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STUDY OF THE INTERACTION OF POTASSIUM CHLORIDE WITH AMMONIUM SULFATE SOLUTION

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Annotation. This comprehensive study investigates the thermodynamic and kinetic aspects of potassium chloride interaction with ammonium sulfate solutions under controlled laboratory conditions. The research focuses on optimizing the conversion process for potassium sulfate production through double salt formation methodology. Experimental investigations were conducted using flotation potassium chloride obtained from the Tyubegatan mineral deposit in Uzbekistan and high-purity ammonium sulfate solutions. The study systematically examines the influence of solid-to-liquid ratios, reaction temperature, and processing duration on the chemical composition of both solid and liquid phases during the conversion process. Results demonstrate that optimal double salt formation occurs at solid-to-liquid ratios of 1:(1.7-2.0), maintaining reaction temperature at 25°C with 60-minute processing duration. Under these conditions, the resulting double salt K2SO4•(NH4)2SO4 exhibits superior quality with K_2O content reaching 50.90-51.20% and minimal impurity levels. The findings provide valuable insights for industrial implementation of environmentally sustainable potassium sulfate production technologies in mineral processing applications.

Keywords: potassium chloride; Ammonium sulfate; Double salt formation; Conversion method; Solid-liquid equilibrium; Mineral processing; Flotation potassium chloride; Tyubegatan deposit; Chemical engineering; Crystallization kinetics.

KALIY XLORIDNING AMMONIY SULFAT ERITMASI BILAN O'ZARO TA'SIRINI O'RGANISH

Absattorov Diyorbek Soxijon o'g'li
Qarshi Davlat Texnika Universiteti 1-kurs magistranti

Annotatsiya. Ushbu keng qamrovli tadqiqot laboratoriya sharoitida boshqariladigan holatda kaliy xloridning ammiak sulfati eritmalari bilan o'zaro ta'sirining termodinamik va kinetik jihatlarini o'rganadi. Tadqiqotning asosiy maqsadi – qo'sh tuz hosil qilish usuli orqali kaliy sulfat olish jarayonini optimallashtirishdir. Eksperimental ishlar O'zbekiston hududidagi Tyubegatan foydali qazilma konidan olingan flotatsion kaliy xlorid hamda yuqori tozalikdagi ammiak sulfati eritmalari asosida olib borildi. Tadqiqot davomida qattiq va suyuq fazalar o'rtasidagi nisbat, reaksiya harorati hamda jarayon davomiyligining kaliy sulfatga aylanish jarayonidagi kimyoviy tarkibga ta'siri tizimli tarzda o'rganildi. Natijalar shuni ko'rsatadiki, optimal qo'sh tuz hosil bo'lishi 1:(1.7–2.0) qattiq-suyuqlik nisbati, 25°C harorat va 60 daqiqa davomida qayta ishlash sharoitida yuz beradi. Ushbu shartlarda hosil bo'lgan K2SO4•(NH4)2SO4 qo'sh tuzi yuqori sifatga ega bo'lib, K2O miqdori 50.90–51.20% gacha yetadi va iflosliklar darajasi minimal bo'ladi. Olingan natijalar foydali qazilmalarni qayta ishlash sohasida ekologik xavfsiz va barqaror texnologiyalarni sanoatga joriy etish uchun muhim amaliy ahamiyatga ega.

Kalit so'zlar: kaliy xlorid; Ammiak sulfati; Qo'sh tuz hosil bo'lishi; Aylantirish usuli; Qattiq-suyuqlik muvozanati; Foydali qazilmalarni qayta ishlash; Flotatsion kaliy xlorid; Tyubegatan koni; Kimyo muhandisligi; Kristallanish kinetikasi.

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INTRODUCTION

Potassium sulfate represents one of the most valuable fertilizer compounds in modern agricultural practices, particularly due to its chloride-free composition and high potassium content, making it especially suitable for chloride-sensitive crops [1]. The global demand for potassium sulfate continues to increase steadily, driven by expanding agricultural requirements and the growing emphasis on sustainable farming practices [2]. Traditional production methods for potassium sulfate often involve complex multi-stage processes that require significant energy input and generate substantial waste streams [3].

The conversion method for potassium sulfate production through the interaction of potassium chloride with sulfate-containing compounds has emerged as a promising alternative technology, offering several advantages over conventional approaches [4]. This method provides greater flexibility in raw material utilization and potentially reduces environmental impact through more efficient resource utilization [5]. The theoretical foundations underlying this conversion process involve complex thermodynamic equilibria and kinetic mechanisms that require detailed investigation to optimize industrial applications [6].

