
HISTORY OF CHEMISTRY AND CHEMICAL TECHNOLOGY

175 Years of Manufacture of Platinum Metals in Russia

The history of platinum manufacture in Russia and the development of research in this field have been the subject of several papers [1–6]; however, all of these cover the period of time before the 1940s. For various reasons, the manufacture of these metals in later period has not been discussed. Here we consider, after a brief review of the main stages of development of the manufacture of platinum-group metals on the basis of the Ural deposits, materials related to manufacture of platinum and concomitant elements from sulfide copper–nickel ores of the Norilsk deposit.

As far back as the early XVIII century, the Europe was well aware of the existence of platinum, which was imported from South America only. The annual production and consumption of platinum were within 320–560 kg. In Russia, platinum-containing samples of osmious iridium were found in gold fields of Upper Iset and Neiva districts in the Urals only in 1819. This stimulated further prospecting for platinum deposits. Purely platinum placers were discovered in the Gornaya Blagodat district in 1824, and in Nizhni Tagil district in the Urals in 1825. By order of the minister of finance, count E.F. Kankrin (1774–1845), who stimulated in every possible way prospecting for, and mining of platinum, all the metal (“raw” platinum) was delivered to St. Petersburg. Samples were analyzed at the laboratory of the Mining Military College (now Mining Institute) by V.V. Lyubarskii (1795–1852). Previously, in 1823, he also analyzed samples of osmious iridium. Having graduated from the Mining Military College in 1816, Lyubarskii worked for several years at laboratories of Ural plants, and then, in 1820–1827, at the laboratory of the Mining Military College, which was rebuilt and expanded in 1826 and later merged with the laboratory of the Department of Mining and Salt Affairs to become United Laboratory of the Department of Mining and Salt Affairs, Mining Military College, and Mining Apothecary [7]. The new laboratory was headed by P.G. Sobolevskii (1781–1841), who played an outstanding part in the development of processes for industrial refining of platinum and production of ductile platinum [7–9]. Sobolevskii graduated from a military educational institution (1798) and then was first in military and then in state service; in 1817–1824, he was an engineer at the Kama–Votkinsk iron-making

plant, and in 1819, became manager of the plant. In 1824, Sobolevskii returned to St. Petersburg and took part in the organization of the United Laboratory and remained its head till the end of his life. For his scientific merits, he was elected corresponding member of the St. Petersburg Academy of Sciences in 1830.

Sobolevskii and Lyubarskii developed a relatively simple, but, at the same time, rather efficient method for refining of raw platinum and its conversion into ductile metal and laid foundations of powder metallurgy [10]. From May till November 1826, about 1600 kg of raw platinum was processed. In 1828, export and trading of raw platinum were prohibited. In the same year, Russia started mintage of platinum coins, which continued till 1845. During this period of time, the production of raw platinum markedly increased, to become 3490 kg in 1843. Before that time, platinum and its compounds had been studied in Russia by A.A. Musin-Pushkin (1760–1805), a chemist, mineralogist, honorary member of the St. Petersburg Academy of Sciences (since 1796), and vice-president of Berg Kollegiya (Mining Board) [11]. In 1797–1805, he published 23 papers devoted to platinum and suggested an original method for production of ductile platinum. Musin-Pushkin’s studies favored the development of methods for analysis and refining of platinum metals in Russia.

To the most important events associated with studies of platinum metals belongs the discovery of ruthenium in 1844 by K.K. Klaus (1796–1864), a professor of Kazan University. Klaus started research in chemistry of platinum metals, which led to this discovery, in 1841. Having headed the chair of pharmacy at Dorpat University on returning in 1852 to his native Dorpat (now Tartu, Estonia), he continued studies in chemistry of ruthenium, osmium, and other platinum-group metals [12, 13]. Klaus wrote fundamental monographs *Issledovaniya ostatkov Ural’skoi platino-voi rudy i metalla ruteniya* (Studies of Residues of Ural Platinum Ore and Ruthenium Metal, 1845) and *Materialy k khimii platinovykh metallov* (Materials for Chemistry of Platinum Metals, 1854). The first of these was awarded the Demidov prize by the St. Petersburg Academy of Sciences. A hundred years after,



K.K. Klaus.

Klaus's works were republished in the series *Klassiki nauki* (Classics of Science).

