

The Alchemy of Air Notes

Christopher Kalitin

Introduction

They turned air into bread!

We are creatures of the air. CO₂ makes trees. Mostly Carbon, Oxygen, and Hydrogen 90%.

Nitrogen is required for life, present in DNA. Atmospheric nitrogen can't be used, fixed nitrogen is required. This is the limiting factor for life on Earth. Manure and rotting plants are rich in fixed nitrogen.

Bacteria on peas beans, etc. produce fixed nitrogen along with lightning.

Starvation is due to logistical issues.

Haber-Bosch system.

Fertilizer and explosives have very similar chemical structures.

The Haber-Bosch process created most of Nazi Germany's munition, without it they would've surrender 2 years earlier than in WW1, so 2 years? Synthetic nitrogen for bombs, also synthetic fuels.

The demon under the microscope book, first antibiotic discovery.

Bosch is a forgotten mogul that built one of the biggest Nazi companies while being anti nazi, giant epic estate too, and Haber is a Jew.

Part I: The Ends of the Earth

Chapter 1

1898, William Crooks talk. Thallium discovery. British empire.

Hundreds of tons of manure per acre applied in city garden plots in Paris. Romans worshiped the god of manure, Homer records horse dung being used on farms.

Europeans tired sea salt, bones, powdered limestone, rotting fish, etc.

In the 1800s, south Eastern China learned the best ways to apply natural fertilizer. Hoarding waste, compost, etc. best in the world.

10 people per acre was the pinnacle of agriculture. Too low during Industrial Revolution in cities.

Crooks warned the earth had no more Great Plains great for agriculture. Can't just keep moving to new land forever.

Repeatedly farming the same land led to loss of fertility in soil. Synthetic fertilizer was the only way to solve this. Chemists saving the world.

NPK are the elements in fertilizer. Nitrogen availability is a limiting factor in most plant ecosystems.

Fixed nitrogen is solid or liquid nitrogen. Fixed in compounds.

Fertilizer was delivered from South America in all English ports. Chilean nitrate was mined from the deserts. Nitrate stocks were traded to make many fortunes.

Crooks predicted these sources would dry up.

The great Caucasian race would die to races that had plenty of fertilizer.

The talk was read by many from all fields. He wrote a book on it.

Only 4 billion could live with traditional farming, low calorie diets.

Chapter 2

Sorcerers are researchers. Making the first wine, metallurgy, paper, math, etc. all before the word science.

Alchemy goes back to ancient Egypt, mummification, trying to find the spirit hidden in matter.

With each step of purifying materials, the ancient alchemists believed they were going closer to the spirit of a thing. This is the reason we call the vapour from heated mashes of fruits: spirits.

The philosophers stone is a Divine substance with curing magical properties, complete purity.

A Chinese alchemist combined sulfur, honey, and potassium nitrate. When heated it exploded. Fire crackers, cannons, muskets. White salt was the most important ingredient, KNO₃.

In England, salt Petrie was collected by the kings men, no matter where it was, no matter how difficult to obtain. Very important for national security.

Salt peter plantations were created, ditches of clay and manure and sewage, 1700s. Fine crystals resulted. 5-10 pounds per cubic meter per year.

1626, King Charles the first demanded all urine be stored for the plantations.

Salt flats of India were discovered as the greatest source of salt peter. East India company started shipping it.

When a group of Indians in the 1700s in South America lit a fire at night, the world set on fire. Fire set from dried cactus. A man gave a sample to a priest. Priest knew chemistry and knew the material was a kind of salt. He threw it out and saw a few weeks later the vegetation there was greener and taller. Said this to a burnish naval officer.

First idea that salt from the earth could be a fertilizer. Importing began in Europe, and local production of explosives.

Charles Darwin on the HMS Beagle on the west coast of South America was interested in the stories of fertilizer. 5 years there. A previous captain of the Beagle had killed himself, Darwin was taken as a scientist to amuse the captain.

Darwin took a local guide and found a white powder, like snow. Many cactus fires. The salt was refined with water and fire to create crystals, coarse table salt. Sodium nitrate.

Chapter 3

1840-1860

Hungarian governor often brief to accelerate loading time.

Chincha islands off the coast of Peru. 10 stories of guano, world's best fertilizer. Rusty red under springy surface.

Workers mostly from China tricked into signing long term labour contracts. 600

They lived almost naked in straw huts with two small meals per day. At any given time a quarter of them could not work.

Sunday only day of rest. Unless you didn't hit the 100 wheelbarrow loads per day. Prison ship or tied to buoys. Thriving drug trade in the camps.

Men in the cargo holds could only work 20 minutes before gasping for breath when leaving.

Merchants were unruly seeing how bad things were? US Pacific fleet sent there.

It's all bird manure. A Spanish conquistador first informed the king of the islands. Ignored for two centuries.

Humboldt took a sample back to Europe. Chemists saw it was high in urea and phosphates.

In 1824, a news paper published that a ship with some guano arrived, the governor of Maryland put it on a field and found the best fertilizer ever.

Horrible smell.

Peru sold contracts for guano extraction to foreign companies for futures on sales.

Hundreds of thousands of tons in the US and GB.

A third of each sale went to Peru. Three quarters of the budget. Collateral for loans.

In the late 1850s they hit rock.

1856, guano island act in US, US citizens could claim any deserted guano island anywhere in the world. One of the only times in history this happened. 94 islands in pacific between Hawaii and Samoa or Caribbean.

Fake guano was sold. In Baltimore a guano inspector was hired.

A Spanish naval force captured an island, attacked by combined navies of Peru and Chile led by a civil war Virginian general. Spain lost. This marked true independence from Spain.

11 million tons total. Then Peru went bankrupt.

Chapter 4

Still unknown why the deserts of South America had so many nitrates, likely the lack of rain.

An early attempt to import nitrate ended when the port of Liverpool refused to accept it on risk of exploding, it was dumped into the water.

It was mostly used as ballast on returning European ships. Then guano ended and a chemist found a way to turn it from a bad explosive into a true salt Peter. Only a single atom differed. It could then be turned into nitric acid for powerful explosives.

Peru was late to realize the value of what they had, but their ownership of the deposits is not what mattered, just the ability to tax.

Towns transformed into boom towns.

Very unsophisticated sailors, poor manners says a British man. Tons of drinking. Some traded life aboard a ship for life here.

Tons of industrial buildings and pipes going between every building.

Late 1870s, Peru wanted to nationalize the nitrate industry. Still not making enough tax revenue.

Revolution funded by Chileans to take some of the nitrate holdings. Many Chilean workers. It failed.

Peru was exploited by Spain while Chile was relatively progressive. It was stable.

1879, nitrate wars. Chilean had uniforms for the forests.

Dasa, a Bolivian general, was attacked by Chile. Peru sent their troops to be commanded by him, they failed. He fled with some of the national treasury, then was shot when returning to Bolivia. This started the nitrate war.

Navy was an important component. Chile had newer ships but Peru had a ship with 4 inches of iron and an experienced commander.

Town of Iquique, Peruvian export port, blockaded. Grau, commander, tried breaking the blockade.

Cheering Peruvians lined the shore.

They traded shots for an hour and a half. Peru immune to cannons, Chilean surgeon killed and assistant beheaded.

Esmeralda (Chilean) boiler burst and was a sitting duck.

Hoscar rammed the Esmeralda (determined to not surrender) and hit below the water line. Gatling gun firing.

Prat, commander of Esmeralda? tried boarding with his men, they didn't hear. After another ram, 10 Chileans jumped aboard, all killed by gatling gun.

Hoscar lost one sailor, Esmeralda lost 148 of 198.

Grau was impressed by Arturo Prat's final minutes, sent all his personal belongings to his widow. The letter was recorded!

Grau promoted to grand admiral. Destroyed many ships working its way down the coast.

In fall 1879, Chile sent 6 ships to destroy the Hoscar.

On Oct 8, they met. A lucky Chilean shot hit the bridge and killed Grau. Celebrations in the street, "onto Lima."

Hoscar captured, entire Pacific coast of South America controlled by Chile. 15 months after the Hoscar was lost, Chileans were attacking the capital.

Lima was in chaos, as an American writes, Chileans marched in and restored order.

Chapter 5

All nitrate rich deserts given to Chile.

Chilean nitrates made it possible to blast through the Panama Canal.

Cities grew faster, more advanced diets (meats, sugars, oils, etc.), higher agricultural output required. GB and Germany bought most of the Chilean nitrate, $\frac{2}{3}$ of the world's supply from there.

Germany founded in 1870, too late for colonies. Biggest importer from Chile. 350kt per year in 1900, 900kt in 1912. 2x America, 3x France imports.

The Lürseny company in Hamburg built sailing ships for moving nitrate, even faster than steam!

3 months standard sailing time from Iquique to Germany, a Lürseny ship once did in the 65 days!

