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Interaction of Heterocyclic Nitrones With Organometallic Reagents As a Method For the Synthesis of New Types of Nitroxides

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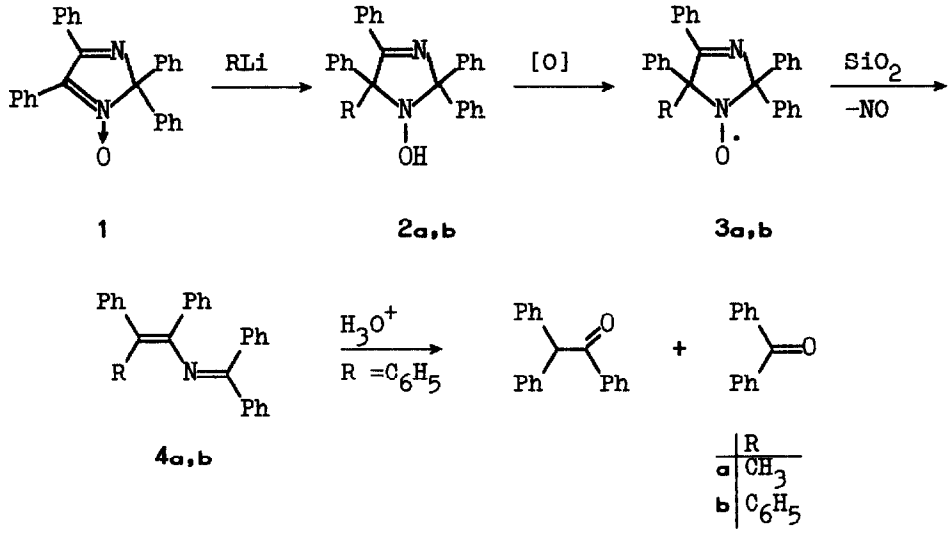
Abstract: The reactions of heterocyclic nitroxides: 3-imidazoline-3-oxides, 2H- (4H)-imidazole mono- and dioxides, dihydropyrazine-1,4-di-oxides, with organometallic reagents and subsequent oxidation led to heterocyclic nitroxides of 3-(2)-imidazoline and 3-(2)-imidazoline-3-oxide, dihydropyrazine oxide, monocyclic imidazolidine biradicals and stable acyclic nitroxides with hydrogen at the α-carbon atom.

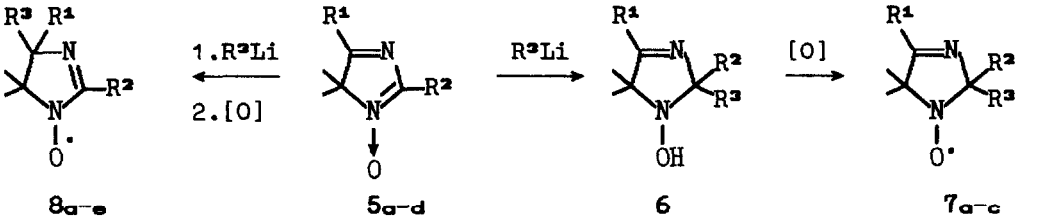
The addition of organometal compounds to the nitrone group and subsequent oxidation under mild conditions is a widely used method for the synthesis of various nitroxides.[1] The application of this approach to heterocyclic nitrones makes it possible to essentially expand the potential of synthetic chemistry of nitroxides and to synthesize new heterocyclic and acyclic nitroxides, including those having such a radical centre environment that may not be obtained by other methods. This paper discusses methods for the preparation of some acyclic and heterocyclic mono- and biradicals using the reaction of addition of organometal reagents at the nitrone group of heterocycle: imidazoles, imidazolines and dihydropyrazines.

The interaction of 2H-imidazole-1-oxide **1** with methyl- and phenyl-lithium and subsequent oxidation of the intermediate hydroxylamines **2** with MnO_2 gave the polyphenyl-substituted 3-imidazoline nitroxides **3**. It was unexpectedly found that upon chromatographing these radicals **3** on silica gel they are quantitatively transformed into azabutadienes **4**. The structure of compound **4b** was confirmed by its hydrolysis leading to phenyldiphenylmethylketone and benzophenone. It is well known that such a reaction of nitroxides can occur photochemically (ref.[2]) but its occurrence on silica gel is reported here for the first time.



In the reactions of 4H-imidazole-3-oxides **5a,b** with phenyllithium or methyllithium excess, only one mole of the reagent is added, the addition occurring predominantly at the phenylnitrone group. Subsequent oxidation of the hydroxylamino derivatives **6** with MnO_2 led to 3-imidazoline nitroxides **7a-c**. This method makes it possible to introduce into the 2-position of heterocycle substituents which may not be introduced at the stage of 3-imidazoline heterocycle construction (cf.[3]). This method affords compounds **7b,c** which are of interest as paramagnetic chelating reagents (cf.[4,5]). So the reaction of 4H-imidazole-3-oxides with organolithium compounds is a new convenient method for the synthesis of 3-imidazoline nitroxides, similar to the one used for the preparation of pyrrolidine nitroxides.[1]

It is interesting to note that the reactions of 4H-imidazole-3-oxides **5a,b** with phenyllithium usually give not only 3-imidazoline derivatives **7** but also iminonitroxides **8a-c**, the products of addition at the phenylimino group (R^1=C_6H_5). The possibility for the reaction to occur by this route seems to be due to the conjugation of the imino group with the nitrone group (cf.[6]). The yields of these iminonitroxides were significantly lower than of 3-imidazoline nitroxides **7a-c** formed in this reaction. In the case of compounds **5c,d**, the reaction with methyllithium proceeded entirely as the addition at the imino group, forming iminonitroxides **8d,e**, which are of interest as paramagnetic ligands.



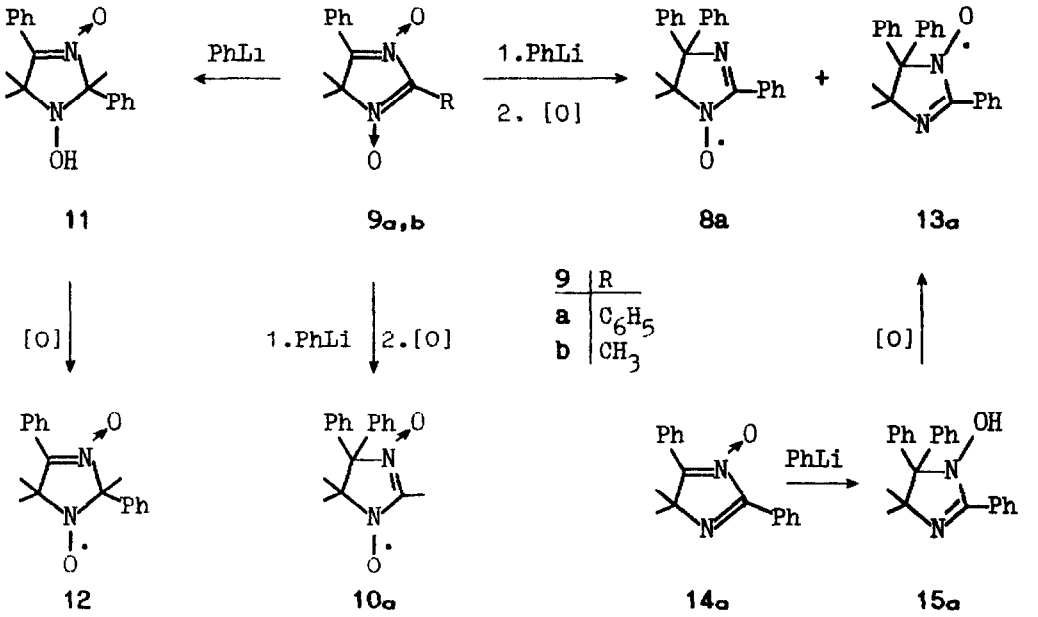
8a-e 5a-d 6 7a-c

8	R¹	R²	R³
a	Ph	Ph	Ph
b	Ph	2-HO-C_6H_4	CH_3
c	Ph	2-HO-C_6H_4	Ph
d	Ph	pyrrolyl-2	CH_3
e	CH_3	pyrrolyl-2	CH_3

5	R¹	R²
a	Ph	Ph
b	Ph	2-HO-C_6H_4
c	Ph	pyrrolyl-2
d	CH_3	pyrrolyl-2

7	R¹	R²	R³
a	Ph	Ph	Ph
b	Ph	2-HO-C_6H_4	CH
c	Ph	2-HO-C_6H_4	Ph

The reaction of 4H-imidazole-dioxide **9b** with phenyllithium excess led to the addition of only one mole of the reagent predominantly at the phenylnitrone group to form nitronylnitroxide **10a** after oxidation. Such a reaction route seems to be associated with metallation of the methylnitrone group which hinders addition of phenyllithium to it (cf.[7]). This reaction unexpectedly gave a small amount of 3-imidazoline-3-oxide **11**, the product of addition of PhLi at the methylnitrone group whose oxidation with MnO_2 formed nitroxide **12**.

