

IMPROVEMENT OF CAUSTIC SODA PRODUCTION TECHNOLOGY FROM MIRABILITE VIA THE LIME METHOD

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Abstract. The chemical industry is a strategic sector of any country's economy, requiring manufactured products to be based on advanced technologies and meet international standards.

Therefore, modernizing the chemical industry and widely implementing resource-saving and highly efficient technologies is one of the most pressing priorities in Uzbekistan. In this context, particular attention is paid to the efficient utilization of aqueous sodium sulfate solutions, minimizing the adverse impact of raw material impurities on process efficiency, increasing the reactivity of the lime suspension, and intensifying mass transfer during the causticization process. The main stages of the technological system under consideration include the dissolution of mirabilite, preliminary purification of the solution, monitoring the chemical transformations of sodium sulfate, separation of intermediate products, and the purification and concentration of the alkaline solution. The primary focus of optimization is directed toward the rational use of raw materials and reagents, reducing energy consumption, controlling the properties of generated solid residues, and enhancing the environmental performance of production.

Keywords: caustic soda, mirabilite, lime method, sodium sulfate, calcium hydroxide, sodium carbonate, physicochemical process, solubility polytherm, process flowsheet, material balance.

СОВЕРШЕНСТВОВАНИЕ ТЕХНОЛОГИИ ПРОИЗВОДСТВА КАУСТИЧЕСКОЙ СОДЫ ИЗ МИРАБИЛИТА ИЗВЕСТКОВЫМ СПОСОБОМ

Аннотация. Химическая промышленность является стратегической отраслью экономики любой страны, и к производимой продукции предъявляются высокие требования по использованию передовых технологий и соответствию международным стандартам. Поэтому модернизация химической промышленности Узбекистана, широкое внедрение ресурсосберегающих и высокоэффективных технологий являются одними из наиболее актуальных приоритетных задач. При этом особое внимание уделяется эффективному использованию водных растворов сульфата натрия, минимизации негативного влияния примесей сырья на эффективность процесса, повышению реакционной способности известковой суспензии и интенсификации массообмена в процессе каустификации. К основным стадиям рассматриваемой технологической системы относятся растворение мирабилита, предварительная очистка раствора, контроль химических превращений сульфата натрия, отделение промежуточных продуктов, очистка и концентрирование щелочного раствора.

Оптимизация направлена на рациональное использование сырья и реагентов, снижение энергозатрат, контроль свойств образующихся твердых остатков, а также на повышение экологических показателей производства.

Ключевые слова: каустическая сода, мирабилит, известковый метод, сульфат натрия, гидроксид кальция, карбонат натрия, физико-химический процесс, политерма растворимости, технологическая схема, материальный баланс.

MIRABILITDAN OHAK TA'SIRI USULIDA KAUSTIK SODA ISHLAB CHIQRISH TEKNOLOGIYASINI TAKOMILLASHTIRISH

Annotatsiya. Kimyo sanoati har qanday mamlakat iqtisodiyotining strategik tarmog'i bo'lib, ishlab chiqarilayotgan mahsulotlar ilg'or texnologiyalarga asoslangan va xalqaro standartlarga javob berishi talab etiladi. Shu bois O'zbekistonda kimyo sanoatini modernizatsiya qilish, resurs tejovchi va yuqori samarali texnologiyalarni keng joriy etish eng dolzarb ustuvor vazifalardan biri hisoblanadi. Bunda natriy sulfatning suvli eritmalaridan samarali foydalanish, xomashyo aralashmalarining jarayon samaradorligiga salbiy ta'sirini minimallashtirish, ohak suspenziyasining reaksiya qobiliyatini oshirish va kaustikatsiya jarayonida massa almashinuvini jadallashtirishga alohida e'tibor qaratilmoqda. Ko'rib chiqilayotgan texnologik tizimning asosiy bosqichlariga mirabilitni eritish, eritmani dastlabki tozalash, natriy sulfatning kimyoviy o'zgarishlarini nazorat qilish, oraliq mahsulotlarni ajratish, ishqoriy eritmani tozalash va konsentrlash kiradi. Optimallashtirishning asosiy yo'nalishi xomashyo va reagentlardan oqilona foydalanish, energiya sarfini kamaytirish, hosil bo'ladigan qattiq qoldiqlarning xossalari nazorat qilish hamda ishlab chiqarishning ekologik ko'rsatkichlarini oshirishga yo'naltirilgan.

