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THE INDUSTRIAL SIGNIFICANCE OF ALIPHATIC AMINES AND ISSUES OF IMPROVING THE TECHNOLOGY OF THEIR SYNTHESIS FROM LOCAL RAW MATERIALS

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Abstract

This scientific thesis provides an in-depth analysis of the strategic role of aliphatic amines in the modern chemical industry and technological processes, their diverse practical applications across the national economy, the fundamental principles of industrial-scale synthesis technologies based on paraffin hydrocarbons, process kinetics, and the influence of catalytic systems on selectivity. The study examines the relationship between the structure of heterogeneous catalysts, activation energy, and reaction mechanisms in improving product yield, and further addresses the technical and economic aspects of establishing the production of high-molecular-weight amines from local raw materials — namely, the paraffin fractions of the Shurtan and Muborak oil-and-gas chemical complexes. The growth dynamics of the global amine market and Uzbekistan's import-substitution potential in the chemical industry are considered separately.

Keywords: aliphatic amines, paraffins, catalytic amination, heterogeneous catalysis, corrosion inhibitors, cationic flotation reagents, chemical technology, selectivity, reaction kinetics, import substitution.

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INTRODUCTION

Aliphatic amines — ranging from methylamines to high-molecular-weight alkylamines — belong to the group of functional intermediate products with the highest demand and profitability in the modern chemical industry. The presence of an active amino group (—NH_2, =NH, or ≡N) in their molecular structure, together with the nature of the hydrocarbon radical, imparts to these compounds distinctive surface-active, basic, and nucleophilic properties. Today, the global chemical industry produces thousands of types of chemical reagents, agrochemicals, and specialty composite materials based on aliphatic amines.

Recent analytical reviews indicate a steady growth trend in the global amine market, driven primarily by rising demand from the agrochemical, oil-and-gas, and pharmaceutical sectors. In particular, the use of ethanolamines and aliphatic amines in gas-purification processes (absorption of carbon dioxide and hydrogen sulfide) is expanding, which places these compounds among chemical products of strategic importance. In Uzbekistan, where the mining and oil-and-gas sectors serve as key drivers of the national economy, demand for these products continues to grow steadily, making the development of technology for their production from local raw materials an urgent task.

The relevance of this study lies in the fact that the Republic currently imports a substantial share of its high-molecular-weight aliphatic amines, despite possessing the raw-material base (paraffin fractions) necessary for their synthesis domestically. For this reason, the development of technological solutions that are adapted to local conditions, economically viable, and environmentally safe is of considerable scientific and practical importance.

The aim of the study is to analyze the chemical-technological foundations of the process of synthesizing high-molecular-weight aliphatic amines through the catalytic amination of paraffin hydrocarbons, to investigate the influence of

heterogeneous catalysts on process selectivity, and to formulate proposals for organizing production based on the local raw-material base.

MAIN PART: CHEMICAL-TECHNOLOGICAL ANALYSIS

1. Synthesis Methods and Raw-Material Selection

On an industrial scale, low-molecular-weight aliphatic amines (C_1–C_4) are mainly obtained through the heterogeneous catalytic amination of aliphatic alcohols (reaction with ammonia) [1]. However, for the synthesis of high-molecular-weight amines (C_{10}–C_{20}) required for beneficiation processes in the mining industry and for the protection of oil-and-gas pipelines, the use of paraffin hydrocarbons is regarded as the most economically and technologically promising route [2]. This is due to the lower cost of paraffin fractions relative to alcohols, their availability in large volumes as by-products at local oil-and-gas chemical complexes (Shurtan GCC, Muborak GPP), and the fact that this route eliminates the need for a separate step of introducing oxygen-containing functional groups.

2. Process Mechanism and Kinetic Characteristics

The production of aliphatic amines from paraffins is generally carried out according to either a two-stage scheme or a direct catalytic hydroamination scheme. In the direct amination process, paraffin hydrocarbons react with ammonia in a hydrogen atmosphere at elevated temperature (typically 180–280°C) and pressure (10–25 MPa). The generalized chemical reaction scheme of the process can be expressed as follows:

$$\mathbf{R—CH_3 + NH_3 \rightarrow R—CH_2—NH_2 + H_2}$$

The reaction mechanism proceeds stepwise as follows: (1) dehydrogenation of the paraffin molecule on the catalyst surface produces an intermediate olefin or alkyl radical; (2) the resulting active species interacts with an ammonia molecule at the catalytic site, forming an adsorbed aminoalkyl complex; (3) during the hydrogenation stage, the final amine product is desorbed. Because of this sequential-parallel mechanism, primary ($R—NH_2$), secondary (R_2NH), and tertiary (R_3N) amines are formed simultaneously within the system, which makes selectivity control the most critical technological issue of the process.

