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TELOMERLASH REAKSIYASI ASOSIDA SINTEZLAR

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Annotatsiya. Ushbu tadqiqotda zamonaviy usullar orqali telomerlanish reaksiyalari asosida organik birikmalar sintezi o‘rganildi. Ish davomida adabiyotlar asosida 1,3-butadien, etilen va izopren kabi olefinlar turli spirtlar (1,3-propandiol, glitserin, izopropil va izoamil spirtlari) bilan Pd va Ni katalizatorlari ishtirokida telomerlanish reaksiyalari tahlil qilindi. Sintez qilingan mahsulotlarning kimyoviy tuzilishi va xossalari IQ-, Raman spektr, xromato-mass spektrometriya, fizik-kimyoviy metodlar, kvant-kimyoviy hisoblashlar va matematik modellashtirish orqali aniqlangan. Reaksion sharoitlar (harorat, bosim, katalizator) mahsulot hosil bo‘lishi, selektivlik va samaradorlikka ta’siri batafsil tahlil qilingan. Shuningdek, sintez qilingan izopropil va izoamil spirtlarining fizik xossalari – qaynash temperaturasi, zichligi, sindirish ko‘rsatkichi va molekulyar refraksiyasi aniqlangan.

Kalit so‘zlar: telomerlanish, olefinlar, Pd/Ni katalizatorlari, spirtlar, mono-telomerlar, di-telomerlar, FTIR spektr, Raman spektr, xromato-mass spektroskopiya, kvant-kimyoviy hisoblash, fizik-kimyoviy xossalar, organik sintez, yuqori funksional birikmalar.

Аннотация. В данном исследовании изучался синтез органических соединений на основе реакции теломеризации с использованием современных методов. In the course of the study, based on the literature, the telomerization reactions of olefins such as 1,3-butadiene, ethylene, and isoprene with various alcohols (1,3-propandiol, glycerol, isopropyl alcohol, and isoamyl alcohol) in the presence of Pd and Ni catalysts were analyzed. Химическая структура и свойства синтезированных продуктов определялись с помощью ИК-спектроскопии, спектроскопии Рамана, хромато-масс-спектрометрии, физико-химических методов, квантово-химических расчетов и математического моделирования. Влияние условий реакции (температура, давление, катализатор) на выход, селективность и эффективность продуктов было подробно проанализировано. Кроме того, физико-химические свойства синтезированных изопропилового и изоамилового спиртов, включая температуру кипения, плотность, показатель преломления и молекулярную рефракцию, были определены.

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Ключевые слова: теломеризация, олефины, катализаторы Pd/Ni, спирты, монотеломеры, дителомеры, ИК-спектр, спектр Рамана, хромато-масс-спектроскопия, квантово-химические расчеты, физико-химические свойства, органический синтез, высокофункциональные соединения.

Abstract: This study investigated the synthesis of organic compounds via telomerization reactions using modern methods. In the course of the study, based on the literature, the telomerization reactions of olefins such as 1,3-butadiene, ethylene, and isoprene with various alcohols (1,3-propandiol, glycerol, isopropyl alcohol, and isoamyl alcohol) in the presence of Pd and Ni catalysts were analyzed. The chemical structure and properties of the synthesized products were determined using FTIR and Raman spectroscopy, chromatograph-mass spectrometry, physicochemical methods, quantum-chemical calculations, and mathematical modeling. The effects of reaction conditions (temperature, pressure, catalyst) on product yield, selectivity, and efficiency were thoroughly analyzed. Additionally, the physicochemical properties of the synthesized isopropyl and isoamyl alcohols, including boiling point, density, refractive index, and molecular refraction, were determined.

Keywords: telomerization, olefins, Pd/Ni catalysts, alcohols, mono-telomers, di-telomers, FTIR spectroscopy, Raman spectroscopy, chromatograph-mass spectrometry, quantum-chemical calculations, physicochemical properties, organic synthesis, highly functional compounds.

INTRODUCTION.

In our country, the application of modern technologies has enabled the production of novel types of organic compounds, which serve as the basis for polymers, plastic materials, hormones, fungicides, solvents, stimulants, emulsifiers, plasticizers, antibiotics, adhesives, dyes, and other products, obtained through the chemical processing of oil and gas. In this context, the development of unsaturated compound chemistry and the implementation of a localization program—by utilizing industrial products and by-products in manufacturing—are of significant scientific and practical importance.

