ISSN 1070-3632, Russian Journal of General Chemistry, 2013, Vol. 83, No. 7, pp. 1330–1335. © Pleiades Publishing, Ltd., 2013. Original Russian Text © D.N. Bazhin, Yu.S. Kudyakova, T.I. Gorbunova, Ya.V. Burgart, A.Ya. Zapevalov, V.I. Saloutin, 2013, published in Zhurnal Obshchei Khimii, 2013, Vol. 83, No. 7, pp. 1077–1082.

Synthesis and Properties of Water-Soluble 2-Aminomethylidene Derivatives of 1,3-Dicarbonyl Compounds

D. N. Bazhin, Yu. S. Kudyakova, T. I. Gorbunova, Ya. V. Burgart, A. Ya. Zapevalov, and V. I. Saloutin

Postovskii Institute of Organic Synthesis, Ural Branch, Russian Academy of Sciences, ul. S. Kovalevskoi 22, Moscow, 620990 Russia e-mail: bazhin@ios.uran.ru

Received July 9, 2012

Abstract—A series of [(2-dimethylamino)ethylamino]methylidene-1,3-dicarbonyl compounds was synthesized for the first time starting from the corresponding 2-ethoxymethylidene derivatives and *N*,*N*-dimethylethylene-diamine. It was shown that further alkylation of aminomethylidene derivatives with methyl iodide occurs regioselectively at the tertiary nitrogen atom. Quaternization products obtained exhibit high corrosion inhibition of mild steel in hydrochloric acid medium.

DOI: 10.1134/S1070363213070050

Reaction of 2-ethoxymethylidene-1,3-dicarbonyl compounds with various amines is a convenient method of synthesis of 2-aminomethylidene derivatives of 1,3-dicarbonyl compounds, which are multidentate ligands. The latter can be used to prepare different complexes [1–9] and heterocyclic compounds having a wide spectrum of biological activity [10–12].

Earlier aliphatic amines, as well as (het)aryl amines have been brought introduced into the reaction with 2ethoxymethylidene-1,3-dicarbonyl compounds. 2-Aminomethylidene derivatives of 1,3-dicarbonyl compounds obtained were insoluble in water, but they were selectively soluble only in organic media. The synthesis of water-soluble 2-aminomethylidene derivatives of 1,3-dicarbonyl compounds is a probable and promising task: the synthetic potential of 2-aminomethylidene derivatives of 1,3-dicarbonyl compounds makes it possible to create new classes of compounds with other physicochemical properties expanding the areas of their practical application.

The modification of 2-aminomethylidene derivatives of 1,3-dicarbonyl compounds can be carried out both by transformation of functional groups in the aminoalkyl or (het)aryl substituent, and by functionalization of 1,3-dicarbonyl moiety. The aim of this work is the synthesis of new 2aminomethylidene derivatives of 1,3-dicarbonyl compounds by modifying the aminoalkyl substituent and studying of their practically useful properties in aqueous media.

The initial 2-ethoxymethylidene-1,3-dicarbonyl compounds Ia-Id were synthesized by reacting 1,3-dicarbonyl compounds with triethyl orthoformate in the presence of acetic anhydride according to [13–16]. The reaction of compounds Ia-Id with N,N-dimethylethylenediamine proceeds under mild conditions to give 2-aminomethylidene derivatives of 1,3-dicarbonyl compounds IIa-IId according to addition-elimination mechanism. The high reaction rate (5-10 min, monitored by TLC) is due to the high nucleophilicity of the starting amine. In the obtained products IIa-IId the enamine moiety is a push-pull system, which leads to the existence of an equilibrium of geometric isomers in solution [15]. The ¹H NMR spectra of compounds IIa-IId contain the proton signals of NH- and -CHgroups as the doublets (coutling constant \sim 14 Hz), which are characteristic of enaminodiketone form. The presence of the signals of NH-protons in the downfield region ($\sim \delta_{\rm NH}$ 9.3–11.03 ppm) suggests the existence of compounds IIa-IId as enaminodiketone tautomers,

where a hydrogen atom of amino group is intramolecularly associated with one of the carbonyl groups. The presence in the molecule of the intramolecular interactions of this kind is confirmed also by IR spectroscopy data. The absorption band of the stretching vibrations of NH and C=O groups are shifted to lower frequencies compared to the free groups.

