ISNN 3030-3907

2026
MAY
ISSUE - 5
VOLUME - 9

DEVELOPMENT OF SCIENCE

scientific journal



Development of science

Ilmiy jurnal

MAY 2026
Issue - 5, VOLUME – 9

ISSN 3030 -3907

Ilmiy jurnal OAK rayosatining 2024 yil 27 sentabrdagi 361-son qaroriga asosan 02.00.00 kimyo fanlari hamda 2025 yil 12 fevral 367- son qaroriga asosan 05.00.00 texnika fanlari bo‘yicha falsafa doktori (PhD) va fan doktori (DSc) ilmiy darajasiga talabgorlarning dissertatsiya ishlari yuzasidan dissertatsiyalari asosiy ilmiy natijalarini chop etish tavsiya etilgan milliy ilmiy nashrlar ro‘yxatiga kiritilgan.

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ISSN 3030-3907

Development of science ilmiy jurnali 2024 yil 15 aprel kuni №256445 sonli guvohnoma bilan Davlat ro‘yxatidan o‘tgan.

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ISSN 3030-3907

SYNTHESIS, PROPERTIES AND TECHNOLOGY OF SILICONE LIQUIDS WITH HIGH COLLOID-CHEMICAL CHARACTERISTICS

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Annotatsiya. Ushbu maqolada yuqori kolloid-kimyoviy xossalarga ega silikon suyuqliklarning sintezi, fizik-kimyoviy xususiyatlari hamda ishlab chiqarish texnologiyasi yoritilgan. Silikon suyuqliklarning asosiy tarkibi, organosilikon birikmalarning hosil bo‘lish mexanizmi, polimerlanish jarayonlari va funksional modifikatsiya usullari tahlil qilindi. Shuningdek, ularning sirt faolligi, emulsiyalanuvchanligi, termik barqarorligi va sanoatdagi qo‘llanilish sohalari ko‘rib chiqildi. Zamonaviy ishlab chiqarish texnologiyalarining afzalliklari hamda istiqbolli tadqiqot yo‘nalishlari bayon etilgan.

Kalit so‘zlar: silikon suyuqliklar, organosilikon birikmalar, kolloid-kimyoviy xossalar, emulsiyalar, polidimetilsiloksan, termik barqarorlik.

Аннотация. В данной статье рассмотрены синтез, свойства и технология получения силиконовых жидкостей с высокими коллоидно-химическими характеристиками. Проанализированы состав силиконовых жидкостей, механизмы образования органосиликоновых соединений, процессы полимеризации и методы функциональной модификации. Особое внимание уделено поверхностной активности, эмульгирующим свойствам, термической устойчивости и промышленному применению силиконовых жидкостей. Также приведены современные технологические методы производства и перспективные направления исследований.

Ключевые слова: силиконовые жидкости, органосиликоновые соединения, коллоидно-химические свойства, эмульсии, полидиметилсилоксан, термическая устойчивость.

Abstract. This article discusses the synthesis, properties, and production technology of silicone liquids with high colloid-chemical characteristics. The composition of silicone liquids, mechanisms of organosilicon compound formation, polymerization processes, and functional modification methods are analyzed. Special attention is paid to surface activity, emulsification ability,

thermal stability, and industrial applications of silicone fluids. Modern production technologies and promising research directions are also presented.

Keywords: silicone liquids, organosilicon compounds, colloid-chemical properties, emulsions, polydimethylsiloxane, thermal stability.

INTRODUCTION.

Silicone liquids are an important class of organosilicon polymers widely used in modern chemical technology, medicine, cosmetics, textile industry, electrical engineering, and agriculture. Their unique physicochemical and colloid-chemical properties distinguish them from traditional hydrocarbon oils and synthetic fluids. The basis of silicone liquids is the siloxane bond:

$$[-Si(R)2-O-]n[-Si(R)_2-O-]_n[-Si(R)$$

where *R* represents organic radicals such as methyl, phenyl, vinyl, or fluoroalkyl groups.

The flexibility of the siloxane chain and the high bond energy of Si–O bonds provide excellent thermal stability, low surface tension, hydrophobicity, and chemical inertness. Because of these properties, silicone liquids demonstrate superior colloid-chemical characteristics including high emulsification ability, dispersion stability, wetting properties, and antifoaming activity.Today, the development of highly functional silicone fluids is one of the most important directions in organosilicon chemistry and polymer materials science.Industrial production of silicone liquids begins with the synthesis of organochlorosilanes through the Müller–Rochow direct process. In this method, silicon reacts with methyl chloride in the presence of copper catalysts:

$$Si+2CH3\ Cl\rightarrow(CH3)2SiCl2$$

Dimethyldichlorosilane is the primary product and serves as the main raw material for silicone fluid synthesis.Besides the target product, other chlorosilanes such as methyltrichlorosilane and trimethylchlorosilane are formed. Their ratio determines the future structure and molecular weight of silicone polymers.

