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PYRIDYLETHYLATION OF OPTICALLY ACTIVE AMINES

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A study has been made of the addition of (R)- and (S)-1-phenylethylamines and (R)- and (S)-1-cyclohexylethylamines to the C=C bond of 2- and 4-vinylpyridines in the presence of an acid catalyst. The corresponding monoadducts have been synthesized with high preparative yields. By reactions of these adducts with 2- and 4-vinylpyridines, bis-adducts have been obtained. All of the products had high optical purities (91-99%, HPLC).

Research has been pursued vigorously over the past few years in the area of asymmetric catalysis by complexes of transition metals with N-chelating bis-, tris-, and higher-dentate ligands [1-4]. For use as ligands, optically active pyridine derivatives may be competitive with phosphines in various catalytic processes such as hydrogenation and hydrogen transfer [5], and especially in hydrosilylation [6-12]. It is also known that aminoethylpyridines exhibit biological activity; a specific example is the pharmaceutical preparation Merislon, based on 2-[2-(methylamino)ethyl]pyridine, which is effective in improving blood circulation [13].

One of the convenient methods for synthesizing aminoethylpyridines from amines is the pyridylethylation reaction, which is an analog of cyanoethylation (by acrylonitrile of compounds with a motile hydrogen atom) [14, 15]. The pyridylethylation of amines may be performed either without catalyst or over a basic or acidic catalyst, depending on the nature of the amine [16-20]. In practice, the pyridylethylation of amines is most often performed by means of acidic catalysis, usually by hydrochloric or acetic acid [21].

Only one study [22] has been reported on the pyridylethylation of the optically active amine (S)-(−)-1-phenylethylamine by 2-vinylpyridine with HCl as a catalyst. These investigators obtained the product of monopyridylethylation, but they were not successful in synthesizing the bis-pyridylethylated derivative; they attributed this failure to steric hindrance to the addition of the second vinylpyridine molecule.

Here we are reporting results from an investigation of the interaction of 2- and 4-vinylpyridines (2-VP and 4-VP) with (R)- and (S)-1-phenylethylamines (I, II) and (R)- and (S)-1-cyclohexylethylamines (III, IV) in the presence of various acidic catalysts; we are also reporting on the pyridylethylation of the synthesized monoadducts with the aim of obtaining bis-adducts — the products of addition of two vinylpyridine molecules to the amine.

The optical purity of the original amines I-IV was monitored by measuring optical rotation; also, the optical purity of their derivatives — amides of trifluoroacetic acid — was determined by GLC in a column with a chiral stationary phase. Values of optical purity, which are listed in Table 1, were in the 92-98% range.

The reactions of the vinylpyridines with amines were performed under argon in a methanol solution in the presence of an acid catalyst at 70°C (bath temperature), with periodic sampling for analysis by GLC and GLC—MS.

The following acids were investigated as catalysts (the numbers in parentheses denote pK_a in water at 25°C [23]): hydrochloric (−7), trifluoroacetic (0.23), chloroacetic (2.86), malonic (2.86 — I), succinic (4.21 — I), and acetic (4.75), and also polyacrylic acid (4-6) and H^+-cation exchange resins, both the weakly acidic Amberlite CG-50 I and IRC-50 (—COOH, 6.1) and the strongly acidic Amberlyst 15 and Wofatit OK (—SO_3H, 1-2). In the presence of strong carboxylic acids, we observed formation of the corresponding amides as byproducts. The ion-exchange resins and the polymer catalyze the reaction

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TABLE 1. Analytical Characteristics of Original Amines

Amine	$[\alpha]_D^{24°C}$ (c = 1, $CHCl_3$)	ee, % (GLC)
(R)-(+)-1-Phenylethylamine (I)	+33	96
(S)-(−)-1-Phenylethylamine (II)	−33	94
(R)-(−)-1-Cyclohexylethylamine (III)	−1,3	92
(S)-(+)-1-Cyclohexylethylamine (IV)	+1,4	98