We believe that one of the simplest methods of converting compounds **IIa–IId** into water-soluble derivatives is their quaternization at the nitrogen atom by an alkyl halide. This interaction usually results in quaternary ammonium salts, which are capable to dissolve in aqueous media. However, the compounds **IIa–IId** contain two nitrogen atoms, secondary and tertiary, which are potential quaternization centers.

Under mild conditions the addition of an excess methyl iodide to compounds **IIa–IId** results in the quaternization products **IIIa–IIId** as white precipitates. According to spectral data (IR, ¹H NMR), the regioselective methylation of compounds **IIa–IId** occurs at the tertiary nitrogen atom. In this case, NHgroup of the enamine fragment does not react with methyl iodide because of the participation of the lone electron pair of this nitrogen atoms in the conjugation with C=C bond.



a: H₂NCH₂CH₂NMe₂, Et₂O, 25°C; *b*: MeI, 25–30°C. $R^1 = R^2 = Me(\mathbf{a})$; $R^1 = R^2 = OEt(\mathbf{b})$; $R^1 = OEt, R^2 = Me(\mathbf{c}), C_3H_7(\mathbf{d})$.

Note that compounds **IIIa–IIId** in solutions also exist as enaminodiketone tautomers and exhibit the same spectral characteristics as compounds **IIa–IId**.

All synthesized compounds **IIIa–IIId** belong to the class of quaternary ammonium salts and exhibit high water solubility and stability in acidic media. They are characterized by the same structure of the hydrocarbon moiety adjacent to the ammonium group and various substituents bonded directly to dicarbonyl moiety. Both ammonium group and 1,3-dicarbonyl moiety may potentially exhibit activity against corrosion of metals in acidic media. The synergy of their action has not yet been established.

It is known that most organic compounds containing ammonium groups, including those commercially available, have a high solubility in water even if the ammonium nitrogen contains four hydrophobic substituents. Furthermore, it was shown that often quaternary ammonium salts containing iodide anion as counter ion possess the greatest inhibitory activity against acid corrosion of low carbon steels [17, 18].

Inhibitory activity of quaternary salts is mainly based on the electrostatic interaction between the positively charged nitrogen atom of ammonium group and the negatively charged electrode [19]. In the case of 1,3-dicarbonyl fragment the inhibition mechanism is more complex: the unpaired electrons of oxygen atoms can interact with the vacant *d*-orbitals of the metal; stable chelates can be formed on the electrode surface creating significant barriers to corrosion; π -electrons (if any) can interact with the metal; and the combination of all these types of interactions is possible [20–22].

The rate of the uniform corrosion (K_n) of lowcarbon steel and inhibitory activity of the quaternary ammonium salts **IIIa–IIId** ($c \ 1 \times 10^{-3}$ M) were studied in 1 M HCl solution at room temperature by the polarization resistance method. For each value of K_n (Fig. 1) four parallel measurements were performed; the standard deviation is no more than 3%.

Reducing the concentration of quaternary ammonium salt **IIIa–IIId** to 1×10^{-4} M results in approximately 2-fold increase in K_n (Fig. 2).

The analysis of the graphic and numeric data on K_n show that the quaternary ammonium salts **IIIa–IIId** exhibit similar characteristics: In relatively low concentrations they inhibit corrosion processes of



Fig. 1. Uniform corrosion rate of Steel-3 in 1 M HCl solution in the presence of 1×10^{-3} M of ammonium salts **IIIa–IIId**. (1) in the absence of ammonium salt; (2) in the presence of **IIIa**; (3) in the presence of **IIIb**; (4) in the presence of **IIIc**; (5) in the presence of **IIId**.

