

“Try and Fall Sick ...”—The Composer, Chemist, and Surgeon Aleksandr Borodin

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aldol addition · Borodin, Aleksandr · fluorine chemistry ·
history of science · Hunsdiecker degradation

Dedicated to Professor Hartmut Bärnighausen

Although Aleksandr Porfir'evič Borodin^[1] is considered one of the outstanding Russian composers of the 19th century, he left only a very small volume of musical work. He is particularly renowned for the world-famous “Polovtsian Dances” from the opera “Prince Igor” and for his membership in “The Mighty Handful”. Also noteworthy, aside from the forementioned opera “Prince Igor”, are his three symphonies, two string quartets, and a symphonic poem “In the Steppes of Central Asia”. The reason for his small œuvre is that he considered himself a Sunday composer, composing for fun and only in his rare spare time or when he was ill. In fact, he was a professor of chemistry, and chemistry was avowedly his first passion.^[2] There were also other fields, besides chemistry, to which he was more committed than composition. Despite this declared priority for chemistry, Aleksandr Borodin is mostly unknown as a chemist to chemists of today, and—much to my regret—even as composer. This surely is not justified, since he is the discoverer of outstanding reactions, although unfortunately at a time when it was uncommon to name reactions after their inventors.^[3] This Essay is intended to shed light on all the various facets of Borodin, with a special focus on his chemical work.

Son of a Prince, Serf, and Aesthete

Aleksandr Borodin was born on November 12, 1833^[4] in Saint Petersburg as an illegitimate son of the Imeretian (Georgian) prince Luka Stepanovich Gedianov and his 24-year-old concubine Avdotya Konstantinovna Antonova. As was not uncommon at that time, he was registered as the son of one of the prince's serfs (Porfiry Borodin), even though he was raised exclusively through his mother. Although he formally grew up as a serf, he was generously supported by the prince and broadly educated by home schooling. His father died when Borodin was seven years old; shortly before, he

had granted freedom^[5] to his son and provided Avdotya Antonova with sufficient financial resources. Borodin developed a passion for both music and natural sciences, especially for chemistry. The first preserved composition is a polka—actually worth listening to—for piano with four hands, which he wrote as a 9-year-old boy passionately in love with a domestic servant. His mother was seriously alarmed by his chemical experiments, fearing that her house would be set on fire—not all his experiments were as harmless as his self-made watercolors, which he used for painting. His general education was substantial and comprehensive—for example, he learned to speak German, English, and French fluently (later he learnt Italian as well)—but his musical education was only cursory. He learnt some musical instruments in a rough-and-ready manner, mainly through private study, and studied some composers, mostly through their chamber works.

Despite his social origin, he was admitted to the medical faculty of the Medico-Surgical Military Academy in Saint Petersburg^[6] in 1850; however, the registration formalities made it necessary to make him one year older. He immediately became the best in the class, and he completed his studies “cum eximia laude” in 1856. Only a bad mark in religious studies prevented him from being honored with a medal.

At that time, chemistry was taught in the academy by the grandmaster of Russian chemistry, Nikolay Zinin.^[7] Borodin could not bring himself to approach Zinin for some considerable time, but in his third academic year he explained that he would very much like to work in this laboratory. Zinin was quite astonished to have this request from a student in medicine, but he accepted.

Hence Borodin finished his doctorate in 1858 with a chemical thesis. He was, in fact, not suited to medical practice at all because of his sensitive nature.^[8] He happened to be on duty one day when six serfs were brought in belonging to a Colonel who had flogged them for locking him in the stables because of the cruel way he had treated them. Borodin had the job of pulling out the splinters from their backs. He fainted three times at the sight of the skin hanging in tatters from their backs; in the case of two of them, their flesh had been flayed to the bones. From today's standpoint it is incredible that it would have been part of his job as a surgeon to attend executions and to punish offenders by branding. Knowing his character and his scientific interests, it is not astonishing that he continued his chemical education almost

