's theorem and Haber's ammonia data played a role in recognizing the theorem's value and helped to secure a Nobel Prize for Nernst, in 1920 [Barkan 1999].

In the industrial-scale Haber-Bosch process, developed by Carl Bosch (1874-1940) with his coworkers at BASF, the expensive osmium catalyst was replaced by a cheap iron catalyst.

Haber wondered, in 1910, about it [Stoltzenberg 2004, p. 90]:

> [It] is remarkable how ... new special features always come to light. Here iron, with which Ostwald had first worked and which we later tested a hundred times in its pure state, is now found to function when impure.

What happened was that Bosch and his coworker Alwin Mitasch (1869-1953) made use of Swedish iron ore, which introduced aluminum and potassium as beneficial impurities that acted as promotors of iron's catalytic activity. The elementary steps of the said heterogeneous catalytic reaction would be investigated in the 1980's by Gerhard Ertl & coworkers and the role of the promoters only then fully understood: While potassium stabilizes the chemisorbed molecular nitrogen intermediate and thus enhances its dissociation rate, the aluminum precludes sintering of the granular iron catalyst [Ertl 2007].

The catalytic synthesis of ammonia from its elements was a momentous discovery that revolutionized chemical industry and, through its use in the

[4] Haber recognized Le Rossignol's contribution by yielding 40% of the royalties to him [Sheppard 2017]. Le Rossignol also invented the needle valve – in use by gas-phase scientists until this day to fine-control gas flow.

production of fertilizers, paved the way for the growth of the world population from about 1.6 billion in 1900 to about 7.6 billion today [Erisman 2008].

By 1920, the Haber-Bosch process and its imitators[5] became the dominant means of nitrogen fixation [Smil 2001, 112]. The Haber-Bosch process is a cornerstone of organized life on the planet.

As shown in **Figure 3**, the biosphere is capable of sustaining only about one half of the world's population. The other half can be fed thanks to the Haber-Bosch process.

However, about 40% of the food produced is wasted. In the absence of this wasting – and if people ate reasonable amounts of food, that is in the absence of obesity – 6 billion could be fed by the biosphere [Erisman 2018].

The process of converting fixed nitrogen into food is quite inefficient – between 4% and 14%, depending on the kind of food (with meat at the lower and vegetables at the higher end of the efficiency rate). Hence much of the reactive ammonia is being dumped into the environment.

The environmental impact of producing current levels of reactive nitrogen – about four-times more than what the biosphere can deal with – leads to the loss of biodiversity as well as to other deleterious effects.

[5] BASF licensed the process only in the 1930s, to Japanese firms, cf. [Travis 2018, pp. 225-261 and pp. 329-346].

Founding Director of the Kaiser Wilhelm Institute for Physical Chemistry and Electrochemistry in Berlin

While Haber was toiling on the ammonia synthesis in Karlsruhe, a group of prominent scientists and officials in Berlin pondered on creating an elite institution of a new type capable of securing Germany's world-wide leadership in basic research. Aided by their contacts with the royal librarian and distinguished theologian Adolf von Harnack (1851-1930), who had the Kaiser's ear, they developed the idea for what was to become the Kaiser Wilhelm Society (the forerunner of the Max Planck Society) for the Advancement of Science. The Kaiser Wilhelm Society came into being in 1911, and its first two institutes were inaugurated – by Wilhelm II – a year later in Berlin-Dahlem [James 2011, pp. 1-16].

One of them was the Kaiser Wilhelm Institute for Physical Chemistry and Electrochemistry, funded from a private endowment created by the banker and entrepreneur Leopold Koppel (1854-1933), **Figure 4**. On the recommendation of Svante Arrhenius (1859-1927), one of the founders of physical chemistry, and under pressure from Koppel, Fritz Haber was offered to become its founding director.

It was an offer that Haber could not resist: He was guaranteed a generous operating budget, the status of a state official, honorary professorship at the Berlin university, and membership in the Prussian Academy. The Institute was designed to Haber's image by the chief imperial architect, Ernst von Ihne (1848-1917), and included a director's mansion that served as Haber's residence [James 2011, pp. 17-24], **Figure 5**.

Figure 6 shows Haber and his scientific staff shortly after they settled in Berlin. Among Haber's early staff members was also the pioneer of quantum statistical mechanics, Otto Sackur (1880-1914). He would die in a laboratory accident at the beginning of World War One [Badino and Friedrich, 2013]. Sackur was a close friend of Haber's first wife Clara, nee Immerwahr. More about Clara below.

And there was also Albert Einstein, **Figure 7**, whose arrival in Berlin in 1914, orchestrated with Haber's help, made Berlin's academic luster even brighter. Einstein and Haber developed quickly a close personal bond that would transcend their differences on issues as important as war, patriotism, and Zionism. Einstein made use of an office at Haber's institute during 1914-1915 while finalizing his General Theory of Relativity. He would also discuss the fledgling quantum mechanics with Haber [Wolff 2018a].

According to a Dahlem legend [Ertl 2005], Haber called upon Einstein "to do for chemistry what he [Einstein] did for physics." After all, Einstein's first two papers and his thesis dealt with molecules ...

World War One

The era of peace and prosperity that Prussia had enjoyed for forty-three years came to an end with the outbreak of World War One. Its first salvos were echoed by verbal exchanges between the academics of the warring parties.[6] This "war of the spirits" [Wolff 2001, Wolff 2003, Berg und Thiel 2018] took a lethal form once the scientific communities became ensnarled in promoting and developing new weapons systems, in breach of the ethos of the *Republique des Lettres* – and, eventually, of international law.

[6] While, for instance, William Ramsay and Joseph John Thomson argued on 1 August 1914 that a war against Germany would be a "sin against civilization," they reversed their position three days later when Germany invaded Belgium [Collins 2018, pp. 185-192]. This invasion was then defended by the infamous "Manifesto of the ninety-three," a public-relations disaster – and not only for German Academia [Ungern-Sternberg 1996].

Haber's initiative to develop chemical weapons and his involvement in their deployment remain among the best examples of the breach of both.

Haber's letter to Arrhenius from August 1914 captures well his patriotic attitude towards the war [Zott 1997, p. 77]:

> This is a war in which our entire people is taking part … to its utmost abilities. … You know Germany all too well not to realize that such a unanimous commitment to a cause is only possible … when all are conscious that the good of the nation must be defended through a just struggle. You should give no credence to the absurd fiction, according to which we are conducting a war out of military interests ... [W]e now see it as our ethical duty to take down our enemies with the use of all our strength and bring them to a peace that will make the return of such a war impossible for generations and lay a solid foundation for the peaceful development of western Europe.

In keeping with his patriotism,[7] Haber applied himself in extraordinary ways to aid the German war effort and became, in the process, the driving force behind the development of chemical warfare in Germany. The chlorine cloud attack at Ypres on 22 April 1915 that Haber had orchestrated amounted to the first use of a weapon of mass destruction/extermination and as such marks a tragic turning point in world history. Following the "success" at Ypres, Haber, eager to employ science in resolving the greatest strategic challenge of the war – namely the stalemate of trench warfare – promptly transformed his Kaiser Wilhelm Institute into a center for the development of chemical weapons.[8] And of protective measures against them, since within a few months of Ypres, the *Entente* introduced its own potent chemical arsenal [Friedrich et al. 2017].

[7] Haber paraphrased Archimedes when he declared, at various occasions: "In peace for mankind, in war for the fatherland!"
[8] The chemical weapons/poison gases were produced mainly at Bayer [Stoltzenberg 2004, p. 141].

The universal abhorrence of chemical weapons as manifestly inhumane is surprisingly recent. At the time of their use in the First World War, the perverse-sounding notion that chemical weapons were in fact humane had been a part of the vocabulary of war experts of the Central Powers and the Entente alike. For instance, the U.S. Assistant Secretary of War and Director of Munitions, Benedict Crowell (1869-1952), noted [Crowell 1919, p. 396]:

> The methods of manufacturing toxic gases, the use of such gases, and the tactics connected with their use were new developments of this war; yet during the year 1918 from 20 to 30 per cent of all American battle casualties were due to gas, showing that toxic gas is one of the most powerful implements of war. The records show, however, that when armies were supplied with masks and other defensive appliances, only about 3 or 4 per cent of the gas casualties were fatal. This indicates that gas can be made not only one of the most effective implements of war, but one of the most humane.

