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NEW HYBRID AGGREGAT STATE OF SOME ORGANIC SUBSTANCES AND THEIR PROSPECTS IN OIL-FIELD NANOTECHNOLOGY

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Abstract:

In this work, the rheological and tensiometric properties of some samples of liquid-crystal nanodemulsifiers based on oxyalkylene ethers of glycerin were investigated. Certain correlation expressions are established for the nanodemulsifiers under study. Scientific novelty of the work: For the first time, a correlation relation of the type, property-property-efficiency of use; Liquid crystals of organic origin were first noted as a new hybrid aggregat state of matter. Highly efficient nano-emulsifiers of a liquid-crystalline hybrid aggreganted state are recommended for cleaning oil from formation water, as well as for cleaning formation water from oil under conditions of primary oil preparation at the oil field "Karazhanbasmunai".

Key Words: Oil-field nanotechnology, Nanodemulsifiers, Liquid crystal, Nano liquid crystal demulsifiers, Hybrid aggregate state of matter, Interfacial tension of nanodemulsifiers & Viscosity of nanodemulsifiers

Introduction:

The first results on the application of nanotechnology in the field of oil production to increase oil recovery are associated with the work of scientists under the leadership of the famous academician A.Kh. Mirzadzhanzade [1-5]. The scientists of Azerbaijan continue fruitful research work in this area [6-9].Similar works have been published by scientists and experts from Russia and other foreign countries [10]. The possibilities of increasing the flow rate of wells with the use of polymers with свойствами nano-liquid crystalline properties have been established [11]. For the first time, nanodemulsifiers (types of the ND) were tested in the practice of oil preparation in the fields of Azerbaijan and Kazakhstan, by SOCAR scientists and specialists under the leadership of F.S.Ismaylov [12-22].

Literature Survey:

Oilfield nanotechnology as a basic science is justified in three areas: oil-field chemistry; oil-field physical chemistry; oil-field physics. Oilfield chemistry includes sections of analytical chemistry (methods for analyzing oil emulsions, commercial oil, produced water and associated gas) and colloid chemistry (oil emulsions and various compositional compositions based on surface-active substances). Oilfield physical chemistry consists of physico-chemical methods for studying the above-listed products of oil wells. The main methods of oil-field physics with various types of effects on oil colloids: thermal methods; magnetic methods; electric field; ultrasound method; vibration; centrifugal force; nanoparticles, etc. This paper discusses the possibilities of destroying all types of oil emulsions in the framework of oil-field chemistry, using nano-liquid crystals in the conditions of primary oil preparation (PPO). From this point of view, is of interest a brief overview on the use of liquid crystals in oil production, although there is little information, i.e. new direction. The authors studied the formation and persistence of liquid-crystalline nanocolloids with the addition of barium titanate nanoparticles ($BaTiO_3$), depending on the chemical nature of surfactants [23]. The production of liquid-crystalline nanocolloids based on cross-linked polymers in the presence of non-ionic surfactants (nonionic surfactants) or ionic surfactants is carried out using the micro-emulsion technology [24]. Microemulsion technology is a relatively classical terminology, but in reality on the dimension it is nanoemulsion. Nanocolloids synthesized in the presence of anionic surfactants turned out to be stable in two-dimensional hexagonal structures. Liquid nanocolloids synthesized using nonionic surfactants (polyvinyl alcohol) in the aquatic environment were stable. However, when dried, crystals were freed with large sizes. These studies give some ideas about polymer liquid crystals [25]. Naturally, polymeric liquid crystals are promising in polymer injection technologies in wells. In general, there are quite numerous data in the literature on liquid crystals. Therefore, there is a need to determine their identity by the state of aggregation of the substance. Recently, nano liquid crystals (NLC) have found wide applications in the field of household chemicals and cosmetics [26]. Employees of the Tyumen State University under the leadership of Professor L.P.Semixina for the first time conducted research in the field of oil preparation using a TND nanodemulsifier with liquid-crystalline properties [27]. However, the issues of purification of formation water from oil, as well as the problems of destruction of all types of oil emulsions using liquid crystals, are little studied. Therefore, the development and implementation of nanodeemulsifiers with liquid-crystalline properties is one of the priorities direction of oilfield nanotechnology [28]. The establishment of a correlation relationship property-property, property-structure will be the focus of attention when conducting serial studies with liquid-crystalline nanodemulsifiers (LCND). As a “property”, the values of viscosity and interfacial tension will be studied for the objects of research, which are reflected in the requirements imposed on the demulsifiers.

The Requirements for Demulsifiers:

Since the requirements for demulsifiers are developed and updated, we try to present them in each article and at the end of the article mark some new requirements as important results or as scientific novelty in work. From this point of view, below are the requirements for demulsifiers:

- ✓ Demulsifiers should be effective, i.e. must ensure high quality of the prepared oil at the minimum specific consumption, minimum sludge time at the minimum temperature;
- ✓ The demulsifier must have a large surface activity from the phase in which it is introduced;
- ✓ The demulsifier should be well dispersed in the dispersion medium;
- ✓ Molecules of demulsifiers should have peptizing properties with respect to the "armor cover" (molecular adsorption layer) around the globules of the dispersed phase;
- ✓ The demulsifier molecules should have a high wetting effect on the elements of "armor cover", without which it is impossible to transfer solid particles into a dispersion medium;
- ✓ The demulsifiers should not form strong films, i.e. should not be stabilizers of the emulsion of the opposite type, and should also be cheap, transportable, universal, should not affect the commodity properties of oil and significantly change their properties when change the of externals conditions.
- ✓ The demulsifiers should be liquids with a relatively low viscosity (no more than 100 mPa·s), should not undergo delamination during long-term storage (especially in the storage period of 1-3 years) and not solidify at low temperatures;
- ✓ The demulsifiers should provide high quality separated water in the conditions of primary oil preparation, allowing it to be used in the reservoir pressure maintenance system without additional preparation;
- ✓ The demulsifiers should not cause corrosion of pipes and equipment and reduce the effectiveness of all other reagents;
- ✓ The demulsifier should not coagulate in the formation waters;
- ✓ The demulsifiers must have certain anti-foam properties;
- ✓ It is desirable that the demulsifier is oil soluble and non-ionic;
- ✓ The demulsifier must have a high speed action;
- ✓ Demulsifiers should exhibit thermodynamic and aggregative resistance under various technical, thermal, technological, and climatic conditions for oil preparation;
- ✓ With the aim of maximum efficiency of destruction of all types of oil emulsions (inverse emulsions of type W/O; direct emulsions of type O/W; medium emulsions of type W/O/W), taking into account their natural nanostructures, and of all types of technological residues [hard to destroy water-oil emulsions (HDWOE), hard to destroy water-oil suspensions (HDWOS), trap oil, granary oil, bottom sediments of process and commercial tanks, oil sludge, etc.] of primary oil preparation, demulsifiers should have a nanostructure, i.e. must be nanodemulsifiers;
- ✓ The surface pressure for nanodemulsifiers should be at least 40 mJ/m^2;
- ✓ In order to ensure high efficiency of the thermochemical method in the process of demulsification of all types of oil emulsions and corresponding sludges, finding nanoemulsifiers in the hybrid aggregative states of a substance (for organic substances, the term “hybrid aggregative state” of the substance is used for the first time) are the most expedient;
- ✓ The components of the active phase of nanodemulsifiers should show a synergistic effect in the destruction of reverse, direct and medium emulsions;
- ✓ Highly effective nanodemulsifiers as a wetting agent should contain a synergistic component from homologous series of low molecular weight nonionic surfactants such as ethoxylated ethers of n-aliphatic alcohols, acids and other compounds that cause the maximum wetting ($\cos\theta=0$, or $\cos\theta\rightarrow0$) of components of the molecular adsorption layer ("armor cover");
- ✓ In order to ensure the ability of the destructor-solvent in relation to the "armor cover" in all types of oil emulsions, high-performance nanodemulsifiers should have the lowest interfacial tension values (σ_M) at the water-oil interface ($\sigma_M\approx0$) or $\sigma_M\rightarrow0$);
- ✓ High-performance nanodemulsifiers, regardless of the value of their specific consumption, should not show the ability of the emulsifier in relation to all types of oil emulsions;
- ✓ Replacement of surfactants, (which are used to increase oil recovery), with nanodemulsifiers (or demulsifiers), at these fields is quite appropriate;