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exclusively. He became Zinin's favorite student and his designated successor. Nevertheless, Zinin disapproved of Borodin's musical activities. Once he said: "*Mr. Borodin, it would be better if you gave less thought to writing songs. I have placed all my hopes in you, and want you to be my successor one day. You waste too much time thinking about music. A man cannot serve two masters.*"^[9]

To gain the experience necessary for the post of adjunct professor it was considered indispensable by Zinin and the academy that he learn further chemical techniques and visit foreign laboratories and chemical plants. From 1859 to 1862 he was sent to Germany and France as well as other countries. It was intended that he would work at first in Robert Bunsen's laboratory in Heidelberg, but he did not find this useful and worked instead in the laboratory of Privatdozent Emil Erlenmeyer. At that time, Dmitri Mendeleev and Aleksandr Butlerov were also staying in Heidelberg, and over time a very deep and enduring friendship developed between these three. At this time, he also became acquainted with his later wife, the asthmatic Yekaterina Sergeevna Protopopova, who had taken refuge in Heidelberg from the unhealthy climate in Russia. As a gifted pianist she was a kindred spirit to Borodin, they spent as much time together as possible. His finding that she had absolute pitch and could determine the key of a composition by listening possibly tipped the scales and they fell in love. He followed her to Pisa, where she had to travel for health reasons. In the laboratory of Sebastiano de Luca and Paolo Tassinari he developed a synthesis of benzoyl fluoride, one of the first syntheses of an organofluorine compound.^[10]

He returned to Saint Petersburg in 1862, where he was appointed adjunct professor and, after the retirement of Zinin in 1864, full professor at his alma mater (Figure 1). He and Yekaterina married one year after his appointment and over time they adopted three daughters. His primary duty was of course the chemical education of medical students at the academy, but his special passion, to which he was enthusiastically devoted from 1872, was the higher medicinal education of women, which was tolerated by Tsar Aleksandr II. For that he gave special lectures and organized practical instruction for the female students.

Borodin died when he was only 53 years old on February 27, 1887,^[4] from an apoplectic stroke or possibly a heart attack,^[11] at a fancy dress party he gave for colleagues. He had undoubtedly been weakened by the enormous workload; help



Figure 1. Founders of the Russian Chemical Society (1868). Borodin is standing fifth from the left. (Source: wikipedia; A detailed caption is given in the Supporting Information.)

was not possible, even though a lot of physicians were present. His wife, terminally ill in the last years but also a hypochondriac, lived only a few months longer. He was interred at the Tikhvin Cemetery of the Alexander Nevsky Monastery in Saint Petersburg next to his friend Modest Mussorgsky.

Aleksandr Borodin as Composer

Borodin had learnt to play the piano, flute, and cello as a young boy, although he did not master any of these instruments as a virtuoso.^[12] As an adolescent, during his studies and his stays abroad, he composed chamber music and he participated, for example, in Italy, in orchestras. Wherever he was, he visited all kind of concerts and he studied various composers through the available sheet music. He was undoubtedly a dilettante and but had hardly any knowledge of orchestration, compositional techniques, or contemporary composers (Figure 2). In this respect, he considered it to be one of the most important events in his life when, back in Saint Petersburg, he met Mily Balakirev, an important composer at that time but not significant today. He introduced Borodin to a group of composers, whose intention was—together with the music critic Vladimir Stasov—to promote an original Russian music (as opposed to a Central European music) in the style of their role model Mikhail Glinka.^[13] Besides Balakirev, this group consisted of the critic and almost forgotten composer César Cui, the composers Nikolai Rimsky-Korsakov and Modest Mussorgsky, and from that time onwards also Borodin. The group was called at first disrespectfully, but later appreciatively, "The Mighty Handful", "The Mighty Heap", or just "The Five"; they referred to themselves as "Balakirev's circle" (Figure 3). This group inspired, motivated, and helped each other. Borodin got familiar with contemporary composers by studying piano scores, was instructed in the essential techniques, was given advice and—most importantly—was assured that he was an able composer, even though he considered himself to have only moderate talent.



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Figure 2. Portrait of Borodin by Ilya Repin. (Source: wikipedia.)



