

Organic Hydroxylamine Derivatives. XII.*

Structural Analogues of γ -Aminobutyric Acid (GABA) of the Isoxazole Enol-betaine Type. Synthesis of Some 3-Hydroxy-5-(1-aminoalkyl)isoxazole Zwitterions

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The syntheses of three 3-hydroxy-5-(1-aminoalkyl)isoxazole zwitterions (VIIIa–c), which are conformationally restricted analogues of γ -aminobutyric acid (GABA), are described. The syntheses are based on 3-methoxy-5-isoxazolecarboxylic acid (I), which is transformed into the final products (VIIIa–c) *via* the ketones and oximes (IVa–c) and (Va–c), respectively. The pK_A values of (VIIIa–c) have been determined.

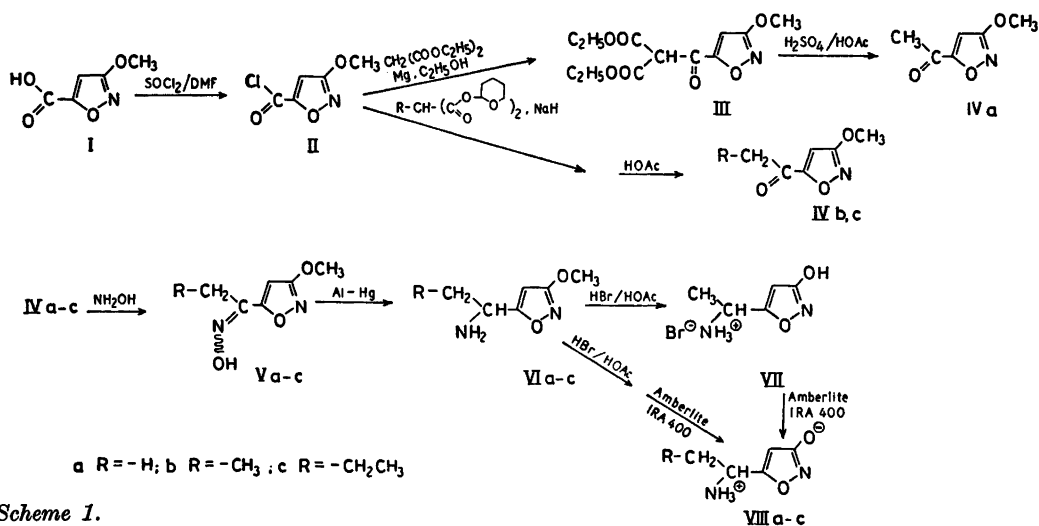
Muscimol (3-hydroxy-5-aminomethylisoxazole zwitterion), which is a conformationally restricted analogue of the inhibitory synaptic transmitter γ -aminobutyric acid (GABA),^{1,2} is a valuable model compound in the investigations of structure-activity correlations for GABA agonists.^{3–6} The present paper describes the synthesis of three 3-hydroxy-5-(1-aminoalkyl)isoxazole zwitterions (VIIIa–c), which are structurally related to muscimol. The aim of this work is to make available some structurally closely related GABA analogues in which the geometry of the preferred conformations is systematically changed. The increasing size of the alkyl groups of the compounds through the series (VIIIa–c) may increase the energy barriers separating the accessible conformations of the respective molecules.

Biological investigations of the racemates (VIIIa–c) are in progress. When the results of these investigations are available, efforts will be made to obtain the optical isomers of perti-

nent compounds of the series (VIIIa–c) for an investigation of the stereospecificity of the GABA receptor(s).