Albert Einstein's pacifist views contrasted sharply with those of his friend Haber. As Einstein would put it later [Rowe and Schulmann 2007, p. 224]: "Warfare cannot be humanized. It can only be abolished." Strangely enough, there is no record of Einstein's criticism of Haber's World War One efforts, although Einstein must have been aware of what was going on at the institute that was hosting him at the time.

The character of World War One as a total war was amplified by a major escalation of chemical warfare in July 1917 – namely the deployment of mustard gas by Germany. Haber, whose brainchild mustard gas was, urged the third Supreme Command to use it only if the war could be won before the Allies developed the ability to retaliate in kind, that is with their own mustard gas. Otherwise, Germany's situation would become "hopeless," in Haber's words [Szöllösi-Janze 1998, p. 332]. Which it eventually did, but also for a number of other reasons.[9]

Although Haber had no regrets about his involvement in chemical warfare, he never anticipated its use against civilians. As Daniel Charles put it [Charles 2005, p. 174], "In this respect, Fritz Haber's imagination remained trapped in the nineteenth century."

Artillery shells filled with chemical agents grew from a negligible proportion in 1915 to about 50% of the German, 35% of the French, 25% of the British, and 20% of the American ammunition expenditure by the Armistice [Spiers 2017]. Providing little advantage to either of the equally equipped belligerents, chemical weapons greatly increased the already unspeakable suffering of the troops on both sides of both the Western and Eastern fronts.[10] The British historian Edward Spiers recently characterized the WWI chemical weapons as "weapons of harassment" [Spiers 2017].

Gruesome as they were, chemical weapons have been banned only since 1997 (when the Chemical Weapons Convention was finally ratified).

The development of chemical weapons was by far not the only involvement of Haber's in the German war effort.

On the eve of World War One, Germany was the world's largest importer of Chilean saltpeter (sodium nitrate) [Smil 2001, p. 58], used for the

[9] Haber could not imagine that the German Empire would be defeated until about September 1918 [Stoltzenberg 2004, p. 149].
[10] According to Augustin Prentiss's count [Prentiss 1937, p. 649], a total of about 90,000 soldiers were killed and 1.3 million injured by chemical weapons in World War One.

production of both fertilizers and explosives. With its supply cut off by the British naval blockade, the German government quickly recognized the need for alternative sources of nitrates and other war chemicals.

Fritz Haber, led by his belief that all economic, military, and even social problems can be solved by science, promptly found his way into the circle of Germany's decision makers. As pointed out by Margit Szöllösi-Janze, Haber acted as an expert, that is an intermediary between the producers and consumers of knowledge [Szöllösi-Janze 2017]. He was behind the so called "Saltpeter Coup" [Szöllösi-Janze 2018], in which BASF monopolized, around 1916-1917, much of Germany's production of the two main explosives ingredients, the aromatic nitro compounds (such as TNT) and ammonium nitrate. Both were produced starting with Haber-Bosch synthetic ammonia, see **Figure 8**, which was catalytically oxidized to nitric acid [Travis 2018, pp. 139-146].

For better or worse – it was the production of nitro compounds and nitrate by the German chemical industry that enabled Germany to sustain her war endeavor.

Let me add that although Germany lost the war, its chemical industry did not. In fact, its massive build-up, funded in large part by state loans, could never have happened in a peace economy. Moreover, the loans had actually not been paid back – because of hyperinflation that descended upon Germany after the war.

Dr. Clara Haber, nee Immerwahr (1870-1915)

When in April 1901 the German Electrochemichal Society convened in Freiburg for its annual meeting, there was, for the first time, a woman among the scientific participants. This was Clara Immerwahr from Breslau, who had completed her PhD just a few months earlier. She thus ranks among a small, yet significant group of women scientists who entered, at the turn of the 20th century, the then exclusively male domain of scientific research [Friedrich and Hoffmann 2019]. Clara's PhD advisor was Fritz Haber's friend Richard Abegg, a physical chemist already well-known at the time for his work on chemical valence. Upon her graduation, the "doctissima virgo" was celebrated by the dean with caution, however, as he didn't wish to see the dawn of a new era with women enlisted outside of home and family.

At her scientific debut appearance in Freiburg, Clara met Fritz Haber whom she had known from the dancing classes they took together in Breslau as teenagers. The love affair between them that ensued – or was rekindled – resulted quickly in marriage.

During the first years of her married life, Clara, in the absence of job opportunities, lectured on science in the household, mainly to housewives, while struggling not to become a housewife herself. She also appeared at the lectures as well as in the laboratories of the *Technische Hochschule Karlsruhe*. That was the case even after the birth of their son Hermann, in 1902. In her letter to Richard Abegg, who would become her confidant, Clara declared that she will get back to the laboratory "once we become millionaires and will be able to afford servants. Because I cannot even think about giving up my [scientific work]" [Friedrich and Hoffmann 2016].

As we know, the Habers did get rich, but Clara would never return to the laboratory nevertheless. As years went by, she would fall increasingly into the traditional role of a professorial wife, a housewife preoccupied with the wellbeing of the family and a caring mother, **Figure 9**. An equitable and reciprocal scientific marriage, like the one between Marie and Pierre Curie in Paris, would not materialize.

When Haber celebrated the “success” at Ypres – and his promotion to the rank of captain[11] – at a gathering in his directorial mansion in Dahlem, Clara Haber committed suicide. She shot herself, with Haber’s army pistol.

The motive for Clara Haber’s suicide is as unclear as the available sources are ambiguous – and rare. Nevertheless, during the 1990s, a narrative took root according to which Clara Haber was an outspoken pacifist (not unlike the 1905 Nobel Peace Prize laureate Bertha von Suttner) and a star scientist (not unlike Marie Curie) who was destroyed – as both a person and a scientist – by her oppressive and opportunistic husband. It appears that this narrative was catapulted into the public sphere in Germany and beyond by Gerit von Leitner’s book *Der Fall Clara Immerwahr. Leben für eine humane Wissenschaft*, published in 1993, as well as various dramatizations derived from it. The sources in von Leitner’s book are either not given or tapped selectively [Friedrich and Hoffmann 2016, 2017].[12] In particular, von Leitner’s account ignores sources that suggest that the reasons for Clara’s suicide may have had to do with her mental disposition and private life [Friedrich and Hoffmann 2016, 2017].

The ambiguity of the sources has been somewhat reduced by several recently surfaced letters. Especially telling is a letter in which Clara replies to Haber’s former Japanese collaborator, Setsuro Tamaru [Oyama 2015]. Tamaru had to leave Germany after the outbreak of the war and

[11] Non-Jewish members of the German professoriate typically received the rank of a major, [Szöllösi-Janze 1998, pp. 63-64, 267.

[12] [Friedrich and Hoffmann 2016] provides a partial list of statements and quotations related to chemical warfare in [Leitner 1993] that are of unknown origin.

complained bitterly in his letter to Clara, written on Christmas Eve of 1914, about the war's politics.

Clara's reply to Tamaru's letter, written just three and half months before her suicide, is revealing in several respects: Firstly, she describes her own patriotic feeling and a need to be "helpful" and "useful" to her country; Secondly, she mentions that her husband was working "18 hour days" and that she herself was taking care of "57 poor children" in a make-shift kindergarten, while her son Hermann had been "constantly sick since November." The Kindergarten was set up for children whose fathers were on the front and whose mothers had to make ends meet. Thirdly, in response to Tamaru's political litany – he wrote for instance that "A war doesn't decide anything, it just breeds the next war" – Clara stated that she was "... too ignorant in the matters of foreign affairs to be able to properly answer [Tamaru's] points ..."

Clara's letter to Tamaru is difficult to reconcile with her image as an outspoken pacifist whose disagreements with her husband about the conduct of the war would drive her to suicide.