- ✓ In the oil fields, the transition to a downhole demulsification using nano demulsifiers allows: to achieve a high effect for the purification of oil from formation waters and salts, as well as for the purification of formation waters from oil in conditions PPO; maximum prevention of negative effects due to residues of oil colloids from technology PPN. Nano-emulsifiers in these technologies will in fact be able to perform the function of strong universal inhibitors of the formation of all types of oil emulsions, viscoelastic systems and gas hydrates in the turbulent motion of fluid starting from the bottomhole formation zone to the workshop of primary preparation and oil pumping (WPPOP);
- ✓ The most suitable solvents for nanodemulsifiers are critical nano-emulsions, which with the active phase can produce a synergistic effect;
- ✓ The demulsifier with the solvent should not give a visco-elastic systems;
- ✓ Molecules of the active phases of nanodemulsifiers should easily overcome of nanostructured barriers in the dispersion medium and in the dispersed phase of oil emulsions;
- ✓ Demulsifiers, including nanoemulsifiers should not contain nanopowder components, which can further increase the resistance of oil emulsions;

Side Requirements for Nanodemulsifiers in the Condition Primary Preparation of Oil:

- ✓ Nanodemulsifiers may also possess depressant, anticorrosive and bactericidal properties;
- ✓ Nanodemulsifiers can also perform the function of a nanodesuspensifier (the term “nanodesuspensifier” and in general "desuspensifier" are used for the first time) for treating bottom sediments consisting of a mixture of HDWOE and HDWOS;
- ✓ Nanodemulsifiers can also perform the function as an inhibitor and solvent of visco-elastic systems in the condition primary preparation of oil;
- ✓ Nanodemulsifiers can also perform the function as an inhibitor and solvent of gas hydrates in the condition primary preparation of oil;
- ✓ Nanodemulsifiers can also perform function as a neutralizer of hydrogen sulfide and highly dispersed iron sulfide in oil in the condition primary preparation of oil;
- ✓ Nanodeemulsifiers should have a high surface activity relative to dispersion, dispersed phases, as well as relative to the phases of molecular adsorption layers (molecular adsorption layers are for the first time considered as a separate phase) of all types of oil emulsions;
- ✓ For the predominance of maximum efficiency, nanodemulsifiers should have the properties of a nano-liquid-crystalline hybrid aggregative state (for organic substances, the existence of a nano-liquid-crystalline hybrid aggregative state was first announced by the authors A.K.Nugmanov, A.A.Gasanov and T.K.Dashdiyeva);
- ✓ Demulsifiers can also contribute to the prevention of salt deposits and mechanical impurities in the technological equipments;

Requirements number 14-34 formulated by us. Thus, the development and implementation of nanoemulsifiers (as much as possible meet the above requirements) for the treatment of formation water from oil in the conditions of primary oil preparation is one of the priorities directions of oilfield nanotechnology.

Experimental Part:

In the work as the objects of investigation were used oxyalkylene copolymers based on glycerin with different molecular weights (M = 2500, 3500, 4000, 5000, 6000) and with different degrees of hydroxyethylation (α = 10, 12, 20, 30, 40, 50), and also with different concentrations (weight percent: C = 40%, 50%, 55%, 60%) copolymers in methanol. Representatives of copolymers of the indicated homologous series mainly refer to liquid crystalline mesomorphic state of matter. They are characterized by a smectic structure [29]. Liquid crystals are formed from molecules having different geometric shapes (most often elongated or disc-like), for example surfactants [25]. Molecules of oxyalkylene ethers of various alcohols and including glycerin, like other surfactants, also have a similar molecular structure.

As the research methods in the work, were used reological, spectrophotometric and tensiometric methods. The viscosity of liquid crystalline nanodemulsifiers (LCND) was determined on an NDZ-8S viscometer. The NDJ-8S (China, Shanghai Ping Xuan Scientific Instrument Co., Ltd.) NDJ Series and SNB Series Viscometer are used in checking the viscous resistance and dynamical viscosity of liquid. It is widely used in measuring the viscosity of various liquid such as grease, painting, food stuff, dope, paper making, cosmetics, chemical industry, oil industry, capsule stickiness agent and medicines. NDJ Series Viscometer is a digital display viscometer by adopting the high accuracu driven step-motor and 16 bit micro-computer control processor with a LCD (liquid crystal display) night visual display. The display directly demonstrates the viscosity, rolating speed, spindle code and the maximum viscosity masured for spindle selected for the current rolating speed. The main controlling board, subsection driven board are all manufactuted by adopting the Surface Mount Technology (SMT).

The concentration of oil in waste water was determined on a SPECTROPHOTOMETER UV755B (China, Shanghai, YK Scientific). The instrument is a single beam, general purpose instrument designed to meet the needs of the Conventional Laboratory. This instrument is ideal for various applications, such as: Chemistry;

Biochemistry; Petro-chemistry; Environmental Protection; Food and Beverage Labs; Water and Waste Water Labs and other fields of quality control and research. The instrument incorporates a 128x64 dots matrix LCD display for photometric results, easy operation and wavelength range of 190 nm to 1100 nm. This instrument is an ideal for messurements in the visible and ultraviolet wavelength region of the electromagnetic spectrum.