For Uzbekistan's mineral processing industry, the development of efficient potassium sulfate production methods is particularly significant given the country's substantial potassium chloride reserves in the Tyubegatan deposit [7]. The flotation potassium chloride obtained from this deposit presents unique characteristics that influence the conversion process parameters and require specific optimization approaches [8]. Understanding the interaction mechanisms between potassium chloride and ammonium sulfate under various processing conditions is crucial for developing economically viable and environmentally sustainable production technologies [9].

The formation of double salts during the conversion process involves intricate chemical equilibria that are influenced by multiple parameters including temperature, concentration, pH, and solid-to-liquid ratios [10]. Previous studies have investigated various aspects of these interactions, but comprehensive optimization of the process parameters for specific mineral compositions remains an active area of research [11]. The present study aims to address these knowledge gaps by providing detailed experimental data and analysis of the conversion process under carefully controlled conditions.

LITERATURE REVIEW

The scientific literature concerning potassium sulfate production through conversion methods has evolved significantly over the past several decades. Early foundational work by Zaslavsky et al. [12] established the theoretical framework for understanding the exchange reactions between potassium chloride and various sulfate-containing compounds. Their research demonstrated that the conversion process could be optimized through careful control of reaction parameters and phase equilibria.

Subsequent investigations by Samani and Sokolov [13] expanded upon these theoretical foundations by examining the kinetic aspects of double salt formation. Their studies revealed that reaction rates are significantly influenced by temperature, concentration gradients, and mixing conditions. The research highlighted the importance of maintaining optimal solid-to-liquid ratios to achieve maximum conversion efficiency while minimizing impurity incorporation.

Recent advances in understanding the thermodynamic properties of the K_2SO_4-$(NH_4)_2SO_4$-H_2O system have provided valuable insights into the phase behavior and solubility relationships [14]. These studies have identified critical composition ranges where double salt formation is thermodynamically favored, providing guidance for process optimization [15]. The influence of ionic strength and activity coefficients on the equilibrium conditions has been systematically investigated, revealing complex interactions that affect the overall process efficiency [16].

Experimental studies focusing on the characterization of flotation potassium chloride from various deposits have revealed significant variations in mineral composition and impurity content that influence conversion process parameters [17]. The presence of trace elements and secondary minerals can significantly affect the reaction kinetics and product quality, requiring careful consideration in process design [18]. Understanding these compositional variations is essential for developing robust industrial processes that can accommodate feedstock variability [19].

Industrial applications of the conversion method have been reported in several countries, with varying degrees of success depending on local conditions and raw material characteristics [20]. Economic analyses have demonstrated that the conversion method can be competitive with traditional production routes under appropriate market conditions. Environmental impact assessments have generally favored the conversion method due to reduced energy requirements and lower waste generation.

RESEARCH METHODOLOGY

The experimental investigation was conducted using a systematic approach designed to evaluate the interaction between potassium chloride and ammonium sulfate under controlled laboratory conditions. The research methodology encompasses comprehensive material characterization, solution preparation, reaction optimization, and product analysis phases.

Flotation potassium chloride samples were obtained from the Tyubegatan deposit and subjected to comprehensive characterization including X-ray diffraction analysis, chemical composition determination, and particle size distribution measurement. The potassium chloride samples were purified through recrystallization to achieve consistent composition and eliminate interference from trace impurities. High-purity ammonium sulfate (analytical grade, 99.5% purity) was used as the sulfate source to ensure reproducible experimental conditions.

The conversion experiments were conducted in a temperature-controlled reactor equipped with mechanical stirring and automated pH monitoring systems. The solid-to-liquid ratio was systematically varied from 1:1.2 to 1:2.0 to evaluate its influence on the conversion process. Each experiment was initiated by introducing saturated ammonium sulfate solution into saturated potassium chloride solution while maintaining the molar ratio of components at 1:1.

The reaction mixture was stirred continuously at 200 rpm to ensure homogeneous mixing and optimal mass transfer conditions. Process temperature was maintained at 25°C using a thermostatic water bath, and the reaction duration was fixed at 60 minutes based on preliminary kinetic studies. After the specified reaction time, the mixture was allowed to settle for 15 minutes before phase separation.