The acid chloride (II) is a key compound in the syntheses of the products (VIIIa–c). An unpurified product of (II) has previously been prepared in an apparently rather low yield as an intermediate in a synthesis of muscimol.⁷ Reaction of the carboxylic acid (I) with a dimethylformamide-thionyl chloride reagent, however, gave (II) in good yields and in a pure state. Attempts to synthesize the methyl ketone (IVa) by reaction of the acid chloride (II) with lithium dimethylcuprate according to the method of Posner and Whitten⁸ gave (IVa) in rather low yields. Reaction of (II) with diethyl ethoxymagnesiummalonate gives compound (III), which is converted into (IVa). The ketones (IVb, c) are synthesized *via* the appropriately substituted bistetrahydropyranyl malonates, using a method analogous to that described by Bowman and Fordham.⁹ The oximes (Va–c), prepared by a conventional method, are reduced by aluminium amalgam to give the corresponding primary amines (VIa–c) as described by Bowden *et al.* for an analogous reaction.⁷ Cleavage of (VIa) with hydrogen bromide in glacial acetic acid gives the hydrobromide (VII), which is subsequently converted into the enol-betaine (VIIIa) using a strongly basic ion exchange resin. Likewise the amines (VIb, c) are transformed into the final products (VIIIb, c), respectively, without isolation of the intermediately formed hydrobromides.

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Scheme 1.

The structure determinations of (II)–(IVa–c), (VIa–c), (VII), and (VIIIa–c) are based on IR, UV, and ^1H NMR spectroscopy and supported by elemental analyses. The IR and ^1H NMR spectroscopic data originating in the 3-methoxy- and 3-hydroxyisoxazole moieties of (II)–(IVa–c), (VIa–c), and (VII), are in accordance with the general findings described by Jacquier *et al.*¹⁰ The UV spectra

of the compounds (II)–(IVa–c) are consistent with the presence of carbonyl groups in conjugation with the isoxazole nucleus. As revealed by IR, UV, and ^1H NMR spectroscopy compound (III) is largely in the enol form. The oximes (Va–c) are shown by ^1H NMR spectroscopy to consist of mixtures of the *Z*- and *E*-forms. Separation of the oximes (Va–c) in the isomeric forms and the determination of

Table 1. Some IR and UV data of the compounds (II)–(IVa–c), (VIa–c), (VII), and (VIIIa–c) and the pK_A values of (VIIIa–c).

	IR data (cm^{-1})	UV data ^a λ_{max} (nm)	$\epsilon \times 10^{-3}$	pK_A ^b
II ^{c,e}	3145(m),1760(s),1605(s),1515(s)	242	9.5	
III ^c	3145(m),1760–1700(s, several bands),1605(m),1515(s)	245, 286	7.3, 6.8	
IVa ^c	3140(m),1700(s),1600(m),1510(s)	238	9.0	
IVb ^d	3125(m),1700(s),1600(s),1510(s)	237	8.8	
IVc ^c	3140(m),1700(s),1600(s),1510(s)	238	8.9	
VIa ^c	3450–3200(m),3145(m),1605(s),1520(s)	211	6.8	
VIb ^c	3450–3200(m),3150(m),1610(s),1515(s)	211	6.6	
VIc ^c	3600–3200(m),3145(w),1605(s),1520(s)	213	6.1	
VII ^d	3600–2400(s),1625(s),1510(s)	212	6.1	
VIIIa ^d	3145(m),3100–2000(s),2210(m), 1620(s),1520–1460(s, several bands)	211	6.0	4.69 ± 0.04 8.45 ± 0.01
VIIIb ^d	3200–2000(s),2200(m),1630(s), 1520–1440(s, several bands)	211	6.6	4.65 ± 0.03 8.42 ± 0.05
VIIIc ^d	3300–2000(s),2200(m),1640(s), 1540–1460(s, several bands)	212	6.6	4.69 ± 0.03 8.49 ± 0.04

^a Unless otherwise stated the UV spectra were recorded in 99.9 % ethanol solutions. ^b The pK_A values were determined by titration in aqueous solutions at 17 °C. ^c The IR spectra were recorded using the film technique. ^d The IR spectra were recorded in the solid state (KBr). ^e The UV spectrum was recorded in cyclohexane solution.

their configuration have been performed and will be published in the near future. The spectroscopic properties of the zwitterions (VIIIa-c) are in accordance with those published for muscimol,¹¹ 3-hydroxy-5-(2-aminoethyl)-isoxazole zwitterion,^{7,12} and 3-hydroxy-5-(3-aminopropyl)isoxazole zwitterion,¹³ the structures of which have been established by X-ray diffraction analyses.^{2,12,13} The pK_A values of muscimol (4.78 and 8.43)¹¹ and those determined for the enol-betaines (VIIIa-c) (cf. Table 1) are almost alike. This is an important fact since the compounds (VIIIa-c) together with muscimol are model compounds in the conformation-biological activity investigations.