Interfacial tension was determined using a stalagmometer. Interfacial tension is a phenomenon that, at the molecular level, results from the difference in energy between molecules at a fluid interface when compared to their bulk counterparts. It is equally correctly described as a measure of how much energy is required to make a unit area of interface between two immiscible liquids, thus taking units of Joules per square metre. Interfacial tension is a concept of fundamental importance in colloid science, describing phenomena as diverse as the formation, shape and stability of liquid drops [30-34], the surface energy value in forming an emulsions. Determination of the interfacial tension allows deductions to be made regarding the chemical composition of fluid interfaces and the adsorption and desorption of surfactants. Further, interfacial tension is the dominant force in interphase phenomena at the interface phases of the liquid-liquid , in particular water-oil. Therefore, accurate measurement of interfacial tension has scientific and applied values. Many techniques have been proposed to measure interfacial tension [34]. Arguably the simplest (in terms of instrumentation), most robust, and most versatile of these methods is pendant drop tensiometry, where the measurement consists simply of a fluid droplet. Based on these considerations, the stalagmometric method is one of the most common methods used to determine surface tension. In many oil production processes it is desirable to have fluids with an interfacial tension of zero or about zero. Therefore conditions $\sigma_M \approx 0$ or $\sigma_M \to 0$ is one of the requirements for the formation and destruction of nano emulsions, which is of great importance for treatment waste water from hydrocarbons in the conditions primary preparation of oil. Therefore, the determination of the minimum concentration at which the surfactant is a stabilizer of nanoemulsions has a great practical and theoretical implications in the field of nano colloid chemistry. Experimental determination of the minimum concentration at which the surfactant has a stabilizing effect on the nanoemulsion is a difficult task. To calculate the minimum concentration (Cm), at which the surfactant is a stabilizer of conventional or so-called macroemulsions, by A.A. Abramson was proposed the following expression [32, 33]:

$$C_m = \Gamma_m / \sigma_M \cdot \exp(-W_a/RT) \quad (1)$$

However, for nanoemulsion systems, the minimum concentration (C_s) of the surfactant at which spontaneous emulsification is observed is much higher than the value of C_m, i.e. $C_m >> C_s$. Therefore, formula (1) is not applicable for nanoemulsion systems. In addition, direct methods for determining ultra-low interfacial tension are also not widely used due to complexity and inaccuracy. In addition, direct methods for determining ultra-low interfacial tension are not widely used due to complexity and inaccuracy. Are absent also the simplest equations for calculating the surface activity at the liquid-liquid interface for nanoemulsion systems, in the cases $\sigma_M \approx 0$ or $\sigma_M \to 0$. Therefore, we focus on indirect methods of determining C_s. When measuring σ_M at the interface, aqueous solutions of a surfactant with a variable concentration - a hydrocarbon liquid, with the help of a stalagmometer USRI (Ufa Scientific Research Institute), at a certain concentration of surfactants, for the first time we detected the effect of spontaneous detachment of a hydrocarbon drop from a capillary (effect of SDDC) in an aqueous surfactant solution, that is The detachment of a hydrocarbon drop from the tip of the capillary occurs spontaneously, without squeezing the liquid out of the syringe with a micrometer. The concentration at which the effect of SDDC is detected is denoted by Cs. It should be noted that spontaneous emulsification occurs precisely with $C \geq C_s$. Therefore, Cs is the desired minimum concentration at which nanoemulsions are formed [31]. We have no doubt that the effect of SDDC is associated with the appearance in the investigated systems of ultra-low interfacial tension ($\sigma_M \approx 0$ or $\sigma_M \to 0$). Values of C_{oil} for the same system are reproduced with high experimental accuracy, since the deviation of the data does not exceed ±4.7% (Table 1). Thus, to detect the effect of SDDC, the most convenient instrument was the USRI stalagmometer. The remaining σ_M measurements were performed using an optical tensiometer SVT 20 N ("DataPhysics" company of Germany). The optical tensiometer SVT 20 N is a special optical device for measuring very small interfacial tension (Table 2). Measurements and calculations of interfacial tension on this device are justified by the rotating drop method or by the vibrational rotating drop method with an accuracy of $1 \cdot 10^{-6} \div 2 \cdot 10^{3}$ mJ/m^2. SVT 20 N opens up unique opportunities for analyzing the effect of tensides on the formation of an emulsion and their influence on the process of oil extraction by tertiary methods.

Results and Discussion:

On the basis of the data Tables 1 and 2, were established the following of correlation relationships (property-property and property-structure) for some liquid crystal nano demulsifiers (LCND) of the type oxyalkylene copolymers based on glycerol:

$\mu = 23.5 - 0.446T$ (2) at M=2500; C_{AF}=40%; α =10 % (Figure 1);
$\mu = 0.0066 \cdot M + 56.9$ (3) at T= -10°C; C_{AF}=40%; α =50 % (Figure 2);
$\mu = 0.815 \cdot C_{AF} + 49.2$ (4) at T= -10°C; M=6000; α =50 % (Figure 3);
$\mu = 0.468 \cdot \alpha + 7.5$ (5) at T= -10°C; M=6000; C_{AF}=40%; (Figure 4).

Where m is the dynamic viscosity, mPa·s; T is the temperature, ^oC; M is the molecular weight of the demulsifier; C_{AF} - concentration (in weight percent) of the active phase in methanol, %; α is the degree of oxyethylation or the percentage of oxyethylene from the molecular weight of the copolymer,%.

The correlation equation of the type $C_{oil} = f(\sigma_M)$ was first established for the investigated LCND:

$$C_{oil} = 10.3\sigma_M + 36.1 \quad (6) \quad \text{(Figure 5)}$$

Where C_{oil} is the concentration of oil in the waste water, mg/dm^3; σ_M - interfacial tension, mJ/m^2.

With the aid of equation (6), the values of oil concentration in water were calculated. In Table 3 the comparisons of the experimental and calculated data are presented. As follows from the data in Table 3, the deviations of the calculate data are within the experimental error. Based on the data in Tables 1-3, the following conclusions can be drawn:

- ✓ Liquid crystalline nanodemulsifiers simultaneously exhibit the highest effective demulsification, both for reverse water-oil emulsions (W/O) and for direct oil-water emulsions (O/W), up to the level of existing standards;
- ✓ The maximum efficiency is also achieved in inhibiting the formation of intermediate layers in the processes of oil preparation;
- ✓ For the purpose of the purposeful synthesis of liquid crystalline nano-emulsifiers and predicting the most optimal compositions of oxyalkylene copolymers based on glycerin with different molecular weights (M = 2500, 3500, 4000, 5000, 6000), and also with different degrees of hydroxyethylation (α = 10, 12, 20 , 30, 40, 50) with ultra-low interfacial tension ($\sigma_M \rightarrow 0$) the equation (6) turned out to be very applicable for monitoring wastewater degree treatment in the conditions primary preparation of oil, at the oil field “Karazhanbasmunai”;
- ✓ By means of purposeful management and control of wastewater treatment technology in the conditions of primary oil treatment, the maximum degree of wastewater treatment was achieved at the oil field “Karazhanbasmunai”. The best LCND samples on Tables 2 and 3 were highlighted with bold fonts.
- ✓ It should be noted that for these demulsifiers, relatively low viscosity values (12-67 mPa·s) are established (Table 1) at -10°C ÷30°C, which is a satisfaction of one of the requirements for demulsifiers.
- ✓ Therefore, with the measurement of the interfacial tension value for the above-mentioned demulsifiers (Tables 2 and 3), it is possible to predict the purification degree of the formation waters of the oil field “Karazhanbasmunai”.
- ✓ Physico-chemical meaning of equation (6) is also of interest: at $\sigma_M = 0$, $C_{oil} = 36.1$ mg/ dm^3 is obtained. As follows from Table 3, the average value for C_{oil} for all experimental data at $\sigma_M = 0$ is 35.95 mg/dm^3, and the existing deviation (0.4%) with respect to the calculated (Coil = 36.1 mg/dm^3) in within error of experiment. Thus, the constant value of equation (6) corresponds to a high degree of waste water treatment with the help of the most effective LCND samples, under the conditions of the primary oil preparation at the oil field “Karazhanbasmunai” of the Republic of Kazakhstan.