The term “telomerization” originates from the Greek words telos meaning “body” and meros meaning “part” or “portion.” It refers to a chain reaction in which the repeating fragment of a monomer (M) is inserted between the two parts of an X–Y (telogen) compound, resulting in a series of homologous telomers X–M_n–Y (n = 2–40) [1].

Telomerization reactions represent one of the promising methods for utilizing natural and industrial gases in organic synthesis. Through these reactions, simple olefins such as ethylene and propylene can be converted into various mono-

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, di-, and multifunctional compounds of practical importance [2]. Currently, this reaction is employed in the production of synthetic disinfectants, as well as detergents, waxes, lubricants, coatings, solvents, dielectrics, plasticizers, resins, and synthetic fibers [3].

Telomerization reactions occupy an important place in the development of chemistry. As the number of carbon atoms in aliphatic molecules increases, the difficulties associated with their synthesis rise sharply. Consequently, compounds containing 15 or more carbon atoms in a single molecule are relatively rare. Existing experimental data indicate that telomerization reactions represent a scarcely explored area of organic chemistry [4].

Depending on the nature of the X particle, telomerization reactions can proceed via coordination, free radical, or ionic mechanisms. The telomerization reaction can be represented by the following scheme:

$$nRCH = CH_2 + XY \rightarrow_{(initiator)} X(RCHCH_2)_nY$$

Here, XY serves as the chain-transfer agent.

However, such schemes do not imply that all studied telomerization reactions are strictly chain-like [5]. In compounds where the X–Y bond is prone to homolytic cleavage, telomerization predominantly occurs via a free radical mechanism. Reactions involving compounds containing only C–F bonds are generally not feasible. Telomerization of aromatic compounds with unactivated C–N bonds proceeds poorly, and in acetylene homologs, telomerization is almost negligible [6]. While C–H bonds in amino acids can participate in the reaction, telomerization does not occur via C–N bonds. In cyclic compounds, telomerization may proceed with either preservation or opening of the ring [7].

Peroxides are the most commonly used compounds as initiators in telomerization reactions. Azobisisobutyronitrile (AIBN), oxygen, as well as UV or γ-irradiation, can also promote the occurrence of telomerization. Unsaturated compounds are often employed as monomers in these reactions [8].

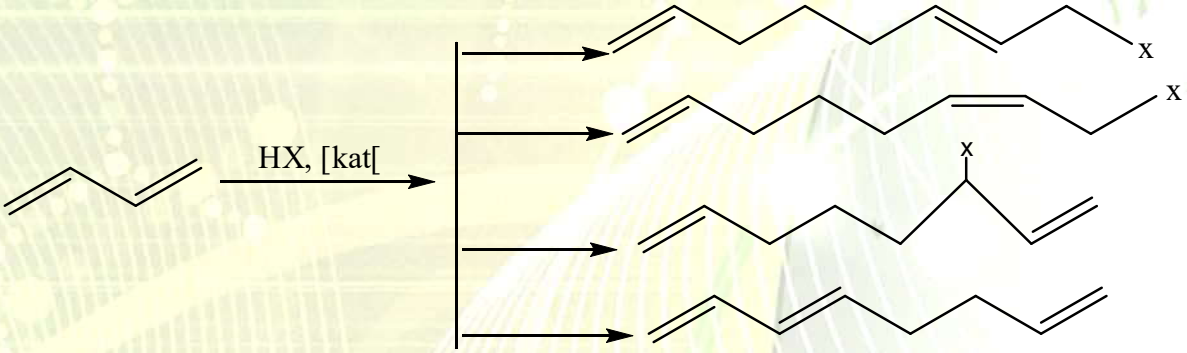
Many researchers have made significant contributions to the development of this field. Notably, N. Semenov developed the chain reaction theory, S. Medvedev and collaborators proposed chain transfer mechanisms, and S. Bagdasaryan investigated the initiation and inhibition mechanisms of polymerization reactions, all of which contributed to the advancement of telomerization chemistry [9,10].

