

## Inhibitor protection of copper in citric acid solutions

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### Abstract

The kinetics of copper corrosion and the effect of convection on this process were studied in freely aerated citric acid ( $C_6H_8O_7$ ) solutions. The copper corrosion rate in this medium does not depend significantly on the duration of contact between copper and the corrosive medium (1–20 days) and  $C_6H_8O_7$  concentration (0.001–2 M). The corrosivity of this medium towards copper increases with the transition from static to dynamic conditions of the experiment. Also, the corrosivity of  $C_6H_8O_7$  solutions toward metallic copper is enhanced in the presence of the corrosion product, Cu(II) cations. This effect is especially pronounced when it comes into contact with a dynamic corrosive medium. A triazole derivative, IFKhAN-92, is recommended for copper protection in freely aerated  $C_6H_8O_7$  solutions. The efficiency of this compound does not depend considerably on the duration of contact between the metal and the corrosive medium,  $C_6H_8O_7$  content, and hydrodynamic characteristics of the solution. An important feature of the IFKhAN-92 inhibitor is that its protective ability toward metallic copper is preserved even if Cu(II) cations are accumulated in the corrosive medium, which is true not only in static but also in dynamic media. The dependence of the copper corrosion rate on the convective factor in freely aerated solution 2 M  $C_6H_8O_7$ +0.05 M Cu(II), both in the absence and in the presence of the corrosion inhibitor, is formally described by the equation  $k = a + b \cdot n^{1/2}$ , where  $a$  and  $b$  are empirical parameters and  $n$  is the rotation frequency of the magnetic stirrer. The addition of IFKhAN-92 decreases the parameters  $a$  and  $b$  in this equation.

**Keywords:** corrosion, corrosion inhibitors, copper, citric acid, copper(II) cations, triazole.

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### Introduction

Citric acid solutions, alongside with hydrochloric and sulfuric acid solutions, are process liquids for removal of mineral impurities and corrosion products from metal surfaces [1]. An advantage of citric acid ( $C_6H_8O_7$ ) in comparison to HCl and  $H_2SO_4$  is that its corrosivity toward the most important engineering materials, such as steels, is low. This allows using them in industry, as opposed to inorganic acids, without additional inhibitor protection [2]. Technological equipment that often contacts acidic solutions is partly or wholly made of copper or its alloys. The corrosion stability of copper in HCl and  $H_2SO_4$  solutions and the

possibility of its inhibitor protection in these media are widely discussed [3–15]. Triazole derivatives are often used to protect copper in acid solutions [16–25]. In contrast, the stability of copper in  $C_6H_8O_7$  solutions and the possible ways of its corrosion protection are insufficiently covered in the available literature [26–29]. Our earlier studies on the corrosion ability of low carbon steel in  $C_6H_8O_7$  solutions showed the possibility of its efficient protection in this medium by formulations based on a triazole derivative, the IFKhAN-92 inhibitor [30]. IFKhAN-92 is an effective inhibitor of copper corrosion in acetic acid solutions [31]. The result obtained allows one to hope that efficient protection of copper in  $C_6H_8O_7$  solutions by this inhibitor is possible.

It should be noted that no direct reaction is possible between metallic copper and acetic acid. Copper corrosion occurs only in the presence of atmospheric oxygen in the corrosive medium that acts as its oxidant. It is reasonable to assume a multistage mechanism of this corrosion process. It is important to point out that the final corrosion product, Cu(II) cations, are also involved in metal corrosion. As Cu(II) cations are accumulated in the solution, their reaction with metallic copper becomes possible [32]:



In turn, the Cu(I) cations formed in the solution will be oxidized again by oxygen to Cu(II). Altogether, this effect must lead in time to acceleration of copper corrosion. It is known that in the case of acid solutions containing additional oxidants (oxygen, metal cations), participation of the latter in metal corrosion causes acceleration of the cathodic process. Besides, reduction of additional oxidants occurs under diffusion control [33]. As oxygen and Cu(II) cations are the oxidants in the system under consideration, one might make the assumption that the corrosion process on the whole is controlled by diffusion and its rate must considerably depend on the hydrodynamic parameters of the corrosive medium.

