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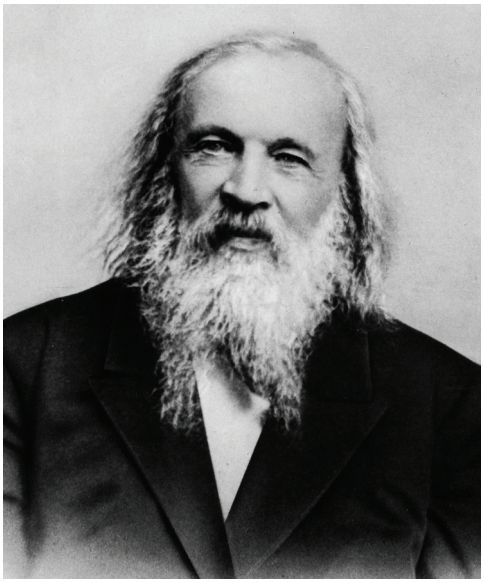

Dmitrii I. Mendeleev
(1834–1907)

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On February 8, 2009 it is 175 years since the birthday of Dmitrii Ivanovich Mendeleev, the author of the Periodic Law and Periodic System of Chemical Elements, with whose name our journal is connected.

The life of this versatile person was extremely rich in events, and his anniversary is a good occasion to remind some important points of Mendeleev's scientific biography.†

Dmitrii Ivanovich Mendeleev was born on February 8, 1834 in Tobolsk, Siberia, Russia. From the outset of his study Mendeleev showed his persistence, activity and deep knowledge of subjects he took an interest in. In 1849, Mendeleev graduated from the gymnasium at the age of 15, and in 1855, from the Principal Educational Institute in St.-Petersburg with golden medal for excellence. In 1856 at St. Petersburg Imperial University, he defended two magisterial theses: 'On Isomorphism and Specific Volumes' and 'On the Structure of Silica Compounds'.

After lecturing (theory and history of chemistry, and organic chemistry) as private docent of the university, in 1859 Mendeleev was sent to Europe, where he visited a number of universities, met with famous scientists, such as Berthelot, Würtz, Dumas, Liebig, Bunsen, Erlenmeyer and Kirchhoff, established a private laboratory at Heidelberg, took part in the First Chemistry Congress in Karlsruhe. During his work in Heidelberg, Mendeleev designed a number of devices (including his famous Mendeleev's picnometer) and discovered a phenomenon of absolute boiling point (now known as critical temperature).

Just after his return to St. Petersburg in 1861, he began to write a handbook 'Organic Chemistry', for which he was rewarded with the Demidov Prize of 1862. In 1861–1862 as the editor of the translation of Wagner's 'Technology', Mendeleev wrote for this book additional chapters on Starch, Sugar, Alcohol and Glass Industry. His study in the field of technology Mendeleev continued as a docent at the Technology Chair of the University and a professor at St. Petersburg Practical Technological Institute. At the same time, he engaged in fundamental problems of the physical chemistry of liquids and solutions and in 1865 he received his PhD from the University for his Doctoral thesis 'On the Compounds of Alcohol and Water' and the position of a professor on technical chemistry at the University.

Mendeleev made a very important contribution to the creation in October 1868 of the Russian Chemical Society, which ten years later was transformed to the Russian Physico-Chemical Society with two autonomous divisions – physical and chemical. He wrote the regulation for the Russian Chemical Society and served as the president of the Russian Physico-Chemical Society in 1883–1887. Since 1932, the national Chemical Society has the name of D. I. Mendeleev.

In 1868, Mendeleev received a new duty to teach students with the course of inorganic chemistry, the topic relatively new for himself. Surprised by the lack of suitable handbooks (to be recommended for students), he decided to write his own course. Such an idea led to the appearance of his most famous book 'Foundations of Chemistry' ('Osnovy Khimii'). This two-volume handbook was printed stepwise (two issues of the first volume in 1868–1869, and the rest in 1871), survived 13 editions (8 during his life) and was later translated into German, English and French. Every new edition was expanded and deepened by the author. With no doubts, work on this book (and its further

† This text has been prepared on the basis of the materials by Dr. E. Babaev. For the full version of Mendeleev's biography, see the paper by E. Babaev available from the website of Mendeleev Communications (http://www.mendcomm.org/Mendeleev.aspx).

permanent improvements) was the main reason for the discovery and future development of the Periodic System.

The handbook started from the common organogen-elements (H, O, N and C) and their combinations, and the further plan was clear: halogens – alkali metals – alkaline earths. However, the plan for next chapters was less clear: where to put and how to order heavier elements? Trying to avoid any arbitrary order, Mendeleev noticed patterns in the properties of several families of light elements, arranged in the order of increasing atomic weights, and found a sort of periods:

Li = 7;	Be = 9.4;	B = 11;	C = 12;	N = 14;	O = 16;	F = 19
Na = 23;	Mg = 24;	Al = 27.4;	Si = 28;	P = 31;	S = 32;	Cl = 35.5
K = 39;	Ca = 40;		Ti = 50;	V = 51;		

He realized that this pattern could be applied to arrange heavier elements. As he wrote: 'Li, Na, K and Ag relate to each other as C, Si, Ti and Sn, or as N, P, V and Sb'. However, the further task was complicated by the existence of triads (like Fe–Co–Ni, similar both in weights and properties), rare earths, unclear or wrong atomic weights *etc*. Nevertheless, Mendeleev printed first draft of the Periodic Table with all 63 known elements on March 1, 1869. (In that early version the rows of halogens and alkali metals were joined together to avoid emptiness in the middle of the table.) Most important was that he left places (like ? = 68, ? = 70) for unknown elements. On March 13, this small printout (150 copies in Russian and 50 in French) was sent to his colleagues.

In his further studies of 1869–1871, Mendeleev investigated the change of atomic volumes of elements and oxidation steps in their highest oxides (from R_2O to R_2O_7), which he proved to be periodic function of atomic weight. Finally, he realized the difference in the nature of odd and even periods (thus finding a place for triads) and drew a chart (short form of the Periodic Table) as it was later used in most handbooks.

The history and further development of the Periodic Law is well known. The strict law found by Mendeleev required not only changes of some known atomic weights but, more importantly, the existence of some yet undiscovered elements with certain atomic weight and properties. Three elements predicted by Mendeleev have been discovered during his life by European chemists:

Predicted	Found	Discovery details
eka-aluminium (M=68)	gallium (M=70)	1875, P. E. Lecoq de Boisbaudran
eka-boron (M=44)	scandium (M=45)	1879, L. Nilson
eka-silicium (M=72)	germanium (M=73)	1886, C. Winkler

The properties of gallium nearly matched those predicted by Mendeleev for eka-aluminium, except of the density; later de Boisbaudran re-measured the density and proved Mendeleev's value.

Of course, the Periodic Table had several precursors and 'cocursors': Dobereiner (1829), Kremers (1852), Gladston (1853), Cooke (1854), Lenssen (1857), Pettenkofer (1858), Dumas (1858), Strecker (1859), Hinrichs (1867), Odling (1857, 1864), De Chancourtois (1862), Newlands (1865) and, of course, Meyer (1864, 1871). However, only Mendeleev realized that the Periodic Table reflects the law of nature (not just a convenient taxonomy), and only Mendeleev used it for successful prediction of unknown elements and for correction of atomic weights. L. Meyer, who strongly contributed to understanding the periodicity of atomic volumes, commented in the following way 'It would be too hasty from so uncertain starting point to change accepted atomic weights'.

Although Mendeleev continued to popularize his discovery and update the book 'Foundations of Chemistry', since 1872 the topic of his interest dramatically changed to the physics of gases. In his theoretical studies, he re-examined the ideal gas laws and contributed to the equation $pV = nRT$ (Mendeleev–Clapeyron equation).

His scientific authority had grown not only in Europe (especially after the glorious story with gallium in 1875) but also in Russia. In 1876, he was elected to the St. Petersburg Academy of Sciences as a corresponding member. He frequently consulted the government and private business, and one of the topics was oil industry.