Figure 3. "The Mighty Heap"—Borodin is seated on the far right. (Source: www.stumbleupon.com/stumbler/Perko/tag/the-russian-five/; see the Supporting Information.)

This interaction rapidly led to the finalization of a first symphony, which at once made him renowned in the musical world. It is very interesting to read Borodin's report on his first encounter with Franz Liszt, the doyen of music at that time. The intended external promotion of two students, of which one was his favorite student, right hand, prospective successor, and later son-in-law Aleksandr Dianin, resulted in him visiting Jena in 1878, and he used the opportunity to call on Liszt, who lived in Weimar. According to the plausible report of Borodin, Liszt welcomed him enthusiastically; he knew Borodin's symphony in detail and had the highest opinion of it. The comprehensive report on this (and one further) meeting with Liszt is worth reading, and also serves as a useful source for research on Liszt.^[14] The "Heap" disapproved that Borodin still continued to compose chamber music; this genre was frowned upon by the group. Besides some further, lesser works, he composed two famous and frequently performed string quartets. Motivated by the positive reception of his first symphony and especially by the encouragement of Liszt, he composed a similarly appealing second symphony. A third one was not finished; it was

completed posthumously by Aleksandr Glazunov.^[14] Further eminent compositions are the symphonic poem "In the Steppes of Central Asia", dedicated to Liszt, which exists as a version for piano four hands and one for an orchestra, and the very nice "Petite Suite" for piano. The humorous ambience^[15] in the "Heap" is best described by the Tati paraphrases ("Cutlet Polka") that were initiated by Borodin and arranged by four composers. An extremely simple theme, played with two fingers continuously without modification, was supplemented by rather sophisticated accompaniments that resulted in dances and pieces with various musical styles.^[16] Borodin contributed a polka, a funeral march, a mazurka, and a requiem. The polemic reviews of the critics made Liszt furious; he used to play these variations regularly with his (mostly female) students. For a second edition of the sheet music he contributed a further variation to show his solidarity with the composers. Also from Borodin's œuvre are 16, partly posthumously published, very melancholic romances, whose roots deep in the Russian folk music are apparent at first listening.

A constant worry to Borodin was his opera "Prince Igor" (Figure 4). Its development lasted 17 years, but he did not finish it himself. The opera was completed after Borodin's



Figure 4. "O, give me my freedom and I shall save my honor and free Russia" from Igor's aria in the 2nd act of the opera "Prince Igor".^[1a]

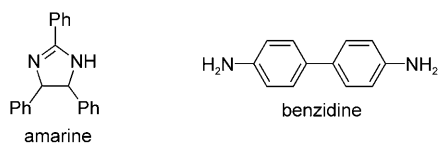
death by Rimsky-Korsakov and Glasunov; it was partly based on sketches left and partly from memory,^[17] and the remaining missing parts were composed in the style of Borodin. Nevertheless, the opera is afflicted with protraction and is thus considered to be dramaturgically (but not musically) of lower quality. Consequently, various revisions of this opera exist, particularly trying to reconstruct the originally intended composition of Borodin; occasionally the third act (almost completely composed by Glasunov) is shortened or even omitted in the performance. The parts completed by Borodin had made such an impression on the "Heap" that his friends did everything to make him continue composing. Circumstances prevented him from proceeding seriously; he made only very slow progress.

The "Polovtsian Dances", a scene from the opera, already composed in 1875, today belongs to the literature of the musical world and is known to many as a catchy tune without awareness of its origin. The opera was accepted quickly and is frequently performed. In 1953 the Broadway musical "Kismet" was completely assembled from Borodin's music.^[18] The song "Stranger in Paradise" based on the music of the "Polovtsian Dances", and performed, amongst others, by Bing Crosby, became a hit.