Some spectroscopic data of the compounds (II-IVa-c), (VIa-c), (VII), and (VIIIa-c), which are all new, and the pK_A values of (VIIIa-c) are listed in Table 1.

EXPERIMENTAL

Unless otherwise stated the determination of melting points, the recording of IR, UV, and ¹H NMR spectra, and the performance of microanalyses were accomplished as described in a previous paper.¹⁴ pH Values were measured on a Radiometer pH meter 26. Thin layer and column chromatographic procedures were accomplished using silica gel GF₂₅₄ plates (Merck) and silica gel, 0.05-0.20 mm (Merck), respectively. The pK_A values were determined according to the method of Albert and Serjeant¹⁵ as described in a previous paper.¹³

3-Methoxy-5-chloroformylisoxazole (II). To a mixture of 14.3 g (100 mmol) of 3-methoxy-5-isoxazolecarboxylic acid (I)¹⁶ and thionyl chloride (160 ml) was added 5.1 g (70 mmol) of dimethylformamide. After reflux for 5 min the excess of thionyl chloride was removed *in vacuo* and the residue was extracted with six 30 ml portions of ether. The combined ether phases were concentrated *in vacuo* and the residue was distilled to give 11.1 g (69%) of (II) as a pale yellow oil, b.p. 80-85 °C/14 mmHg. (Found: C 37.15; H 2.60; Cl 22.13; N 8.68. Calc. for C₆H₇ClNO₂: C 37.18; H 2.50; Cl 21.95; N 8.67). ¹H NMR data (CCl₄): δ 6.73 (s, 1 H, C=CH-C); 4.03 (s, 3 H, O-CH₃).

Ethyl 2-ethoxycarbonyl-3-oxo-3-(3-methoxyisoxazol-5-yl)propanoate (III). To a solution of 5.28 g (33 mmol) of diethyl malonate, 2.4 g (50 mmol) of ethanol and 150 μl of tetrachloromethane in ether (30 ml) was added 0.84 g (35 mmol) of magnesium. The mixture was refluxed for 2 h and filtered, and to the refluxing filtrate was added slowly and with stirring a solution of 4.83 g (30 mmol) of (II) in ether (20 ml). Reflux was continued for

further 30 min, and after cooling to room temperature 60 ml of sulfuric acid (2 M) were added and the ether phase was isolated, dried, and concentrated *in vacuo* to give 7.8 g (91%) of (III) as a yellow oil. An analytical sample was distilled at 0.01 mmHg to give (III) as a very viscous oil. (Found: C 50.32; H 5.32; N 5.19. Calc. for C₁₂H₁₅NO₅: C 50.52; H 5.30; N 4.91). ¹H NMR data (CCl₄): δ 12.7-12.3 (broad s, 0.4 H, enol-OH); 6.50 and 6.29 (two s, 0.4 H and 0.6 H, respectively, C=CH-C); 4.94 (s, 0.3 H, CH-C=O); 4.5-4.0 (m, 4 H, 2 × CH₂-CH₂-O); 3.96 and 3.93 (two s, total 3 H, CH₃-O); 1.5-1.1 (m, 6 H, 2 × CH₃-CH₂).

