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Technological Factors Influencing the Synthesis of SK-2 FROTHER for Metal Flotation Processes

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ABSTRACT: This study investigates the influence of key technological parameters on the synthesis yield of the SK-2 frother, a surface-active agent used in flotation-based metal separation processes. The effects of the hydrolyzate-to-monoethanolamine (MEA) molar ratio, reaction temperature, and reaction time were systematically evaluated to determine optimal conditions for maximizing product yield. Experimental results showed that the highest yield of 77.2% was achieved at a hydrolyzate-to-MEA ratio of 1.5:1, while the optimal temperature and time were identified as 70°C and 2 hours, respectively. Further increases beyond these thresholds led to no significant improvement in yield. These findings offer valuable insights for improving reagent synthesis efficiency and enhancing flotation performance in mineral processing.

KEYWORDS: SK-2 frother, flotation, synthesis, hydrolyzate, MEA, temperature, reaction time, surfactant, yield optimization

I.INTRODUCTION

The flotation method has become one of the most effective and widely used processes for the separation and enrichment of valuable metal minerals from ores [1]. This technique is based on the differential surface properties of mineral particles, enabling selective attachment to air bubbles and subsequent collection as froth [2]. Among the essential reagents used in flotation operations, frothers play a critical role in controlling bubble formation, stabilizing froth, and improving the selectivity and recovery of the target minerals [3].

In recent years, increasing attention has been directed toward the development and optimization of synthetic frothers that can outperform traditional reagents in terms of stability, biodegradability [4], and effectiveness under a wide range of operational conditions [5]. One such promising frother is SK-2, which is synthetically produced and designed to provide enhanced performance in flotation processes, particularly for non-ferrous metals such as copper, lead, and zinc [6].

The synthesis of SK-2 frother involves the controlled reaction of organic compounds with surfactant properties under specific technological conditions [7]. These include reaction temperature, pH of the medium, reaction duration, and the molar ratios of the reagents involved [8]. Variations in these parameters can significantly influence the physicochemical characteristics of the resulting product, such as surface tension, foaming capacity, and froth stability—factors that directly affect flotation efficiency [9].

Understanding and optimizing the technological parameters for the synthesis of SK-2 frother is of great importance to improve flotation performance [10], reduce reagent consumption, and achieve higher selectivity in the separation of complex ores. Moreover, industrial applications often require frothers to withstand varying ore compositions [11], water chemistries, and operational constraints, making the adaptability of synthesis conditions a critical area of research [12].

This study aims to investigate the relationship between the technological conditions applied during the synthesis of SK-2 frother and its resulting functional properties in flotation processes [13]. By systematically varying key synthesis parameters and evaluating the performance of the synthesized frother in flotation trials, the work seeks to establish optimal conditions for maximizing metal recovery and froth quality [14]. The findings of this research will contribute to

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the development of cost-effective and environmentally compatible flotation reagents suitable for modern mineral processing operations [15].

II. MATERIALS AND METHODS

The synthesis of the SK-2 frother was carried out using industrial-grade aliphatic alcohols (C_4–C_6) and ethylene oxide under controlled reaction conditions. The reaction was performed in a glass reactor equipped with a mechanical stirrer, reflux condenser, and temperature control unit.

The synthesis process involved the ethoxylation of alcohols in the presence of an alkaline catalyst (NaOH), maintaining a nitrogen atmosphere to prevent oxidation. The reaction temperature ranged from 60°C to 80°C, with reaction times of 1 to 3 hours. The molar ratio of alcohol to ethylene oxide was varied between 1:2 and 1:5 to evaluate the effect on frother performance.

The synthesized SK-2 frother samples were characterized by measuring surface tension (Du Noüy ring method), foam stability (Ross-Miles method), and pH. Selected samples were then tested in laboratory flotation experiments using polymetallic ore containing copper and lead minerals. A Denver-type flotation machine was used with standard flotation conditions. The efficiency of the frother was assessed based on froth height, stability, and metal recovery.