In view of this, it appears expedient to study the regularities of copper corrosion in  $C_6H_8O_7$  solutions and also to consider the possibility of its protection by inhibitors. The corrosion inhibitor studied is IFKhAN-92, while the compound used as a reference is the commercial cationic surfactant, Catamine AB (alkylbenzyltrimethylammonium chloride  $[C_nH_{2n+1}N^+(CH_3)_3CH_2C_6H_5]Cl^-$ , where  $n=10-18$ ). The factors to be assessed include the duration of corrosion tests,  $C_6H_8O_7$  concentration, the presence of the corrosion product – Cu(II) cations, the presence of corrosion inhibitors, and convection that may affect copper corrosion in the medium in question.

## Experimental

The corrosion rate of M1 copper (up to 0.005 Fe; up to 0.002 Ni; up to 0.004 S; up to 0.002 As; up to 0.005 Pb; up to 0.004 Zn; up to 0.05 O; up to 0.002 Sb; up to 0.001 Bi; up to 0.002 Sn; Cu (99.90)) in  $C_6H_8O_7$  solutions was determined from the sample mass loss (at least three samples per point) using the sample size of  $50.0 \times 30.0 \times 1.0$  mm per 165 ml of the acid solution at a temperature of  $t=20 \pm 2^\circ C$ . Prior to an experiment, the samples were

cleaned on P 600 sandpaper and degreased with acetone. The experiment duration was 1–20 days.

The effect of convection on the copper corrosion rate was studied in  $C_6H_8O_7$  solutions stirred with a magnetic stirrer at rotation rates of  $n=0, 250, 420$  and  $750$  rpm.

The efficiency of inhibitors was estimated by protection degrees:

$$Z = \frac{k_0 - k_{in}}{k_0} \cdot 100\%,$$

where  $k_0$  and  $k_{in}$  are the corrosion rates in the background solution and in a solution with an additive being studied.

$C_6H_8O_7 \cdot H_2O$  (GOST 908-2004) and distilled water were used for solution preparation. The basic concentration of IFKhAN-92 and Catamine AB was  $C_{in}=0.5$  mM. As the solubility of IFKhAN-92 in  $C_6H_8O_7$  solutions is low, it was added as a solution in ethanol.

Copper(II) citrate solutions were obtained by the reaction of basic copper(II) carbonate with  $C_6H_8O_7$ . Basic copper(II) carbonate was obtained by precipitation with sodium hydrocarbonate (“chemically pure” grade) from copper(II) sulfate (“pure” grade) solution followed by long-term rinsing of the precipitate with distilled water.

## Results and Discussion

Copper corrosion in  $0.5$  M  $C_6H_8O_7$  occurs relatively slowly (Table 1). Note that the sample mass loss ( $\Delta m$ ) in the course of long-term corrosion tests (20 days) reaches a significant value of  $30$  g/m<sup>2</sup>. The mean copper corrosion rate  $k$  weakly depends on the duration of exposure of metallic samples to the corrosive medium. The maximum  $k$  value was obtained after 2 and 13 days of tests:  $0.071$  g/(m<sup>2</sup>·h). The content of  $C_6H_8O_7$  in a solution weakly affects the  $k$  value of copper (Table 2). The result obtained is in good agreement with the fact that copper is oxidized by the air oxygen dissolved in a corrosive medium studied whose content is similar in these solutions, rather than by citric acid. Accumulation of Cu(II) cations in the corrosive medium reduces its corrosivity somewhat (Table 3). In fact, the  $k$  value of copper decrease 1.2-fold in the presence of  $0.05$  M Cu(II).

These results on the copper corrosion in  $C_6H_8O_7$  solutions correspond to static conditions that are rarely encountered under industrial conditions. More often, metals contact a stream of a corrosive medium. In cases where the corrosion process is controlled by diffusion limitations, this may result in a considerable acceleration of metal degradation.

