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Instrumentation, expérimentation et expertise des matériaux énergétiques (poudres, explosifs et pyrotechnie), du XVIe siècle à nos jours
No Smoking Gun:
D. I. Mendeleev
and Pyrocolloiddion
Gunpowder

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In 1890 the long sought-after search for personal stability of D. I. Mendeleev - the famous Russian chemist best known for his 1869 formulation of the periodic system of chemical elements - appeared to be at an end. He had resigned from St. Petersburg University on 19 March 1890, read his last academic lecture three days later, and though he temporarily still resided in a University-subsidized apartment, he was free of the one career that had sustained him both personally and financially for almost thirty years. Instead of lapsing into desperation, Mendeleev turned to the bosom of the Naval Ministry to begin six years of official involvement that would take him all over Europe and the elaborate contours of the Imperial Russian bureaucracy.

Mendeleev's involvement with the Navy began before the dust from his previous career had time to settle. That spring, after Mendeleev's last lecture, Mining Officer Ivan Mikhailovich Chel'tsov, a specialist in explosives, approached Mendeleev's former student V. E. Tishchenko and asked him if he knew of any chemist who would be able to spearhead the Navy's quest for a new form of smokeless gunpowder, a chemist who could both command authority among working assistants and maneuver through the Imperial bureaucracy. Tishchenko pointed him towards Mendeleev, who accepted almost instantly. On 20 May, he had already contacted N. M. Chikhachev, the Naval Minister, and agreed to take the job with Chel'tsov and L. G. Fedotov (then head of a factory to produce a particular sort of smokeless gunpowder), and began preparation to head to Europe that June to begin their investigations.

Mendeleev got on the boat to leave on 7 (19) June, arriving seven days later in London. The trip was a resounding success. While in England he visited the Woolwich Arsenal with Chel'tsov on 4 July (N.S.), and went on a guided tour led by Frederick Abel, discoverer of cordite, the British version of smokeless gunpowder. Far from feeling restricted on their obviously military-finding mission, the Russians were given red-carpet treatment at sites generally considered restricted. On 27 June (9 July), Mendeleev wrote Chikhachev describing the tour, and explained that he had received a sample of the
British smokeless powder directly from the hands of its inventors at the Arsenal. These blizzardings were not distributed without a check, however. V. I. Anderson, director general of the British powder factories and a native Russian speaker, told Mendeleev that the samples of British powder would only be released on the condition that the Russians send back all extant forms of Russian smokeless powder and black powder americas. Mendeleev encouraged Chel'tsov to agree, and the eventual exchange led to an extremely relaxations of visitation restrictions for Russian officers at British ordnance sites. Support was so unanimous that even the noted chemist and gunpowder expert James Dewar wrote Mendeleev on 17 July (N.S.) that he would "support any action you may take about powder in Russia." On 9 July (N.S.), Mendeleev and crew left London for Paris, the world center of smokeless gunpowder research and legendary for its secrecy and resistance to distributing samples. First Berthelot, then Sarrau, directors of the Laboratoire central des poudres et salpêtres, pleaded secrecy to Mendeleev's requests for a sample, so Mendeleev went higher up the administrative food chain, in the end eventually given what the French called "a scientific sample for personal use" in the quantity of 2 grams. Mendeleev bragged in a letter: "It seems no one had yet been able to achieve this." This sample, combined with the personal tours Mendeleev and Chel'tsov received from the French, convinced him that the still-classified production process of the French powder could at least be reverse-engineered to at least its original form. Mendeleev left Paris on 17 July for Petersburg with samples gained by the very attribute he had cultivated over his entire career: open scientific exchange between European peers, as long as that exchange worked to Russia's advantage.

Thus began Mendeleev's involvement with the Naval Ministry's quest for smokeless gunpowder, an involvment that formed just one strand of what may be considered the great arms race of the second half of the nineteenth century. This paper traces the history of Mendeleev's search for smokeless gunpowder to his failure to support Mendeleev's engagement with the military would be a grievous oversight for anyone wishing to understand the politics of science and technology in late Imperial Russia, a politics heavily centered on notions of "homogeneity" of all sorts. As we shall see, proposals to underwrite the military, whether from Mendeleev or others, were highly charged attempts to formulate a new vision of a "modern Russia." One of the central issues explored here, and one often omitted in discussions of this period, is the remarkable variety of "modernizations" in Russia at this time. While one strand of modernization started Mendeleev on his search, another, fearful that he was going too far, blocked his path. The process of Mendeleev's development of his "pyrocolloid powder," and its eventual rejection by the Russian military, highlight not only aspects of Mendeleev as a skilled manipulator of both society and technology, but also provide an illuminating episode in the history of the category of technologi determinism.

Making Smoking History: Nitrocellulose Powders

Scientists had been enrolled (and willingly so) in state-bred gunpowder research for well over a century by the time Mendeleev became involved with the Russian Navy. Ever since the introduction of conventional gunpowder to the West in the fourteenth century, the simple mixture of saltpeter, sulfur, and charcoal dominated warfare until the end of the nineteenth century, when it was replaced universally with smokeless variants. While the original gunpowder from the fourteenth century, suitably modified by generations of craft
have already begun to see the disadvantages of nitroglycerin, which we have known about for a long time already." These disadvantages, Mendeleev claimed, ruled out for now "the possibility of a useful and safe general application of nitroglycerin." 65 And, after the Russo-Turkish War broke out, Mendeleev wrote the War Minister on 21 April 1877: "If for the needs of the war that has already begun my knowledge of various areas of the natural sciences with their applications to technology...do not refuse to demand them in practice." 66 On 27 April General Lesovski in fact asked Mendeleev what the effect of humidity would be on gunpowder on ships, and Mendeleev recommended sealing the casks with the adhesive gum. In June, the Navy actually built one ship in accordance with Mendeleev's suggestions. 67