Klaus suggested new techniques for refining of platinum metals, described methods for their tests for purity, considered properties of a large number of compounds of these metals, and suggested procedures for analysis of "platinum residues." In contrast to his predecessors, who studied separate problems of chemistry and metallurgy of platinum, Klaus created the chemistry of platinum metals of that time [4].

From 1841 till 1867, platinum was refined at St. Petersburg Mint. After mintage of platinum coins was terminated (June 1845), export of platinum obligatorily refined at the Mint was allowed. Thus, the refining works continued to exist in Russia, but it terminated in 1867 when export of raw platinum was allowed.

In 1879, platinum refining was commenced in limited amounts (130–150 kg in a year) at the Tentelevskii chemical plant (St. Petersburg). However, this plant, and also another small plant refining platinum in St. Petersburg, belonged to foreigners. About 10–13% of platinum produced at the Urals was refined. As noted in [4], 92% of investment into the Ural platinum industry belonged to foreigners. At the same time, the Ural platinum fields gave more than 90% of world's platinum.

Quite a number of known Russian geologists were engaged in studies of platinum deposits in the Urals. A.A. Inostrantsev (1843–1919), a professor of St. Petersburg University, published in 1893–1894 studies of bedrock deposits in the Nizhni Tagil district. By

that time, only placer deposits were used in the Urals. Bedrock deposits, whose disintegration produced placers, had not been studied. The geology of bedrock deposits was also the subject of a study by Academician A.P. Karpinskii (1846–1936), published in 1893. During many years, the platinum deposits of the Urals were studied by N.K. Vysotskii (1864–1932), a geologist from St. Petersburg. The platinum deposits of the Nizhni Tagil district were described in a paper by N.A. Zavaritskii (1884–1952), published in 1909. A number of Ural platinum deposits were described by F.Yu. Levinson-Lessing (1861–1939), a professor of St. Petersburg Polytechnic Institute, in his publications of 1909–1910.

In the field of chemical analysis of minerals containing platinum metals, much was done by B.G. Karpov (1870–1940). Having graduated from the St. Petersburg University (1896) with first-degree diploma, he started to work as chemist-analyst at the Geological Committee (St. Petersburg). Already in 1900, Karpov established for the first time, together with A.A. Antipov (1858–1911), the presence of uranium in the geological material from Fergana province. In the same year, he was sent to a business trip abroad for further improvement of his skills and worked at H. Le Chatelier's laboratory (1850–1936) in Paris. Beginning in 1907, Karpov specialized in analysis of platinum metals. He wrote a manual *O metodakh analiza samorodnoi platiny* (On Methods for Analysis of Native Platinum) and made several hundred analyses of both native platinum and platinum ores from Ural deposits [4, 14].

In the late XIX century, Professor N.S. Kurnakov (1860–1941, academician since 1913) carried out at the chemical laboratory of the Mining Institute studies in chemistry of complex compounds of platinum-group metals [6, 15, 16]. Already the first scientist's communication devoted to this subject, on "products of thiourea combination with platinum salts" (1889), aroused much interest among chemists. The results of the study were included by D.I. Mendeleev (1834–1907) in the fifth edition of *Osnovy khimii* (Fundamentals of Chemistry). Later (1889–1893), these studies were continued. It was emphasized in the monograph [15] that Kurnakov was the first among Russian scientists to appreciate the coordination theory of A. Werner (1866–1919), an outstanding Swiss chemist, later a Nobel Prize laureate (1913). The results of Kurnakov's studies in the field of chemistry of complex compounds were summarized in a separate collection of works [17].

At the turn of the XX century, it became clear that chemistry of platinum metals is intimately associated with chemistry of coordination compounds. Platinum metals form various complex compounds characterized by high stability. Already in the beginning of the XX century, investigations carried out by L.A. Chugaev shifted the center of research in the field of complex compounds and also in chemistry of platinum metals to Russia [6]. Chugaev graduated from the natural department of the physicomathematical faculty at Moscow University in 1895. The initial period of his scientific activities was devoted to studies of organic compounds. In 1903, Chugaev defended his master dissertation "Studies in the Field of Terpenes and Camphor." However, his doctoral dissertation "Studies in the Field of Complex Compounds" (1906) was devoted to synthesis and studies of properties of compounds formed by a number of metals, including platinum and palladium, with imides and α -dioximes. In the following years, Chugaev's interests were focused exclusively on the chemistry of coordination compounds. Chugaev was a professor of the Moscow Higher Technical School (1904–1908) and extraordinary (since 1908) and ordinary (since 1911) professor of the St. Petersburg University [18].