The additional recently surfaced letters were written in the immediate aftermath of Clara's suicide by people from her circle: Lise Meitner (1878-1968) and Edith Hahn (1887-1968), the wife of Otto Hahn (1879-1968). These letters indicate that the reasons for Clara's desperation had to do with her personal life, especially with her feeling of being neglected by her husband [Henning 2016].

Thus it seems that Clara's suicide resulted from circumstances considerably different and more complex than those described in von Leitner's book or its derivatives. In light of the available evidence, Clara Haber's suicide appears to have resulted from a "catastrophic failure" (to borrow an engineering term as a metaphor) brought about by a confluence of a host of unfortunate circumstances. These included, apart from her unfulfilling life, Haber's philandering, the premature deaths of her PhD advisor and confidant Richard Abegg (in a ballooning accident) and of her friend and *Kommilitone* Otto Sackur (in a laboratory accident), as well as the death and destruction of the war itself, amplified by the horrors of chemical warfare.

This recent perspective makes the "myth of Clara Immerwahr" questionable, however without belittling Clara's actual achievements or courage. Her admirable feat of graduating *magna cum laude* in chemistry in 1900 Prussia was not only unusual but also difficult, or unusual *because* it was difficult. It took the first thirty years of her life to achieve it, for she was denied a straight path, free of hurdles and chicanes, and had to take lengthy detours.

However, we should refrain from projecting our contemporary ideas on Clara. What she achieved in her time does not need to be embellished with exaggerations or even wishful thinking fashioned by present-day aspirations.

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Fritz Haber remarried in 1917. His second wife Charlotte, nee Nathan (1889-1979), was a manager of the club "Deutsche Gesellschaft 1914," where she and Haber likely got to know each other. In their wedding picture, **Figure 10**, they are shown with Hermann (1902-1946), the only child of Fritz and Clara.

Fritz and Charlotte had two children, Ludwig/Lutz (1921-2004) and Eva (1918-2016). Ludwig, an economic historian, wrote "The poisonous cloud," an authoritative volume on chemical warfare in World War One. Ludwig was spurred to write the book by what he witnessed at his father's centennial in Karlsruhe in 1968 [Haber 1986, p. 1].

When World War One finally ended, largely due to the economic collapse of Germany [Mommsen 2011], the victorious powers compiled a list of 895 alleged war criminals with the Kaiser on top of the list. Haber's name was also included (as were the names of Adolf von Baeyer, Carl Engler, Emil Fischer, and Walther Nernst) but dropped later for reasons that are not entirely clear. In the end, nobody was extradited anyway.

Haber would, however, testify about chemical warfare before an investigative committee of the Reichstag in 1923. In his testimony [Haber 1924], Haber put the blame for any transgressions against international law squarely on the German Supreme Command. Haber also claimed that chemical weapons were first used in World War One by the French – already in August 1914 – when they fired rifle grenades filled with the highly toxic ethyl bromoacetate. This claim was later validated by a parliamentary investigation as well as by historians [Stoltzenberg 1994, p. 152]. The early French chemical attacks were ineffective – and thus remained largely unknown – because of the low concentrations achieved of the frightful poison.

During the turmoil that followed the end of World War One, Haber was concerned about the restoration of basic services in Germany as well as in neutral countries ravaged by the war. In September 1919, he co-founded with his comrade-in-arms, Otto Lummitzsch (1886-1962), the *Technische Nothilfe* aid organization [James 2011, pp. 35-36]. Haber enlisted Albert Einstein to help find suitable contacts in the affected countries, especially in the Netherlands.

When Haber received the 1918 Nobel Prize in Chemistry for finding a way for making “bread from air,”[13] **Figure 11**, there was no mention during the Nobel proceedings of “gunpowder from air” at all, not to speak about Haber’s involvement in chemical warfare – of “poison instead of air.”[14] Let me add that the award was made at a considerable risk not only to the reputation of the Royal Swedish Academy but even to the neutrality of Sweden as a country in the new world order [Friedman 2018, pp. 155-174].[15]

Second Heyday Period: **Berlin 1918-1933**

At the outset of the post World War One period, Haber hired a great number of young first-class researchers and gave free rein to their pursuits. The “golden age” of his Kaiser Wilhelm Institute – and the second heyday period of Haber’s scientific career – had begun [James et al. 2011, pp. 35-88]. Unfortunately, Haber himself would be plagued by illness.

The diversity and quality of the work done at Haber’s Institute is astounding. Although physical chemistry remained the principal subject, the themes pursued ranged from fundamental physics to physiology.

The exemplary workings of Haber’s institute entered the annals of the sociology of science, through the writings of Michael Polanyi (1891-1976), one of this field’s founders and a former Haber affiliate [Friedrich 2016].

[13] Haber’s coinage, cf. [Haber 1920].
[14] Haber had been involved in chemical warfare even as he spoke at the Nobel ceremony, in June 1920: In 1919 Germany launched a secret program to continue the development and production of chemical weapons, under Haber’s tutelage. In order to avoid inspections instituted by the Versaille treaty, the program had been moved to third countries, with the Soviet Union being one of them.
[15] What surely made the situation even more precarious was that among the laureates who received the Nobel prize at the ceremony in June 1920 were four additional Germans: Max von Laue (Physics, 1914), Max Planck (Physics, 1918), Johannes Stark (Physics, 1919), and Richard Willstätter (Chemistry, 1915). While William Henry and William Lawrence Bragg (Physics 1915) refused to share the stage with the German laureates, Charles Glover Barkla (Physics, 1917) was not only present, but graciously lavished praise on both Planck and Stark.

At the same time, Haber was able to secure adequate funding, mainly through his contacts with industry. Funding was also provided by the *Notgemeinschaft der Deutschen Wissenschaft* [James et al. 2011, p. 50] (the forerunner of today's *Deutsche Forschunsgemeinschaft*), which Haber co-founded in 1920. Remarkably, under Haber's guardianship, the *Notgemeinschaft* was largely run by academics. Haber also co-founded, in 1926, the Japan Institute, to foster cultural and economic cooperation with Japan, which became a major importer of German goods, thereby offsetting the loss or weakness of European markets at the time. Some of the funds for the *Notgemeinschaft* came from Japan [James et al. 2011, pp. 51-57].

Haber, along with Einstein, also actively pursued the restoration of relations with the academic communities of the Allied countries. For instance, at the Benjamin Franklin centennial in Philadelphia in 1924, Haber made a case for academic and technological internationalism.

Moreover, between 1920-1926, Haber toiled on the secret patriotic "gold from seawater" project – in an attempt to help to meet Germany's obligations under the Versaille treaty, namely the payment of war reparations, which were denominated in gold (fifty thousand tons of it). But the concentration of gold in seawater turned out to be too low and so the project had to be scrapped [Stoltzenberg 2004, pp. 241-249].

Haber must have been unimaginably busy during this period – perhaps one of the reasons for his absence in the memorable colloquium photo, see **Figure 12**, with six Nobel laureates – present and future – in it. And most likely a reason for his absence from home. In 1927, he broke up with his second wife Charlotte and from 1930 on it was his stepsister Else Freyhan (1877-1960) who would lead Haber's household for the remaining four years of his life. We may add that Haber was also spending inordinate amounts of time in various sanatoria or at his farm in Witzmanns near Bodensee – in vain attempts to restore his health.

Haber, however, is present in the unique photo shown in **Figure 13** – as Mr Chemistry, playfully perched on one of the armrests of the sofa, while Mr Physics (i.e., Einstein) occupies the other. James Franck (1882-1964), flanked by his wife Ingrid and by Lise Meitner, jokes with his assistant Hertha Sponer (1895-1968), while Otto Hahn makes himself ready to jump in the conversation. Standing in the back are Gustav Hertz (1887-1975) as well as other distinguished physicists and chemists. This photo embodies what the Austrian-American biochemist and essayist Erwin Chargaff must have meant when he characterized Berlin during the Weimar era as the "very empyrean [the highest heaven] of science" [Chargaff 1978].

Resignation, Exile, and Death: **1933-1934**

The heaven would start turning into hell in 1933. With the Nazis at the helm, Germany "was done with the Jew Haber" – in the words of Bernhard Rust (1883-1945), the infamous *Kultusminister* [Stern 1963, p. 99]. Haber became a persona non grata under the Nazis, who would deny him credit for anything they viewed as admirable, including, ironically, Haber's involvement in chemical warfare!