In Figure 6 shows three bottles with samples of the liquid-crystal (LC) state of nanodemulsifiers of the "IKHLAS" type: 1 - “IKHLAS” LCND- 6003-20; 2 - “IKHLAS” LCND-5003-15; 3 - “IKHLAS” LCND-4003-10. The locations of the bottles in the vertical and horizontal positions demonstrate the liquid states of the substance. Some authors have established nanodimension for LC [35]. Insofar as, nanocrystalline nuclei in the LC volume have a high surface activity, take place corresponding adsorption processes. This is a specific aggregate state of matter, in which it manifests the properties of a crystal and a liquid at the same time. Each of the compounds of liquid crystals behaved like a liquid in its mechanical properties and as a crystalline solid body - according to the optical properties of [35]. From this point of view, demulsifiers of the type “IKHLAS”, which were studied in the work, have a double nanostructure: a micellar nanostructure and a nano-liquid-crystalline structure [28, 36]. In this case, the visual images of nanoscale liquid crystals may be questionable. Therefore, there is a need for clarification on this issue. Since nanoparticles, including nanocrystals, have very high surface activity at interphase boundaries, in this case, at the interface of liquid crystal - glass (inner wall of a glass bottle), nano crystals are adsorbed according to BET theory (Brauner-Emmett-Teller [37]). As a result, a polymolecular film is formed, which is easily can observed visually. Similar images with nanoscale particles of bentonite and iron salts were observed by F. Ismayilov and others with the destruction of some oil-water emulsions [12]. It should be noted that in both papers similar effects are observed for the first time. In the work not found the relevant information on the visual images of nano liquid crystals when analyzing the literature data**.** Liquid crystals depending on the ordering of the axes of the molecules are divided into three groups: nematic; smectic and cholesteric [38]. Other authors liquid crystals are called “mezofaza” (“intermediate phase”) [39]. The investigated liquid crystals by the visual external images correspond to the microscopic images of the smectic variant. When melt some crystals, a liquid-crystalline phase is formed, which exists in the temperature interval from the melting point of the crystal to a certain temperature value. With a subsequent increase in temperature, the liquid crystal transfers to a normal liquid [23, 25, 29]. From this work we can conclude that the liquid crystals that are obtained by melting the crystalline substance exist in certain temperature interval. The lower point of the interval is known as the melting point of the corresponding crystalline substance, and the upper point of the interval, must be determined. On the other hand, it is not known that this will be a specific point or also some interval. In general, there are many unexplored issues in the field of physical chemistry of liquid crystals. As noted above, the similarity of liquid crystals with liquids lies in the fact that they are liquid and take the form of the container on which they are placed. Liquid crystals differ from traditional crystals in these properties. In addition, liquid crystals also have some properties characteristic of crystals. For example, the spatial ordering of molecules. The main mechanism of inadequate orderliness is explained by the fact that in liquid crystals, unlike ordinary crystals, the spatial arrangement of the centers of gravity of the molecules is not quite regular. This shows that liquid crystals do not have a rigid crystal cell [34]. Besides all this, not every substance can be a liquid crystal. Some organic substances with a complex molecular structure, including the copolymers under study (cooligomers) of the "IKHLAS" brand, can be in a liquid-crystalline state. Most authors of liquid crystals consider the of fourth aggregate state of substance. However, it should not be forgotten that, fourth aggregate state of the substance, it is plasma [34]. According to our considerations, alongside with the main aggregative states (gas, liquid, solid, plasma, neutron), are possible also hybrid aggregate state of matter. From this point of view, liquid crystals can be considered as a hybrid of liquid and solid (crystalline) aggregative states of matter. On the other hand, the dominant role of the aggregate in the hybrid version is of great importance. For investigated liquid crystals, the liquid aggregate state plays a dominant role. For the symbol of the hybrid state will be used two letters, the first letter corresponds to the first letter of the dominant. For investigated the hybrids described here, the sign LC (L - liquid; C - crystal) is suitable. It is known that a solid may be present in the form of a crystalline and amorphous state. Consequently, if in the hybrid state of liquid-amorph the liquid is dominant, the corresponding sign will be LA. Based on these considerations, the following hybrid variants of the aggregat state of can be listed: LC; LA; CL; AL; LG; GL; CG; AG; GC; GA (Q - gas). Due to the lack of relevant information about the hybrid aggregative state for organic substances, the problem is of particular interest as one of the new directions in the field of the molecular physics, of the oilfield chemistry, oil-field physics and in general, of the oilfield nanotechnology. By the way, it should be noted that prof. L.P. Semixina noted in her time (2009) that TND (Tyumen Nano demulsifier) demulsifier is a liquid crystal [27]. However, the problem of the hybrid aggregat state was not considered. Each hybrid aggregat state of manifests a previously unknown new property of the corresponding substance that may be the subject of discovery. For example, in Scotland, under the direction of the physicists of the Edinburgh University, S. Kennedy and A. Herrman, a discovery was made (published April 10, 2019) about the existence of a hybrid state of aggregation such as liquid crystals for potassium and sodium atoms in extreme synthesis conditions (high temperature and atmospheric pressure 20 000) [41]. Thus, the hybrid aggregat state of is a new area for both alkali metals and also for some nanodemulsifiers under investigation.

The Most Important Results, Scientific Novelty and Propositions:

Important Results:

For samples of nanodemulsifiers that are in a hybrid aggregative state, were installed correlation expressions type of the property-property and property-structure;

Certain samples of LCND show high efficiency when cleaning oil from formation water and when cleaning formation water from oil. The $\sigma_M \leq (1\text{-}1,3)$ mJ/m^2 condition can be taken as an efficiency criterion;

For high-performance LCND samples, the actual values of the dynamic viscosity (μ= 10-77 mPa·s) satisfy the requirements ($\mu \leq 100$ mPa·s) for demulsifiers;

For the selected samples of LCND, in contrast to the basic demulsifier Randem-2208 (at the "Karazhanbasmunai" field), the formation of intermediate layers (HDWOE) was not detected;

In equation (6) with σ_M=0, it turns out C_{oil} = 36.1 mg / dm3. The constant value of 36.1 mg / dm3 for highly efficient LCND (σ_M=0 or $\sigma_M \rightarrow 0$) corresponds to the average value of the degree of maximum purification of formation water from oil;

New requirements are formulated against demulsifiers:

