THE KAZAN SCHOOL OF CHEMISTRY: A RE-INTERPRETATION (1)

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Introduction

One of the most remarkable aspects of chemistry in nineteenth-century Russia was the emergence of a succession of chemists who worked at the isolated and remote Kazan University and produced path-breaking research over the course of most of that century. As early as the 1860s, contemporary Russian chemists began to term their colleagues there as belonging to the "Kazan School." This concept of the Kazan School of Chemistry has become well-entrenched in the historiography of Russian chemistry up to the present day and is normally cited without further reflection or consideration. However, in this paper I would like to take a closer look at the idea of a series of chemists in Kazan forming an unbroken school of chemistry in the nineteenth century. In particular, I would like to examine what most scholars see as the early years of this school, from the 1830s through the 1860s. I aim to argue that instead of a succession of chemists forming a Kazan School of chemistry, we should more properly see chemistry in Kazan as forming several successive schools, beginning with A. M. Butlerov in the late 1850s.

What we usually take as the canonical description of the Kazan School of Chemistry was laid down by one of its members—A. E. Arbuzov—in a 1940 popular science article that was reprinted and revised many times in the ensuing decades (2). Arbuzov had a long-standing interest in the history of chemistry that spanned his entire career. He saw the Kazan School of Chemistry as an apostolic succession of chemists who taught at Kazan beginning with N. N. Zinin in the 1830s and continuing up through the time of Arbuzov himself, from Imperial times extending well into the Soviet era. Zinin—and Karl Klaus who arrived at Kazan around the time of Zinin—taught A. M. Butlerov. Butlerov took over the teaching of chemistry after, first, Zinin left Kazan to go to St. Petersburg in 1848, and then completely after Klaus as well departed Kazan for Dorpat in 1852. Butlerov trained many prominent chemists, including A. N. Popov, M. D. L'vov, V. V. Markovnikov and A. M. Zaitsev, the last two of whom succeeded Butlerov at Kazan after their mentor moved to St. Petersburg in 1868. Markovnikov—as was his wont—soon had a falling out with the administration and some other faculty members at Kazan University and moved to Novorossiisk University in Odessa in 1871, but quickly received a call to Moscow University where he established his own flourishing school of chemistry, beginning in 1873. Zaitsev, however, remained at Kazan until his death in 1910, teaching E. E. Vagner, S. N. Reformatskii, A. N. Reformatskii, A. A. Al'bitskii, and A. E. Arbuzov, among many others. A number of these chemists taught for a short time at Kazan but most soon moved on to other higher educational institutions in Russia. When Zaitsev died, he was succeeded in the chair of chemistry by Arbuzov in 1911, who taught at Kazan until his death in 1968. Arbuzov had many students of his own, who became chemistry professors during the Soviet era, including his two sons and one daughter. Arbuzov's eldest son, B. A. Arbuzov, became a chemistry professor at Kazan, as well as a member of the Academy of

Sciences of the USSR, the highest honor for a scientist in the Soviet Union.

This is a convenient and appealing story. Many historians of chemistry have written about it. I have written about it—and our distinguished award winner David Lewis has as well, which is why I selected this topic for my paper.

This is a convenient and appealing story. But it is wrong.

Let me briefly explain briefly. My argument is that we should not see an unbroken apostolic succession of chemists constituting a Kazan School of Chemistry. Only using the loosest definition for a School of Chemistry can we see a Kazan School of Chemistry running from Zinin through to B. A. Arbuzov. Instead, I will argue that what we have in Kazan is the **Butlerov** School of Chemistry beginning in the late 1850s, perhaps followed by the Zaitsev School or later by the Arbuzov School. Zinin and Klaus did not found a School of Chemistry. That only happened later with Butlerov, and then, not until after Butlerov's first trip abroad at the end of the 1850s.

One more thing before I get into the meat of the discussion. I will focus in this paper on the biographies of the chemists involved. I believe that it is through presenting specific biographical details that we can discern the contours of what defines these research schools (3). Most treatments of the Kazan School of Chemistry that I am aware of have been relatively general in scope, so they miss the finer, granular details that can reveal patterns about the research school. It is like we are viewing a part of the Milky Way Galaxy with a telescope. At first you can see a blurry continuous image, but if you increase the power of the telescope you are then able to see more individual stars and notice the gaps between them.