3-Methoxy-5-acetylisoazole (IVa). A mixture of 7.8 g (27 mmol) of (III), glacial acetic acid (15 ml), concentrated sulfuric acid (2 ml), and water (10 ml) was refluxed for 3 h. After cooling to room temperature and after addition of water (60 ml) the solution was adjusted to pH 6 by addition of an aqueous solution of potassium hydroxide (10 M) and extracted with three 50 ml portions of ether. The combined ether extracts were dried, and evaporated *in vacuo*. Distillation of the residue afforded 3.0 g (78%) of compound (IVa) as a colourless oil, b.p. 92-98 °C/15 mmHg. (Found: C 50.95; H 5.11; N 9.92. Calc. for C₈H₇NO₃: C 51.06; H 5.00; N 9.93). ¹H NMR data (CCl₄): δ 6.34 (s, 1 H, C=CH-C); 3.95 (s, 3 H, O-CH₃); 2.47 (s, 3 H, CO-CH₃).

3-Methoxy-5-(1-hydroxyiminoethyl)isoxazole (Va). A solution of 5.0 g (35 mmol) of (IVa), 5.3 g (39 mmol) of sodium acetate trihydrate, and 2.7 g (39 mmol) of hydroxylammonium chloride in aqueous ethanol (35 ml; 50%) was refluxed for 30 min. Evaporation of the solution to ca. 15 ml followed by filtration afforded 5.0 g (90%) of a colourless crystalline product. An analytical sample was recrystallized (water) to give (Va) as colourless crystals. The product was by thin layer chromatography shown to consist of two compounds with $R_F=0.38$ and $R_F=0.33$ (eluent: methylene chloride). (Found: C 45.95; H 5.19; N 18.02. Calc. for C₈H₉N₂O₃: C 46.15; H 5.16; N 17.94). ¹H NMR data of (Va) [CDCl₃-DMSO-*d*₆ (6:1)], which are consistent with a mixture (ca. 1:4) of the isomeric oximes: δ 11.37 (s, 1 H, N-OH); 6.73 and 6.04 (two s, 0.2 H and 0.8 H, respectively, C=CH-C); 2.91 (two coincident s, 3 H, O-CH₃); 2.10 (two coincident s, 3 H, C-CH₃).

3-Methoxy-5-(1-aminoethyl)isoxazole (VIa). To a solution of 5.0 g (32 mmol) of (Va) in aqueous methanol (150 ml; 50%) aluminium amalgam was added. [The latter was prepared by treatment of 10.5 g (388 mmol) of aluminium strips with an aqueous mercuric chloride solution (300 ml; 5%) for 30 s followed by washing with ethanol]. After stirring for 90 min at room temperature the mixture was filtered and concentrated *in vacuo* to give a colourless oil, which was distilled to give 3.1 g (67%) of (VIa) as a colourless oil, b.p. 106-110 °C/16 mmHg. (Found: C 50.75; H 7.19; N 19.88. Calc. for C₈H₁₀N₂O₂: C 50.69; H 7.09; N 19.71).

^1H NMR data (CCl_4): δ 5.58 (s, 1 H, C=CH-C); 4.1-3.7 (partly overlapped q, CH_2 -CH-NH $_2$), and 3.75 (s, CH_3 -O) total 4 H; 1.52 (s, 2 H, NH $_2$); 1.35 [d ($J=6$ cps), 3 H, CH_3 -CH].

3-Hydroxy-5-(1-aminoethyl)isoxazole hydrobromide (VII). A solution of 1.47 g (10.3 mmol) of (VIa) in glacial acetic acid (10 ml) containing 43 % of hydrogen bromide was heated to reflux for a total of 20 min. After reflux for 10 min an additional 10 ml of glacial acetic acid containing hydrogen bromide was added. After cooling to 25 °C the solution was evaporated to dryness *in vacuo*. The residue was dissolved in methanol (15 ml) and concentrated *in vacuo* to give an oil, which slowly crystallized. The product was recrystallized (ether-propan-2-ol) to give 1.57 g (72 %) of (VII) as slightly coloured crystals, m.p. 150 °C (decomp.). (Found: C 28.66; H 4.59; Br 38.15; N 13.47. Calc. for $\text{C}_5\text{H}_9\text{BrN}_2\text{O}_2$: C 28.73; H 4.34; Br 38.23; N 13.40). ^1H NMR data (DMSO- d_6): δ 9.0-8.2 (broadened s, 4 H, OH and NH $_3^+$); 6.17 (s, 1 H, C=CH-C); 4.54 [q ($J=7$ cps), 1 H, CH_2 -CH-NH $_3^+$]; 1.51 [d ($J=7$ cps), 3 H, CH_3 -CH].