As already noted, Russia was the main supplier of platinum to the world market at the beginning of the XX century, but platinum refining was not performed on due scale. The question of necessity for organization of industrial refining of Ural raw platinum was raised by Russian scientists more than once; however, this was hindered by the existing Russia's treaty commitments. The export of raw platinum was completely prohibited only after the beginning of World War I.

In July 1914, the government made a contract with the management of the Joint-Stock Society of Nikolae-Pavda mining district to build and equip in accordance with the requirements of modern technology a refining plant in Yekaterinburg with annual output capacity of no less than 450 poods (~7400 kg) and manufacture simple articles from refined platinum [5, 6, 19]. The government surrendered its rights to build a state-owned plant for platinum refining to the joint-stock society.

In February 1915, the Permanent commission for analysis of natural productive forces of Russia (KEPS) was organized by decision of the Academy of Sciences, and Academician V.I. Vernadsky (1863–1945) was appointed its chairman, and Academician Kurnakov, its vice-chairman. In his keynote address devoted to the goals of the Commission, Vernadsky mentioned that, for Russia's natural resources to be used proper-



L.A. Chugaev.



N.N. Baraboshkin.

ly, "it is necessary to go Russia's own way without using as prescriptions the achievements of the West or America... We must search not only for sources of new natural productive forces in our country, but also for methods and procedures for their use, and devise these methods" [20].

In August 1915, the Nikolae-Pavda joint-stock society invited mining engineer N.N. Baraboshkin (1880–1935) to head work on building of a refining plant in Yekaterinburg. N.N. Baraboshkin entered the Mining Institute in St. Petersburg in 1899 and graduated therefrom in 1914, having worked during his education period in gold and platinum fields of the Urals and Siberia and at other metallurgical plants. Beginning in 1911, he made a great number of analy-



O.E. Zvyagintsev.

ses of platinum metals at a laboratory of the Mining Institute. Karpov's paper [21] mentions that "It is necessary to mention as one of the most outstanding representatives of Kurnakov's analytical school N.N. Baraboshkin, who applied to the greatest extent his analytical talents to studies of analysis of platinum ore and products of its processing. These studies... brought to him honorable fame and key position at... the refining plant." In 1914–1915 at the Mining Institute, N.N. Baraboshkin was engaged, together with N.I. Podkopaev (1872–1930), in improvement of methods for platinum refining, with the result that the Klaus–Baraboshkin method was devised and later used for a long time at the refining plant [6, 22]. At the beginning of 1916, a temporary laboratory for refining and production of technical-grade spongy platinum, headed by N.N. Baraboshkin, was put into operation. In October of the same year, the construction of the first Russia's refining plant was, for the most part, finished. The commonly accepted official data of its starting-up is October 10 (23), 1916, when the Ministry of Trade and Industries approved a special "Instruction" regulating all aspects of the functioning of the new plant. From November 1916 till November 1917, 900 kg of platinum was refined; by the beginning of 1918, the output capacity of the refining plant reached 400 kg of platinum per month and increased gradually. However, on February 6 (19), 1918, the plant was nationalized and soon was closed. The civil war suspended work on platinum refining, but the plant was not evacuated and all the equipment remained intact. Mainly owing to N.N. Baraboshkin's efforts, the refining plant resumed its work in the

spring of 1920. Soon, other metals started to be produced together with platinum: palladium in 1922, iridium in 1923, rhodium in 1925, osmium in 1927, and ruthenium in 1930. Manufacture of extra-brand platinum was started in 1928, melting of platinum to obtain platinum bullion, in 1923, and manufacture of platinum alloys and fabrication of articles from platinum and platinum alloys, in 1928.

Professor N.N. Baraboshkin was one of organizers of higher metallurgical education in the Urals, headed metallurgical chairs at the Ural Polytechnic Institute, and dealt with a wide variety of issues related to manufacture of copper and nickel at plants of the Ural region [19, 23–25].