After the promulgation of the "Law for the Restoration of the Professional Civil Service" in April 1933, Haber found himself under the obligation to dismiss all his coworkers of Jewish descent (twelve out of forty nine paid from the funds of the KWI [Szöllösi-Janze 1998, p. 651; Friedrich et al. 2019]). Haber soon realized that what remained for him to do was to help to secure a future abroad for his people – and to quit.[16] He handed in his resignation on April 30, 1933 with these memorable words of protest [Stoltzenberg 2004, p. 280]:

> My sense of tradition requires of me that … I only choose staff members according to their professional abilities and character, without regard to their racial make-up.

Max Planck (1858-1947), in his capacity as President of the Kaiser Wilhelm Society, made an attempt at saving Haber's institute by pleading with Minister Rust, and after being turned down, by asking Hitler, in person, to intercede. But this was to no avail. As Planck later vividly recollected [Planck 1947], Hitler concluded the audience by a fit of rage worthy of a furious Führer. Haber had become just another Jew in Germany …

In 1940, the Nazis would turn Haber's institute into a Model National Socialist Enterprise (*NS Musterbetrieb*). It was the only academic establishment that achieved this "honor" [James et al. 2011, p. 120]

The nets that Haber had spread on his own behalf brought him job offers from Britain, Japan, and Palestine, while negotiations were also conducted with institutions in France, Spain, and Sweden. Haber decided for Britain – and accepted an invitation from Sir William Pope (1870-1939) to join him at the University of Cambridge. Sir William worked for the British Chemical Warfare Service in World War One – for which he developed a new synthesis of mustard gas.

During his two-month stay in Cambridge,[17] Haber may have lived through his last happy moments in science: a reunion with some of his Dahlem

[16] Haber was under pressure not only from Rust's ministry directly but also indirectly through Planck and Friedrich Glum (the main KWG administrator): they were threatened by Johannes Achelis (the personnel officer at Rust's ministry) with a takeover of the whole KWG by a Nazi commissioner should the Jewish scientists not be purged in large numbers and right away.

coworkers. As Haber's former "chief of staff," Hartmut Kallmann (1896-1978), recollected "a scientific discussion [unfolded] more wonderful than you can imagine" [Stoltzenberg 2004, p. 289].

From his hotel in Cambridge, Haber wrote to Pope the following lines [Charles 2005, p. 228]:

> My most important goals in life are that I not die as a German citizen and that I not bequeath to my children and grandchildren the civil rights of second-class citizenship, as German law now demands … The second thing that's important to me is to spend my last years in a scientific community, with honor but without heavy duties.

In Cambridge, Haber wrote his last paper, on catalytic decomposition of hydrogen peroxide [Haber and Weiss 1934]. According to Haber's stepsister Else, it cost him the last ounce of his strength [Stoltzenberg 2004, p. 290]. The co-author was his Berlin assistant Josef J. Weiss (1905-1972).[18] On January 23, Haber gave his last lecture [Szöllösi-Janze 1998, p. 691].

One can see in **Figure 14** that the distribution of Haber's publications over the timeline of his life is bimodal. The two hills corresponding to the heyday periods of his scientific career are separated by the slump of World War One.

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[17] Haber left Berlin on 5 August 1933 – unawares that he would never come back again. His protracted journey via, among other places, Santander, Zermatt, Mammern, Zurich, Paris, and London brought him to Cambridge on November 7. From a sanatorium in Mammern, Haber bid on 1 October 1933 a farewell to his KWI in a letter addressed to Otto Hahn as the institute's interim director.

[18] Josef Joshua Weiss, who accompanied Haber to Cambridge, would speak at Fritz Haber's centennial in Karlsruhe, on 23 November 1968.

In summer 1933, Haber entered into negotiations with the principal Zionist leader, Chaim Weizmann (1874-1952), about establishing physical chemistry in mandate Palestine. Weizmann, preoccupied with building Jewish academic institution in Palestine, visited Haber at his KWI in 1932 and was impressed by what he had seen to the point that he modeled the Daniel Sieff Institute (now The Weizmann Institute of Science) in Rehovot on Haber's. By bringing Haber to Palestine, Weizmann likely hoped for Haber's help with identifying and recruiting faculty for the Hebrew University, such as Ladislaus Farkas[19] for the chair in physical chemistry. At the same time, Weizmann wanted to keep Haber for his pet project – the Daniel Sieff Institute, which was due to be inaugurated on 1 March 1934, possibly with Haber as director.[20] Weizmann also tried to win for the Zionist project Haber's best friend, Richard Willstätter, **Figure 15**, as well as other distinguished German Jewish scientists.

The Palestine idea, which was in competition with Haber's commitments in Cambridge,[21] had not come out of the blue: In his exchange with Einstein during the summer of 1933, Haber noted, "I was never in my life so Jewish as now" [Charles 2005, p. 229]. Weizmann encouraged Haber to come to Palestine with the words: "The climate will be good for you. You will find a modern laboratory, able assistants. You will work in peace and honor. It will be a return home for you – your journey's end" [Weizmann 1949, p. 354].

According to Else, Haber's son Hermann was "much more of a Jew" than his father and it was actually Hermann who pushed the Palestine idea in

[19] Haber proposed Herbert Freundlich as an alternative should the Farkas appointment not pan out. In the end, the chair went to Farkas, who is celebrated today as the founder of physical chemistry in Israel.
[20] The Daniel Sieff Institute opened on 3 April 1934, with Weizmann as its director.
[21] William Pope was able to generate a call for Haber from the University of Cambridge, to stay on until he turned seventy, without any specified duties – and any pay [Stoltzenberg 2004, p. 289].

the first place [Szöllösi-Janze 1998, p. 683]. Haber had difficulties detaching himself emotionally from Germany.[22]

The harsh English winter in 1933/34 took a toll on Haber's fragile health. According to his letter to Weizmann of 6 January 1934 [Stoltzenberg 2004, pp. 296-297], Palestine was no longer an option at the time – for health reasons: "the idea that seemed self-evident to me, that I could set out on and complete the journey to Palestine for recuperation, has been changed by my state of health into the very opposite." On January 26, Haber went to London, where he met Weizmann for the last time [Stoltzenberg 2004, p. 298], whereupon he set out on a southbound journey, with Orselina in southern Switzerland as the likely destination [Stern 1963, p. 102].

Before his departure from Cambridge, Haber wrote a letter addressed to the vice chancellor of the University in which he stressed that the "chivalry from King Arthur's time still [lived] among [English] scientists" and expressed a "strong hope" that he "will be able to return within a few weeks" [Stoltzenberg 2004, p. 291]. At this time of humility and contrition, Haber also drafted his testament. In it, he expressed his wish to be buried alongside his first wife Clara [Stoltzenberg 2004, p. 300].

Haber died of a heart attack on January 29, 1934 during a stopover in Basel, Switzerland, and was buried there. In accordance with his will, Clara's ashes were reburied, four years later [Stoltzenberg 2004, p. 300], beside his.

[22] In September 1933, Haber offered the Deutsches Museum in Munich a new replica of the Le Rossignol-Haber apparatus, to be made in the machine shop of his KWI. This offer was accepted [Wolff 2019].

Postlude

Haber was revered in many quarters, including the highest echelons of industry, the military, and academia.

Two weeks after Haber's death, Max von Laue (1879-1960) eulogized Haber in an obituary that was published by *Naturwissenschaften* [von Laue 1934]. The very writing and publication of the eulogy, not to speak about its moral message, was an act of political defiance, given Haber's official status as "enemy of the National Socialist state."

Obituaries were also presented by Richard Willstätter and Max Bodenstein (1871-1942) on behalf of the Bavarian and Prussian Academies, respectively, as well as by the daily press.

It was not only Haber's Jewishness but also his democratic attitudes that were a thorn in the flesh of the Nazis. Haber was an open supporter of the Weimar republic and its democratic institutions and contributed to the coffers of the *Deutsche Demokratische Partei* – later the *Deutsche Staatspartei*.