- ✓ In order to ensure the ability of the destructor-solvent in relation to the "armor cover" in all types of oil emulsions, high-performance nanodemulsifiers should have the lowest interfacial tension values (σ_M) at the water-oil interface ($\sigma_M \approx 0$) or $\sigma_M \rightarrow 0$);
- ✓ High-performance nanodemulsifiers, regardless of the value of their specific consumption, should not show the ability of the emulsifier in relation to all types of oil emulsions;
- ✓ Replacement of surfactants, (which are used to increase oil recovery), with nanodemulsifiers (or demulsifiers), at these fields is quite appropriate;
- ✓ In the oil fields, the transition to a downhole demulsification using nano demulsifiers allows: to achieve a high effect for the purification of oil from formation waters and salts, as well as for the purification of formation waters from oil in conditions PPO; maximum prevention of negative effects due to residues of oil colloids from technology PPO. Nano-emulsifiers in these technologies will in

fact be able to perform the function of strong universal inhibitors of the formation of all types of oil emulsions, viscoelastic systems and gas hydrates in the turbulent motion of fluid starting from the bottomhole formation zone to the workshop of primary preparation and oil pumping (WPPOP);

- ✓ For the predominance of maximum efficiency, nanodemulsifiers should have the properties of a nano-liquid-crystalline hybrid aggregative state (for organic substances, the existence of a nano-liquid-crystalline hybrid aggregative state was first announced by the authors A.K.Nugmanov, A.A.Gasanov and T.K.Dashdiyeva).

Scientific Novelty:

- ✓ The expression $C_{oil} = 10.3\sigma_M + 36.1$ allows for the establishment a new of correlation relationship: property-property-efficiency of applying;
- ✓ Due to the high surface activity of bulk nano-liquid crystals (LC), intense adsorption occurs at the border of the LCND wall of the glass bottle, as a result of which a visually visible polymolecular layer is formed;
- ✓ Liquid crystals of organic origin were first noted as a hybrid state of matter.

Proposition:

- ✓ Using equation (6), it is possible to carry out express analytical monitoring on the degree of purification of formation water from oil under the conditions of a PPO at the “Karajanbasmunay” field.
- ✓ Continuing research on deep oil cleaning from stratal waters and stratum waters from oil under PPO conditions using liquid-crystalline nano-demulsifiers that are in a hybrid state of aggregation is one of priorities directions of the oilfield nanotechnology;
- ✓ Highly effectives samples of the LCND hybrid state are were recommended for implementation experimental-industrial testing at the “Karazhanbasmunai” field.

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Table 1: Viscosity values for the oxyalkylene copolymers based on glycerin

Type of liquid-crystalline nano demulsifier (LCND)	α, %	Viscosity LCND solutions in methanol depending on the concentration (in weight%) of the active part and temperature, mPa·s																			
		40					50					55					60				
		temperature, °C																			
		-10	0	10	20	30	-10	0	10	20	30	-10	0	10	20	30	-10	0	10	20	30
"IKHLAS" LCND-2503-10	10	28.0	23.4	19.0	12.5	10.1	30.8	23.8	19.0	13.6	11.0	32.2	25.7	20.0	14.3	11.7	33.6	26.4	20.8	14.8	12.1
"IKHLAS" LCND-2503-12	12	30.7	24.0	18.4	13.4	10.7	33.7	25.5	20.1	14.7	11.6	35.3	27.6	21.2	15.4	12.0	36.8	28.8	21.9	16.1	12.7
"IKHLAS" LCND-2503-15	15	32.7	26.5	20.7	14.5	13.2	35.0	28.9	22.3	16.0	14.5	37.6	30.0	23.8	17.0	15.2	38.9	31.5	24.8	17.5	15.8
"IKHLAS" LCND-2503-20	20	38.9	31.7	23.1	17.0	15.1	43.1	34.2	25.0	18.3	16.6	44.3	36.1	26.8	19.4	17.3	46.7	37.7	28.0	20.0	18.0
"IKHLAS" LCND-2503-30	30	50.4	40.2	30,3	21.6	18.6	53.9	43.8	33.3	24.0	20.5	57.4	46.7	34.8	24.8	21.5	59.4	47.6	36.4	25.2	22.3
"IKHLAS" LCND-2503-40	40	61.6	49.8	36.6	26.3	23.0	64.9	54.7	40.2	28.4	25.3	70.8	56.5	42.1	30.2	26.2	73.9	59.7	44.3	31.6	27.8
"IKHLAS" LCND-2503-50	50	73.3	58.6	43.0	30.9	27.1	78.4	63.3	45.9	33.9	29.8	82.0	67.2	48.7	35.8	31.1	85.7	70.3	51.6	37.1	32.5
"IKHLAS" LCND-3503-10	10	30.0	24.2	18.4	13.3	10.7	33.1	25.4	20.3	14.4	11.7	34.4	27.3	21.4	15.3	12.5	36.0	28.0	22.1	15.7	13.0
"IKHLAS" LCND-3503-12	12	32.9	25.7	19.9	14.2	11.5	36.4	27.4	21.3	15.7	12.4	37.7	29.6	22.7	16.4	12.8	39.2	30.8	23.4	17.2	13.7
"IKHLAS" LCND-3503-15	15	35.0	28.5	22.1	15.7	14.2	37.4	31.0	24.0	17.3	15.5	40.3	32.2	25.5	18.0	16.1	41.6	33.7	26.5	18.6	16.9
"IKHLAS" LCND-3503-20	20	41.6	33.6	25.0	18.1	16.1	46.0	36.5	26.8	19.6	18.0	47.9	38.7	28.6	20.7	18.5	50.0	40.1	30.2	21.4	19.2
"IKHLAS" LCND-3503-30	30	53.9	43.0	32.4	23.0	19.9	57.1	46.3	35.9	25.8	21.9	61.4	50.1	37.2	26.5	23.2	62.9	50.9	38.9	27.2	23.8
"IKHLAS" LCND-3503-40	40	66.0	53.2	38.8	28.4	24.7	69.0	58.2	43.0	30.5	27.1	75.8	60.8	45.0	32.4	28.0	78.7	68.8	47.4	34.0	29.7
"IKHLAS" LCND-3503-50	50	79.9	63.1	46.0	33.0	29.0	83.1	67.7	49.3	36.2	31.8	86.2	71.2	52.2	38.3	33.1	91.7	74.5	55.4	39.8	34.8
"IKHLAS" LCND-4003-10	10	31.2	25.0	19.1	13.8	11.1	34.4	26.3	21.0	14.9	12.1	35.7	28.3	22.1	16.0	12.9	37.3	29.0	22.9	16.2	13.4
"IKHLAS" LCND-4003-12	12	34.0	26.6	20.6	14.7	12.0	37.8	28.4	22.1	16.3	12.9	39.0	30.7	23.6	17.0	13.3	40.7	32.0	24.3	17.8	14.2
"IKHLAS" LCND-4003-15	15	36.4	29.5	22.9	16.3	14.8	38.9	32.2	24.9	18.0	16.0	41.8	33.3	26.5	18.7	16.7	43.0	34.9	27.5	19.3	17.5
"IKHLAS" LCND-4003-20	20	43.0	34.7	26.0	18.7	16.7	47.5	37.7	27.6	20.3	18.8	49.7	40.0	29.7	21.5	19.1	51.7	41.5	31.4	22.2	20.0
"IKHLAS" LCND-4003-30	30	55.8	44.7	33.5	23.8	20.6	59.0	47.8	37.3	26.7	22.7	63.8	51.8	38.5	27.6	24.1	65.1	52.9	40.4	28.1	24.7
"IKHLAS" LCND-4003-40	40	68.6	55.0	40.2	29.5	25.7	71.3	60.5	44.7	31.6	28.1	78.8	62.8	46.8	33.5	29.1	81.7	71.3	49.0	35.3	30.8
"IKHLAS" LCND-4003-50	50	83.3	65.6	47.6	34.2	30.0	86.4	70.0	51.1	37.7	33.0	89.4	74.0	54.2	39.6	34.4	95.3	77.1	57.4	41.0	36.2
"IKHLAS" LCND-5003-10	10	34.0	27.1	20.7	15.0	12.0	37.4	28.5	22.9	16.2	13.1	38.7	30.6	23.9	17.3	14.0	40.5	31.4	24.8	17.6	14.5
"IKHLAS" LCND-5003-12	12	36.9	28.8	22.4	16.0	13.1	41.2	30.7	24.0	17.7	14.0	42.5	33.2	25.6	18.5	14.4	44.3	34.6	26.3	19.3	15.4
"IKHLAS" LCND-5003-15	15	39.5	32.0	24.9	17.7	16.0	42.1	35.0	27.1	19.5	17.3	45.4	36.0	28.7	20.3	18.1	46.8	37.9	30.0	21.0	19.0

