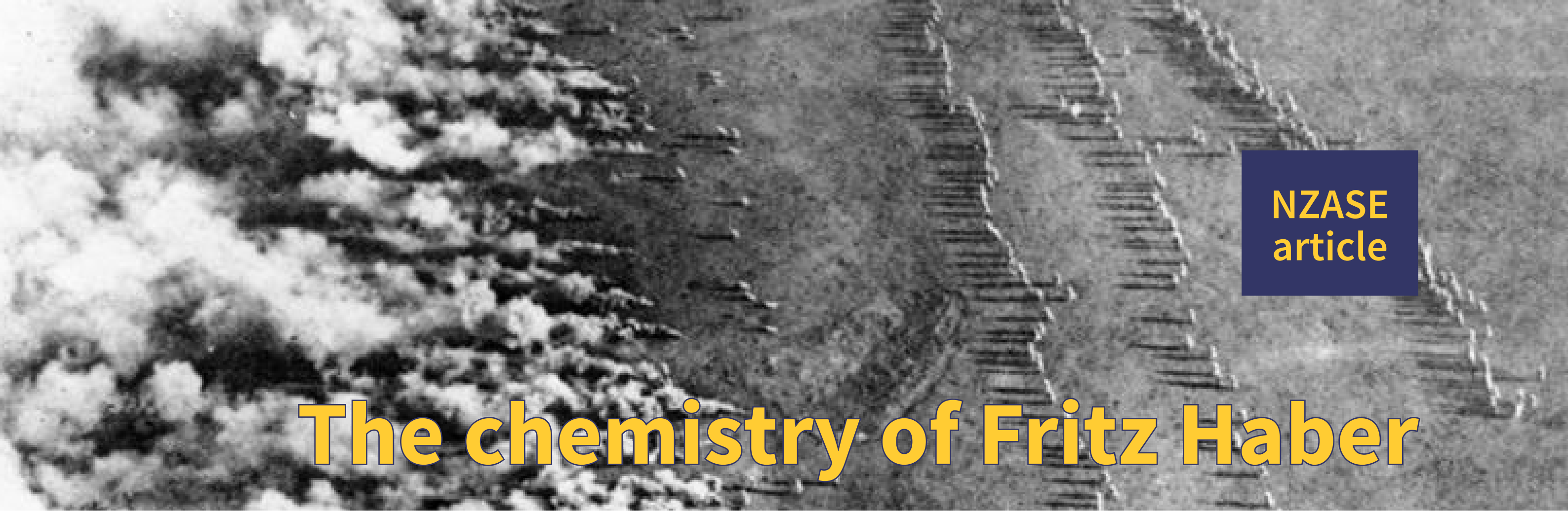


A German gas attack on the eastern front in World War I; Wikipedia.

NZASE article

The chemistry of Fritz Haber

Fritz Haber was a German chemist whose work resulted in world-wide renown, used for life and death. He is at once revered and reviled. NZASE Science Communicator Mike Stone describes his achievements.

Haber was born in 1868 to a Jewish family in Prussia (now Germany). His mother died when he was three weeks old and his father was a dye and paint merchant.

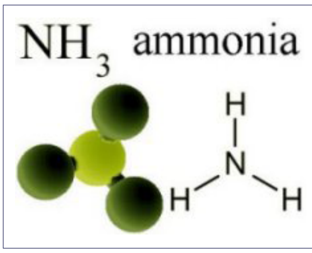
After completing a year's military service, Fritz studied chemistry, completing his doctoral thesis on the reactions of piperonal (an organic molecule found in peppers). Around this time he converted from Judaism to Christianity and married Clara Immerwahr, who also had a PhD in chemistry. Her work focused on the conductivity and other characteristics of heavy metal salt solutions.

When appointed professor at Karlshruhe Polytechnic, Fritz's focus turned to physical chemistry, pioneering work on the glass electrode, which formed the basis for the later development of the pH meter. He also explored the thermodynamics of gas reactions, which culminated in developing a method to synthesise ammonia.

Clara Immerwahr as a PhD student. Fritz Haber is pictured much later in his life.

Ammonia synthesis

In the 1890s, scientists were concerned that the world's population would soon exceed its food supply unless crop yields were increased through the use of nitrogen fertilizers. Most fertiliser at the time came from natural deposits of guano (bird droppings) and saltpetre (nitrate salts of potassium, sodium or calcium), much of which was found in South America.