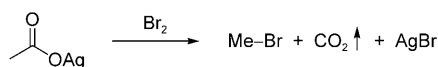
Fluorine Chemistry, Hunsdiecker Degradation, and Aldol Reaction

The chemical literature from the time when Borodin lived is difficult to read. There were no generally accepted rules of how to depict chemical formula; without substantiated chemical-historical knowledge, the stoichiometry of described compounds cannot be recognized. Qualified rules were not defined until the famous Karlsruhe Congress of 1860,^[19] but these were not immediately applied by everyone. Borodin was in Heidelberg at that time and joined this congress (together with Zinin, Mendeleev, and four more Russians^[20]). Although Borodin was elected as a member of the congress committee, no contributions made by him to the discussion are known. Nevertheless, it should be noted that the doctrine for the representation of chemical compounds constituted at the end of the congress was supported by him (as one of only a few) even before the congress.^[21]

The scientific work of Borodin was comprehensively analyzed and compiled by Rae.^[22] Borodin published about 20 major papers. His first contribution was his doctoral thesis dealing with the chemical and toxicological analogy of arsenic acid and phosphoric acid. In Zinin's laboratory and at the beginning of his time in Heidelberg he worked on amarine (triphenylimidazolidine)^[23] and benzidine,^[24] although this work was unproductive and of minor significance.



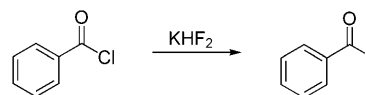
He stayed in Paris for several months, where he met Louis Pasteur. Here he worked on the action of bromine on silver carboxylate^[25] and found a reaction, which was later rediscovered by Heinz and Claire Hunsdiecker without having knowledge of Borodin's contribution.^[26] This reaction is today referred to as the Hunsdiecker reaction, and only occasionally as the Borodin–Hunsdiecker reaction (Scheme 1).



Scheme 1. The degradation of silver carboxylate with bromine, known as the Hunsdiecker reaction.

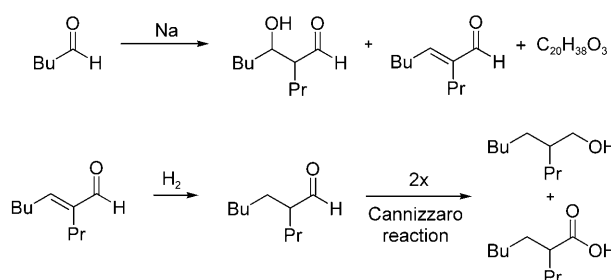
Borodin's previously mentioned stay in Pisa was very productive. Enthusiastically, he realized that the laboratory of de Luca and Tassinari was equipped with platinum crucibles, which allowed experimental work with hydrogen fluoride. He took the opportunity and worked on the synthesis of organofluorine compounds. The reaction of benzoyl chloride with potassium hydrogenfluoride (KHF₂) led to the formation of benzoyl fluoride (Scheme 2).^[27]

The eight original publications published during his postdoctoral studies met with universal approval on his



Scheme 2. Synthesis of benzoyl fluoride.

return to Saint Petersburg; nothing got in the way of his election to the post of adjunct professor. From that time on he performed his most important scientific investigations. From 1863 on he was definitely the first to work systematically on the aldol addition. The reaction of valeric aldehyde, enanthaldehyde (heptanal), and acetaldehyde with sodium as a— from today's point of view, uncommon—base led to several products. Borodin paid particular attention to the identification of the alcohol, which is known to be the product of an aldol addition (Scheme 3) and the product of an aldol



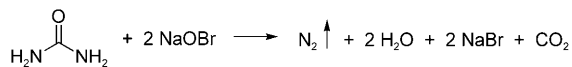
Scheme 3. Aldol addition of valeric aldehyde. Products described by Borodin.

condensation. The constitution of some higher condensation products could not be elucidated unambiguously. Further products, which depended on the reaction conditions, were formed by hydrogenation of the double bonds in the presence of hydrogen, which was used as a protective atmosphere, or by Cannizzaro disproportionation of the aldehyde. Furthermore, he was the first to note that the aldol addition is a reversible process, with the monomeric aldehyde returning on heating the aldol.