After 1871, Mendeleev's interests also turned to the problems of higher education and fine arts.

In the early 1880 (soon after the discovery of scandium and the proof of its identity to eka-boron), Meyer initiated a disput on the question of the priority on the discovery of the Periodic System, and Mendeleev had to write an emotional respond.

In November 1880, Mendeleev tried to ballot to the full membership of the National Academy of Sciences without success (he got 9 votes against 10 in favor of F. Beilstein). The scientific community strongly protested against the decision of the Academy, and many foreign institutions and societies nominated Mendeleev as their full or honorary member. The Royal Society (London) awarded him a Davy medal (though jointly with Meyer).

His main chemical interest after 1882 was the theory of solutions. His early ideas on definite and indefinite compounds (from his magisterial and doctoral theses) now grew to the chemical theory of solutions, summarized in the monograph 'The Study of Densities of Aqueous Solutions' (1887).

In 1886, Mendeleev made two trips to Caucasus for the inspection of oil plants in Baku and suggested new ways of heavy oil utilization. In 1888, he examined the coalmines and plants in Donbass and suggested some key economic decisions (new credit and rent policies, canceling any plants taxation for a decade, favorable transportation tariff *etc.*).

Since 1889, as the member of the Governmental Council of Trades and Manufacturing, Mendeleev tried to arrange all possible tariffs in a sort of system. This result (known as the Mendeleev tariff) was published as a 700-page book.

After leaving the University in 1890, as a scientific consultant of the Navy ministry, Mendeleev received a new task of the development of smokeless gunpowder. He established a laboratory in St. Petersburg and during next two years succeeded to find a formula and to develop the technology.

In 1892, Mendeleev accepted the proposal to serve as a scientific keeper of the Bureau of Weights and Measures. Mendeleev was keen from this new service and performed a series of reforms in metrology. The small bureau was transformed into the Main Chamber, which soon became third in Europe (after France and Germany) center of excellence in metrology studies. First, he renewed the standards for traditional Russian units of mass (pound) and length (arshin and sazhen), made them from a special alloy (Pt–Ir) and calibrated in Paris. Then, he built an observatory and labs for studying the standards of other physical units (time, pressure, electric current, light, *etc*.), and in the later period explored the ways of their measurements with unbelievable accuracy.

He visited the Urals and wrote a book with the detailed plan of its industrialization. He thoroughly elaborated a programme of reforms in education with suggestions to cancel examinations. He collaborated with Navy and assisted to open the first ship-testing basin, although the ministry refused another his project – an icebreaker of his own design to explore Arctic. He wrote excellent popular chapters to the famous Encyclopedia by Brockhaus–Efron. Furthermore, Mendeleev combined all these

activities with significant extension of his 'Foundations of Chemistry' (7th edition, 1903). He finally turned to the topics of demography, politics and the problems of society.

Mendeleev never received the Nobel Prize. After 1904, when the prize was given to Sir William Ramsay for discovery of noble gases – a new group in the Periodic System – chemists revived the interest to the system creator. Mendeleev was nominated in 1905, but the prize was given to Adolf von Baeyer. Mendeleev was nominated again in 1906, but the prize now was given to Henri Moissan. (Both times Mendeleev was second on the list.). The third consideration of his name as a nominee was interrupted by his death from influenza on February 2, 1907. Streets were crowded. The funeral procession was headed by students who carried big Periodic Table. In the same year, in memory of the great scientist, the Mendeleev Congress on General and Applied Chemistry was held in St. Petersburg. Afterwards, the Mendeleev Congresses, as the most prestigious national chemistry forums in this country with worldwide participation were held every 4–5 years. The last XVIII Mendeleev Congress, dedicated to the centenary of Mendeleev Congresses, was held in Moscow in September 2007 and became the largest and most representative during its century-long history.

Mendeleev's Periodic Table has promoted the discovery of new elements and the development of chemical science as a whole. In 1955, Glenn T. Seaborg *et al.* synthesised an element with the atomic number 101 and named it Mendelevium (Md) in recognition of the pioneering role of the great Russian chemist.

Being improved and enriched with new data as the science advanced, Mendeleev's Periodic Table has retained its basic principles and structure, which proves once more its fundamental nature.

The most recent results on evolution of Mendeleev's Periodic System were obtained by Professor Yu. Ts. Oganessyan and his co-workers (*Mendeleev Commun*., 2005, 1) at the Joint Institute for Nuclear Research, Dubna, Moscow Region, Russia. On the basis of fusion reactions of accelerated ionised ^{48}Ca nuclei with target nuclei, thirty-five isotopes of new chemical elements with atomic numbers from 104 to 118 have been synthesised. The half-life of some of them is up to 30 h (depending on the number of protons and neutrons in the nuclei) that gives the experimental proof of the existence of an 'island of stability' and the possibility to perform their chemical identification and study their chemical properties. The results obtained provide the first experimental confirmation of relativistic effects on the properties of elements in Mendeleev's Periodic Table.

On February 8, 2009 the humanity commemorated the 175th anniversary of Dmitriy Mendeleev (1834-1907), Father of the Periodic Table, the great scientist, thinker and patriot. The Editorial Board has decided to contribute to this memorable event with a novel version of the Mendeleev's biography, which was put together and interpreted by a Russian chemist. Due to a large size, only a part of this biography appeared in the printed version of our journal (2009, No.2). We believe that the website our Journal, Mendeleev Communications, is an appropriate site for the story about Mendeleev's life, Mendeleev's contributions, and Mendeleev Communications.

Dmitriy Mendeleev: A Short CV, and A Story of Life

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The comments on earlier Mendeleev biographies are presented on the webpage of this site. With the goal of approaching carrier and achievements of Dmitriy Mendeleev in a format readily recognizable by a modern scientist, student, or even an employee, the author takes the liberty presenting the biography as a relatively standard CV.

The author's comments to the biography are provided in brackets [i] – [xxviii] for a fact or time period (chronologically, wherever possible). The author refers only to selected publications (given in parentheses **(1)** - **(17)**) from the full list of more than 500 Mendeleev's publications. (For some of them, it was possible to find the digital objects identifier, **doi**.) The most recent bibliography on the studies of the Periodic system is given as subscript numbers[1-11].

CURRICULUM VITAE

Mendeleev, Dmitriy Ivanovich
Born: Feb. 8, 1834 (Jan. 27, old style) in Tobolsk, Russia [i].
Father: **Mendeleev, Ivan Pavlovich**.
Mother: **Mendeleeva (Kornilyeva), Maria Dmitrievna**.

Education, employment, and teaching experience
1841-1849: Primary education at the Tobolsk gymnasium [ii].
1850-1855: Student at the Main Pedagogical Institute, St. Petersburg [iii].
Graduated with diploma of Senior Teacher [iv].
1855-1856: Teacher at middle school in Odessa [v].
1856: Magister of Chemistry at the St.-Petersburg University [vi].
1857-1859: Private Docent at the St.-Petersburg University [vii].
1859-1861: Postgraduate researcher in Heidelberg, Germany [viii].
1861-1863: Lecturer at several high schools in St.-Petersburg [ix]; handbook writing [x];
editorial activity [xi]; technical consultancy for the Ministry of Finances [xii].
1864-1866: Professor at the Technological Institute [xii].
1864: Docent at the St.-Petersburg University [xii].
1865: PhD in Chemistry [xiii].
1865-1890: Professor at the St.-Petersburg University.
1865: Prof. of Technical Chemistry [xiv]-[xv].
1867: Prof. of Pure Chemistry [xvi]-[xxv].
1885: Emeritus Professor and lecturer.

1891-1895: Scientific consultant to the Navy Ministry [xxvi].
1892-1907: Service at the Depot (Chamber) of Weights and Measures [xxvii].
1892: Scientific keeper (since **1893**: the Head of the Chamber).

