ACUMEN: INTERNATIONAL JOURNAL OF MULTIDISCIPLINARY RESEARCH
ISSN: 3060-4745 IF(Impact Factor)10.71 / 2025 Volume 3, Issue 11

IMPROVEMENT OF THE TECHNOLOGY FOR THE SEPARATION OF N-HEXANE, N-HEPTANE, AND N-OCTANE FROM GTL NAPHTHA USING RECTIFICATION AND SELECTIVE ADSORPTION METHODS

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Abstract: This article examines the technology for separating normal paraffins, particularly n-hexane, n-heptane, and n-octane, from GTL naphtha produced through Fischer–Tropsch synthesis. The hydrocarbon composition of the feedstock was investigated based on gas chromatographic analysis using the ASTM D6729 method. The results revealed that the total content of normal paraffins was 79.5000 wt.%, while the combined content of n-hexane, n-heptane, and n-octane was 47.9360 wt.%. To recover these components, a technological approach based on the sequential application of rectification and selective adsorption using 5A molecular sieve zeolite was proposed. The mechanism of fractionating hydrocarbons according to their boiling points through rectification, followed by the separation of normal paraffins from branched isomers through adsorption, was scientifically substantiated.

Keywords: GTL naphtha, Fischer–Tropsch synthesis, normal paraffins, n-hexane, n-heptane, n-octane, rectification, 5A zeolite, selective adsorption.

1. Introduction

GTL (Gas-to-Liquids) technology is one of the promising technologies that enables the conversion of natural gas into liquid hydrocarbon products. Synthetic naphtha produced through Fischer–Tropsch synthesis contains normal and isoparaffins, as well as small amounts of other hydrocarbons. The recovery of these components as individual products is of considerable importance to the petrochemical industry.

Among normal paraffins, n-hexane, n-heptane, and n-octane have particular technological value. Their separation is based on two different principles: rectification relies on differences in boiling points, whereas adsorption using molecular sieves relies on molecular structure and pore size.

Rectification makes it possible to fractionate hydrocarbons according to the number of carbon atoms. However, the complete separation of normal and branched paraffins with the same number of carbon atoms is relatively difficult. Therefore, the use of 5A zeolite for the selective adsorption of normal paraffins, followed by their desorption, represents a promising approach.

The aim of this study is to scientifically substantiate a technology that combines rectification and 5A zeolite adsorption processes for the separation of n-hexane, n-heptane, and n-octane from GTL naphtha.

2. Materials and Methods

A sample of synthetic naphtha produced using Uzbekistan GTL technology was selected as the research object. The component composition of the feedstock was investigated by detailed hydrocarbon analysis (DHA) using gas chromatography in accordance with ASTM D6729. The analytical results were evaluated based on the mass fractions of the hydrocarbons.