"IKHLAS" LCND-5003-20	20	46.8	37.7	28.3	20.3	18.2	51.6	40.8	30.0	22.1	20.4	54.1	43.5	32.3	23.3	20.7	56.3	45.1	34.1	24.1	21.7
"IKHLAS" LCND-5003-30	30	60.8	48.5	36.5	25.8	22.4	64.1	52.0	40.3	29.0	24.7	69.2	56.3	41.8	30.0	26.2	70.5	57.6	43.8	30.5	26.8
"IKHLAS" LCND-5003-40	40	74.5	59.6	43.7	32.0	27.9	77.5	65.6	48.5	34.4	30.5	85.9	68.3	51.0	36.4	31.7	88.4	77.2	53.2	38.4	33.5
"IKHLAS" LCND-5003-50	50	89.7	71.2	51.9	37.2	32.7	93.7	76.0	55.6	41.0	35.8	97.0	80.5	58.7	42.9	37.4	103.8	83.7	62.2	44.2	39.4
"IKHLAS" LCND-6003-10	10	37.1	29.7	22.6	16.5	13.2	41.4	31.1	25.0	17.8	14.3	42.5	34.2	26.3	18.9	15.3	44.2	34.4	27.0	19.3	15.9
"IKHLAS" LCND-6003-12	12	40.4	31.5	24.6	17.6	14.3	45.3	33.8	26.3	19.5	15.3	46.4	36.4	28.0	20.1	15.8	48.6	38.0	28.9	21.0	16.9
"IKHLAS" LCND-6003-15	15	43.3	35.2	27.3	19.4	17.5	46.0	38.2	30.0	21.4	19.0	49.6	39.6	31.3	22.3	19.8	51.5	41.3	33.0	23.1	21.0
"IKHLAS" LCND-6003-20	20	51.2	41.3	31.0	22.3	20.0	56.6	44.9	32.9	24.3	22.4	59.5	47.5	35.5	25.5	22.7	61.6	49.5	37.3	26.4	23.7
"IKHLAS" LCND-6003-30	30	66.9	53.2	40.0	28.3	24.5	70.5	57.0	44.2	31.9	27.1	75.7	62.0	46.8	33.0	28.9	77.3	63.0	47.7	33.3	29.2
"IKHLAS" LCND-6003-40	40	81.8	65.1	47.9	35.2	30.7	89.9	71.6	53.8	37.8	33.4	94.0	75.0	55.8	39.9	34.7	98.1	84.7	58.3	42.2	36.8
"IKHLAS" LCND-6003-50	50	96.6	77.9	57.1	40.3	35.8	102.9	83.1	60.8	44.9	39.1	106.4	88.2	64.6	46.8	41.0	114,3	91.6	68.4	48.5	43.1

Table 2: The level of pollution of waste water of the "Karazhanbasmunai" field with oil (Coil), depending on σ_M

Type of liquid-crystalline nano demulsifier (LCND)	The level of waste water contamination with oil (C_{oil}), depending on the interfacial tension (σ_i) LCND with different concentrations in methanol															
	40				50				55				60			
	σ_M, mJ/m^2	C_w, %	C_{oil}, mg/dm^3	SDDC	σ_M, mJ/m^2	C_w, %	C_{oil}, mg/dm^3	SDDC	σ_M, mJ/m^2	C_w, %	C_{oil}, mg/dm^3	SDDC	σ_M, mJ/m^2	C_w, %	C_{oil}, mg/dm^3	SDDC
"IKHLAS" LCND-2503-10	1.24	0.78	49.4	-	0.87	0.49	45.0	-	0.59	0.37	42.2	-	0.51	0.12	41.4	+
"IKHLAS" LCND-2503-12	1.64	0.80	52.8	-	1.08	0.54	47.1	-	0.89	0.43	45.3	-	0.77	0.18	44.0	-
"IKHLAS" LCND-2503-15	1.90	0.83	56.0	-	1.47	0.71	51.4	-	1.13	0.58	47.8	-	1.07	0.35	47.1	-
"IKHLAS" LCND-2503-20	2.49	0.92	61.5	-	1.83	0.76	54.9	-	1.59	0.62	52.5	-	1.54	0.42	52.0	-
"IKHLAS" LCND-2503-30	3.70	0.95	74.2	-	3.01	0.89	67.0	-	2.62	0.69	63.2	-	2.39	0.55	60.7	-
"IKHLAS" LCND-2503-40	4.83	1.03	85.9	-	4.15	0.94	78.8	-	3.63	0.74	73.4	-	3.44	0.59	71.5	-
"IKHLAS" LCND-2503-50	5.98	1.06	97.6	-	5.12	0.99	88.7	-	4.58	0.83	83.4	-	4.37	0.64	81.1	-
"IKHLAS" LCND-3503-10	0.62	0.70	42.5	-	~0	0.07	38.6	+	~0	0	36.6	+	~0	0	35.4	+
"IKHLAS" LCND-3503-12	0.80	0.74	44.7	-	0.50	0.11	41.4	+	~0	0	38.7	+	~0	0.02	37.0	+
"IKHLAS" LCND-3503-15	1.19	0.79	48.3	-	0.76	0.48	43.9	-	0.51	0	41.3	+	0.47	0.09	40.9	+
"IKHLAS" LCND-3503-20	1.76	0.84	54.2	-	1.32	0.69	49.7	-	1.01	0.45	46.5	-	0.84	0.15	44.8	-
"IKHLAS" LCND-3503-30	2.83	0.89	65.4	-	2.28	0.76	59.5	-	1.90	0.62	55.8	-	1.82	0.21	55.0	-
"IKHLAS" LCND-3503-40	3.94	0.93	76.9	-	3.40	0.85	71.2	-	2.93	0.67	66.3	-	2.78	0.36	64.7	-
"IKHLAS" LCND-3503-50	5.05	1.08	88.0	-	4.25	0.92	80.0	-	3.80	0.86	75.2	-	3.50	0.50	72.1	-
"IKHLAS" LCND-4003-10	~0	0	34.9	+	~0	0	32.3	+	~0	0	30.0	+	~0	0.03	28.6	+
"IKHLAS" LCND-4003-12	~0	0	37.2	+	~0	0	34.1	+	~0	0	31.8	+	~0	0.03	31.0	+
"IKHLAS" LCND-4003-15	~0	0.14	41.1	+	~0	0	37.4	+	~0	0	35.1	+	~0	0	33.4	+
"IKHLAS" LCND-4003-20	1.01	0.69	47.0	-	0.60	0.53	42.3	-	~0	0.15	40.2	+	~0	0.05	39.2	+
"IKHLAS" LCND-4003-30	2.19	0.80	58.9	-	1.59	0.58	52.5	-	1.37	0.45	50.3	-	1.25	0.09	49.0	-
"IKHLAS" LCND-4003-40	3.37	0.89	70.7	-	2.71	0.71	64.0	-	2.40	0.60	60.9	-	2.31	0.14	59.9	-
"IKHLAS" LCND-4003-50	4.62	1.12	83.5	-	3.85	1.0	75.8	-	3.43	0.67	71.4	-	3.13	0.19	68.4	-
"IKHLAS" LCND-5003-10	~0	0	32.2	+	~0	0	29.2	+	~0	0	27.7	+	~0	0	26.5	+
"IKHLAS" LCND-5003-12	~0	0	34.1	+	~0	0	31.3	+	~0	0	29.1	+	~0	0	27.7	+
"IKHLAS" LCND-5003-15	~0	0.09	37.4	+	~0	0	34.0	+	~0	0	32.1	+	~0	0	31.6	+
"IKHLAS" LCND-5003-20	0.70	0.16	43.0	-	~0	0	39.8	+	~0	0	36.8	+	~0	0.03	36.0	+
"IKHLAS" LCND-5003-30	1.75	0.47	54.0	-	0.60	0.39	42.4	-	1.02	0.18	46.5	-	0.89	0.08	45.3	-
"IKHLAS" LCND-5003-40	2.80	0.62	64.8	-	1.91	0.44	55.8	-	1.86	0.26	55.3	-	1.73	0.08	53.9	-