The achievements in refining of platinum and associated metals were closely related to wide-scale studies carried out, in the first place, in Petrograd. On Chugaev's initiative supported by academicians Kurnakov and A.E. Fersman (1883–1945), the Institute of Platinum and Other Noble Metals (Platinum Institute) was organized in Petrograd in April 1918 [26, 27]. This made it possible to unite specialists working in the field of chemistry of platinum metals at laboratories of the University, Mining and Polytechnic Institutes, and some other institutions. The explanatory memorandum devoted to the organization of the institute read: "Platinum-group metals, i.e., platinum, iridium, rhodium, palladium, osmium, and ruthenium, constitute the exclusive national treasure of the Russian state, since more than 95% of the whole world's production of placer platinum falls on Russia..." [4]. Chugaev was appointed the first director of the Platinum Institute. The aims of the Institute, formulated by its director, were diverse and extensive, with the development of methods for separation of platinum and associated metals and their manufacture in pure state occupying the first place [28]. After the untimely death of Chugaev in September 1922, Kurnakov was elected director of the Institute. During the entire period of his scientific activities, Kurnakov was incessantly interested in platinum and other platinum-group metals: in their complex compounds, manufacture technology, alloys on their base, and use of the metals and alloys in various fields of technology.

In 1922, the State Association of plants producing and processing platinum, Uralplatina of VSNKh (Supreme Council for National Economy), was created. In agreement with this association, the Platinum Institute engaged itself in a number of investigations in the field of refining and analysis of platinum metals. To accomplish these tasks, two commissions were organized at the Institute: that of refining, headed by

Kurnakov, and analytical, headed by Karpov. A number of known specialists working at the Platinum Institute were, simultaneously, members of both the commissions: S.F. Zhemchuzhnyi (1873–1929), O.E. Zvyagintsev (1894–1967), and V.V. Lebedinskii (1888–1956). A detailed report about the activities of the Platinum Analytical Commission can be found in [21]. A major contribution to the organization of joint work of Uralplatina and the Platinum Institute was made by Zvyagintsev, an engineer at Uralplatina in 1922 to 1926 and later one of the leading Russian specialists in chemistry, geochemistry, and technology of platinum metals, the author of a number of monographs and books on history of chemistry [29].

In 1923–1925, KEPS, Russian Academy of Sciences, initiated publication of capital work of N.K. Vyotskii [30], devoted to deposits, production, and refining of platinum in Russia. Results obtained in studies carried out by staff members of the Institute of Platinum and in other investigations in the field of chemistry of platinum metals appeared on regular basis in *Izvestiya Instituta* (Transactions of the Institute), which started to be published in 1920.

In 1919, in lower reaches of the Yenisei River, beyond the Polar circle, prospecting for deposits of coal and other minerals was commenced, with only rather scarce relevant information available. The expedition was led by N.N. Urvantsev (1893–1985), a young mining engineer and graduate of the Tomsk Technological Institute [31]. The systematic studies carried out in the following years on the southern periphery of the Taimyr tundra led to discovery of a coal field and deposits of copper–nickel ores containing platinoids, which constituted the mineral and energy base for Norilsk mining-and-smelting combine. The decision to construct the combine was made by the Council of People's Commissars of the USSR on June 23, 1935. The implementation of the plan was entrusted to Chief Administration of Prison Camps (GULAG). The exceedingly severe climate of the Polar region made construction under the ever-frost conditions a very complicated task. Nevertheless, first hundreds of tons of raw nickel were obtained in 1939, production of electrolytic nickel commenced in the spring of 1942, that of electrolytic copper, in 1943, and that of cobalt, in 1944. As nickel and copper were produced, platinoid-containing sludges were accumulated.

On April 7, 1939, the country's leadership made a decision to construct a refining plant in Krasnoyarsk. The construction and functioning of the plant were also entrusted (till 1953) to NKVD (People's Comis-

sariat for Internal Affairs). The construction site was chosen with participation of Zvyagintsev. The design was made by specialists of the Soyuznikel'olovoproekt Institute (now Gipronikel' Institute, St. Petersburg), with participation of specialists from the Institute of General and Inorganic Chemistry, Russian Academy of Sciences, and Mining Institute. Professors N.P. Aseev (1871–1952), K.F. Beloglazov (1887–1951), N.S. Greiver (1900–1971), and Yu.V. Morachevskii (1894–1961) took part in extensive studies of the behavior of platinum metals in processing of sulfide copper–nickel ores, carried out at the Leningrad Mining Institute.