Kalit so'zlar: kaustik soda, mirabilit, ohak usuli, natriy sulfat, kalsiy gidroksid, natriy karbonat, fizik-kimyoviy jarayon, eruvchanlik politermasi, texnologik sxema, moddiy balans.

INTRODUCTION

Currently, "Navoiyazot" is the only enterprise in the country producing caustic soda. Its annual production capacity is 26,000 tons, but this volume does not fully meet domestic demand.

Therefore, there is a clear need to increase caustic soda production and implement technologies based on inexpensive local raw materials. Developing and optimizing a technology for producing caustic soda from mirabilite ($\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$) in the presence of lime ($\text{Ca}(\text{OH})_2$) will contribute to the comprehensive processing of Uzbekistan's natural resources. The initial stage of process optimization begins with raw material preparation. Reducing mechanical impurities in the natural mineral, grinding the raw material to the required particle size, and determining its moisture content can enhance the stability of the dissolution process. However, excessive grinding can increase energy consumption and elevate the concentration of fine, dispersed particles in subsequent separation stages. Therefore, the optimal particle size must be selected based on technological experimentation. Determining the sodium sulfate content in the raw material through chemical analysis is essential for calculating reagent consumption and estimating theoretical product yield. Furthermore, identifying the levels of chlorides, calcium, magnesium, and insoluble mineral components determines the necessity and scope of subsequent purification steps. During the dissolution of mirabilite, key controllable parameters include temperature, the liquid-to-solid ratio, stirring speed, and dissolution time. An increase in temperature can influence crystal dissolution and mass transfer within the solution; however, the solubility of sodium sulfate exhibits a complex temperature dependence. Consequently, higher temperatures should not automatically be assumed to provide the optimal operating regime. The dissolution temperature must be selected according to raw material composition, the target solution concentration, and subsequent crystallization or separation operations. Monitoring density and electrical conductivity during solution preparation helps ensure process reproducibility. When necessary, the actual concentration of sodium sulfate is verified via chemical analysis, and reagent quantities are adjusted accordingly.

Purification of the raw material solution significantly impacts subsequent stages of caustic soda production. Insoluble particles remaining in the solution can lead to sediment buildup in reactors and pipelines, impair pump performance, and reduce filtration efficiency.

Moreover, under certain process conditions, calcium and magnesium compounds form secondary precipitates that complicate product composition. Therefore, the feasibility of combining solution clarification, mechanical filtration, and—if necessary—chemical treatment must be evaluated. In selecting a purification method, consideration must be given not only to the degree of impurity removal, but also to sodium-bearing solution losses, water consumption, and the volume of generated residue. One of the primary areas for technological improvement is the economic and technical optimization of producing sodium carbonate or another suitable intermediate from sodium sulfate. In this context, the conversion degree, reagent consumption, process temperature, pressure, reaction duration, and intermediate separation capabilities must be comprehensively studied. If the selected conversion method converts only a portion of the sodium sulfate, the feasibility of recycling the unreacted component into the recycle stream is evaluated. However, recycling must not lead to the accumulation of extraneous ions in the solution. To this end, it is possible to routinely analyze the composition of process streams, establish a solution balance, and, if necessary, implement a controlled partial purge stream. Such an approach helps maintain a stable chemical composition of the solution while minimizing raw material losses.