Key scientific interests

Periodic law [xix]; inorganic chemistry [xviii]; physical chemistry of solutions [iv], [viii], [xii], [xiii], [xxiv]; theory of gases [xx]; physics of liquids, hydro- and aerodynamics [xxi]; technology [xi], [xxv], [xxviii]; agrochemistry and agriculture [xv]; oils [xxii], [xxv]; organic chemistry [x]; mineralogy and isomorphism [iv], [vi]; gunpowder [xxvi]; problems of high education [xxiii], [xxviii]; metrology [xxvii]; economics [xxv], [xxviii]; philosophy [xxviii].

Selected publications

(1) Mendelejeff D. Chemische Analyse des Orthits aus Finnland. Verhanlungen der Russ. Kais. Mineral. Gesellchaft. St. Petersburg, 1854, s. 234.

(2) **(a)** Mendelejeff D. Ueber die Ausdehnung der Flussigkeiten beim Erwarmen uber ihren Siedepunkt. Ann. Chem. Pharm. 1861, 119 (1), 1-11. doi: 10.1002/jlac.18611190102.
(b) Mendelejeff D. Bemerkungen zu den Untersuchungen von Andrews uber die Compressibitat der Kohlensaure. Ann. Physik u. Chem. 1870, 217 (12), 618-626. doi: 10.1002/andp.18702171218.

(3) Mendeleev D. Chemical Congress in Carlsruhe [in Russian]. Sankt- Peterburgskie Vedomosti (daily newspaper), 1860, № 280.

(4) Mendeleev D. Organicheskaya Khimiya [Organic Chemistry, in Russian], St. Petersburg: Tipogr. tovarishchestva "Obshchestvannaja Polza", 1st Edition, 1861. 2nd Edition, 1862.

(5) Mendeleeff D. The compounds of ethyl alcohol with water. J. Chem. Soc., Trans., 1887, 778-782. doi: 10.1039/CT8875100778.

(6) Mendeleev D. Osnovy Khimii (Foundations of Chemistry) [in Russian]. St. Petersburg: Tipogr. tovarishchestva "Obshchestvannaja Polza," 1869-1871, 5 parts in 2 volumes, 1st Edition.
(a) English transl. (Principles of Chemistry, Longmans: London): 1891, 1897, 1905. (Last - reprinted in 1969.)
(b) German transl. (Mendelejeff D. Grundlagen der Chemie. Ricker, St. Petersburg, 1891.)
(c) French transl. 1895.

(7) Mendeleev D. Experience on the System of the Elements [in Russian]. Zhurnal Russkogo Khimicheskogo Obshchestva (below - Zhurnal), 1869, 1 (2-3), 35. [Appeared in German at Z. Prakt. Chem. 1869, 106 (4), 251].

(8) **(a)** Mendeleev D. On the Relationship of the Properties of the Elements to their Atomic Weights [in Russian], Zhurnal, 1869, 1 (2-3), 60-77. [Abstracted in Z. Chem., 1869, 12, 405-406.] doi: 10.1002/prac.18691060141.
(b) Abstracts of talks of D. Mendeleev in 1869-1870 [in German]: Ber. Deutsch. Chem. Gesell., 1869, 2, 553; ibid. 1870, 3, 990-992. (Available online from the Gallica project.)
(c) Mendeleev D. Natural System of the Elements and its Application to Prediction of Properties of yet undiscovered elements [in Russian], Zhurnal, 1871, 3 (2), 25-56.
(d) Mendelejeff, D. Zur Frage uber das System der Elemente, Ber. Deutsch. Chem. Gesell., 1871, Bd. 4, H. 1, 348-352. doi: 10.1002/cber.187100401120.
(e). Mendeleeff D. The Periodic Law of the Chemical Elements (Faraday lecture, June 4th, 1889.) J. Chem. Soc., 1889, 55, 634-56. doi: 10.1039/CT8895500634.

(9) **(a)** Mendeleef D. Researches on Mariotte's Law, Nature, 1877, Vol.15 (388), p. 498-500. doi: 10.1038/015498a0.
(b) Mendelejeff D. Ueber Siljestrom's Versuche zur Ermittelung der Dichtigkeitsveranderungen verdunnter Gase. Ber. Deutsch. Chem. Gesell., 1874, Bd. 7, H. 2, 1339-1344. doi: 10.1002/cber.187400702125.
(10) Mendeleev D. Flight at an Air Balloon from Klin during Eclipse of the Sun [in Russian]. Severniy Vestnik, No.11/12, 1887.
(11) Mendeleev D. Materials for the Conclusion on Spiritism. [in Russian]. St.Petersburg, 1876.
(12) Mendeleev D. Oil Industry in the Northern-American State Pennsylvania and in Caucasus. [in Russian]. St. Petersburg: Tipogr. tovarishchestva "Obshchestvannaja Polza", 1877.
(13) Mendeleev D. Construed Tariff or Investigation on the Development of Industry of Russia in Relation to its Custom Tariff of 1891 [in Russian]. St. Petersburg: Tipogr. Demakova, 1891.
(14) Mendeleev D. On the Methods of Exact or Metrological Pondering (O priyomah tochnyh ili metrologicheskih vzveshivaniy) [in Russian]. St. Petersburg, 1895.
(15) Mendeleeff D. An Attempt towards a Chemical Conception of the Ether. [Engl. transl.] NY : Longmans, Green & Co, 1904. (Original publication [in Russian], 1902.)
(16) Mendeleev D. Cherished Thoughts (Zavetnie mysli.) [in Russian]. Moscow: Mysl' Publ., 1995.
(17) Mendeleev D. Towards Learning Russia (K poznaniyu Rossii.) [in Russian]. Editions:
(a) St. Petersburg: Typogr. Frolovoy, 1906;
(b) Moscow: Iris-Press Publ., 2002, 576 p.

Honors, awards, medals, societies

Demidov Prize (1862). Eight Honorary diplomas and medals including: Davy medal from the England Royal Society (1882); Gold medal from the Paris Academy of Flight (1887); Faraday medal from the English Chemical Society (1889), the Copley medal from the Royal Society of London. (1905).
Doctor at the following Universities: St.-Petersburg, Edinburgh, Goettingen, Oxford, Cambridge, Princeton, Glasgow, and Yale. Professor at the St.-Petersburg University and the St.-Petersburg Technological Institute.
Member of Academies in Paris, Denmark, Vienna, Krakow, Rome, Belgium, Prussia, America, and Serbia.
Member of the following societies: Royal Society of London, Royal Societies of Edinburgh and Dublin, Russian Chemical Society, Mineralogical Society of St.-Petersburg, Moscow Agricultural Society, Society of Addicts of Natural Sciences, and Society of Anthropology and Ethnography at the Moscow University, German Chemical Society, Society of Biological Chemistry, Italian Scientific Society, Imperial Academy of Arts, International Committee of Weights and Measures.
Corresponding member at the St.-Petersburg Academy of Sciences, Society of Support of National Industry, Rotterdam Society of Natural Sciences, Hungarian Academy of Sciences, Royal Society of Sciences in Goettingen, Royal Academy of Sciences in Turin, Royal Academy of Science in Rome.
Honorary member of the Royal Institute of Great Britain, Imperial Universities of Moscow, Kazan, Kharkov, Kiev, Odessa, Yuryev, Tomsk, the Imperial Medical Surgery Academy, Moscow Technical High School, Peter the Great Agricultural Academy, Institute of Agriculture in New Alexandria, St.-Petersburg Polytechnic Institute, Tomsk and St.-Petersburg Technological Institutes, American Academy of Art and Sciences in Boston, Irish Royal Academy, Swedish Academy of Sciences,

Academy of Sciences at the Bologna Institute, Russian Physical-Chemical Society, American Chemical Society, Imperial Russian Technical Society, the Societies of Natural Sciences in Kazan", Kiev, Riga, Yekaterinburg, Cambridge, Frankfurt-on-Main, Goeteborg, Brunswig, Moscow Polytechnic Society, Moscow and Poltava Agricultural Societies, Society of Preservation of the National Health, Society of Russian Doctors, Medicinal Societies in St.-Petersburg, Vilno, Caucasus, Vyatka, Irkutsk, Archangelsk, Simbirsk, Ekaterinoslav, Pharmaceutical Societies in Kiev, Great Britain, Philadelphia, Society of Physical Sciences in Bucharest, Cambridge Philosophical Society, American Philosophical Society, Russian Astronomic Society, etc.