Until the 1930s, nitrates most important factor in Chile's economy. 2x factory growth, 3x worker growth.

British man supplied water from the North to Iquique, then the war destroyed all existing deals. North, his name, began buying nitrate plants after the war. Worked with the Chilean inspector. Sometimes turned around in one day for 2-4x.

Mid 1880s, nitrate futures trading. 10-20% dividends per year!

North promoted to colonel.

At peak, he hosted a fancy dress ball at his mansion with the Rothschilds, Sir Randolph Churchill, 15 knights. Dressed as Henry the Eighth.

Bubble burst, refineries over produced to keep revenue climbing and controlled prices? 4x decline in 1-2 years.

Chile very dependent on foreign capital and expertise, a few companies owned by Chileans.

Along the coast were many amenities, in land, many poor labourers. 6 days a week.

3 pesos per day paid in company scrip, only used in company stores, Fichas.

Hardest working men in the world. They were unhappy with the situation, and began the growth of the left wing in Chile.

In 1907, they went singing as a mass into Iquique. Earlier, business owners refused to bargain and the government stepped in.

This time, they protested in town. First peaceful. Letter recorded from little girl to her mothers.

Many conflicting reports. In 1900, ekikae had 16k population, in the protest there were 6-20k. Peaceful.

Milk owners refused to give into demand. Even the government offered to pay half the increased wages. They were drinking all ekikaes water.

2 Chilean ships arrived, general Silva. Martial law. Deadline given for dispersion, missed, then arms readied.

Men refused to raise arms, esp. though from ekikae. Men from the ships brought in. Strike leaders shot. Straddled the school yard being used by strikers for a few minutes. 126-500, or 1000-3000 (modern) killed. Largest labour massacre in history. Fische system abandoned eventually, but in the owners terms.

General Silva later assassinated. Chilean soldiers not allowed to serve in home towns.

Now, Ekikae trying to be a resort town.

Nitrates still plentiful in Ekikae, but artificial fertilizer was invented.

Part II: The Philosophers Stone

Chapter 6

Habers stress built up about once per year to the point where he went to a spa for a couple weeks.

At a gathering of German scientists, he was insulted by Walter Yernst, One of the great German chemists. Yernst created the third law of thermodynamics.

They disagreed on the energy involved with the synthesization? of Ammonia.

Haber did work on turning nitrogen in the air into ammonia.

Dinitrogen is inert. N_2 . O_2 is very reactive. Single nitrogen atoms are reactive. N_2 has a triple bond. 1000 C required to break it apart. Only present in nature with lightning.

Temp would be so higher to get nitrogen that ammonia is destroyed. Platinum containers, iron would glow cherry hot.

Haber thought it was impossible, published results. Yernst thought Haber produced much more ammonia than possible, put an assistant on the problem.

Haber used higher pressure and other changes to recreate Yernsts experiment. Never the same result, always "too much."

High pressure allowed for lower temperature, less ammonia destruction.

Yernst said it was a shame Habers numbers were wrong, if they were right it might be commercially viable to create ammonia.

Haber born in Bartslav Poland. After speaking to Yernst he dove deeper into work and was extremely stressed. Inpatient insecure young man.

German Jews allowed to attend and teach at great universities, not so in other countries.

German Jews and Christian's intermarried, 30% of Jewish marriages. It looked like anti semitism was on the way out. Many very patriotic German Jews.

Restless student, went many places. Joined army for 1 year, required, couldn't serve longer as a Jew.

Earned a doctorate in the dye industry. Various boring jobs.

At 24, be converted to Christianity. Family already saw Christmas as more important than yom kippur.

Germany was poor on natural resources expect for iron and coal.

Science powered Germany's advance. Making the worlds best steel, machines, etc.

At 26, professor of physical and electro chemistry.

Married the first woman the get a phd at her university.

He always wanted more, was a distant husband.

Chapter 7

Wilhelm Ostwald. One of the greats and one of the first to answer sir William Crooks call to solve the nitrogen problem.

With the Bohr war in Africa, he became concerned with Germany's position in war with Britain. A blockade would cripple them.

Ostwald created a machine that could create Ammonia. Wanted to sell it for one million marks to a company. BASF - Germany's biggest chemical company - assigned a novice employee, Bosch, to replicate the machine. He found that it was erroneous, the ammonia was actually contaminants in the machine.

Ostwald compared the hunt for fixed nitrogen/ammonia to the hunt for the philosophers stone. The hunt could make one go mad.

Haber and Le Rosenthal? Kept increasing pressure, getting better results. They explored various pressure, temp, and catalyst combinations through the summer.

Le Rosenthal invented new values, etc.

After about 8 months, they had forgotten about Yernst and found it was possible to produce ammonia in significant amounts from the air.

Start of 1908, best in the world at Ammonia from air by several multiples.

Engler le Rosenthal?

Engler gave Haber an introduction to the head of BASF. Heinrich con Brunk. Gambler, rarely used his own money, rich, built BASF. Business gambler. First bet on dye made from cheap coal.

For decades after founding, BASF was just another dye firm.

Indigo dye was the most sought after. Made from Mediterranean snails, Phoenicians? When enotgbwss applied it went more purple. Egypt, Romans, Indians. Indigo = India.

Brunk joined BASF in 1869 and after working up to technical director, he started the company's search for synthetic indigo.

Brunk believed the future belonged to firms that worked at higher scale with more professional chemists. He convinced the board for funding and failed for years.

Out of the investment, he saw he had created the systems needed for a large chemical company.

Many acids required for their process, so they saved by making them in bulk and selling them. A BASF found a ether way to synthesize chlorine and they started selling it.

150 chemists in 1899, Brunk put all profits put into more research.

Germany's industry led the change in the Industrial Revolution from iron and steam to r&d.

Brunk was right in his strategy and every new discovery fueled the next.

Brunk knew information on chemistry would always spread, even in an industrial setting. Just move faster.

By the time they synthesised indigo he was head of BASF. Many investors wanted dividends and to stop the program.

He built up cash reserves to forego the complexity of loans and sales and marketing was built up, faster speed of iteration.

When it was put on the market it was immediately cheaper and better than natural indigo. In 3 years, BASF was the worlds largest chemical company.

Brunk knew the chemical industry was spreading around the world, indigo may be the last great discovery of the German chemical industry.

Brunk, like Ostwald, realized the strategic importance of synthesising fixed nitrogen.

Fixed nitrogen could be 2-3 or 10x bigger than dyes.

Pennies per lol was the difference between profit and loss. litre?

Brunk began work two years before crooks address. 1897.

Over a decade they developed furnaces for arcs. Norsk Hydro partnership/investment. Electricity was too expensive, but there was a solution if the Chilean deserts ran dry. Then, Haber's letter.

Chapter 8

They signed Haber, he wouldn't publish without permission and get 10% of net earnings.

Haber and Le Rosenthal pushed pressure with their new equipment. Impossible with previous equipment other chemists used. 100-200 atm.

Thick walled quartz tube in an iron jacket.

Haber heard that yernst was making progress and worked harder, this was false info.

Habers lab thought of a heat pump. Using the heat of the reaction to heat incoming nitrogen and hydrogen.

1000->600 C with increased pressure.

Osmium used as a catalyst, after many other metals, yield shot up. Haber had osmium from light bulb filaments he got when experimenting for another company. Ge showed it to all the chemists in the building.

In Mar 23 he reported the success to BASF and recommended purchase of all available Osmium.

BASFs head of research was skeptics of the device. Machined quartz can't scale up. The world supply of Osmium was likely a few hundred pounds.

Carl Engler spoke to Brunk. Brunk, Bernstein, and Bosch (shot down the earlier machine) showed up to see the machine.

Machine worked best at 200 atm, 100 is higher than the surface of Neptune.

Bosch had worked on nitrogen chemistry for 8 years since the previous machine.

Bosch knew a lot about metals, his dad had a shop and let his kids use it. Disassembled his mothers seeing machine. Went to his fathers business often. Studied mech eng for two years before switching to chemistry.

Chemists were prized as BASF. Bosch was less sophisticated.

He was taken with replicating Ostwalds machine because his machining expertise was known. Didn't take long to make it. Ostwald made sure Bosch had his personal flower wire catalyst.

Using the wire, the apparatus would give off a little ammonia, then stop. The wire was contaminated with iron nitride, which under heat can form ammonia.

Ostwald was outraged, but someone in the lab used the same wire to study ammonia.

BASF was impressed by Bosch, taking on Ostwald, he was soon put in charge of all nitrogen research, including the showhair furnace and partnership in Norway.

Bosch needed a win, if the furnace worked it wasn't on him. Bosch said they should risk it, he knew what the steel industry could do.

Brunk was a careful gambler. He boosted Habers support but held off until an osmium replacement was discovered. They were cornering the world market of Osmium, but there wasn't enough of it to work.