N. Nesmeyanov and his students conducted a series of studies on the telomerization of olefins with carbon tetrachloride, chloroform, and silicon hydrides. The first telomerization reaction between ethylene and carbon tetrachloride was carried out. In 1948, American chemists R. Joys, N. Xanford, and I. Harmon studied the telomerization of ethylene with carbon tetrachloride under

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pressure in the presence of benzoyl peroxide. They isolated products containing 3 to 9 carbon atoms in the molecule and confirmed the following structure: $[Cl(CH_2CH_2)_nCCl_3]$. Subsequent research by G. B. Ovakhimyan and A. A. Beer demonstrated a simple continuous method for the industrial synthesis of such compounds. A. Karapetyan's studies further revealed that the composition of the telomer mixture largely depends on the molar ratio of ethylene to carbon tetrachloride introduced into the reactor [11].

Takahashi and Smutny independently discovered the telomerization reaction of 1,3-butadiene. In this process, telomerization represents the dimerization of 1,3-butadiene in the presence of a telogen. The products of this reaction are referred to as telomers, and the reaction scheme is presented below [12]



Products of the 1,3-butadiene Telomerization Reaction

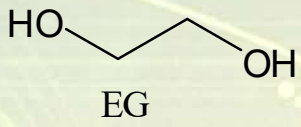
Several isomers can be formed in this reaction. In addition to 1,3-butadiene, other dienes or cyclic dienes such as cyclopentadiene can also be used. Various compounds, including water, ammonia, alcohols, or acidic substances, can serve as telogens. When water is used, unsaturated alcohols are obtained [13]. Kuraray Company has industrially produced 1-octanol (5,000 tons per year), using mainly palladium and nickel organometallic compounds as catalysts. The production of octen-1 from butadiene was launched in 2008 by Dow Chemical in Tarragona. In this process, 1,3-butadiene undergoes telomerization with methanol in the presence of a palladium catalyst to form 1-methoxy-2,7-octadiene, which is then fully hydrogenated to 1-methoxyoctane. In the subsequent step, 1-octen-1 and methanol are produced from 1-methoxyoctane [14].

Regina Palkovis and her students studied the telomerization reactions of 1,3-butadiene with various alcohols in the presence of several catalysts. Palladium and phosphine were used as catalysts. This research focused on the activity of the telomerization process under the new Pd/phosphine system and its nucleophilic reactivity, which subsequently aided in developing the telomerization of 1,3-butadiene using different nucleophiles. In this study, nucleophiles such as ethylene glycol, 1- and 2-propanol (1-PrOH, 2-PrOH), 1,2- and 1,3-propandiol (1,2-PD, 1,3-

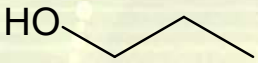
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PD), glycerol (Gly), and 1,2- and 1,4-butandiol (1,2-BD, 1,4-BD) alcohols were employed [15].

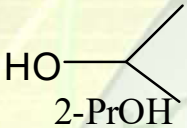
Products obtained from the telomerization reaction of 1,3-butadiene in the presence of palladium and nickel catalysts.



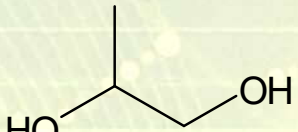
EG



1-PrOH



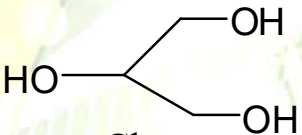
2-PrOH



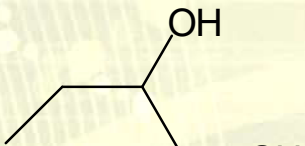
1,2-PD



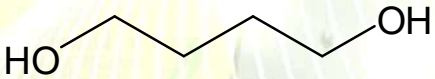
1,2-PD



Gly



1,2-BD



1,4-BD

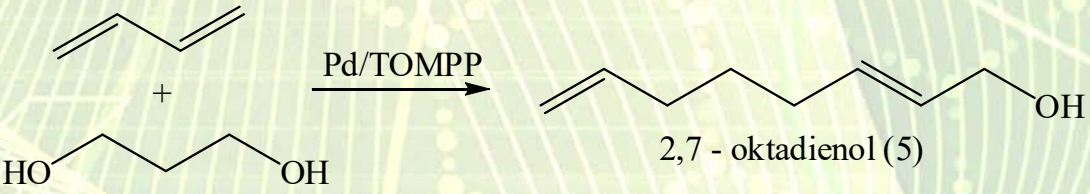
In this study, the products obtained from the telomerization of 1,3-butadiene with 1,3-propandiol (1,3-PD) are as follows.