"IKHLAS" LCND-5003-50	**3.80**	**0.70**	**75.7**	**-**	**2.78**	**0.57**	**64.7**	**-**	**2.77**	**0.41**	**64.7**	**-**	**2.45**	**0.12**	**61.4**	**-**
"IKHLAS" LCND-6003-10	**~0**	**0**	**30.0**	**+**	**~0**	**0**	**27.6**	**+**	**~0**	**0**	**25.8**	**+**	**~0**	**0**	**25.2**	**+**
"IKHLAS" LCND-6003-12	**~0**	**0**	**32.5**	**+**	**~0**	**0**	**29.3**	**+**	**~0**	**0**	**27.8**	**+**	**~0**	**0**	**27.6**	**+**
"IKHLAS" LCND-6003-15	**~0**	**0**	**35.4**	**+**	**~0**	**0**	**32.3**	**+**	**~0**	**0**	**30.2**	**+**	**~0**	**0**	**29.5**	**+**
"IKHLAS" LCND-6003-20	**0.40**	**0.03**	**40.3**	**+**	**~0**	**0**	**36.6**	**+**	**~0**	**0**	**34.7**	**+**	**~0**	**0**	**33.0**	**+**
"IKHLAS" LCND-6003-30	**1.31**	**0.17**	**49.6**	**-**	**0.95**	**0.10**	**45.9**	**-**	**0.75**	**0.03**	**42.4**	**-**	**0.50**	**0**	**41.3**	**+**
"IKHLAS" LCND-6003-40	**2.30**	**0.38**	**60.0**	**-**	**1.78**	**0.29**	**54.5**	**-**	**1.49**	**0.15**	**51.5**	**-**	**1.37**	**0.07**	**50.2**	**-**
"IKHLAS" LCND-6003-50	**3.35**	**0.57**	**70.3**	**-**	**2.74**	**0.44**	**64.5**	**-**	**2.31**	**0.23**	**60.0**	**-**	**2.26**	**0.09**	**59.5**	**-**
"Randem" 2208 (Nalko, USA)	**4.74**	**0.58**	**105.8**	**-**	**4.39**	**0.51**	**101.0**	**-**	**3.88**	**0.45**	**94.7**	**-**	**3.70**	**0.37**	**77.2**	**-**

Table 3: The experimental and calculated values of oil concentrations in the waste water of the "Karazhanbasmunai" field, as well as the corresponding errors