Uranium was discovered as another catalyst.

Habers machine was designed to produce Ammonia in a flow, not in batches. High uptime required for profit. Reliable operation had to be proven.

Bosch arranged a trip to Habers lab in Carlsrura in early 1909 for himself, a chemist, and machinist. They found an uproar, over tightened bolt meant pressure couldn't be held, no demonstration.

Germans have a name for inatimate objects that pick the worst possible time to break down. Huka des objects.

Bosch left to another appointment, the technicians stayed. After repairs, Ammonia began to flow.

6-8% of input nitrogen became ammonia. High enough for commercial use. 5 hours of continuous production until they shut it down and wrote reports.

Chapter 9

Great big party, very drunk.

Haber and Bosch worked together for the next few weeks. Bosch wanted to build a bigger machine in Ludwigshafen.

Haber went to a Swiss health resort.

Haber and Le Rosenthal had many offers of work, Le Rosenthal left for Berlin.

Haber wanted to renegotiate his revenue sharing deal.

In October, 3 months after demonstration, he told BASF he was approached by AEG, General Electric of Germany. 8x salary, great lab, etc.

New contract, 10 pages, guaranteeing Haber 23000 marks per year. A few pennies per kilo of ammonia too.

Bosch became Bruns' protégé. Many similarities. They both agreed on fearless innovation, as soon as one product works start another.

Haber was less optimistic. He didn't build his own larger machine.

Bosch outfitted a machine shop. Haber's machine was 2.5 ft high. He knew he'd be too overwhelmed by thinking about all the problems, so he just started building. Wanted to build a 10x bigger machine asap.

BASF purchased all the osmium in the world, 100kg for 400,000 marks. This limited to 750 t ammonia per year, below 10-20x less than target.

Catalysts had to run for days. Long parallel testing.

Mitash, head of catalyst testing, found that Scandinavian magnetite - iron oxide - produced a good amount of ammonia. Iron did nothing, there must be a contaminant.

Iron would be used as a base, and a promoter element added. Some machine explosions, catalyst test lab became like a bunker. "The work would not be allowed to stop because of a little shrapnel."

New era of chemistry using promoters. Haber was happy with the result.

Haber was no longer needed. Advances happening without him and they had his patents. With income assured, he turned to his reputation.

Winter of 1909, he did a talk on the basics of the discovery, not mentioning iron. Ran out of reprints of the talk. Asked the company for help but they were not interested.

Leopold Cappel, head of AWA, told Haber he was planning a new institute, Walter will helm institute for chemistry. In 1911, Haber joined and left BASF. Wife begrudgingly came.

Chapter 10

Alwin Mitosh. 20,000 catalyst experiments.

Keeping out contaminants to protect the catalyst was important.

In Ireland, a Dublin brewery developed a method for extracting pure nitrogen N_2 from the air. They asked a German inventor to make it.

The machine was an air conditioner. Cool air down to liquid, then the boiling point can be used to separate gases.

Liquid air for the nitrogen.

No system for getting the required amount from water as the demands were extremely high.

First tried running electricity through brine. Then the water gas method, blowing steam over glowing coke, but CO is produced.

A variation was created that produced more with less CO, but slightly impure hydrogen. Tall water towers to screen the hydrogen, then through a charcoal purification system.

Enough CO produced that it's dangerous. Copper containing solution tried but that corroded iron.

There still wasn't unanimous board support on the nitrogen project. CO was raised as yet another issue.

Carl Crouch was put on the copper solution corrosion problem. After a few months, the solution was adding a little ammonia.

Catalyst and pure inputs were solved; now the reactor was the focus. Completely new problems, no examples in industry.

The reactor had the real problems. The biggest compressors of the time were used to pump air into mines, too small. Then compressors for cooking air, those could be scaled but used copper soldering on joints, high temps blew the joints. They were also leaky, can't do that with hydrogen.

20x higher pressures than steam locomotive boilers.

New gauges and valves needed for precise input and monitoring output.

Design hints looked for in steam and diseased engines. Looked at Rudolf Diesels new engine. Learned about the Bessemer process for making steel from men working in the steel industry.

Bosch kept saying this was about billions of marks. Sufficient motivation?

Just a year after Habers machine started to work, Bosch decided he was ready to build a bigger machine. Nothing apart from catalyst ready. Building a bigger prototype was key.

First two ovens 8 feet tall steel cylinders, 1 inch thick. Made by Krupp, Germanys best cannon maker. Heated by gas flames from the outside. Prototypes wrapped in reinforced concrete in case hydrogen escaped. Scaled for hundreds of pounds of ammonia per day.

Heavy glass in concrete to observe the blue flames. Ammonia started to flow, 3 days later they burst. The one inch walls cracked. Bosch joked, but was disappointed, good thing they didn't just osmium and destroy the world supply in a single afternoon.

After examination, because Bosch knew metallurgy, they saw that the inner metal lost elasticity, many hairline cracks.

Temperature gradient was an idea, moved heat source inside. Heating became more efficient but still cracks. Maybe ammonia reacting with oxygen to produce iron nitride was the problem, no significant amounts of it though.

Carbon was disappearing from the steel, but it wasn't turning into pure iron.

Hydrogen was being pushed into the steel, making it crack. First time this was ever seen.

Temp was needed to break apart the N_2 , pressure for formation of Ammonia.

Carbon steel was the only economical material, they tried adding molybdenum, tungsten, etc.

Started testing liners. Considered gilding (gold coating) the containers, dismissed. 6 months after the burst, no solution. Scores of chemists.

Bosch went bowling with beer on a Friday night, one time a week he relaxed like this.

He realized he could separate the uses of the steel cylinder. Separate high pressure containment and keeping hydrogen in.

He thought to add a sacrificial thick liner to stop high pressure reaching the pressure vessel. Common steel would work. Could last for months.

He also thought to let a little hydrogen out in a controlled manner. A little leak.

They drilled pencil sized holes in the outer steel. Bosch had created a full materials testing lab, better than in the steel industry.

They found that steel lost its strength at 300 C, 50% at 500. They found ways to make the heat more uniform.

N₂ was used to flush the copper heat exchanger, corroded by the steel.

By end of 1911, prototype ovens running reliably for long periods. Producing tons for cheaper than the market.

Early 1911, >2 tons per day.

Further plans to turn ammonia into fertiliser and scale up more.

They found a site at Ludwigshafen and started planning the production site. Needed to be near water. First synthetic nitrogen factory.

Bosch stated this was the largest scientific effort in history.

A company sued to invalidate BASFs Haber patent, saying Yernst proved ammonia could be synthesised under high pressures. Facts were in the open, unlikely suit to succeed.

Heinrich von Brunk died two months later. Dec 4, 1911.

Chapter 11

Hersht was trying to cut off BASFs lead before it grew too much. Nothing public went out of BASF since Habers talk.

Kaiser Wilhelm institutes were a new idea. Government sponsored and mostly privately funded. Modelled partly on carriage institute in the US.

Jews were 1% of the population, but gave 30% of the starting funds. A way to show pride in Germany without serving.

Fritz Janet completed his path from great researcher to great German.

Haber asked BASF what to do about the suit, and he transferred over all remaining patents. Yernst was provided with a lab (BASF Lab?).

Care to be argued in national court in Leipzig in early 1912.

BASF research director Bernstein, Yernst, and Haber met before court. They didn't like their position.

Yernst provided a statement that it was a scientific outcome to increase pressure, not specific to Haber.

While the BASF team was making a short response (not much they thought to say), Haber and Yernst walked in arm in arm. Yernst did a speech and said after experiments, he realized that Haber did do something new deserving of a patent.

A few weeks prior, Yernst signed a 5 year consultant contract for 10,000 marks per year with BASF. Hersht paid the legal fees.

The victory suppressed board concerns, a full scale factory was approved. First shovel in May 1911. Bosch oversaw construction.

10,000 workers. Lab for 180 chemists and 1000 assistants. All steps of the process from nitrogen freezing to 4x larger ovens. Railcard, etc.

Bosch cared more about functionality than look, but the buildings ended up looking like 1950s designs. Oppaw opened 16 months after start of construction. Within a year, tons of ammonia based fertiliser made per hour. Selling at competitive prices.

Arc furnace and deal with Norsk hydro dropped now. Board kept it on or what?

Bosch saw Oppaw as another bigger prototype o the path to a larger plant. He wanted to go to the limit of the German steel industry, a 20 ft long cylinder. Bosch attached two end to end, angled bolts to hold the pressure.

Oppaw ran 9 hour overlapping shifts. Bosch increased headcount 20% in 2 years. Only stops to check quality.

Oppaw was the invention of a new field, high pressure chemistry. All patented. Quick acting magnetic valves, quick acting gas meters, new gaskets, etc.

Bosch began thinking of what else could be created with the new processes.

Yernst and Max Planck took the night train to Zurich to lure Einstein back to Berlin to become head of the KWI.