That is what I want to do in this paper. I want to give a fine-grained analysis that will show **why** we need to re-evaluate our ideas about the Kazan School of Chemistry. Viewed in a wider perspective, the traditional view of the Kazan School of Chemistry seems reasonable. But when we look closer—in a more fine-grained analysis—the gaps reveal problems with the traditional view.

However, I would first like to briefly summarize some of my guiding ideas for considering the idea of a scientific research school. While scientists often used the term "school" in the nineteenth century and after, historians of science have generally settled on the term "research school" to describe "small groups of mature scientists pursuing a reasonably coherent programme of research side-by-side with advanced students in the same institutional context and engaging in direct, continuous social and intellectual interactions" (4). J. B. Morrell published one of the most influential discussions of the concept of a research school in 1972 (5). In this work, Morrell contrasted the research schools of J. Liebig and Thomas Thompson, which allowed him to point out some of the most important factors contributing to the success (or lack of success) of a research school. While these factors should not be taken as a rigid model, they are useful as a point of departure for examining research schools as a unit of analysis (6). Morrell emphasized that the director played the key role in the success of the research school. The director offered a program of work for his students to follow and conduct, as well as a body of techniques that students could learn without undue difficulty. A successful director needed to be sufficiently charismatic to attract a sufficient number of students on a continual basis for the school to flourish. In addition, the director should have an outlet for publishing his work and that of his students, if the research school was to garner more than a local recognition. Furthermore, a successful director should have sufficient institutional power and support to maintain the school on an ongoing basis.

In the years since Morrell analysis appeared, there have been many studies of research schools that have refined and contested the factors he presented (7). For the purposes of this paper, however, I will use Morrell's factors as a general lens through which to analyze the Kazan School of Chemistry.

Chemistry at Kazan

Kazan University was founded in 1804 as one of the building blocks of the new Russian university system being developed during the early years of the nineteenth century. Located about 500 miles east of Moscow along the Volga River, the university in Kazan was designed to provide education for those from Siberia and the eastern regions of the Russian Empire. The first chemistry professors engaged to teach at Kazan University were foreigners who had difficulty speaking in Russian, as was the case for many university professors at other Russian universities at this time (8). However, the relative isolation of Kazan from the more populated centers in Russia made it difficult for the university administrators there to engage qualified professors, especially those who could speak Russian. Eventually, Russian education officials turned to solve this problem by grooming their own promising students as future faculty members or hiring

the few Russian-speaking graduates from other Russian higher educational institutions. Thus, the Curator of the Kazan Educational District in 1811 requested to hire I. I. Dunaev, a recent graduate of the Main Pedagogical Institute in St. Petersburg. Dunaev was one of the first generation of native Russian professors at the universities during the nineteenth century (9). However, Dunaev was undistinguished as a teacher or scholar and conducted no laboratory research or even laboratory instruction for his students.

During Dunaev's time at Kazan University, the institution was rocked by considerable controversies, especially those connected with the Curatorship of M. Magnitskii, an extreme reactionary who severely weakened the university by persecuting various professors, succeeding in purging some of them (10). Magnitskii also disrupted teaching at the university by hiring multiple instructors for some subjects, like chemistry, who had no training in the field or who could not even speak Russian. In 1826, Magnitskii was replaced by Count M. N. Musin-Pushkin, a wealthy and high-ranking military officer from a prominent noble family near Kazan. Musin-Pushkin would begin to bring order to the university and improve its academic quality. Chemistry would benefit from Curator Musin-Pushkin's efforts, with the construction and extensive equipping of a new laboratory and the solidification of instruction by engaging N. N. Zinin (1812-1880) and K. K. Klaus (1796-1864) as professors.

Zinin was born in 1812 into a lower-ranking military officer family. He was orphaned at an early age and was raised by a relative not too far from Kazan. He was able to obtain a solid education and was intending on studying at a state institute in St. Petersburg after graduation, but then his relative died, forcing him to attend Kazan University instead, beginning in 1830. Zinin studied in the physics-mathematics faculty, likely influenced by another relative who was an astronomy professor at the time. At Russian universities at this time, students did not "major" in a specific field but rather took a wide range of courses offered in their faculty. The main way to show a specialization was by working on a thesis in the third and fourth years as a student. Zinin wrote a *kandidat* thesis about the motion of the planets, showing that he was mainly interested in mathematics and physics. Writing a *kandidat* thesis gave Zinin the qualifications to continue on for further education at a university and after graduation in 1833 Zinin began to teach courses in physics and mathematics at Kazan while studying for a master's degree. Obviously, Zinin was being groomed to become a professor of physics or mathematics. But then, as it were, fate intervened.