NB: Mendeleev once received the list as it appeared above. He angrily asked to strike it off, saying:
"Are you mad? Is it possible to print such a title that is even longer that the Tsar has…"

Personal data

In 1862 married to **LESCHOVA, Feozva Nikitchna** (1828-1905);
children Maria (1863-1863), Vladimir (1865-1898) and Olga (1868-1950). Divorced in 1881.
In 1882 married to **POPOVA, Anna Ivanovna** (1860-1942);
children Lyubov (1881-1939), Ivan (1883-1936), Vasiliy (1886-1922), and Maria (1886-1952).

Comments

[i]. Mendeleev's grandfather Pavel Maximovich Sokolov was the priest of the Russian Orthodox Church in a small village of Tikhomandritcy (2 km away from the Udomlya lake, Tver' region, Russia). According to the church books, four of his children, Timofey, Natalya, Tatyana and Praskovya, were given the family name 'Sokolov,' whereas Alexander was recorded as Tikhomandritckii, Vasiliy - as Pokrovskiy, and Ivan - as Mendeleev.

Ivan Pavlovich Mendeleev (1783-1847), father of the great scientist, graduated from the Orthodox Seminary in Tver' (1804) and then from the St.-Petersburg Pedagogical institute (1807). He was a teacher at several schools (initially, in Tobolsk, and then in Tambov and Saratov). In 1820s, he returned to Tobolsk (Siberia) to serve as the director of gymnasium through 1834.

In 1809, Ivan Mendeleev married Maria Dmitrievna Kornilyeva (1793-1850). Maria's grandfathter, Vasiliy Kornilyev (died in 1795), a successful merchant and owner of the first Siberian glass factory (built in 1749) has become the first Siberian typographer and publisher in 1780s. Maria's father, Dmitriy Kornilyev (1763-1830) continued the family publishing activity, though being less successful.

Dmitriy Mendeleev was the 17th (and the last) child in the Mendeleevs' family; 3 children died on their births, and therefore only 14 children got Christian names: Maria (1811- 1826), Olga (1815-1866), Ekaterina (1816-1901), Appolinaria (1822- 1848), Elizaveta (1823-1852), Ivan (1826-1862), Maria jr. (1828- 1911), Pavel (1832-1902), and Dmitriy (1834-1907); five others (to some sources - Victor, Varvara, Nikolay, Varvara jr. and Ilya) died in their childhood.

Many intellectuals used to visit the Mendeleevs' house in Tobolsk, including the liberal political exiles, the Decembrists, who were sentenced to the labor in Siberia after their anti-tsar revolt in 1825 in St. Petersburg. The Mendeleevs had an excellent library and lived in comfort. However, in 1834 Ivan Mendeleev went blind as the result of the eye cataract, and, despite the successful surgery, had to retire with an insufficient pension. His wife, Maria tried to support her family by governing her brother's glass factory, although without much of success. Eventually, the factory was burnt down, and shortly thereafter Maria's husband, Ivan Mendeleev died.

[ii]. Dmitriy Mendeleev entered the gymnasium at the age of 7, one year younger than it was allowed, and therefore had to study for two years in the first class. Anyways, he graduated too early, at the age of 15. To avoid the administrative problems, his teachers noted him as a 16 years old in his attestation (certificate) list on July 12, 1849. Dmitriy was successful in the natural sciences and mathematics, and not so good in languages.

Maria's wanted her son to study in Moscow, where her wealthy brother Vasiliy resided. In summer 1849, she took Dmitriy and his sister Liza for a long journey from Siberia to Moscow. However, the strict regulation for the school graduates allowed the Tobolsk residents to enter only the geographically nearest regional university, which was located in Kazan. For this reason, the Moscow University rejected Dmitriy Mendeleev's application in 1849. When the family moved to the Russian capital (that times it was St.-Petersburg) next year, rejection for the similar reason happened to Dmitriy's application at the St.-Petersburg University.

[iii]. Finally, Maria found a school that had accepted Dmitriy. It was the Main Pedagogical Institute in St.-Petersburg, which taught students for teaching in Gymnasia, and from which the Dmitryi's father, Ivan graduated in the past. The last fact was helpful, and Prof. Chizhov, a coursemate of Ivan Mendeleev, supported the Dmitryi's application. In summer 1850, Dmitriy was allowed to take the admission tests, which he passed, although not with honors (his average score was 3.22 at the five-point scale) but good enough to receive a full scholarship with residency in the dormitory. A scholarship student had to sign an obligation for teaching at middle schools after graduation, in a ratio of two years of service for each year of education.

Shortly after Mendeleev became a student, his mother died (on Sept. 20, 1850); soonafter, his uncle Vasiliy died in Moscow (in 1851), and then his elder sister Liza (died in 1852). Dmitriy himself got seriously ill; he was coughing with blood, and doctors suspected tuberculosis. In 1853, he spent a few months in the hospital, and once received a physician verdict: "This one will never recover". However, he did recover leaving the hospital shortly for passing exams and getting applauds from his fellow students.

[iv]. Mendeleev stayed for two years as the first year student (similarly to his experience in the middle school). During the first year, he had moderate marks (between 2 and 3.5; only chemistry had a score of 3.75), and his initial education rates were rather poor (in 1851, he was only on the 25th place in the group of 28 students). However, in spite of poor health, Mendeleev worked really hard: in 1854 he raised to the 7th place in overall rating, and in 1855 graduated with the gold medal for excellence.

The student themes in the Mendeleev's student research were extremely broad and diverse. As a few examples, those were “The Primary education in China”, “Rodents of the St. Petersburg Region”, “Influence of heat on animals' spreading”, “Ancient plants”, “Inorganic analysis of umbra”, “Analysis of pyroxene”. His first published student scientific research was in German **(1)** on analysis of a mineral, and one of the supervisors of that work was Prof. A. Voskresensky (a disciple of Liebig in 1830s). Voskresensky is known in the Russian scientific history as “The Grandfather of Russian chemistry”; further, Voskresensky played an important role in the Mendeleev's life.

[v]. During the final exams, Mendeleev impressed the committee with profound knowledge. His talent for science was fully appreciated, and the administrators planned keeping him at the institute for the preparation to magister degree. However, Mendeleev followed the doctor's advise to relocate to the southern region where the climate was better for his health. He picked up a teacher position in Odessa; the gymnasium in that big city was a part of the famous Richelieu Lyceum (former Jesuit College), which had an excellent library. However, by mistake in the documents, the Ministry sent him to the small city

Simferopol. Mendeleev arrived to Simferopol on Aug. 25, 1855, but the place was too dangerous to stay. Witnessing the Crimean War, the town resembled a military camp being in close proximity to surrounded Sevastopol, and overcrowded with many hospitals. One positive output occurred for Mendeleev in Simferopol: he met the famous surgeon Pirogov, who examined Dmitiy and did not confirm any early diagnosis on tuberculosis. Two months later, on Oct. 30, 1855, Mendeleev succeeded moving to Odessa. During a 6-month stay in Odessa, he combined teaching of math and natural sciences in the classroom with preparation of his magister thesis on isomorphism. He sent a letter to his former mentors in St.-Petersburg asking to assist with habilitation, and if possible, with his studies abroad. Finally, he got an assurance, and on May 1856 returned to St.-Petersburg.

