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KINETIC RESEARCH RESULTS OF PF-1 BRAND CORROSION INHIBITORS BASED ON CHLORINATED ORGANIC WASTE PROCESSING

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Abstract. Corrosion inhibitors with a new composition were obtained based on the processing of organochlorine waste and the results of testing at different temperatures, concentrations and aggressive environments were studied. The results of kinetic research and atomic adsorption of these corrosion inhibitors were studied. Corrosion is a major cause of many industrial accidents. A study of the causes of equipment failure in the oil and gas industry found that corrosion accounted for 60% of all costs incurred for the maintenance of oil and gas equipment in the North Sea on production platforms. The inhibitory effect can be related to the adsorption of molecules or its ions in anodic or cathodic sites, an increase in cathodic and anodic overpotentials and the ability to form a protective barrier.

Keywords: *Adsorption, activation energy, corrosion, entropy, enthalpy, inhibitor.*

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1. Introduction

The world's leading oil and gas companies announced that the annual cost of anti-corrosion was 900 million dollars (Jamshid *et al.*, 2023; Ge *et al.*, 2022; Pavon *et al.*, 2021). Another survey conducted in 2006 indicated that corrosion losses in the United States oil and gas industry amounted to $1.372 billion annually (Jamshid, 2024). These data show that the economic consequences of corrosion in the oil and gas industry over the years are enormous. The global cost of corrosion in the oil and gas industry will increase further in the near future due to extremely high energy demand (Jamshid, 2024). These inhibitory effects include chain length, molecular size, bond strength, aromaticity/configurational bonding, type and number of bonding atoms or groups (P or S) in the molecule, cross-linking ability and environment. The solubility of the environment is included. At the same time, with an increase in the length of the hydrocarbon chain, there is a tendency for the anti-corrosion performance to decrease due to the decrease in solubility in the environment solution. If the hydrogen atom attached to the ring carbon is replaced by electron-donating substituents such as $–NH_2$, $-NO_2$, -CHO or $–CO_2H$, the inhibition efficiency can be increased (Jamshid, 2024; Scialdone *et al.*, 2021; Xu *et al.*, 2023). This causes a change in the electron density in the metal at the point of attachment, resulting in a delay in the cathodic or anodic reaction, thereby reducing corrosion. Below are the different classes of liquid organic corrosion inhibitors discussed in this section.

Azoles consisting of simple organic compounds (imidazole, benzimidazole, benzotriazole, triazole, tetrazole), amines, urea, mercaptobenzothiazole (MBT), aldehydes, heterocyclic nitrogen compounds, sulfur-containing compounds, acetylenic acid, as well as many studies.

2. Materials and methods

Our researched PF-1 brand corrosion inhibitor was tested by gravimetric method. This method is used to determine the corrosion rate for the purpose of corrosion control and to evaluate the protective ability of corrosion inhibitors. The gravimetric method is based on measuring the difference in the mass of control metal samples before and after exposure to a corrosive environment.

A limitation with the use of this method is that it characterizes the average corrosion rate without taking into account the unevenness of the corrosion.

In general, when working, it is necessary to follow the current standard GOST 9.506-87 “Methods for determining the protective ability of metal corrosion inhibitors in water-oil environment”.

According to it, the product based on oil and alkanolamines is first placed in a three-necked flask equipped with a reflux condenser, a thermometer and a stirrer for interaction and mixed until a homogeneous mass is formed. Stirring was continued at a certain temperature for several hours. The obtained corrosion inhibitor was dissolved in 1%, 3% and 5% in gasoline, condensate and motor oil media. Later, many studies were conducted on the obtained solutions.

3. Experimental part

As a result of the tests, the influence of the concentration and temperature on the protection levels of the PF-1 brand corrosion inhibitor synthesized by us was studied.

Table 1. Effect of concentration of inhibitors on protection levels

	T, K	C, mg/l	CR	γ	Z, %	θ
PF-1	293	-	0,07863	-	-	-
		25	0,0148	5,31	81,1	0,811
		50	0,0103	7,63	89	0,89
		75	0,0034	23,05	98,5	0,985
		100	0,00031	68,97	99,6	0,996
	303	-	0,0861	-	-	-
		25	0,0198	4,34	75,61	0,7561
		50	0,0178	4,83	81,53	0,8153
		75	0,0073	11,86	88,21	0,8821
		100	0,0037	23,5	91,27	0,9127
	313	-	0,124	-	-	-
		25	0,0847	1,46	71,16	0,7116
		50	0,0515	2,4	78,31	0,7831
		75	0,0236	5,25	84,67	0,8467
		100	0,0143	8,67	89,91	0,8991
	323	-	0,313		-	-
		25	0,118	2,65	70,04	0,7004
		50	0,0961	3,25	72,46	0,7246
		75	0,0658	4,75	81,84	0,8184
		100	0,0364	8,59	87,14	0,8714

As a result of the tests, the corrosion rates and protection levels of our PF-1 brand corrosion inhibitor, which we researched, were studied in various aggressive environments.

Values of activation parameters for steel St3 in condensate medium without inhibitor and in the presence of PF-1 brand inhibitor.

Table 2.