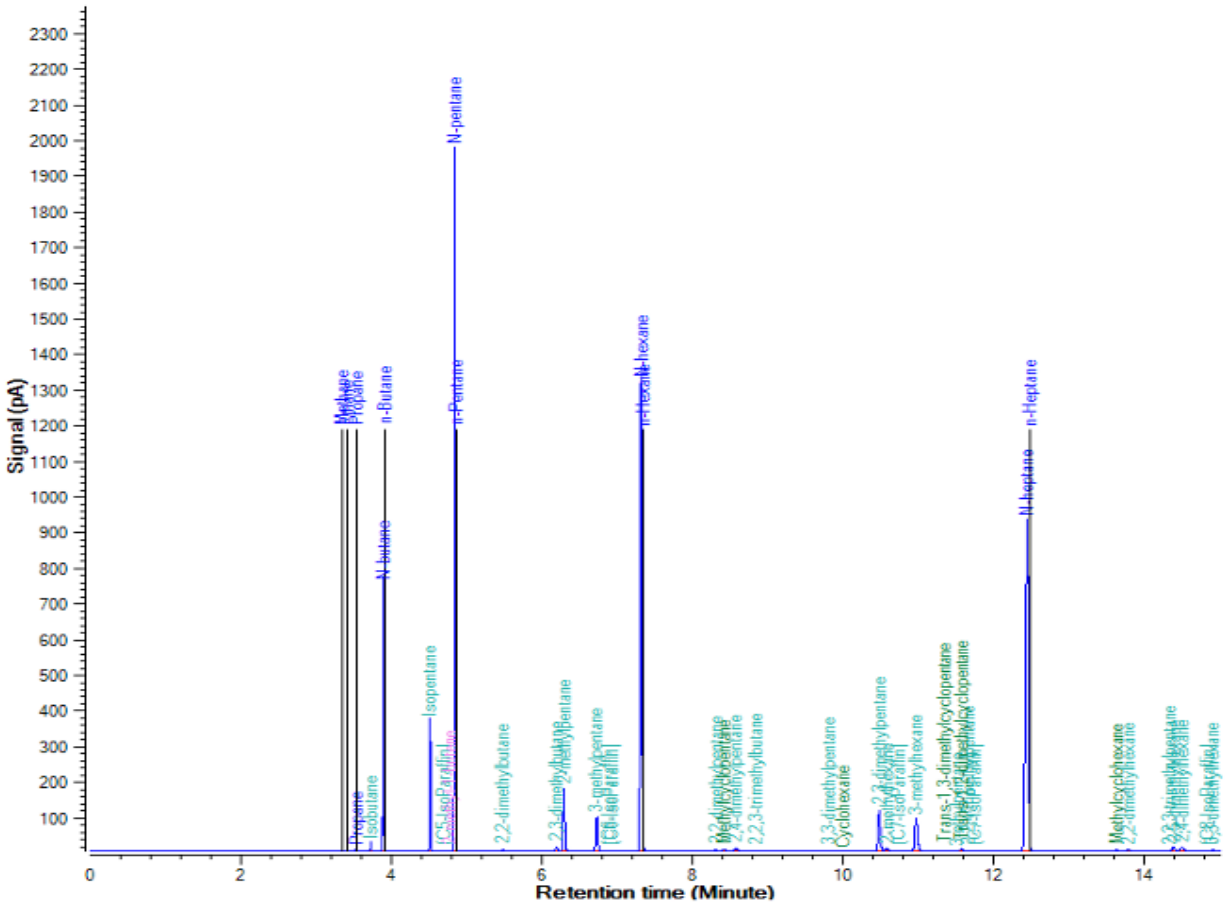


Figure 1. Gas chromatographic analysis chromatogram of GTL naphtha produced at the Uzbekistan GTL plant (ASTM D6729).

The hydrocarbon composition of GTL naphtha produced at the Uzbekistan GTL plant was analyzed using gas chromatography (GC) in accordance with the ASTM D6729 standard. The analysis identified the quantitative proportions of the hydrocarbon components present in the naphtha, including n-paraffins, isoparaffins, naphthenes, olefins, and aromatic compounds. Based on the obtained chromatographic data, the concentrations of the target components, particularly n-hexane, n-heptane, and n-octane, were determined, and the initial compositional parameters required for investigating their separation process were established. The chromatographic analysis results (chromatogram) of the GTL naphtha are presented in the following figure.

The target components selected for this study were n-hexane (C_6H_{14}), n-heptane (C_7H_{16}), and n-octane (C_8H_{18}). Their boiling points at atmospheric pressure are 68.7 °C, 98.4 °C, and 125.6 °C, respectively. These differences provide the basis for separating C_6, C_7, and C_8 fractions by rectification.

In the proposed technology, GTL naphtha is initially fed into a rectification column, where hydrocarbons are fractionated according to their boiling points. In the subsequent stage, the obtained C_6, C_7, and C_8 fractions are processed in adsorbers containing 5A zeolite. The zeolite pores, approximately 5 Å in size, allow linear normal paraffin molecules to enter, while restricting the entry of branched isoparaffins. The adsorbed normal paraffins are recovered through desorption and subsequently fractionated into individual products by final rectification.

The process efficiency is intended to be evaluated using adsorption capacity, normal paraffin recovery, product purity, and material balance parameters.

3. Results and discussion

The chromatographic analysis of the GTL naphtha sample showed that normal paraffins constitute the predominant hydrocarbon group in the feedstock.

Table 1.

Group composition of GTL naphtha by hydrocarbon type.

№	Hydrocarbon group	Content, wt.%
1	Normal paraffins	79.5000
2	Isoparaffins	19.5199
3	Olefins	0.0159

4	Naphthenes	0.7684
5	Aromatic hydrocarbons	0.0794
6	Unknown and heavy components	0.1164
	Total	100.0000

The analysis results indicate that the presence of normal paraffins at 79.5000 wt.% demonstrates the availability of a favorable feedstock base for their separation. The isoparaffin content of 19.5199 wt.% further substantiates the need for applying a selective adsorption stage to improve the separation efficiency of normal paraffins.