Steel-3 in hydrochloric acid medium more than 10 times. Protection degree (Z) calculated from the equation for compound IIIa is 92%, IIIb 91% IIIc 90%, IIId 89%.

$$Z = \frac{K_{\rm n1} - K_{\rm n2}}{K_{\rm n1}} \times 100\%$$

where K_{n1} and K_{n2} are uniform corrosion rates without inhibitor and with the addition of inhibitor, respectively.

The quaternary ammonium salts **IIIa**, **IIIb** having a symmetrical structure of 1,3-dicarbonyl fragment show the greatest inhibitory effect. Anticorrosive properties of **IIId** containing heptafluoropropyl substituent are similar to those of the quaternary ammonium salts **IIIc**, although there are examples of a more effective corrosion inhibition in the presence of fluorine-containing quaternary ammonium salts, as compared with non-fluorinated [17, 23].

The mechanism of chelation of the metal surface, as well as a significant effect of 1,3-dicarbonyl fragment on the polarization properties of the terminal ammonium nitrogen atom are questionable. Noteworthy is the absence of the alkyl groups having strong hydrophobic properties in the structure of the synthesized compounds.



Fig. 2. Uniform corrosion rate of Steel-3 in 1 M HCl solution (1) in the absence of ammonium salt and (2) in the presence of 1×10^{-4} M of ammonium salts **IIIc**.

In an acidic medium the protonation of both the dicarbonyl moiety and the nitrogen atom of aminomethylidene fragment of compounds IIIa-IIId is possible. Obviously, the double electric layer of the electrode is formed by orientation of the positively charged ammonium nitrogen atoms to negatively charged metal surface due to electrostatic interaction. The difference in the behavior of compounds IIIa-**IIId** occurs due to varying the nature of the substituents in the 1,3-dicarbonyl moiety. Consequently, for **IIIa** both the formation of hydroxy groups from the corresponding keto groups and the participation of the NH-moiety in the coordination with the metal electrode surface is presumable. It should also be noted that the best results in the test series were observed for the symmetric molecules, suggesting the possible contribution of intermolecular interactions leading to a more ordered structure of the protective layer on the metal. [24]

Unlike ammonium salts of diphilic structure [23], the explanation of the effect of the structure of functional derivatives of 1,3-dicarbonyl compounds on their properties requires further study.

Thus, we developed an efficient approach to the synthesis of water-soluble 2-aminomethylidene derivatives of 1,3-dicarbonyl compounds comprising quaternization of the starting compounds with methyl iodide. The reaction proceeds regioselectively at the terminal tertiary nitrogen atom. A series of quaternary ammonium salts was obtained in preparative yields. The developed techniques allow wide variation of functionalities in both dicarbonyl and aminoalkyl fragments. The synthesized quaternary ammonium salts **IIIa–IIId** show high anticorrosion activity for steel in hydrochloric acid medium: The corrosion of the metal is reduced 10-fold.

EXPERIMENTAL

The IR spectra were recorded on a Perkin-Elmer Spectrum One B spectrophotometer. The NMR spectra were obtained on a Bruker DRX-400 instrument (¹H, 400 MHz, internal reference Me₄Si; ¹⁹F, 376 MHz, internal reference C₆F₆). Elemental analysis was carried out on a Perkin Elmer PE 2400 elemental analyzer of series 2 CHNS-O EA 1108.4. Melting points were measured in open capillaries on a Stuart SMP3 instrument. The reaction progress was monitored by thin-layer chromatography using Alugram Sil G/UV₂₅₄ plates.

The rate of uniform corrosion of low-carbon steel was studied in a 1 M HCl solution using the universal automatic corrosion gage Expert-004 and a two-electrode sensor (LLC "Ekoniks–Expert," Moscow). The electrode material is Steel-3 (composition, %: Si 0.05–0.15, Mn 0.40–0.65, P \leq 0.04, Cr \leq 0.30, S \leq 0.05); the area of each electrode is 0.00078 m².

2-Ethoxymethylidene-1,3-dicarbonyl compounds were prepared by methods [13–16].