Einstein wanted more time to ruminate, went to Berlin, still didn't like Germany too much. He met Haber. Completely different people, one a proud prussian, other a free thinking bohemian.

Einstein punctured Habers ego. He enjoyed fame too much. Still, they respected each other as scientists. They were close friends.

Einstein talked about the madness of war while Haber already enlisted.

Chapter 12

Haber spent the first half of 1914 optimising the Oppaw plant.

A research farm and lab was built in a field near Oppaw. The simplest fertiliser to manufacture was Ammonium sulphate, but Chilean sodium bitrate was still preferred.

Haber was the initial inventor, Bosch turned it into an industrial process.

Norwegian arc process fertiliser still produced more than the Haber-Bosch process. Nitrate imports even higher.

Calcium syanamid fertiliser synthesis action process was backed by many important German businessmen. High temp N_2 and calcium carbide. American Syanamid used the process with electricity from Niagra Falls.

BASF started making a profit from nitrogen in 1913. Tons of demand, Haber-Bosch process just needed scale.

BASF's board hesitated on Oppaw expansions. Then the war started and all Germans expected a brief march to Paris. Figured Chilean nitrate stores would last 6 months, enough time.

Haber was too old to hold a rifle and too Jewish to serve, but he could be an advisor. He realized that if the war extended, there'd be a critical shortage of nitric acid for munitions.

Haber sent a letter to BASF to ask if they could turn the Ammonia into nitric acid. He still made a few cents per kilo. They said it was impossible. But there would soon be too great demand for Chilean imports or the Syanamid process.

There was an international response to Germans going through neutral Belgium. Much propaganda.

Marne river near Paris, Britain and France dug in and stopped the German advance. Artillery used up more nitrate. They scoured the country to find more and seized private stockpiles, bought from neutral countries. They found a warehouse in Antwerp with thousands of tons of Chilean fertiliser, lasted a little bit.

In Nov 1914, they estimated its take 29kt of fixed nitrogen to last a year of war. A year later they were burning that much in 10 weeks, another year later, 5 weeks. Fixed nitrogen would determine the war.

Haber didn't like the German funding of the Syanamid process because it was inefficient in energy and labour. And he wasn't paid.

Willhelm Ostwald had patented a method for turning fixed nitrogen into nitric acid using a platinum catalyst. They found a new catalyst, iron with bismuth promoter. Big Cyanamid lobby wanted funding too.

Bosch realized they could do an indirect conversion into nitric acid. First turn it into Chilean salt peter, then nitric acid. Bosch pledged at a war meeting that the Oppaw plant could be refitted in 6 months to produce 5000 tons of white salt per month.

Ammonium sulphate was still a worse fertiliser than Chilean salt peter. They'd get a stream of income in the short term and the best fertiliser after the war.

6 million marks for the salt peter promise with the military. 5000 scaling to 7500 tons per month. BASF became a part of the defence industry, Bosch didn't like this and didn't talk about it much.

The first major naval battle of WW1 in November was off the coast of Chile. Modern German ships sank many British ships. Royal Navy's first significant defeat since Napoleon. Insurers refused to cover British nitrate ships.

US military expert: "The destruction of a nitrate carrier was a greater blow to the allies than the loss of a battle ship."

Within weeks the allies dispatched a fleet to destroy the German fleet. They fled to Germany around Cape Horn, raided the British coal bunkers on the Falklands. British predicted this and on Dec 8, the British destroyed the ships. 2000 dead including Admiral Scheppe and his two sons. Allied shipments doubled.

On Oct 24, construction began on the salt peter process. New generation of ammonia ovens too. In 6 months, 150 tons per day. They won against the Cyanamid process in government. After 1915, all investment in Cyanamid ceased.

May 27, 1915, French bombing attack. Little damage. Anti air guns added. Shutting it down temporarily could do damage by repeatedly restarting ovens, compressors, etc.

German government proposed a contract to build a 2x bigger plant. Bosch chose central Germany. Discussions for months, BASF concerned this would be over supply after the war, wanted government money. Germans said it could be a government facility with BASF operating it.

Finally, BASF would build, operate and own the plant for a 30 million mark loan to be repaid after production started.

During the battle of Verdun, a site was chosen near the town of Loigny, near Liepzig.

The overproduction could drive all other fertiliser suppliers out of the world market.

The plant could be converted quickly between fertiliser and munitions. Secret industrial weapon.

Fears of crop failures in summer of 1915. White salt could be fertiliser or turned into TNT.

Part III: Syn

Chapter 13

Haber became more Prussian by the day. His son on Haber: “an uncritical acceptance of the states wisdom.”

Otto von bismark forged a nation by staking the identity on great historic German artists (poets, etc.) and instilling a constant sense of war.

Willhelm was insane. Extremely competent one minute, diving into conspiracies the next. One monarch ruling the worlds most advanced technological power.

Once to amuse the kaiser and distract him during a military crisis, the head of his military cabinet dressed in a feather hat and a tutu, then died of a heart attack dancing. LMAO SKILL ISSUE

A young man struck the kaiser when minorly insulted, he was given the opportunity to kill himself and did.

Queen Victoria was willhelms grand mother.

He came to power in 1888, talks of a coup in 1890s.

WW1 was Germany’s “chemists war.” Chemistry rose even above politics. Willhelm was proud of scientists, even the Jews.

Haber wore his uniform whenever possible. Very cold in pursuit of his goals.

His wife dispeared the more war like her husband became. Haber left a couple weeks after the birth of their first child for a four month tour of American science facilities. She felt a trap closing around her. Haber married a talented phd but wanted a traditional German wife. Kids, cooking and church.

“Women are like lovely butterflies to me, I admire their colours and glitter, but I get no further.”

Fritz destroys any personality incapable to assert itself more than him. That's the case of his wife. She spent all her energy on her son.

At a Berlin private club, he met the club's business manager. As much a butterfly as Clara was a mouse.

“Every war is a war against the soul of a soldier, not the body.”

In 1899, many countries pledged to not use poison in war. This was mainly around projectiles whose main purpose was delivering gas. France broke it first.

Haber decided he could turn gas into a super weapon. He got a role in the Prussia war ministry. He was a captain, a position open to Jews.

He'd need a heavy gas, and couldn't deliver via artillery as it'd disperse the gas too much. Canisters released when the wind was right. He didn't want a tear gas, but a killing gas.

His team settled on chlorine. BASF had many chlorine machines sitting idle while the dye market dries up during the war.

Haber argued that the French already broke the pact and that by ending the war sooner, countless lives could be saved.

Clara accompanied him to some tests, nervous woman. In one test Haber rode a horse too close to the gas and almost suffocated.

German generals didn't like how long the weapon took to set up. And War was not about chivalry anymore. Wind was a problem, no wind was just as bad as a contrary wind. Shrapnel would puncture some canisters.

Crown prince Rupprecht of Bavaria complained about the idea because the allies would use it and have more effectiveness as the wind was to their advantage. Haber said their chemists were far behind the Germans.

In the first use at war, a wall of chlorine gas 4 miles long suffocated the French. Men running as fast as they could away from it.

Germans slowly moved forward, fearful of the gas. Didn't take full advantage of it. Only a few hundred killed, most scared away.

Haber was awarded an iron cross before his emperor.

Another smaller attack two days later against Canadians was less successful, only pushed back a bit. Troops educated and given makeshift respirators with rags. Then allies began work on gas of their own.

5 months later the first British attack failed, wind. Just as many British as Germans killed.

Both sides developing deadlier gases.

Clara Haber told a friend she was in despair. She loved chemistry, but not this.

Haber was ordered to the eastern front. He hosted a party before leaving, attended by Charlotte Nathan, the young woman from the club. Clara shot herself in the heart. Her son was first there. Haber boarded a train two days later to the eastern front, without his son.

Clara was disappointed by her life, stifled.

Wars continuous demand on all his strength calmed him.

There was a manifesto signed by 90 German scientists about Germanys constant battle to be a civilized nation and survive. It backfired and was ridiculed.

Haber became a war criminal in many minds.

2.5 square miles of farmland was bought (military forced this) and levelled for the new factory. Deal signed in April 1916, for 5000 tons per year a year later.

Half of BASFs 1914 workforce was conscripted, many of the construction workers were soldiers. Loina is the city. Even women worked.

Carl Craush was Bosch's main fixer. He solved a corrosion problem at Oppaw. Top assistants supervised operational details.

One year from groundbreaking to full functionality.

36,000 t/year at opening, 160 kt at end of war, plans for 240kt.

Paul von Hindenburg recognized the importance of BASF - Germanys supreme military director.

Some estimates that WW1 could've ended 1-2 years sooner with the Haber-Bosch process.

The British sea blockade and war with the US is what caused Germanys loss, not technological.