The refining plant in Krasnoyarsk was constructed in severe war years; however, already in November 1942, the first batch of sludges formed in nickel electrolysis was delivered to the plant for processing. On March 23, 1943, first platinum (1291 g) and palladium (3235 g) were produced on the pilot installation from Norilsk sludges. This date is considered the birthday of the Krasnoyarsk Refining Plant (Krasnoyarsk Plant of Nonferrous Metals since 1967). On June 1, 1943, the plant commenced manufacture of finished products in conformity with the established State plan. In May 1944, manufacture of rhodium was started. In January 1945, the main shop for refining of platinum and palladium was put into operation and large-scale manufacture of these metals was commenced. In 1946–1947, melting of platinum and palladium was made possible and manufacture of these metals in the form of bullion was organized. In November 1946, recovery of ruthenium by distillation with ammonium persulfate was started. In 1948, processing of Ural placer platinum and secondary raw materials containing precious metals was organized. In May 1950, a technology for electrochemical recovery of gold from solutions to give commercial technical-grade metal was developed. In 1952, a method for electrochemical recovery of rhodium from solutions of its pure salt was introduced into practice [32].

In September 1994, Russia's largest goldsmith's work was created, and in 1996, an effective technology for gold and silver refining was developed.

Together with the traditional research centers at which sulfide copper–nickel ores and chemistry of platinum-group metals were studied, scientists and specialists exiled to Krasnoyarsk (professors I.Ya. Bashilov and S.M. Anisimov) or detained there (professors R.L. Myuller and V.V. Nedler, engineers K.K. Beloglazov, A.P. Sergeev, A.N. Fedorova, and others) much helped to staff members of the plant during its early years, in 1943–1953, in developing

the technology for processing of novel types of raw materials and refining of platinum metals.

I.Ya. Bashilov (1892–1953) studied at the Petrograd Polytechnic Institute. Already in 1921, he, together with V.G. Khlopin (1890–1950, member of the Academy of Sciences of the USSR since 1939), developed and implemented a technology for production of radium and other valuable components (uranium, vanadium) from the ore delivered from Central Asia (Fergana). In 1932, he created and headed the chair of rare metals at the Moscow Institute of Fine Chemical Technology. In the same year, Bashilov was appointed scientific supervisor of the Institute of Rare Metals (Giredmet). In August 1938, professor Bashilov, one of those who organized the industry of radioactive and rare metals in Russia, was groundlessly repressed and, on finishing his detention term in June 1943, sent to Krasnoyarsk, to the refining plant [32–35]. First, he worked as researcher and then as head of the research department of the Central factory laboratory. Despite the previous conviction, which was not expunged, Bashilov was awarded a State Prize in 1948. Already after the scientist's death, the decision of the Special Board of NKVD of February 14, 1939, was repealed by the Supreme Court of the USSR on January 30, 1957 "because of the absence of a crime."

S.M. Anisimov (1901–1970), a disciple of a prominent metallurgist V.Ya. Mostovich (1880–1935) and a professor of the North-Caucasian Mining-and-Smelting Institute (Vladikavkaz), was repressed in 1941, served his sentence at Norilsk labor camps, and then worked at the Krasnoyarsk Refining Plant. He did much in organizing at the plant an assay laboratory for analyzing raw, and other industrial, materials with low content of noble metals. Anisimov paid much attention to training plant's staff members for assay techniques and carried out a number of technological studies [32]. In 1954, Anisimov was fully rehabilitated, returned to Vladikavkaz, and headed the chair of metallurgy of noble and rare metals at the same institute as before.

Head of the chair of electrochemistry at Leningrad University, professor R.L. Myuller (1899–1964) was sentenced to 10 years of imprisonment for "anti-Soviet propaganda" [36, 37]. In 1946–1949, Myuller demonstrated, together with specialists from the plant, the possibility of using electrochemical methods in various stages of the refining process. A shop for fractional electrolysis operated at the plant for a long time. Such methods as cathodic deposition of metallic rhodium from solutions of hexachlororhodic acid and

electrochemical purification of iridium solutions proved to be successful [32].

In 1956, after full rehabilitation, Myuller resumed his rather successful scientific activities at the Leningrad University.