These years in the 1830s were an era of transition at Russian universities, and particularly at Kazan University, as Russian education officials, especially the Curator Musin-Pushkin, were trying to upgrade the quality of the teaching staff as well as to replace with Russians as many as possible of the foreign professors currently teaching at Russian higher educational institutions. The position of Curator was an immensely powerful one, having direct control over all of the educational institutions sponsored by the Ministry of Education in one of the six educational districts of the empire, each of which had a university at its apex (11). Magnitskii had attempted to curry favor with Tsar Alexander I and his entourage following their turn towards mysticism and nationalism after the victory over Napoleon, coming very close to actually shutting down Kazan University. The chemistry professor at Kazan during these years was the undistinguished Russian Dunaev, who had been educated in Russia but had also studied at a European university for a year. He had fallen into disfavor with Magnitskii but was able to regain his standing by giving several public lectures, including one entitled "The use and misuse of the natural sciences and the need for them to be based on Christian piety." Magnitskii eventually was replaced as Curator in 1826 by Musin-Pushkin. While Musin-Pushkin is usually described as an ignorant, crude, and overbearing official, he seems in actuality to have been quite sincere and dedicated to improving conditions at Kazan University. One of Musin-Pushkin's tasks was to upgrade the teaching staff and when in he made a list of professors to be replaced in conjunction with the new University Statutes in 1835, Dunaev's name headed the list. But who could replace Dunaev? There was only a very tiny pool of possible candidates in Russia at this time and the earlier typical solution of hiring someone from a foreign country was frowned upon now. So Russian higher educational institutions looked inward and began grooming their own students to become professors. This could prove to be difficult as it often was tricky to precisely predict when a chair (*kafedra*) would become available for the Russian student. And this type of complication happened for Zinin. Curator Musin-Pushkin evidently began to see Zinin as the replacement for Dunaev (12). In 1835, Zinin was transferred to teaching in support of Dunaev and given a topic in chemistry for his master's thesis, which he received in 1836. The next year, he was given a fellowship to study abroad. The plan outlined for this trip was to attend lectures at various universities in Berlin and other places in Germany, as well as with Berzelius in

Sweden. No research or laboratory work was envisioned, and at this time at Russian universities no experimental research was necessary to receive a doctorate. However, once Zinin was abroad, he evidently heard about Liebig at Giessen and went there to attend lectures and eventually gained a spot in Liebig's laboratory where he conducted some original research on a topic of interest to Liebig. Thus, everything seemed to be proceeding according to plan, even if it wasn't the exact one outlined for Zinin before his departure. But then a big snag happened.

Karl Klaus, a Baltic German pharmacist educated in Russia, moved to Kazan to open a pharmacist's shop (13). He became popular with the local citizens of the town and evidently decided in about 1838 that he wanted to become a chemistry professor at Kazan. This was not an outrageous plan, although it was not a common one at Russian universities, as pharmacists usually became laboratory assistants there, not professors. Indeed, Kazan University had another Baltic German serving as laboratory assistant at this time. Therefore, it was a logical decision to have Klaus become the chemistry professor and it would be a good fit. But what to do about Zinin, who was currently abroad, and intending on returning to become the chemistry professor? Curator Musin-Pushkin decided that since the chair of technology also was vacant, Zinin could take an extra year of study abroad to expand his knowledge of technology and then return to Kazan as the professor of technology. It seems that Zinin was not thrilled with this change in plans, but he accepted it in part because it provided him with an extra year of state support for study abroad. With Zinin's acceptance of this change in direction, things seemed to be working out with the plans for chemistry and technology at Kazan. Curator Musin-Pushkin assisted Klaus to obtain a doctorate in chemistry which would give him the formal qualifications to be named as professor of chemistry, while Zinin returned from abroad, wrote his doctoral thesis in St. Petersburg and then returned to Kazan as professor of technology. While in St. Petersburg, Zinin did attempt to gain the appointment as professor of chemistry at Kharkov University, but Curator Musin-Pushkin intervened to squelch that idea.

