

CHEMICAL ENGINEERING

1. Introduction

Scientific researches with the purpose of improvement of operative methods of control of the composition of dissolved substances in liquids during the course of technological processes, environmental monitoring, are timely and relevant.

The standard conductometric method is intended for rapid studies in binary solutions of concentrations of substances that affect the conductivity of a liquid. This method does not allow to determine the concentration of a single controlled substance in a multicomponent fluid by the measured value of the specific conductivity, with one standard frequency of the electromagnetic field defined for all liquids. The study of the electrical properties of aqueous solutions as liquid dielectrics and the analysis of the components of complex electrical parameters at different frequencies of the electromagnetic signal deepen the theory in the study of the dependences of the electrical properties of liquids on their composition. The attention to such research is enhanced by the improvement of experimental techniques.

The aim of research is development of a new approach to the method of dielectric and conductometric measurements to determine the concentrations of constituents of multicomponent liquids by electrical parameters.

The object of research is the electrical properties of liquids of different chemical nature of constituents. The subject of research is fluid, concentration of dissolved substances in water and electrical methods of their control.

Before performing the experimental studies, the main features, trends and prospects of the development of modern electrical methods for controlling the composition of liquids were analyzed to establish the measurement conditions.

2. Methods

To describe the research conditions, let's consider the theoretical propositions regarding the electrical methods for studying the composition of liquids. The electrical properties of any

CHEMICAL MEASUREMENTS BY ELECTRICAL PARAMETERS TO CONTROL THE COMPOSITION OF MULTICOMPONENT LIQUIDS

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Abstract: The authors substantiated the relevance of scientific studies of the electrical properties of multicomponent liquids. Such liquids are real objects that require stock control during operation. This applies to many areas of human activity: environmental monitoring, the chemical and food industries, medicine, and the like. Laboratory methods are unable to meet the following requirements.

The electrical properties of substances, including liquids, have been well studied by scientists. In addition, the high level of modern experimental technology allows to combine theoretical and practical achievements, in this case chemical and physical-electrical sciences.

In the theoretical provisions regarding the electrical methods for the study of the composition of liquids, the authors, based on the classical knowledge of dielectric conductivity physics, argue for their use for applied chemical measurements. After all, physico-chemical electrical measurements have long been used for the study of two-component standard solutions. The authors propose to improve such measurements and use them for multicomponent liquids. At the same time, it is proposed to use the developed primary converters and a new informative parameter – complex conductivity components (admittance). On the basis of the obtained experimental results, the research conditions are formulated. The measuring system consists of a primary capacitive transducer (carbon electrodes in vessels with the test liquid); multi-frequency current generator (RLC meter) and computer.

The dependences of the values of the complex components of conductivity on the frequency of the electromagnetic field between the electrodes for liquids with dissolved substances of different chemical nature and concentrations were investigated. Some individual properties have been established for such substances, which allow to develop methods and methods of operational control of the composition of multicomponent liquids by electrical parameters.

The article discusses the scientific and practical results of research and the advantages of the developed methods and methods of composition control for real liquids. Also, some of the scientific facts obtained allow to further develop and develop methods of electro-chemical research with a wider range of constituents, for low concentrations and without complex laboratory manipulations.

Keywords: concentration, solutions, properties, dielectric, polarization, conductivity, liquid, spectroscopy, transducer, control.

material are determined by the presence of charges and the possibility of their movement. For all media except vacuum, the carrier velocity is proportional to the electromagnetic field strength.

Carrier mobility is characterized by the coefficient of charge carrier velocity and field strength. The types of charge carriers and their mobility may be different in different environments. The mobility of the media is also significantly dependent on the environment.

The essence of the proposed research method is the dependence of the liquid composition on its dielectric constant. The current representation of the conductivity of dielectric fluids is as follows.

Virtually all material properties are temperature dependent. As a rule, this effect is taken into account by the introduction of a temperature coefficient, which is not technically difficult to implement. On the one hand, liquids can be considered as dielectric substances in which the accumulation, storage and propagation of electrical energy are possible. On the other hand, fluid can be considered a resistive substance in which some of the electrical energy is converted into thermal energy. There is no absolute difference between the dielectric and resistive state of a substance, because depending on the conditions, the same substance may be a dielectric and a resistor. The basic condition that explains the physical essence of a substance's behavior on resistive and dielectric is based on the concept of Maxwell's time of dielectric relaxation. The representation of a real capacitor in the form of a coupling of a capacitor and a support is a substitution scheme. A simple dielectric replacement scheme consists of a parallel coupling of capacitance and resistance. Dielectric AC losses are conductivity and polarization losses. In the case of AC, the losses are due to polarization.

Under the influence of alternating voltage, the dipoles begin to rotate and orient themselves along the action of the electric field until about the end of the first half-life of the voltage. In the next half-period, they are

deployed in a new direction until about its completion. This phenomenon is reminiscent of resonance.

It should be noted that the dielectric loss in any material depends on the temperature, frequency, field strength, nature of the material. Therefore, the frequency dependence of losses is a characteristic of the material and is determined for each substance (solvent) not only by its properties but also by the presence of impurities.

As a rule, losses are maximal at one or more frequencies, depending on the type of molecule. Highs are due to the rotation of polar molecules in a liquid dielectric. Such a study of the frequency behavior of losses is known as “dielectric spectroscopy”, which studies the structure of substances. The dielectric properties depend on the polarization mechanism to which a certain frequency and time of the process belong. Electron polarization occurs in a neutral atom when the electron cloud shifts relative to its nucleus. Atomic polarization occurs when an electron cloud is deformed by the action of a field. Relaxation effects arising from the rotation or vibration of particles (atoms, ions or electrons) are observed in the vicinity of their characteristic absorption frequencies.