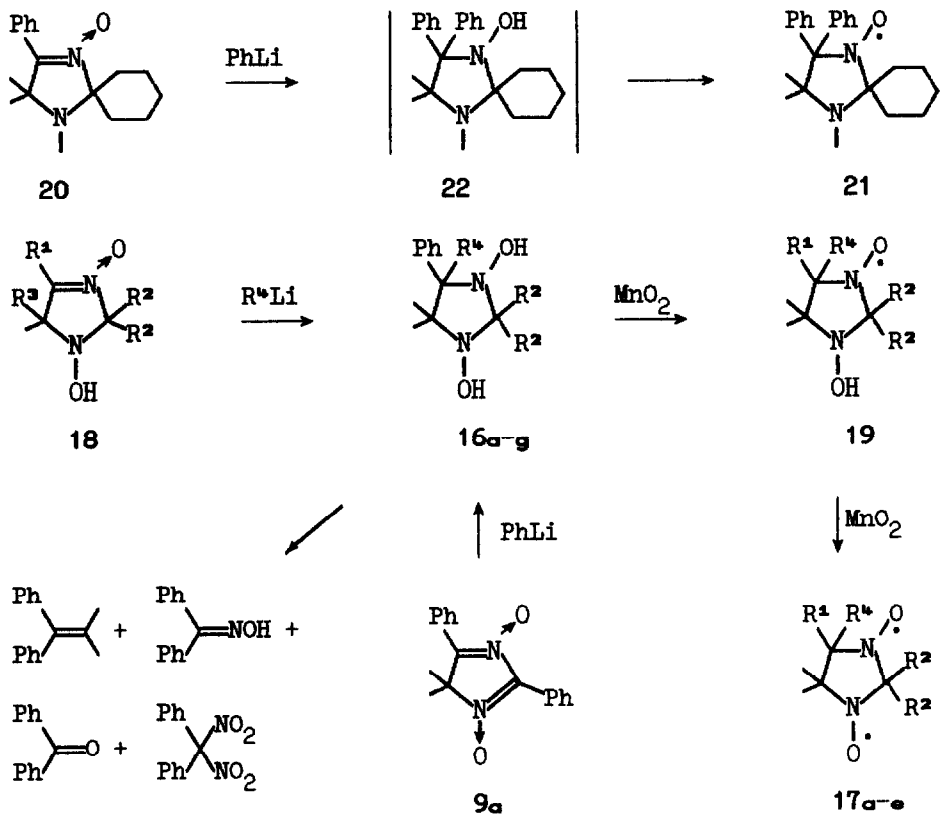


9	R
a	C_6H_5
b	CH_3

11 9a,b 8a 13a 12 10a 14a 15a

In the reaction of 4H-imidazole dioxide **9a** containing two phenylnitrone groups in a molecule with an equimolar amount of phenyllithium, two isomeric iminonitroxides **8a** and **13a** were isolated. The position of the oxygen atom in the heterocycle was determined by an alternative synthesis of compound **13a** which was formed in a high yield in the reaction of 4H-imidazole-1-oxide **14a** with excess phenyllithium and subsequent oxidation of the hydroxylamino-derivative **15a** (cf.[8]). It should be noted that the addition of phenyllithium at the C=N bond of the phenylimino group did not take place (cf.[9]).

In the reaction of 4H-imidazole dioxide **9a** with phenyllithium excess, the addition occurs at both nitrone groups. The dihydroxy imidazolidine product **16d** is unstable and gradually decomposes both in a solid state and upon boiling in solutions of organic solvents. In the oxidation of compound **16d** with MnO_2, the respective biradical **17** could not be isolated. It should be noted that practically only one biradical **17a** with two nitroxyl groups in one heterocycle is known.[10]



16	R^2	R^4
a	CH_3	Ph
b	CH_3	CH_3
c	$2R^2=(CH_2)_5$	Ph
d	Ph	Ph
e	CH_3	C_4H_9
f	OC_2H_5	Ph
g	$2R^2=OCH_2CH_2O$	Ph

17	R^1	R^2	R^4
a	CH_3	$2R^2=(CH_2)_5$	CH_3
b	Ph	CH_3	Ph
c	Ph	CH_3	CH_3
d	Ph	CH_3	C_4H_9
e	Ph	$2R^2=(CH_2)_5$	Ph

18	a	b	c	d	e	f
R^1	Ph	Ph	Ph	Ph	CH_3	$R^1+R^3=(CH_2)_4$
R^2	CH_3	$2R^2=(CH_2)_5$	OC_2H_5	$2R^2=OCH_2CH_2O$	CH_3	CH_3
R^3	CH_3	CH_3	CH_3	CH_3	CH_3	-

3-Imidazoline-3-oxides **18a-f** may suggested to be potential precursors of various monocyclic biradicals of imidazolidine series (cf.[1]). However, it is known that in the reactions of 3-imidazoline-3-oxides **18** with organomagnesium compounds, the imidazoline heterocycle undergoes cleavage to form acyclic α-hydroxylaminooximes.[11] It seemed that a similar reaction would take place between 1-hydroxy-3-imidazoline-3-oxides **18** and organolithium compounds.[12] Therefore, it was suggested the use of other 1-substituted 3-imidazoline-3-oxides as nitroxide precursors instead of the 1-hydroxy derivatives **18**.[12] Indeed, the use of 1-methyl-substituted 3-imidazoline-3-oxides or the tetrahydropyranyl derivatives afforded dihydroxyimidazolidines **16a,b** as a result of a few stages synthesis, but they could not be oxidized into the corresponding biradicals **17**; only monoradicals **19a,b** were obtained in a small yield.[12] Based on these data, it might be assumed that monocyclic biradicals would be stable provided that the imidazolidine heterocycle contains a spiro group in the 2-position (cf.[10]).

In order to verify this assumption, we have performed the reaction of phenyllithium with 3-imidazoline-3-oxide **20**. Subsequent oxidation smoothly led to the monoradical **21**. To obtain the corresponding biradical **17e**, a series of transformations have been used including the acylation of the hydroxylamino derivative **22**, its oxidation, removal of the acyl protection and subsequent oxidation under mild conditions (cf.[10]). However, even at the stage of oxidation of the $N-CH_3$ group into the nitroxyl group in H_2O_2/Na_2WO_4, the heterocycle undergoes destruction and the only reaction product which was isolated was benzophenone.

In the reaction of 3-imidazoline-3-oxides **18a-d** with organolithium compounds, unlike organomagnesium reagents, there was no heterocycle

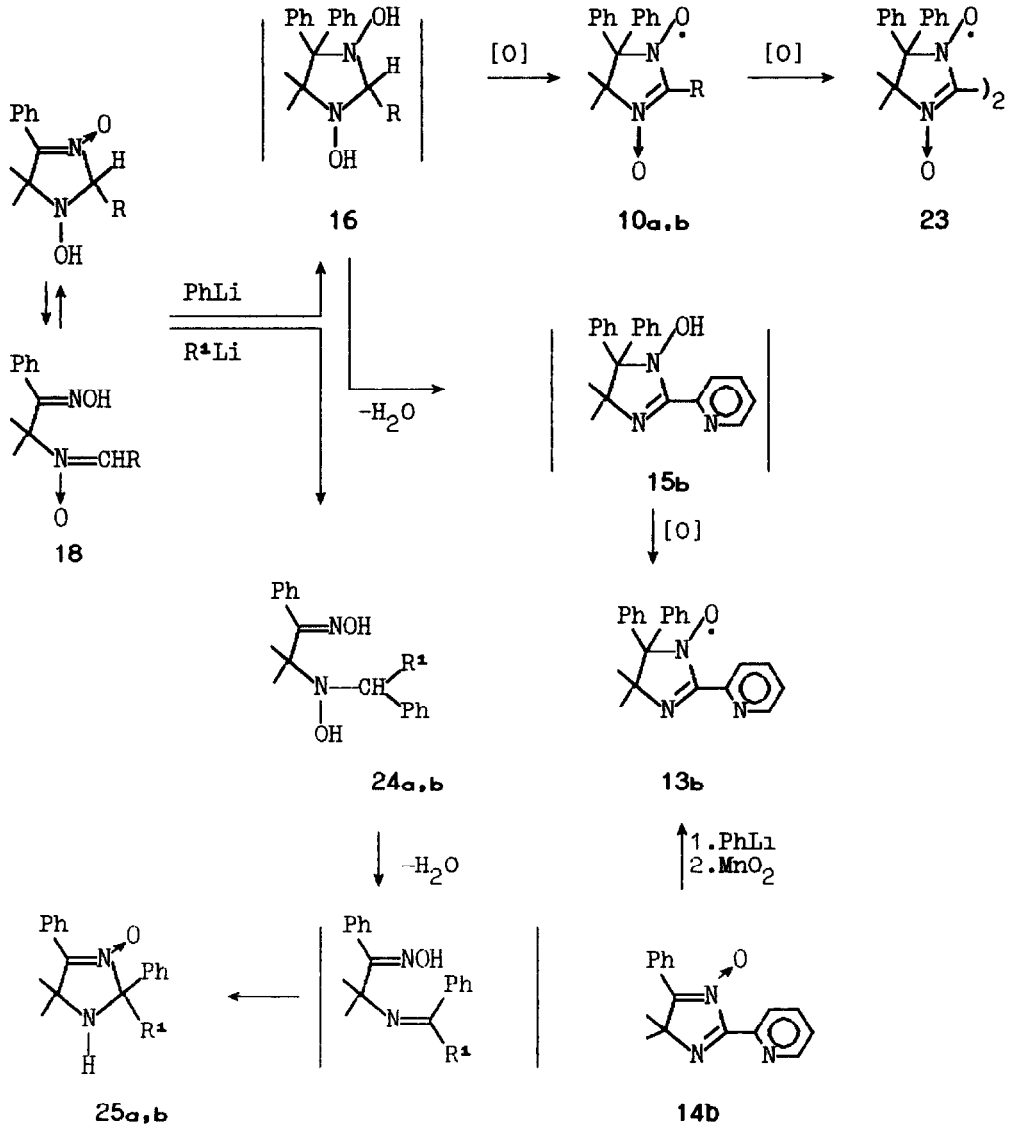
cleavage. The reaction products were dihydroxyimidazolidines **16a-g**, the products of addition at the nitrone group. Addition of butyllithium and especially phenyllithium proceeded under mild conditions and gave high yields of the products. But the reaction of imidazoline **18a** with methyllithium was rather sluggish and was not completed even with a 10-fold excess of the reagent. The 4-alkyl-substituted 3-imidazoline-3-oxides **18e,f** did not form any addition products with phenyllithium, possibly because of the metallation reaction at the alkylnitrone group (cf.[7]).