Zinin remained at Kazan University from 1841 until 1848, when he was appointed professor at the St. Petersburg Medical-Surgical Institute (14). Since the Institute was under the auspices of the Minister of War, the Curator of the Kazan Educational District could not block the appointment as the university was controlled by a different Ministry, the Ministry of Education. While in Kazan, Zinin continued the research he had initiated as a student at Giessen under Liebig, although it proved difficult to obtain the compounds he wanted to work with in Russia. It was during this time that Zinin discovered his method for the reduction of nitrobenzene to produce aniline. This was the work that gained Zinin great renown some years later, with A. W. Hoffmann stating that this work will be written in golden letters in history (15).

Klaus also did famous research work during these years on the platinum-group metals. He discovered and isolated the new element ruthenium, announced in a publication in 1843, and continued work on other platinum-group metals until he left Kazan in 1852 to move back to his native Dorpat, in Estonia, then part of the Russian Empire, but which was culturally German at that time.

Both Zinin and Klaus worked in home laboratories, not in the university laboratory. This is an important point because it limited the amount of time and attention either of them could give to any students working in the university chemistry laboratory. Thus, when A. M. Butlerov was an undergraduate student at Kazan from 1844 until his graduation in 1849, he most likely would have had only scant opportunities to do original laboratory work with Zinin or Klaus (16). Instead, while Butlerov took the usual chemistry courses for students in the physics-mathematics faculty, he seemed to be more interested in botany and other natural sciences rather than chemistry. In fact, Butlerov wrote his *kandidat* thesis in 1849 on "The diurnal butterflies of Volga-Ural fauna." Similar to the situation with Zinin, it appears that Butlerov was interested in becoming a university science professor, but not in chemistry. However, soon after Butlerov graduated with his *kandidat* degree in 1849, Klaus's health declined significantly and he needed help teaching chemistry. Butlerov turned out to be the only possible choice readily available. So soon Butlerov was unofficially assisting Klaus in his chemistry classes and by 1851 was appointed adjunct in chemistry, having received his master's degree in chemistry the year before. It was clear that Butlerov was viewed as Klaus's successor as chemistry professor once he had obtained the necessary doctoral degree. Butlerov did do some experimental work on osmium compounds under Klaus's direction, which formed part of his master's thesis, but these experiments were quite minimal in scope and Butlerov did not continue them after he was awarded his degree.

I am arguing here that Butlerov was not influenced in his subsequent research by either Zinin or Klaus. Historians often use a quote written by Butlerov from an 1880 obituary of Zinin (17) to indicate Zinin's influence

on Butlerov. But I believe this quote does not prove what these historians seem to imply.

> I attracted [Zinin's] attention and soon he acquainted me with the course of his work and with the various subjects of the benzoyl and naphthalene series, with which he was then working. Little by little I began to work primarily under his direction, who did not limit himself to his personal investigations, but also was interested in repeating experiments of others. Assigning these in part to his students, he would undertake the major part himself. Thus, together with him we completed a whole series of many well-known experiments…

Yes, this quote shows that Zinin introduced the young Butlerov to chemistry experimentation, but the influence on Butlerov was limited. There is nothing subsequent in Butlerov's career to show that he ever conducted organic chemistry research along the lines of Zinin's work, even in the years immediately after Zinin's departure from Kazan.

There is another example from Butlerov's life which we might say helps prove the rule. In 1854, Butlerov was attempting to defend his doctoral thesis, a literature review of some essential oils. However, Butlerov's thesis was rejected at Kazan University, likely mainly due to personal jealousy from a faculty member who was one of the official evaluators of the thesis but possibly partly due to its lack of scientific rigor (18). Butlerov asked Klaus, who was now a professor of pharmacy at Dorpat University, for help. Klaus believed that it would be very difficult for Butlerov to defend the thesis at Dorpat (because the thesis and the defense would need to be conducted in German and Klaus was in the medical faculty not the physics-mathematics faculty where the defense would be conducted), but suggested Butlerov try Moscow or St. Petersburg. Also, Klaus recommended a few experiments for Butlerov to add to the thesis. We have many letters sent by Klaus to Butlerov which indicate how much Butlerov relied on Klaus's advice (19). But the information in these letters, plus Butlerov's actions in the 1850s, indicate that Klaus's research had no impact on Butlerov's research career. Klaus had personal influence on Butlerov, but no influence on Butlerov's scientific choices. Indeed, it did not appear at that time that Butlerov had any intention of pursuing experimental chemistry research.