Therefore, the fundamental characteristic of dielectrics is the dielectric constant based on the processes of electric polarization.

According to Debye's theory, the relaxation time of particles depends on their size, solvation processes and other local factors. Hence, considering complex systems such as multicomponent liquids, where solvent molecules, solution, their self-associates and solvation complexes are present, the region of anomalous dispersion corresponds not to one value of relaxation time, but to a set of such values. Each of these values corresponds to the independent relaxation of particles of different types.

Carrying out rapid chemical analysis of the composition of liquids in production is a difficult task. At the time, a basis for advanced metrological provision of such control is a technique that would satisfy the following requirements: low cost of equipment and methodological support; minimal cost of analysis.

The essence of the imitative method is to supply a small-amplitude sinusoidal signal to the test system and to study the signal it is called – the output response

The capabilities of the method are determined by the combination of the following advantages: the impedance (or admittance) measured in a sufficiently wide frequency domain has all the information that can be obtained using different constant current methods; Experimental performance (the amount of information obtained compared to the cost of the experiment) is high [1–3].

In this work, the RLC-meter was used to scientifically search for the dependence of the electrical parameters of aqueous solutions on the chemical nature and the concentration of the constituents. Using the information obtained from studies at large frequency ranges, it is proposed to improve the metrological characteristics of the express conductometric process of determining and controlling the composition of multicomponent liquid mixtures, such as selectivity and sensitivity. Since the composition of substances in industrial fluids, liquid wastes and sewage of this production is known, it is always possible for experimental studies to create model mixtures that correspond to real objects.

3. Results

The main scientific result of the research was the ability to determine the qualitative and quantitative composition of liquids by the complex parameters of electrical conductivity. This

allowed to do thanks to the scientific facts obtained on the basis of the analysis of the dependence of the admittance values on the frequency of the test signal from 50 to 10 KHz.

The main scientific facts obtained and their possible practical application:

1. In the study of liquids with a controlled substance that increases the specific conductivity of the fluid (electrolyte), the existence of a single frequency at which the reactive component of conductivity for the corresponding range of concentrations of the controlled substance in the mixture takes a certain single value, which allows to selectively detect such a substance in a liquid constituents with further determination or control of its concentration.

2. A method is proposed, which allows to control the maximum permissible concentrations of the component at the determined experimentally determined frequency when measuring the value of the reactive conductivity component (positive, zero, negative).

3. A method of operative control of a substance that reduces the specific electrical conductivity of a fluid (non-electrolyte) is proposed, which allows to detect and determine its concentration in a multicomponent fluid of variable concentrations of components by a measured value of the active and reactive conductivity components at one frequency.

4. It is established that the modified electrode of carbon electrodes achieves the amplification of the electrical signal in the presence of copper salts in the liquid, which allows the measured value of the reactive component of conductivity, at a certain frequency, to quickly and selectively control the presence and small concentrations (from thousandths of g/l) of vitriol in a multicomponent fluid of unknown composition [4–10].

Table 1 illustrates the measurement results, which confirm the points 1 and 2 above.

The influence of external factors on the electrical parameters of liquids – temperature and ultrasonic radiation is also investigated, to further take into account their influence on the values of informative measurement parameters.

Table 1

Dependence of the reactive component of the electrical conductivity of the CuSO₄ solution from the frequency with increasing concentrations in the range from 2.5 g/l to 5.0 g/l

| Concentration, g/l | Frequency, kHz | | | | |
|--------------------|----------------|---------|---------|----------|----------|
| | 5 | 10 | 20 | 40 | 50 |
| 2.534 | 0.01580 | 0.00780 | 0.00006 | -0.00790 | -0.01591 |
| 2.980 | 0.01997 | 0.00897 | 0.00005 | -0.00890 | -0.01999 |
| 3.112 | 0.02144 | 0.00944 | 0.00005 | -0.00948 | -0.02167 |
| 3.690 | 0.02335 | 0.01135 | 0.00004 | -0.01131 | -0.02297 |
| 4.231 | 0.02868 | 0.01468 | 0.00003 | -0.01469 | -0.02793 |
| 4.987 | 0.03772 | 0.01772 | 0.00001 | -0.01768 | -0.03562 |
| 5.068 | 0.04106 | 0.02106 | 0.00001 | -0.02100 | -0.04100 |

Methods of operative chemical control of the concentration of controlled substances are developed in two main stages: study of the control model – liquids with the maximum permissible concentration of the controlled substance, which are performed under laboratory conditions; and the actual process for controlling the object itself.

Conclusions on exceeding the maximum permissible concentration of a controlled substance are based on determining

the sign of the measured values of the reactive conductivity component.

Methods of operative control of concentration of controlled substances in multicomponent liquids are developed, which consist of two main stages: study of control model – liquids with maximum permissible concentration of controlled substance, which are performed in laboratory conditions; the actual process of control for a real object.

4. Discussion and conclusions

The proposed electrical method for investigating the composition of liquids has several advantages over existing ones, in particular:

– the lowest concentration of a substance that can be determined by the developed methods – 0.01–0.001 mg/l;

– measurements are made in real time (without sampling and concentration);

– the accuracy of the analysis is (1.0–10.0) % and sufficient for the needs of industry;

– an important advantage of the method is the small measurement time, which does not exceed a few seconds;

– the simplicity of the design of the primary transducer enables rapid mass analysis for a wide range of controlled substances.

The developed methods allow to automate the express control of the chemical composition of liquids and can be developed and used in real production conditions and in combination with the current production and environmental standards of a particular enterprise; will contribute to the saving of material resources and will ensure minimal impact of liquid waste on the environment.

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Received date 10.10.2019

Accepted date 10.11.2019

Published date 23.11.2019

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