The stability of the dihydroxy-derivatives **16** depends on the size of substituents in the 2- and 4-positions of the heterocycle. Thus, imidazolines **16a-c,e** are stable both in a solid state and in solution in inert atmosphere, while compounds **16d,f,g** decompose in a solid state or upon recrystallization with liberation of nitrogen oxides and formation of a complex mixture of products which was separated to give 1-phenyl-2,2-dimethylstyrene, benzophenone oxime, benzophenone and dinitrodiphenylmethane. A similar mixture of products was formed in the oxidation of these dihydroxy-derivatives with MnO_2. But when the dihydroxy-derivatives **16a,e** were oxidized with MnO_2 in ether, the biradicals **17b,d** were isolated. These biradicals are bright red crystal products, which are stable in a solid state at 0°C for an unlimited period of time and unstable when kept in solutions: at 20° they decompose almost completely during 2 or 3 hours. The biradical **17c** is somewhat less stable, it may not be isolated in an analytically pure form. It should be noted that the biradical **17e** with a spiro group in the 2-position which is a close analogue of the above-described monocyclic biradical **17a** is unstable and decomposes upon attempted concentration of the solution or its storage during several minutes, liberating nitrogen oxides and forming a complex mixture of products, from which benzophenone oxime has been isolated.

The above-mentioned cleavage of the 3-imidazoline-3-oxide heterocycle by organomagnesium compounds was attributed to the possibility of its existence as a mixture of two isomeric forms, the cyclic and acyclic ones, and addition of the organomagnesium reagent at the nitrone group of the acyclic form.[11] On the other hand, the 4-phenyl-2,2,5,5-tetrasubstituted 3-imidazoline-3-oxides **18a-d** react with organolithium compounds only at the nitrone group of the cyclic form (cf. above) to form the addition products at the C-4 atom.

When compounds **18g-n** contain hydrogen as one of substituents in the 2-position of heterocycle, they can really exist in solution as a mixture of two tautomers.[13,14] When imidazolines **18g-k** which exist in solution as cyclic tautomers interact with phenyllithium, the addition occurs at the nitrone group of the heterocycle to form intemediate dihydroxy-

derivatives of type **16**. In the case of compound **18k**, the water molecule is eliminated with intermediate formation of compound **15b**. Subsequent oxidation leads to the iminonitroxide **13b**. The structure of compound **13b** was identified by its alternative synthesis from 4H-imidazole-1-oxide **14b** (cf.[8]). In the oxidation of dihydroxyimidazolidines **16** (R = H, CH_3), the water molecule is not eliminated and the nitronylnitroxides **10a,b** are formed. Compound **10b** may not be isolated individually because of its low stability, but its further oxidation with potassium ferrocyanide in the presence of NaH leads to the stable nitronyldinitroxide **23** (cf. [15]).



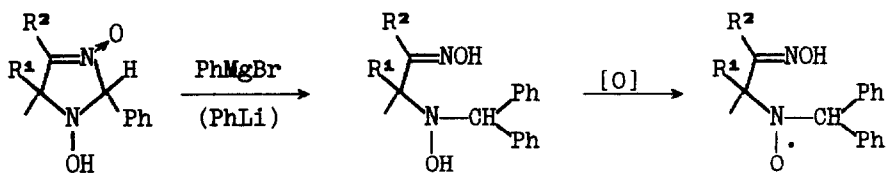
10	R
a	CH_3
b	H

18	g	h	k	l	m
R	H	CH_3	2-pyridyl	Ph	α-furyl

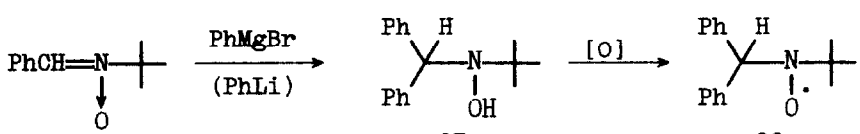
24,25	R^1
a	Ph
b	α-furyl

Compounds **18l,m**, existing in solution mainly in the acyclic tautomeric form, react with phenyllithium in this form to give hydroxylaminooximes **24a,b**. In the case of imidazoline **18m**, compound **24b** undergoes dehydration, and further cyclization leads to 3-imidazoline-3-oxide **25b**. In chromatographing on silica gel, the hydroxylaminooxime **24a** is also partially dehydrated, leading to the formation of imidazoline **25a**.

It was unexpectedly found that the oxidation of hydroxylaminooxime **24a** with MnO_2 gave a stable acyclic nitroxide **26a** containing hydrogen at the α-carbon atom of the nitroxyl group in a quantitative yield, but not the 3-imidazoline-3-oxide of type **18** (cf.[11]). This compound was isolated individually and proved to be stable in a crystal state at 0°C for an unlimited period of time. Evidently, such compounds are stable provided they contain two phenyl groups at the α-carbon atom bonded with hydrogen. Similar reactions gave other stable radicals with the α-hydrogen atom **26b,c**. It should be noted that the hydroxylaminooximes **24** are also formed in the reactions of compounds **17l,n,o** with phenylmagnesium bromide. The product of the reaction of phenyl-N-tert-butylnitrone with phenyllithium, hydroxylamine **27**, also forms a stable radical **28** on oxidation, which is known as a spin adduct and was even synthesized for use as a spin probe.[16,17] However, this nitroxide **28** has not been isolated and characterized as an individual compound. It should be noted that the radicals **26** and **28** do not undergo the disproportionation reaction to form the corresponding hydroxyamine and nitrone, and are not transformed into nitrones upon oxidation by MnO_2, as is usually observed for the radicals containing the hydrogen atom at the α-carbon atom of the nitroxyl group (cf.[1]).



18l,n,o **24a,c,d** **26a-c**



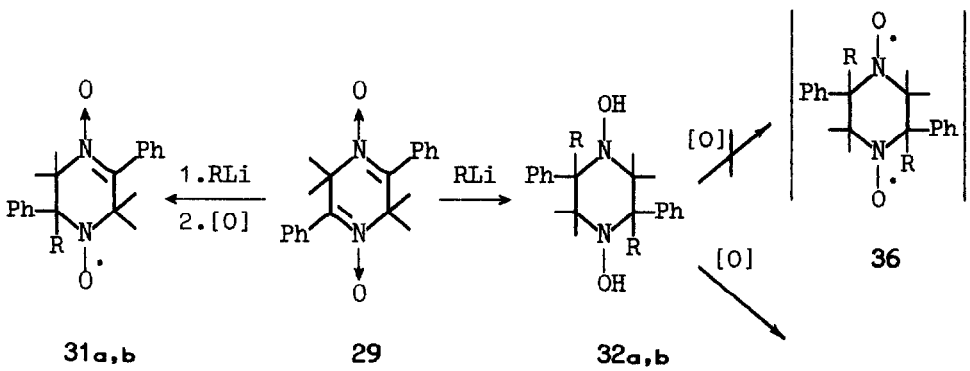
27 **28**

18	R^1	R^2
l	CH_3	Ph
n	CH_3	CH_3
o	$(CH_2)_4$	

24	R^1	R^2
a	CH_3	Ph
c	CH_3	CH_3
d	$(CH_2)_4$	

26	R^1	R^2
a	CH_3	Ph
b	CH_3	CH_3
c	$(CH_2)_4$	

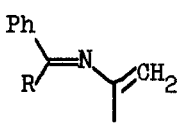
A similar procedure based on the reaction of heterocyclic nitrones with organolithium compounds was used to synthesize pyrazine mono- and dinitroxides. The comparatively low stability of monocyclic imidazolidine biradicals might be attributed to the 1,3-position of nitroxyl groups in the heterocycle. The piperazine dinitroxides with the 1,4-position of nitroxyl groups might prove to be more stable. The pyrazines **29**, **30** do not react with methylmagnesium iodide or phenylmagnesium bromide. Even with a 10-fold excess of methyllithium, the addition occurs only at one nitrone group of pyrazine **29**, and subsequent oxidation leads to the monoradical **31a**. But in the reaction of pyrazine **29** with phenyllithium excess, the addition smoothly proceeded at both nitrone groups to form the dihydroxy-derivative **32a**. Treatment of pyrazine **29** with an excess of butyllithium led to a mixture of isomeric dihydroxypyrazines **32b**.



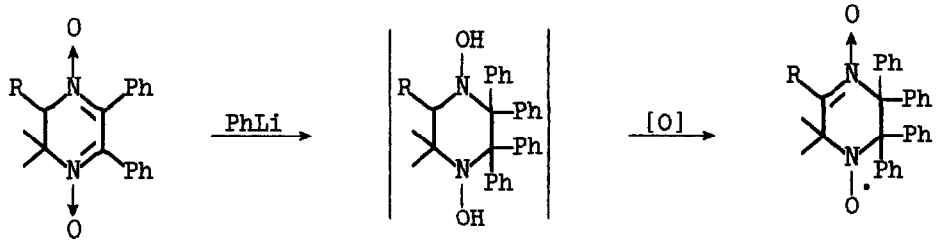
31a,b **29** **32a,b** **36**

31,33,35	R
a	CH_3
b	C_6H_5

32,37	R
a	C_6H_5
b	C_4H_9



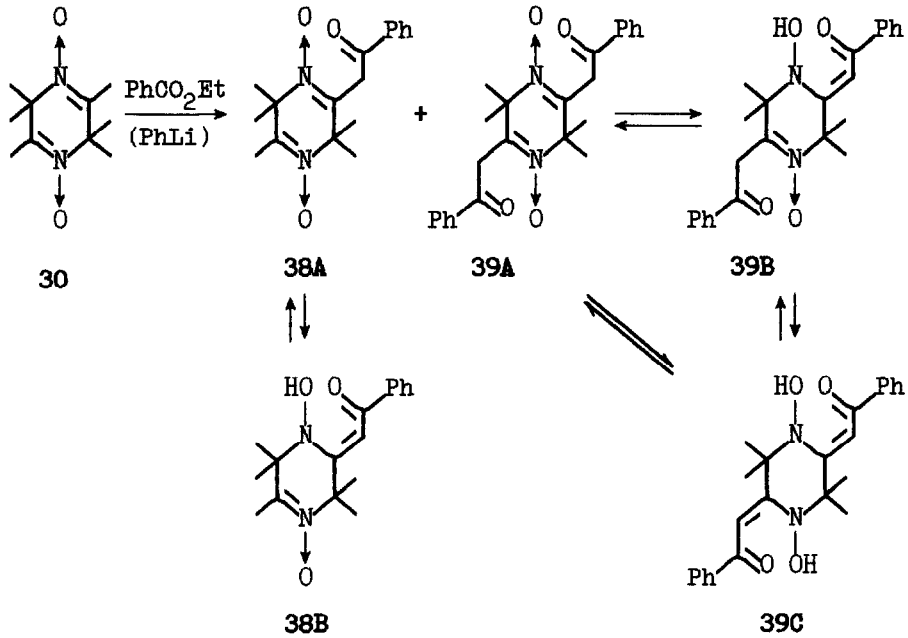
37a,b



33a,b **34** **35a,b**

The reaction of 2,3-dihydropyrazine-1,4-dioxides **33a,b** with phenyllithium excess also proceeds at both nitrone groups. After oxidation of the initially formed dihydroxy-derivatives **32**, the mononitroxides **35a,b** were isolated.