RESULTS AND DISCUSSION

Among the existing methods of obtaining potassium sulfate, the most acceptable for the conditions of Uzbekistan is the conversion method, based on the interaction of potassium chloride and various sulfate-containing products. The chemistry of the process consists of the exchange reaction of potassium chloride and ammonium sulfate to form a double salt

$$2KCl + 2(NH_4)_2SO_4 = K_2SO_4 \bullet (NH_4)_2SO_4 + 2NH_4Cl$$

and the interaction of the double salt solution with potassium chloride

$$K_2SO_4 \bullet (NH_4)_2SO_4 + 2KCl = 2K_2SO_4 + 2NH_4Cl$$

To obtain potassium sulfate from flotation potassium chloride of the Tyubegatan deposit and ammonium sulfate by the conversion method, a saturated (39.1%) solution of ammonium sulfate, a saturated solution of potassium chloride (26.8%) and a solution containing 10% potassium chloride were used. The conversion process was carried out at 25°C and the process duration was 60 minutes by introducing a saturated solution of ammonium sulfate into a saturated solution of potassium chloride until the molar ratio of the components was 1:1. The T:L ratio at the conversion stage was maintained by introducing an additional amount of potassium chloride or a saturated solution. After a specified time, the liquid and solid phases were separated by filtration.

The technology for producing potassium sulfate consists of two stages. At the first stage, potassium chloride was converted with ammonium sulfate to obtain a double salt, and at the second stage, potassium sulfate was obtained by dissolving the double salt in water and introducing potassium chloride.

To obtain a double salt, crystalline potassium chloride was introduced into the ammonium sulfate solution to a specified molar ratio of $KCl:Na_2SO_4$. Separation of the solid and liquid phases was carried out on a filter unit at a vacuum of 300 mm Hg. The area of the filtering surface of the funnel is 0.005 m^2. The data obtained are given in Tables 1 and 2.

Table 1. Effect of T:F on the chemical composition of the solid phase of the process of conversion of flotation potassium chloride with ammonium sulfate

T:F	Composition of the solid phase, mass %			
	K_2O	NH_4^+	Cl^-	SO_4^{2-}
1:1.2	40.91	7.37	7.78	50.91
1:1.5	44.93	4.24	6.68	50.12
1:1.7	50.96	2.16	5.94	49.60
1:2.0	51.20	1.95	5.80	49,65

As can be seen from Table 1, with an increase in the proportion of the liquid phase from 1:1.2 to 1:2, the content of K2O in the solid phase increases from 40.91 to 51.20%, and that of the other components decreases. Thus, the content of NH^{4+} decreases from 7.37 to 1.95%, chlorine from 7.78 to 5.80%, SO_4^{2-} from 50.91 to 49.65%.

The resulting double salt $K_2SO_4 \bullet (NH_4)_2SO_4$ is contaminated with the original components, as evidenced by the presence of ammonium and chlorine ions in the solid phase.

The composition of the liquid phase does not change so significantly with an increase in S:L from 1.2 to 2:1 (Table 2). Thus, the content of K_2O increases from 12.93 to 15.20%, and the content of the other components decreases. The obtained results indicate that the technologically acceptable S:L ratio is 1:(1.7-2). The resulting double salt contains (mass %): K_2O – 50.90-51.20; SO_4^{2-} – 49.60-49.65; NH^{4+} – 1.95-2.16; Cl^- – 5.80-5.94.

Table 2. Effect of S:L on the chemical composition of the liquid phase of the process of conversion of flotation potassium chloride with ammonium sulfate

S:L	Chemical composition of the liquid phase, mass %			
	K_2O	NH_4^+	Cl^-	SO_4^{2-}
1:1,20	12,93	3,722	15,998	1,50
1:1,5	13,32	2,97	15,11	1,28
1:1,70	13,90	2,473	14,516	1,14
1:2,00	15,20	1,522	13,795	0,93

CONCLUSION.

This comprehensive experimental investigation has successfully demonstrated the feasibility and optimization of potassium sulfate production through the conversion method using flotation potassium chloride and ammonium sulfate. The systematic study revealed that optimal double salt formation occurs at solid-to-liquid ratios of 1:(1.7-2.0), with reaction temperature maintained at 25°C and processing duration of 60 minutes. Under these optimized conditions, the resulting double salt $K_2SO_4 \bullet (NH_4)_2SO_4$ exhibits superior quality characteristics with K_2O content reaching 50.90-51.20% and minimal impurity levels of NH_4^+ (1.95-2.16%) and Cl^- (5.80-5.94%). The research provides valuable scientific foundation for industrial implementation of environmentally sustainable potassium sulfate production technologies, particularly relevant for Uzbekistan's mineral processing industry utilizing Tyubegatan deposit resources.

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