REVIEW

of supervisor on the dissertation work written by Mussapyrova Lyazzat Arkhatovna "Hydrometallurgical processing of copper smelter slags", presented for the degree of Doctor of Philosophy (PhD) in the specialty 6D072000 "Chemical technology of inorganic substances"

Mussapyrova Lyazzat Arkhatovna in 2013 graduated from the bachelor's degree at the Faculty of Chemistry and Chemical Technology, al-Farabi Kazakh National University; in 2015 she graduated from the magistracy at the specified faculty, and in 2017 she entered the doctoral program in the specialty "Chemical technology of inorganic substances". The title "Hydrometallurgical processing of dump copper slag" was approved as the topic of the thesis.

The chosen topic of work is of high relevance. A decrease in reserves of copper and zinc ores, both in Kazakhstan and in the world, and a decrease in the content of target components in them, make it necessary to seek new raw materials for these metals. Such a resource is potentially copper smelter slag. This slag is a by-product of pyrometallurgical copper production. Each ton of refined copper is accompanied by an average estimate of 3 tonnes of slag. The content of copper and zinc in the slag is about 0.7 and 5%, respectively, which is comparable (and in some cases even higher) with the content of these metals in ores. The features of the mineralogical composition of the dump slag are such that it is a rather difficult task to extract zinc and copper from it. Due to the high-temperature transformations of the charge in the smelting furnaces, fayalite (Fe_2SiO_4) is formed, in which the target minerals of zinc and copper are impregnated. The processes of pyrometallurgical processing of copper smelter slag, which make it possible to achieve a high extraction of the indicated non-ferrous metals, have been well studied; however, for economic reasons, pyrometallurgical processing of the slag is impractical. At present, the copper smelter slag is subjected to flotation enrichment to obtain copper concentrate, however, the technical and economic indicators of this approach do not allow it to be regarded as satisfactory.

In her dissertation work, Mussapyrova Lyazzat tried to develop a scheme for the hydrometallurgical processing of copper smelter slag using sulfuric acid solutions as the main leaching agent. To increase the reactivity of the target minerals copper and zinc in the slag, mechanical activation of the starting material was used in a planetary ball mill, as well as in an attritor. Besides, an attempt was made to selectively recover copper from slag using potassium dichromate as a component of the leach solution. During implementing dissertation work, Lyazzat perfectly mastered such experimental methods as mechanical activation of solid bulk materials in a planetary ball mill and in an attritor, leaching of target components from solid crushed raw materials with varying experimental factors. To process the experimental results, a number of statistical methods were involved, including the Taguchi method, as well as analysis of variance (ANOVA).

All the tasks set in the dissertation work have been completely solved. The main kinetic parameters of sulfuric acid leaching of copper, zinc and iron from copper

smelter slag have been determined. The influence of the conditions of slag mechanical activation on its characteristics, as well as the subsequent recovery of the target components during leaching, is found. The conditions for the mechanical activation of the slag and the subsequent sulfuric acid leaching of the slag in the presence of potassium dichromate are optimized to maximize the degree of copper extraction, as well as the selectivity of the extraction of the specified metal. A schematic diagram of low-temperature two-stage sulfuric acid leaching of copper smelter slag has been developed.

The results of the dissertation are of great theoretical and practical significance, and contribute to the knowledge of mechanical activation and sulfuric acid leaching of copper smelter slag.

Methods such as X-ray diffractometry, scanning electron microscopy, atomic absorption spectrometry, nitrogen adsorption to determine the specific surface area, dynamic light scattering to determine the particle size distribution, and others were used to characterize the starting, intermediate and final materials. Statistical processing of the experimental results was carried out in accordance with generally accepted methods.

In doctoral studies, Mussapyrova L.A. proved herself to be a responsible and executive young scientist. Good theoretical knowledge and experimental skills allowed her to complete her dissertation work at a high level.

Mussapyrova L.A. published personally and co-authored 8 scientific papers, including one article by the first author in the «Journal of Materials Research and Technology», which is included in the first quartile (Q1) of the Web of Science database.

I strongly believe that Mussapyrova Lyazzat Arkhatovna deserves to be awarded the required academic degree of Doctor of Philosophy (PhD) in the specialty 6D072000 "Chemical technology of inorganic substances".

Supervisor,
PhD in Chemistry,
Professor of the Department of General
and Inorganic chemistry at al-Farabi KazNU **R.K. Nadirov**

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научных кадров КазНУ им. аль-Фараби
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