After a final failed offensive in spring 1918, Germanys allies began to give up. Austria-Hungary, Bulgaria, Ottoman Empire.

The kaiser abdicated and fled to Holland.

Chapter 14

In the year after the war, Germany was in a state of anarchy. Spontaneous worker revolts, soviet republic briefly declared in Berlin. The Freikorps quelled the leftist uprising (group of former soldiers), then staged their own uprising.

A centrist group from the city of Weimar prevailed and tried to establish a centrist democratic republic.

German chemical patents were used, Germany was very far behind after the war.

The area around Oppaw and the original dye plant (other place) was captured. Bosch knew that if the plants were seized, the ammonia secret would be out.

Before Dec 6 1918, when the French marched in, they carted as much of their inventory as possible across the Rhine. The French confiscated a million marks worth of dyes, and shipped to France.

Bosch shut down the ammonia ovens at Oppaw before the French arrived, stating there was a coal shortage. The French demanded he bring them back online to observe how they functioned, he and BASF argued they didn't have to because the French were clearly doing industrial espionage.

Germany had to give information to the allies after the war, but BASF argued this only had to do with inputs and outside and not German technology. Even though they won, they didn't have the right to German technology. The French and British parties visiting Oppaw disagreed, claiming the plant was a military munitions facility and not civilian. Half true.

The French set up a military post at Oppaw. Insisted on seeing all production documents. Photographed BASF employees as if they were prisoners.

When French inspectors arrived, machines were turned off and the men stared at the French. Ladders missing to stop them, etc. They continued producing dye. The French could not understand the Haber Bosch process.

Bosch needed to keep the Ammonia secret safe while keeping profit flowing and workers busy to avoid revolt. Repairs were done so that production could resume when the French left, could be years.

Tens of thousands of marks lost per week with Oppaw shut down. Estimated 25 million marks lost in the first four months of 1919.

During WW1, there was an attempt at a Haber Bosch plant in the US and Britain, both failed.

British chemists from large chemical firms went to Oppaw. BASF told the French that dismantling equipment to see how it worked would lead to them shutting down the plant and laying off workers, and that the French would have to deal with the consequences.

Sketches and notes were kept in a locked railway wagon under guard, someone got under and stole it all. The British had to make their report from memory.

Bosch spoke for German industry at Versailles. Like all other German delegates there, he was thrown into a high class protective custody prison, armed guards.

The Germans quickly realized they were not to negotiate a peace but accept one.

French country side was far worse than German from the war. They demanded closing all German armament plants and reparations paid in anything.

Bosch argued his plants were necessary to feed the Germans and give work to prevent the spread of bolshivism. He was politely listened to and ignored.

Bosch snuck out one night to a secret meeting with a French chemist businessman. He offered the opportunity for the French to build a Haber Bosch plant for Oppaw and Ioina staying open. French access to BASF advancements for the next 15 years. Small royalty to BASF.

In early 1920, the French forces left Oppaw. Ovens restarted.

Bosch was made head of the company. He liked engineering but also wanted to guide the company.

Dye prices were falling as France flooded the market and the allies used German patents to create their own plants. The allies began to appreciate chemists in war time.

Bosch would increase Ammonia production while looking for the next big thing. He knew the ammonia monopoly was temporary.

Bosch didn't give info on civilian products like dyes and fertilisers.

The riddle of the Rhine book made more public sentiment to shut down the plants. Disarmament not complete until all ability to create munitions was destroyed.

An ornithologist along the Rhine heard a soft splash. A man knee deep in the water with a net hunting for some marine animals. The man was Bosch, relaxing.

Chapter 15

Proposed to Charolette 2 years after his wife died, 20 years younger and beautiful. She converted to Christianity and they got married in the center of Berlin. 1917.

10 months later, daughter, failing marriage. She complained of his workaholicism. Haber didn't mind, he understood this wife no more than the first.

Haber was a war criminal in British and French eyes, fled to Switzerland. Tried getting citizenship. Haber wasn't actually out for arrest, returned to Berlin.

Got a Nobel prize at this time. More chemist than war criminal. Accepted it in summer 1920, protests against this didn't change anything.

He continued research into chemical warfare. He kept a framed picture of the first gas attack in his office.

He was a middleman, describing to other countries how Germany had done chemical warfare. Soviet Russia and Spain. Russia built a plant on the Volga for production for both Germany and Russia, Trotsky was involved in this.

Haber wanted to revive and rebuild Germany. 132 B marks reparations. He wanted to personally pay that off.

He wanted to get gold from the sea 6mg per ton. Read everything, electrochemistry.

50,000 t gold required, 10x Fort Knox.

Metal free equipment to measure gold content.

Cupilation used after much testing, Babylonian method. Lead sulphide used to precipitate lead, gold, and silver. Burn lead away and separate silver. This was tested in lab created sea water.

Secret testing in the ocean. In 1923, an ocean liner bound for New York had a secret room installed below deck. Lab with gas, its own power source, etc. Rumors onboard ship. Haber and his men started some rumours to divert attention from what they're really doing.

Disappointing results, perhaps low concentration in North Atlantic waters. 100-500x lower concentration.

Haber and his assistants got off in New York. He was quickly chased by reporters. Enjoyed himself getting an immigration card.

Fall 1923, new lab and voyage to the south Atlantic. Then to South America again, around equator. Still disappointing results. He shipped out 10,000 1 gallon bottles to anyone he could find to collect water. Analysis of all the samples showed all results were low.

After 5 years in 1927, he gave up and concluded previous estimates were false. He didn't publish most of the data.

Chapter 16

Bosch didn't know people well, many crisis. Brunk had been a part of the worker paternalism that was common in Germany. 49 workers died building Loina.

He was interested in labour theory and read books on socialism. 8x5 workweek. He was more comfortable giving gifts than negotiating.

Bosch instituted scientific management. Judging every action of a worker. Loina workers revolted for 10 days, then police fired artillery, full scale battle. 30 labourers and one policeman died. Every worker fired at Loina, then some hired back. No labourers under the age of 25 rehired. ID cards instituted. People needed jobs, factory soon back up to full production.

He thought of himself as a liberal giving man, but he looked very mechanical. Worker expectations had changed, paternalism didn't work as well. He was an engineer who had built a massive machine, managing workers was harder.

In Hildesheim, 100 km from Oppau, he heard a massive sound, immediately rushed to the factory. 300x60 ft smoking crater where part of the plant was. Perhaps hundreds dead.

He quickly talked with officials and went to the admin building to plan how to most quickly bring the factory back online. Then made wood spools on his lathe for the mother back at his villa.

4 days later, he hosted a memorial service. He felt responsible for his factory's explosion.

Massive investigation over 13 years.

He realized his people didn't want to hear him speak technically, but a eulogy. He spoke about the betrayal of the machine, pained him.

Bosch tried to motivate workers the only way he knew how, the fatherland and their own economic survival.

Most personal statement of Bosch's on record.

On his way home from the service, he collapsed. Not much known, or the cause of the collapse. But he stayed in seclusion for months during winter 1921. Drank heavily, more and more over the years.

While he recovered, his lieutenants tried to investigate. Haber felt the shock in Frankfurt.

The blast started in a storage silo of fertiliser. The granular fertiliser would cake, soaking up water and solidifying. Workers would use small explosives to break it apart for shipping.

It was thought to be safe as the primary fertiliser product was ammonium sulphate. Small blasts used for years without error. Chilean sulphate would not be safe with explosions. A little stayed in production after the war, mixed with the other fertiliser.

BASF chemists determined the nitrate-sulphate mixture would be safe with low nitrate. They were wrong.

4,500 metric tons of fertiliser. 561 dead, 1700 injured, 7000 homeless. Half a billion marks in repairs!

Carl Croush led the effort to get the plant back in production. He did it in 3 months, insurance covered a third, company didn't take responsibility but paid one time sums to the families of employees. Families of contractors got \$50 USD.

In 1922, communists got control of the workers factory council. Three BASF labour leaders fired for attending a communist meeting. Oppaw workers struck, 1300 then fired, similar to Loina.

Summer 1922, Bosch returned. Now less able to talk to people, no more jokes, quiet and withdrawn. He cut back on the size of his team until decisions were made with just a dozen men. Lieutenants given more power.

Chapter 17

Mid May 1923, French marching to Oppaw. Arrest Bosch, get reparations, and occupy the factories. One day to prepare. Similar process, 3 deputy directors left behind. Germans had stopped paying reparations as a matter of survival. Hyperinflation. A pound of butter would cost a billion marks.

At one point, BASF printed its own money backed by foreign deposits.

France didn't give time for Germany to grapple with their inflation problem. Sent troops to occupy. They took everything they could, emptied BASFs fertiliser storage silos. Took steel and wood to rebuild war damaged housing.

Bosch again stopped factory operation and refused to restart it.

BASF labour and management united in goals for a time. Remaining BASF managers arrested and BASF board charged with refusing to cooperate.