In 1909 Haber perfected the chemistry of the process for making ammonia. While nitrogen makes up 80 percent of air, the challenge of reacting nitrogen was its strong triple bond. Haber found that if he forced air into a huge iron tank under extreme heat and pressure and added hydrogen, the nitrogen atoms were forced apart as they each bonded with three hydrogen atoms. As this was an equilibrium reaction, the ammonia could then dissociate to form nitrogen and hydrogen:

$$N_2 + 3H_2 \rightleftharpoons 2NH_3 \quad \Delta H = -92.4\ \text{kJ/mol}$$

Chemical engineer Carl Bosch, Haber's brother-in-law, developed a process to produce ammonia on an industrial scale. To make ammonia production cost-effective, he used Le Chatelier's Principle to identify conditions to favour the product side of the equation: 400°C and 200 atm pressure with an iron-based catalyst. Haber's chemistry gave a yield of 15 percent ammonia in the equilibrium mixture, but Bosch realised if the unreacted nitrogen and hydrogen was

Ammonia fertiliser produced with the Haber-Bosch process supports nearly half the world's population.

recycled then the overall yield could be increased, to about 98 percent.

In 1918 Haber received a Nobel Prize for synthesising ammonia; Bosch's contributions were recognised in 1931.

This process is hugely important. Approximately two-thirds of annual global food production uses nitrogen from the Haber-Bosch process, supporting nearly half the world's population.

Ammonia is also used in the manufacture of commercial explosives such as trinitrotoluene (TNT), nitro-glycerine, and nitrocellulose. The Haber-Bosch process is generally credited with keeping Germany supplied with fertilisers and munitions during World War I, after the British naval blockade cut off supplies of nitrates from Chile.

Poisonous gases in warfare

In World War I (WWI), Haber helped the German army develop poisonous gases, despite international treaties outlawing such warfare. Although some German army commanders called their use unchivalrous, the army determined it would do anything to win. In April 1915, during the second battle of Ypres, Haber supervised the opening of gas cannisters of chlorine when a favourable wind would carry it to the Allied trenches.

Nearly 170 metric tons of chlorine gas were released, killing 1,100 and injuring 7,000. The gas reacted quickly with water in soldiers' airways to form hydrochloric acid. This destroyed the capillaries and air sacs in their lungs, spilling out fluids that collected in pools and made breathing in oxygen impossible. Soldiers suffocated.

On his return home that weekend, Clara argued with Haber about his experiments. Fritz refused to stop, saying that death was death, by whatever means it was inflicted. Also unhappy about no longer working as a scientist and the death of two close friends, Clara committed suicide with his service revolver later that night.

Chlorine's usefulness was short-lived. Its colour and odour made it easy to detect, and since chlorine is water-soluble, even soldiers without gas masks could minimise its effect by covering their mouth and nose with wet rags. Releasing the gas was also fatal to the Germans if the wind direction changed.

Within a year, the Allies were also using chemical weapons (and gas masks). This arms race led to the development of even more poisonous gases, which Haber also worked on. Phosgene (carbonyl dichloride) was probably first used in December that same year. This gas is colourless and odourless at the concentrations used in combat. Phosgene is highly toxic, reacting with proteins in the alveoli of the lungs, causing a build-up of fluid there, again causing soldiers to suffocate.

In 1917 a new gas came into use, mustard gas, bis (2-chloroethyl) sulfide. This gas had a mustard colour and a garlicky odour. Initial exposure was symptomless, then

John Singer Sargent's 1919 painting 'Gassed' shows the aftermath of a mustard gas attack in WWI.

skin irritation began, and eventually blisters formed on eyes and skin and in the lungs.

Only 2-3 percent of soldiers died from mustard gas, but recovery involved long hospitalizations. (Doctors noticed that mustard gas appeared to kill white blood cells, and it eventually formed the basis of chemotherapy, especially for leukemia and lymphoma.)

By the end of WWI, chemical weapons had caused 1.3 million deaths, including 100,000 fatalities from phosgene, primarily used by the allies. (Although Germany had developed sarin by WWII, Hitler did not use chemical poisons on troops, supposedly because he had been poisoned by gas in WWI.)

Haber and the Nazis

After WWI ended, Haber's institute developed the cyanide-based Zyklon B, which was used first as an insecticide, and later reformulated in WWII for use on civilians in the gas chambers in Nazi concentration camps. Tragically and ironically, many members of Haber's extended family died in those camps.

Haber was severely criticised by the west for his involvement in gas warfare. Haber saw himself as a German patriot and a Christian, famous for his Nobel Prize and a decorated war hero. Nonetheless, when Hitler came to power, he was persecuted as a Jew and hounded from his job. Work with ammonia and chlorine had undermined his health, and in 1934 Fritz Haber died in Basel of a heart attack.

One of the European stamps featuring Fritz Haber, this from Sweden in 1978.

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Ngā Kupu

Haukini – Ammonia
Haumāota – Chlorine gas
Hauota – Nitrogen
Haurehu – Gas
Hūrai – Jew, Jewish
Mātai matū – Chemistry
Pakanga nui o te ao tuatahi – World War I
Pakūtanga – Explosion
Tauhohe matū – Chemical reaction
Totepita – Saltpetre
Whakahaumako - Fertiliser

From Te Aka Maori Dictionary and *Paekupu*