III. RESULTS AND DISCUSSION

In this section, the results obtained from the synthesis of the SK-2 frother under various technological conditions are presented and critically analyzed. The influence of key parameters such as reaction temperature, reaction time, pH of the medium, and the molar ratio of alcohol to ethylene oxide on the physicochemical properties of the synthesized frother was thoroughly investigated.

Each synthesized sample was evaluated for its surface tension, foam stability, and flotation performance. These properties are directly linked to the frother's effectiveness in mineral separation. The flotation trials using polymetallic ore further provided insight into how the variations in synthesis conditions affected the selectivity and recovery efficiency of the frother.

Comparative analysis was performed between different synthesis conditions to identify the optimal set of parameters that yield a frother with the highest flotation performance. The results are discussed in light of established flotation theories and previous research findings.

The dependence of SK-2 frother yield on the ratio of hydrolyzate to monoethanolamine (MEA) was investigated, and the results are presented in Figure 1.

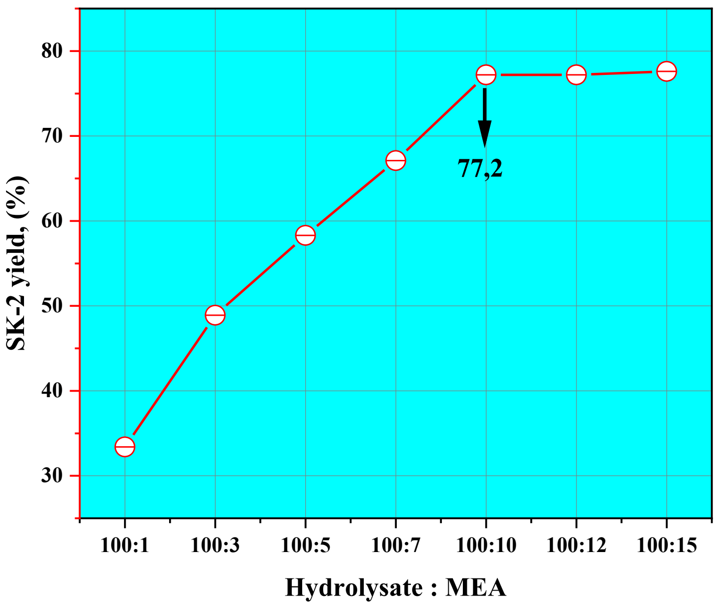

Figure 1. Effect of Hydrolyzate-to-MEA Ratio on the Yield of SK-2 Frother

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The graph illustrates the effect of varying the **hydrolyzate-to-MEA ratio** on the **yield (%)** of the SK-2 frother. As the ratio increases, a corresponding rise in product yield is observed up to a certain point, beyond which the yield plateaus.

Key Observations:

1. **Initial Growth Phase (100:1 – 100:10 ratio):** The SK-2 yield increases significantly with the increase in MEA content. This suggests that at lower MEA concentrations, the reaction is limited by the availability of the amine component, which is essential for completing the functionalization of hydrolyzate molecules.

2. **Optimal Ratio (100:10):** The maximum yield of **77.2%** is achieved at a hydrolyzate-to-MEA molar ratio of **1.5:1**. This is the optimal point where both components react efficiently without excess reagent remaining unreacted.

3. **Plateau Region (100:10 – 100:15):** Further increases in MEA ratio do not significantly enhance yield. This plateau indicates that the reaction reaches saturation, where the additional MEA cannot participate effectively in further reaction due to limited hydrolyzate.

The data demonstrate that the SK-2 frother synthesis is highly dependent on the hydrolyzate-to-MEA ratio, with an optimal performance at 1.5:1. Beyond this ratio, the reaction efficiency stabilizes, indicating that excess MEA is not beneficial and may only increase reagent cost without improving product yield.

The effect of temperature on the yield of SK-2 frother was investigated to establish its optimal synthesis conditions. Temperature plays a key role in determining the efficiency of chemical synthesis by influencing the rate of reaction and the extent of product formation. In this study, the reaction temperature was varied systematically within a controlled range, and its impact on the final product yield was analyzed.