Synthesis of compounds IIa-IId. To a solution of 2-ethoxymethylidene-1,3-dicarbonyl compound Ia–Id (0.02 mol) in 30 ml of diethyl ether at room temperature was added dropwise N,N-dimethylethyl-enediamine (0.024 mol). The reaction mixture was stirred for 10 min and then washed with water. The organic layer was separated and dried over CaCl₂. Thereafter, the solvent was evaporated and the precipitate formed was recrystallized from hexane. Compound IIa was obtained as pale yellow crystals. The products IIb–IId were obtained as yellow oily substances after the solvent removal.

3-[(2-Dimethylamino)ethylamino]methylidenepentane-2,4-dione (IIa). Yield 3.80 g (96%), mp 57–58°C. IR spectrum, ν, cm⁻¹: 3180 br.s (N–H); 2966, 2943, 2861, 2822 (C–H); 1615 (C=O); 1586 (C=C); 1567 (N–H). ¹H NMR spectrum (CDCl₃), δ, ppm (*J*, Hz): 2.26 s (3H, Me), 2.28 s (6H, 2 Me), 2.49 s (3H, Me), 2.52 t (2H, CH₂, *J* 6.1), 3.41 q (2H, CH₂, *J* 6.1), 7.80 d (1H, CH, *J* 13.4), 11.05 br.s (1H, NH). Found, %: C 60.48; H 9.10; N 13.99. $C_{10}H_{18}N_2O_2$. Calculated, %: C 60.58; H 9.15; N 14.13.

Diethyl 2-[(2-dimethylamino)ethylamino]methylidenemalonate (IIb). Yield 5.04 g (97.5%). IR spectrum, v, cm⁻¹: 3290 br.s (N–H); 2978, 2946, 2902, 2863, 2822 (C–H); 1684, 1660 (C=O); 1609 (C=C); 1518 (N–H). ¹H NMR spectrum (CDCl₃), δ , ppm (*J*, Hz): 1.29 t and 1.34 t (6H, Me, *J* 7.1), 2.24 sand 2.27 s (6H, Me), 2.49 t (2H, CH₂, *J* 6.1), 3.41 q (2H, CH₂, *J* 6.1), 4.19 q and 4.24 q (4H, CH₂, *J* 7.1), 8.02 d (1H, CH, *J* 14.4), 9.21 br.s (1H, NH). Found, %: C 55.76; H 8.52; N 10.79. C₁₂H₂₂N₂O₄. Calculated, %: C 55.80; H 8.58; N 10.84.

Ethyl 2-[(2-dimethylamino)ethylamino]methylidene-3-oxobutanoate (IIc). Yield 5.04 g (98.5%). IR spectrum, v, cm⁻¹: 3182 br.s (N–H); 2977, 2947, 2904, 2856, 2822 (C–H); 1695, 1638 (C=O); 1581 (C=C). ¹H NMR spectrum (CDCl₃), δ , ppm (*J*, Hz): *E,Z*, 2.26 s and 2.27 s (6H, Me), 2.50 t (2H, CH₂, *J* 6.2), 3.41 q (2H, CH₂, *J* 6.2); *E* (12%), 1.35 t (3H, Me, *J* 7.1), 2.43 s (3H, Me), 4.25 q (2H, CH₂, *J* 7.1), 8.16 d (1H, CH, *J* 14.9), 9.27 br.s (1H, NH); *Z* (88%), 1.30 t (3H, Me, *J* 7.1), 2.47 s (3H, Me), 4.19 q (2H, CH₂, *J* 7.1), 8.00 d (1H, CH, *J* 13.8), 11.03 br.s (1H, NH). Found, %: C 57.90; H 8.78; N 12.21. C₁₁H₂₀N₂O₃. Calculated, %: C 57.87; H 8.83; N 12.27.