3-Hydroxy-5-(1-aminoethyl)isoxazole zwitterion (VIIa). A solution of 756 mg (36.0 mmol) of (VII) in water (10 ml) was passed through a column containing an ion exchange resin [Amberlite IRA 400, (OH), 110 ml] using acetic acid (1 M) as an eluent. Recrystallization of the crude product (water-ethanol) gave 290 mg (63 %) of (VIIa) as colourless crystals, m.p. 213-215 °C (decomp.). (Found: C 46.70; H 6.26; N 21.67. Calc. for $\text{C}_5\text{H}_9\text{N}_2\text{O}_3$: C 46.87; H 6.29; N 21.87). ^1H NMR data [D_2O (sodium 3-(trimethylsilyl)propanesulfonate was used as an internal standard)]: δ 5.75 (s, 1 H, C=CH-C); 4.76 (s, 4 H, DOH); 4.48 [q ($J=7$ cps), 1 H, CH_2 -CH-NH $_3^+$]; 1.59 [d ($J=7$ cps), 3 H, CH_3 -CH].

3-Methoxy-5-propionylisoxazole (IVb). To a stirred solution of 18.9 g (225 mmol) of 3,4-dihydro-2H-pyran and 75 μl for concentrated sulfuric acid in benzene (75 ml) 8.85 g (75 mmol) of methylmalonic acid was added in portions with cooling to < 30 °C. After stirring for 30 min potassium hydroxide (6.0 g) was added and stirring was continued for 30 min. The solution was decanted from inorganic material and concentrated to 30 ml *in vacuo* (bath temperature < 30 °C). This solution was dropwise added to a stirred suspension of sodium hydride (ca. 75 mmol, prepared from 3.6 g of a 50 % dispersion of sodium hydride in oil) in benzene (75 ml) with cooling to < 30 °C. To the clear solution 10.9 g (67.5 mmol) of compound (II) dissolved in benzene (40 ml) was slowly added. After stirring for 2 h acetic acid (7.5 ml) was added and the solution was refluxed for 45 min. Upon addition of ether (150 ml) the mixture was extracted with water (200 ml). The organic phase was dried and concentrated *in vacuo* to give 30 g of a yellow oil, which was subjected to column chromatography (silica gel: 570 g;

eluent: methylene chloride). Sublimation of the product at 0.2 mmHg (bath temperature 50 °C) yielded 6.4 g (61 %) of (IVb) as pale yellow crystals. An analytical sample was recrystallized (ethanol-water) to give (IVb) as colourless crystals, m.p. 64.5-65.5 °C. (Found: C 54.30; H 5.91; N 9.05. Calc. for $\text{C}_7\text{H}_9\text{NO}_3$: C 54.19; H 5.85; N 9.03). ^1H NMR data (CCl_4): δ 6.30 (s, 1 H, C=CH-C); 3.91 (s, 3 H, CH_3 -O); 2.85 [q ($J=7$ cps), 2 H, CH_2 -CH $_2$ -CO]; 1.17 [t ($J=7$ cps), 3 H, CH_2 -CH $_3$].