In the oxidation of the dihydroxy-derivatives **32a,b** with MnO_2, the biradicals **36** were not isolated, probably because of their low stability; the compounds which were isolated from the reaction mixture were azabutadienes **37a,b**.

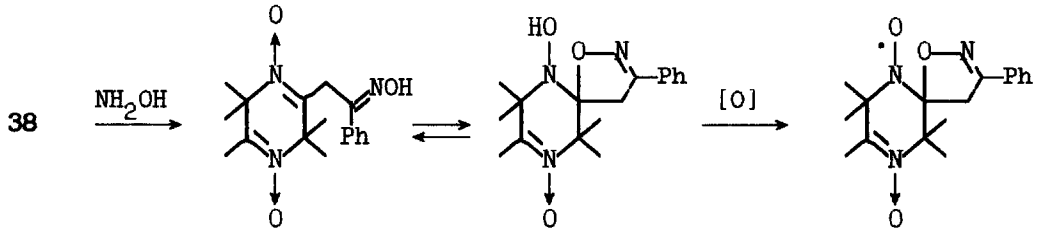


30 **38A** **39A** **39B** **38B** **39C**

As opposed to pyrazines **29**, **32**, the pyrazine **30** having two methylnitrone groups in a molecule does not form any addition products in the reactions with phenyl- or butyllithium, which is probably explained by the metallation of the methylnitrone group.[7] Treatment of pyrazine **30**

with phenyllithium and ethylbenzoate in series afforded the products of mono- **38** and diacylation **39**. It should be noted that compound **38** may be obtained as a result of the condensation reaction of pyrazine **30** with ethylbenzoate in the presence of sodium hydride (cf.[18]).

According to ^{1}H NMR data, compounds **38** and **39** exist in the $CDCl_3$ solution as a mixture of enolized and non-enolized tautomeric forms. The content of the non-enolized tautomeric form **38A** is ≈ 55%. It is difficult to determine the ratio of tautomeric forms for compound **39**. The predominant form in the $CDCl_3$ solution is the **A** form, the **C** form being in the least amount. Each of the enolized forms seems to be represented by the enehydroxylaminoketone and enolnitrone forms (cf.[19]).



In the reaction of pyrazine **38** with hydroxylamine, compound **40** was formed which exists in the DMSO solution, as shown by the ^{13}C NMR data, in the spirobicyclic tautomeric form **B**. In the oxidation of compound **40** with manganese dioxide, a stable spirobicyclic nitroxide **41** was formed (cf.[20]).

Experimental.

The IR spectra were recorded on a Specord M-80 spectrometer in KBr pellets (0.25% concentration) and in $CDCl_3$ and CCl_4 solutions (5% concentration). The UV spectra were recorded on a Specord UV VIS spectrometer in ethanol. The ^{1}H and ^{13}C NMR spectra were measured on the Bruker WP-200 SY and Bruker AC-200 (200 MHz) instruments at 300 K in $CDCl_3$ and DMSO-d_6 solutions (5% concentration). The chemical shift values were determined relative to the signal of the solvent. The paramagnetism of the radicals synthesized was determined on an ESR spectrometer Minsk-12M, the ESR spectra were recorded on a Bruker ER-200D-SRC instrument. The elemental analyses of the compounds synthesized were carried out at the Microanalysis Laboratory of the Novosibirsk Institute of Organic Chemistry. The melting points of the compounds were determined on a microheating table "Boetius" (uncorrected). Compound **1** was prepared according to ref.[21], 4H-imidazole-3-oxides **5,9** according to ref.[22], **18a,b,e,f** accor-

ding to ref.[3], **18c,d** according to ref.[23], **18g-n** according to ref.[22], **29, 30** according to ref.[24], **33** according to ref.[25] The reactions with organometal compounds were carried out in an argon atmosphere in ether dried twice over $CaCl_2$ or in its mixture with tetrahydrofurane dried over KOH and distilled over $LiAlH_4$. The concentration of organolithium and -magnesium compounds was not determined. Other solvents and reagents were used without preliminary purification. The reaction mixtures were chromatographically separated on silica gel in all cases except as mentioned. The hydroxylamino-derivatives were oxidized into the corresponding nitroxides with MnO_2 in ether dried over $CaCl_2$ or in $CHCl_3$ in all cases except as mentioned. The solutions were evaporated on a rotary evaporator. The compounds synthesized alternatively were identified by their IR and UV spectra and chromatographically on Silufol UV-254 plates.

1-Hydroxy-2,2,4,5-tetraphenyl-5-R-3-imidazolines (2a,b). Imidazole **1** (1g, 2.6 mmol) was added portionwise with stirring to a solution of methyl- or phenyllithium prepared from 15 mmol of bromobenzene or methyl iodide and 30 mmol of lithium in 30 ml of ether. Stirring was continued for 15 min., then 15 ml of water was added, the ethereal solution was separated and the aqueous one extracted with ether (2x20 ml). The extract was dried over $MgSO_4$, the solution was evaporated, the residue crystallized when ground with 5 ml of hexane, and the residue of imidazolines **2** was filtered off and washed with hexane. Yield of compound **2a** 90%, m.p. 159-161° (from hexane-ethylacetate mixture), IR, ν, cm^{-1}: 1565, 1605 (C=C, C=N), 3510 (OH), UV, λ_{max}, nm (lg ε): 247 (4.24). NMR ^1H ($CDCl_3$), δ ppm: 1.73s (3H, 5-CH_3), 4.33s (1H, OH), 7.4m (20H, $(C_6H_5)_4$). Found, %: C, 83.2; H, 6.1; N, 6.9. $C_{28}H_{24}N_2O$. Calculated, %: C, 83.4; H, 5.9; N, 6.9. Yield of compound **2b** 90%, m.p. 170-172° (from hexane-ethylacetate mixture), IR, ν, cm^{-1}: 1565, 1600 (C=C, C=N), UV λ_{max}, nm (lg ε): 248 (4.20). Found, %: C, 84.7; H 5.7; N, 5.8. $C_{33}H_{26}N_2O$. Calculated, %: C, 84.9; H, 5.6; N, 6.0.

In the oxidation of imidazolines **2a,b** in $CHCl_3$, the corresponding nitroxides **3** were obtained in a quantitative yield. Compound **3a** was not isolated in an analytically pure form, IR, ν, cm^{-1}: 1565, 1605 (C=C, C=N); UV, λ_{max}, nm (lg ε): 253 (4.34). **2,2,4,5,5-pentaphenyl-3-imidazoline-1-oxyl (3b)**, m.p. 165-167° (from ethanol), IR ν, cm^{-1}: 1565, 1600 (C=C, C=N), UV, λ_{max}, nm (lg ε): 248 (4.22). Found, %: C, 85.0; H, 5.3; N, 5.8. $C_{33}H_{25}N_2O$. Calculated, %: C, 85.2; H, 5.4; N, 6.0.

In the chromatographing of radicals **3** with a (1:1) mixture of $CHCl_3$ and hexane as eluent, **1,1,3,4-tetraphenyl-4-R-2-azabutadienes 4** were ob-

tained in yields 95% (**4a**) and 100% (**4b**). Compound **4a**, oil, IR ν, cm^{-1}: 1570, 1595, 1620 (C=C, C=N), UV, λ_{max}, nm (lg ε): 253 (4.40), 360 (2.90), Found, %: C, 89.8; H, 6.3; N, 3.6. $C_{28}H_{23}N$. Calculated, %: C, 90.1; H, 6.2; N, 3.8. Compound **4b**, m.p. 189-190° (from ethylacetate), IR, ν, cm^{-1}: 1565, 1575, 1595, 1605 (C=C, C=N), UV, λ_{max}, nm (lg ε): 250 (4.34), 310 (4.02), 385 (3.48). Found, %: C, 90.8; H, 5.8; N, 3.2. $C_{33}H_{25}N$. Calculated, %: C, 91.1; H, 5.8; N, 3.2.