Furthermore, Soviet and Russian historians of chemistry often point to a visit Butlerov had with Zinin in 1854 when Butlerov was in St. Petersburg contemplating where to defend his doctoral thesis (20). Again, in Butlerov's obituary of Zinin, Butlerov mentions this visit and commented that Zinin recommended that he become acquainted with the work of Laurent and Gerhardt (17). Soviet and Russian historians of chemistry use this incident to help forge another link between Zinin and Butlerov, strengthening the idea of an unbroken Kazan School of Chemistry transmitted from Zinin to Butlerov. This conclusion is quite weak, in my view. While Butlerov does appear to have adopted the ideas of the French chemists or to have become receptive to them, this meeting with Zinin did not influence Butlerov's experimental work. Perhaps the strongest evidence, however, for the limited influence of Zinin on Butlerov at this time is simply the fact that there are no extant letters from Zinin to Butlerov from this time. Butlerov seems to have saved most, if not all, of the letters he received and they have been published. Also, I have checked the original letters located in Butlerov's archive at the Academy of Sciences in St. Petersburg and no letters from Zinin are found there for these years.

After he defended his doctoral thesis, Butlerov devoted little effort to laboratory work in chemistry. He published three short articles, in effect three abstracts, on widely varied subjects. One concerned a study of mineral water and another examined the monochloride of turpentine oil or "artificial camphor," in Butlerov's term. There was no apparent scientific connection between these works, and Butlerov seemed to be casting around for a suitable subject for detailed investigation (21). Clearly, these investigations done by Butlerov show no influence from Zinin and the type of research studies he was conducting up to this time.

At the same time, however, as Butlerov was dabbling with these chemical researches, he was devoting a great deal of effort to activities quite distant from the study of chemistry. During 1853-1857, Butlerov published far more articles in journals of botany and agriculture than he did in chemistry journals. He published more than 27 articles and reviews in the local Kazan economic society journal, ranging from the cultivation of certain seeds to notes for lovers of fruit gardens. As I have argued elsewhere, these publications show that during these years, Butlerov's outlook was oriented toward local concerns (21). Also, Butlerov gave a series of public lectures on chemistry and technical chemistry designed for the townspeople of Kazan. In addition, he made a futile foray into producing an egg soap for sale to the local community as well as an attempt to produce phosphorous matches (22).

Thus, considering all of these activities of Butlerov, I argue that there was no scientific continuity from Zinin

and Klaus to Butlerov. There is no reason to posit any kind of Kazan School of Chemistry beginning with Zinin and Klaus that was transmitted through Butlerov.

However, we **can** discern a specific **Butlerov** School of Chemistry at Kazan that began in the late 1850s. Butlerov's life and career changed dramatically in the aftermath of the Crimean War and the death of Tsar Nicholas I in 1855. Among the series of Great Reforms that the new Tsar Alexander II initiated, some of the most important concerned education, since it was widely believed that learning and science were necessary for Russia to achieve parity with the other European powers. The first important reform concerning education was the re-establishment of the right to travel and study abroad (23). The consequences of these reforms for Butlerov—and for all of Russian chemistry—were profound as many young Russian chemists began to travel and study abroad, bringing back to Russia new ideas and laboratory experiences from Europe. These young Russian chemists helped professionalize the study of chemistry in Russia in the next decades (24).

Although Butlerov was not as young as most other Russian chemists who went abroad at this time, the impact of his travel abroad in 1857-1858 was highly consequential for him. However, judging from Butlerov's plans for his trip, he originally conceived of it more as a vacation rather than undertaking serious scholarly activities, and his wife would accompany him on the travels. The original itinerary included many sites of no particular scientific interest, but which were prime vacation areas. After only a few weeks, though, Butlerov's plans completely changed. He had arranged some visits with Kekulé and Erlenmeyer, who both apparently affected him greatly. From this time, Butlerov began to be drawn into the current theoretical controversies in organic chemistry, especially concerning structural theory, and he was gradually beginning to develop his own views. Butlerov had felt isolated in Kazan, but his travels in Europe gave him the opportunity to establish personal contacts that would last for many years.