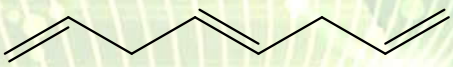
Oktadienilefir (1)

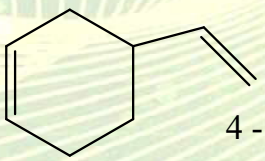


Bis-oktadienilefir (2)



2,7 - oktadienol (5)


1,4,7 - oktatrien (3)


4 - vinilsiklogeksen (4)

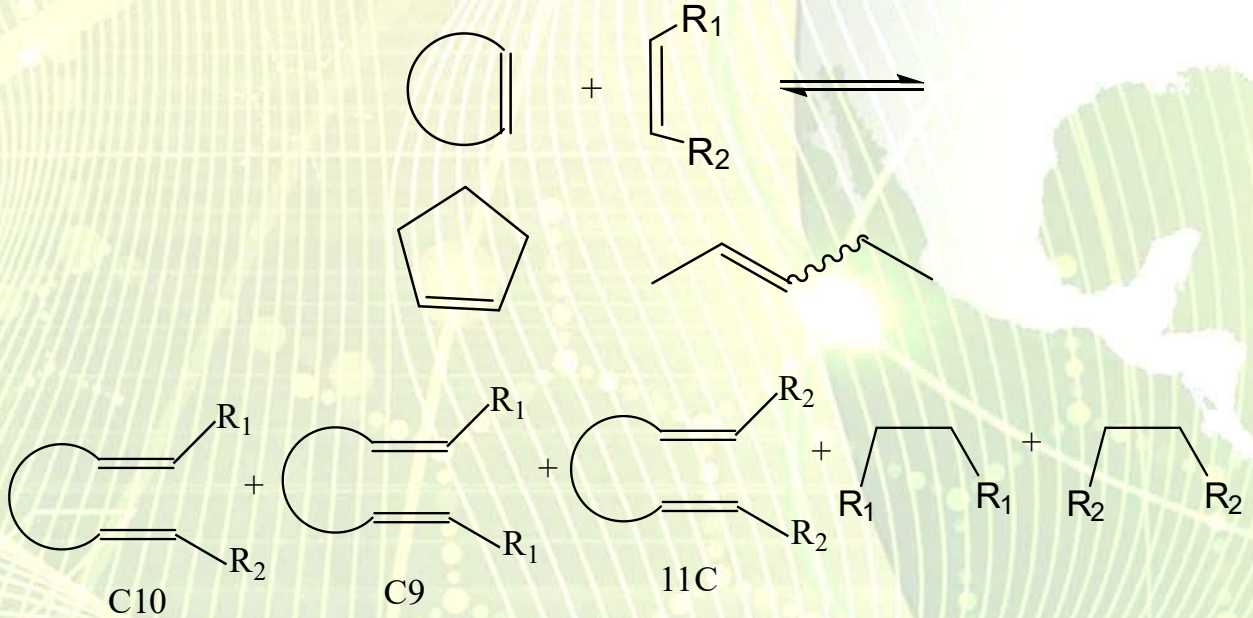
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In this reaction, the products obtained include mono-telomers (octadienyl esters) (1) and di-telomers (bis-octadienyl esters) (2); hydrolysis of these products with water yields 2,7-octadienol (5), while dimerization products include 1,4,7-octatriene (3) and 4-vinylcyclohexene (4). The telomerization of 1,3-butadiene with various alcohols and its effect on diols was studied using Pd/TOMPP catalysts.

The raw materials suitable for telomerization (ethylene, other olefins, and their halogenated derivatives) allow the synthesis of highly mono- and bifunctional compounds, including acids. Halogen-substituted acids obtained during telomerization can be further used for the synthesis of saturated and unsaturated acids [16].

Several researchers, including S. Bigot, J. Lai, I. Switzerland, and M. Sauthier, investigated the telomerization of 1,3-butadiene with glycerin under two-phase aqueous conditions and studied the effect of reaction conditions on product yield. During the reaction, butadiene was continuously added while maintaining constant pressure, and the influence of various parameters on the activity and selectivity of the resulting mono-, di-, or tri-telomers was analyzed.