[vi]. Due to the problems with the Pedagogical institute, which was soon completely shut down, Mendeleev applied for his magister degree to the Council at the St.-Petersburg Imperial University, with the thesis on isomorphism and specific volumes. On Sept. 9, 1856 he passed the exams and became a magister. Soonafter, he completed his second magister thesis (which was required for a docent position) on the structure of silica compounds, and next month defended his degree on Oct. 21, 1856.

[vii]. An impressive activity of Mendeleev quickly opened doors for his lecturing as a private docent at the University for the next two years (though without any permanent salary). Since Jan. 9, 1857 he started the seminar lectures (theory and history of chemistry, later organic chemistry) and supervised the laboratory studies for undergraduate students. His salary was insufficient, and Also, he earned for living by writing short popular reports on natural sciences for the Journal of the Ministry of Education, and by private lessons. In 1856 he was engaged, but a year later his bride (Sofya Kash) unexpectedly broke the engagement.

[viii]. At the end of 1858, the University Administration decided to send the Private Docent Mendeleev abroad for improvement in sciences. The 22 months fellowship started on Apr. 14, 1859. Initially, Mendeleev made a long trip choosing the place (during a couple of months, he visited a dozen of the European Universities). In Paris, he met Berthelot, Wurtz and Dumas, and later in Munich had a conversation with Liebig (who warmly recalled Voskresensky). Finally, Mendeleev decided to stay and work at the Heidelberg University (with famous professors Bunsen, Erlenmeyer, and Kirchhoff). The town of Heidelberg also attracted him with its a large Russian diaspora community. (In early 1860s, about 10% of the students there were from Russia.) Soon Mendeleev was surrounded by the new friends: a chemist and composer Borodin (the author of "Prince Igor" opera), physiologist Sechenov, the famous chemist Zinin, and some others.

At the Bunsen's laboratory, Mendeleev was soon dissatisfied with the lack of some precise equipment, which was necessary for his research. He resolved the problem in somewhat unusual way. He built up a private laboratory in his apartment (adding there a gas pipeline) and purchased himself the precise thermometers, cathetometers, pumps, etc. from the experienced masters in Bonn and Paris, One device from that period, which was designed by Mendeleev, is known nowadays as the Mendeleev's picnometer. In his home lab, he started measuring specific volumes (molecular weights divided by density) for the series of liquids. To calculate the density, Mendeleev evidently put a certain mass of a liquid in his picnometer (with a fine open capillary attached); clearly, the density depended also on the temperature, therefore the scientist had to perform many measurements. One day he heated a liquid in sealed capillary and made his first discovery. He found the phenomenon, which he called an absolute boiling point **(2a)**, now known as critical temperature **(2b)**.

On Sept. 3, 1860 Mendeleev took part (along with Zinin, Borodin and three other Russians) in the First Chemistry Congress at Karlsruhe, which was attended by 140 famous

European chemists (including Kekule, Bayer, Dumas and others), where the participants "voted" for novel definitions of equivalent, atom and molecule. Mendeleev got the brightest impression from a talk by Canizzaro, who suggested essential improvements of the common atomic weights. Mendeleev valued the crucial importance of this event so greatly that (with the help of Voskresensky) he published his report about the event in the Russian daily newspapers **(3)**.

[ix]. Attempts of Mendeleev to prolong his studies abroad were rejected by the Russian Ministry, and he had to come back to St.-Petersburg. Dissatisfied, on Feb. 14, 1861 he arrived at the capital of the Russian Empire, which was on the edge of reforms and changes. A few days later, on Feb. 19, the Emperor Alexander II signed his Manifest of serf' freedom which caused a huge political unrest. Suddenly, Mendeleev learned that he had lost his position at the University (which was temporarily closed), while the Pedagogical Institute was permanently shut down. Mendeleev suffered from the lack of money; as he wrote that time, "debts to sew coat and boots, always hungry". It was still unclear how to repay his huge debt (borrowed to support Rosa, his and the actress Agnes Feuchtman's daughter, whom he left in Heidelberg but continued supporting until Rosa got married). He accepted any paid lessons or text writings, started lecturing at several high schools (>20 hours per week) like the Corpse of Railroad Engineers (chemistry course), Engineering School (physics), Cadet /later Artillery/ Corpse (chemistry and geography) etc., quickly moving from place to place.

[x]. One option for earning money is always open to a scientist: receiving a prize for the scientific writing. Just in a week after his return to Russia, Mendeleev started writing a handbook on Organic Chemistry **(4)** and completed the manuscript in an extremely short timelines (24 Feb. - June 18, 1861). He worked so rapidly for the reason of timely reaching the deadline for a prestigious Demidov Prize (for excellent writings). The book was not a complete compilation of earlier materials but had a few fresh ideas. For example, trying to classify the hydrocarbons according to their composition, Mendeleev formulated his theory of limits (probably the first documented statement that the C:H ratio for alkanes is minimal among other hydrocarbons, i.e. there is the limit of possible saturation). This 500-pages book was very popular, and actually, was the first Russian organic chemistry handbook. Its first edition was sold quickly, and next year, the publishers printed the second edition . The Mendeleev's application for the Demidov Prize was supported by Zinin and appraised by Voskresensky (both organic chemists); for this book, Mendeleev received the Demidov Prize in 1862. With the big Prize money, he finally paid almost all of his debts.

The prize also influenced his personal life: on Apr. 30, 1862, he married Feozva Leschova. (F. Leschova was the daughter-in-law of the well-known Russian poet and fairy tale teller P. Ershov, who in 1850s was the Director at the Tobolsk gymnasium where Dmitriy studied.) Initially, there was a hesitation at both sides, if the marriage should have occurred at all. Mendeleev did initiated with this marriage, although this happened mainly on insistences of his 20- year older sister Olga, who thought he needed a wife and convinced him to marry. During the honeymoon, the newly-weds traveled abroad, and attended the World Exhibition in London, along with other places.

[xi]. During the complicated period of his life in 1861-1862, Mendeleev accepted a job of the editor for translation from German of the Technology by J.-R. Wagner. Soon he was keen from the work, decided to expand the book, and from the duty of paid corrector quickly changed to the author of several chapters (on Starch, Sugar, Alcohol, and Glass industries). Finally the book appeared in 4 volumes in 1862 as Technical Encyclopedia. Here, probably, were the roots of further Mendeleev's interest in technology (and industry) topics. Indeed, on Christmas week of 1861 he helped his friend Reichel (owner of a wood distillation plant in Novgorod region) to optimize the technology. Next year he did a similar

job at oil-refinery in Caucasus for Kokorev, a millionaire, dissatisfied with low output of his plant.

[xii]. The editorial activity shortly brought to Mendeleev the reputation of qualified technologist. As a result, he got the docent position at the University (at its Technology Chair). But even more important was the fact, that without any Doctor degree he was accepted as professor at the St.-Petersburg Practical Technological Institute (those times headed by Ilya Tchaikovsky, father of brilliant Russian composer) and moved to its communal apartments. At the Technological Institute he lectured, supervised chemical laboratory and chaired the Graduation Board.

In early 1860s Russian Finances' Ministry decided to reconsider its excise-duty system to tax the alcohol production, and therefore, claimed a strong need in new exact methods and devices to measure the concentration of ethanol solutions. In 1863 Mendeleev (as recent editor of the Alcoholometry chapter, see [xi], and as designer of new picnometer, see [viii]) was invited to consult special Technical Committee organized by the Ministry on this topic. He suggested a project and received the support (which, besides salary, included 2 barrels of alcohol). Mendeleev obtained extremely purified ethanol (by several cube distillations), thoroughly studied variation of the volume and density against the temperature and water-ethanol ratio and received exact (though quit complex) formula to be used for further calibrations in industry.