The precedence of Borodin's aldol results is unambiguously clear, his first publication available to all of Europe was printed in the *Journal für praktische Chemie* in 1864.^[28] Nevertheless, he soon had the feeling that August Kekulé was usurping his field of research. Kekulé first published in this field in 1869,^[29] but he only cited Borodin in his second paper (1870). Here, he claimed he would no longer work on the condensation of valeric aldehyde, the primary subject of Borodin's research.^[30] Borodin claimed to expand his priority on other aldehydes, but saw no chance to compete with the rival groups of Kekulé and Adolphe Wurtz,^[31] and thus decided not to insist on his priority: “*I made up my mind not to answer Kekulé but simply to continue my work. Otherwise he can think that I was really startled by his statement. When my work is finished, I will make a casual note in passing on Kekulé. This is far more tactful.*”^[32]

The development of a new method for the quantitative determination of urea in urine is frequently added to

Borodin's achievements, although the chemical foundation was most probably not developed by him (Scheme 4). Only the clearly tricky apparatus was undoubtedly designed by him.^[33]



Scheme 4. Determination of urea in urine.

It is not easy to decide whether Borodin considered his pupils' contributions to be a part of his work, as did most of his contemporaries in Central Europe. It was not uncommon that the doctoral advisers published without even mentioning the co-authorship of their students.^[34] Borodin frequently gave accounts at Russian congresses of his students' scientific studies. These reports were abstracted in the journal *Berichte der Deutschen Chemischen Gesellschaft*, mostly by Victor von Richter and Georg Wagner. These synopses make it clear that Borodin reported on his students' work and not on his own research. This indirect publication of his students' research amusingly led to the confusion that von Richter was mentioned as the inventor of the oxidative dimerization of naphthol in a important review on biaryls.^[35] In fact, von Richter abstracted a report of Borodin on Dianin's discovery of this reaction, which is frequently used nowadays.^[36] Nevertheless, the distinguished Borodin researcher, his grandson Sergei Dianin, the son of his favorite student and son-in-law Aleksandr Dianin, always mentioned Borodin as a co-author in the context of his father's work.^[37]

The Final Years

In his later years Aleksandr Borodin was increasingly depressive, felt miserable, and doubted the meaning of his work. "His once so beloved work at the university became a burden, even a torture."^[38] He was worried about the deteriorating health of his wife, which forced him to move from Saint Petersburg with its detrimental climate to the scientifically and musically nonproductive neighborhood of Moscow during the summer months. As a consequence of her sickness, his wife could not sleep before early morning; since he used to get up very early for his compositions, he had only very few hours of sleep. A further reason preventing his recovery were his numerous relatives and friends living in his rather small official residence.^[39] In his final years he was virtually unproductive in his scientific research. Unlike, for example, his colleagues in Germany, he had no scientific assistants who supported his research or helped him with his teaching duties.^[22] The bureaucracy in the tsardom forced him to cooperate in numerous commissions and to sit in meetings which lasted for hours.^[39] He was shattered by the information that his favorite project, the medical education of women, was no longer allowed under the regency of Tsar Aleksandr III from 1882 on and had to be stopped definitively in 1885. Borodin burst into tears when the women's laboratory had to be closed. Various honorary positions were offered to him,

which he did not refuse because of his good nature, but these brought a greater workload. Despite increasing musical success—his compositions were now performed regularly all over Europe and even in the United States; in Russia he was still not appreciated by the critics and musical directors—he had serious financial problems that made his scientific research increasingly impossible. He hardly found time to compose: "In winter I cannot compose unless I am sick and obliged to give up my lectures. So my friends, contrary to custom, never say to me, 'Try and keep well!' but rather, 'Try and fall sick!'"^[40]

In an environment of permanently changing amities and enmities, Borodin was a calming influence; he was the only one that maintained friendly contacts with all members of the "Heap". Everybody held him in high regard because of his friendly character. Rimsky-Korsakov wrote about him: "Borodin was a man of rare kindness and of high education, a stimulating and inimitably witty conversation partner."^[41] His generosity was often taken advantage of. Even if the circumstances were not favorable, his altruistic character would come to the fore; it was most probably this characteristic that contributed significantly to his early passing. He left compositions of incredible density—virtually all are of similarly high quality^[42] and had significant influence on most of his successors. Chemically he performed some eminent reactions for the first time, for example, the aldol reaction, although one has to admit that, in the long term, chemistry would have developed in a similar way without his contributions.^[43]


Borodin was neither a composer nor a scientist in the first line; nevertheless he deserves our attention because of his double gift and his significant achievements. I hope that this Essay helps him to receive adequate recognition.