3-Methoxy-5-(1-hydroxyiminopropyl)isoxazole (Vb). (Vb) was synthesized as described above for (Va) using 4.65 g (30 mmol) of (IVb), 4.5 g (33 mmol) of sodium acetate trihydrate, and 2.41 g (33 mmol) of hydroxylammonium chloride as starting materials. (Vb) (5.2 g; 97 %) was isolated as colourless crystals. An analytical sample was recrystallized (water-ethanol) to give (Vb) as colourless crystals. The product was by thin layer chromatography shown to consist of two compounds with $R_F=0.47$ and $R_F=0.33$ [eluent: methylene chloride-ethyl acetate (9:1)]. (Found: C 49.65; H 6.02; N 16.57. Calc. for $\text{C}_7\text{H}_{10}\text{N}_2\text{O}_3$: C 49.40; H 5.92; N 16.46). ^1H NMR data of (Vb) (CDCl_3) which are consistent with a mixture (ca. 1:2) of the isomeric oximes: δ 9.2-8.8 (broad s, 1 H, N-OH); 6.77 and 6.05 (two s, 0.3 H and 0.6 H, respectively, C=CH-C); 3.96 (two coincident s, 3 H, CH_3 -O); 2.9-2.4 (m, 2 H, CH_2 -CH $_2$ -C); 1.4-0.9 (m, 3 H, CH_2 -CH $_3$).

3-Methoxy-5-(1-aminopropyl)isoxazole (VIb). (VIb) was synthesized as described above for (VIa) using 3.6 g (21 mmol) of compound (Vb) and aluminium amalgam prepared from 6.86 g (254 mmol) of aluminium. The filtered reaction mixture was concentrated *in vacuo* to ca. 10 ml. Upon addition of concentrated hydrochloric acid (3 ml) the mixture was extracted with ether (10 ml). Upon addition of an aqueous solution of potassium hydroxide (3 ml; 10 M) the aqueous phase was extracted with two 5 ml portions of ether, which were combined, dried, and concentrated *in vacuo*. The residue was distilled to give 1.85 g (56 %) of compound (VIb) as a colourless oil, b.p. 120-124 °C/17 mmHg. (Found: C 54.10; H 7.91; N 17.89. Calc. for $\text{C}_7\text{H}_{12}\text{N}_2\text{O}_2$: C 53.83; H 7.74; N 17.94). ^1H NMR data (CCl_4): δ 5.53 (s, 1 H, C=CH-C); 4.0-3.5 (partially overlapped t, CH_2 -CH-NH $_2$), 3.83 (s, CH_3 -O), total 4 H; 1.9-1.3 (m, 2 H, CH_2 -CH $_2$ -CH); 1.36 (s, 2 H, NH $_2$); 0.90 (t, 3 H, CH_2 -CH $_3$).

3-Hydroxy-5-(1-aminopropyl)isoxazole zwitterion (VIIb). A solution of 416 mg (2.64 mmol) of compound (VIb) in glacial acetic acid (6 ml) containing 43 % hydrogen bromide was refluxed for a total of 10 min. After reflux for 5 min an additional amount of 6 ml of glacial acetic acid containing hydrogen bromide was added. The solution was concentrated *in vacuo* to give an oily residue, which was dissolved in water (10 ml). The solution was treated with activated charcoal and passed through a

column containing ion exchange resin [Amberlite IRA 400, (OH), 14 ml) using acetic acid (1 M) as an eluent. The fractions containing (VIIIb) were treated with activated charcoal and concentrated *in vacuo* to give 478 mg of an oily product. Crystallization from ethanol-methanol (1:1) afforded 96 mg (26 %) of (VIIIb) as colourless crystals, m.p. 167–168 °C (decomp.). (Found: C 50.60; H 7.17; N 19.66. Calc. for $C_6H_{10}N_2O_2$: C 50.69; H 7.09; N 19.71). 1H NMR data [D_2O (sodium 3-(trimethylsilyl)propanesulfonate was used as an internal standard)]: δ 5.77 (s, 1 H, C=CH-C); 4.77 (s, 3 H, DOH); 4.30 [t ($J=8$ cps), 1 H, $CH_2-CH-NH_3^+$]; 2.1–1.7 (m, 2 H, CH_3-CH_2-CH); 0.95 (t, 3 H, CH_3-CH_2).