There were three main explanations for Mendeleev's interest: one scientific, one historical, and one political. For the scientific justification, Mendeleev pointed out in an appendix to an encyclopedia article on explosive substances in 1892 that most physics situations occur at low temperatures and pressures, and studying explosions gives one the opportunity to explore nature at the high extremes. One could also, he postulated, even use explosions in the air to precipitate rain during droughts. 68 The historical justification concerned Mendeleev's desire to continue the substantial tradition of gunpowder research by Russian chemists such as N. N. Zinin and V. F. Petrushevskii, for example, invented a magnesium-based dynamite (later dubbed "Russian dynamite") and also pioneered the research of nitroglycerin before Nobel. 69

Mendeleev's political justification for gunpowder is perhaps the most interesting. In his encyclopedia supplement, Mendeleev noted that when gunpowder was introduced, warfare became more deadly and thus more and more people were required to wage war, while battles had become more dispersed as firing ranges increased. The net result of an even more powerful gunpowder would be to make warfare yet more deadly and thus deter war. "These observations lead only to the conclusion: the study of explosive substances and the perfection of the strength of firearms is one of the best and truest paths to the achievement of general peace." 70 Mendeleev was convinced that his work on gunpowder would have substantial real-world effects, and it would be like the "eternal" thesis in response to a galactic proponent of such claims that would make more turbulencia for his variant of smokeless powder. Given the appropriate set of circumstances, even flowery self-justifications can make or break a new technology. In the 1890s, the circumstances were just so.

SHOOTING DAGGERS: RUSSIAN REARMAMENT AFTER CRIMEA

When Mendeleev came upon the Russian military in 1890, he was dealing with a military entirely transformed, both technologically and sociologically. It was also a military quite uncertain about whether technological modernization boded well or ill for the stability of forces and, hence, of the Empire itself. Only when the traumas of military modernization are realized can the modern objects and forces of the past be understood. Mendeleev was savage in his attacks on the author's technical mistakes and for not addressing the native Russian literature on this topic: "It is highly to be hoped that professors speak more often on nitroglycerin. Ten years ago we were already preparing it for exploding mines, its properties were studied by our chemists, and not any later than anywhere else. At the present time in Europe they

1890 laboratory notebook, Mendeleev wrote: "Everything is from the French, but stupidly done," and: "[The Army] believe the French at their word, but they can swindle." 59 The various disasters of Army involvement with the French were a large part of why the Navy wanted Russian scientists to engineer a gunpowder which met their specific needs.

Those needs were highly particular and could not be met by just copying a foreign smokeless gunpowder. In the cannon that formed almost the entire battery of Navy artillery, for example, one could not just heap in more pyroxylon to propel bigger shells, since such "scaling up" would also scale up burning temperatures and risk permanent damage to the gun, as well as increase the chances of spontaneous detonation. The crucial feature of smokeless powder for naval battles was increased muzzle velocity. Given that essentially all war-bound Navy vessels in Europe in the 1890s were ironclads, one needed substantial propellant force to penetrate their hulls. In addition, as a Naval Ministry report to the Naval Technical Committee put it on 28 May 1899, "Gunpowder is absolutely necessary for rapid-fire shells, and thus the demands of the Navy cannot be satisfied by just the results of the trials carried out by the War Ministry." 59

As a result, the Navy initiated its own smokeless-gunpowder research program largely independent of that administered by the Army at Oktinski Arsenyov. 60 M. Chel'stov, the officer who had approached Mendeleev, had in fact been hired to work on pyroxylon for the Navy as far back as 1878, although he had been unable to convert it into a workable naval gunpowder. 61 By the spring of 1890, Chel'stov had worked out a plan to copy the French gunpowder production, and not the actual powder, as the Army had: He wanted to build a naval research laboratory into smokeless powders, and then, if possible to collaborate with the Army to work out a new Russian variant. 62 The problem with Chel'stov's proposals was Chel'stov himself: he lacked the necessary base knowledge of the art and thus no skills to get his programs off the drawing board. This is why he received authorization to invite Mendeleev to join the Navy program.

Mendeleev had a long-standing interest in explosives, and it was more than financial necessity and a lack of professional alternatives that led him to accept Chel'stov's proposal. In October 1857, Mendeleev started lecturing at the second cadet corps, where he met several Russian chemists involved in military affairs. 63 Mendeleev's first article on gunpowder topics appeared in that same year, a discussion of a form of pyroxylon created out of cotton paper, part of a series of popular-scientific pieces he abstracted from Western journals for the Journal of the Ministry of Public Enlightenment. Although this article was ostensibly about a form of smokeless gunpowder, Mendeleev was much more interested in discussing how the radical NO4 worked in the various pyroxylins and how that related to assorted versions of organic type theory. 64 Explosiveness was beside the point, let alone smokiness. 65

Later Mendeleev's interests in explosives intensified. On 10 January 1869, he responded to a request by the editors of the Journal Activity for his opinions on an article about glycerin they were considering publishing. Mendeleev was savage in his attacks on the author's technical mistakes and for not addressing the native Russian literature on this topic: "It is highly to be hoped that professors speak more often on nitroglycerin. Ten years ago we were already preparing it for exploding mines, its properties were studied by our chemists, and not any later than anywhere else. At the present time in Europe they
most radical of the Reforms - the 1861 Emancipation of the serfs - the series of concomitant military reforms may have been even more far-reaching in their fundamental rethinking of how this pillar of autocracy was to function. The most salient of these reforms was the universal military draft in 1874, the last of the canonical Great Reforms. Military transformation had begun long before this, and it was almost immediately upon the end of the Crimean War in 1856 that Tsar Alexander II began to instruct his advisors to reform the military radically. Newly appointed War Minister Dmitrii Miliutin decentralized military administration on 6 August 1864 into a nationwide network of 15 military districts, which, when coupled with reforms of military education and industry, was designed to create a new generation of military bureaucrats who would be able to administer a modern fighting force efficiently.}