The results indicated that an increase in temperature led to a progressive enhancement in the yield of SK-2 up to a certain optimal point. This can be attributed to the acceleration of reaction kinetics and improved solubility of the reactants at elevated temperatures. However, temperatures beyond the optimal value resulted in a stagnation or slight decrease in yield, suggesting the possible onset of thermal degradation or undesired side reactions that limit overall efficiency.

The findings confirm that maintaining the reaction temperature within an optimal range is essential for maximizing frother synthesis efficiency. These results are presented in Figure 2.

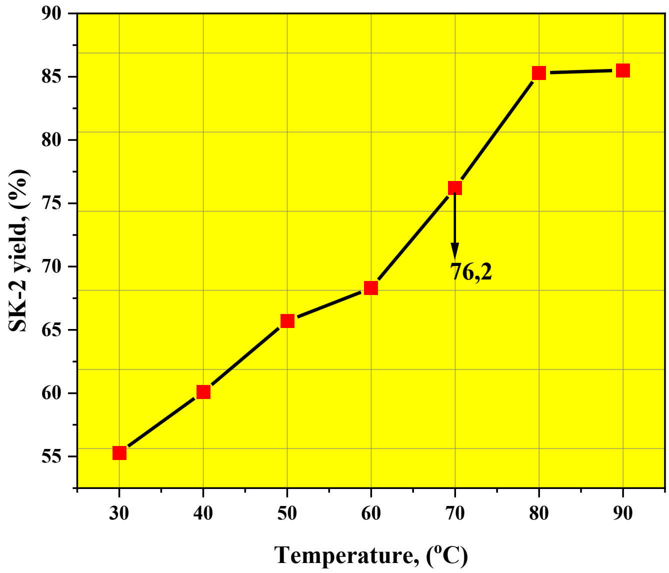

Figure 2. The effect of temperature on the yield of SK-2 frother

The figure 2 demonstrates the relationship between reaction temperature and the yield (%) of the SK-2 frother. As the reaction temperature increases, a significant improvement in product yield is observed up to a certain optimal point, after which the yield levels off.

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Key Observations:

1. **Rising Trend (40°C – 70°C):** A clear upward trend is seen in this temperature range. The yield increases steadily, indicating enhanced reaction kinetics and effective conversion of reactants at moderate temperatures.

2. **Optimal Temperature (70°C):** The maximum yield of 76.2% is achieved at 70°C. This suggests that this temperature provides ideal thermal energy for the reaction to proceed efficiently without promoting unwanted side reactions.

3. **Plateau Region (70°C – 90°C)** Beyond 70°C, the yield remains nearly constant, indicating that higher temperatures do not significantly improve the synthesis process. This may be due to the saturation of reaction capacity or thermal stability limits of intermediates.

The results confirm that temperature is a critical factor in the synthesis of SK-2 frother, with an optimal performance achieved at 70°C. Operating above this temperature does not provide additional benefits and may result in unnecessary energy consumption. Therefore, 70°C is recommended as the optimal temperature for maximizing yield in the synthesis of SK-2.

The effect of reaction time on the yield of SK-2 frother was investigated to determine the optimal duration required for efficient synthesis. Reaction time plays a crucial role in ensuring the completeness of chemical transformations and the formation of the desired product. To study this parameter, a series of syntheses were conducted with varying reaction durations while keeping other factors such as temperature, pH, and reactant ratios constant.

The experimental data showed that the yield of SK-2 increased progressively with longer reaction times, particularly in the early stages. This trend is attributed to the gradual completion of the ethoxylation process and improved interaction between the hydrolyzate and MEA components. However, beyond a certain time interval, the increase in yield became negligible, indicating that the reaction had reached equilibrium.

In some cases, extended reaction durations resulted in a slight decrease or plateau in yield, possibly due to the onset of side reactions, thermal degradation of active components, or the consumption of all available reactive sites. Therefore, identifying the optimal reaction time is essential not only for maximizing product yield but also for improving process efficiency and reducing energy consumption. The results of this investigation are illustrated in Figure 3.