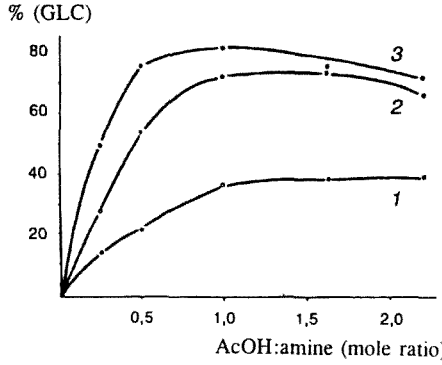
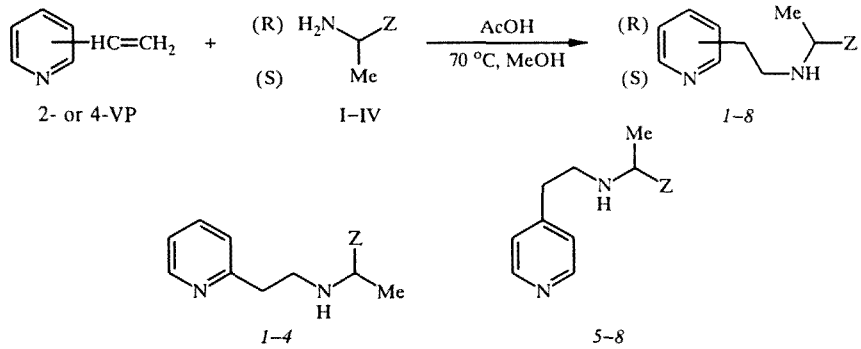


Fig. 1. Influence of quantity of catalyst (acetic acid) on yield of adduct *1*, depending on duration of reaction of 2-vinylpyridine with (R)-1-phenylethylamine: 1) 4.5 h; 2) 13 h; 3) 21 h. Mole ratio of 2-VP to amine I = 1.2:1; solvent methanol; $[\text{amine I}]_0$ = 1.5 M; 60°C.

only at a slow rate. We found that acetic acid was the optimal catalyst. When hydrochloric acid was used, the pyridylethylation was slower, particularly with the cyclohexyl derivative, and there was more of a problem with tar formation.

Our studies showed that in the reactions of 2- and 4-VP with the amines I-IV, the corresponding adducts *1-8* are formed (Scheme 1).

Scheme 1



Product	Configuration	Z	Product	Configuration	Z
1	*R*	C_6H_5	*5*	*R*	C_6H_5
2	*S*	C_6H_5	*6*	*S*	C_6H_5
3	*R*	C_6H_{11}	*7*	*R*	C_6H_{11}
4	*S*	C_6H_{11}	*8*	*S*	C_6H_{11}

In the example of the reaction of 2-VP with the amine I, we investigated the influence of catalyst quantity on the yield of product *1*, in relation to the duration of the process (Fig. 1). The maximum yield of compound *1* was observed with equimolar quantities of the amine and acetic acid.

TABLE 2. Characteristics of Reactions of 2- and 4-Vinylpyridines with Amines I-IV, and Analytical Data for Products of Monoaddition

Reaction product	Yield, %* (and purity, % GLC)	Reaction time, h	bp, °C/mm Hg	$[\alpha]_D^{24°C}$ (c = 1, $CHCl_3$)	ee, % (HPLC)
1	60...62	8	$105/6 \cdot 10^{-2}$	+46	97
2	(98...99)			-48	93
3	58...63	15	$97/7 \cdot 10^{-2}$	-10	94
4	(97...99)			+9	99
5	60...63	6	$122/1 \cdot 10^{-1}$	+48	97
6	(97...98)			-46	93
7	*43...57*	10	$115/2 \cdot 10^{-1}$	-9	93
8	*(94...98)*			+10	97

*Preparative yield. Reaction conditions: VP:amine:AcOH mole ratio 1.2:1:1, solvent methanol, $[amine]_0$ = 1.5 M, 70°C.

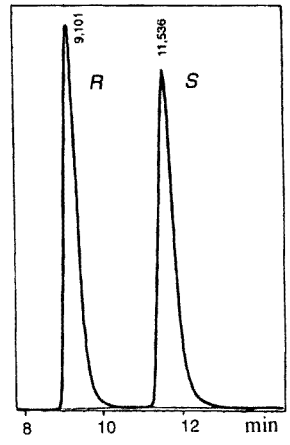


Fig. 2. Separation of mixture of enantiomers — adducts 5 and 6 — by HPLC. Column with Chiralcel OD-H 250×4.6 mm; eluent n-hexane:2-propanol (98:2) + 0.02% diethylamine, 2 ml/min; DAD detector, λ = 240 nm).