[xiii]. Fortunately, Mendeleev's research on applied topic met his early interest to more fundamental problems of physical chemistry of liquids and solutions. He realized that his very precise numbers and curves clearly indicate formation of definite molecular compounds with clear molar constitution between the components (e.g. with molar ratio C_2H_5OH:H_2O = 1:3, 3:1, and even 1:12). (This work could be traced to his further "chemical theory" of solutions.) That result became the topic of Mendeleev's Doctoral thesis "On the compounds of alcohol and water" **(5)**, and on Jan 31, 1865 he received his PhD from the University. (Some legends linked this research to origin of the secret of the Russian Vodka, but that viewpoint was recently criticized.)

[xiv]. After habilitation in 1865 Mendeleev became extraordinary professor (Apr. 24), and soon (Dec. 7) received Professor of Technical Chemistry position at the University. On Aug. 31, 1866 he withdrew from his professorship at Technological Institute (although kept to lecturing there with organic chemistry till 1872). In autumn (Nov. 24) his family moved to big communal apartments at the University campus, where 3 years later he wrote the first draft of his Periodic Chart.

[xv]. In June 1865 Mendeleev bought a private house in the village Boblovo (12 km from the town Klin, Moscow region), and his family started to spend summer seasons in the country side. Mendeleev built a new house (with laboratory), and equally enjoyed to work both in lab and garden. In the village Mendeleev's interest to agriculture fully flourished. Mendeleev was fond of modern agrochemical ideas (particularly of Liebig, who claimed to use phosporites and other mineral fertilizers in agriculture) and decided to test them experimentally. With this goal he ran in Boblovo experimental fields and a farm. Mendeleev behaved very actively: he gave a lecture at the Imperial Free Economic Society on agricultural topics, became its member, received support from the Society for his experiments in Boblovo, and in two years, indeed, succeeded to improve the quality of his soils and the yield of crops. He was so deeply involved in the Economic Society's activities that later in 1869, at the day of the first announcement of his Periodic chart to the Russian Chemical Society, he was absent at the inspection trip to cheese breweries and therefore asked N. Menshutkin to substitute him at the talk.

[xvi]. In 1867 Voskresensky withdrew from all his University positions (due to his move to Kharkov) and offered his vacancy of Pure chemistry professor to Mendeleev. This shift (adopted on Oct. 18, 1867) caused another changes: A. Butlerov (from Kazan) became ancestor of Mendeleev's professor vacancy. Finally, N. Menshutkin (as extraordinary professor) complemented the duet of two famous chemists to an excellent trio.

[xvii]. In 1860s the chemists of Russia were not joined into any official union (like Royal Chemical Society or Gesellschaft Deutscher Chemiker) and they have even no journal. Instead they gathered in private apartments and communicated occasionally (though quite regularly). Mendeleev strongly contributed to creation of the Russian Chemical Society and personally wrote its regulation. The novel union (later called Mendeleev Chemical Society) was established in October 1868 and officially recognized by the government. The society started its own Journal (Zhurnal) in early 1869 and became the first audience acquainted with the idea of the Periodicity four months after it was created.

[xviii]. As the ancestor of Voskresenskii, Mendeleev received a new duty to teach students with the course of inorganic chemistry, the topic relatively new for himself. Surprised by the lack of suitable handbooks (to be recommended for students), he decided to write his own course. Such an idea led to appearance of his most famous book "Foundation of Chemistry" (Osnovy Khimii). This two-volume handbook **(6)** was printed stepwise (2 issues of first volume in 1868-1869, and the rest in 1871), survived 13 editions (8 in Mendeleev lifetime) and was later translated to German, English, and French. Every new edition was expanded and deepened by the author. With no doubts, work on this book (and its further permanent improvements) was the main reason of the birth (and future development) of the Periodic system.

[xix]. The handbook started from the common elements-organogens (H, O, N, C) and their combinations, and the further plan was clear: halogens - alkali metals - alkaline earths. However, the plan for next chapters was less clear: where to put and how to order heavier elements? Trying to avoid any arbitrary order, Mendeleev noticed patterns in the properties of several families of light elements, arranged by increase of their atomic weights, and found a sort of periods:

Li=7;	**Be=9,4;**	**B=11;**	**C=12;**	**N=14;**	**O=16;**	**F=19**
Na=23;	**Mg=24;**	**Al=27,4;**	**Si=28;**	**P=31;**	**S=32;**	**Cl=35,5**
K=39;	**Ca=40;**		**Ti=50;**	**V=51**		

He realized that this pattern could be applied to arrange heavier elements. As he wrote: "**Li**, **Na**, **K**, **Ag** relates to each other as **C**, **Si**, **Ti**, **Sn**, or as **N**, **P**, **V**, **Sb**". However, the further task was complicated by existence of triads (like Fe-Co-Ni, similar both in weight and properties), rare earths, unclear or wrong atomic weights etc. Nevertheless, Mendeleev printed first draft of the Periodic chart **(7)** with all 63 known elements on March 1, 1869. (In that early version the rows of halogens and alkali metals were joined together to avoid emptiness in the middle of the table.) Most important was that he left places (like ?=68, ?=70) for unknown elements. On March 13 this small printout (150 copies in Russian and 50 in French) was sent to many his colleagues.

In his further studies of 1869-1871 (see his papers **(8a-d)** and the later review **(8e)**) Mendeleev investigated the change of atomic volumes of elements and oxidation steps in their highest oxides (from R_2O to R_2O_7), which he proved to be periodic function of atomic weight. Finally, he realized the difference in nature of odd and even periods (thus finding a place for triads) and drew a chart (short form of the Periodic system) as it was later used in most handbooks. There are two stories on his discovery: that he saw the Table in a dream,

and that he used cards with elements for a sort of "solitaire" patience, although both are not well documented.

The history and further development of the Periodic law is well known. (The discovery of the Periodic law by Mendeleev was extensively reviewed in the comprehensive books[1-3] and other recent studies[4-10].) The strict law found by Mendeleev required not only changes of some known atomic weights, but more importantly, existence of some yet undiscovered elements with certain atomic weight and properties. Three elements predicted by Mendeleev have been discovered during his lifetime by European chemists:

Predicted	Found	Discovery details
Eka-Aluminium (M=68)	Gallium (M=70)	1875, P. E. Lecoq deBoisbaudran
Eka-Boron (M=44)	Scandium (M=45)	1879, L. Nilson
Eka-Silicium (M=72)	Germanium (M=73)	1886, C. Winkler

The properties of gallium nearly matched those predicted by Mendeleev for eka-aluminium, except of the density; later de Boisbaudran re-measured the density and proved Mendeleev's value. Of course, the Periodic table had several precursors and cocursors (the term of Benfey[6]): Dobereiner (1829), Kremers (1852), Gladston (1853), Cooke (1854), Lenssen (1857), Pettenkofer (1858), Dumas (1858), Strecker (1859), Hinrichs (1867), Odling (1857, 1864), De Chancourtois (1862), Newlands (1865) and of course, Meyer (1864, 1871). However, only Mendeleev realized that Periodic table is the Natural law (not just a convenient taxonomy), and only Mendeleev used it for successful prediction of unknown elements of the Matter and for the change of existed atomic weights.

[xx]. Although Mendeleev continued to popularize his discovery and update the book, since 1872 the topic of his interest dramatically changed to the physics of gases. Because the chemical affinity and weight (mass) were the central concepts of his Periodic law, in his mind both were naturally linked to the concept of the Ether, the media equally responsible for transmission of chemical forces and gravitation. Mendeleev associated the Ether with a sort of an element with extremely small atomic weight. He expected to find the Ether experimentally by achieving highest possible vacuum (as he believed, the residue should be the Ether with non-zero mass). To test this hypothesis he successfully applied for support to the Russian Technical Society (linked to the military ministry) with a project to study elasticity of gases at highest pressures (as in the guns), received quit generous funding and bought the best possible pumps. However (see[3]), he frequently attached the pumps in wrong way (not to output but to input) thus obtaining lowest possible pressure instead of the highest. The lack of instruments for such ultra-fine measurements stimulated Mendeleev to invent some new devices by himself. (One such inventory - Mendeleev differential barometer - was later used in geodesy.). In his theoretical studies he re-examined the ideal gas laws and contributed to the equation **pV=nRT** (Mendeleev-Clapeyron formula, see **(9)** and later analysis[11]). However, after several years of hard work on the search of the Ether he realized in 1876 his failure to find it. He cancelled the project, dissatisfied the sponsors, and gave up.