Y. Chuamin and his students carried out the telomerization reactions of cyclopentane and 2-pentene [17].



A. Rjevskiy, A. Topchiy, and others investigated the telomerization of isoprene with methanol in the absence of a solvent using heterocyclic palladium complexes. The telomerization of butadiene with arylamines in the presence of palladium complexes was studied by R. Aripov, Ye. G‘anieva, R. Izhberdina, R. Khusnutdinov, K. Khusnutdinova, and I. Abdurakhmanov. O. B. Penrhyn-Lou and his students examined radical telomerization reactions of ethylene glycol dimethacrylate, 1,6-hexanediol dimethacrylate, and 1,12-dodecanediol

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dimethacrylate. To prepare functional telomers of macromonomers with variable molar masses, A. Bechkoc, M. Belbachir, B. Guyot, and B. Butevin studied the telomerization of styrene with mercaptans [18].

Telomerization reactions have significant practical importance in the production of macrocylcic lactones, ω-amino acids, high-carbon acids, and other organic compounds. In the telomerization of ethylene, the rearrangement of radicals has been thoroughly studied using carbon acids and their derivatives as examples. In contrast, studies on radical rearrangement during the telomerization of alcohols remain limited [19,20].

In the study, a high-pressure reactor equipped with a heater, pressure gauge, thermocouple, ethylene gas inlet, and agitator was charged with 93 ml of methyl alcohol, 8 ml of hydrogen peroxide, and 18 ml of acetone. Ethylene gas was introduced into the reaction mixture through a special tube, and the pressure (calculated as ethylene) was increased to 40 atm. The reaction was carried out at 60 °C for 4 hours. After completion, the reaction was stopped and cooled. The product obtained by distillation was separated from the reaction mixture, yielding a flammable, colorless liquid with a characteristic odor; empirical formula C_3H_8O; molar mass M_r = 60.12 g/mol; boiling point T_b = 82.4 °C; density d = 0.7851 g/cm³. FTIR spectrum: 3334 cm^{-1}, 950 cm^{-1} (C–OH); 2932 cm^{-1} (CH); 2969 cm^{-1}, 1466 cm^{-1} (CH_3). Raman spectrum: 2883 cm^{-1} (CH); 2922 cm^{-1}, 1453 cm^{-1} (CH_3); 818 cm^{-1} ($O–C(CH_3)_2$); 951 cm^{-1} (C–C); 1130 cm^{-1} (C–O).

In a subsequent experiment, a high-pressure reactor (autoclave) similarly equipped with a heater, pressure gauge, thermocouple, agitator, and ethylene inlet was charged with 134.7 ml of methyl alcohol, 11.34 ml of hydrogen peroxide, and 24.84 ml of acetone . Ethylene gas was introduced through a special tube, and the pressure was increased to 40 atm. The reaction proceeded at 80 °C for 6 hours. After completion, the reaction was stopped and cooled. The product obtained by distillation was a colorless, characteristic-odor liquid; empirical formula $C_5H_{12}O$; molar mass M_r = 88.174 g/mol; boiling point T_b = 132.1 °C; density d = 0.8140 g/cm³. FTIR spectrum: 3328 cm^{-1} (C–OH); 1055 cm^{-1} (C–O); 2956 cm^{-1}, 1367 cm^{-1} (CH_2); 2872 cm^{-1} (CH); 1384 cm^{-1} (CH_3). Raman spectrum: 2872 cm^{-1} (CH); 2936 cm^{-1}, 1453 cm^{-1} (CH_3); 830 cm^{-1} (C–C); 954 cm^{-1} (C–O).

In this study, FTIR, GC-MS, and Raman spectroscopy, along with physicochemical, quantum-chemical, and mathematical modeling methods, were employed to investigate and analyze the structure and composition of products obtained from chemical synthesis processes. Chromatographic-mass spectra were recorded in the liquid phase using a standard HP-5MS column, with the control temperature ranging from 0 °C to 320 °C, starting at 50 °C up to 120 °C, on an

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"Agilent MSD 5975C-GC7890A" gas chromatography–mass spectrometer. In the GC-MS spectrum of the synthesized isopropanol, ions corresponding to the molecular mass of the compound and to fragment ions resulting from its decomposition were clearly identified.