To ensure process selectivity and to suppress cracking (decomposition) reactions, multicomponent heterogeneous catalysts — based on cobalt, nickel, copper-chromium, or zeolite systems — are employed. To control the rate of formation of secondary and tertiary amines and to increase the yield of the target primary amines, the stoichiometric ratio of reactants (for example, NH_3 : hydrocarbon ranging from 4:1 to 8:1) is maintained within a strictly balanced range — an excess of ammonia shifts the equilibrium toward the primary amine, thereby reducing the share of secondary and tertiary products.

3. Catalyst Systems: A Comparative Analysis

1. Nickel- and cobalt-based catalysts — exhibit high hydrogenation activity, but carry the risk of forming saturated hydrocarbons as by-products (through excessive hydrogenation of paraffins); promoters (copper and chromium oxides) are therefore added to regulate activity;

2. Copper-chromium systems — demonstrate adequate selectivity even at lower temperatures, but exhibit relatively low thermal stability, resulting in activity loss (deactivation) during prolonged operation;

3. Zeolite-based catalysts — possess shape-selective catalytic properties owing to their microporous structure, enabling the targeted separation of amines of a

specific chain length; however, under industrial conditions they are more prone to coking (surface fouling).

Ultimately, catalyst selection is determined by the fractional composition of the raw material, the required product specifications, and economic factors (catalyst cost, service life, regeneration potential). Developing polyfunctional catalytic systems based on inexpensive, locally available metal oxides represents an important direction for reducing import dependency.

PRACTICAL INDUSTRIAL SIGNIFICANCE OF ALIPHATIC AMINES

From a chemical engineering perspective, the strategic industrial applications of aliphatic amines can be grouped into the following main categories:

4. Corrosion inhibitors in the oil-and-gas industry: High-molecular-weight aliphatic amines are among the most effective protective agents against corrosion caused by hydrogen sulfide (H_2S) and carbon dioxide (CO_2) — the aggressive media encountered during oil and gas extraction and transportation through pipelines [3]. Amines chemisorb onto the metal surface by forming donor-acceptor bonds with vacant d-orbitals, creating a hydrophobic protective film that fully isolates the metal from the external environment. Inhibition efficiency depends directly on the length of the amine molecule, the electron density at the nitrogen atom, and the adsorption energy, with long-chain primary amines typically providing the highest degree of protection.

5. Cationic flotation reagents in the mining industry: Aliphatic amines and their acetate or hydrochloride salts are used as cationic collectors. They play a decisive role in the production of potassium fertilizers (beneficiation of sylvinite ores), as well as in the flotation separation of phosphorites, quartz, and rare metals, by rendering mineral surfaces hydrophobic and promoting foam separation. Collector properties strengthen with increasing chain length, though

decreasing solubility means that amines in the optimal C_{12}–C_{18} range predominate in practice.

6. Agrochemistry and fine organic synthesis: Lower aliphatic amines serve as key building blocks in the synthesis of effective defoliants, herbicides, and modern pharmaceutical agents required in agriculture. In addition, they are widely used in the production of surfactants (detergents, emulsifiers) and polymeric materials (polyamides, epoxy hardeners).

7. Gas-purification technologies: Aliphatic amines — in particular, compounds structurally related to the ethanolamine family — are widely used in the purification of natural and associated petroleum gases, absorbing carbon dioxide and hydrogen sulfide, which makes these products strategically important for gas-chemical complexes.

DISCUSSION:

OPPORTUNITIES AND CHALLENGES OF LOCALIZATION

The volume and composition of paraffin fractions generated at the Shurtan and Muborak gas-chemical complexes in Uzbekistan make it possible to consider this raw material as a local base for the synthesis of aliphatic amines. However, several challenges must be overcome before the technology can be implemented at an industrial scale: (1) a shortage of reactor equipment capable of withstanding high pressure and temperature; (2) limited domestic experience in producing catalysts adapted to local conditions with long-term activity retention; and (3) the high energy intensity of the separation and purification stages required to isolate the resulting mixture of primary, secondary, and tertiary amines by quality.

To address these challenges, further research is warranted in the following directions: the synthesis of low-cost supported catalysts based on locally available natural minerals (bentonite, zeolite); the optimization of process

parameters (temperature, pressure, NH_3-to-hydrocarbon ratio) through mathematical modeling; and the gradual transition to industrial scale following the testing of technological regimes at small-capacity pilot units.

CONCLUSION

One of the important tasks facing scientists and young researchers at Termez Institute of Engineering and Agrotechnology is the development of a system for localizing the synthesis of aliphatic amines based on the country's abundant hydrocarbon raw materials — specifically, the paraffin fractions generated at the Shurtan and Muborak oil-and-gas chemical complexes. Optimizing the catalytic amination technology of paraffins, synthesizing heterogeneous catalysts with high selectivity suited to local conditions, and increasing target-product yield would enable the creation of a domestic production base for corrosion inhibitors and import-substituting chemical products for the mining industry.

Future research is planned to focus on optimizing catalyst composition, developing a more detailed kinetic model of the process, and providing an economic justification based on pilot introducing this technology into the national chemical industry.

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