Following Scheme 1, after optimizing the reaction conditions, we obtained the adducts I-VIII when using a reactant ratio VP:amine:AcOH = 1.2:1:1, heating time 6-15 h (the process was continued up to 92-97% conversion of the original amine). The preparative yields of the products (isolated by vacuum distillation) were 43-63%, with 94-99% purity as determined by GLC (Table 2). The values found for the optical rotation of all of the adducts were higher than for the corresponding original amines (see Table 1). The optical purity of the adducts *1-8* was determined by HPLC in a column with the optically active phase Chiralcel OD-H (accuracy of determination ±1%). In Fig. 2 we show as an example the separation of a mixture of adducts *5* and *6*. The data obtained on the optical activity of the adducts *1-8* (Table 2) demonstrate the absence of any racemization during the course of monopyridylethylation.

Our studies showed that the reactivity of 1-phenylethylamine is higher than that of 1-cyclohexylethylamine, and the reaction of the 4-VP with the amines I-IV is faster than that of the 2-VP (Table 2). It is known that the 4-VP (pK_b 8.38) is a stronger base than 2-VP (pK_b 9.08) [24]. No information can be found in the literature regarding the basicity of the amines I-IV; it is clear, however, that these amines are considerably stronger bases than vinylpyridines and that the cyclohexyl derivatives are more basic than the corresponding phenyl derivatives.

From a comparison of all of these data, we can postulate the following mechanistic scheme for these reactions. In the first stage, under the influence of the acid catalyst, the strong bases (amines I-IV) are protonated; the resulting electron-acceptor quaternary ammonium ions are oriented toward the strongest electron-donor atom of the vinylpyridines, i.e., the ring nitrogen atom, forming an intermediate complex and thus increasing the polarization of the vinyl group and facilitating subsequent

TABLE 3. Characteristics of Product Yields in Reactions of Adducts *1-8* with 2- and 4-Vinylpyridines, and Analytical Data for the Bis-Adducts

Reaction product	Yield, %* GLC (Purity, % GLC) Prep.	Reaction time, h	Reaction temperature, °C	Add.:VP: AcOH, mole ratio	$[\alpha]_D^{24°C}$ (c = 1, $CHCl_3$)	ee, % (HPLC)
9	72...78 66...71	24	100	1 : 3...6 : 0,8	-42	95
10	(94...96)				+41	92
11	64...68 60...62	36	100	1 : 3 : 0,8	-114	*3
12	(94...96)				+112	*3
13	51...56 35...40	21	100	1 : 3 : 0,8	-32	95
14	(93...95)				+32	91
15	49...54 45...48	31	70	1 : 2,2 : 1	-82	92
16	(97...98)				+83	97
17[2]	28 22 (95)	24	70	1 : 2,2 : 1	+87	*4

*Reaction conditions: Solvent methanol; $[adduct]_0$ = 1.5 M.

*[2]Product *17* was obtained from the adduct *4* and 4-vinylpyridine.

*[3]We were not able to separate the bis-adducts *11* and *12* by HPLC.

*[4]Optical purity of bis-adduct *17* was not determined.

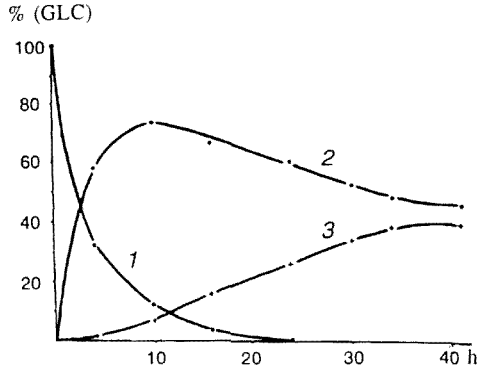
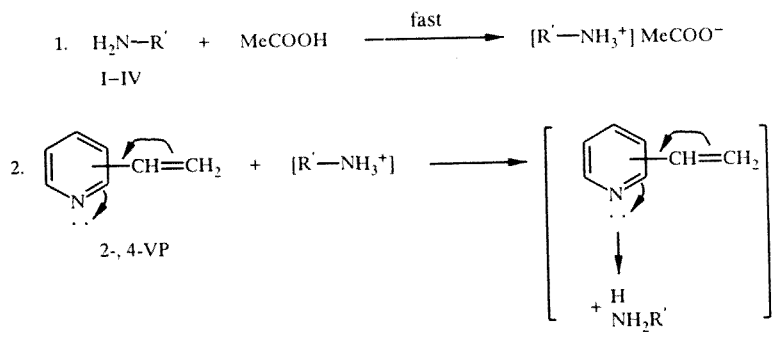


Fig. 3. Characteristics of reaction of (R)-1-cyclohexylethylamine with excess 4-vinylpyridine. (Mole ratio 4-VP:amine III:AcOH = 2.2:1:1; solvent methanol; $[amine\ III]_0$ = 1.5 M, 70°C; 1) fraction of unconverted amine III; 2,3) yields of adduct *7* and bis-adduct *15*.)

addition of the amine (Scheme 2). The reactions are favored by high basicity of the VP and by the pronounced proton-donor properties of the ammonium ions that are formed (i.e., lower basicity of the original amine).