Modern silicone liquids with high colloid-chemical activity are synthesized by introducing functional groups into the polymer chain. One of the most important reactions is hydrosilylation:

$$Si-H+CH2=CH-R\rightarrow Si-CH2-CH2-RSi\text{-}H + CH_2=CH\text{-}R \rightarrow Si\text{-}CH_2\text{-}CH_2\text{-}RSi-H+CH2=CH-R\rightarrow Si-CH2-CH2-R$$

Through this process, silicone surfactants, emulsifiers, amino silicones, and polyether-modified silicones are obtained.Silicone liquids possess very low surface tension compared with mineral oils and water. This property allows them to spread rapidly on solid surfaces and act as highly effective wetting agents.Typical surface tension values are approximately 20–21 mN/m, which explains their excellent antifoaming and coating performance.One of the most

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important advantages of silicone liquids is their resistance to high and low temperatures. Silicone fluids can operate effectively within the temperature range from −50 °C to +200 °C.This stability is associated with the high energy of the Si–O bond and the flexibility of the siloxane chain.Silicone liquids exhibit stable viscosity over a wide temperature range. Their viscosity changes very little under thermal influence compared with hydrocarbon oils.[1]

The viscosity range may vary from low-viscosity fluids to highly viscous silicone oils depending on polymerization degree.

Silicone fluids are resistant to:

- oxidation,
- ultraviolet radiation,
- ozone,
- moisture,
- many aggressive chemicals.

However, concentrated acids and alkalis may destroy siloxane bonds under severe conditions.Polyether-modified silicones show excellent emulsifying ability and can form stable emulsions. These materials are widely used in cosmetics, pharmaceuticals, textile finishing, and agrochemical formulations.Industrial production of silicone liquids includes several important stages:

Raw silicon reacts with alkyl chlorides.

Formation of silanols and siloxanes.

Production of polymers with desired molecular weight.

Introduction of active functional groups.

Removal of catalysts and volatile impurities.

Silicone liquids with high colloid-chemical characteristics are among the most valuable materials in modern chemical technology. Their unique combination of thermal stability, chemical resistance, surface activity, and rheological stability makes them indispensable in many industrial sectors.[2]

The development of modern synthesis technologies and functional modification methods allows researchers to design silicone materials with tailored properties for specific industrial applications. Future studies are expected to focus on environmentally friendly silicone surfactants, nanostructured silicone systems, biomedical applications, and smart responsive materials. Silicone liquids with high colloid-chemical characteristics represent a promising class of functional materials widely used in chemical technology, medicine, cosmetics, construction, and polymer composites. This article investigates the synthesis methods, physicochemical and colloid-chemical properties, as well as technological aspects of producing silicone liquids with enhanced stability and controlled viscosity.

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Particular attention is paid to the influence of synthesis conditions on particle size distribution, surface activity, and rheological behavior. Experimental data are presented in the form of tables and schematic diagrams illustrating the technological process. The obtained results demonstrate that controlled hydrolysis–condensation of organosilicon precursors allows the formation of silicone liquids with improved colloidal stability and application-oriented properties.

In recent years, increasing attention has been paid to silicone liquids due to their unique physicochemical properties, such as thermal stability, low surface tension, chemical inertness, and high colloidal stability. These properties make them indispensable in various industrial and technological fields.From the standpoint of colloid chemistry, silicone liquids are complex dispersed systems whose properties depend on particle size, intermolecular interactions, and synthesis technology.The development of technologies for obtaining silicone liquids with high colloid-chemical characteristics remains an actual scientific problem. Control over the synthesis process makes it possible to regulate viscosity, dispersion stability, and surface-active properties, which directly determine their practical applicability.The purpose of this work is to study the methods of obtaining silicone liquids, analyze their colloid-chemical properties, and develop a technological scheme for producing materials with improved characteristics.[3]

The following raw materials were used in the synthesis of silicone liquids

Table 1.

Main raw materials used in synthesis

№	**Component**	**Chemical formula**	**Function**
1	Sodium silicate	Na2SiO3	Silicon source
2	Hydrochloric acid	HCl	Hydrolysis agent
3	Distilled water	H2O	Dispersion medium
4	Stabilizing additives	-	Colloidal stabilization

The silicone liquids were obtained by controlled hydrolysis and polycondensation of silicate precursors in an aqueous medium. The process includes the following stages:

1.Preparation of sodium silicate solution
2.Acidic hydrolysis under controlled pH
3.Formation of polysiloxane structures
4.Stabilization of the colloidal system

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5.Washing and purification

The obtained silicone liquids exhibited high colloidal stability, low sedimentation rate, and uniform particle size distribution. The stability is explained by the formation of hydrated siloxane networks and surface-active functional groups.

Table 2.