Butlerov eventually changed his plans for the trip and spent an extended period of time in Paris, working in the laboratory of Wurtz as well as attending lectures and participating in sessions of the Paris Chemical Society (25). The work Butlerov performed in Wurtz's laboratory was his first significant experimental research. He began working on methylene and its derivatives, continuing this work for more than four years and publishing the results in various French and German journals. One important aspect about this work was that it was a **series** of investigations, not just some individual and isolated experiments. From this time forward, a characteristic of Butlerov's research would be a systematic approach to his subject, often to prove a theoretical point, as in his later work on the structural theory.

When Butlerov returned to Russia in July 1858, his attitude toward his teaching and research had changed dramatically. Butlerov's experiences induced him to shift his intellectual focus from concerns that were important to the local community in Kazan to a concentration on issues that were important to the international community of chemists.

It was at this time that Butlerov also began to lay the foundations of what we can term the **Butlerov** School of Chemistry. Butlerov began a concerted effort to improve the chemistry laboratory at Kazan University and have every chemistry student conduct laboratory exercises, with advanced students even pursuing original research work that was associated with his own studies. For example, in one petition to the Kazan University authorities, Butlerov stated: "All foreign laboratories have significantly more resources than our laboratory, including space, equipment, glassware, and materials" (26). He kept up these petitions, and even when he succeeded in wrenching additional resources for the laboratory, he kept asking for more. In addition, Butlerov shed many of his extra duties, like teaching extra classes for additional salary that he had eagerly sought in years past, and began to devote all of his time to his core chemistry teaching and to his research (27).

Butlerov gradually began to construct a career path for his students—one with specific fellowships and positions that would support them until they could receive the degrees that would allow them to become professors in their own right. Butlerov's two most famous students were V. V. Markovnikov (1837-1904) and A. M. Zaitsev (1841-1910), who both became professors at Kazan University following Butlerov's move to St. Petersburg University in 1868. Markovnikov soon (1871) left Kazan University for Novorossiisk University in Odessa following a dispute with other faculty members at Kazan, but then quickly obtained a professorship at Moscow University (1873), where he established his own flourishing research school. Zaitsev remained at Kazan University for the rest of his career and trained a generation of chemists who continued Butlerov's excellence in organic chemistry. For example, A. N. Popov (1840-1881) established Warsaw University as a center of organic chemistry research and was succeeded after his premature death by another Kazan University gradu-

ate, E. E. Vagner (1849-1903) (28). In addition to these students who became chemistry professors, the graduates of Kazan University obtained positions at nearly every higher educational institution in the Russian Empire in the first few decades after Butlerov first established his research school. Thus, Butlerov's influence as a chemist extended far beyond the confines of Kazan University and had a lasting impact on chemistry throughout Russia.

Conclusion: The Research School under Butlerov

Finally, I would like to conclude with a consideration of what a Research School of Chemistry at Kazan was around the time Butlerov was teaching at Kazan.

If we use the characteristics of a Research School outlined by Morrell and Geison, we can see that the Butlerov School fits quite nicely into this model. We have a charismatic leader—Butlerov—who was rapidly gaining an international research reputation through his work on developing the structural theory of organic chemistry. He conducted his own experimental work in direct view of his students and thus could serve as an example and model for his students. He was able to gain institutional resources and attract students to do research under his direction. He had a focused research program that could provide students with a variety of suitable paths for experimentation. Moreover, with the founding of the Russian Chemistry Society in 1868, chemistry students had a suitable place to publish the fruits of their research and they took ample advantage of this publication outlet (29). With their experience in Butlerov's laboratory, his students were well prepared to compete for positions at other higher educational institutions in Russia. The overwhelming success of Kazan students in gaining employment elsewhere in Russia testified to the strong foundations instilled in them while at Kazan University. All of these—and more—added up to make Butlerov's laboratory and students a productive Research School.

Perhaps the key aspect in the formation of the Butlerov School of Chemistry at Kazan University was Butlerov's adoption of the structural theory of organic chemistry and making it the central focus of research. The fruits of this choice can be seen in Markovnikov's research while at Kazan University during the 1860s. Markovnikov contributed key research on the structural theory that helped establish its essential theoretical foundations.