Scheme 2



Such a mechanism explains the fact that the reaction (Scheme 1) does not take place with 3-vinylpyridine, a compound in which there is no conjugation of the vinyl group with the heteroatom. The proposed Scheme 2 is also consistent with the

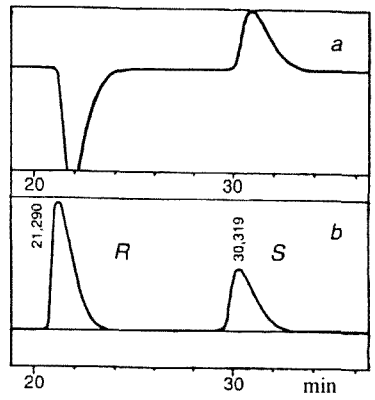
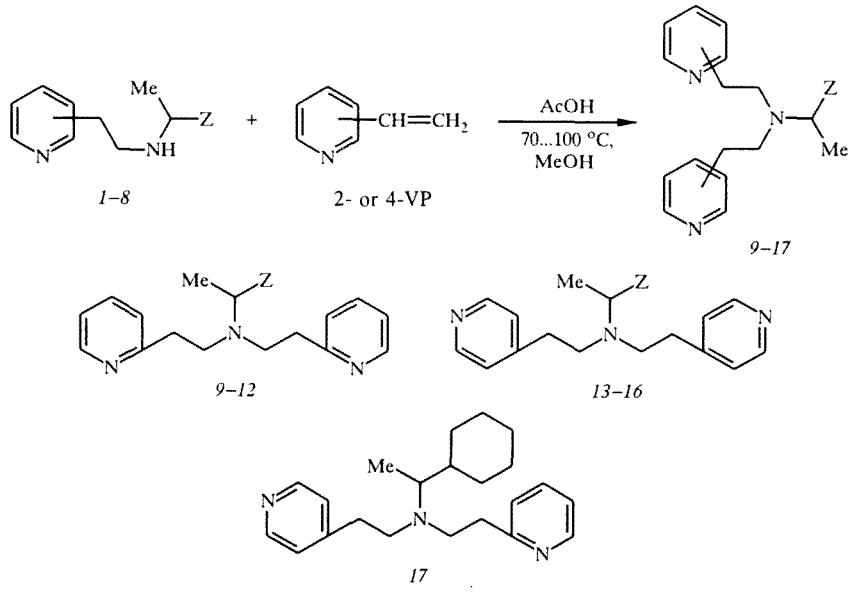


Fig. 4. Separation of mixture of enantiomers — bis-adducts *11* and *12* — by HPLC. Column with Chiralcel OD-H 250 × 4.6 mm; eluent n-hexane:2-propanol (95:5) + 0.02% diethylamine, 1 ml/min; a) Chiralyser polarimetric detector; b) diode detector DAD, λ = 220 nm:)

fact that acetic acid is a better catalyst than hydrochloric acid. This can possibly be explained by competition of the HCl with the ammonium ions for a place on the N atom of the pyridine ring. There is no agreement in the literature regarding the mechanism of pyridylethylation of amines in the presence of acid catalysts; however, the proposed Scheme 2 is in accord with [21, 25].

When the processes represented by Scheme 1 were carried out in the presence of excess vinylpyridine in the reaction mixture, we detected products of bis-addition to the amines, particularly in the case of the cyclohexyl derivatives. In Fig. 3 we present results from our investigation of the interaction of the amine III with excess 4-VP. The character of the time dependences of the product yields from monoaddition and bis-addition demonstrates that these products are formed sequentially. With phenylethylamines under the same conditions, only insignificant quantities of the bis-adducts were formed.