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- [1] Essential literature on Alexander Borodin: a) K. Laux, *Die Musik in Russland und in der Sowjetunion*, Henschelverlag, Berlin, 1958; b) V. I. Seroff, *Das mächtige Häuflein*, Atlantis, Zürich, 1963; c) S. Dianin, *Borodin*, Oxford University Press, London, 1963; d) A. Habets, *Borodin and Liszt*, Digby/Long, London, 1977; e) D. Brown, G. Abraham, D. Lloyd-Jones, E. Garden, *Russian Masters 1*, W. W. Norton, New York, 1986; f) N. A. Figurovskii, Y. I. Solov'ev, *Aleksandr Porfir'evich Borodin—A Chemist's Biography*, Springer, Berlin, 1988; g) *Alexander Borodin—Sein Leben, seine Musik, seine Schriften* (Ed.: E. Kuhn), Ernst Kuhn, Berlin, 1992; h) S. Neef, *Die Russischen Fünf: Balakirew—Borodin—Cui—Mussorgski—Rimski-Korsakow*, Ernst Kuhn, Berlin, 1992; i) W. Stassow, *Meine Freunde Alexander Borodin und Modest Mussorgsky*, Ernst Kuhn, Berlin, 1993; j) T. Gorischek, *Russische Nationalkomponisten*, Kurt Pachla, Graz, 2005.
- [2] "Others have the composition of music [...] the goal of their lives. For me it is only rest, fun which takes time from my serious business as a professor." From a letter by Borodin; Ref. [1f], p. 89.