Although there was a series of other reforms as well, the most important for this paper was technical, and is often dubbed the Russian "firearms revolution." It was assumed by many veterans of the fighting in Crimea that the .70-caliber smooth-bore, muzzle-loading musket that had been the staple of Russian small arms since the early eighteenth century had to be replaced. In 1857 it was officially replaced by a .40-caliber rifled muzzle-loader made in Germany and Belgium, and 260,106 of these vintokvi were issued by 1862. The 1866 Austro-Russian war demonstrated to European observers that not only were rifled bore necessary to increase accuracy, but breech-loading substantially increased firing rates over muzzle-loaders. Russian officials now had to decide whether to acquire new weapons or modify the vintokvi, they opted for both, with rather poor results. The problems of Russian modernization in the 1870s were due less to military caution than to overt problems with standardization, training, finances and supply endemic to Russia's large army. Nevertheless, when war broke out with Turkey in 1877, Russia's substantial military reforms were put to the test - and found wanting. Although Russia emerged victorious, losses were heavy, and victory more tenuous than it should have been against a second-rate power. The military reforms stayed in place, but the triumph in the war led many to construe them as failures. For the Army, as for many states of Russian society, the benefits of the Great Reforms were not contested.

The Navy was as much, if not more, transformed during the epoch of the Great Reforms. Grand Duke Konstantin Nikolaevich, Alexander II's brother, was appointed Minister of the Navy at the start of the Crimean War, and as the Navy began to embrace English assaults, he and his advisors fashioned a reform program for their branch which in many ways exceeded the transformations in the Army, both in terms of social policy and technical modernization. Just like the Army, however, the Navy had substantial difficulties remaking its heavy artillery, with perhaps the slowest performance of all the armed forces. This was not unrelated to the lack of an appropriate smokeless gunpowder. Since one needed a clean-burning powder in order to sustain rapid-fire shelling without risk of fouling, the absence of large-caliber nitrocellulose powders was a limiting factor in the entire naval modernization effort. Thus when Mendeleev first set down in his laboratory - initially still the St. Petersburg University laboratory - to perform nitration experiments, many layers of competing interests in the Russian military were prepared to attribute decisive significance to whatever his results might be.

A ROOM OF ONE'S OWN: THE SCIENTIFIC-TECHNICAL LABORATORY

Characteristic of Mendeleev's imperial vision, he coupled the technical project of developing a workable naval smokeless powder with a reform project for generating unity within the Russian Empire. In order to trace Mendeleev's vision for restructuring the Empire through its military, we need to start where he did: in the laboratory. Mendeleev's earlier researches on nitrocellulose substances were intimately connected with building in Russia a new way of conducting such research: the Scientific-Technical Laboratory.

The idea of a state-run laboratory for explosive substances was not new. Lavosov had directed one in ancien régime France, and France and England had revealed to Mendeleev and Cheil'skov the benefits of active research in nitrocellulose substances. Mendeleev was convinced that smokeless gunpowder in itself demand such research, and if Russia had survived before without a stable research environment for black powder, it could no longer do so. Crucial was not just scientific research, but scientific research properly organized, as he wrote in his personal gunpowder notebooks in 1890:

The currently established Chief Organizational and Executive committees which are carrying out the entire rearmament matter, and consequently also the matter of gunpowder production, along with the inspector of gunpowder factories, have no possibility of entering in a detailed fashion into all the conditions which can serve to lower the cost and improve the preservation of the qualities of a new gunpowder so new in industrial terms as pyroxylin, because this gunpowder comprises a new product in chemical terms, demanding most of the fundamental familiarity with chemical reactions and products, deeply differing from regular gunpowder. In view of these considerations I consider the establishment of a new organ entirely unavoidable, an organ which is free of all traces of direct authority, and designated for the chemical-technical supervision of the production of smokeless gunpowder and for the recognition of competent judgments of the purely chemical-technical properties relating to the new powders...

The standard argument to convince the military to reform was to point out that Western European powers were conducting such researches, and Mendeleev emphasized that almost all European states were gearing up for factory production of smokeless powders. In order to prepare for this, one needed to test various factory conditions in a laboratory. The subsidiary fail-safe argument, that laboratory research had been empirically proven to lower costs of production, was not far behind. As he reported to the Army on 27 November 1890, staffing the military with the right chemical experts would solve many gunpowder problems:

I cannot do everything by myself and, I admit, I am afraid to be morally responsible in a matter of such great importance, although I am prepared to put the remaining of my powers into the matter of Russian military might, because I consider such a matter a satisfactory conclusion of a life dedicated to science. Thus, I considered it my duty to bring into the open: 1. The necessity of inviting to the matter of smokeless gunpowder several Russian chemical scientists in order to grasp the current tasks in their breadth. 2. The necessity to form from them a special committee on explosive substances. 3. The necessity to equip this committee not with exclusive power, but with trust to its knowledge and the right of scientific control in all issues which relate to smokeless gunpowder. 4. The necessity to give to the committee all required for the new laboratory study of explosive substances and for the systematic scientific control of the study of questions related to this, in order to form the necessary kernel of autonomous experts of this branch of science...
Mendeleyev then offered a list of people who could head the Laboratory, including Chel’tsov. Approval for the establishment of the Naval Scientific-Technical Laboratory was forthcoming, and Mendeleyev - although officially only a consultant - immediately began to organize it and integrate the military hierarchy. Chel’tsov, the actual director of the imminently Naval laboratory, settled back and let his mentor do most of the thinking. An appropriate site was quickly found on the island of New Holland, located in the center of the Admiralty Canal in St. Petersburg (A Naval laboratory still stands on that island today.) It had already been begun to be equipped through Chel’tsov’s expenditures in France on manometers, thermometers, and other equipment for ballistic and chemical research. Mendeleyev, on the other hand, was more concerned with issues of personnel. He started with defining the tasks of the laboratory director (Chel’tsov). The director was to be the nerve center of all operations, and needed to oversee all activity; he should be an academic professor of some kind, Mendeleyev insisted, so he would know how to process scholarly information, and should possess "not only scientific training, but also a scientific name," so he could maintain contacts with Westerners.

Mendeleyev specifically envisioned a dialogue between the Navy and the Laboratory on the specifics of smokeless powder. It was one of the benefits of scientific investigation, Mendeleyev argued, that it could respond to real-world problems and contribute to revisions in naval practice. He insisted that "a living connection must exist between naval practice and the laboratory of explosive substances." Of course, understanding how sensitive military bureaucracies were to innovation meddling, he insisted that everyone involved be made "fully aware of the scientific and collegial advisory," and were meant to process information from the military, not to dictate tactics.

So much for Mendeleyev's laboratory in the abstract. The Scientific Technical Laboratory was actually meant to conduct research to find the holy grail of a naval smokeless powder, and indeed discover such a powder. But Mendeleyev did not. All engineering these things on, market turned out, had some flaws that made them unusable for naval artillery. Mendeleyev now considered pyroxylin an inadequate starting point. First, pyroxylin was inhomogeneous in composition, which led to irregular burning and thus irregular pressures, which often damaged the interior of the gun. Vielle’s pyroxylin was only good for temperatures of 50° to 110°C, but since naval guns frequently generated higher temperatures, this would lead to the disintegration of the gunpowder. Furthermore, pyroxylin had the unfortunate property of spontaneously detonating. Abel’s cordite and Nobel’s ballistite, both having nitroglycerin components, tended to burn too hot, causing internal barrel damage. Mendeleyev would have to start from scratch.

Mendeleyev’s approach was one that had led to fruitful results over his entire career: he would abandon empirical reasoning and start with theory, deriving the best possible result, and then try to actualize that ideal formula. Gunpowder was to be found in his tried-and-true fashion. The chemical properties that Mendeleyev needed were those of a substance that was entirely soluble (so it could form a good powder) and that evolved the greatest possible volume of gases for a given weight. Physical properties like temperature invariance, stability over time, and smooth burning, he would worry about later. Since the substance would be a combination of hydrogen, oxygen, nitrogen, and carbon, Mendeleyev deduced that the ideal formula should take the form of C₆H₅(NO₂)₃. Upon total burning, this would evolve the maximum amount of gas for the least weight, and Mendeleyev considered it the limiting case, the most perfect possible smokeless powder. 

C₆H₅(NO₂)₃, dubbed "pyroxylin," was burned into 30°C/194°C, and could be easily formed by a simple polymerization of five molecules of cellulose (C₆H₁₀O₅) with nitric acid. After Mendeleyev had deduced the theoretical structure of the compound, he then worked indefatigably from 9 am to 6 or 7 pm daily attempting to synthesize the substance. When Mendeleyev finally tried to dissolve it in 20°C alcohol and ether, he exclaimed with glee to his assistant, S. P. Vukolov: "Look, look, it dissolves like sugar!" When it turned out this substance did not detonate spontaneously, he had even more cause to celebrate.

Mendeleyev’s achievement in making pyroxylin - so called because it had explosive properties like photographic gels and the explosive properties of pyroxylin - was only part of the picture. As one can see from following his seven laboratory notebooks on pyroxylin, Mendeleyev first consulted with a wide variety of experts in the field of gunpowder production, then performed a systematic variational analysis of each type in terms of acid concentration, soaking time, drying temperature, etc., until he came up with a list of definitive properties. In this fashion, Mendeleyev clarified many theoretical problems that remained unresolved in the West until at least 1907. Now that he had a gunpowder that was chemically homogeneous, Mendeleyev could directly claim greater homogeneity than any other smokeless powder. Making "homogeneity" a compelling selling point was another matter.

THE WELL-ORDERED CHEMICAL STATE: HOMOGENEITY

Post-Emancipation Russia was a state under transformation, a culture striving for unity. Yet unity, perhaps paradoxically, is a very diverse concept. Throughout Mendeleyev’s career, as he wove his way through the social tapestry of St. Petersburg, he experimented at defining modes of unity - through classification, expertise, economics, labor - and then attempted to sell these "unities" to the broader Russian audience. Smokeless gunpowder was no different. In this case, the brand of unity seized upon was "homogeneity" (odnorodnost’ or odnoodnozriye). Throughout this section, I will use the same categories as Mendeleyev, who deployed the seemingly ill-fitting term "homogeneity" for a multitude of ends. Pyroxylin for Mendeleyev was a perfect weapon because it was homogeneous, its homogeneity made it also a reliable weapon because it was homogeneous, and its homogeneity made it the model for a new, stand-in, and a metaphor to the soldier and reform and unify the Russian military. Once the military was reformed, Russian society would be stabilized, because the Army and Navy served as bulwarks for the autocratic state which was more and more appallingly unraveling at the seams. In this section, I will trace the explicit metaphorical rhetoric of homogeneity Mendeleyev chose to sell pyroxylin to the Navy and then to the army, students, etc. Generally, his efforts failed, the reason why being a question for the next section. For now, we will start with the internal composition of the gunpowder and move slowly outward, observing how broader and broader swaths of concepts become embedded in the cultural logic of homogeneity.
Pyrocloidon, unlike pyroxylon or cordite, was a chemical compound, not a mixture, and thus had the initial advantage of being chemically homogeneous. Mendeleev was most explicit on the elementary form of homogeneity; at this point, his claim was as far removed from metaphor as he ever became:

"As to its chemical composition, pyrocloidon may be designated homogeneous, and herein consists one of its most important qualities. All previous and present forms of powder did not have and do not have this property to the degree here implied. From their very method of preparation, black and brown powders are coarse mechanical mixtures, for which any consideration of homogeneity is out of the question. The same is true for those smokeless powders containing ammonium nitrate, picrates, etc. Nitro-glycerin powders may be regarded as gelatinous solutions of nitro-cellulose in nitroglycerin, which, from their composition, are chemically, non-homogeneous, moreover, various solvents (alcohol, ether, acetone, etc.) dissolve certain constituents out of them, leaving others."

Chemical homogeneity was occasionally cited by Mendeleev as important for practical reasons, for example that one could test the purity of a particular batch of pyrocloidon simply by examining its weight and volume. Thus, the chemical homogeneity of pyrocloidon was so certain that it could be black-boxed and mere physical measuring processes could determine purity. This trope of homogeneity was not drawn out of thin air. Vice-Admiral Popov made a clear in a letter to the administration of the Russian Society for Production and Sale of Gunpowder on 29 January 1892, the issue of gunpowder's homogeneity (in terms of its stability) in storage was dominant concern for the Navy. Mendeleev picked up on a prevalent worry and ran with it.

If it was not a case of chemical homogeneity, one could overlook the rhetorical function of Mendeleev's assertions and believe that he was merely describing a chemical property. Yet this language was extrapolated further and further from a strict chemical sense. The second type of homogeneity for Mendeleev's pyrocloidon was called homogeneity in substance and homogeneity "by nutrition," and the latter was a consequence of its chemical homogeneity. This meant that it could be used in any caliber weapon; burning in a laminar fashion, the thickness of a pyrocloidon charge was all that needed to be adjusted to move from pistols to naval howitzers:

"The usual pyroxylon which serves for the preparation of smokeless powders and for mines is a histology of cellulose, whether "cotton or flax" or hemp. Since Mendeleev had an argument for radically simplified production; it was virtually impossible to run out of raw materials for pyrocloidon, and, anyway, the process was not finicky, and could even be performed by unskilled workers. It was at this point that Mendeleev began to expand homogeneity outside of gunpowder production, and directly to move to homogeneity of military procurement and production.

Smokeless gunpowder production in Russia had a short history by the time Mendeleev proposed pyrocloidon, but already it was one of increased growth. Pyroxylon began to be produced in St. Petersburg in 1888, and the production values for the first seven years are striking, achieving almost eight-fold growth, capping at 884 pud annually. By 1900, in reality, Russia had 1,324,079 pud, and in 1903, 1,500,000 pud, all of pyroxylon. The traditional place where the Navy had made pyrocloidon's powder would have been Okhtenskii, and the Army at several points seemed more than ready to oblige, arguing they could make 15,000 pud a year without difficulties. Mendeleev, however, disliked both the Army's production facilities and state-led production altogether. Instead, Mendeleev proposed..."
sed decentralizing production to private factories - chemical plants that already produced sulfuric and nitric acids - and then giving the contracts for the various components of the gunpowder. The particular plant he had in mind was the factory of P. K. Uskrov in Elagin. By 1893, Mendeleev's pressure had taken hold. The commission was eliminated from the military hierarchy to replace pyroxylin with his new, "more perfect" form of nitrocellulose. On 26 October 1895, however, Mendeleev received a dismayingly letter from new Naval Minister Pavel Tsyrov stating that, not touching on the principal question of the superiority of either pyroxylin or pyroxylin gunpowders until the end of their comparative testing, the Naval Ministry has rushed in the present year to the services of Oktenski gunpowder factory for the most speedy supply of ships that are heading abroad with smokeless pyroxylin gunpowder. Shortly afterward, Mendeleev retired, leaving Navy service for good on 1 December. But Mendeleev continued to advise. On 5 December 1901, he received a letter from the Navy asking him about the potential closing of the independent Navy smokeless powder factory. He responded on 8 December angrily:

This invention... is gradually proliferating... abroad... and the preservation of a small factory of the Navy for the preparation of an explosive substance is very useful for the defense of the state, and one could wish for the expansion of the activity of this factory... The expense demanded for the content of the small naval factory should be considered infinitesimal. And as this infinitesimal is connected with a continuous Russian progress in the matter of explosive substances, then I consider the closing of the Naval factory premature.

Although Mendeleev still lobbied for resumed comparative testing to War Minister M. I. Dragomirov, the Russo-Japanese War (1904-1905) forced all experimental quantities into battle and by 1909 the Navy's pyroxylin factory was shut down "for lack of economy."