Haber's characterization of the Nazis is both revealing and instructive: Haber viewed the Nazis as people who hated their political adversaries more than they loved their country.

On the first anniversary of Haber's death, in January of 1935, Max Planck as president of the Kaiser Wilhelm Society held a memorial service for Haber in Harnack House, **Figure 16**. After a *musikalischer Auftakt*, he opened the meeting with a Hitler salute. As Otto Hahn recollected [Hahn, 1960]:

> Privy councilor Planck gave the introductory address, pointing out that had Haber not made his magnificent [ammonia synthesis] discovery, Germany would have collapsed, economically and militarily, in the first three months of World War I. In his speech, General Joseph Koeth [a retired general] also emphasized Haber's great significance during the World War. Without Haber's discoveries and organizational talents it would have been impossible to succeed in maintaining resistance to the enemy's blockade over so many years. ... The two main speeches, by myself and [Karl Friedrich] Bonhoeffer, dealt with Haber's personal side, the significance of his famous institute [the Kaiser Wilhelm Institute for Physical Chemistry and Electrochemistry], as well as his scientific work. As ... Bonhoeffer was not able to be present – had been forbidden to come – I read Bonhoeffer's manuscript in his name.

The prohibition to partake in the memorial service was issued to all academics who fell under the jurisdiction of Bernhard Rust's ministry. This is why much of the audience were the professors' wives who attended the service in lieu of their husbands. Among notable exceptions were Lise Meitner, Max Delbrück (1906-1981), Fritz Strassmann (1902-1980), all from KWI for Chemistry,[23] and Richard Willstätter. Nevertheless, the lecture hall that seated five hundred was packed. Curiously, although Bernhard Rust's directive with his signature on it was posted at every German university for everybody to see – and observe, Rust later denied ever issuing such a directive [Archiv 1935].

Max von Laue and Karl Friedrich Bonhoeffer (1899-1957) became key figures in the reconstruction of German academia after World War Two [Zeitz 2006; James et al. 2011, pp. 148-149]. Their great scientific

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[23] KWI for Chemistry, headed by Otto Hahn, was funded independently of Rust's ministry and was, technically, exempted from Rust's directive.

reputation and irreproachable past had made them uniquely qualified for such a role. And it was von Laue and Bonhoeffer who put forward the initiative to rename Haber's Kaiser Wilhelm institute after its founding director, **Figure 17**.

Because of Haber's principled attitude towards the Nazis – and the banishment that he had to suffer as a result – there was a strong anti-Nazi component to the renaming. Moreover, upon Haber's death in exile, Einstein noted that this was "the tragedy of the German Jew: the tragedy of unrequited love" [Charles 2005, p. 241]. The renaming of the institute after Haber therefore signaled that Haber's affection for his country was not unrequited after all – and that there was no room for Nazism in Germany any more.

Haber is also remembered in Israel: The Hebrew University of Jerusalem jointly with the Minerva Foundation established, in 1981, the Fritz Haber Center for Molecular Dynamics. And the library of the Weizmann Institute of Science in Rehovot holds Haber's private book collection, donated to the institute via Haber's son Hermann.

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Figure Captions

Figure 1: Haber as a freshly-minted graduate of Berlin's Friedrich-Wilhelms-Universität, 1891. Unless stated otherwise, all photos were provided by the Archive of the Mas Planck Society.

Figure 2: Diagram of the Le Rossignol-Haber laboratory apparatus for the continuous synthesis of ammonia from nitrogen and hydrogen. Reproduced from [Travis 2018, p. 108].

Figure 3: Trends in human population and nitrogen use throughout the twentieth century. Reproduced from [Erisman et al. 2008].

Figure 4: The banker, enterpreneur, and philanthropist Leopold Koppel (1854-1933). Koppel was the first and biggest single benefactor of Haber's KWI.

Figure 5: Kaiser Wilhelm Institute for Physical Chemistry and Electrochemistry, founded in 1911 in Berlin-Dahlem. The rightmost building is the directorial mansion. Circa 1913.

Figure 6: Fritz Haber (3rd from left) with his scientific staff (from left to right: Richard Leiser, Setsuro Tamaru, and Gerhard Just) upon settling in the KWI for Physical Chemistry and Electrochemistry in 1912. In the background KWI for Chemistry.

Figure 7: Fritz Haber (left) and Albert Einstein in the stairwell of Haber's KWI. Photo taken by Setsuro Tamaru, circa 1914.

Figure 8: Leuna-Werke (Merseburg) of BASF. The factory, opened in April 1917, supplied synthetic ammonia to sites in Germany for further processing. Painting by Otto Bollhagen, 1920. Courtesy Detlef Kratz and Timo Gehrlein, BASF Ludwigshafen.

Figure 9: Clara Haber, nee Immerwahr (2nd from right), on a family photo from 1906 with her son Hermann (seated in the center), her husband Fritz Haber (standing behind Hermann) and the landlady (2nd from left) of Habers' Karlsruhe apartment on Moltkestrasse 29b with her children; on the right is Habers' maid servant.

Figure 10: Fritz Haber and his second wife Charlotte, nee Nathan, upon their wedding at the Kaiser Wilhelm Memorial Church in Berlin on 25 October 1917. On the left Hermann Haber.

Figure 11: Fritz Haber's Nobel diploma.

Figure 12: "Boss-free" colloquium held during Niels Bohr's visit to Berlin, April 1920. Left to Right: Otto Stern, Wilhelm Lenz, James Franck, Rudolf Ladenburg, Paul Knipping, Niels Bohr, Ernst Wagner, Otto von Baeyer, Otto Hahn, George von Hevesy, Lise Meitner, Wilhelm Westphal, Hans Geiger, Gustav Hertz, Peter Pringsheim.

Figure 13: Gathering in Berlin-Dahlem in 1920 in honor of James Franck's appointment to a professorship at the University of Göttingen. Left to right, seated: Hertha Sponer, Albert Einstein, Ingrid Franck, James Franck, Lise Meitner, Fritz Haber, Otto Hahn; Standing: Walter Grotrian, Wilhelm Westphal, Otto von Baeyer, Peter Pringsheim, Gustav Hertz.

Figure 14: Fritz Haber's scientific production along the timeline of his life. There are a total of 209 items on Haber's publication list.

Figure 15: Fritz Haber (left) with his best friend, Richard Willstätter, in Kloster, Switzerland, in 1929.

Figure 16: Announcement of the memorial service for Fritz Haber on 29 January 1935 at Harnack-Haus.

Figure 17: Renaming of the KWI for Physical Chemistry and Electrochemistry after its founding director (9 December 1952). Karl Friedrich Bonhoeffer delivers the speech he was forbidden by the Nazis to give at the memorial service for Haber on 29 January 1935. The Fritz Haber Institute was incorporated into the Max Planck Society in 1953.