- [3] The oldest named reaction might be the Kolbe reaction: H. Kolbe, *Justus Liebigs Ann. Chem.* **1849**, 69, 257–294.
- [4] According to the Gregorian calendar.
- [5] Serfdom was not abandoned in Russia until 1861.
- [6] Only noblemen were allowed to study.
- [7] Zinin's most important finding was the reduction of nitrobenzene with hydrogen sulfide to yield aniline.
- [8] An appreciation of Borodin as physician can be found in: I. Konstantinov, *Surgery* **1998**, 123, 606–616.
- [9] Ref. [1i], p. 138.
- [10] The first synthesis of an organofluorine compound was presented by Dumas and Péligot ($\text{H}_3\text{CSO}_3\text{OK} + \text{KF} \rightarrow \text{H}_3\text{CF} + \text{K}_2\text{SO}_4$): J. Dumas, E. Péligot, *Ann. Chim. Phys.* **1836**, 61, 193–201.
- [11] G. Böhme, *Medizinische Porträts berühmter Komponisten*, Vol. 2, Gustav Fischer, Stuttgart, **1987**, pp. 143–157.
- [12] Liszt needed to urge him to play some of his compositions on the piano. When he played a wrong note or had to skip a part, Liszt commented: “Why did you not do that; it is so fine?” and “O my dear composer! So well composed and not willing to perform!”, Ref. [1g], p. 153.
- [13] The group furthermore declined training at the conservatory since they thought that this would narrow a composer's freedom of musical expression. With this point of view they were in opposition to most influential composers and critics in their environment: *Die Musik in Geschichte und Gegenwart* (Ed.: F. Blume), Bärenreiter, Kassel, **1949–1986**.
- [14] Borodin disclosed to his friends on the day of his death that his just completed finale of his 3rd symphony was the best piece of music he had ever composed. Regrettably he did not get round to writing it down or playing it for someone.
- [15] O. Krätz, *Chem. Unserer Zeit* **2004**, 38, 89–99; see also the nonpreserved compositions of Borodin (see the Supporting Information).
- [16] The dedication of the Paraphrases is: “Dedicated to all small pianists able to play the theme with one finger of both hands by Aleksandr Borodin, César Cui, Anatoly Lyadov, and Nikolai Rimsky-Korsakov.”
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- [17] Borodin did not write down the overture, but played it occasionally to his friends on the piano. Glasunov seemed to have proven that he knew it note for note (Ref. [1c], p. 155). This perspective has been doubted by some authors—partly supported by a commentary of Glasunov himself: M. Bobeth, *Borodin und seine Oper “Fürst Igor”*, Emil Katzschler, München, **1982**, p. 166.
- [18] For this, Borodin was posthumously awarded the 1954 Tony Award for the best musical.
- [19] M. Mönnich, *Nachr. Chem.* **2010**, 58, 539–543.
- [20] Ref. [1f], p. 39.
- [21] In his thesis he advanced the view of the unitary theory by Laurent and Gerhardt and declined the dualistic theory of Berzelius and his successors. Ref. [1f], p. 25.
- [22] I. D. Rae, *Ambix* **1989**, 36, 121–137; see also F. H. Getman, *J. Chem. Educ.* **1931**, 8, 1778–1780.
- [23] A. Borodine, *Justus Liebigs Ann. Chem.* **1859**, 110, 78–85. [Borodin used different spellings for his name.].
- [24] A. Borodin, *Z. Chem. Pharm.* **1860**, 3, 533–536; A. Borodin, *Z. Chem. Pharm.* **1860**, 3, 641–643.
- [25] A. Borodin, *Z. Chem. Pharm.* **1861**, 4, 5–7; A. Borodine, *Justus Liebigs Ann. Chem.* **1861**, 119, 121–123; A. Borodine, *J. Prakt. Chem.* **1861**, 84, 474–475.
- [26] H. Hunsdiecker, C. Hunsdiecker, *Ber. Dtsch. Chem. Ges.* **1942**, 75, 291–297.
- [27] A. Borodine, *Justus Liebigs Ann. Chem.* **1863**, 126, 58–62.
- [28] A. Borodin, *J. Prakt. Chem.* **1864**, 93, 413–425.
- [29] A. Kekulé, *Ber. Dtsch. Chem. Ges.* **1869**, 2, 365–368.
- [30] A. Kekulé, *Ber. Dtsch. Chem. Ges.* **1870**, 3, 135–137.
- [31] Wurtz found previously that glycol was dehydrated with ZnCl_2 to acetaldehyde, which reacted further to an undefined compound of the same composition: A. Wurtz, *Ann. Chem. Pharm.* **1858**, 108, 84–88.
- [32] Ref. [1f], p. 66.
- [33] A. Borodin, *Zh. Khim. Fiz. Obshch.* **1876**, 8, 145.
- [34] A. J. Rocke, *The Quiet Revolution: Hermann Kolbe and the Science of Organic Chemistry*, University of California Press, Berkeley, **1993**, p. 19.
- [35] Ref. [1c], p. 80.
- [36] J. M. Brunel, *Chem. Rev.* **2005**, 105, 857–898.
- [37] V. von Richter, *Ber. Dtsch. Chem. Ges.* **1873**, 6, 1249–1260.
- [38] Ref. [1i], p. 21.
- [39] A dramatic description of Borodin's disastrous living conditions is given in Ref. [1b], p. 106.
- [40] a) F. H. Getman, *J. Chem. Educ.* **1931**, 8, 1762–1780; b) H. B. Friedman, *J. Chem. Educ.* **1941**, 18, 521–525.
- [41] Ref. [1g], p. 33.
- [42] Musicologist Sir Henry Hadow noted about Borodin: “No musician has ever claimed immortality with so slender an offering”, Ref. [1e], p. 58.
- [43] The reasoning of Gordin that Borodin's contribution to chemistry was insignificant seems not to be justified: M. D. Gordin, *J. Chem. Educ.* **2006**, 83, 561–565; a reply to this has already been published: E. J. Behrman, *J. Chem. Educ.* **2006**, 83, 1138.