Seen in this light, perhaps we should not consider Zaitsev as a direct successor to Butlerov and as a member of Butlerov's research school. Zaitsev had a rather unusual background and had spent some of his early years working in Marburg with Kolbe, who influenced him greatly (30). Upon his return to Kazan, Zaitsev presented a dissertation to Butlerov, based on the work done in Kolbe's laboratory. Butlerov angrily rejected this study, as Zaitsev—perhaps naively—parroted Kolbe's theoretical ideas which were fundamentally opposed to those of Butlerov himself. Zaitsev did revise this work and eventually regained the good graces of Butlerov. Still, Zaitsev's research never seemed to reflect the degree of influence from the structural theory of organic chemistry that was shown by the work of Markovnikov and other young chemists at Kazan University. Therefore, perhaps we should not consider Zaitsev as a direct successor to Butlerov and his research school. Zaitsev seemed to have a different research agenda than did Butlerov and Markovnikov. While Zaitsev's research agenda was based on the structural theory, the essence of his work was in a different direction than the work of Butlerov or Markovnikov. In a similar vein, Arbuzov's work did not evolve out of Zaitsev's work and so he should not be considered a direct successor to Zaitsev, as predicated by the unified Kazan School of Chemistry approach.

References and Notes

1. Presented at the 256th National Meeting of the American Chemical Society, Boston, MA, Aug. 21, 2018, HIST 32 in the HIST Award Symposium Honoring David Lewis.
2. A. E. Arbuzov, "Kazanskaia shkola khimikov," *Uspekhi khimii*, **1940**, *9*, 1378-1394. This is reprinted in A. E. Arbuzov, *Izbrannye raboty po istorii khimii*, Nauka, Moscow, 1975, pp 109-131.
3. On this point, also see John W. Servos, "Research Schools and Their Histories," *Osiris*, **1993**, *8*, 2-15.
4. G. L. Geison, "Scientific Change, Emerging Specialties, and Research Schools," *Hist. Sci.*, **1981**, *19*, 20-40.
5. J. B. Morrell, "The Chemist Breeders: The Research Schools of Liebig and Thomas Thompson," *Ambix*, **1972**, *19*, 1-46.
6. See G. L. Geison, "Research Schools and New Directions in the Historiography of Science," *Osiris*, **1993**, *8*, 226-238.
7. For example, see the articles in G. L. Geison and F. L. Holmes, Eds., "Research Schools. Historical Reappraisals," *Osiris*, **1993**, *8*, 1-248; L. Klosterman, "A Research School of Chemistry in the Nineteenth Century: Jean Baptiste Dumas and His Research Students," *Ann. Sci.*, **1985**, *42*, 41-80; and M. P. Crosland, "Research Schools

of Chemistry from Lavoisier to Wurtz," *Br. J. Hist. Sci.*, **2003**, *36*, 333-361.