Ethyl 2-[(2-diethylamino)ethylamino|methylidene-4.4.5.5.6.6.6-heptafluoro-3-oxohexanoate (IId). Yield 5.04 d (98.5%). IR spectrum, v, cm⁻¹: 3245 br.s (N-H); 2981, 2907 (C-H); 1700, 1650 (C=O); 1630 (C=C), 1230–1119 (C–F). ¹H NMR spectrum (CDCl₃), δ, ppm (J, Hz): E,Z, 2.27 br.s (6H, 2Me), 2.53 m (2H, CH₂), 3.48 m (2H, CH₂); E (63%), 1.29 t (3H, Me, J 7.2), 4.23 g (2H, CH₂, J7.2), 8.09 d (1H, CH, J14.7), 10.52 br.s (1H, NH); Z (37%), 1.31 t (3H, Me, J 7.2), 4.26 q (2H, CH₂, J 7.2), 7.96 d (1H, CH, J 14.7), 9.65 br.s (1H, NH). ¹⁹F NMR spectrum (CDCl₃), δ_F , ppm (J, Γμ): E (63%), 38.35 m (2F, β-CF₂), 48.67 m (2F, α-CF₂), 81.52 t (3F, γ-CF₃, J 9.8); Z (37%), 37.66 m (2F, β-CF₂), 49.33 m (2F, α-CF₂), 81.69 t (3F, γ-CF₃, J 9.8). Found, %: C 40.77; H 4.45; N 7.29; F 34.70. C₁₃H₁₇F₇N₂O₃. Calculated, %: C 40.84; H 4.48; N 7.33; F 34.79.

Synthesis of ammonium salts IIIa–IIId. To amine IIa–IId (0.01 mol) was added MeI (0.03 mol). The mixture was stirred for 15 min. Then an excess of MeI

was removed. The products **IIIa–IIId** were obtained as white powders.

2-[(2-Acetyl-3-oxobuten-1-yl)amino]-*N*,*N*,*N*-trimethylethaneammonium iodide (IIIa). Yield 3.37 g (99%), mp 202–203°C. IR spectrum, v, cm⁻¹: 3178 br.s (N–H); 2996, 2982, 2901 (C–H); 1621 br.s (C=O); 1586 (C=C); 1570 (N⁺–CH₃). ¹H NMR spectrum (DMSO-*d*₆), δ , ppm (*J*, Hz): 2.22 s and 2.31 s (6H, Me), 3.11 s (9H, 3 Me), 3.57 t (2H, CH₂, *J* 6.5), 3.86 q (2H, CH₂, *J* 6.5), 8.12 d (1H, CH, *J* 13.4), 10.65 m (1H, NH). Found, %: C 38.77; H 6.18; N 8.27. C₁₁H₂₁N₂O₂I. Calculated, %: C 38.84; H 6.22; N 8.23.

2-[{2,2-(Diethoxycarbonyl)propen-1-yl}amino]-*N,N,N*-trimethylethaneammonium iodide (IIIb). Yield 3.92 g (98%), mp 192–193°C. IR spectrum, v, cm⁻¹: 3191 br.s (N–H); 3000, 2901 (C–H); 1709, 1698 (C=O); 1652, 1620 (C=C); 1598 (N⁺–CH₃). ¹H NMR spectrum (DMSO- d_6), δ , ppm (*J*, Hz): 1.20 t and 1.21 t (6H, Me, *J* 7.1), 3.10 s (9H, 3 Me), 3.52 t (2H, CH₂, *J* 6.6), 3.83 q (2H, CH₂, *J* 6.6), 4.06 q and 4.12 q (2H, CH₂, *J* 7.1), 8.07 d (1H, CH, *J* 14.4), 9.14 m (1H, NH). Found, %: C 39.06; H 6.25; N 6.97. C₁₃H₂₅N₂O₄I. Calculated, %: C 39.01; H 6.30; N 7.00.