The FTIR spectra of the synthesized compounds were obtained using a Bruker "INVENIO-S FTIR" spectrometer (2021), with an optical spectral resolution of <0.25 cm^{-1} and a spectral range of 4000–400 cm^{-1}. Raman spectra were recorded using an "InVia Raman spectrometer BRAVO," which allows observation of distinct molecular features, including molecular "fingerprints," bond configurations, strain, and deformation changes. Measurements were carried out with a laser beam focused on a sample area of 10 μm in diameter.

Quantum-chemical calculations, as a physicochemical investigation method, were used to evaluate molecular geometry, calculate the stability of intermediates and transition states, and determine the properties of complex organic compounds. The chemical properties and reactivity of molecules were analyzed in terms of their electronic structure and energetic characteristics. Within the study, quantum-chemical calculations provided data on formation energy, total energy, enthalpy of formation, electronic energy, electron density distribution, nuclear energy, dipole moment, and potential reactive sites of both initial and synthesized compounds using the "HyperChem Professional" software.

Mathematical modeling and processing of experimental results were employed to quickly determine, optimize, and modernly design chemical reaction processes while minimizing costs. The synthesis of isopropyl and isoamyl alcohols was modeled and processed using Maple 2018 software, applying the least squares method to analyze the experimental data.

Determination of Density. In chemical industry laboratories and pharmaceutical plants, pycnometers are commonly used alongside hydrometers for technical analyses. Density is an important parameter for assessing the quality of liquid substances in various industrial processes. It allows verification that both raw materials and final products meet established standards.

Before starting the measurement in a pycnometer, it was thoroughly rinsed first with a chromatic mixture and then with distilled water. A clean, dry pycnometer was weighed on an analytical balance. Next, the glass vessel and distilled water were heated to the temperature at which the density of the studied liquid was to be measured. Distilled water was poured into the empty pycnometer up to the mark on its neck, and the mass of the pycnometer with water was precisely determined. The water was then poured out, and the measuring apparatus was dried in a special oven. The isopropyl alcohol sample was poured into the prepared glass

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pycnometer up to the neck mark, maintaining the same temperature as during the water measurement. The pycnometer was then weighed again.

The density of isoamyl alcohol was determined using the same procedure: the masses of the pycnometer filled with distilled water and with the isoamyl alcohol sample were measured.

In the final stage, calculations were performed using the following formula. Considering that the density of water at 20 °C is 0.9982 g/cm³, the relative density is determined as:

$$d_4^{20} = \frac{m}{W} * 0{,}998230$$

m – mass of the substance in the pycnometer at 20 °C;
W – mass of an equal volume of water at the same temperature (20 °C).

Boiling Point. The boiling point of liquid organic compounds is used to determine their purity and for separation purposes. This measurement can be carried out using a distillation apparatus.

For the measurement, a 100 ml flask equipped with a thermometer was filled with 75 mL of isopropyl alcohol and heated in an electric oven. The boiling point of isopropyl alcohol was determined to be $T_{(b)}$ (iso-propanol) = 82.4 °C.

The boiling point of isoamyl alcohol was determined using the same procedure, yielding $T_{(b)}$ (isoamyl alcohol) = 132 °

Refractive Index and Molecular Refraction. These are used to determine the purity of liquid compounds. When light passes from one medium to another and changes its direction, this phenomenon is called the refraction of light.

The incident light ray, the refracted ray, and the perpendicular drawn at the point of incidence on the boundary between the two media all lie in the same plane. If the angle of incidence on the plane separating the less dense medium from the denser medium is denoted as α, and the angle of refraction as β, then the ratio of the sine of the angle of incidence to the sine of the angle of refraction is a constant for those two media. This ratio is defined as the refractive index.

$$\frac{\sin\alpha}{\sin\beta} = \frac{C_1}{C_2} = n$$

In this case: C_1 and C_2 are the speeds of light in the first and second media, respectively; n is a constant for the two media and is called the refractive index. Most often, air serves as the first medium. The refractive index depends on temperature and dispersion. Increasing the temperature by 1 °C typically decreases the refractive index by approximately 0.0004.