[xxi]. Mendeleev suspected that the Ether might exist at natural vacuum - in the highest levels of the Earth atmosphere. At least by that reason he explained the growth of his interest in 1870s to meteorology and air flying. (Decade later in 1887 he made an adventurous solo balloon flight to observe the solar eclipse, see his report **(10)**.) From aerodynamics (and aeromechanics) he naturally shifted to hydrodynamics (and hydromechanics) and even to the theory of shipbuilding. All those problems were inseparable in his mind, as he called them the media resistance. In 1882 he summarized his results in the monograph "On the Resistance of Liquids and Air flying".

Another way to seek the mysterious Ether was to study unexplained psychological phenomena. The newspapers of 1870s were full of reports about the mediums and spirits - the persons capable to move objects distantly, violating the physical laws (and common sense). Many scientists (including Butlerov) considered the phenomena seriously. Mendeleev decided to study these forces experimentally. In 1875 he headed the Scientific Commission to examine the phenomena (he put hidden sensitive manometers under the table with mediums sitting around). He confirmed that most of the demonstrations were tricks and published special report **(11)** on this topic.

[xxii]. His scientific authority had grown not only in Europe (especially after the glorious story with gallium in 1875), but also in Russia. In 1876 he was elected to St. Petersburg Academy of Science as corresponding member. He frequently consulted the government and private business, and one of the topics was oil industry. The oil crisis of 1875 in Russia led to devastation of national oil industry, and Mendeleev, as the consultant of a government commission, made in 1876 a trans-ocean trip to Pennsylvanian oil refineries. After he got acquainted with modern state of art and taxation system (summarized in his book **(12)**) he advised the government to cancel the excise-duty for the kerosene and oil. His advice was accepted in 1877, and the industry revived next decade. With this new experience (combined with his early experience at Caucasus oil plants in 1863, see [xi]) he helped his disciple Ragozin to build in 1879 a perfect oil refinery close to Yaroslavl. One scientific output of this period has been his hypothesis of 1877 about the mineral origin of oil (which he supposed to appear from the interaction of iron carbides with water at high temperatures in the Earth's depths).

[xxiii]. After 1871 Mendeleev's interests also turned to humanitarian topics. The first was the problem of high education. In 1871 he contributed to foundation of the first Women courses and started lectures there. In one his publication he called the need of reform in gymnasiums (to direct them in the system of permanent education). The second area of his interest was fine art. In 1871-1873 launched a unique lecture course for a group of famous painters (Repin, Yaroshenko, Vrubel, Kuindji, Shishkin and others) on the chemistry of pigments and colors. He joined the club of photographers ("to assist distribution of Russian art". Mendeleev became frequent visitor of art galleries, and after one exhibition he wrote his impressions in a short pamphlet with parallels between the art and science. Every week he hosted famous Mendeleev Wednesdays in his apartment, where the scientists met artists. Later he was elected to the Imperial Academy of Art as the full member.

In 1877 Mendeleev (who was 43) met young lady Anna Popova (19 years old), who studied painting in the Academy of Art and who was a friend of his cousin Nadezhda. This meeting changed his private life dramatically, and in next few years caused his divorce with F. Leschova. Around 1880 Mendeleev survived the biggest crisis of his life. Several negative events quickly changed each other. In early 1880 (soon after discovery of Scandium and the proof of its identity to eka- boron) Lothar Meyer initiated a dispute on his priority on the discovery of the Periodic system, and irritated Mendeleev had to write emotional respond. The same year his teacher Voskresensky died. In November Mendeleev tried to ballot to the national Academy of Sciences (as full member), however, without any success (10 votes against 9); the favor was given to Beilstein. The sunlight in the darkness was the birth of his daughter Lyubov, but the Church prohibited his second wedding. Mendeleev made an attempt to withdraw from the University. His spouse remembered a moment when he thought on suicide.

Slowly the things ran more positively. On Apr. 1882 he violated the ban and did have married officially. (The priest Kutnevich, who assisted this wedding for big money, immediately lost his job.) Mendeleev remained at his place at the University, and from now he paid all his professor salary to his former wife. Newspapers and the scientific community strongly protested against the unexpected decision of the Academy, and many institutes and

societies elected Mendeleev as their full or honorary member. The Royal Society awarded him the Davy medal (jointly with Meyer). In consonance with these changes, his project on media resistance was also finalized, and in the first half of 1882 he switched to research at another topic.

[xxiv]. His main chemical interest after 1882 was the solutions theory. His early ideas on definite and indefinite compounds (from his magisterial and doctor thesis) now grew to the chemical theory of solutions, summarized in the monograph "The Study of Densities of Aqueous Solutions" (1887), which he dedicated to the memory of his mother. For solutions of 233 compounds he thoroughly studied the density as a function of concentration (at different temperatures). He proved formation of definite compounds (common, like $H_2SO_4*H_2O$, or less common, like $H_2SO_4*150H_2O$) by finding extreme points on continuous curvatures (now referred as singular points). He claimed this to be a general principle to study solutions. His viewpoint found some followers, but Arrenius and his school, developers of the physical theory of solutions, mostly criticized it. (Decades later both theories were considered to be complementary.)

[xxv]. In early 1880s Russia faced deep crisis; its economics (after the war 1877-1878) was closed to bankruptcy. A special event, the Congress on Industry and Trade, was organized in Moscow in 1882 for business community with the goal to elaborate new tools for saving the situation. One of most active speakers there was Mendeleev, who gave 7 (!) talks on the key topics of national industry (cast iron, oil, fuels, salts, coal, leather, flax, cotton, paper, wool, silk, mechanization problems). In fact, it was a program of his activity for next decade.
In 1886 Mendeleev made two trips to Caucasus for inspection of oil plants in Baku and suggested new ways of heavy oil utilization (cf. his famous statement "Oil is not fuel; if you reason otherwise, why not burn money?"). In 1888 he made three trips to coal fields in Donetzk area (Donbass) to examine the coalmines and plants there and suggested some key economic decisions (new credit and rent policies, canceling any plants taxation for a decade, favorable transportation tariff etc.). His reports and public writings were acknowledged and partially accepted by the government. In 1886 Russia stopped the kerosene import from USA; the coal extraction increased significantly, and the revived industry became competitive.

Since 1889 Mendeleev became the member of the Council of Trades and Manufacturing. Initially he consulted the Council at a local topic (custom protective tariff for some chemicals, like raw sulfur), but soon he realized how crucial was the overall tariff problem. He tried to arrange all possible tariffs in a sort of system. This result (known as Mendeleev tariff) was published as a 700-page book **(13)**. The following Russia's protectionism policy initiated a sort of tariff war with Europe in 1893-1894 and strongly stimulated domestic industrialization.

[xxvi]. On March 1890 Mendeleev tried to bring students' petition to the Minister of education Delyanov. After receipt of rejection he immediately resigned from the University. He was unemployed only shortly, and from Sept. 1891 became scientific consultant of the Navy ministry. His new task was development of smokeless gunpowder, and in 1891 he made an official trip to UK and France to study the topic. He established a laboratory in St. Petersburg and during next two years succeeded to find a formula and to develop the technology. The first trials of 1893 confirmed that his gunpowder (pyrocollodiy, sometimes translated as pyrrocollodion) surpassed the foreign samples.