Type of LCND	Comparison of experimental and calculated values for oil concentrations in water (mg/dm^3)											
	40			50			55			60		
	C_{oil}, exp	C_{oil}, calc	error, %	C_{oil}, exp	C_{oil}, calc	error, %	C_{oil}, exp	C_{oil}, calc	error, %	C_{oil}, exp	C_{oil}, calc	error, %
LCND-2503-10	49.4	48.9	--1.0	45.0	45.1	+0.2	41.2	42.1	+2.2	41.8	41.3	-1.2
LCND-2503-12	52.5	52.9	+0.7	49.1	47.2	-3.9	45.3	45.3	0	43.2	44.0	+1.8
LCND-2503-15	56.0	55.7	-0.5	51.4	51.2	-0.4	48.6	47.7	-1.8	47.1	47.1	0
LCND-2503-20	62.9	61.8	-1.7	54.9	54.9	0	52.5	52.5	0	49.9	51.9	+4.0
LCND-2503-30	74.2	74.2	0	65.0	67.1	+3.2	63.2	63.0	-0.3	63.0	60.7	-3.7
LCND-2503-40	84.0	85.8	+2.1	79.3	78.8	-0.6	73.4	73.5	+0.1	69.7	71.5	+2.6
LCND-2503-50	99.6	97.7	-1.9	88.7	88.8	+0.1	82.1	83.2	+1.4	78.3	81.0	+3.4
LCND-3503-10	42.5	42.4	-0.2	38.6	36.1	~0	36.6	36.1	~0	35.4	36.1	~0
LCND-3503-12	42.7	44.3	+3.7	40.2	41.2	+2.5	38.7	36.1	~0	37.0	36.1	~0
LCND-3503-15	48.3	48.4	+0.2	43.9	43.9	0	41.3	36.1	~0	41.1	40.9	-0.5
LCND-3503-20	54.2	54.2	0	49.7	49.6	-0.2	46.1	46.5	+0.9	42.8	44.8	+4.7
LCND-3503-30	67.4	65.2	-3.2	61.5	59.6	-3.1	55.8	55.6	-0.4	56.2	54.8	-2.5
LCND-3503-40	76.9	76.3	-0.7	70.4	71.1	+1.0	66.8	66.2	-0.9	64.4	64.7	+0.5
LCND-3503-50	85.4	88.1	+3.2	82.0	79.8	-2.7	75.2	75.2	0	73.1	72.1	-1.4
LCND-4003-10	34.9	36.1	~0	32.2	36.1	~0	30.0	36.1	~0	28.6	36.1	~0
LCND-4003-12	37.2	36.1	~0	34.1	36.1	~0	31.8	36.1	~0	31.0	36.1	~0
LCND-4003-15	41.1	41.2	+0.2	37.1	36.1	~0	35.1	36.1	~0	33.4	36.1	~0
LCND-4003-20	49.0	46.5	-5.1	44.3	42.2	-4.7	40.0	40.2	+0.5	38,8	39.2	+1.0
LCND-4003-30	58.9	58.6	-0.5	50.5	52.4	+3.8	48.5	50.2	+3.5	50.3	48.9	-2.8
LCND-4003-40	70.7	70.8	+0.1	65.3	64.0	0	62.7	60.8	-3.0	59.5	59.9	+0.7
LCND-4003-50	81.5	83.7	+2.7	75.8	75.7	-0.1	73.9	71.4	-3.4	67.9	68.3	+0.6
LCND-5003-10	32.2	36.1	~0	29.2	36.1	~0	27.7	36.1	~0	26.5	36.1	~0
LCND-5003-12	33.9	36.1	~0	31.3	36.1	~0	29.1	36.1	~0	27.7	36.1	~0
LCND-5003-15	37.4	36.1	~0	34.0	36.1	~0	32.1	36.1	~0	31.6	36.1	~0
LCND-5003-20	45.0	43.3	+2.7	39.8	36.1	~0	36.8	36.1	~0	36.0	36.1	~0
LCND-5003-30	52.0	54.1	+4.0	41.7	42.3	+1.4	48.5	46.6	-3.9	45.0	45.3	+0.7
LCND-5003-40	64.8	64.9	+1.5	58.8	55.7	-5.3	57.2	55.3	-3.3	55.2	53.9	-2.3
LCND-5003-50	75.7	75.2	-0.7	64.7	64.7	0	62.0	64.6	+4.2	61.4	61.1	-0.5
LCND-6003-10	30.0	36.1	~0	27.6	36.1	~0	25.8	36.1	~0	25.2	36.1	~0
LCND-6003-12	32.5	36.1	~0	29.3	36.1	~0	27.8	36.1	~0	27.6	36.1	~0
LCND-6003-15	35.4	36.1	~0	32.3	36.1	~0	30.2	36.1	~0	29.5	36.1	~0
LCND-6003-20	40.3	40.2	-0.2	36.6	36.1	~0	34.7	36.1	~0	33.0	36.1	~0
LCND-6003-30	49.6	49.6	0	45.9	45.8	-0.2	44.0	42.8	-2.7	41.5	41.2	-0.7
LCND-6003-40	60.0	59.8	-0.3	51.5	54.3	+5.4	52.9	51.4	-2.8	48.3	50.2	3.9
LCND-6003-50	68.3	70.6	+3.3	67.5	64.3	-4.7	58.3	59.9	+2.0	59.5	59.4	-0.2

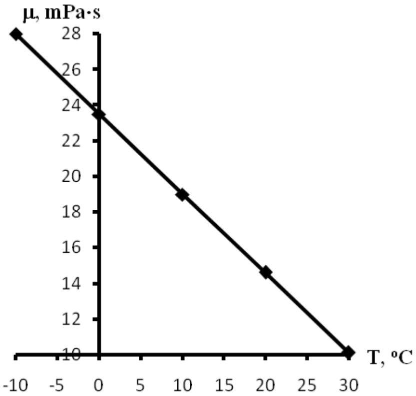

Fig1. Dependence μ=f(T) for LCND (at M=2500; C_{AF}=40%; α=10%).

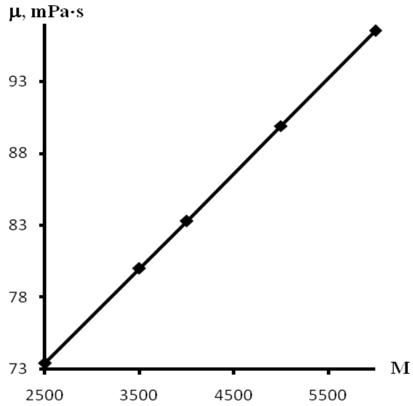

Fig 2. Dependence μ=f(M) for LCND (at T= -10°C; C_{AF}=40%; α =50 %)

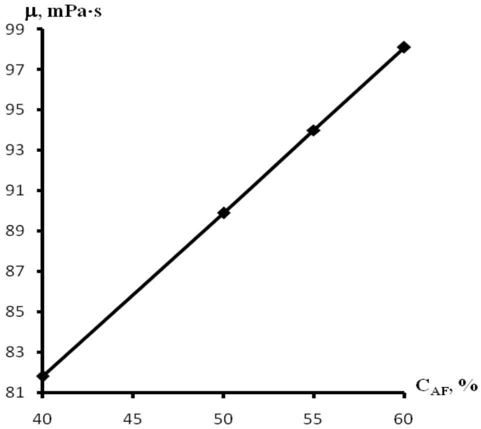

Fig 3. Dependence μ=f(C_{AF}) for LCND (at T=-10°C; M=6000; α=50%)

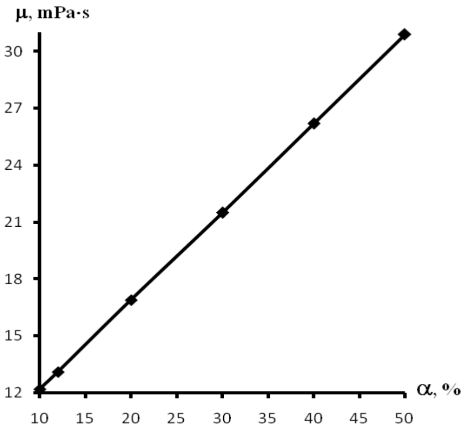

Fig 4. Dependence μ=f(α) for LCND (at T=20°C; M=2500; C_{AF}=40%)

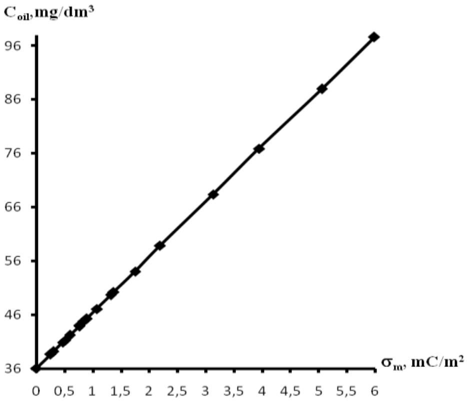

Fig. 5. Dependence C_{oil} = f (σ_M) for methanol solutions of LCND

1

2

3

1 2 3

Figure 6: Appearance of some "IKHLAS" LCND samples from bottles in vertical and horizontal positions: 1 - “IKHLAS” LCND- 6003-20; 2 - “IKHLAS” LCND-5003-15; 3 - “IKHLAS” LCND-4003-10.