Scheme 3



Product	Configuration	Z	Product	Configuration	Z
9	*R*	C_6H_5	*13*	*R*	C_6H_5
10	*S*	C_6H_5	*14*	*S*	C_6H_5
11	*R*	C_6H_{11}	*15*	*R*	C_6H_{11}
12	*S*	C_6H_{11}	*16*	*S*	C_6H_{11}
			17	*S*	C_6H_{11}

With the aim of obtaining products of the addition of two molecules of vinylpyridine to the amines I-IV, we investigated the interaction of the isolated adducts *1-8* with excess 2- and 4-VP (Scheme 3). A similar approach was used in [17] in carrying out the reaction of 2-VP with n-butylamine. And in fact, we have used this method successfully in synthesizing the bis-adducts *9-17* (Table 3). By means of HPLC in a column with a chiral phase, using a polarimetric detector, we were able to separate the (R)- and (S)-isomers (an example is shown in Fig. 4). The data we obtained on the optical purity of the bis-adducts (Table 3) provide evidence that there was no significant racemization in the course of their synthesis from the adducts *1-8*.

The mechanism through which the products of bis-addition are formed from the monoadducts is evidently analogous to Scheme 2 when using acetic acid as a catalyst. However, the protonated aminopyridines, being weaker proton donors than the protonated original amines, probably cannot compete with hydrochloric acid for a place on the ring nitrogen atom of the second vinylpyridine molecule being added when hydrochloric acid is used as the catalyst, as was done in [22]; this apparently explains why those investigators did not detect any bis-adducts in the products.

EXPERIMENTAL

PMR spectra were registered on a Bruker AC 250 instrument (250 MHz), solvent $CDCl_3$, internal standard $CHCl_3$ impurity. The GLC-MS spectra were obtained by means of an HP 5890 (II) chromatograph on an HP 101 capillary column (methyl silicone fluid, 25 m × 0.2 mm), vaporizer temperature 200°C, connected to an HP Engine 5989 A mass spectrometer (70 eV). FT-IR spectra were taken in a Nicolet Magna 550 instrument (400-4000 cm^{-1}), using specimens in the form of films. The GLC analysis was performed in an HP 5880 A chromatograph with a flame ionization detector, in a capillary column, SE-54 phase (25 m × 0.2 mm), carrier gas argon (1 ml/min), temperature programmed from 80° to 250°C at 8°C/min. The separation of the trifluoroacetamide derivatives of the original amines I-IV was performed in an HP 5890 (II) gas—liquid chromatograph with a Macherey-Nagel capillary column containing a Lipodex C phase, at 120°C. The optical purities of the adducts that were obtained were determined by HPLC in an HP 1090 (LC) chromatograph with a DAD diode detector and a Chiralyzer polarimetric detector (IBZ Messtechnik); column with Chiralcel OD phase (250 × 4.6 mm), eluent n-hexane:2-propanol + 0.02% diethylamine (1-2 ml/min). The optical rotation values were determined in a Gyromat-HP instrument (Automatisches Prazisions-Digitalpolarimeter).

In this work we used 2- and 4-vinylpyridines, (R)-(+) and (S)-(−)-1-phenylethylamines, and (R)-(−)- and (S)-(+)-1-cyclohexylethylamines, Merck products. The chemical experiments were performed in an argon atmosphere, in glass apparatus.

General Procedure for Obtaining Adducts *1-8*. A mixture of 10 ml of methanol, 1.6 ml (15 mmoles) of 2- or 4-vinylpyridine, 12.5 mmoles of the amine (1.6 ml of 1-phenylethylamine or 1.8 ml of 1-cyclohexylethylamine), and 0.72 ml (12.5 mmoles) of acetic acid was heated at 70°C (bath temperature) with a reflux condenser, for a period of 6-15 h (Table 1). After taking off the methanol in a vacuum rotary evaporator, the reaction mixture was neutralized with an aqueous Na_2CO_3 solution and extracted with toluene. The extract was dried over $MgSO_4$ and then filtered. After concentrating the filtrate, the product was obtained by vacuum distillation.