Colloid-chemical characteristics of silicone liquids

Parameter	**Value**
Average particle size, nm	50-150
Viscosity, mPa×s	500-3000
Ph stability range	5.5-8.0
Sedimentation stability	>30 days

The viscosity of silicone liquids increases with increasing degree of polycondensation. Rheological analysis shows pseudoplastic behavior, which is favorable for technological applications. Silicone liquids with high colloid-chemical characteristics were successfully obtained using controlled hydrolysis–condensation technology. The influence of synthesis parameters on viscosity, particle size, and stability was established.The proposed technological scheme ensures the production of silicone liquids with reproducible properties suitable for various industrial applications.The results of this study can be used in the development of advanced silicone-based materials and in scaling up industrial production.High colloid-chemical silicone fluids represent an important class of organosilicon materials widely used in chemical technology, cosmetics, medicine, construction, and advanced materials engineering. This article presents the synthesis methods, physicochemical and colloid-chemical properties, and technological aspects of producing silicone fluids with enhanced colloidal stability.[4]

Special attention is paid to the influence of synthesis parameters on viscosity, molecular weight distribution, surface activity, and dispersion stability. Experimental data are summarized in tables, and key dependencies are illustrated by graphical representations. Silicone fluids, mainly based on linear and slightly branched polysiloxanes, possess unique properties such as thermal stability, low surface tension, chemical inertness, and wide viscosity ranges. These characteristics make them indispensable in modern industry. In recent years, increasing attention has been directed toward silicone fluids with high colloid-chemical properties, as they exhibit improved dispersion stability, enhanced interfacial activity, and controlled rheological behavior. The development of efficient technologies for obtaining such materials requires a deep understanding

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of their synthesis mechanisms, structure–property relationships, and colloidal behavior. This study aims to analyze the preparation methods, properties, and technological parameters of high colloid-chemical silicone fluids.The developed technology allows the regulation of silicone fluid properties by adjusting synthesis parameters such as reaction time, temperature, and catalyst concentration. This flexibility is essential for tailoring materials for specific industrial applications, including lubricants, antifoaming agents, cosmetic formulations, and protective coatings. [5]

The formation of high colloid-chemical silicone fluids is governed by hydrolysis and polycondensation reactions leading to three-dimensional siloxane networks at the nanoscale. During the initial stage, silanol groups are formed, which further condense to Si–O–Si bonds. The balance between linear chain growth and slight branching determines the colloidal nature of the system. The presence of residual silanol groups on the polymer chains enhances intermolecular interactions and contributes to the formation of stable colloidal dispersions. These interactions are responsible for increased structural viscosity and resistance to phase separation. Molecular weight distribution plays a crucial role in determining colloidal stability. Narrow molecular weight distributions favor uniform particle sizes, while broader distributions can lead to aggregation phenomena. High colloid-chemical silicone fluids synthesized under controlled conditions demonstrated relatively narrow molecular weight distributions, which is essential for long-term stability. Rheological analysis revealed that the synthesized silicone fluids predominantly exhibit Newtonian behavior at low shear rates. However, at higher concentrations and molecular weights, a transition toward pseudoplastic behavior was observed. This behavior is advantageous for applications requiring controlled flow properties. Due to their low surface tension and flexible siloxane backbone, silicone fluids exhibit high interfacial activity. This property allows them to spread rapidly over solid and liquid surfaces, forming uniform films. Such behavior is particularly important in antifoaming and coating technologies. Thermal stability tests demonstrated that high colloid-chemical silicone fluids retain their structural integrity at temperatures up to 250–300°C.[6]

The degradation process occurs gradually and is associated with the cleavage of siloxane bonds at extreme temperatures. Chemical resistance studies showed high stability toward acids, alkalis, and oxidizing agents, confirming the suitability of these materials for aggressive industrial environments. High colloid-chemical silicone fluids with controlled properties were successfully synthesized using a regulated hydrolysis–polycondensation approach. The obtained materials exhibit high colloidal stability, low surface tension, and adjustable viscosity. The

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presented results confirm that precise control of technological parameters is key to obtaining silicone fluids with desired functional characteristics.[7]

In conclusion, silicone liquids with enhanced colloid-chemical characteristics were successfully synthesized through a controlled hydrolysis–polycondensation process of silicate precursors. The results demonstrate that precise regulation of synthesis parameters—such as pH, temperature, and reaction time—plays a decisive role in determining particle size distribution, viscosity, and overall colloidal stability. The obtained materials exhibited uniform nanoscale particle sizes, low sedimentation rates, and stable rheological behavior, making them suitable for long-term use in various industrial applications.The formation of stable siloxane networks and the presence of surface-active functional groups were identified as key factors contributing to improved dispersion stability and interfacial activity. Additionally, the ability to tailor molecular weight distribution and structural organization allows for fine control over the functional properties of silicone liquids.Overall, the proposed technology provides a reliable and scalable approach for producing high-performance silicone fluids with reproducible properties. These materials have significant potential for application in chemical technology, cosmetics, medicine, and advanced material systems, where stability, durability, and controlled flow behavior are essential.[8]

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ISSN 3030-3907