All found guilty, fined, and sentenced to prison. Bosch got 8 years. He stayed across the river in Hildesheim.

This continued into fall of 1923. BASF hemorrhaging money. The French had realized they took everything of value and realized the occupation was costing more than it was worth. The French went home.

The US would broker a new reparations plan and the German government made a new currency backed by real estate.

BASF was able to repay government loans easily during hyperinflation.

Selling abroad gave them a stream of foreign currency.

In 1924, inflation was under control and more farmers were buying fertilizer. Record profits. 2/3 from Bosch's plants. New streamlining techniques.

The French now has a Haber Bosch plant that they learned to run without German help.

Two Alsation engineers went to Britain to sell their knowledge. Only known as K and A. They bought the stolen material, didn't pay licensing fees.

Paid about a million marks in stages. In 5 months, they had a pilot plant, then built more. BASF paid nothing.

Lucrative market for Haber Bosch engineers. The US got some.

BASF's gamble didn't work, no licensing fees. BASF chemists were looking for new applications of high pressure chemistry among the increased competition. Methanol first, wood alcohol.

In late 1923, Bosch took a long trip to the US. US and German chemists interacted a lot. They saw the US as the only real competition. They wanted to see standard oil and saw all the cars.

2 million cars produced in 1920, 3.5 in 1923. The S curves are really getting faster.

BASF realized gasoline was the next big thing. He liked standard oil's push for an integrated gasoline business evolving out of just refining.

In the early 1920s, every expert said the world would run out of oil. No big new fields were being found despite a world wide search.

Synthetic gasoline was the solution. Friedrich Berigorous was a German chemist that dabbled with making products out of coal for years. One system for grinding up coal, joining with oil, heating, and putting in hydrogen. Hydrogenated coal slurry output. Coal into crude oil. The process never caught on.

The process would be done in Loina. Bosch loved that factory.

Berigorous never found a catalyst. BASF would have to.

The company couldn't find complete conversion of loina themselves, and German government was still weak. International deals required.

Bosch wanted to band all dye firms together into a super business. Not the only one with that idea.

In Britain post war, four firms joined to create the imperial chemical Industries. Allied chemical in the US.

In early 1920s, Germany created laws that favoured formation larger businesses, made clear it was time to merge. Nov 1924, the council of the gods. Duessberg, head of beyer, hosted. He and Bosch debated. Bosch wanted a cartel. Beyer a total merger. Beyer team in the billiard room, Bosch team in the villa bar, with a mediator rushing proposals between them. Most sided with Bosch.

The interest community of the dye industry. Abbreviated Farben. Third largest org in the world, only verses by US Steel and General Motors. Bosch named head. This is just what was needed for the gasoline project.

In 1921, his enormous villa was built. Near a castle in Hildesheim with a view of the Neckar river valley. Aristocratic home. Fully equipped mechanical workshop, astronomical observatory, many scientific rooms. Many people worked there.

At one hosted dinner at the villa Bosch was about an hour late because he disassembled a grand father clock and "lost track of time."

He had a large private library, learned about chemistry and physics. Friendship with Walter Nernst, and could chat with Einstein about physics. Loved astronomy. Spent cold winter nights in the unheated observatory.

He needed order and serenity to offset the chaos of work at Farben.

Chapter 18

Haber was good at sighting good chemists. His institute became an International mecca for chemists. It became his life after the failed gold project.

He asked pointed difficult questions and told jokes.

"Haber wanted to be both your best friend and god at the same time."

In 1924, they took a cruise around the world to aid their marriage. Not many jokes in the household. They were happy but it didn't last long after returning.

"I either want to direct things or let them go." - Haber

By 1927, divorced. He viewed it as a great personal failure, wrote to Einstein. Got depressed, worked harder. Insomnia, heart problems, very ill.

He realized he was still a Jew, Christianity was just a matter of convenience. He noticed Jews were being more excluded.

He took a lump sum settlement from BASF years before, ending the ammonia income stream. Then lost major investments. Still kept up an amazing lifestyle, but couldn't stop worrying about money.

Loiwa looked like a small city around 13 smokestacks. 2 mile long assembly line, one mile wide. Had its own police force. 30k workers, random searches.

A German journalist went undercover in Loiwa. A giant iron worm. Workers were paid by the task, they worked themselves into exhaustion. Sick days every few weeks.

Bosch saw it as a triumph to human ingenuity, not an industrial inferno. Workers proving what humans were capable of.

Bosch wanted to complete the final expansion planned late in the war. Loina was a huge money sink for BASF, part of Farben was finding a way to finance the expansion. Loina was his obsession, he would finish it no matter the cost.

Bosch spent more on labs and less on dividends.

“The future of the chemical industry is unlimited. There is no natural product that cannot - with perseverance - be manufactured.” - Bosch

Synthetic fuels and international business was required for success. Esp. US. Needed to aggressively make foreign subsidiaries and forge alliances with foreign companies.

He took a different approach than Brunk. Instead of keeping it secret, he would share it and sign lucrative deals. He needed the money, and the secretive strategy didn't work.

He'd finance remaining dev costs with deals.

Allied chemical backed out of the deal with Farben and Imperial chemical. They went with DuPont and General Motors. Instead of signing allied, Bosch spent time with standard oil and Ford.

Standard oil was concerned over the predict oil shortage. Their refining rockets turned four barrels of crude into one of gasoline. Farben tech could do it closer to 1:1.

A standard oil executive was amazed by Oppaw, never saw anything so impressive.

Bosch felt that money spent on competition was wasted. Better to partner. When Ford began sales in Germany, Farben bought 40% of that subsidiary. Similar deal with Farben in the US.

Germany had no oil wells. Synthetic required to become a global power again.

Germany would need to join the automotive revolution. He'd save money by not exporting overseas for oil, more for reparations.

Standard oil bought the rights to use the Farben process outside Germany for 35M USD (150M Marks) in stock. The cash was needed.

Farben made predictions in fall 1926 of mass production, hundreds of thousands of tons of gasoline. 6 months later, only a few barrels. Technical delays.

13,000 labourers rebuilding and expanding Loina. Farben predicted 100,000 ton goal by end of 1927. Some experts predicted a fifth of gas would be synthetic by 28.

Some directors of the Farben cartel didn't like the delays and costs. Bosch was unmoved, problems would continue to be solved.

Then, a new oil field was found in Oklahoma. Biggest ever. They found the edge of an underground sea of oil. Oil wells went up across 6 states.

There'd be no shortage, predictions of \$1/gallon, in fact nine cents.

Farben projections assumed declining supplies of oil. Loina was just starting production. They could not compete on cost.

They told themselves even the new fields would run dry and that Germany would still benefit from becoming self sufficient.

All possible deals were exhausted, he went to the government. Every litre produced was a litre of money not sent elsewhere. They called it Loinabenzene. They wanted tariffs, they showed politicians the factory to impress them.

Farben was making deals to build Haber Bosch plants overseas. Germans were still the best in the world at it.

They expanded dyes and made pharmaceuticals.

Wages were rising, armed rebellions a thing of the distant past.

Large new admin building built in Frankfurt.

Research into plastics and a popular new mixed fertiliser. Synthetic rubber under dev.

Chapter 19

US stock market crash. Many German loans from the US were called to be paid.

4x increase in unemployment. Workers listened more to extremes. Farben income from nitrogen fell by a third, the next year, half again.

A portrait of him exists from this time. A thin haunted face.

Carl Dousberg, head of Beyer. Bested during council of gods. He generally supported Bosch but led a group to cancel the Loina expansion and gasoline project, at least putting it on hold.

They put out a report. Estimated 400M marks more required to complete. Bosch argued for the sink cost fallacy and economies of scale with more pructupn at Loina.

Bosch and supporters concluded that shutting down the project would cost more. They were close to full production.

The 100,000 ton production goal was finally hit four years late. Tariffs instituted too.

Loina running at 20% and some sections mothballed. Repairs delayed, instead just swap in an extra machine not in use.

In 1931 Bosch and Beigerous got the Nobel prize in chemistry. He took full part in the event in Stockholm.

Bosch believed Heinrich Brüning, new chancellor, could lead Germany through the depression. Soldier and doctorate in economics. He would pull Germany out of depression through firmness, reason, and economic theory. Both were centrists.

Bosch was a liberal technocrat. The purpose of the state is to make sure employment and other nation states continued with low friction.

The Brüning administration banned nitrogen imports and raised oil tariffs. Farben left with almost a monopoly on ammonia.

Bosch wanted a subsidy for synthetic gasoline, thought it was in the best interest of Germany, but Brüning was gone in April (1931?).

The nation wanted a stronger individual. Hitler got almost as many votes as von Hindenburg for president. Nazis worried Bosch, they were bad for business. Bosch spent his career working with Jewish scientists.