4,4-Dimethyl-5-phenyl-2-(α-pyrrolyl)-4H-imidazole-3-oxide (5c). A solution of 3.07 g (20 mmol) of N-(2,3-dimethyl-3-oxobutyl-2)hydroxylamine chlorohydrate **42a**, 14 ml of 25% aqueous NH_3 and 1.9 g (20 mmol) of α-formylpyrrole in 20 ml of methanol was kept for 12 h at 20°, then methanol was evaporated. The residue was diluted with 10 ml of a cool saturated NaCl solution in H_2O, the precipitate of **N-(2,3-dimethyl-3-oxobutyl-2)-C-(α-pyrrolyl)nitrone 43a** was filtered off, washed with 5 ml of cool water and dried. Yield 3.1 g (80%), m.p. 144-146° (from ethylacetate-hexane mixture). IR, ν, cm^{-1}: 1600, 1640 (C=C, C=N), 1715 (C=O), 3300, 3400 (NH). UV, λ_{max}, nm (lg ε): 322 (4.35). NMR ^1H, ($CDCl_3$), δ, ppm: 1.59s (6H), 2.14s (3H), 6.27m (1H), 6.55m (1H), 6.89m (1H, pyrrol), 7.53s (1H, CH=N), 11.95 broad signal (1H, NH), Found, %: C, 61.9; H, 7.4; N, 14.4. $C_{10}H_{14}N_2O_2$. Calculated, %: C, 61.9; H, 7.2; N, 14.4.

Under similar conditions, **N-(2-methyl-3-oxo-3-phenylpropyl-2)-C-(α-pyrrolyl)nitrone 43b** was prepared from N-(2-methyl-3-oxo-3-phenylpropyl--2)hydroxylamine chlorohydrate **42b** in an 80% yield, m.p. 139-141° (from heptane-ethylacetate mixture). IR, ν, cm^{-1}: 1570, 1595, 1605 (C=C, C=N), 1695 (C=O), 3330 (NH). UV, λ_{max}, nm (lg ε): 246 (4.04), 326 (4.38). NMR ^1H, ($CDCl_3$), δ ppm: 1.81s (6H), 6.32m (1H), 6.54m (1H), 6.92m (1H, pyrrol), 7.3m (3H), 7.9m (2H, C_6H_5), 7.56s (1H, CH=N), 11.85 broad signal (1H, NH). Found, %: C, 70.0; H, 6.3; N, 10.8. $C_{15}H_{16}N_2O_2$. Calculated, %: C, 70.2; H, 6.3; N, 11.0.

A solution of 1.25 g of nitrone **43b** in 40 ml of methanol saturated with NH_3 was kept for 14 days at 20°, then evaporated. The residue crystallized when ground with 5 ml of dry ether, and the precipitate of imidazole **5c** was filtered off and washed with hexane. Yield 0.9 g (73%), m.p. 212-214° (from hexane-ethylacetate mixture). IR, ν, cm^{-1}: 1600 (C=C, C=N), 3330 (NH). UV, λ_{max}, nm (lg ε): 307 (4.42), 409 (3.60). NMR ^{13}C (DMSO-d_6), δ ppm: 23.35 (4-(CH_3)$_2$), 78.70 (C-4), 109.58, 112.05, 120.30, 121.92 (pyrrol), 127.27, 129.16, 130.13, 131.82 (C_6H_5), 140.40 (C-2), 176.37 (C-5). Found, %: C, 70.9; H, 5.7; N, 16.8. $C_{15}H_{15}N_3O$. Calculated, %: C, 71.2; H, 5.9; N, 16.6.

Nitrone **43a** was treated in a similar way to give imidazole **5d** which was purified by chromatographing, $CHCl_3$-methanol (30:1) mixture as an eluent, yield 50%, m.p. 172-173° (from hexane-ethylacetate mixture). IR, ν, cm^{-1}: 1590, 1605 (C=C, C=N), 3300 (NH). UV, λ_{max}, nm (lg ε): 273 (4.47). NMR ^1H, ($CDCl_3$), δ ppm: 1.44s (6H), 2.29s (3H), 6.33m (1H), 6.92m (1H), 6.99m (1H, pyrrol), 11.46 broad signal (1H, NH). Found, %: C, 62.9; H, 6.9; N, 22.0. $C_{10}H_{13}N_3O$. Calculated, %: C, 62.9; H, 6.8; N, 22.0.

4,4-Dimethyl-2-(2-pyridyl)-5-phenyl-4H-imidazole-1-oxide (14b). A solution of 1.94 g (10 mmol) of N-(3-hydroxyimino-2-methyl-3-phenylpropyl-2)hydroxylamine **44** and 1.6 g (15 mmol) of pyridine-2-carbaldehyde in 30 ml of methanol was boiled for 3 h, then evaporated. Imidazole **14b** was isolated by chromatographing, with $CHCl_3$ as eluent, in a 45% yield. NMR ^1H ($CDCl_3$), δ, ppm: 1.70s (6H, 4-$(CH_3)_2$), 7.7-8.8m (9H C_6H_5, 2-pyridyl); NMR ^{13}C ($CDCl_3$), δ ppm: 25.08 (4-$(CH_3)_2$), 73.02 (C-4), 124.25-150.18m (C_6H_5, 2-pyridyl), 158.05 (C-5), 160.61 (C-2).

5,5-Dimethyl-2,2,4-triphenyl-3-imidazoline-1-oxyl (7a) was obtained under the conditions as described for imidazolines **2**. **1-Hydroxy-5,5-dimethyl-2,2,4-triphenyl-3-imidazoline 6a** was obtained in an 80% yield, m.p. 172-174 (from hexane-ethylacetate mixture). IR, ν, cm^{-1}: 1570, 1600 (C=N, C=C), 3560 (OH). UV, λ_{max}, nm (lg ε):243 (4.18). NMR ^1H ($DMSO-d_6$), δ ppm: 1.30s (6H, 5,5-$(CH_3)_2$), 7.5m (15H, 2,2,4-$(C_6H_5)_3$). Found, %: C, 80.5; H, 6.6; N, 8.0. $C_{23}H_{22}N_2O$. Calculated, %: C, 80.7; H, 6.6; N, 8.2.

Nitroxide **7a** was prepared by oxidation of imidazoline **6a** in a 95% yield, m.p. 137-139° (from hexane). IR, ν, cm^{-1}: 1565, 1605 (C=N, C=C), UV, λ_{max}, nm (lg ε): 253 (4.33). Found, %: C, 81.1; H, 6.4; N, 8.2. $C_{23}H_{21}N_2O$ Calculated, %: C, 80.9; H, 6.2; N, 8.2. **5,5-dimethyl-2,2,4-triphenyl-2-imidazoline-1-oxyl (8a)** isolated from mother liquer after recrystallization of nitroxide **7a** by chromatographing with $CHCl_3$-hexane (1:1) mixture as eluent in an 5% yield. M.p. 142-143° (from hexane). IR, ν, cm^{-1}: 1545, 1560 (C=C, C=N), UV, λ_{max}, nm (lg ε): 237 (4.36), 309 (3.74), 455 (2.90). Found, %: C, 80.9; H, 6.1; N, 8.1. $C_{23}H_{21}N_2O$. Calculated, %: C, 81,0; H, 6.2; N, 8.2.

A similar procedure gave the hydroxy-derivative **6c**, nitroxides **7b,c** and iminonitroxides **8b-e**. Yield of compound **6c** was 95%, m.p. 144-146° (from hexane-ethylacetate mixture). IR, ν, cm^{-1}: 1570, 1575, 1610 (C=C, C=N), 3580 (OH); UV, λ_{max}, nm (lg ε): 250 (4.04). Found, %: C, 77.1; H, 6.3; N, 7.6. $C_{23}H_{22}N_2O_2$. Calculated, %: C, 77.1, H,6.1; N, 7.8. Yield of compound **7b** was 60%, oil, purified by chromatographing with $CHCl_3$ as

eluent. IR, ν, cm^{-1}: 1570, 1605, 1640 (C=C, C=N), 3100-3400 (OH). UV, λ_{max}, nm (lg ε): 250 (4.33). Found,%: C, 73.0; H, 6.6; N, 9.2. $C_{18}H_{19}N_2O_2$. Calculated, %: C, 73.2; H, 6.4; N, 9.5. In the process of chromatographing, the whole amount of iminonitroxide **8c** decomposed. Yield of compound **7c** was 80%, m.p. 140-142° (from ethylacetate). IR, ν, cm^{-1}: 1570, 1600 (C=C, C=N), 3100-3400 (OH), UV, λ_{max}, nm (lg ε): 253 (4.29). Found, %: C, 77.5; H, 6.1; N, 7.9. $C_{23}H_{21}N_2O_2$. Calculated, %: C, 77.4; H, 5.9; N, 7.9. Yield of compound **8b** was 5%, m.p. 112-114° (from hexane). IR, ν, cm^{-1}: 1545, 1570, 1580, 1615 (C=C, C=N), UV, λ_{max}, nm (lg ε): 244 (4.0), 273 (3.72), 302 (3.62), 485 (2.84). Found, %: C, 73.2; H, 6.5; N, 9.2. $C_{18}H_{19}N_2O_2$. Calculated, %: C, 73.2; H, 6.4; N, 9.5. Yield of compound **8d** was 40%, m.p. 102-104°(from hexane). IR, ν, cm^{-1}: 1605 (C=C, C=N), 3370 (NH). UV, λ_{max}, nm (lg ε): 267 (4.31), 296 (3.79). 545 (2.84). Found, %: C, 71.5; H, 6.9; N, 15.5. $C_{16}H_{18}N_3O$. Calculated, %: C, 71.6; H, 6.7; N, 15.7. To prepare the iminonitroxide **8e**, the aqueous solution obtained after the reaction of imidazole **5d** with methyllithium was treated with a five-fold excess of $K_3Fe(CN)_6$ and extracted with $CHCl_3$. The extract was dried over $MgSO_4$, the solution was evaporated, and compound **8e** was isolated by chromatographing, hexane-methyl acetate (1:1) mixture as eluent, yield 25%, m.p. 125-127°. IR, ν, cm^{-1}: 1600 (C=C, C=N), 3370 (NH). UV, λ_{max}, nm (lg ε): 265 (4.24), 550 (2.80). Found, %: C, 63.9; H, 7.8; N, 20.2. $C_{11}H_{16}N_3O$. Calculated, %: C, 64.1; H, 7.8; N, 20.4.