In naturally aerated  $2$  M  $C_6H_8O_7$ , the effect of forced convection ( $n=750$  rpm) on corrosion is significant. The corrosion loss gain is 213% (Table 4). The effect of forced convection on  $k$  of copper in naturally aerated  $2$  M  $C_6H_8O_7+0.05$  M Cu(II) is also significant. The  $k$  values of copper in a static and dynamic ( $n=750$  rpm) medium differ by a factor of 3.2. In freely aerated  $2$  M  $C_6H_8O_7+0.05$  M Cu(II), copper corrosion occurs due to the presence of two oxidants in the corrosive medium: molecular oxygen and Cu(II) cations. It seems of interest to establish the effective copper corrosion rates in this medium related solely to the presence of Cu(II) cations by calculating them as a difference in the  $k$  of copper in aerated acid

solutions in the presence and in the absence of 0.05 M Cu(II). This approach is correct on the assumption of independent corrosion processes on copper caused by the presence of molecular oxygen and Cu(II) in an  $C_6H_8O_7$  solution. The effective  $k$  of copper due only to the presence of Cu(II) cations is sensitive to convective effects. The effective  $k$  values of copper in static and dynamic ( $n = 750$  rpm) media differ 3.4-fold.

**Table 1.** Effect of the duration of exposure of copper samples in 2 M  $C_6H_8O_7$  ( $20 \pm 2^\circ C$ ) on the mass loss ( $\Delta m$ ), corrosion rate ( $k$ ), and degree of metal protection by the inhibitor ( $Z$ ).

Corrosion process parameter	Exposure time, days					
	1	2	4	8	13	20
Without an inhibitor						
$\Delta m$ , g/m <sup>2</sup>	1.7	3.4	5.9	13	22	30
$k$ , g/(m <sup>2</sup> ·h)	0.071	0.071	0.061	0.068	0.071	0.063
0.5 mM Catamine AB						
$\Delta m$ , g/m <sup>2</sup>	0.89	1.0	1.6	2.2	4.3	5.7
$k$ , g/(m <sup>2</sup> ·h)	0.037	0.021	0.017	0.011	0.014	0.012
$Z$ , %	47.6	70.6	72.9	83.1	80.5	81.0
0.5 mM IFKhAN-92						
$\Delta m$ , g/m <sup>2</sup>	0.33	0.56	0.93	1.6	3.2	4.5
$k$ , g/(m <sup>2</sup> ·h)	0.014	0.012	0.010	0.008	0.010	0.009
$Z$ , %	80.6	83.5	84.2	87.7	85.5	85.0
1 mM IFKhAN-92						
$\Delta m$ , g/m <sup>2</sup>	–	–	–	1.2	–	3.3
$k$ , g/(m <sup>2</sup> ·h)	–	–	–	0.006	–	0.007
$Z$ , %	–	–	–	91.2	–	88.8
5 mM IFKhAN-92						
$\Delta m$ , g/m <sup>2</sup>	–	–	–	1.2	–	2.4
$k$ , g/(m <sup>2</sup> ·h)	–	–	–	0.006	–	0.005
$Z$ , %	–	–	–	91.2	–	92.1

**Table 2.** Effect of the concentration of  $C_6H_8O_7$  ( $20 \pm 2^\circ C$ ) on the rate of copper corrosion ( $k$ ) and degree of metal protection by the inhibitor ( $Z$ ) based on the data of 8-day tests.

Corrosion process parameter	$C(C_6H_8O_7), M$							
	0.001	0.005	0.01	0.05	0.1	0.5	1	2
Without an inhibitor								
$k, g/(m^2 \cdot h)$	0.041	0.047	0.050	0.052	0.057	0.068	0.052	0.045
0.5 mM Catamine AB								
$k, g/(m^2 \cdot h)$	0.010	0.011	0.011	0.011	0.012	0.011	0.011	0.010
$Z, \%$	73.2	76.6	78.0	78.8	78.9	83.1	78.8	77.8
0.5 mM IFKhAN-92								
$k, g/(m^2 \cdot h)$	0.008	0.009	0.010	0.009	0.009	0.008	0.008	0.005
$Z, \%$	80.5	80.9	80.0	82.7	84.2	87.7	84.6	88.9

**Table 3.** Effect of the concentration of copper(II) cations on the rate of copper corrosion in 2 M  $C_6H_8O_7$  ( $20 \pm 2^\circ C$ ) based on the data of 4-day tests.