8. For a more detailed discussion of chemistry at Kazan University, see: N. M. Brooks, The Formation of a Community of Chemists in Russia: 1700-1870. Ph.D. dissertation, Columbia University, 1989, pp 198-291; A. Al'bitskii, "Kafedra khimii I khimicheskaia laboratoriia imp. Kazanskogo universiteta v ikh proshlom I nastoiaschchem," in *Lomonosovskii sbornik. Materialy dlia istorii razvitiia khimii v Rossii*, Moscow, 1901; and D. E. Lewis, "The University of Kazan—Provincial Cradle of Russian Organic Chemistry. Part I: Nikolai Zinin and the Butlerov School. Part II: Aleksandr Zeitsev and his Students," *J. Chem. Educ.*, **1994**, *71*, 39-42, 93-97.
9. For information about Dunaev, see Al'bitskii, Ref. 8, pp 8-10; and N. P. Zagoskin, Ed., *Biograficheskii slovar' professorov I prepodavatelei imp. Kazanskogo universiteta za sto let (1804-1904)*, vol. 2, Kazan', 1904, p 317.
10. For information about Magnitskii, see J. T. Flynn, "Magnitskii's Purge of Kazan University: A Case Study in the Uses of Reaction in Nineteenth-Century Russia," *J. Mod. Hist.*, **1971**, *43*, 1971, 598-614; and C. H. Whittaker, *The Origins of Modern Russian Education: An Intellectual Biography of Count Sergei Uvarov, 1786-1855*, Northern Illinois University Press, DeKalb, 1984.
11. Other Ministries had control of different types of higher educational institutions besides the universities. For example, the Russian Orthodox Church controlled the seminaries, while various technical institutes were under the direction of the corresponding ministries. Thus, the Ministry of War controlled the Military Medical-Surgical Institute.
12. For details, see N. M. Brooks, "Nikolai Zinin at Kazan University," *Ambix*, **1995**, *42*, 129-142.
13. For information about Klaus, see N. N. Ushakova, *Karl Karlovich Klaus, 1796-1864*, Nauka, Moscow, 1972.
14. See Ref. 12 for details about Zinin's study and career at Kazan.
15. See N. M. Brooks, "Nikolai Zinin and Synthetic Dyes: The Road Not Taken," *Bull. Hist. Chem.*, **2002**, *27*, 26-36.
16. For information about Butlerov, see G. V. Bykov, *Aleksandr Mikhailovich Butlerov*, Nauka, Moscow, 1961; and N. M. Brooks, "Alexander Butlerov and the Professionalization of Chemistry in Russia," *Russ. Rev.*, **1998**, *57*, 10-24.
17. A. P. Borodin and A. M. Butlerov, "Nikolai Nikolaevich Zinin. Vospominaniia o nem I biograficheskii ocherk," *Zhurnal Russkogo Fiziko-Khimichekogo Obshchestva*, **1880**, *12*, 215-252.
18. G. V. Bykov, Ed., *Pis'ma russkikh khimikov k A. M. Butlerovu. Nauchnoe nasledstvo. 4*, Akademiia Nauk SSSR, Moscow, 1961, 161. Letter of Klaus to Butlerov dated 12 May 1854.
19. G. V. Bykov, ed., Pis'ma russkikh khimikov (Ref. 18).
20. Ref. 16 (Bykov), p 57.
21. Ref. 16 (Brooks).
22. S. F. Glinka, "Aleksandr Mikhailovich Butlerov v chastnoi I domashnei zhizni (Po lichnym vospominaniiam)," *Trudy Institut Istorii Estestvoznaniia i Tekhniki*, **1956**, *12*, 182-199.
23. For a good overview of the Great Reforms, see W. B. Lincoln, *The Great Reforms: Autocracy, Bureaucracy, and the Politics of Political Change in Imperial Russia*, Northern Illinois University Press, DeKalb, 1990.
24. For a discussion of this professionalization process, see N. M. Brooks, Ph.D. dissertation (Ref. 8).
25. For information about Wurtz and his laboratory, see A. J. Rocke, *Nationalizing Science: Adolphe Wurtz and the Battle for French Chemistry*, MIT Press, Cambridge, 2001.
26. A. M. Butlerov, *Sochineniia*, t. 3 Akademiia Nauk SSSR, Moscow, 1958, pp 71-72.
27. For example, see Butlerov's petition in 1859 asking that his teaching load not be increased: A. M. Butlerov, *Nauchnaia i pedagogicheskaia deiatel'nost'*, Akademiia Nauk SSSR, Moscow, 1961, p 26.
28. For details about these chemists, see D. E. Lewis, *Early Russian Organic Chemists and Their Legacy*, Springer, Heidelberg, 2012.
29. For information about the Russian Chemical Society, see N. M. Brooks, M. Kaji, and E. Zaitseva, "Russia: The Formation of the Russian Chemical Society and its History until 1914," in Anita Kildebaek Nielsen and Soňa Štrbáňová, Eds., *Creating Networks in Chemistry: The Founding and Early History of Chemical Societies in Europe*, Royal Society of Chemistry, Cambridge, UK, 2008, pp 281-304.
30. For information about Zaitsev, see A. S. Kliuchevich and G. V. Bykov, *Aleksandr Mikhailovic Zaitsev, 1841-1910*, Nauka, Moscow, 1980. For an excellent description of Kolbe, see A. J. Rocke, *The Quiet Revolution: Hermann Kolbe and the Science of Organic Chemistry*, University of California Press, Berkeley, 1993.

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