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Figure 1

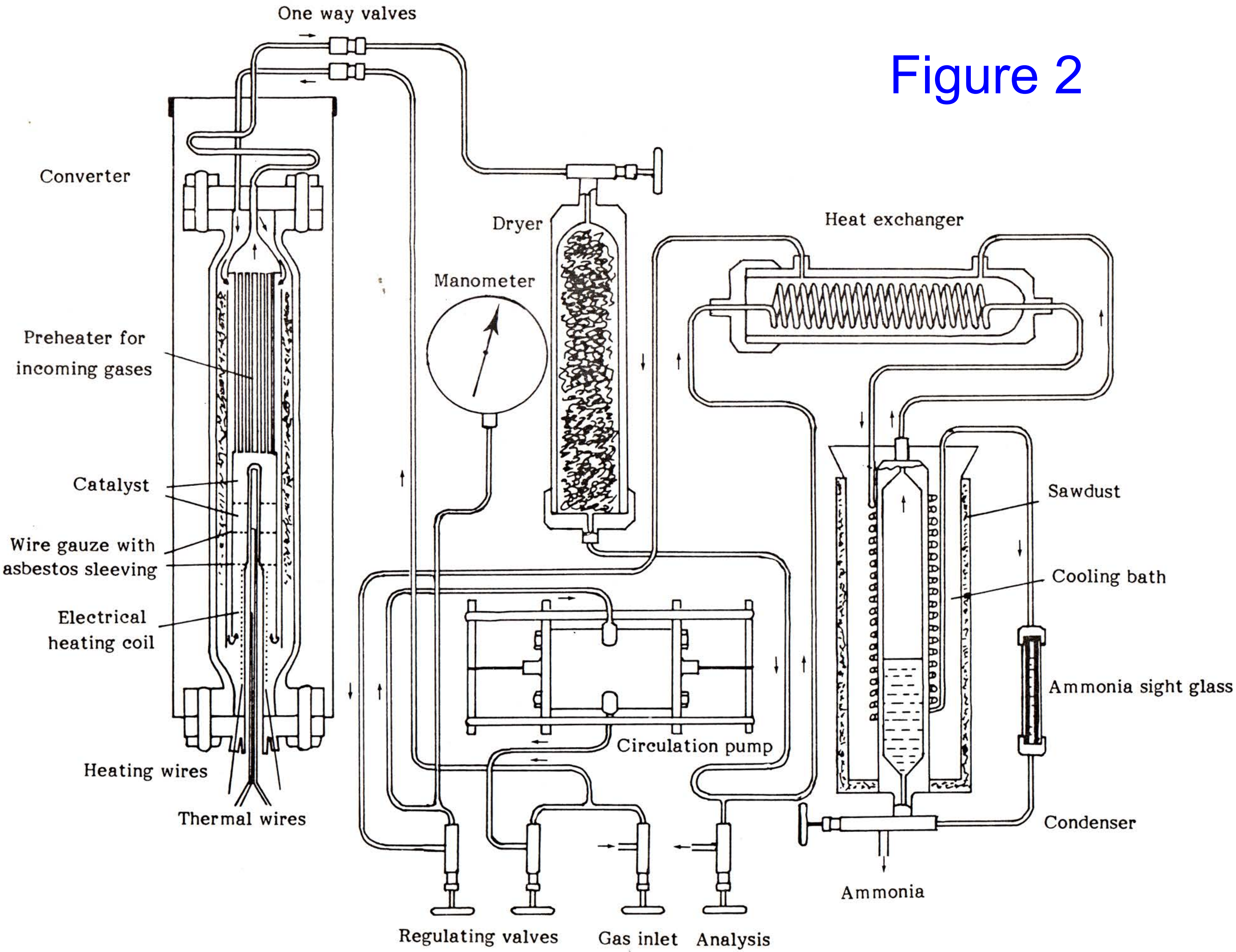
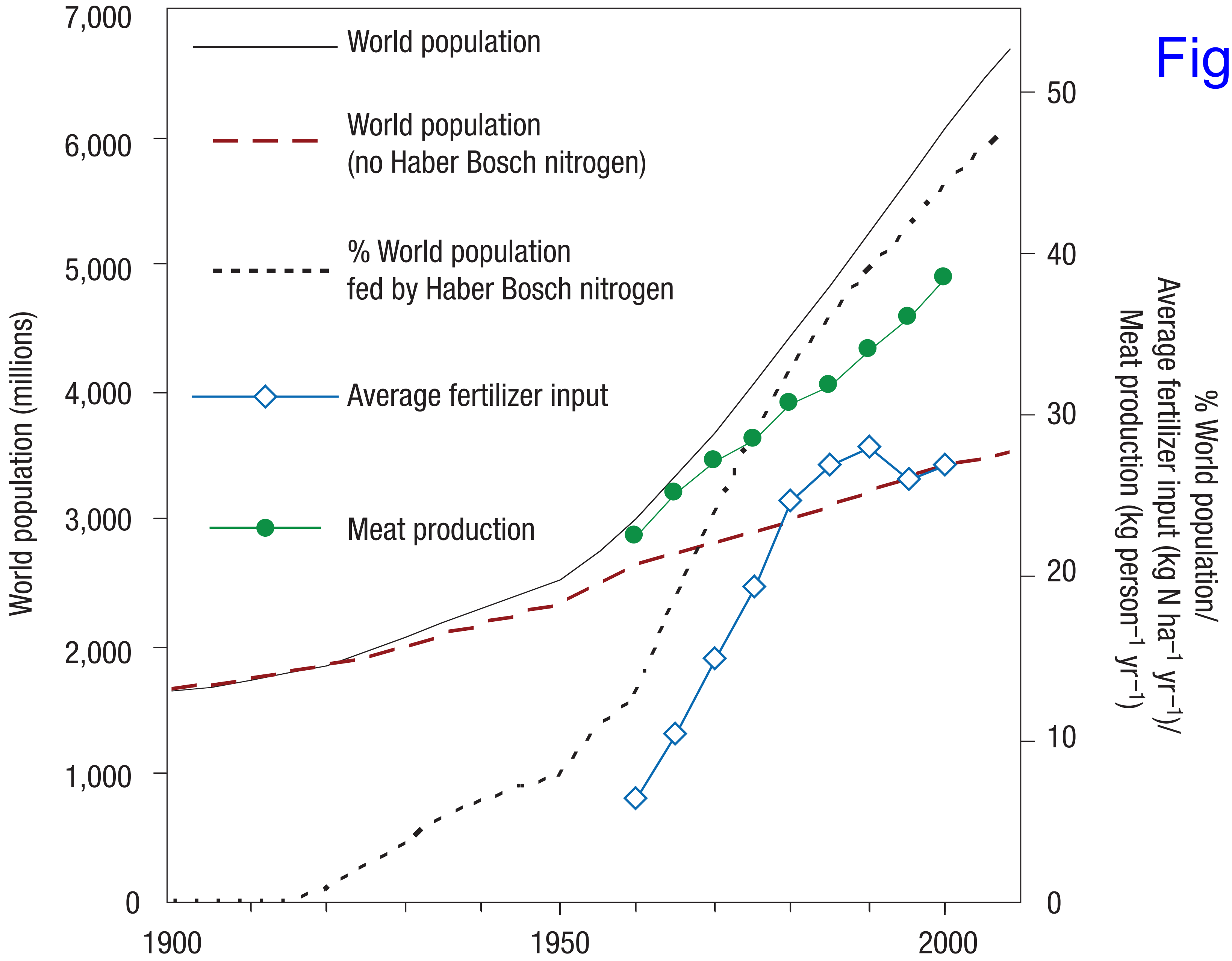

One way valves
Converter
Preheater for
incoming gases
Catalyst
Wire gauze with
asbestos sleeving
Electrical
heating coil
Heating wires
Thermal wires
Manometer
Dryer
Heat exchanger
Sawdust
Cooling bath
Ammonia sight glass
Circulation pump
Condenser
Ammonia
Regulating valves
Gas inlet
Analysis

Figure 2

Figure 3



World population
World population (no Haber Bosch nitrogen)
% World population fed by Haber Bosch nitrogen
Average fertilizer input
Meat production
World population (millions)
% World population/
Average fertilizer input (kg N ha⁻¹ yr⁻¹)/
Meat production (kg person⁻¹ yr⁻¹)
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
50
40
30
20
10
0
1900
1950
2000