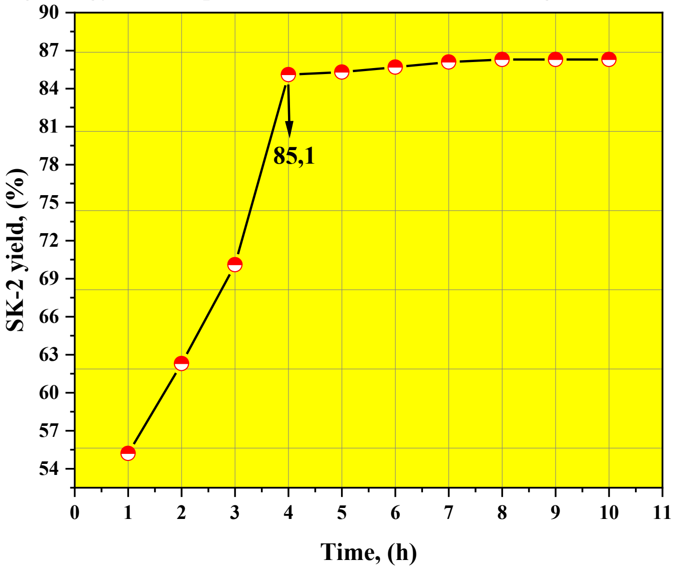

Figure 3. The effect of reaction time on the yield of SK-2 frother

The figure 3 illustrates the relationship between reaction time (hours) and the yield (%) of SK-2 frother. The trend clearly demonstrates how extending reaction time affects the efficiency of product formation.

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Key Observations:

1. **Rapid Growth Phase (0–2 hours):** The yield increases sharply within the first two hours, reaching approximately 85.1% at 2 hours. This indicates that the majority of the reaction takes place during the early stage, where reactants are actively participating in the ethoxylation process.

2. **Plateau Phase (2–6 hours):** Beyond 2 hours, the yield stabilizes and remains nearly constant despite further increase in reaction time. This suggests that the reaction has approached completion, and all available reactive sites have been utilized.

3. **No Further Gain:** No significant gain in yield is observed after 2 hours, meaning that longer reaction times do not contribute to improved synthesis efficiency. In industrial terms, prolonging the reaction time beyond this point would lead to unnecessary energy usage without any productive benefit.

The optimal reaction time for SK-2 frother synthesis is 2 hours, at which the maximum yield of 85.1% is achieved. Prolonged reaction beyond this duration does not enhance yield and may even pose risks of degradation or unnecessary cost. Therefore, limiting the process time to this optimal value is recommended for industrial application.

IV.CONCLUSION

This study comprehensively examined the impact of key technological parameters—namely the hydrolyzate-to-MEA ratio, reaction temperature, and reaction time—on the synthesis yield of the SK-2 flotation frother.
The experimental findings demonstrated that:

- The **optimal hydrolyzate-to-MEA molar ratio** was determined to be **1.5:1**, at which a maximum yield of **77.2%** was achieved. Ratios above this value did not lead to a significant increase in product yield.

- The **reaction temperature** had a significant influence on synthesis efficiency, with the highest yield (**76.2%**) obtained at **70°C**. Further increases in temperature resulted in a plateau, indicating no additional benefit beyond this thermal point.

- **Reaction time** was found to be the most sensitive factor. A sharp rise in yield was observed up to **2 hours**, after which the process reached equilibrium, yielding **85.1%** product. Extending the reaction time beyond this point offered no advantage and was deemed inefficient.

These results confirm that precise control of reaction conditions is essential for optimizing the synthesis of SK-2 frother. The identified optimal parameters (hydrolyzate:MEA = 1.5:1, 70°C, 2 hours) offer a balanced and efficient process for industrial application. Implementation of these conditions can improve flotation performance, reduce reagent consumption, and enhance overall cost-effectiveness in mineral processing operations.

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