What was the real reason why pyroxylin was rejected by both branches of the military, even after such a hard sell by its inventor? One possibility, suggested by Mendeleev's former student and employee at the Scientific-Technical Laboratory, S. P. Vukolet, suggests concerns about Mendeleev's civilian status:

The explanation is extremely simple. In the eyes of those who then moved the gunpowder affairs of the army artillery, D. I. [Mendeleev] had one large disadvantage: he was a civilian man, not a military one, not having a degree from a high artillery school. They could not stomach it when this man, alien to their environment spoke with all the heat of his fervent nature about the burning of gunpowder in the barrel of a weapon, or the reasons for abnormal pressure upon firing, leading to the explosion of the firearm, when he spoke of the inadequacies of their gunpowder (the gunpowder of the French), pointing to the homogeneity, the limit of pyroxylin powder.

What I would like to suggest in this conclusion is that there was in addition a cultural component of the story of Mendeleev's powder: Mendeleev deliberately targeted a particular faction within the military with his pronouncements - a faction of technology determinists whom Mendeleev perceived as rising in the military hierarchy - who were in fact losing power temporarily in the hiatus between Nicholas II's coronation (1894) and the onset of the Russo-Japanese War. Mendeleev's desire to hitch his wagon to their fortunes was part of the reason for his gunpowder's demise.

As Elting Morison has shown in his classic study of the prolonged delays in the adoption of continuous-aim firing by the U.S. Navy in exactly this period, militaries can be highly resistant to technological
innovations that might alter their stable and highly structured social

dynamics. We have seen similar reluctance in the "firearms revolution" in Russia, where the modernization of weaponry only came after a long period of resistance. This account stands in opposition to the philosophy of technology that has been labeled "technological determinism": the belief that technology develops autonomously from its

environment and has a direct impact on that environment once it is

created. Historians of technology have argued for some decades now

however, that it is rarely if ever possible to identify and isolate the

influence of technology on society.

Mendeleev left the Navy in a bit of a hurry, and the Scientific

Technical Laboratory went on without him. It still tested various

gunpowders that emerged, including an improved ballistic, but in

general continued to lean toward the doomed pyrocollodion.

Mendeleev stayed involved with the Navy, consulting on various

questions, such as the combustion hazards of boat fuel, and in general

keeping tabs on the progress of his creation. The laboratory.

But the story of pyrocollodion powder does not end in total obscurity. As it

turns out, in an ironic twist, by 1900 pyrocollodion was adopted as the

naval smokeless powder of the U.S. Navy. Russia's naval agent in the

United States, General Major D. P. Mervy, wrote to the General

Naval Staff on 13 September 1899 that America seemed to have solved

the problem of a naval powder.

The working out of the recipe of this gunpowder was carried out on the basis of the printed researches into the question by Professor Mendeleev. It turned out that there was in the American Navy a Lieutenant Barnado who knew Russian and at the same time gave himself up to chemical researches. This dual quality of Barnado was used and the navy worked out for itself a satisfactory smokeless gunpowder.

Mendeleev was aware of Barnado's research, and did not discourage it; in fact, on 14 November 1900 the American consul in St. Petersburg, W. R. Holloway, told Mendeleev that S. L. Meyers from Chicago was interested in studying Russian smokeless powder and wanted samples sent to him. Mendeleev directed him to published articles. Through publication, Mendeleev's gunpowder had finally trickled from East to West.

*ABBREVIATIONS:


RGAVMF : Rossiskii Gosudarstvennyi Arkhiv Voenno-Morskogo Flota (Russian State Archive of the Navy).

RGIA : Rossiskii Gosudarstvennyi Istoricheskii Arkhiv (Russian State Historical Archive).

TIIEI : Trudy Instituta Estestvoznaniia i Tekhniki.

VIET : Voprosy Istorii Estestvoznaniia i Tekhniki.

All dates are given in the old style Julian calendar, which lags 12 days behind the new-style Gregorian calendar in the nineteenth century, 13 days in the twentieth, unless otherwise indicated by (N.S.). Transliterations follow a modification of the standard Library of Congress format. All unattributed translations are mine.
REFERENCES

[1] V. E. Tishchenko and M. N. Mladentsev, Dmitriy Ivanovich Mendeleev, ego „bista i deteli' nost’,” Universitetskii period, 1861-1890 gg. (Moscow: Nauka, 1995). 127. The official hire only went through on 3 September 1891, when he was brought on as Chel’tsov’s consultant (RGAVMf. f. 410, op. 3, d. 268, l. 1).


[4] Mendeleev to Chel’tsova, 19 July 1890, RGAVMf. f. 421, op. 2, d. 678, l. 130-131. Mendeleev to Chel’tsova, 12 November 1890, RGAVMf. f. 421, op. 2, d. 678, l. 242-244; and V. Anderson to Mendeleev, 19 November 1890 (N.S.) RGAVMf. f. 421, op. 2, d. 678, l. 243-244. On Russian access to factories, see the letter of the Russian Naval Agent in London, Nikolai Zelenyi, to N. I. Ivanov, 28 February (12 March) 1891, RGAVMf. f. 421, op. 2, d. 722, l. 71. 73.

[6] Quoted in Mendeleev to Chel’tsova, 19 July 1890, MS, IX, 12.


[8] Mendeleev to Chel’tsova, 19 July 1890, MS, IX, 11-12. As an indication of how serious the Russians were about the engineering, Chel’tsov was given carte blanche to spend 8,700 francs buying French gunpowder production equipment for the Naval laboratory. See his expenses report, 23 October 1890, RGAVMf. f. 427, op. 2, d. 197, l. 86-89.

[9] As is clear from these accounts, Mendeleev received his pyroxylon samples entirely opaque, and without the least recourse to the ensuing, that romanticizing Soviet historians have frequently attributed them. This story sometimes takes the form of Mendeleev watching the trains arriving at the French gunpowder factory, calculating the composition of the powder from the sizes of the shipments.