Figure 4

Figure 5

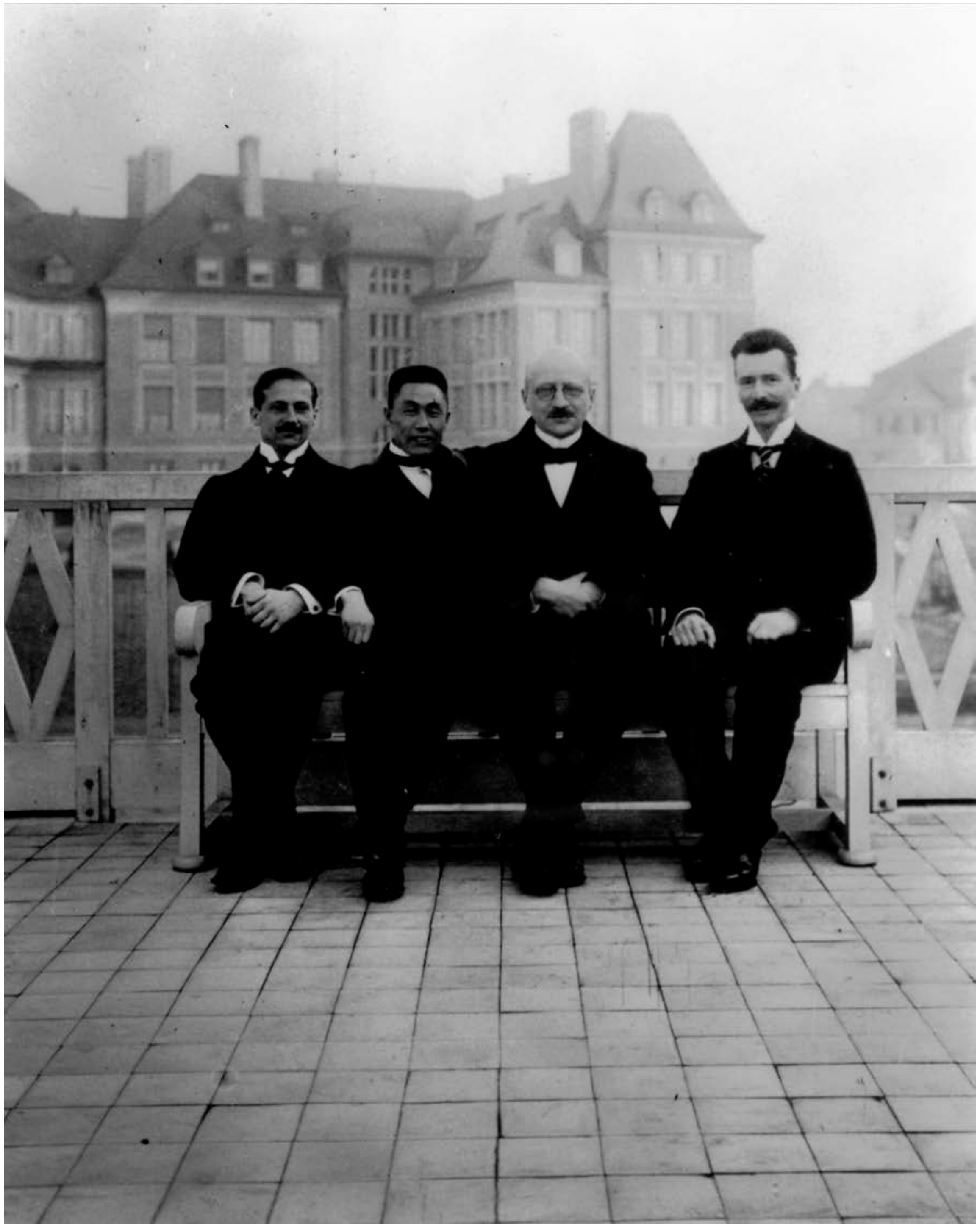


Figure 6

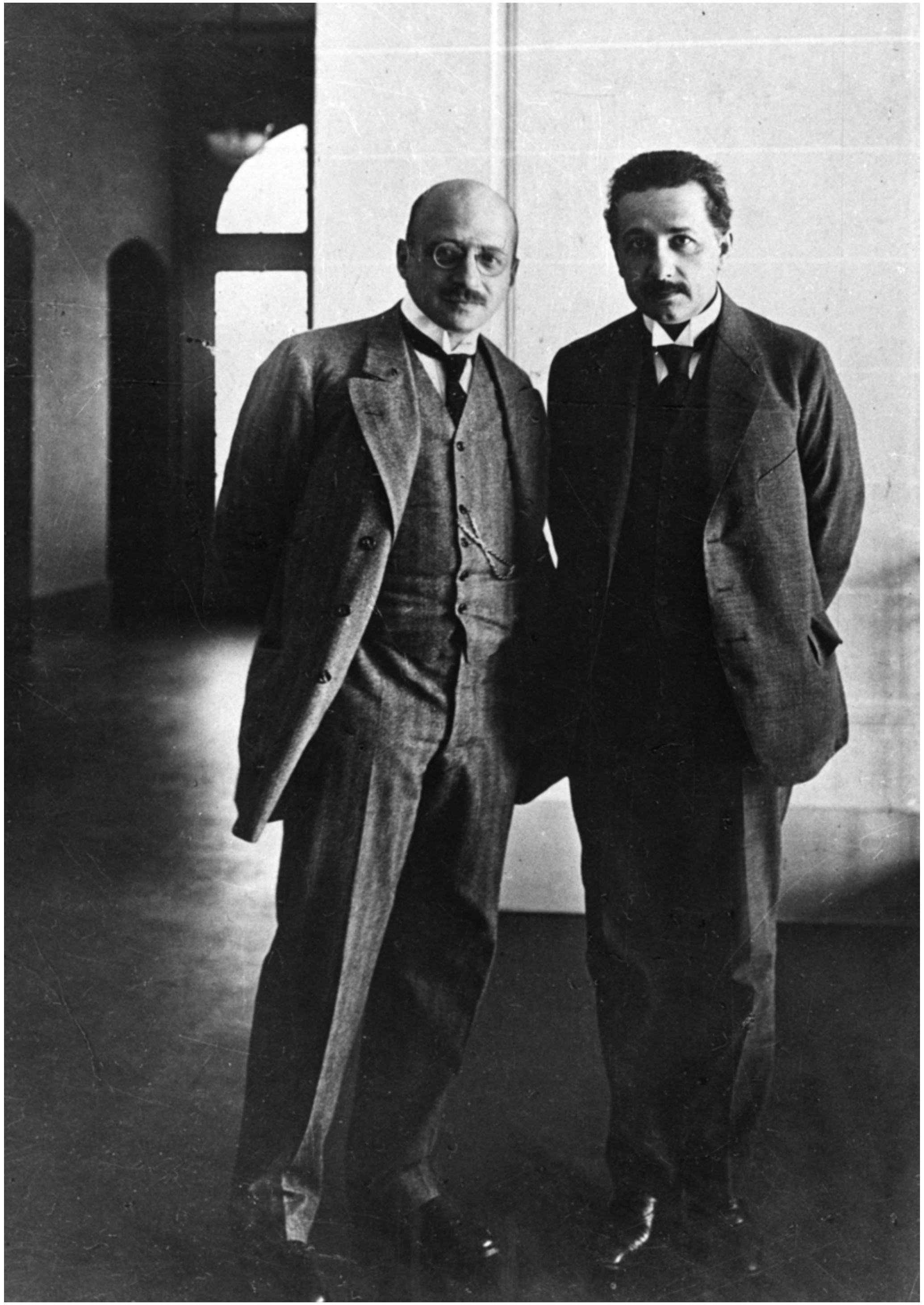


Figure 7

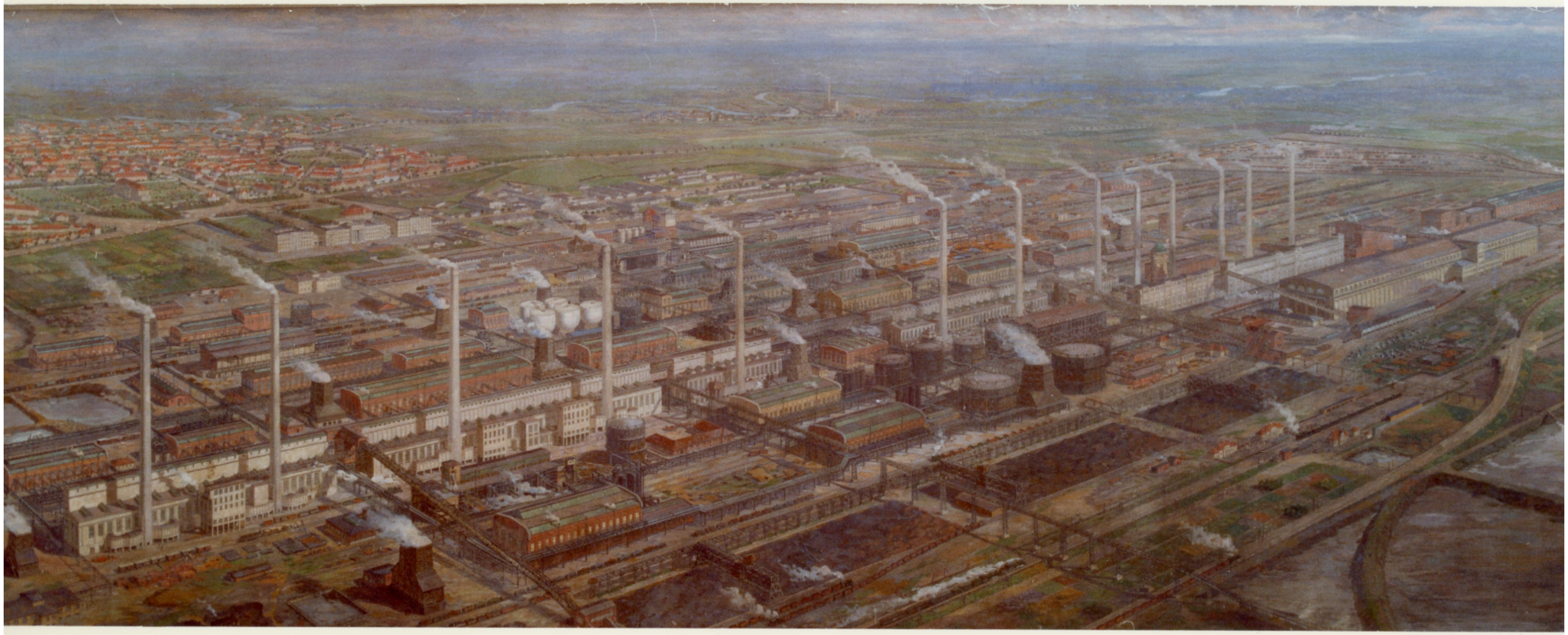


Figure 8

Figure 9

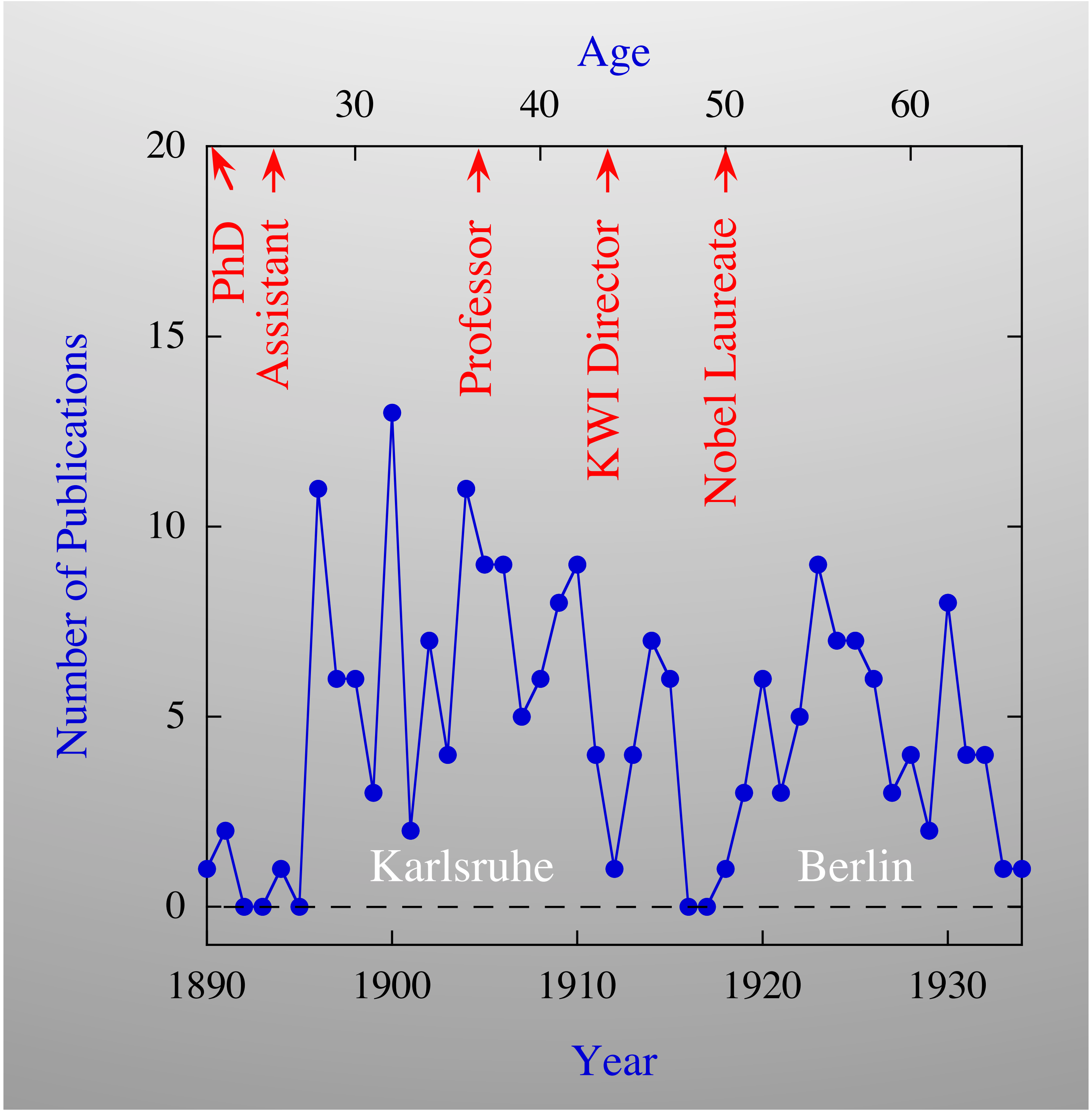
Figure 10

KUNGLIGA SVENSKA VETENSKAPS AKADEMIEN
har vid sammanträde den 13 November 1919 i enlighet med föreskrifterna i det av
ALFRED NOBEL
den 27 November 1895 upprättade testamente beslutat att överlämna det pris som för 1918 bortgives åt den som har gjort den viktigaste kemiska upptäckt eller
$3H_2+N_2 = 2H_3N$
förbättring till
FRITZ HABER
för hans syntes av ammoniak ur dess element.
Stockholm den 1 Juni 1920

Figure 11

Figure 12

Figure 13



Age
30
40
50
60
20
15
10
5
0
PhD
Assistant
Professor
KWI Director
Nobel Laureate
Number of Publications
Karlsruhe
Berlin
1890
1900
1910
1920
1930
Year

Figure 14

Figure 15

Die Kaiser-Wilhelm-Gesellschaft zur Förderung der Wissenschaften

beehrt sich

in Gemeinschaft mit der

Deutschen Chemischen Gesellschaft