In the reaction of imidazole **9b** with PhLi, the ether solution was separated, the aqueous solution was extracted with ether and extract was dried over $MgSO_4$, the solution was evaporated, the residue washed with hexane, and the residue of **1-hydroxy-2,4-diphenyl-2,5,5-trimethyl-3-imidazoline-3-oxide (11)** filtered off, yield 15%, m.p. 220-223° (from ethanol). IR, ν, cm^{-1}: 1545, 1570, 1595 (C=C, C=N), UV, λ_{max}, nm (lg ε): 292 4.10). NMR ^1H (DMSO-d_6), δ ppm: 1.23s (3H), 1.54s (3H), 1.85s (3H, 2,2,5-$(CH_3)_3$); 7.4m (10H, 2,4-$(C_6H_5)_2$); 8.44s (1H, OH). Found, %: C, 73.3; H, 7.1; N, 9.3. $C_{18}H_{20}N_2O_2$. Calculated, %: C, 73.0; H, 6.8; N, 9.5. After the reaction, a five-fold excess of $K_3Fe(CN)_6$ was added to the aqueous solution and extracted with $CHCl_3$. The extract was dried over $MgSO_4$, the solution was evaporated, the nitronylnitroxide **10a** was isolated by chromatographing, eluent $CHCl_3$, yield 60%, m.p. 108-110° (cf.[8]).

4,4-Diphenyl-2,5,5-trimethyl-2-imidazoline-3-oxide-1-oxyl (10a) was prepared under similar conditions by the reaction of imidazoline **18h** with phenyllithium and subsequent oxidation with MnO_2 in a 50% yield. The nitronylnitroxide **10a** was purified by chromatographing, the hexane-ethyl acetate (3:1) mixture as eluent, m.p. 108-110° (from heptane), IR, ν,

cm^{-1}: 1490, 1530 (C=N), UV, λ_{max}, nm (lg ε): 324 (4.08), 575 (3.28). Found, %: C, 73.4; H, 6.6; N, 9.5. $C_{18}H_{19}N_2O_2$. Calculated, %: C, 73.2; H, 6.4; N, 9.5. When imidazoline **18g** was treated with phenyllithium under similar conditions in the ether–THF (1:1) mixture, the nitronylnitroxide **10b** was obtained, which could not be isolated in an analytically pure state but was oxidized to the biradical **23**. For that purpose, 1g of $K_3Fe(CN)_6$ was added portionwise with stirring to a suspension of 0.5 g of the crude radical **10b** and 0.3g of NaH in 10 ml of anhydrous DMF. Stirring was continued for 30 min. at 20°, the reaction mixture was poured into 50 ml of water and extracted with $CHCl_3$ (3x20 ml). The extract was washed with water (5x10 ml) and dried over $MgSO_4$, and the solution was evaporated. **Bis-(4,4-dimethyl-5,5-diphenyl-2-imidazoline-3- oxide-1-oxyl-2-yl) (23)** was purified by chromatographing, $CHCl_3$ as eluent, yield 20% (starting from imidazoline **18g**), m.p. 192-193°, IR, ν, cm^{-1}: 1490 (C=N); UV, λ_{max}, nm (lg ε): 267 (4.0), 327 (4.32), 340 (4.29), 555 (2.78). Found, %: C, 73.1; H, 5.9; N, 9.9. $C_{34}H_{32}N_4O_4$. Calculated, %: C, 72.9; H, 5.7; N, 10.0.

In the oxidation of the hydroxy-derivative **11** with MnO_2 the product **was 2,4-diphenyl-2,5,5-trimethyl-3-imidazoline-3-oxide-1- oxyl (12)** in a 95% yield, m.p. 110–112°(from hexane). IR, ν, cm^{-1}: 1525, 1565 (C=C, C=N), UV, λ_{max}, nm (lg ε): 289 (4.03). Found, %: C, 73.0; H, 6.5; N, 9.3. $C_{18}H_{19}N_2O_2$. Calculated, %: C, 73.2; H, 6.4; N, 9.5.

The interaction of imidazole **14a** with phenyllithium under the above-described conditions afforded **1-hydroxy-2,5,5-triphenyl-4,4-dimethyl-2-imidazoline (15a)**, which precipitated in a quantitative yield when the reaction mixture was diluted with water. M.p. 218–219° (from heptane-ethylacetate mixture). IR, ν, cm^{-1}: 1510, 1565, 1595, 1615 (C=C, C=N), UV, λ_{max}, nm (lg ε): 234 (4.30), 346 (2.90). NMR ^1H ($CDCl_3$), δ ppm: 0.87s (6H, 4,4-$(CH_3)_2$); 7.1m (15H, $(C_6H_5)_3$; 8.40s (1H, OH). Found, %: C, 80.5; H, 6.7; N, 8.0. $C_{23}H_{22}N_2O$. Calculated, %: C, 80.8; H, 6.4; N, 8.2. The oxidation of the hydroxy-derivative **15a** gave the iminonitroxide **13a** in a 95% yield, m.p. 167–169° (from hexane-ethylacetate mixture). IR, ν, cm^{-1}: 1560, 1605 (C=C, C=N), UV, λ_{max}, nm (lg ε): 233 (4.44), 308 (3.58), 450 (2.78). Found, %: C, 81.2; H, 6.5; N, 8.3. $C_{23}H_{21}N_2O$. Calculated, %: C, 81.0; H, 6.2; N, 8.2.

5,5-Dimethyl-2,4,4-triphenyl-2-imidazoline-1-oxyl (13a) and **5,5-dimethyl-2,2,4-triphenyl-2-imidazoline-1-oxyl (8a)**. A PhLi solution prepared from 0.32 ml (3 mmol) of bromobenzene and 0.04 g (6 mmol) of

lithium in 10 ml of abs. ether was added dropwise with stirring to a solution of 0.58 g (2 mmol) of imidazole **9a** in 10 ml of abs. THF. Stirring was continued for 15 min., then 20 ml of water was added, the organic layer was separated and the aqueous layer extracted with ether (3x20 ml). The combined extract was dried over $MgSO_4$, the drying agent was filtered off, then 2 g of MnO_2 was added to the solution, and the mixture was stirred for 30 min. at 20°C. The excess of the oxidant was filtered off, the solution was evaporated, and the mixture of compounds **8a** and **13a** was separated by chromatography, with hexane-$CHCl_3$ (1:1) mixture as eluent. First coloured zone contained compound **8a** (yield 10%), another one compound **13a** (yield 10%).

1,3-Dihydroxy-2,2,4,4,5,5-hexa-substituted imidazolidines (16a-g) were obtained by the reaction of a solution of 30 mmol of CH_3Li, PhLi or C_4H_9Li in ether with imidazolines **18** or imidazole **9a** during 2 h at 20°C under the conditions indicated for the synthesis of imidazolines **2a,b**. In the case of imidazoline **18b**, the reaction was carried out in the ether-THF mixture. In the reaction with imidazolines **2a,b**, the reaction mixture was decomposed with water and 60-70% of the starting compounds were recovered by filtration. Imidazolidines **16a,d-g** were obtained in 75-95% yields, imidazolidines **16b,c** in about 60% yield from the changed imidazolines **18a,b**. In view of their low stability, imidazolidines **16c,d,f,g** were not isolated individually in an analytically pure form. **1,3-Dihydroxy-4-butyl-2,2,5,5-tetramethyl-4-phenyl- imidazolidine (16e)** was obtained in a 75% yield, m.p. 128-131°(from hexane). NMR ^1H ($CDCl_3$), δ ppm: 0.69s (3H), 1.21s (3H), 1.38s (3H), 1.50s (3H, 2,5-$(CH_3)_2$); 0.8-2.2m (9H, C_4H_9); 4.19s (1H, OH), 5.36s (1H, OH), 7.4m (5H, C_6H_5). Found, %: C, 69.3; H, 9.8; N, 9.5. $C_{17}H_{28}N_2O_2$. Calculated, %: C, 69.1; H, 9.6; N, 9.6.

4-Substituted 2,2,5,5-tetramethyl-4-phenylimidazoline-1,3-dioxyls (17). A suspension of 0.2 g of imidazolidine **16a,b,e** and 2g of MnO_2 in 10 ml of a (1:2) mixture of pentane and ether was stirred for 30 sec., the solution was decanted, further 10 ml of the same solvent mixture was added to the residue and the procedure was repeated. Fresh portions of the solvent were added until no more bright red colouring of the solution was observed. Each portion of the solvent was evaporated right after decanting to give the biradicals **17b-d**. The ESR spectra of biradicals **17** in diluted solutions represent a singlet with line width 100-150 G. Yield of biradical **17b** was 80%, m.p. 88-90° (from hexane). Found, %: C, 73.3; H, 7.4; N, 8.8. $C_{19}H_{22}N_2O_2$. Calculated, %: C, 73.6; H, 7.1, N, 9.0. Yield of biradical **17d** was 80%, m.p. 65-66° (from hexane). Found, %: C, 70.6;

H, 9.2; N, 9.7. $C_{17}H_{26}N_2O_2$. Calculated, %: C, 70.4; H, 9.0; N, 9.7.

1,5,5-Trimethyl-2-spirocyclohexyl-4-phenyl-3-imidazoline-3-oxide (20) was obtained by the alkylation of 5,5-dimethyl-2-spiro-cyclohexyl-4-phenyl-3-imidazoline-3-oxide with formaldehyde and HCOOH as in ref.[26] and purified by chromatographing on an alumina column, with ethyl acetate-hexane 1:5 mixture as eluent, yield 75%, m.p. 50-52° (from hexane). IR, ν, cm^{-1}: 1545, 1570 (C=C, C=N), 2800 (N-CH_3). UV, λ_{max}, nm (lg ε): 284 (3.93). NMR ^1H ($CDCl_3$), δ ppm: 1.39s (6H, 5-$(CH_3)_2$), 1.64m (2H), 1.93m (6H, $(CH_2)_5$); 2.37s (3H, N-CH_3); 7.4m (3H), 8.0m (2H, C_6H_5). Found, %: C, 74.7; H, 8.6; N, 10.4. $C_{17}H_{24}N_2O$. Calculated, %: C, 74.9; H, 8.8; N, 10.3.