General Procedure for Obtaining Bis-Adducts *9-17*. A mixture of 1 g of the adduct 1-8, 3-5 ml of methanol, 2-5 ml of 2- or 4-vinylpyridine, and 0.2-0.3 ml of AcOH was stirred while heating at 70-100°C (bath temperature) with a reflux condenser, for 21-36 h (Table 2). The resulting reaction mixture, after driving off the methanol, was neutralized with aqueous Na_2CO_3 solution and extracted with ether. The extract was dried over $MgSO_4$, filtered, and concentrated (40°C/100 mm Hg). From the residue, in a preparative column, the bis-adducts were segregated. Column: 50 g Kieselgel 60, grain size 0.015-0.040 mm (Merck); eluent chloroform:methanol, 8:2. Finally, the products were purified by distillation at 200°C/0.2 mm Hg in a spherical rotary distiller (Buchi GKR-51, Schweiz).

Analytical Characteristics of Synthesized Compounds

(R)- and (S)-2-[2-(1-phenylethylamino)ethyl]pyridines (*1*) and (*2*). PMR spectrum, δ, ppm: 1.31 (d, J = 6.6 Hz, 3H, CH_3), 1.76 (s, 1H, NH), 3.78 (q, J = 6.6 Hz, 1H, CH), 2.77-2.96 (m, 4H, CH_2), 7.15-7.31 (m, 5H, Ph), pyridine-H: 7.03-7.11 (m, 2H), 7.53 (m, 1H), 8.49 (m, 1H). GLC-MS, m/z (I_{rel}, %): 227 (1) [M^+ + H], 226 (1) [M^+], 211 (5) [M^+ − CH_3], 149 (1) [M^+ − Ph], 121 (100) [$pyCH_2CH_2NH^+$], 106 (33), 105 (56), 93 (38), 79 (18), 78 (15), 77 (20). IR

spectrum, ν, cm^{-1}: 702 (vs), 762 (vs), 994 (m), 1131 (m), 1148 (m), 1368 (m), 1435 (s), 1451 (m), 1474 (s), 1492 (m), 1568 (s), 1591 (s), 2837 (m), 2872 (m), 2925 (m), 2961 (s), 3024 (m), 3061 (m), 3082 (w), 3307 (m). Elemental analysis. Found, %: C 79.44; H 8.10; N 12.27. $C_{15}H_{18}N_2$ (226.32). Calculated, %: C 79.61; H 8.02; N 12.38.

(R)- and (S)-2-[2-(1-cyclohexylethylamino)ethyl]pyridines (*3*) and (*4*). PMR spectrum, δ, ppm: 0.92 (d, J = 6.5 Hz, 3H, CH_3), 2.40 (m, 1H, CH), 2.82-3.02 (m, 4H, CH_2), 0.80-1.72 (m, 12H, C_6H_{11} + NH), pyridine-H: 7.01-7.13 (m, 2H), 7.52 (m, 1H), 8.46 (m, 1H). GLC-MS, m/z (I_{rel}, %): 233 (1) [M^+ + H], 217 (1) [M^+ — CH_3], 149 (100) [M^+ — C_6H_{11}], 106 (55) [$pyCH_2CH_2^+$], 93 (10). IR spectrum, ν, cm^{-1}: 727 (m), 788 (s), 993 (m), 1119 (m), 1148 (m), 1372 (m), 1435 (s), 1449 (s), 1474 (s), 1492 (m), 1569 (s), 1591 (s), 2851 (vs), 2923 (vs), 3008 (m), 3065 (m), 3081 (w), 3313 (m). Elemental analysis. Found, %: C 77.11; H 9.98; N 12.26. $C_{15}H_{24}N_2$ (232.37). Calculated, %: C 77.53; H 10.41; N 12.05.

(R)- and (S)-4-[2-(1-phenylethylamino)ethyl]pyridines (*5*) and (*6*). PMR spectrum, δ, ppm: 1.30 (d, J = 6.6 Hz, 3H, CH_3), 1.48 (s, 1H, NH), 3.74 (q, J = 6.6 Hz, 1H, CH), 2.67-2.75 (m, 4H, CH_2), 7.17-7.31 (m, 5H, Ph), pyridine-H: 7.04 (m, 2H), 7.53 (m, 2H). GLC-MS, m/z (I_{rel}, %): 227 (2) [M^+ + H], 226 (1) [M^+], 211 (26) [M^+ — CH_3], 149 (2) [M^+ — Ph], 106 (26) [$pyCH_3CH_2^+$], 105 (100) [$Ph(CH_3)CH^+$], 93 (83), 79 (18), 77 (22). IR spectrum, ν, cm^{-1}: 702 (vs), 763 (s), 807 (m), 993 (m), 1130 (m), 1219 (w), 1368 (w), 1415 (m), 1451 (m), 1465 (w), 1493 (m), 1558 (m), 1602 (vs), 2822 (m), 2861 (w), 2926 (m), 2962 (s), 3025 (m), 3065 (m), 3287 (m). Elemental analysis. Found, %: C 79.54; H 7.76; N 12.51. $C_{15}H_{18}N_2$ (226.32). Calculated, %: C 79.61; H 8.02; N 12.38.