Brüning worked with Hindenburg to not get Hitler elected. Then to appease Hitler he fired Brüning. Nine months and two more chancellors later, Hitler was made chancellor in 1933.

In 34, Brüning fled to the UK then America. He taught.

Haber was testing in the French Riviera at the time, stressed, had to learn to live as a Jew under the Nazis.

4 weeks into Hitler's chancellory, Germany's parliament building was destroyed in a fire. Hitler started suspending civil liberties. An act was passed to give the chancellor the ability to create laws. Even centrist parties supported this.

March 1933, new swastika flags. Haber supervised the raising of the flag on his institute. If he kept his head down, Hitler's regime would pass.

Then a boycott of Jewish businesses was proposed, judged by ancestry. Judges were asked to step down, the most prestigious position for Jews.

April 7 1933, Hitler instituted a decree to remove everyone from government service that wasn't an Aryan. Hindenburg insisted on a military service exception.

Haber was too stunned to do anything for a few days after the edict. This was the end of his German dream.

Chapter 20

The edict was done during the Easter break, institutes only full reopened in a month. Questionnaires sent to all government employees.

Working on poison gas could give them the military exception. But he would have to sign the dismissal papers.

Einstein never returned after this. James Frank, who worked on the gas, resigned.

Haber held out some hope. Jewish scientists were very successful. Then he was told his institute couldn't reopen unless organised on the new edict. The kaiser wilhelm institutes were targeted. Much propaganda about Haber and the institutes.

Two department heads left first, but nazis demanded a complete cleansing except for executives like Haber. He finally decided to resign, sent a letter. He asked to keep his post until October to find a new head and to assist Jews leaving.

Headlines around Germany. Haber was Germany's foremost chemist. Many realized Hitlers new law might mean the end of German leadership in science.

Max Planck wormed for the kaiser wilhelm institutes tried to find a compromise that could keep Haber on. The first response came from the Nazis culture minister who said he was finished with the Jew Haber.

In may, Planck took his case directly to Hitler. Saying it was German scientific self mutilation. No transcript exists. Planck recalls that Hitler said he was more concerned about communists than Jews and that all Jews were communists. When planck tried to talk about science, Hitler talked faster and more aggressively. He had to leave the room. Time passed for planck to recover emotionally.

Exodus of Jews. German youth were pro nazi, wanted to free Germany from Versailles.

Haber felt he had been living a lie. Einstein write to him, agreed he was always living a lie.

Farben wasn't a government institution, but Bosch knew the Germans saw it as a Jewish institution.

Farben reached out to the Nazis after Running was done with. In Nov 1932, Hitler met with some of Brunnings men.

Hitler was a fan of the automobile - volkswagen and autobahn. He knew they needed gasoline. He was surprisingly well informed technically.

He said German fuel had to become a reality. This as everything Farben could have hoped for. Meeting went from 30 to 120 minutes.

Feb 20 1933, secret meeting in Berlin among high level Nazis and two dozen leading German industrialists. Bosch himself didn't attend.

Instead of going, they heard from Hitler himself on economic plans without notes. He insisted that only a Marshall nation could have a flourishing economy. They were asked for money.

Bosch literally shrugged at the Nazi request for funding. A gesture of resignation. Bosch needed government money for Iona, they deposited 400k marks into a political fund for the Nazis. A little of it for a moderate group.

Bosch quickly opened talks for Nazis funding after the Nazis won the election.

Bosch met with Hitler privately, weeks after Habers resignation. He asked Bosch to serve on a government economic council.

Hitlers secret police gathered info on Bosch's political views, typical south west liberal German. He had no intention of joining the nazi party. In 1929 he bailed out a liberal newspaper in Frankfurt. He was friends with Herman bousha, outspoken anti Nazi and head of electrical firm.

The gestapo made files on bousha and Bosch. Bousha was told about his file and had his and Bosch's stolen and burned in his home fireplace.

Bosch talked about gasoline with Hitler, then felt compelled to speak about the civil service law banning Jews. Hitler lost his temper.

"If Jews were so important to physics and chemistry, then we'll just have to work for a hundred years without physics and chemistry."

Hitler made Bosch leave. Bosch commented that he went into a trance when excited, lost in a dream.

Bosch was to speak about the benefits of international cooperation at a speech that Hitler was attending. Hitler left the hall when he heard. This was part of the economics council and it never convened again.

Bosch reconnected with Haber and sent a letter. This was the first communication he got from anyone at Farben.

Haber saw his retirement as a relief. And was looking for a position in another country.

Looked in Britain, France, Spain, Holland, Sweden, Switzerland and Palestine. Didn't get many offers. He didn't seem to focus on his goal, oscillated.

Haber spoke with Jewish chemist and Zionist Hein Wigsman. First president of Israel. He tried to get Haber to go to Israel, he found Haber was not quite a Jew, but he appreciated Habers journey to return to being Jewish.

Haber felt enthusiasm at going to Palestine. In August he took a trip to Spain for a conference, on the way he visited his son in Paris. In Paris he received an offer with a lab and non teaching faculty position at Cavendish in England. Making a new home in a former enemy nation.

One of his most important goals in life was to not die a German citizen, to not make his children and grandchildren second class citizens.

He stayed up all night preparing for a meeting in Spain. The next day he was gasping and taking nitroglycerin to ease the pain of a heart spasm. He still gave the talk, returned to Germany on train. He was flooded with conflicting emotions.

He got to Basel Switzerland when his health got so bad and he had to be carried off the train. Too exhausted, weak, and old to continue.

After recovering, he learned Wigglesworth (Wigglesworth?) was travelling Switzerland. Taking in the Matterhorn. His physician recommended against going to any altitude, he went a mile up.

He launched into a dinner time speech about the importance of a Jewish homeland. Haber spoke of himself as one of the great Germans of history.

Wigglesworth again gave the offer of living in Palestine, it would be good for his health. He said Haber considered taking it up after going to Cambridge.

On his way down the mountain he had a major heart attack. Still alive, but barely. Several weeks at a sanitarium until he recovered. October arrived and a note was posted with a statement. He led the Kaiser Wilhelm Institute for 22 years.

One of his sisters gave him full time care.

He was homeless now and had enough energy to go to Cambridge, stayed in the university hotel. He was given the problem of catalytic decomposition of hydrogen peroxide.

His former colleagues in Germany met him in Cambridge.

Ernest Rutherford refused to meet him.

He became unhappy through fall and winter, excluded. He longed for warmth.

The German government took most of his wealth in an immigration tax. He reached out to Bosch for help. No reply on record.

His doctors told him to not attempt travelling, but in January he did. He only got to Switzerland. He died there.

Requested his ashes to be buried with Clara. Couldn't do this in Germany so Clara's ashes were moved to Switzerland. His son couldn't bear to put anything but dates and names on the tombstone.

Chapter 21

Bosch focused on work during Habers death. He toned down open anti Nazi feelings to help his workers and company. More money flowed from Farben to the Nazis.

He still tried protecting Jewish employees. Beatings and book burnings in 33 and 34. 500,000k Jews in 1933, down 50k immediately with Hitler. Farben Jewish board members resigned.

Most Jews gone by 34. Many reassigned to US or Switzerland.

Synthetic fuels deal signed in dec 1933. Bosch got everything he wanted for Loina.

Hitlers government would buy every unsold gallon at a price that ensured profit. Bosch promised to triple output to 1000t per day.

Bosch wrote a published essay, where there's a will there's a way. "Will" reference to nazism. He saw a growing Germany. He was completely motivated by Loina.

Planck was 76. He wanted to honour Haber. The only top researcher to speak out at Haber's death was max von lawa, fearless man.

Planck would hold a KWI (kaiser willhelm institute) anniversary memorial for Haber. January 29 1935. Nazis banned all government employees attending. Celebration of Hitlers chancellory was jan 30, big holiday.

Nazi men stood at the door of the event, taking names. Many attendees were women, wives of the men banned from attending. Then, led by Carl Bosch, a large contingent of men from Farben arrived. He encouraged all BASF chemists to attend and Farben arranged transport.

The German ministry for public enlightenment and propaganda (at least its 50% descriptive!) made sure no newspapers published the event.

Bosch sent a memorandum to the minister of education defending science that didn't serve a direct immediate goal. Nazis said all science must align with state goals, private and public.

Hitler had quickly defeated the depression, seemed to be leading Germany into an era of plenty.

The board understood they couldn't continue making deals with the Nazis while Bosch spoke out against them. They were negotiating support for artificial rubber.

In 1935, at 60 years old, the board moved him out of day to day decision making and into Dousberg's position as head of Farben's board. Paper promotion.

Herman Schmitz, king time lieutenant, became CEO. He rose through the finance side.

Meanwhile, Hitler was secretly rearming Germany and stopped abiding by the treaty of Versailles.

Alcohol always provided a fast way to decompress for Bosch, now it was his escape. He slowly became solitary, tended only by his wife Elsa.