The refractive indices of the synthesized organic compounds were measured using an Abbe refractometer. Procedure for measurement: First, the prism block is

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opened, and a drop of the liquid sample is placed on the lower prism using a pipette. The upper prism block is then closed. The refractometer is positioned so that the light passes optimally through the sample. The main central adjustment screw is rotated until part of the observed field becomes dark. The compensator of the refractometer is then adjusted until the dark boundary is sharply distinguished, and the central screw is adjusted until the boundary aligns with the intersection of the lines in the eyepiece. The refractometer scale reading is then recorded. To ensure the reliability of the measurement, the procedure is repeated several times. After use, the surfaces of the prisms are first cleaned with a wet cloth and then dried with cotton.

Once the refractive indices and densities of the substances are determined, the molecular refraction (R_m) is calculated using the Lorentz–Lorenz formula.

$$R_M = \frac{n^2 - 1}{n^2 + 1} \cdot \frac{M}{d}$$

Where:

M – molecular weight;

d – density of the substance.

Molecular (or relative) refraction reflects the polarizability of all electrons within a molecule. Molecular refraction does not depend on temperature, pressure, or the physical state of the substance. It is an additive physical property, and the molecular refraction of a compound equals the sum of the refractions of the atoms that make up the molecule.

Telomerization reactions allow the synthesis of mono-, di-, and multifunctional compounds based on aliphatic olefins. The telomerization of 1,3-butadiene and isoprene with alcohols in the presence of Pd and Ni catalysts ensures high selectivity and yield. The structures of the synthesized products were determined using FTIR, Raman, and GC-MS spectroscopy. Quantum-chemical calculations enabled the evaluation of the energetic and electronic properties of the molecules. Physicochemical parameters—density, boiling point, refractive index, and molecular refraction—can be used to monitor product quality and assess raw material characteristics. The results confirm the practical significance of telomerization reactions in organic synthesis, polymer production, and the manufacture of highly functional compounds, as well as their applicability on an industrial scale.

REFERENCES

1. A. Behr, P. Bahke, B. Klinger, M. Becker. Application of carbonate solvents in the telomerisation of butadiene with carbon dioxide // Journal Of Molecular Catalysis, 2007, Volume 267. – Pp. 149-156.

ISSN 3030-3907

2. L. Torrente-Murciano, D. Nielsen, K. Cavell, R. Jackstell, M. Beller, A. Lapkin. Selective telomerisation of isoprene with methanol by a heterogeneous palladium resin catalyst // Catalysis Science And Technology, 2015, Volume 5. – Pp. 1206-1212.
3. P. Neubert, I. Meier, T. Gaide, R.Kuhlmann, A. Behr. First telomerisation of piperylene with morpholine using palladium-carbene catalysts // Catalysis Communications. 2016, Volume 77. – pp. 70-74.
4. D. Vogelsang, T.A. Faßbach, P.P. Kossmann, A.J. Vorholt. Terpene-Derived Highly Branched C30-Amines via Palladium-Catalysed Telomerisation of β-Farnesene // Advanced Synthesis and Catalysis, 2018, Volume 360 (10). – pp. 1984-1991.
5. S.A. Rzhevskiy, M.A. Topchiy, V.N. Bogachev. A.A.Geshina, L.I.Minaeva, G.K.Sterligov, M.S.Nechaev, A.F. Asachenko. NHC PDII complexes for the solvent-free telomerisation of isoprene with methanol // Mendeleev Communications, 2021, Volume 31(4). – pp. 478-480.
6. R. Zaripov, E. Ganieva, R. Ishberdina R. Khusnitdinov, K. Khusnitdinov, I. Abdrakhmanov. Palladium Complexes Catalysed Telomerisation of Arylamines with Butadiene and Their Cyclisation into Quinoline Derivatives // Bulletin of Chemical Reaction Engineering and Catalysis, 2022, Volume 17(2). –pp. 322-330.
7. O.B. Penrhyn-Lowe, S. Flynn, S.R. Cassin. S. Mckeating, S. Lomas, S. Wright, P. Chambon, S.P. Rannard. Impact of multi-vinyl taxogen dimensions on high molecular weight soluble polymer synthesis using transfer-dominated branching radical telomerisation // Polymer Chemistry, 2021, Volume 12(44). – pp. 6472-6483.
8. L. Conceiçao, R. Bogel-Łukasik, E. Bogel-Łukasik. Supercritical CO2 as an effective medium for a novel conversion of glycerol and alcohols in the heterogeneous telomerisation of butadiene // Green Chemistry, 2012, Volume 14(3). – pp. 673-681.
9. M. Terhorst, A. Kampwerth, A. Marschand, D. Vogt, T. Seidensticker, A.J. Vorholt. Facile catalyst recycling by thermomorphic behaviour avoiding organic solvents: A reactive ionic liquid in the homogeneous Pd-catalysed telomerisation of the renewable β-myrcene // Catalysis Science and Technology, 2020, Volume 10(6). – pp. 1827-1834.
10. S.R. Cassin, S. Flynn, P. Chambon, S.P. Rannard. Quantification of branching within high molecular weight polymers with polyester backbones formed by transfer-dominated branching radical telomerisation // RSC Advances, 2021, Volume 11(39). – pp. 24374-24380.