und der Deutschen Physikalischen Gesellschaft

zu einer

Gedächtnisfeier für Fritz Haber

am Dienstag, den 29. Januar 1935, 12 Uhr mittags,
im Harnack-Haus, Berlin-Dahlem, Ihnestraße 16—20,

einzuladen.

1. Andante con moto (Thema mit Variationen)
   aus dem Quartett Nr. 14 von Franz Schubert

2. Einleitende Worte

   Geheimrat Prof. Dr. Max Planck, Präsident der Kaiser-Wilhelm-Gesellschaft zur Förderung der Wissenschaften

3. Gedächtnisreden

   Prof. Dr. Otto Hahn, Direktor des Kaiser-Wilhelm-Instituts für Chemie

   Oberst a. D. Dr.-Ing. e. h. Joseph Koeth

   Prof. Dr. Karl-Friedrich Bonhoeffer, Auswärtiges wissenschaftliches Mitglied des Kaiser-Wilhelm-Instituts für physikalische Chemie und Elektrochemie

4. Cavatine (adagio molto espressivo)
   aus dem Quartett op. 130 von Ludwig van Beethoven

   Die Mitglieder des Philharmonischen Orchesters:
   Konzertmeister Siegfried Borries (1. Violine), Karl Höver (2. Violine), Reinhard Wolf (Viola), Wolfram Kleber (Cello).

Uniform oder dunkler Anzug

Figure 16

Figure 17