Corrosion process parameter	$C_{Cu(II)}, M$		
	0	0.025	0.050
Without an inhibitor			
$k, g/(m^2 \cdot h)$	0.049	0.045	0.042
0.5 mM Catamine AB			
$k, g/(m^2 \cdot h)$	0.013	0.027	0.027
$Z, \%$	73.5	40.0	35.7
0.5 mM IFKhAN-92			
$k, g/(m^2 \cdot h)$	0.010	0.009	0.012
$Z, \%$	79.6	80.0	71.4

**Table 4.** Effect of the convective factor on the copper corrosion in 2 M C<sub>6</sub>H<sub>8</sub>O<sub>7</sub> (20±2°C) based on one-day tests.

Corrosion process parameter	Without an inhibitor	0.5 mM Catamine AB		0.5 mM IFKhAN-92		
	Rotation rate of the magnetic stirrer, rpm					
	0	750	0	750	0	750
2 M C <sub>6</sub> H <sub>8</sub> O <sub>7</sub> (free aeration)						
<i>k</i> , g/(m <sup>2</sup> ·h)	0.040	0.125	0.014	0.025	0.009	0.014
<i>Z</i> , %	–	–	65.0	80.0	77.5	88.8
2 M C <sub>6</sub> H <sub>8</sub> O <sub>7</sub> +0.05 M Cu(II) (free aeration)						
<i>k</i> , g/(m <sup>2</sup> ·h)	0.049	0.156	0.023	0.036	0.018	0.024
<i>Z</i> , %	–	–	53.1	76.9	63.3	84.6
2 M C <sub>6</sub> H <sub>8</sub> O <sub>7</sub> +0.05 M Cu(II)*						
<i>k</i> , g/(m <sup>2</sup> ·h)	0.009	0.031	0.009	0.011	0.009	0.010
<i>Z</i> , %	–	–	–	64.5	–	67.7

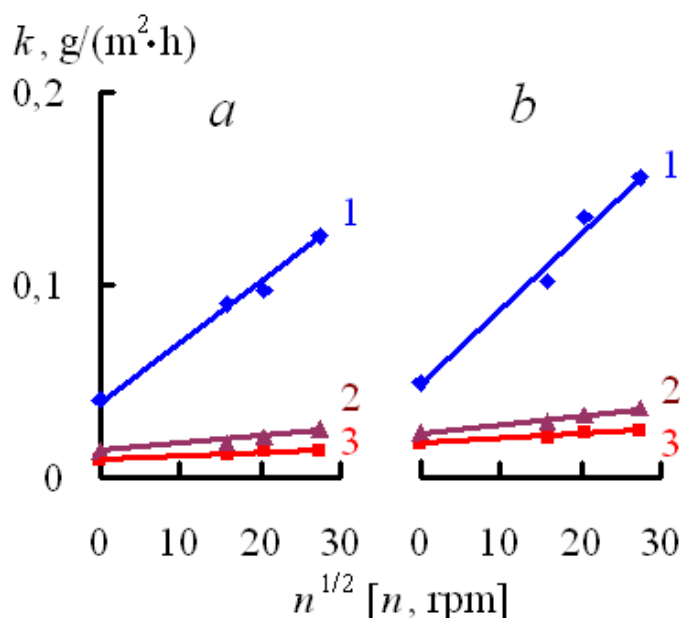
\*Effective contribution of the 0.05 M Cu(II) addition to the corrosion process.