3-Methoxy-5-butylisoxazole (IVc). (IVc) was synthesized as described above for compound (IVb). As starting materials were used 6.6 g (50 mmol) of ethylmalonic acid, 12.6 g (150 mmol) of 3,4-dihydro-2H-pyran, sodium hydride (*ca.* 50 mmol), and 7.3 g (45 mmol) of compound (II). The resulting mixture was subjected to column chromatography (silica gel: 400 g; eluent: methylene chloride to which increasing amounts of ethyl acetate were added). Distillation of the product gave 4.75 g (63 %) of (IVc) as a slightly coloured oil, b.p. 132–137 °C/8 mmHg. (Found: C 56.95; H 6.67; N 8.25. Calc. for $C_8H_{11}NO_2$: C 56.79; H 6.55; N 8.28). 1H NMR data (CCl_4): δ 6.43 (s, 1 H, C=CH-C); 4.03 (s, 3 H, CH_3-O); 2.88 (t, 2 H, CH_2-CH_2-CO); 2.1–1.4 (m, 2 H, $CH_3-CH_2-CH_2$); 1.02 (t, 3 H, CH_3-CH_2).

3-Methoxy-5-(1-hydroxyaminobutyl)isoxazole (Vc). (Vc) was synthesized as described above for (Va) using 1.54 g (22 mmol) of hydroxylammonium chloride, 3.00 g (22 mmol) of sodium acetate trihydrate, and 3.38 g (20 mmol) of compound (IVc) as starting materials. (Vc) (3.5 g; 95 %) was isolated as colourless crystals. The product was by thin layer chromatography shown to consist of two compounds with $R_F=0.65$ and $R_F=0.55$ [eluent: methylene chloride-ethyl acetate (4:1)]. 1H NMR data of (Vc) ($CDCl_3$), which are consistent with a mixture (*ca.* 4:7) of the isomeric oximes: δ 9.3–8.6 (broad s, 1 H, N-OH); 6.80 and 6.06 (two s, 0.4 H and 0.7 H, respectively, C=CH-C); 3.97 (two coincident s, 3 H, CH_3-O); 2.8–2.4 (m, 2 H, CH_2-CH_2-C); 1.9–1.2 (m, 2 H, $CH_3-CH_2-CH_2$); 0.98 (t, 3 H, CH_3-CH_2).

3-Methoxy-5-(1-aminobutyl)isoxazole (VIc). (VIc) was synthesized as described above for compound (VIb). As starting materials were used 2.7 g (15 mmol) of (Vc), and aluminium amalgam from 4.75 g (176 mmol) of aluminium. (VIc) (1.6 g; 64 %) was obtained as a colourless oil, b.p. 87–89 °C/0.5 mmHg. (Found: C 56.70; H 8.25; N 16.62. Calc. for $C_8H_{14}N_2O_2$: C 56.45; H 8.29; N 16.46). 1H NMR data (CCl_4): δ 5.58 (s, 1 H, C=CH-C); 3.9–3.6 (partially overlapped t, $CH_2-CH-NH_2$), 3.86 (s, CH_3-O), total 4 H; 1.9–0.7 (m, 7 H, $CH_3-CH_2-CH_2-CH$); 1.40 (s, 2 H, NH_2).

3-Hydroxy-5-(1-aminobutyl)isoxazole zwitterion (VIIIc). (VIIIc) was synthesized as described above for compound (VIIIb) using 1.02 g (6.0 mmol) of (VIc). Crystallization from methanol gave 262 mg (28 %) of (VIIIc) as colourless crystals, m.p. 172.5–173 °C (decomp.). (Found: C 53.90; H 7.65; N 18.04. Calc. for $C_7H_{12}N_2O_2$: C 53.83; H 7.74; N 17.94). 1H NMR data [D_2O (sodium 3-(trimethylsilyl)propanesulfonate was used as an internal standard)]: δ 5.75 (s, 1 H, C=CH-C); 4.75 (s, 6 H, DOH); 4.35 (t, 1 H, $CH_2-CH-NH_3^+$); 2.1–1.6 (m, 2 H, CH_2-CH_2-CH); 1.6–1.1 (m, 2 H, $CH_3-CH_2-CH_2$); 1.1–0.7 (m, 3 H, CH_3-CH_2).

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