Inhibitor concentration	E_a(kJ/mol^{-1})	ΔH_a (kJ/mol^{-1})	ΔS_a(kJ/mol^{-1}K^{1})	$E_a - \Delta H_a$
0.0	43.67	39.96	105.37	3.71
2	56.26	53.34	-19.04	2.92
4	66.14	63.5	-24.11	2,64
6	78.09	75.04	-54.36	3.05
10	91.34	88.78	-77.89	2.56

According to the results obtained from Table 2, the value of the activation energy Ea was 43.67 (kJ/mol^{-1}) in solutions without an inhibitor and with the introduction of an inhibitor into the solution, this value increased and reached 91.34 (kJ/mol) when the concentration reached 10 g/l -1) formed. Also, the value of entropy ΔSa took a positive value of 105.37 kJ/mol in a solution without an inhibitor and with the addition of an inhibitor to the solution, this value decreased to a negative -77.89 (kJ/mol^{-1}), how small this value is depends on the concentration of the corrosion inhibitor. Depends, association is higher than dissociation in the system, indicating that a stable complex is formed between the inhibitor and the metal. The average difference (RT) between activation energy and enthalpy was 2.97 kJ.

The following is the Arrhenius plot for this PF-1 corrosion inhibitor for steel in a condensate environment at various concentrations:

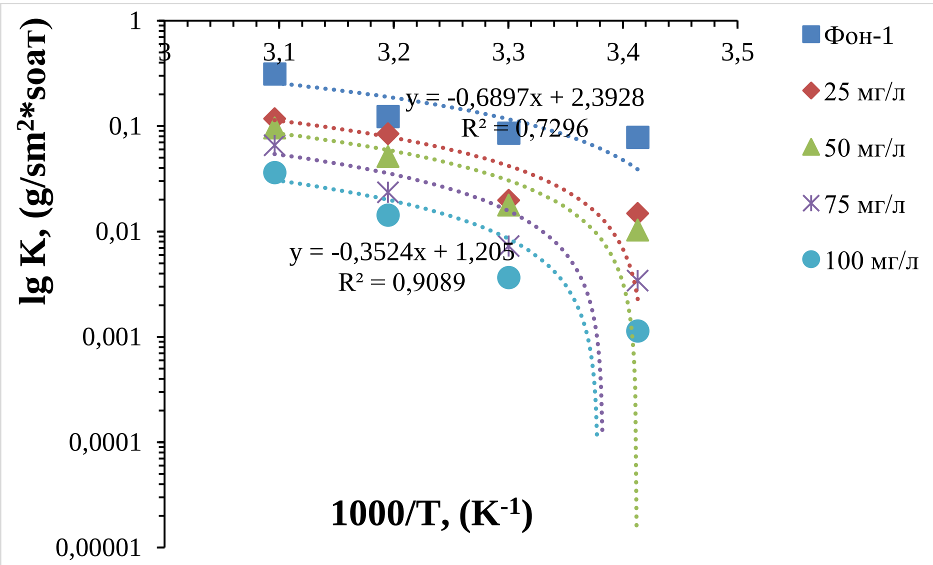

Figure 1. Arrhenius dependence of PF-1 brand corrosion inhibitor for steel in condensate medium at different concentrations

The surface coverage coefficients of the PF-1 brand corrosion inhibitor synthesized as a result of the processing of organochlorine waste at different temperatures and concentrations were determined.

Table 3.

	293	303	313	323	293	303	313	323
C, mg/l	***θ***	***θ***	***θ***	***θ***	C/θ	**C/θ**	**C/θ**	**C/θ**
25	0,8110	0,7561	0,7116	0,7004	31	33,06	35,13	35,69
50	0,8900	0,8153	0,7831	0,7246	56	61,33	63,85	69,00
75	0,9850	0,8821	0,8467	0,8184	76	85,02	88,58	91,64
100	0,9960	0,9127	0,8991	0,8714	100	109,57	111,22	114,76

Below, the results of SEM and elemental analysis of the steel sample, which were tested at different concentrations at a temperature of 25 C, were obtained and analyzed.

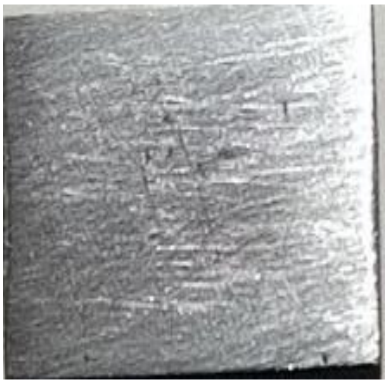

Figure 2. The view of the steel sample before the practical experiment

Figure 3. A photo of a practical experiment of a steel sample in condensate without an inhibitor

Figure 4. Photograph of a practical experiment on a steel sample using PF-1 corrosion inhibitor

4. Conclusion

We can see from the results of this test research that we obtained as a result of the processing of organochlorine waste, the corrosion inhibitor of our brand PF-1 with a new composition in the condensate medium at a concentration of 1 g/l and a temperature of 293 K was 99.6%.

From these tests, we can see that one of the reasons for the inhibition of the metal surface in the inhibitor solution is the absorption of the corrosion inhibitor on the surface. The presence of free ions in the composition of the corrosion inhibitor causes charge transport or the presence of functional groups binds to the metal surface through the donor-acceptor mechanism in exchange for negative charges and the inhibitor protects the metal surface from corrosion.

The protection levels and test results of PF-1 brand corrosion inhibitors obtained based on the processing of organochlorine waste that we researched at different temperatures and concentrations were studied. In the environment, the highest productivity temperature was 293 K, the concentration was 1 g/l and the level of protection was 99.6%.

The value of activation energy Ea was 43.67 (kJ/mol^{-1}) in solutions without inhibitor and with the introduction of inhibitor into the solution, this value increased and reached 91.34 (kJ/mol^{-1}) when the concentration reached 10 g/l. Also, the value of entropy ΔSa took a positive value of 105.37 kJ/mol in a solution without an inhibitor and with the addition of an inhibitor to the solution, this value decreased to a negative -77.89 (kJ/mol^{-1}), how small this value is depends on the concentration of the corrosion inhibitor. Depends, association is higher than dissociation in the system, indicating that a stable complex is formed between the inhibitor and the metal.

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