Analysis of the dependences of the copper corrosion rate on the magnetic stirrer rotation frequency in freely aerated 2 M C<sub>6</sub>H<sub>8</sub>O<sub>7</sub> and 2 M C<sub>6</sub>H<sub>8</sub>O<sub>7</sub>+0.05 M Cu(II) (Table 5, Figure 1) showed that, formally, it is fairly described by the equation:  $k=a+b \cdot n^{1/2}$ . The form of this equation is typical of concurrent processes under kinetic and diffusion control [34]. Parameter  $a$  characterizes the kinetic component, while  $b$  corresponds to diffusion. In our system, however, it is more correct to relate parameter  $a$  to metal corrosion due to natural convection of the corrosive medium in long-term static tests.

**Table 5.** Parameters  $a$  and  $b$  of the kinetic equation  $k=a+b \cdot n^{1/2}$  for copper corrosion in 2 M C<sub>6</sub>H<sub>8</sub>O<sub>7</sub> (20±2°C) based on 1-day tests.

Inhibitor	$a$ , g/(m <sup>2</sup> ·h)	$b$ , g/(m <sup>2</sup> ·h·rpm <sup>1/2</sup> )
2 M C <sub>6</sub> H <sub>8</sub> O <sub>7</sub>		
Without an inhibitor	0.040	0.0031
0.5 mM Catamine AB	0.014	0.0004
0.5 mM IFKhaN-92	0.009	0.0002

Inhibitor	$a, \text{g}/(\text{m}^2 \cdot \text{h})$	$b, \text{g}/(\text{m}^2 \cdot \text{h} \cdot \text{rpm}^{1/2})$
2 M $\text{C}_6\text{H}_8\text{O}_7 + 0.05 \text{ M Cu(II)}$		
Without an inhibitor	0.049	0.0039
0.5 mM Catamine AB	0.023	0.0005
0.5 mM IFKhAN-92	0.018	0.0002



**Figure 1.** Plots of the copper corrosion rate in 2 M  $\text{C}_6\text{H}_8\text{O}_7$  (a) and 2 M  $\text{C}_6\text{H}_8\text{O}_7 + 0.05 \text{ M Cu(II)}$  (b) ( $20 \pm 2^\circ\text{C}$ ) based on the data of 1-day tests versus the frequency of solution stirring by a magnetic stirrer. 1 – without an inhibitor, 2 – 0.5 mM Catamine AB, 3 – 0.5 mM IFKhAN-92.

Thus,  $\text{C}_6\text{H}_8\text{O}_7$  solutions, especially in the absence of prolonged contact with copper, are relatively weakly corrosive to the latter. This is typical of both static and dynamic corrosion conditions. Under static conditions, accumulation of the corrosion product,  $\text{Cu(II)}$  cations, in the acid also fails to affect copper corrosion. Meanwhile, accumulation of  $\text{Cu(II)}$  cations in citric solutions together with dynamic corrosion conditions is capable of considerably enhancing the solution corrosivity, which is extremely undesirable.

According to the data of 8-day tests, the Catamine AB additive ( $C_{\text{in}} = 0.05\text{--}5 \text{ mM}$ ) in 0.5 M  $\text{C}_6\text{H}_8\text{O}_7$  inhibits copper corrosion 3.1–6.2 fold (Table 6). At  $C_{\text{in}} \geq 0.05 \text{ mM}$ ,  $Z > 80\%$ , while at  $C_{\text{in}} \geq 0.5 \text{ mM}$ ,  $Z$  is independent of the inhibitor content. A similar amount of IFKhAN-92 lowers the  $k$  of copper 3.8–11 fold. In the  $C_{\text{in}}$  range studied,  $Z > 73.5\%$ , while at  $C_{\text{in}} \geq 1 \text{ mM}$ ,  $Z$  is independent of the content of IFKhAN-92.

**Table 6.\*** Effect of the inhibitor concentration on the copper corrosion rate in 2 M  $C_6H_8O_7$  ( $20 \pm 2^\circ C$ ) based on 8-day tests.