5,5-Diphenyl-3,4,4-trimethyl-2-spirocyclohexylimidazolidine-1-oxyl (21) was obtained by the reaction of imidazoline **20** with excess phenyllithium under the conditions as indicated for imidazolines **2** with subsequent oxidation with MnO_2 in hexane. Compound **21** was purified chromatographically, eluent hexane, yield 90%, m.p. 154-156° (from hexane). Found, %: C, 78.9; H, 8.3; N, 8.2. $C_{23}H_{29}N_2O$. Calculated, %: C, 79.2; H, 8.3; N, 8.0.

4,4-Dimethyl-5,5-diphenyl-2-(2-pyridyl)-2-imidazoline-1-oxyl (12b) was prepared by the reaction of imidazoline **18k** or imidazole **14b** with phenyllithium as described for imidazolines **2** with subsequent oxidation with MnO_2 in 40 and 45% yields respectively. Compound **12b** was purified by chromatography, with hexane-ethyl acetate (1:2) mixture as eluent, m.p. 97-99° (from heptane). IR, ν, cm^{-1}: 1560, 1570, 1595 (C=C,C=N), UV, λ_{max}, nm (lg ε): 267 (3.90), 305 (3.48). Found, %: C, 77.4; H, 6.1; N, 12.3. $C_{22}H_{20}N_3O$. Calculated, %: C, 77.2; H, 5.9; N, 12.3.

N-(3-Hydroxyimino-2-methyl-3-phenylpropyl-2)-N-diphenylmethyl-hydroxylamine (24a) was prepared as described above by the reaction of imidazoline **18l** with PhLi in a 90% yield, m.p. 139-141° (from hexane-ethyl acetate mixture). IR, ν, cm^{-1}: 1600 (C=N), 3590, 3200-3400 (OH). NMR ^1H ($CDCl_3$), δ ppm: 1.21s (6H), 4.67s (1H, OH), 5.25s (1H, $C\underline{H}Ph_2$), 7.3m (5H, C_6H_5), 8.47s (1H, OH). NMR ^{13}C (DMSO-d_6), δ ppm: 23.39 $(CH_3)_2$, 66.44 ($\underline{C}(CH_3)_2$), 67.59 ($\underline{C}H(C_6H_5)_2$), 126.21-129.17m, 134.61, 143.69 $(C_6H_5)_3$, 160.54 (C=N). Found, %: C, 76.3; H, 6.8; N, 7.7. $C_{23}H_{24}N_2O_2$. Calculated, %: C, 76.3; H, 6.7; N, 7.8. The silica gel chromatography gave, along with hydroxylaminooxime **24a**, 3-imidazoline-3-oxide **25a** in a yield up to 20%, m.p. 149-151° (from ethanol). IR, ν, cm^{-1}: 1555, 1575

(C=C, C=N), 3260 (NH), UV, λ_{max}, nm (lg ε): 294 (4.04). Found, %: C, 76.9; H, 6.8; N, 7.7. $C_{23}H_{22}N_2O \cdot H_2O$. Calculated, %: C. 76.7; H, 6.7; N, 7.8.

The reactions of phenylmagnesium bromide with imidazolines **18n,o** under similar conditions gave hydroxylaminooximes **24c,d** in a 75% yield. Compound **24c**, m.p. 136-137° (from hexane ethylacetate mixture). IR, ν, cm^{-1}: 3600 (OH). NMR ^1H ($CDCl_3$), δ ppm: 1.22s (6H), 1.98s (3H), 4.7 broad signal (1H, OH), 5.14s (1H, $C\underline{H}Ph_2$), 7.4m (10H, $(C_6H_5)_2$, 8.9 broad signal (1H, OH). Found, %: C, 72.4; H, 7.4; N, 9.3. $C_{18}H_{22}N_2O_2$. Calculated, %: C, 72.4; H, 7.4; N, 9.4. Compound **24d**, m.p. 120-122°(from hexane), IR, ν, cm^{-1}: 3600 (OH). NMR ^{13}C ($CDCl_3$), δ ppm: 20.71, 20.93, 24.92, 25.35 ($(-CH_2-)_3$, CH_3), 35.98 ($-\underline{C}H_2-C=N$), 57.78 (C-N), 60.98 ($\underline{C}H-Ph_2$), 125.65-128.33, 145.93, 146.30 (Ph_2), 162.81 (C=N). Found, %: C, 74.2; H, 7.6; N, 8.5. $C_{20}H_{24}N_2O_2$. Calculated, %: C, 74.0; H, 7.4; N, 8.7.

When imidazoline **18m** was treated under similar conditions with PhLi, **5,5-dimethyl-2,4-diphenyl-2-furyl-3-imidazoline-3-oxide 25** was obtained in a 60% yield, which was purified chromatographically, eluent was an ether-hexane (1:1) mixture, m.p. 140-142° (from hexane-ethylacetate mixture). IR, ν, cm^{-1}: 1515, 1560 (C=C,C=N), 3310 (NH). UV, λ_{max}, nm (lg ε): 292 (4.05). NMR ^1H (DMSO-d_6), δ ppm: 1.34s (3H), 1.60s (3H), 3.87s (1H, NH), 6.19m (1H, 3-H, furyl), 6.45m (1H, 4H, furyl), 7.4-8.2m (11H, $(C_6H_5)_2$, 5-H, furyl). NMR ^{13}C (DMSO-d_6), δ ppm: 28.25 (5,5-$(CH_3)_2$), 62.85 (C-5), 91.02 (C-2), 110.48, 112.32 (C-3, C-4, furyl); 127.25-129.60m ($(C_6H_5)_2$, 139.61 (C-4), 142.13, 143.87 (C-2, C-5, furyl). Found, %: C, 75.8; H, 6.2; N, 8.4. $C_{21}H_{20}N_2O_2$. Calculated, %: C, 75.9; H, 6.0; N, 8.4.

N-(3-Hydroxyimino-2-methyl-3-phenylpropyl-2)-N-diphenylmethylnitroxyl (26a) was prepared by the oxidation of hydroxylaminooxime **24a** with MnO_2 in ether with a 90% yield, m.p. 130-132° (from hexane). ESR-spectra ($CHCl_3$, without O_2), a_N = 14.5, a_H = 1.8 G. IR, ν, cm^{-1}: 3600 (OH). Found, %: C, 77.2; H, 6.0; N, 7.8. $C_{23}H_{21}N_2O_2$. Calculated, %: C, 77.4; H, 5.9; N, 7.9.

The oxidation of hydroxylaminooximes **24b,c** under similar conditions gave nitroxides **26b,c** in nearly quantitative yields. Compound **26b**, m.p. 133-135° (from hexane-ethylacetate mixture). ESR-spectra (in water), a_N = 15.7, a_H = 3.2 G. IR, ν, cm^{-1}: 3590 (OH). Found, %: C, 72.5; H, 7.2; N, 9.6. $C_{18}H_{21}N_2O_2$. Calculated, %: C, 72.7; H, 7.1; N, 9.4. Compound **26c**, m.p. 103-104° (from hexane). ESR-spectra (in water), a_N = 16.0, a_H = 2.7 G. IR, ν, cm^{-1}: 3600 (OH). Found, %: C, 74.5; H, 7.2; N, 8.8. $C_{20}H_{23}N_2O_2$. Calculated, %: C, 74.3; H, 7.1; N, 8.7.

The reaction of N-tert-butylphenylnitrone with phenylmagnesium bromide and subsequent oxidation with MnO_2 gave **N-tert-butyl-N-diphenylmethylnitroxyl 28** in a 90% yield, m.p. 111-113° (from hexane). ESR-spectra (in water), a_N = 16.0, a_H = 2.7 G. Found, %: C, 80.3; H, 8.0, N, 5.6. $C_{17}H_{20}NO$. Calculated, %: C, 80.3; H, 7.9; N, 5.5.

2,5-Diphenyl-2,3,3,6,6-pentamethyl-1,2,3,6-tetrahydropyrazine-4-oxide-1-oxyl (31a). Pyrazine **29** (0.64 g; 2 mmol) was added portionwise with stirring to a solution of methyllithium prepared from 0.62 ml (10 mmol) of methyl iodide and 0.14 g (20 mmol) of lithium in 30 ml of ether. Stirring was continued for 10 h at 20°, then 10 ml of water was added, the residue was filtered off and washed with water and ether. The organic layer of the filtrate was separated and the aqueous one extracted with $CHCl_3$, the extract was dried over $MgSO_4$. The drying agent was filtered off, the precipitate isolated earlier was added to the filtrate and the mixture was stirred for 2h at 20°C with 2g of MnO_2. The excess of the oxidant was filtered off, the solution was evaporated, and compound **31a** was isolated chromatographically, eluent $CHCl_3$. Yield 95%, m.p. 145-146° (from hexane). IR, ν, cm^{-1}: 1565 (C=N). UV, λ_{max}, nm (lg ε): 250 (3.91). Found, %: C, 75.0; H, 7.7; N, 8.1. $C_{21}H_{25}N_2O_2$. Calculated, %: C, 74.7; H, 7.4; N, 8.4.

When pyrazine **29** was treated with 1.2 mmol of PhLi, the nitroxide **31b** was obtained in a 40% yield after subsequent oxidation. M.p. 198-200° (from hexane-ethylacetate mixture). IR, ν, cm^{-1}: 1570 (C=N). UV, λ_{max}, nm (lg ε): 252 (3.90). Found, %: C, 78.1; H, 6.7; N, 6.8. $C_{26}H_{27}N_2O_2$. Calculated, %: C, 78.3; H, 6.8, N, 7.0.