When Planck retired as head of the Kaiser Wilhelm Institutes, Bosch was chosen to replace him. 1937. Bosch was assured the institute didn't adopt the Nazi principles on aryan and Jews. Then in the last meeting before Bosch, they did.

Farben was becoming completely Nazified. The deals were fusion of company and state. Farben enabled Hitlers military plans. They adopted Nazi Aryan policies.

Hitler believed progress in science and technology could not be stopped, like art.

Bosch had made Hitlers ambitions possible.

Fall 1938, Bosch - one of the last really honest industry men - visited by the commander of Germany's military and chief of the army. They were concerned the army and industry wasn't ready to do Hitlers secret plan to attack Czechoslovakia. Bosch said they weren't ready.

Bosch was asked to tell German government officials his thoughts. Bosch supposedly had requested a meeting with Goering, he declined.

In may 1939 Bosch would speak at the deutsches Museum in munic. He couldn't do the Nazi salute and praising Hitler so he faked an illness. Showed up anyway, drunk. Friends couldn't stop him from speaking.

He went into a slurred defence of defending science from government. Mentioning Hitler only once in a "rather derogatory way." His remarks were published only after being sanitized by reich censors.

After Poland was invaded, Bosch completely fell from public view. He help plan and fund the Heidelberg zoo.

Health declined and he spent time in a sanatorium.

"It's a terrible gift when one can foresee the future. I have it and what I see it horrible. My entire life's work will be destroyed and I cannot survive that."

He suddenly moved to Sicily, without Elsa. Only took clothes and an ant colony he was given by the kaiser willhelm institutes.

He burned all his correspondence. Refused doctors recommendation of sanatorium.

He predicted the invasion of Denmark and Belgium would go well. Maybe even France and Britain. Then, at war with Russia, dark skies filled with planes and bombs. Hitler would destroy all of Germany.

He died on April 26.

On May 12 1944, the US 8th squadron sent 220 bombers to destroy Loina. Three square miles and 35,000 workers. >25% prisoners / slave labourers.

Loina was making a quarter of all of the Nazis gasoline. Most of the high test fuel for the luftwaffe, fixed nitrogen for bombs and fertiliser, and artificial rubber.

Single most important Nazi factory. Most well defended site in Europe. Blast walls, dummy plants, and fields full of fighter planes. 5000 workers trained as firefighters, and 20,000 train on AA.

Most AA battery had 6-12 guns. Loina had super batteries of 32 radar controlled guns. Guns would fill big chunks of the sky with explosions to create boxes of flak.

Loina had better air defences than Berlin. The sky turned black with smoke from the AA, some bombers miles off target.

In one string of raids, 119 planes lost with no damage to Loina. Summer and fall 1944, many attacks.

In 39, two thirds of German gas was imported. By the end, 75% synthetic. Better than Bosch could've dreamed. Highest synthetic fuel output ever.

In early 1944, fuel stocks were as high as in 1940!

The May 1944 attack killed 126 and shut down the plant temporarily. Reconnaissance photos showed reconstruction in days. 75% capacity by July.

350,000 soldiers from workers were devoted to keeping the plant functioning.

Other plants cannibalised for Loina. "Everything for oil."

Reich minister of armaments and production Albert Speer called it a race between concrete and bombs.

Battle of Loina for a year. On July 7th they shut Loina down, up two days later. Only shut down for days.

Allied bombers shot down in scores. Vibrations loosened bolts, sprung leaks.

In late October, the US airforce was almost winning. For 3 weeks they didn't get any enemy fighter planes over Loina.

The Germans were saving up fuels and planes for a trap. 400 German planes went up on the nov 2 attack. Early jets were there, 600mph.

700 B 17s sent, <400 made it back.

Rocket planes could only fly 8 minutes on their tanks. Now they had little fuel left. Pilot training cut back because of the shortage.

Loina and other synthetic gasoline factories slowly began failing.

Shpair testified that if the allies did nothing but destroy Loina the war would end in 8 weeks. There was a German military vehicle convoy in Italy powered by oxen.

22 total attacks on Loina, 6000 total bombers dropping 140,000t of explosives. Equivalent to Hiroshima.

When the war ended, Loina was at 15% production.

Loina was smashed, but more efficient plants spread around the world to feed humanity.

Chapter 22

In 1958, mass starvation in china. Mao Zedong's the Great Leap Forward. Farm to city, private gardens outlawed.

Great Leap Forward launched when China had an exponentially growing population and a drought.

Cannibalism, eating bark. 30 million dead. Worst mass starvation in history.

10 years later, farmers couldn't keep up with population growth. Most of society on a maintenance diet of rice and a few vegetables. Meat a luxury. Food rationing in major cities. The average diet was worse than a generation prior. 70s.

The first major transaction the Chinese government did after nixons visit in 1972 was ordering 13 of the biggest most modern Haber Bosch plant. Plants were built and the Chinese taught how to operate them.

In a few years the fertiliser in China doubled.

All the plants run on the same principle Haber discovered. All use the same catalyst that Alwin Mitash found a century ago.

Ammonia ovens now reach 100ft, Bosch only got to 30.

In 1938, 1600 workers to produce 1000t of ammonia per day. Now, 55. Now 4x more energy efficient. Haber Bosch plants consume 1% of all energy on Earth.

Ammonia pipelines. One built in 1960s from Texas to Iowa.

Without these plants, 2-3 billion would starve to death.

When crooks predicted starvation when there were 1.6 billion in his day. 4x increase in population (to writing) but 7x increase in food.

Half the nitrogen in my blood is synthetic.

Now, nitrogen is spreading everywhere around Haber Bosch plants. Before, there was only lightning and bacterial nitrogen fixation (from the air). They mainly grow in nodules on legumes (peas and beans).

Haber Bosch plants produce an equal amount to natural sources.

The excess nitrogen means the natural cycle of nitrogen is disrupted. Researchers estimate half of Haber Bosch nitrogen goes into the water and air.

4x level of nitrates in the Mississippi from 1900.

High nitrogen levels in water are linked to "blue baby syndrome."

Nitrogen fuels algae and weeds, cutting off water ways. This lowers sunlight at the seabed, killing plants there, meaning less oxygen is released which means less animals.

1.5 million tons of fixed nitrogen flow into the Baltic Sea every year. Some parts of the seabed are blanketed with bacteria that hate oxygen.

Great Barrier Reef is showing decline due to the use of nitrogen.

There is a dead zone off of Louisiana where life has become too suffocated. Plants bloom, animals die. 150 smaller dead zones around the world.

Nitrogen oxides are released from the Haber Bosch process. 15-50% of the total emissions, depending on how far you go.

Fixed nitrogen comes down from the sky. In some places, the amount equals what American farmers apply to their spring wheat.

Nitrogen oxides cause acid rain. Some less nitrogen in the air. Species distribution changes, favour those that like Nitrogen.

Epilogue

There was a depression in Chile after the kills lost to Haber Bosch. For decades the mills only visited by vandals, now two of the larger ones are world heritage sites.

Kaiser Wilhelm the second loved in Holland for two decades. Bought a Villa, chopped wood for exercise. In old age he sketched planes for grand buildings and impossible to build battleships. When the Nazis captured Paris, he sent Hitler a congratulatory telegram. Died in 1941.

The Smithsonian purchased Bosch's mineral collection. His son took much of his things to New York. One suitcase of gems disappeared between Germany and the US, remains unaccounted for.

Bosch left a final mystery with his minerals. A letter attached to each mineral in a code. When deciphered, it's just the cost for each mineral but hidden.

4 million insect collection went to the Smithsonian.

His private telescope is still used in the university of Tübingen. The books were put in storage in New York, then storage fees not paid and sold by someone piecemeal.

Haber's research into insecticides led indirectly in a poison gas called Zyklon B. Used in the camps. Farben held 40% of the stock in the company that made the gas.

"IG Farben was Hitler and Hitler was IG Farben." - American Senator said after the war. The synthetic rubber was vitally important late in the war.

In the final months of the war Farben was feverishly working on a Buna rubber plant next to Auschwitz. Thousands of Jews and prisoners worked to death.

23 Farben executives tried for war crimes at Nuremberg. Conspiracy and planning of war and enslavement and murder of populations. Carl Krauch, Herman Schmitz (took over Bosch's position) and 11 others given prison sentences from 1.5-8 years. 10 acquitted. Farben cartel was broken into its constituent parts.

A revived BASF appointed Elsa Bosch (widow) to a supervisory board. It's again the world's largest chemical company. Leuna was repaired and operated by the East Germans. Now Europe's largest chemical factory, chemical park housing 24 companies.

Haber's institute at Dölnum was renamed in his honour. Important institute today. Kaiser Wilhelm institutes renamed for Max Planck.

Herman Haber, Fritz and Clara's son committed suicide after the war.