2-[2-(Ethoxycarbonyl)-3-oxobuten-1-yl)amino]-*N,N,N-***trimethylethaneammonium iodide (IIIc).** Yield 3.67 g (99%), mp 149–150°C. IR spectrum, v, cm⁻¹: 3159, 3126 (N–H); 3002, 2984, 2936 (C–H); 1687 (C=O); 1633 (C=C); 1574 (N⁺–CH₃). ¹H NMR spectrum (DMSO-*d*₆), δ , ppm (*J*, Hz): *E,Z*, 3.12 s (9H, 3Me), 3.55 t (2H, CH₂, *J* 6.6), 3.87 q (2H, CH₂, *J* 6.6); *E* (13%), 1.27 t (3H, Me, *J* 7.1), 2.29 s (3H, Me), 4.19 q (2H, CH₂, *J* 7.1), 8.15 d (1H, CH, *J* 14.6), 9.18 m (1H, NH); *Z* (87%), 1.24 t (3H, Me, *J* 7.1), 2.33 s (3H, Me), 4.12 q (2H, CH₂, *J* 7.1), 8.12 d (1H, CH, *J* 13.8), 10.72 m (1H, NH). Found, %: C 38.90; H 6.18; N 7.61. C₁₂H₂₃N₂O₃I. Calculated, %: C 38.93; H 6.26; N 7.57.

2-[2-(Ethoxycarbonyl)-4,4,5,5,6,6,6-heptafluoro-3-oxohexen-1-yl)amino]-*N*,*N*,*N*-trimethylethane**ammonium iodide (IIId).** Yield 5.24 g (100 %), mp 209–210°C. IR spectrum, v, cm⁻¹: 3165, 3140 (N–H); 3010, 2979, 2945 (C–H); 1737, 1680 (C=O); 1630 (C=C); 1582 (N⁺–CH₃); 1269–1118 (C–F). ¹H NMR spectrum (DMSO-*d*₆), δ , ppm (*J*, Hz): *E*,*Z*, 3.11 br.s (9H, 3Me), 3.57 m (2H, CH₂), 3.95 m (2H, CH₂); *E* (65%), 1.22 t (3H, Me, *J* 7.2), 4.15 q (2H, CH₂, *J* 7.2), 8.30 d (1H, CH, *J* 14.7), 10.49 m (1H, NH); *Z* (35%), 1.21 t (3H, Me, *J* 7.2), 4.19 q (2H, CH₂, *J* 7.2), 8.18 d (1H, CH, *J* 14.7), 9.59 m (1H, NH). ¹⁹F NMR spectrum (DMSO-*d*₆), δ_F , ppm (*J*, Hz): *E* (65%), 38.61 br.s (2F, β-CF₂), 49.83 m (2F, α-CF₂), 83.13 t (3F, γ-CF₃, *J* 9.5); *Z* (35%), 39.31 br.s (2F, β-CF₂), 50.20 m (2F, α-CF₂), 83.15 t (3F, γ-CF₃, *J* 9.5). Found, %: C 32.07; H 3.79; N 5.29; F 25.44. C₁₄H₂₀N₂F₇O₃I. Calculated, %: C 32.08; H 3.85; N 5.34; F 25.37.

ACKNOWLEDGMENTS

This work was financially supported by the Ural Branch of the Russian Academy of Sciences (project no. 12-M-123-2045) and the Russian Foundation for Basic Research (project no. 10-03-96017, 12-03-31135).