Corrosion process parameter	$C_{in}, mM$				
	0.05	0.1	0.5	1	5
Catamine AB					
$k, g/(m^2 \cdot h)$	0.022	0.012	0.011	0.011	0.011
$Z, \%$	67.6	82.4	83.1	83.1	83.1
IFKhAN-92					
$k, g/(m^2 \cdot h)$	0.018	0.010	0.008	0.006	0.006
$Z, \%$	73.5	85.3	87.7	91.2	91.2

\*The copper corrosion rate in 2 M  $C_6H_8O_7$  ( $20 \pm 2^\circ C$ ) is  $0.068 g/(m^2 \cdot h)$ .

Both studied inhibitors retain their protective effect in 0.5 M  $C_6H_8O_7$  for at least 20 days (Table 1). The addition of 0.5 mM Catamine AB slows down copper corrosion by a factor of 1.9–5.9, while IFKhAN-92 inhibits it by a factor of 5.2–8.1, *i.e.*, more strongly. It is possible to reduce the  $k$  of copper by a factor of 12.6 with a sample exposure time of 20 days, increasing the  $C_{IFKhAN-92}$  in a corrosive environment to 5 mM. Judging by the mass loss of sample over time, in the presence of both inhibitors, copper corrosion is the fastest in the first day, after which the process slows down. Both organic compounds studied inhibit copper corrosion in a wide range of  $C(C_6H_8O_7) = 0.001–2$  M (Table 2). The protective effect of IFKhAN-92 is better than that of Catamine AB.

In a static corrosive medium, the presence of Cu(II) has an adverse effect on the copper protection by Catamine AB (Table 3). The presence of 0.1 M Cu(II) enhances the  $k$  of copper by a factor of 2.1 compared to the medium free of Cu(II). In contrast, IFKhAN-92 accelerates corrosion only 1.2-fold under similar conditions. This is rather an interesting result, as it is known that the presence of metal cations with oxidizing properties in a corrosive medium causes a significant weakening of the protective effect of acid corrosion inhibitors [35]. This regularity is clearly demonstrated by Catamine AB in the medium we were studying. On the contrary, IFKhAN-92 is quite resistant to the presence of Cu(II) cations in the corrosive medium. Earlier [36], the unique ability of IFKhAN-based composite inhibitors to preserve their protective effect was shown in the case of mild steel corrosion in acid media containing Fe(III) salts. A similar effect is characteristic of copper corrosion in acetic acid in the presence of  $Cu(H_3CCOO)_2$  [31].

It is important to understand whether efficient copper corrosion inhibition is maintained in  $C_6H_8O_7$  solutions on transition from static corrosion to corrosion under dynamic conditions. Indeed, the  $k$  values of copper in freely aerated 2 M  $C_6H_8O_7$  in the presence of



0.5 mM Catamine AB under static conditions and under dynamic ( $n=750$  rpm) conditions differ 1.8-fold (Table 4). In this case, the protective effect of the inhibitor decreases to 80%. In the case of 0.5 mM IFKhAN-92, corrosion is also accelerated 1.6-fold, but the  $Z$  value remains much higher (88.8%), since the  $k$  of copper is considerably lower in the presence of this compound.

The addition of Catamine AB demonstrates a poorer result than that of IFKhAN-92 in freely aerated 2 M  $C_6H_8O_7$ +0.05 M Cu(II). Interestingly, corrosion is accelerated in the presence of both inhibitors under dynamic conditions ( $n=750$  rpm) in comparison with the data of static tests. Nevertheless, on the whole, the protective effect is better under dynamic conditions. This effect is due to a significant acceleration of copper corrosion in the background medium in a stirred solution. Similar regularities are also typical of the effective contribution of Cu(II) cations to the corrosion process.

In inhibited media, the dependences of the copper corrosion rate on the magnetic stirrer rotation rate in freely aerated 2 M  $C_6H_8O_7$  and 2 M  $C_6H_8O_7$ +0.05 M Cu(II), like in the background medium, are satisfactorily described by the equation:  $k=a+b \cdot n^{1/2}$  (Table 5, Figure 1). In the presence of inhibitors, parameters  $a$  and  $b$  are reduced in comparison with the background solution. This effect is most pronounced in the presence of IFKhAN-92.