[12] On the early history of smokeless powder development, see Bernadou, Smokeless Powder, 1-2; Dmitriev, “Oochen’ mityaia Mendeleev,” 135; Eissler, A Handbook of Modern Explosives, v-vi. For a general overview of this history, see John Bernadou, “The Development of Smokeless Powders,” 2nd ed. delivered at the U.S. Naval War College on 20 July 1987, Bernadou, Smokeless Powder, Appendix 4. One of the main difficulties was the lack of a tractable theory of the cellulose molecule, which hindered prediction of the properties of various mixtures of gnn-cotton. See Bernadou, Smokeless Powder, Chapter 4.


[14] On the early history of smokeless powder development, see Bernadou, Smokeless Powder, 1-2; Dmitriev, “Oochen’ mityaia Mendeleev,” 135; Eissler, A Handbook of Modern Explosives, v-vi. For a general overview of this history, see John Bernadou, “The Development of Smokeless Powders,” 2nd ed. delivered at the U.S. Naval War College on 20 July 1987, Bernadou, Smokeless Powder, Appendix 4. One of the main difficulties was the lack of a tractable theory of the cellulose molecule, which hindered prediction of the properties of various mixtures of gun-cotton. See Bernadou, Smokeless Powder, Chapter 4.


[17] Attempts had been made to arm with smokeless powder even before these three types had emerged, although with dubious success. Leading the way was Austria-Hungary, which introduced gun-cotton in around 1874 and then speedily abandoned it. The form they
were using was a compactly wound thread for field guns, but it proved disastrous in the field and the Austrian factory in Hirtensebloom blew up for undetermined reasons. Experiments had begun at Woolwich Arsenal in England even earlier (1867-1868) with compressed gun-cotton, but field usage led to so many problems that 'much evidently remained to be accomplished before the requisite uniformity of action could have been secured.' Eiseler, A Handbook under Modern Explosives, 75. On Hirtensebloom, see Munroe, 'The Development of Smokeless Powder,' 827.

[18] Quotation from Menning, Byaments before Bullets, 104. See also Vernidub, 'One Hundred Years of Russian Smokeless (Nitrocellulose) Powder Industry,' 397; Dmitriev, 'Osnovnaia mis'ia Mendeleeva,' 151; and Averubukh, 'Opposushchii mineralogu liko pirolonnaia,' Zhurnal mineralogii i petrofiziki, no. 1 (1992), 105-115.


[20] RGAVMf, f. 421, op. 2, d. 678, l. 89. See also Vice-Admiral Pilkin and Mayor Dmitriev under the General Administration of Shipbuilding and Equipment, 28 December 1896, RGAVMf, f. 421, op. 2, d. 722, II, 8-18; and Chikhachev to War Minister P. S. Vannovskii, 19 February 1892, RGAVMf, f. 421, op. 2, d. 768, l. 29. See also for approval, RGAVMf, f. 421, op. 2, d. 768, l. 19, and a report by Kuzdzheva, 'Novye dannye ob issledovaniakh D. I. Mendeleeva v oblasti pirolonnda,' 235.


[22] MS, XXV, 444 (extremes) and 446 (meteoroilgy). The suggestion about cloud seeding by explosions is especially interesting, as Mendeleev later explicitly rejected this proposal when consulted by the Ministry of Finance as to its feasibility.
military justice than soldiers due to their traveling, a substantial reform of the judicial and administrative structure was undertaken, removing arbitrary sentencing (1867) and abolishing corporal punishment (1865), as well as substantially unifying naval administration. Aude J. Violette, “The Grand Duke Konstantin Nikolayevich and the Reform of Naval Administration, 1855-1870,” Slavonic and East European Review 52 (1974): 584-601; and idem, “Judicial Reforms in the Russian Navy during the ‘Era of Great Reforms’,” The Reform Act of 1867 and the Abolition of Corporal Punishment,” Slavonic and East European Review 56 (1978): 586-603. See, for example, Mendeleev’s statement: “Black smoky gunpowder was found by Chinese and monks almost accidentally, gropingly, by mechanical fiddling in scientific darkness. Smokeless gunpowder was discovered under the full light of contemporary chemical knowledge. It comprises a new epoch of military affairs not because it does not give off exterior smoke, but primarily because provides the possibility, under less weight, to convey a bullet and other projectiles to a typical speed of 600, 800, even 1000 m per second; and at the same time presents all the advantages of further perfection with the help of scientific research of invisible phenomena completely under its combustion. Smokeless gunpowder comprises a new base, between the power of nations on their scientific development.” MS, IX, 48.


[37] MS, IX, 24, 27, and 38.

[38] MS, IX, 54n. On inhomogeneity in link to laboratory research, see, JR, IX, 45n. MS, IX, 42.

[39] ADIM 11-28:51-1, quoted in Avruba, “D. I. Mendeleev, Nauchno-tekhnikhicheskii laboratoriia Morskogo vedomstva,” 231-232. The potential members of this committee, which Mendeleev listed as: Lenin Nikolayevich Shishkov, former professor of the artillery academy; Aleksei Romanovich Shchukin, chemist at the engineering academy; Chekhov, Nikolay Nikolayevich Sokolov; and Grigori Aleksandrovich Zuboduk.

[40] Mendeleev’s first letter to Chekhov on 2 May 1890 in rejections of the need for a laboratory, (ADIM Alburn 2/474). The “consultant” position was meant for someone who was “especially well-known for his work in the field of the physico-chemical sciences,” and was essentially an tailor-made for Mendeleev after he had already been selected. MS, IX, 421, op. 2, d. 722 II, 8-18. As a consultant, Mendeleev was also free to quit at will.

