1. Introduction

The study of the reaction of phenol sulfomethylation is of practical interest in connection with the availability of phenol and the possibility of synthesizing water-soluble non-toxic compounds on its basis, which are used as additives, bactericidal substances and additives to concrete mixtures. As well as dispersants, plasticizers, ion exchange resins, etc. [1, 2]. One of the studied methods for the synthesis of such compounds is the condensation of phenol with formaldehyde and the further sulfonation of the resulting phenol-aldehyde resin (Novolac) with sulfuric acid, taken in a small amount. The Novolac type resin is sulfonated at a temperature of 110–120 °C with concentrated sulfuric acid for 4–8 hours [3, 4]. The disadvantage of this method is that the reaction product is a rather complex mixture of monomers, dimers, trimmers and free phenol [5]. The production of water-soluble products by another method: phenol sulfomethylation, is carried out with bisulfite compounds of aldehydes. The product of the interaction of formaldehyde with sodium bisulfite, due to its low price, is of great interest in using it as a catalyst (interfacial catalysis – IFC) [9].

So, the object of research is the reaction of phenol sulfomethylation, with the aim of obtaining water-soluble non-toxic products based on it used as surfactants. And the aim of research is studying the possibility of carrying out the phenol sulfomethylation reaction with bisulfite derivative of formaldehyde in an aqueous medium in the presence of interfacial catalysts and the selection of optimal technological conditions for producing surfactants based on them.
2. Methods of research

Under laboratory conditions, a series of reactions of phenol sulfomethylation were carried out in the presence of various surfactants: non-ionic surfactant Neonol AF-9-12 (monoaalkylyphenol oxyethylation) and anion-active surfactants of NF dispersants (the product obtained by sulfonating naphthalene with sulfuric acid followed by condensation with formaldehyde). To stabilize the pH of the system, diethanolamine was used in a volume of 0.05 % of the total mass of the main components. The amount of catalyst was taken at the rate of 0.1; 0.05; 0.005 % of the mass of the feed.

Experiment 1. In a three-neck round-bottomed flask with a capacity of 1.5 dm$^3$ was charged 429 g of 94 % sodium sulfite, 240 ml of water, 190 g of phenol, 204 g of formalin (37 % formaldehyde solution), 1.06 g of Neonol AF-9-12 and 5.3 g of diethanolamine. The reaction mass is heated to 75–80 °C with constant stirring. It is kept at this temperature for 1 hour. (In this case, the reaction mass can self-heat up to 85–90 °C). The mass is cooled and sampled for analysis. The finished product is a viscous orange liquid.

Experiment 2. Conducted by analogy of experiment 1. The amount of catalyst for Neonols AF-9-12 loaded 0.53 g

Experiment 3. Conducted by analogy of experiment 1. The amount of catalyst for Neonols AF-9-12 loaded 0.053 g

Experiment 4. In a three-necked round-bottom flask with a capacity of 1.5 dm$^3$ load 429 g of 94 % sodium sulfite, 240 ml of water, 190 g of phenol, 204 g of formalin (37 % formaldehyde solution), 1.06 g of dispersant NF, as well as 5, 3 g of diethanolamine. The reaction mass is heated to 75–80 °C with constant stirring. The reaction mass is maintained at this temperature for 1 hours with constant stirring. The mass is cooled and sampled for analysis. The finished product is a viscous liquid of reddish-brown color.

Experiment 5. Conducted by analogy of experiment 4. The amount of catalyst dispersers NF loaded 0.53 g

Experiment 6. Conducted by analogy of experiment 4. The amount of catalyst dispersers NF loaded 0.053.

Analysis of the products was carried out in accordance with regulatory documents [10].

Due to the fact that the obtained products are polymeric, in research their composition was characterized by the $K$ value (the ratio of the content of high and low molecular weight fractions).

The degree of sulfonation was determined by the content of organic sulfur and expressed by the number of sulfo group ($S$ value) per 1000 molecular weight units.

According to the characteristic of the surface-active properties of the samples, the critical micelle concentration (CMC) was determined, which was determined by the properties of the solution, depending on the number and size of the kinetically active particles, depending on its optical characteristics.

The most important characteristic of surfactant is the critical micelle concentration (CMC). CMC is the minimum molar concentration of surfactant at which one can experimentally detect a colloid-dispersed phase.

At low concentrations (<10$^4$ mol/l), surfactant form true solutions, and with increasing concentration, micelles appear in them, formed as aggregates of a special structure.

As can be seen from the Table 1, CMC of the obtained products is close in value to the CMC of the sample for comparison.

Also, with an increase in $K$, the value of CMC increases, thus with increasing molecular weight, the surface tension of aqueous solutions increases and leads to a decrease in surface activity. Thus, the largest CMC can be assumed that the resulting products can be used as surfactants.

Based on a study of toxic and hygienic properties, it is found that the resulting product based on sulfomethyl phenol-formaldehyde belongs to the third class of hazard. Therefore, the obtained products can be proposed for use as anionic suractant in various applications: in the textile industry as auxiliary substances (stabilizers, wetting agents, dispersants), in construction (plasticizers for concrete), etc.

| No. | Product | Mass fraction of sodium sulfate, % | Mass fraction of water-soluble substances, % | Water | pH | Sulfonation degree (S) | CMC, g/dm$^3$ |
|-----|---------|------------------------------------|---------------------------------------------|-------|----|-----------------------|--------------|
| 1   | IP dispersant | 0.1                                | 0.1                                         |       |    | 1.1                   | 2.0          |
| 2   | The product of phenol sulfomethylation in the presence of Neonol AF-9-12: | | | | | | |
|     | Experiment 1 | 0.15                               | 0.1                                         | 8     | 0.5 | 1                     | 2.5          |
|     | Experiment 2 | 0.3                                | 0.2                                         | 8     | 1   | 1.5                   | 3.5          |
|     | Experiment 3 | 0.25                               | 0.15                                        | 9     | 0.5 | 1.6                   | 2.4          |
| 3   | The product of phenol sulfomethylation in the presence of NF dispersant: | | | | | | |
|     | Experiment 4 | 0.15                               | 0.1                                         | 9     | 1   | 1.5                   | 3.6          |
|     | Experiment 5 | 0.23                               | 0.2                                         | 8     | 1.5 | 2.0                   | 4.1          |
|     | Experiment 6 | 0.2                                | 0.15                                        | 9     | 1.5 | 2.1                   | 3.7          |
hyde (anion-active surfactant – NF dispersator) is used as a catalyst. Diethanolamine is recommended to stabilize the pH of the system. It has been established that the addition of AF-9-12 as Neonol catalyst or NF dispersant in an amount of 0.1–0.005 % of the total mass of reagents makes it possible to obtain a homogeneous and stable in time reaction mass. The use of these catalysts makes it possible to improve the main technological parameters: reduce the reaction temperature from 125–130 °C to 75–80 °C, shorten the process time from 3 hours to 1 hour, carry out the process at atmospheric pressure. The advantage of this technology is also non-waste, single-stage production and is available to Ukrainian raw materials.

According to the research results, a technology for the production of surfactants is developed, which is environmentally friendly and cost-effective, and can be offered to expand the scope of surfactants and is an alternative substitute for substances already used.

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