Research Purpose and Objectives

The aim of the research is to provide a physicochemical substantiation for the production of caustic soda via the lime method in the presence of mirabilite and to determine optimal manufacturing parameters. Proper organization of the mixing regime during causticization is also of critical importance. Adequate mixing promotes a uniform distribution of the solid reagent throughout the solution volume, reduces local concentration gradients, and enhances mass transfer on the particle surface. However, an excessive increase in stirring speed may increase energy consumption and, under certain conditions, cause the precipitate to form very fine particles. Fine particles can form a dense layer on the filter surface, potentially reducing the filtration rate. Therefore, the mixing intensity is selected taking into account reactor geometry, impeller type, suspension density, and the properties of the solid phase. To optimize the process, it is advisable to experimentally determine the relationship between mixing power, reaction rate, and filtration performance. Temperature control is a key factor affecting the reaction rate, solution viscosity, and solid-phase formation in the causticization system. Although an elevated temperature can accelerate chemical transformations at certain stages, the optimal regime depends on reagent properties and solution composition. Therefore, rather than managing the process based solely on maximum temperature, it is necessary to evaluate the effect of temperature on reaction duration, conversion degree, and precipitate filterability. Automated control of reactor temperature, maintaining a steady mixing speed, and introducing reagents in a designated sequence can improve process reproducibility. Comparing the results obtained for each operating mode using consistent analytical methods allows for a well-founded selection of technological parameters. Separating the resulting solid phase from the alkaline solution after causticization is a crucial operation that determines product quality. The filtration rate depends on the particle size, porosity, moisture content, and cake thickness of the precipitate, as well as the properties of the filter material. Excessive solid loading on the filter or an improperly selected washing mode can result in the loss of part of the alkali with the precipitate.

Therefore, it is necessary to study the feasibility of controlled washing of the solid residue, incorporating the wash water into the material balance, and, if necessary, recycling it back into the process stream. In this case, foreign ions that may accumulate in the recycled water are monitored. To improve the filtration process, the effects of various filter materials and operating modes on filtrate clarity, throughput, and residual alkali content are compared. The concentration process of the resulting sodium hydroxide solution can account for a significant portion of total energy consumption. Since evaporating water from the solution requires thermal energy, the initial solution concentration and product specifications must be considered when selecting the concentration mode. Adequate purification of the solution prior to evaporation helps reduce the risk of scale and sediment deposition on heat exchange surfaces. Heat recovery, increasing the efficiency of heat exchange equipment, and the rational design of evaporation stages are potential avenues for reducing energy consumption. However, conclusions regarding energy savings must be drawn solely on the basis of measured or calculated heat balances for the baseline and improved variants.

The research objectives include:

- analyzing existing literature and patent sources;
- studying the solubility polytherm of the $\text{Ca}(\text{OH})_2\text{--Na}_2\text{CO}_3\text{--H}_2\text{O}$ system;
- determining the effect of mirabilite content on the causticization process;
- studying the rheological properties and establishing the balance for intermediate and commercial products.

Objects and methods of research

The objects of the study were calcined soda, mirabilite, lime milk, and caustic soda.

Modern physicochemical analysis methods were used to determine the phase composition, and analytical chemistry methods were used to determine the amount of solid phases.

Results and scientific novelty

As a result of the research, the patterns of interaction between sodium carbonate and calcium hydroxide in the presence of sodium sulfate were determined, and a new approach to obtaining caustic soda by the lime method was proposed. For the first time, a correlation was established between the composition of the lime suspension and the quality of the product at various mass ratios of the initial components. Furthermore, the developed technological scheme reduces energy consumption and increases the filtration rate.

Scientific and practical significance.

The results of the research created the scientific foundations for the technology of obtaining caustic soda by the lime method in the presence of mirabilite. This will allow for the comprehensive processing of raw materials available in the republic, the production of import-substituting products, and a reduction in production costs. With the introduction of this technology at the Kungrad Soda Plant, Uzbekistan will be able to produce at least 15,000 tons of additional caustic soda per year.

Conclusion

In conclusion, it can be said that as a result of the conducted research, the main physicochemical patterns of the process of obtaining caustic soda by the lime method were studied. The process carried out in the presence of mirabilite is energy-efficient, cost-effective, and environmentally safe.

Promising areas of improvement include justified regulation of reagent consumption, increasing the efficiency of separating solutions and solid phases, reusing process water, reducing heat losses, and safe waste management. The actual effect of these measures must be confirmed by the conversion rate, product composition, material and heat balances, and economic calculations. Such an approach serves to develop a scientifically grounded and practically justifiable technological model for the use of sodium sulfate raw materials such as mirabilite.

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