(R)- and (S)-4-[2-(1-cyclohexylethylamino)ethyl]pyridines (*7*) and (*8*). PMR spectrum, δ, ppm: 0.90 (dd, J_1 = 6.4 Hz, J_2 = 0.8 Hz, 3H, CH_3), 2.38 (m, 1H, CH), 2.66-2.92 (m, 4H, CH_2), 0.80-1.72 (m, 12H, C_6H_{11} + NH), pyridine-H: 7.08 (m, 2H), 8.43 (m, 2H). GLC-MS, m/z (I_{rel}, %): 233 (1) [M^+ + H], 217 (1) [M^+ — CH_3], 149 (100) [M^+ — C_6H_{11}], 106 (21) [$pyCH_2CH_2^+$]. IR spectrum, ν, cm^{-1}: 730 (m), 806 (m), 993 (m), 1119 (m), 1219 (w), 1372 (w), 1415 (m), 1449 (s), 1558 (m), 1602 (vs), 2851 (vs), 2924 (vs), 3025 (w), 3075 (w), 3280 (m). Elemental analysis. Found, %: C 77.38; H 9.93; N 12.01. $C_{15}H_{24}N_2$ (232.37). Calculated, %: C 77.53; H 10.41; N 12.05.

(R)- and (S)-N,N-bis[2-(2-ethyl)pyridyl]-1-phenylethylamines (*9*) and (*10*). PMR spectrum, δ, ppm: 1.31 (d, J = 6.8 Hz, 3H, CH_3), 3.92 (q, J = 6.8 Hz, 1H, CH), 2.82-3.01 (m, 8H, CH_2), 7.10-7.28 (m, 5H, Ph), pyridine H: 6.95-7.08 (m, 4H), 7.48 (m, 2H), 8.45 (m, 2H). GLC-MS, m/z (I_{rel}, %): 332 (1) [M^+ + H], 331 (2) [M], 316 (2) [M^+ — CH_3], 239 (22) [M^+ — $pyCH_2$], 226 (69) [M^+ — $pyCH_2CH$], 225 (31) [M^+ — $pyCH_2CH_2$], 135 (79), 106 (88), 105 (100) [$Ph(CH_3)CH^+$], 94 (19), 79 (33), 78 (26), 77 (22). IR spectrum, ν, cm^{-1}: 508 (m), 546 (m), 702 (vs), 760 (vs), 993 (m), 1051 (m), 1122 (m), 1148 (m), 1434 (vs), 1452 (w), 1474 (vs), 1492 (m), 1568 (s), 1591 (vs), 2818 (m), 2932 (m), 2969 (s), 3007 (w), 3061 (w). Elemental analysis. Found, %: C 79.71; H 7.52; N 12.65. $C_{22}H_{25}N_3$ (331.46). Calculated, %: C 79.72; H 7.60; N 12.68.

(R)- and (S)-N,N-bis[2-(2-ethyl)pyridyl]-1-cyclohexylethylamines (*11*) and (*12*). PMR spectrum, δ, ppm: 0.5 (d, J = 6.6 Hz, 3H, CH_3), 2.32 (m, 1H, CH), 2.63-3.00 (m, 8H, CH_2), 0.47-1.62 (m, 11H, C_6H_{11}), pyridine-H, 7.02 (m, 4H), 7.48 (m, 2H), 8.47 (m, 2H). GLC-MS, m/z (I_{rel}, %): 337 (1) [M^+], 254 (97) [M^+ — C_6H_{11}], 245 (38) [M^+ — $pyCH_2$], 149 (50), 135 (31), 106 (100) [$pyCH_2CH_2^+$], 94 (15), 79 (18), 78 (19). IR spectrum, ν, cm^{-1}: 749 (vs), 885 (m), 993 (m), 1051 (m), 1089 (w), 1109 (m), 1141 (m), 1435 (s), 1447 (w), 1474 (s), 1568 (s), 1591 (s), 2850 (s), 2921 (vs), 2961 (w), 3007 (w), 3065 (w). Elemental analysis. Found, %: C 78.85; H 9.08; N 12.52. $C_{22}H_{31}N_3$ (337.51). Calculated, %: C 78.29; H 9.26; N 12.45.