1,4-Dihydroxy-3,3,6,6-tetramethyl-2,2,5,5-tetraphenyl-piperazine (32a). Pyrazine **29** (0.64 g; 2 mmol) was added portionwise with stirring to a PhLi solution prepared from 1.1 ml (10 mmol) of bromobenzene and 0.14 g (20 mmol) of lithium. Stirring was continued for 3 h at 20°C, then 10 ml of water was added, the precipitate of compound **32a** was filtered off, washed with water and with ether. Yield of the dihydroxy-derivative **32a** is quantitative, m.p. 314-315°C (from pyridine, in a sealed capillary). Compound **32a** forms a crystal solvate with pyridine which decomposes on heating to 90-100°C. IR, ν, cm^{-1}: 3520 (OH). Found, %: C, 80.5; H, 7.3; N, 6.0. $C_{32}H_{34}N_2O_2$. Calculated, %: C, 80.3; H, 7.1; N, 5.9.

Treatment of pyrazine **29** with butyllithium under similar conditions gave the dihydroxy-derivative **32b** as a mixture of two diastereomers with a nearly quantitative yield.

Compounds **35a,b** were obtained by the reaction of a 10-fold excess of

phenyllithium with pyrazines **33a,b** under the conditions indicated for imidazolines **2**. Yield of compound **35a** 10%, m.p. 210-212° (from hexane-ethylacetate mixture). IR, ν, cm^{-1}: 1570, 1595, 1620 (C=C, C=N). UV, λ_{max}, nm (lg ε): 299 (4.22). Found, %: C, 81.0; H, 6.3; N, 6.1. $C_{31}H_{29}N_2O_2$. Calculated, %: C, 80.6; H, 6.3; N, 6.1. Yield of compound **35b** 35%, m.p. 108-110° (from ethanol). IR, ν, cm^{-1}: 1575, 1600, 1620 (C=C, C=N), UV, λ_{max}, nm (lg ε): 299 (4.22). Found, %: C, 82.8; H, 5.6; N, 5.6. $C_{36}H_{31}N_2O_2$. Calculated, %: C, 82.5; H, 5.9; N, 5.4.

1,1-Diphenyl-3-methyl-2-azabutadiene (37a). A suspension of 0.2 g of dihydroxypiperazine **32a** in a mixture of 20 ml of ether and 1 ml of pyridine was stirred with 2 g of MnO_2 for 1 h at 20°C. The excess of the oxidant was filtered off, the solution was evaporated, and compound **37a** was isolated chromatographically, with a $CHCl_3$-hexane (1:1) mixture as an eluent, in a 70% yield, m.p. 74-76° (from pentane). IR, ν, cm^{-1}: 1605, 1630 (C=C, C=N). UV, λ_{max}, nm (lg ε): 248 (4.22). NMR ^1H ($CDCl_3$), δ ppm: 1.76s (3H), 4.0s (1H), 4.15s (1H, $=CH_2$), 7.2-7.7m (10H, $(C_6H_5)_2$). NMR ^{13}C ($CDCl_3$) δ ppm: 21.78 (CH_3), 96.79 ($=CH_2$), 127.7-139.1m (C_6H_5), 152.66, 165.60 (C=N, =C-N). Found, %: C, 86.7; H, 6.8; N, 6.0. $C_{16}H_{15}N$. Calculated, %: C, 86.9; H, 6.8; N, 6.3.

Azabutadiene **37b** was synthesized by the oxidation of dihydroxypiperazine **32b** in hexane under similar conditions, in a 50% yield (oil, purified chromatographically). Partial hydrolysis of compound **37b** occurs in chromatographing on silica gel and upon short-term storage in non-absolute solvents. The structure of valerophenone formed as a result of hydrolysis was established by NMR. IR, ν, cm^{-1}: 1545, 1570, 1595, 1620 (C=C, C=N). UV, λ_{max}, nm (lg ε): 243 (4.08). Found, %: C, 83.3; H, 9.4; N, 6.7. $C_{14}H_{19}N$. Calculated, %: C, 83.6; H, 9.5; N, 7.0.

2,5-Dihydro-2,2,3,5,5-pentamethyl-6-phenacylpyrazine-1,4-dioxide (38) and **2,5-dihydro-3,6-diphenacyl-2,2,5,5-tetramethyl-pyrazine-1,4-dioxide (39) (Procedure 1).** Pyrazine **30** (1g, 5 mmol) was added portionwise with stirring to a phenyllithium solution prepared from 1.1 ml (10 mmol) of bromobenzene and 0.14 g (20 mmol) of lithium in 20 ml of ether. Stirring was continued with boiling for 3 h, then a solution of 1.5 ml (10 mmol) of ethylbenzoate in 5 ml of ether was added dropwise with stirring and cooling to 0°C. Stirring was continued for 1 h with boiling, then 20 ml of water was added. The ether solution was separated and discarded, the aqueous one washed with ether (2x20 ml), acidified to pH 5 with 10% hydrochloric acid, and extracted with $CHCl_3$ (3x20 ml). The extract was dried over $MgSO_4$, the solution was evaporated, and the mixture of com-

pounds **38** and **39** was separated chromatographically, $CHCl_3$ as eluent, with compound **38** eluted first. As shown by TLC, the individual compounds **38** and **39** are represented by two spots, possibly because of their existence as a tautomeric mixture. Yields of compounds **38** and **39** were 30 and 5% respectively. Compound **38**, m.p. 163-165°C (chromatographic purification), IR, ν, cm^{-1}: 1555, 1580, 1595, 1620 (C=C, C=N), 1680 (C=O). UV, λ_{max}, nm (lg ε): 237 (4.46), 353 (3.70). NMR ^1H ($CDCl_3$), δ ppm: 1.68s, 1.74s, 1.85s (12H, 2,5-$(CH_3)_2$), 2.20s (3H, 3-CH_3, **B**), 2.22s (3H, 3-CH_3, **A**), 4.08s (2H, -CH_2-, **A**), 5.61s (1H, -CH=, **B**), 7.4m (5H, C_6H_5), 14.26s (1H, OH, **B**). Found, %: C, 67.9; H, 7.2; N, 9.2. $C_{17}H_{22}N_2O_3$. Calculated, %: C, 67.6; H, 7.3; N, 9.3. Compound **39**, m.p. 160-164° (chromatographic purification), IR, ν, cm^{-1}: 1595, 1605 (C=C, C=N), 1690 (C=O). UV, λ_{max}, nm (lg ε): 223 (4.16), 244 (4.26), 356 (3.63). NMR ^1H ($CDCl_3$), δ ppm: 1.76s, 1.81s, 1.86s, 1.91s (12H, 2,5-$(CH_3)_2$), 4.12s, 4.13s (2H, -CH_2-, **A** and **B**), 5.65s, 5.66s (1H, -CH=, **B** and **C**), 7.4-8.0m (10H, $(C_6H_5)_2$), 14.21s, 14.30s (1H, OH, **B** and **C**). Found, %: C, 71.2; H, 6.4; N, 6.8. $C_{24}H_{26}N_2O_4$. Calculated, %: C, 70.9; H, 6.4; N, 6.9.

Procedure 2. A mixture of 0.5 g (2.5 mmol) of pyrazine **30**, 0.6 g of 80% suspension of NaH in silicon oil (20 mmol) and 0.8 ml (5.4 mmol) of ethylbenzoate in 10 ml of THF was boiled with stirring for 20 h, then poured into 20 ml of water and treated as described in procedure 1. Compound **38** was obtained in a 45% yield.

1-Hydroxy-1,2,3,6-tetrahydro-3,3,5,6,6-pentamethyl-2-spiro-(4',5'-dihydro-3'-phenylisoxazolo)-pyrazine-4-oxide (40). A solution of 0.4 g (1.32 mmol) of pyrazine **38**, 0.46 g (6.6 mmol) of $NH_2OH \cdot HCl$ and 0.22 g (4.0 mmol) of CH_3ONa in 20 ml of methanol was kept for 3 days at 20°C, then evaporated. The residue was diluted with 5 ml of water, and the precipitate of compound **40** was filtered off and dried. Yield 90%, m.p. 223-226° (from water-ethanol mixture). IR, ν, cm^{-1}: 1600 (C=N). UV, λ_{max}, nm (lg ε): 250 (4.04). NMR ^1H (DMSO-d_6), δ ppm: 1.31s (3H), 1.36s (3H), 1.47s (3H), 1.56s (3H, 3,6-$(CH_3)_2$), 1.98s (3H, 5-CH_3), 3.65s (2H, -CH_2-), 7.45m (3H), 7.65m (2H, C_6H_5), 8.56s (1H, OH). NMR ^{13}C (DMSO-d_6), δ ppm: 15.37 (5-CH_3), 19.90, 21.07, 25.85, 27.00 (3,6-$(CH_3)_2$), 62.16 (C-6), 72.67 (C-3), 105.23 (C-2), 126.30, 128.75, 129.28, 129.93 (C_6H_5), 144.95 (C-5), 155.62 (C-3').The signal of the C-4 atom is screened by the signal of the solvent. Found, %: C, 64.3; H, 7.3; N, 13.0; $C_{17}H_{23}N_3O_3$. Calculated, %: C, 64.3; H, 7.3; N, 13.3.

1,2,3,6-Tetrahydro-3,3,5,6,6-pentamethyl-2-spiro-(4',5'-dihydro-3'-phenylisoxazolo)-pyrazine-4-oxide-1-oxyl (41) was prepared by the

oxidation of pyrazine **40** with MnO_2 in a $CHCl_3$-methanol mixture during 20 min. and purified chromatographically, with a $CHCl_3$-methanol (30:1) mixture as an eluent . Yield of radical **41** was 90%, m.p. 175-177°. IR, ν, cm^{-1}: 1570 (C=N), UV, λ_{max}, nm (lg ε): 246 (4.31). Found, %: C, 64.2; H, 7.0; N, 13.1. $C_{17}H_{22}N_3O_3$. Calculated, %: C, 64.6; H, 6.9; N, 13.3.

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