REFERENCES

- Gottschaldt, M., Wegner, R., Gorls, H., Klufers, P., Jager, E.-G., and Klemm, D., *Carbohydrate Res.*, 2004, vol. 339, p. 1941.
- Wegner, R., Gottschaldt, M., Gorls, H., Klufers, P., Jager, E.-G., and Klemm, D., *Chem. Eur. J.*, 2001, vol. 7, p. 2143.
- 3. Uzu, T. and Sasaki, S., Org. Lett., 2007, vol. 9, p. 4383.
- 4. Zhang, X., Zhou, H., Ding, C., and Zhang, S., Chem. Commun., 2009, p. 5624.
- Kudyakova, Yu.S., Goryaeva, M.V., Burgart, Ya.V., Saloutin, V.I., and Slepukhin, P.A., *Russ. Chem. Bull.*, 2009, p. 1241.
- Kudyakova, Yu.S., Goryaeva, M.V., Burgart, Ya.V., Slepukhin, P.A., and Saloutin, V.I., *Russ. Chem. Bull.*, 2010, p. 1582.
- 7. Kudyakova, Yu.S., Goryaeva, M.V., Burgart, Ya.V., and Saloutin, V.I., *Russ. Chem. Bull.*, 2010, p. 1753.
- Kudyakova, Yu.S., Goryaeva, M.V., Burgart, Ya.V., and Saloutin, V.I., *Russ. J. Org. Chem.*, 2011, vol. 47, no. 3, p. 331.
- 9. Kudyakova, Yu.S., Burgart, Ya.V., and Saloutin, V.I., *Chem. Heterocycl. Compd.*, 2011, vol. 47, p. 558.
- Altenbach, R.J., Liu, H., Banfor, P.N., Browman, K.E., Fox, G.B., Fryer, R.M., Komater, V.A., Krueger, K.M., Marsh, K., Miller, T.R., Pan, J.B., Pan, L., Sun, M., Thiffault, C., Wetter, J., Zhao, C., Zhou, D., Esbenshade, T.A., Hancock, A.A., and Cowart, M.D., *J. Med. Chem.*, 2007, vol. 50, p. 5439.
- 11. Pochat, F., Tetrahedron, 1986, vol. 42, p. 3537.
- Nosova, E.V., Lipunova, G.N., Charushin, V.N., and Chupakhin, O.N., *J. Fluor. Chem.*, 2010, vol. 131, p. 1267.
- Palanki, M.S.S., Erdman, P.E., Gayo-Fung, L.M., Shevlin, G.I., Sullivan, R.W., Suto, M.J., Goldman, M.E., Ransone, L.J., Bennett, B.L., and Manning, A.M., *J. Med. Chem.*, 2000, vol. 43, p. 3995.

- Sanfilippo, P.J., Urbanski, M.J., Beers, K.N., Eckardt, A., Falotico, R.,Ginsberg, M.H., Offord, S., Press, J.B., Tighe, J., Tomko, K., and Andrade-Gordon, P., *J. Med. Chem.*, 1995, vol. 38, p. 34.
- Pryadeina, M.V., Burgart, Ya.V., Saloutin, V.I., Slepukhin, P.A., Kazheva, O.N., Shilov, G.V., D'yachenko, O.A., and Chupakhin, *Russ. J. Org. Chem.*, 2007, vol. 43, no. 7, p. 945.
- 16. Wang, J.-H., Shen, Y.-Q., Yu, C.-X., and Si, J.-H., *J. Chem. Soc., Perkin Trans. 1*, 2000, p. 1455.
- Zotikov, V.S., Ryabinin, N.A., Gankin, E.A., Novozhilov, E.N., Kasaeva, D.Ya., and Shal'man, B.Ya., *Book of Abstracts, IV Vsesoyuznaya konferentsiya po khimii ftororganicheskikh soedinenii* (Union Conference on the Chemistry of Organofluorine Compounds), Tashkent, 1982, p. 5.
- 18. Niu, L., Zhang, H., Wei, F., Wu, S., Cao, X., and Liu, P.,

Appl. Surf. Sci., 2005, vol. 252, p. 1634.

- 19. Mairanovskii, S.G., *Dvoinoi sloi i yego effekty v* polyarografii (Double Layer and Its Effects in Polarography), Moscow: Nauka, 1971.
- 20. Lebrini, M., Traisnel, M., Lagrenŭe, M., Mernari, B., and Bentiss, F., *Corros. Sci.*, 2008, vol. 50, p. 473.
- 21. Singh, A.K. and Quraishi, M.A., *Corros. Sci.*, 2010, vol. 52, p. 1373.
- Flores, E.A., Olivares, O., Likhanova, N.V., Dominguez-Aguilar, M.A., Nava, N., Guzman-Lucero, D., and Corrales, M., *Corros. Sci.*, 2011, vol. 53, p. 3899.
- 23. Gorbunova, T.I., Bazhin, D.N., Zapevalov, A.Ya., and Saloutin, V.I., *Russ. J. Appl. Chem.*, 2011, vol. 84, no. 6, p. 972.
- Herrag, L., Hammouti, B., Elkadiri, S., Aouniti, A., Jama, C., Vezin, H., and Bentiss, F., *Corros. Sci.*, 2010, vol. 52, p. 3042.