Table 2.

Content of target normal paraffins in GTL naphtha.

Component	Molecular Formula	Mass Fraction, %
n-Hexane	C_6H_{14}	15,5019
n-Heptane	C_7H_{16}	16,2298
n-Octane	C_8H_{18}	16,2043
Total		47,9360

The total content of the three target components was calculated as follows:

$$W = 15{,}5019 + 16{,}2298 + 16{,}2043 = 47{,}9360\ \%$$

Thus, 100 kg of GTL naphtha theoretically contains 47.9360 kg of the target components: n-hexane, n-heptane, and n-octane.

Based on the obtained results, the sequential application of rectification and adsorption processes was considered appropriate. Rectification is used to separate hydrocarbons into C_6, C_7, and C_8 fractions according to their boiling-point differences. However, the corresponding isoparaffins may also be present in these fractions. A 5A zeolite, in turn, enables the selective adsorption of normal paraffins based on their molecular structure.

It should be emphasized that 5A zeolite does not separate n-hexane, n-heptane, and n-octane individually. Instead, it primarily separates normal paraffins from their branched isomers. Therefore, a final rectification stage is required after the desorption process to obtain n-hexane, n-heptane, and n-octane as individual products.

The proposed technological process follows the following principal sequence:

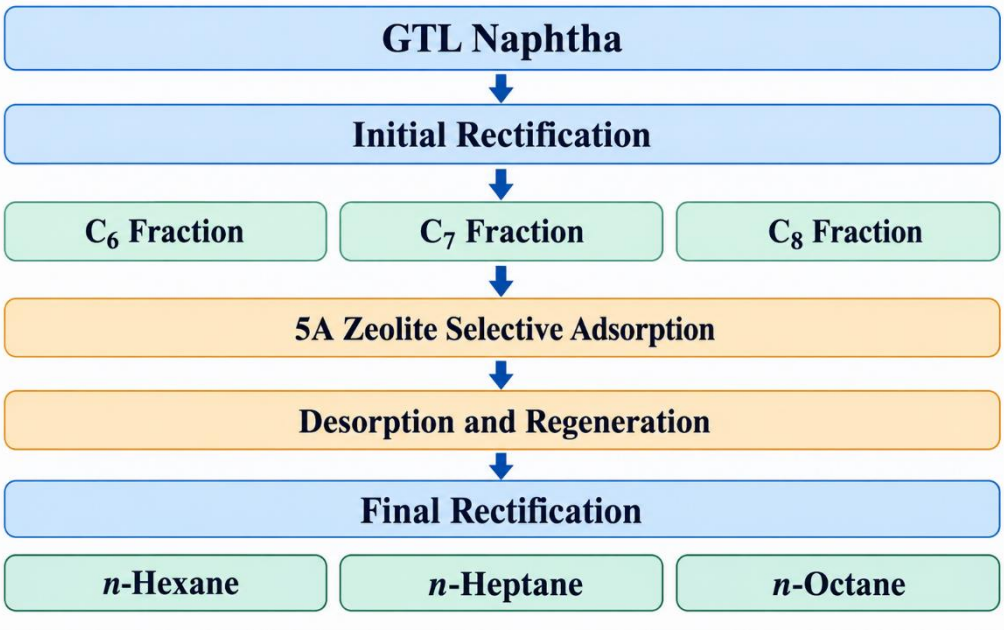


Figure 2. Proposed technological sequence for the separation of normal paraffins from GTL naphtha.

The expected advantage of the proposed technology lies in the use of different separation mechanisms through the combination of rectification and adsorption processes. предварительное fractionation of the feedstock supplied to the adsorber allows the process to be controlled and enables separate investigations of the target components.

4. CONCLUSION

Analysis of the GTL naphtha composition using the DHA method revealed that the total content of normal paraffins was 79.5000 wt.%. In particular, the combined content of n-hexane, n-heptane, and n-octane was determined to be 47.9360 wt.%.

Based on these results, a technology combining rectification and 5A zeolite-based selective adsorption was proposed for the separation of normal paraffins. Rectification is intended to fractionate hydrocarbons according to their boiling points, whereas 5A zeolite selectively separates normal paraffins from isoparaffins. Following desorption, a final rectification stage is proposed to obtain individual n-paraffins.

To determine the practical efficiency of the proposed technology, experimental evaluation of adsorption capacity, desorption efficiency, product purity, and energy consumption under laboratory conditions is required.

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