(R)- and (S)-N,N-bis[4-(2-ethyl)pyridyl]-1-phenylethylamines (*13*) and (*14*). PMR spectrum, δ, ppm: 1.30 (d, J = 6.7 Hz, 3H, CH_3), 3.89 (q, J = 6.7 Hz, 1H, CH), 2.59-2.80 (m, 8H, CH_2), 7.20 (m, 5H, Ph), pyridine-H: 6.93 (m, 4H), 8.42 (m, 4H). GLC-MS, m/z (I_{rel}, %): 332 (1) [M^+ + H], 316 (2) [M^+ — CH_3], 254 (1) [M^+ — Ph], 239 (64) [M^+ — $pyCH_2$], 135 (68), 106 (32) [$pyCH_2CH_2^+$], 105 (100) [$Ph(CH_3)CH^+$], 79 (20), 78 (10), 77 (17). IR spectrum, ν, cm^{-1}: 525 (m), 548 (m), 703 (s), 771 (m), 808 (s), 993 (s), 1029 (m), 1070 (m), 1082 (m), 1122 (m), 1219 (m), 1371 (m), 1415 (s), 1452 (m), 1493 (m), 1558 (m), 1601 (vs), 2821 (m), 2935 (m), 2968 (s), 3025 (m), 3066 (m). Elemental analysis. Found, %: C 79.77; H 7.61; N 12.64. $C_{22}H_{25}N_3$ (331.46). Calculated, %: C 79.72; H 7.60; N 12.68.

(R)- and (S)-N,N-bis[4-(2-ethyl)pyridyl]-1-cyclohexylethylamines (*15*) and (*16*). PMR spectrum, δ, ppm: 0.85 (d, J = 6.6 Hz, 3H, CH_3), 2.65 (m, 1H, CH), 2.47-2.62 (m, 8H, CH_2), 0.55-1.79 (m, 11H, C_6H_{11}), pyridine-H: 7.21 (m, 4H), 8.44 (m, 4H). GLC-MS, m/z (I_{rel}, %): 337 (1) [M^+], 332 (2) [M^+ — CH_3], 254 (100) [M^+ — C_6H_{11}], 245 (27) [M^+ — $pyCH_2$], 149 (6), 135 (23), 106 (28) [$pyCH_2CH_2^+$]. IR spectrum, ν, cm^{-1}: 555 (m), 732 (m), 807 (s), 993 (m), 1029 (w), 1068 (w), 1114 (w), 1140 (w), 1218 (w), 1384 (w), 1415 (m), 1448 (m), 1558 (m), 1601 (vs), 2851 (s), 2922 (vs), 3024 (w), 3068 (w). Elemental analysis. Found, %: C 78.36; H 9.36; N 12.34. $C_{22}H_{31}N_3$ (337.51). Calculated, %: C 78.29; H 9.26; N 12.45.

(S)-N-[2-(2-Ethyl)pyridyl],N-[4-(2-ethyl)pyridyl]-1-cyclohexylethylamine (*17*). PMR spectrum, δ, ppm: 0.81 (d, J = 6.6 Hz, 3H, CH_3), 2.26 (m, 1H, CH), 2.49-2.91 (m, 8H, CH_2), 0.46-1.67 (m, 11H, C_6H_{11}), pyridine-H: 6.95-7.19 (m, 4H), 7.49 (m, 1H), 8.36-8.48 (m, 3H). GLC-MS, m/z (I_{rel}, %): 338(1) [M^+ + H], 337 (2) [M^+], 254 (52) [$M^+ - C_6H_{11}$], 245 (41) [$M^+ - pyCH_2$], 149 (81), 135 (34), 106 (100) [$pyCH_2CH_2^+$], 94 (15), 78 (16). IR spectrum, ν, cm^{-1}: 555 (m), 751 (s), 807 (s), 993 (m), 1114 (m), 1140 (m), 1215 (m), 1257 (m), 1383 (m), 1414 (s), 1436 (s), 1448 (s), 1474 (s), 1568 (m), 1599 (vs), 2851 (s), 2922 (vs). Elemental analysis. Found, %: C 77.92; H 9.51; N 12.44. $C_{22}H_{31}N_3$ (337.51). Calculated, %: C 78.29; H 9.26; N 12.45.

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