Thus, the IFKhAN-92 inhibitor efficiently slows down copper corrosion in  $C_6H_8O_7$  solutions. It retains its protective effect if the corrosion product, Cu(II) cations, is accumulated in  $C_6H_8O_7$  solutions. It is important to note that IFKhAN-92 protects copper both in static and dynamic corrosive media. Under all experimental conditions, the IFKhAN-92 inhibitor provides  $Z>63.6\%$ , while the largest  $k$  of copper observed under severe corrosion conditions (0.05 M Cu(II),  $n=750$  rpm) is as small as  $0.024 \text{ g}/(\text{m}^2 \cdot \text{h})$ . Under similar conditions, Catamine AB is inferior to IFKhAN-92 as regards the inhibition of copper corrosion.

The results obtained are important from the practical point of view, since they open new prospects for using  $C_6H_8O_7$  solutions where they potentially can come into contact with metallic copper. The corrosion rate in  $C_6H_8O_7$  solutions is rather low,  $k=0.041\text{--}0.071 \text{ g}/(\text{m}^2 \cdot \text{h})$ , but accumulation of the corrosion product, Cu(II) cations, combined with forced convection of the medium may cause its increase to  $0.156 \text{ g}/(\text{m}^2 \cdot \text{h})$ . If 0.5 mM IFKhAN-92 is used for copper protection, then, irrespective of the hydrodynamic mode in an  $C_6H_8O_7$  solution and the presence of Cu(II) cations, the  $k$  value for copper is  $0.005\text{--}0.024 \text{ g}/(\text{m}^2 \cdot \text{h})$ , which is a good result.

It is important to understand the origin of the higher inhibitor effect of the IFKhAN-92 triazole derivative in comparison with Catamine AB. They largely due to the unique regularities of the mechanism of the protective action of triazoles [37]. These compounds can be chemisorbed on the surface of a metal being protected followed by the formation of polymolecular protective surface layers that are extremely efficient in corrosion inhibition.

The results presented in this paper deal with the specifics of the corrosion behavior of copper in citric acid media and the effect of corrosion inhibitors on this process. The discussion of the reasons for the observed regularities of the corrosion behavior of copper is

tentative and requires additional studies involving electrochemical and physicochemical methods. Their results will be presented in our further papers on this subject.

## Conclusions

1. The copper corrosion rate in freely aerated acetic acid solutions weakly depends on the duration of contact between copper and the corrosive medium and on the concentration of  $C_6H_8O_7$ . The corrosivity of these solutions toward copper increases significantly in case of transition from static to dynamic conditions.
2. The corrosivity of  $C_6H_8O_7$  solutions toward copper is enhanced in the presence of  $Cu(II)$  cations. This effect is most noticeable when copper comes into contact with a moving corrosive medium.
3. The IFKhAN-92 inhibitor can be used for copper protection in freely aerated  $C_6H_8O_7$  solutions. The efficiency of this compound does not depend considerably on the duration of contact between the metal and the corrosive medium, the  $C_6H_8O_7$  content, and the hydrodynamic parameters. An important feature of the IFKhAN-92 inhibitor is that it maintains protection of copper even where  $Cu(II)$  cations is accumulated in the corrosive medium. This effect is observed not only in static but also in dynamic media.
4. The protective effect of IFKhAN-92 toward copper in  $C_6H_8O_7$  solutions is much stronger than that of Catamine AB, a well-known inhibitor of acid metal corrosion.
5. The dependence of the copper corrosion rate on the convective factor in freely aerated 2 M  $C_6H_8O_7$  and 2 M  $C_6H_8O_7 + 0.05$  M  $Cu(II)$ , both in the absence and in the presence of corrosion inhibitors, is formally described by the equation:  $k = a + b \cdot n^{1/2}$ , where  $n$  is the rotation frequency of the magnetic stirrer. The addition of the inhibitors studied, especially IFKhAN-92, decrease the parameters  $a$  and  $b$  in this equation.

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