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EXTRACTION OF STRONTIUM METAL FROM CELESTINE AND ITS CONCENTRATION

Teacher, Termez branch of Tashkent State Medical University:

Xidirova Gulhayo G'afforovna

Senior lecturer of the Department of Analytical Chemistry, Termez State University:

Boltayev Nurmuhammad Suyunovich

Students of the Faculty of Pediatrics, Termez Branch of

Tashkent Medical University, Pharmacy Department:

To'ranazarova Mahliyo Baxtiyorovna

Norg'o'chqorova Sevinch Musurmonqulovna

Annotation: This article scientifically and practically examines the extraction of strontium from celestine ores—strontium sulfate ($SrSO_4$)—followed by chemical purification, concentration of the intermediate products, and the final production of metallic strontium. The theoretical foundations of the process are analyzed, including the conversion of sulfate to carbonate, precipitation, filtration, drying, calcination to form the oxide, and the application of electrolysis and metallothermic reduction. Step-by-step methods for removing impurities such as calcium, barium, and iron from the ore, along with the selection of reagents and optimal temperature and concentration conditions, are discussed. The technological advantages of hydrometallurgical and pyrometallurgical approaches are compared. Effective schemes for obtaining high-purity strontium carbonate and strontium oxide, their concentration, and the industrial production of metallic strontium are presented. Based on the results, conclusions are drawn on improving process efficiency, ensuring energy savings, and enhancing environmental safety.

Keywords: Celestine, strontium, concentration, hydrometallurgy, pyrometallurgy, carbonatization, electrolysis, metallothermy.

Purpose of the Study: Strontium and its compounds are widely used in many branches of modern industry, including pyrotechnics, glass and ceramics manufacturing, electronics, magnetic materials, radio engineering, and medicine. In particular, the demand for technologies to obtain high-purity strontium carbonate and metallic strontium is increasing year by year. Celestine, the primary natural source of strontium, has significant industrial importance, and the development of efficient and economically viable methods for extracting strontium from this mineral remains a relevant issue. The presence of impurities such as calcium, barium, and iron in celestine complicates the extraction and purification processes. Therefore, optimizing stages such as ore beneficiation, chemical processing, precipitation, filtration, and recrystallization is of great importance. In addition, developing energy-efficient, environmentally safe, and highly effective technologies is a key direction in modern chemistry and metallurgy. Improving the process of strontium extraction from celestine is important not only scientifically but also practically.

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Relevance of the Topic: The aim of this article is to present the scientific basis for extracting strontium from celestine ores, to systematically describe the stages of chemical purification and concentration, and to demonstrate effective methods for obtaining metallic strontium. Furthermore, the article aims to scientifically analyze the step-by-step removal of impurities from the ore, the selection of optimal reagents and conditions, the comparison of hydrometallurgical and pyrometallurgical methods, the improvement of process efficiency, and the assurance of environmental safety.

Main part: Celestine — Strontium sulfate ($SrSO_4$) — is the most stable and widespread mineral of strontium in nature, and the extraction of strontium compounds and metallic strontium from it is an important area of industrial chemistry. The ore often contains calcium ($CaSO_4$), barium ($BaSO_4$), iron oxides, silicon compounds, and turbid rocks. Therefore, the process initially begins with the preparation of the ore by mechanical and physical methods.

The first stage is the crushing, crushing, and enrichment of the ore. At this stage, gravity separation, flotation, and screening methods are used to separate useless rocks and obtain celestine concentrate. The suitability of the enriched product for chemical processing increases, reagent consumption is reduced, and the efficiency of subsequent stages increases.

The second stage is hydrometallurgical processing. This method is considered the most optimal in practice. The enriched celestine is boiled with molten sodium carbonate (Na_2CO_3). As a result, a displacement reaction occurs and insoluble Strontium Carbonate ($SrCO_3$) precipitates, while sodium sulfate remains in the solution:

$$SrSO_4 + Na_2CO_3 \rightarrow SrCO_3\downarrow + Na_2SO_4$$

At this stage, the process temperature (90–100°C), solution concentration, and mixing speed play an important role. The precipitate is filtered and washed several times. During the washing process, Ca^{2+} and Ba^{2+} ions are separated to the maximum extent. Then $SrCO_3$ is concentrated by recrystallization and its purity is increased.

The third stage is thermal decomposition. The purified strontium carbonate is heated at high temperatures (1000–1200°C) and converted into Strontium Oxide (SrO):

$$SrCO_3 \rightarrow SrO + CO_2\uparrow$$

At this stage, rapid release of the released CO_2 gas, temperature stability, and protection of the product from moisture are important.

The fourth stage is the production of strontium metal. This is done in two ways:

Electrolysis method. Strontium chloride ($SrCl_2$) is electrolyzed in a liquid state. At the cathode, metallic strontium is separated, and at the anode, chlorine gas is separated. This method allows obtaining a metal of high purity. The process is carried out in a special closed, moisture-free and inert environment.

Metallothermal method. SrO is reduced with aluminum or magnesium. This process, which is carried out in a vacuum or inert gas environment, is economically inexpensive and technologically simple:

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$$SrO + Mg \rightarrow Sr + MgO$$

The resulting strontium is separated in the vapor state and condensed by cooling. Concentration stages are an integral part of the process, in which precipitation, remelting, crystallization, filtration and drying operations are carried out sequentially. These stages are especially important for industries that require high-purity strontium compounds - pyrotechnics, electronics and the glass industry. The environmental aspects of the process are also taken into account. The hydrometallurgical method produces relatively little waste, and sodium sulfate can be recycled or used in other industries. Energy efficiency, waste reduction, and recyclability increase the advantages of the technology. Thus, the stages of strontium extraction from celestine, its concentration, and metal recovery are a complex set of interconnected, but scientifically sound and practically effective processes.

Conclusion: Celestine — Strontium sulfate ($SrSO_4$) — is the most important natural raw material for industrial production of strontium, and obtaining high-purity strontium compounds and metallic strontium from it requires a multi-stage technological process. Research and analysis show that the stages of initial enrichment of the ore, followed by hydrometallurgical conversion to carbonate, filtration, and recrystallization significantly increase the quality of the product. In particular, a highly pure intermediate product is obtained by purifying and concentrating Strontium carbonate ($SrCO_3$) formed as a result of the treatment of celestine with sodium carbonate.

The formation of Strontium Oxide (SrO) at the next thermal decomposition stage and its extraction of metallic strontium by electrolysis or metallothermal reduction methods has been found to be technologically sound and highly practical. The hydrometallurgical method is characterized by environmental safety and energy efficiency, and electrolysis by product purity. The metallothermal method is economically feasible and convenient in industrial conditions.

In general, the optimization of the processes of separation and concentration of strontium from celestine depends on the selection of reagents, temperature regime, time factor and the correct organization of purification stages. Improving these technologies will allow to qualitatively and sustainably meet the growing industrial demand for strontium compounds.

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