ISSN 3030-3907

11. S. Bigot, J. Lai, I. Suisse, M. Sauthier, A. Mortreux, Y. Castanet. Telomerisation of 1,3-butadiene with glycerol under aqueous biphasic conditions: influence of the reaction conditions on the products distribution // Applied Catalysis A: General, 2010, Volume 382 (2). – pp. 181-189.
12. P.J.C. Hausoul, T.M. Eggenhuisen, B.M. Weckhuysen, P.C.A.Bruijnincx, R.J.M. Klein Gebbink, D. Nand, M. Baldus. Development of a 4,4′-biphenyl/phosphine-based COF for the heterogeneous Pd-catalysed telomerisation of 1,3-butadiene // Catalysis Science and Technology. – 2013. – Vol. 3, No. 10. – P. 2571-2579.
13. J. Guiot, J. Alric, B. Ame'duri, A.Rousseau, B.Boutevin. Synthesis of fluorinated telomers. Part 6. Telomerisation of chlorotrifluoroethylene with methanol // New Journal of Chemistry, 2001, Volume 25(9). – pp. 1185-1190.
14. M. Duc, B. Boutevin, B. Ameduri Radical telomerisation of vinylidene fluoride with diethyl hydrogenphosphonate - Characterisation of the first telomeric adducts and assessment of the transfer constants // Journal of Fluorine Chemistry, 2001, Volume 112(1). – pp. 3-12.
15. A. Bessmertnykh, F. Hénin, J. Muzart. Palladium-catalysed telomerization of butadiene with aldoses: A convenient route to non-ionic surfactants based on controlled reactions // Journal of Molecular Catalysis A: Chemical, 2005, Volume 238(1-2). – pp. 199-206.
16. T. A. Faßbach, A. J. Vorholt, W. Leitner. The Telomerization of 1,3-Dienes-A Reaction Grows Up // Journal Of Molecular Catalysis, 2019, Volume 11(4). – pp. 1153-1166.
17. Dmitry S. Suslov, Mikhail V. Bykov, Marina V. Belova, Pavel A. Abramov, Vitaly S. Tkach. Palladium(II)–acetylacetonate complexes containing phosphine and diphosphine ligands and their catalytic activities in telomerization of 1,3-dienes with diethylamine // Journal of Organometallic Chemistry, 2014, Volume 752. – pp. 37-44.
18. Peter J. C. Hausoul, Sinedu D. Tefera, Jelle Blekxtoon, Pieter C. A. Bruijnincx, Robertus J. M. Klein Gebbink, Bert M. Weckhuysen. Pd/TOMPP-catalysed telomerisation of 1,3-butadiene with lignin-type phenols and thermal Claisen rearrangement of linear telomers // Catal. Sci. Technol, 2013, Volume 3(5). – pp. 1215-1223.
19. Qi Li, Zhen Wang, Vy M. Dong, Xiao-Hui Yang. Enantioselective Hydroalkoxylation of 1,3-Dienes via Ni-Catalysis // Journal of the American Chemical Society, 2023, Volume 145(7). – pp. 3909-3914.
20. Hatice Mutlu, Andrei N. Parvulescu, Pieter C. A. Bruijnincx, Bert M. Weckhuysen, and Michael A. R. Meier . On the Polymerization Behavior of

ISSN 3030-3907

Telomers: Metathesis versus Thiol // Ene Chemistry. Macromolecules, 2012, Volume 45(4). – pp. 1866-1878.

ISSN 3030-3907