[41] Report of Chief Engineer-Builders of St. Petersburg Port, 12 June 1890, RGAVMF, f. 421, op. 2, d. 679, l. 106-110. For the specifications of laboratory, see Vice-Admiral Kazakov, Znamentnyi prikladnoi laboratoriia Morskogo Ministerstva dla Issledovaniy po Vozvrascheniyu Botanicheskoy vostochnoy ekspeditsii,” 276; MS IX, 257, 266.

notebooks. In Appendix 2 of Bernadou, Smokless Powder, 123-125, Mendeleev extensively worked through the various theoretical considerations that would discriminate the various smokeless powders.


[31] MS, IX, 185n3.

[32] RGAVMf, f. 427, op. 2, d. 305, l. 27.

[33] To be fair, he was aware that he could not claim absolute homogeneity for his powder, and in a footnote he hazarded a qualification: "About complete chemical homogeneity in the purely scientific sense one is not speaking here, and one should not be, as even in cellulose itself there is no certainty. One speaks of relative or technical homogeneity, compared with other types of smokeless (and, of course, smoky) gunpowder." MS, IX, 254n1.

[34] Mendeleev to Chikhachev, June 1895, MS, IX, 183. Emphasis in original. See also Mendeleev to Chikhachev, 5 May 1893, RGAVMf, f. 421, op. 2, d. 821, II. 134-139.

[35] Mendeleev to Chikhachev, 5 May 1893, RGAVMf, f. 421, op. 2, d. 821, II. 134ob.-135; Mendeleev to Chikhachev, June 1892, RGAVMf, f. 421, op. 2, d. 768, MS, I, 178. See also MS, IX, 171.

[36] RGAVMf, f. 421, op. 2, d. 1233, l. 51. See also the letter to the Chief Inspector of Naval Artillery, 8 May 1895, RGAVMf, f. 421, op. 31 (art. chat.), d. 41, 1895, l. 3, reproduced in Luk'yanov, O neizvestnykh pis'makh D. I. Mendeleeva, arkhivykh dokumentakh, kazaishskihshka ego rabe po pirotolodnomu porokhu, p. 265.

[37] "Zvornik morskogo tekhnicheskogo komiteta po artillerii", 21 June 1895, RGAVMf, f. 427, op. 2, d. 879, II. 54-86; quotation and Filkin's hand-written referral both on 84.

[38] Mendeleev to Chikhachev, 5 February 1894, RGAVMf, f. 421, op. 2, d. 821, II. 134-139, on 137, MS, IX, 53.

[39] See RGAVMf, f. 427, op. 2, d. 288. The entire discussion concerns gunpowder purchasing affairs in 1890-1891, before Mendeleev had set up his laboratory.


[41] MS, IX, 147.

[42] Note by A. Brink on the margin of Chel'tsov's letter to the Chief Inspector of Naval Artillery, 5 April 1893, RGAVMf, f. 421, op. 2, d. 821, l. 52. "These questions [of storage] are very important and I consider it helpful to discuss them together with the Army..." See also Mendeleev to Chikhachev, 5 May 1893, RGAVMf, f. 421, op. 2, d. 821, l. 135; and MS, IX, 159 on unifying both forces in a joint laboratory.

[43] MS, IX, 58.

[44] MS, IX, 81. "Such a plan of action [for gunpowder] will find itself in harmonious agreement with the views of the government on the establishment of all types of national industry, which is expressed in the highest injunctions, relating both to the review of the customs tariff and, especially, to its temporary increase to set up on 16 August 1895." RGAVMf, f. 427, op. 2, d. 527, l. 409.

[45] According to Mendeleev's own account, he had already expected friction from military decision-makers, and thus constantly carried a copy of a resignation letter in his pocket to be produced in time of need. Yukolov, "D. I. Mendeleev i bezdnyatyi porokh," 1557.


[48] Yukolov, "D. I. Mendeleev i bezdnyatyi porokh," 1557. It is not exactly true that Mendeleev was totally foreign to the military establishment, however. He was unstrengthen to Vukolov, Mendeleev had taught courses at the Nikolaevski military academy and at the Cadet corps. See L. G. Beskovnov, "Russkaiia armia i fiat v XIX veke: Voyenno-ekonomicheskii potencial Rossii" (Moscow: Nauka, 1986), 192.


[50] For an example, see MS, XXV, 444. Mendeleev's employee at the Laboratory, P. F. Rybsov, also echoed a similar sentiment in 1907, showing the persistence of such rhetoric: Rybsov, "Otechestvenniia voinen no-istoricheskiia mysli v poslednei chetverti XIX veka," Voyenno-istoricheskaia Zhurnal (1959), 60-72.

[51] N. P. Mikhnevich, "Taktika i ee evolutsiia v zavisimosti ot usloviia komplektovaniia voisk i tekhnicheskikh izobretenii dannoi epokhi," in L. G. Beskovnov, ed., Russkaiia voennoe-teoreticheskaiia mysli XIX i nachala XX veke (Moscow: Voennoe izd. Min. Oborony SSSR, 1969), 441-451, on 444. See also the excerpt of Mikhnevich's most important discussion of gunpowder "Vilanie noxveishkikh tekhnicheskikh iz obretniia na taklizku voisk," in RGAVMf, f. 427, op. 2, d. 527, l. 415-440. A substantial portion of this document discusses the exact changes smokeless powder would bring about on the battlefield. By the end of the nineteenth century, the Nikolaevski academy had switched to Mikhnevich's textbook on strategy. N. P. Mikhnevich, Istoria voyennogo iskusstva s doreznetskoi vremena do nachala devjatidesiatogo