V.V. Nedler (1908–1997), a known physicist-spectroscopist from Moscow, served his four years term of imprisonment in Krasnoyarsk. His contribution to implementation of spectral analysis at the plant and personnel training is invaluable. In the early 1950s, spectral analysis became the most important method for monitoring processes, testing the quality of finished products, and analyzing other materials at a plant. On returning to Moscow, Nedler, a doctor of chemical science, professor, and State Prize laureate, worked successfully at Giredmet Institute for many years [38]. The organization at the plant of a research department, which actually functioned as an applied-research institute, was much assisted by scientists from the Institute of General and Inorganic Chemistry, Academy of Sciences of the USSR: Academician I.I. Chernyaev, corresponding members of the Academy of Sciences of the USSR Lebedinskii and N.K. Pshenitsyn, Professor A.M. Rubinshtein, and, especially, Professor Zvyagintsev. I.I. Chernyaev (1893–1966), a disciple and follower of Chugaev, graduated from the Petrograd University in 1915, worked at the Institute of Platinum in 1918–1934 and at the Institute of General and Inorganic Chemistry, Academy of Sciences of the USSR beginning in 1934; in 1941–1966 he was director of the Institute. Chernyaev was a prominent specialist in chemistry of complex compounds and discoverer of the *trans* effect. The methods for osmium recovery from ore and production of high-purity platinum, developed by Chernyaev, are used in the industry. Beginning in 1918, Lebedinskii and N.K. Pshenitsyn (1891–1961), graduates from St. Petersburg (Petrograd) University and Chugaev's disciples, worked at the Institute of Platinum and at the Institute of General and Inorganic Chemistry, Academy of Sciences of the USSR. The main Lebedinskii's investigations were devoted to methods for production and refining of rhodium. Pshenitsyn made a major contribution to analytical chemistry of platinum metals and developed an industrial method for iridium recovery [16, 26].

Of promise and interest are investigations in the field of electrocrystallization and refining of platinum metals with molten electrolytes, carried out the most extensively at the Institute of High-Temperature Electrochemistry, Russian Academy of Sciences, Yekaterinburg and also at the Yekaterinburg Plant for Proc-

essing of Nonferrous Metals (former Refining Plant). These studies were initiated and supervised by Academician A.N. Baraboshkin (1925–1995), N.N. Baraboshkin's son [39].

Platinum-group metals play an important part both in monetary reserves of states and in quite a number of diverse, and newest branches of technology [40]. Platinum metals, and also their alloys and compounds, are irreplaceable in electronics, radio engineering, instrument building, chemical and petrochemical industries, space and nuclear engineering, medicine, and goldsmith's works. Platinum and platinum–rhenium catalysts are used in manufacture of high-octane gasoline and numerous monomers for manufacture of synthetic rubber and other synthetic materials. Platinum metals and their alloys are used in fuel cells, microelectronics, growth of single crystals of precious gems, and special glass making. Alloys of platinum with rhodium and palladium neutralize noxious components of exhaust gases of internal combustion engines.

By the end of the XX century, the share of Russia and Republic of South Africa (RSA) exceeds 92% of world's production of platinum metals and 96% of their resources [41]. However, the structures of resources and production in these countries differ significantly. Platinum predominates in RSA ores and its output is approximately twice that of palladium. By contrast, the palladium resources in raw materials in Russia much exceed those of platinum, and, therefore, producing a comparable amount of palladium, our country lags far behind RSA (by a factor of more than 4.5) in production of platinum. An analysis of the world market of platinum metals in the 1990s was made in [41]. During the period from 1993 to 1998, the world consumption of platinum-group metals increased by 74% (from 263 to 458 tons), and that of platinum, by 41.7% (from 126 to 179 tons).

In Russia, more than 98% of the proven resources of platinum-group metals is concentrated in the Arctic zone, with more than 95% of these metals manufactured from sulfide copper–nickel ores of the Norilsk industrial region [40, 42, 43]. The factors determining the unique properties of Norilsk platinoid–copper–nickel ores have been analyzed by D.A. Dodin *et al.* [43, 44]. However, the fraction and quality of ores rich in platinum metals delivered to the Norilsk mining-and-smelting combine decreases gradually. In this context, much attention is given by the program “Platinum of Russia” (1992) to studies of new, untypical of Russia, kinds of platinum-containing raw materials [40, 44–46].

Russia possesses sufficient natural resources for extending the existing, and creating new, sources of raw materials for production of platinum metals and raising their manufacture in order to ensure the leading position in the world market in the XXI century.

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