[xxvii]. In 1892 Mendeleev accepted the proposal of the Finance Minister Sergey Witte to serve as scientific keeper of the Bureau of Weights and Measures. Mendeleev was keen from this new service and performed the series of big reforms in metrology. The small

bureau was transformed into the Main Chamber, which soon became third in Europe (after France and Germany) center of excellence in metrology studies. First, he renewed the standards for traditional Russian units of mass (pound) and length (arshin and sazhen'), made them from special alloy (Pt-Ir) and calibrated in Paris. Then he built an observatory and labs for study the standards of other physical units (time, pressure, electric current, light etc.), and in the later period explored the ways of their measurements with unbelievable accuracy, see e.g. his monograph **(14)**. (One such device of his design is now known as Mendeleev balances.) He assisted opening the depots of standards (verification offices) in most big cities and suggested stepwise-harmonized plan for Russia to join the International metric system and the Calendar.

[xxviii]. Witte and Mendeleev had shared viewpoints on key aspects of modernization of the country, and The Minister used the authority of The Scientist to convince the Tsar in necessity of certain economical reforms (like protective system, nationalization issues or stable golden ruble concept). Mendeleev contributed to such reforms through his talks, reports and recommendations. His public activity involved him in many disputes with angry mass media and private business.

He visited the Urals and wrote a book with the detailed plan of its industrialization. He thoroughly elaborated a program of reforms in high and middle education with suggestions to cancel examinations. He collaborated with Navy and assisted to open first ship-testing basin, although the ministry refused another his project - icebreaker of his own design to explore Arctic. He wrote excellent popular chapters on miscellaneous topics to Encyclopedia. Furthermore, Mendeleev combined all these activities with significant extension of his Foundations of Chemistry (7th edition, 1903). Evolution of his thoughts on the Ether was published in 1902 in the book **(15)**. He finally turned to the topics of demography, politics and problems of society, and expressed his futuristic and philosophical ideas in the last books **(16)** and **(17)**.

In 1905 he wrote in the diary: "only four subjects built my name: the Periodic Law, the study of elasticity of gases, understanding of solutions as associates, and the "Foundations of Chemistry". A year later, in his letter to Witte, Mendeleev considered his life as three services: first - research, second - teaching, and third - less visible service to the national industry. Decades later the physicist Vavilov called him as "physicist in chemistry and chemist in physics".

He never received the Nobel price. After 1904, when the prize was given for the discovery of noble gases - a novel group in the Periodic system - chemists revived the interest to the system creator. Mendeleev was nominated in 1905, but the prize was given to Bayer. Mendeleev was nominated again in 1906, but the prize now was given to Moissan. (Both times Mendeleev was second in the list.) Mendeleev was nominated third time for the year 1907, before the deadline on Jan. 31. Too late.

On Feb. 2, 1907 Dmitriy Ivanovich Mendeleev died from influenza. Streets were crouded. The funeral procession was headed by students who carried in their hands big Periodic table.

Memorial places

St. Petersburg: Memorial Mendeleev Museum-Archive at the University (apartments where he lived in 1866-1890); Metrological museum at the Institute for metrology (apartments where he lived in 1892-1907) at the Metrology Institute (with the Periodic system on the stone wall). The grave of Mendeleev (and many his relatives) is at the Volkov cemetery. Tobolsk: Mendeleev museum; the grave of his father. Boblovo: memorial museum (still under restoration.) St. Petersbug, Udomlya, Simferopol, Odessa and some other places have memorial signs on the buildings where he lived or worked. Moscow: compact exposition in Politechnical museum (with the basket from Mendeleev baloon). Heidelberg: the house where he lived (Schulgasse 2) is preserved. Connecticut: Mendeleev

name is drawn at the unique science wall of honor commemorating 37 of the world's "Immortals of Science" at the University of Bridgeport.

Named in memory of Mendeleev

Mendelevium, the chemical ***element*** No.101 (Md) without stable isotopes. Half-life time for isotopes is 51 day (for M=258) and 28 days (for M=260). Discovered by A. Ghiorso, G.R. Choppin, B.G. Harvey, S.G. Thompson and G.T. Seaborf (Berkeley, USA) in 1955.

Mendeleevit, a ***mineral*** of general formula $Ca_2UTi_2Nb_2O_{13}$ (with up to 26% of U_3O_8) from the family of pyrochlores. Radioactive. Crystal structure (habitus) dodecahedral and octahedral. Rigidity 4 - 5,5; density 3,7 - 5 g/cm^3; color black; very rare. Described by geologist K. Egorov in 1912 near the Lake Baikal, Siberia. The name assigned by V. Vernadskii in 1914.

Mendeleev, an ***asteroid*** No. 2769. Small planet (diameter 21.6 km, period 5.55 years) between Mars and Jupiter discovered on Apr.1, 1976 by astronomer N.S. Chernykh from Crimean observatory.

Mendeleev, a ***crater on*** the dark side of ***the Moon*** (5°42'N, 140°54'E) with the diameter 313,0 km. First pictured by Soviet automatic space ship "Luna-3" on Oct. 7, 1959 (at 6:30), and the photo appeared in world's newspapers on Oct. 27. The name was adopted on March 18, 1960 by International Astronomic Union. The nearby catena (6°3'N/139°4'E, diameter 188 km) later pictured by Apollo is also called Mendeleev catena.

Mendeleev, an ***undersea ridge*** in Arctic Ocean (between the islands Vrangel and Elsmir). Length ~1500 km, width 900 km, height up to 3-4 km. Discovered in 1948 (later examined in 1954) by Soviet polar expeditions. Confirmed as being geologically the part of Russian continental shelf by "Transarctika-2000" expedition.

Mendeleev, a ***mountain peak*** with elevation 4122 m in Tien-shan Mountains near Issyk-Kul Lake, Kyrgystan. First climb reported at 1954; initial name Mendeleevetz.

Mendeleev, a ***volcano*** on the Kunashir island at Southern Kurile Islands (44°0'N, 145°7'E) with elevation 887 m. It is a stratovolcano last erupted in 1880. Named after 1946.

Mendeleev ship, a research ***vessel*** of Soviet Academy of Science (built in 1968 at Wismar Werft, Germany; destroyed in 2001, at Bhavangar). With displacement of 6840 tons, a space for 77 scientists and 10 laboratories it served for science 24 years and made 50 cruises through all globe's oceans. After its resource was exhausted, the enthusiast made from its details a museum in Shirshov Oceanography Institute.

Mendeleevsk is an industrial ***city*** in Tatarstan, Russia (N55°54' E52°21'), and the name of local newspaper sounds exactly like "Mendeleev's News"). The name Mendeleevo is assigned to the ***airport*** of Yuzhno-Kurilsk as well as to several ***villages*** and small ***towns*** in the regions of Tobolsk, Moscow, Perm', and Tula. In the Far East, at Komsomolsk-na-Amure, there is a small Mendeleev ***island*** (at the delta of Amur river), and on the "Far West" in Kaliningrad - the Mendeleev ***lake***. On maps of most Russian big cities one can find Mendeleev ***Street*** (in two capitals it is linked to Chemistry departments of Moscow and St.-Petersburg universities). Such street also exists in Bucharest and some other cities abroad, and Mendeleevskaya is the name of Moscow underground ***metro station***.

Mendeleev Public Library exists in Tyumen, and recently a business center "Mendeleev-house" appeared there. The students of Ekaterinburg may enjoy staying at "Mendeleev" jazz-and-rock cafe and being careful with vodka "Mendeleev". Mendeleev portraits can be found not only in picture galleries, but also at Russian stamps and even Ruble coins. In the new Millennium "Mendeleev 4.0" is the template for chemical formula in Microsoft Word.

Nowadays it is possible to graduate from Mendeleev school (like that in Udomlya) or Mendeleev College (at Novosibirsk or St.-Petersburg), attend Mendeleev Chemistry Olympiad, study at Mendeleev Technical University (in Moscow) or at Mendeleev Pedagogical Institute (in Tobolsk), work at Mendeleev Oil-refinery (at Yaroslavl') or

continue research at Mendeleyev Institute for Metrology (at St.-Petersburg), attend regular Mendeleev Congresses, organized by Mendeleev Chemical society, and even receive the Mendeleev Golden Medal from National Academy (of course, after publication at Mendeleev Communications).

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