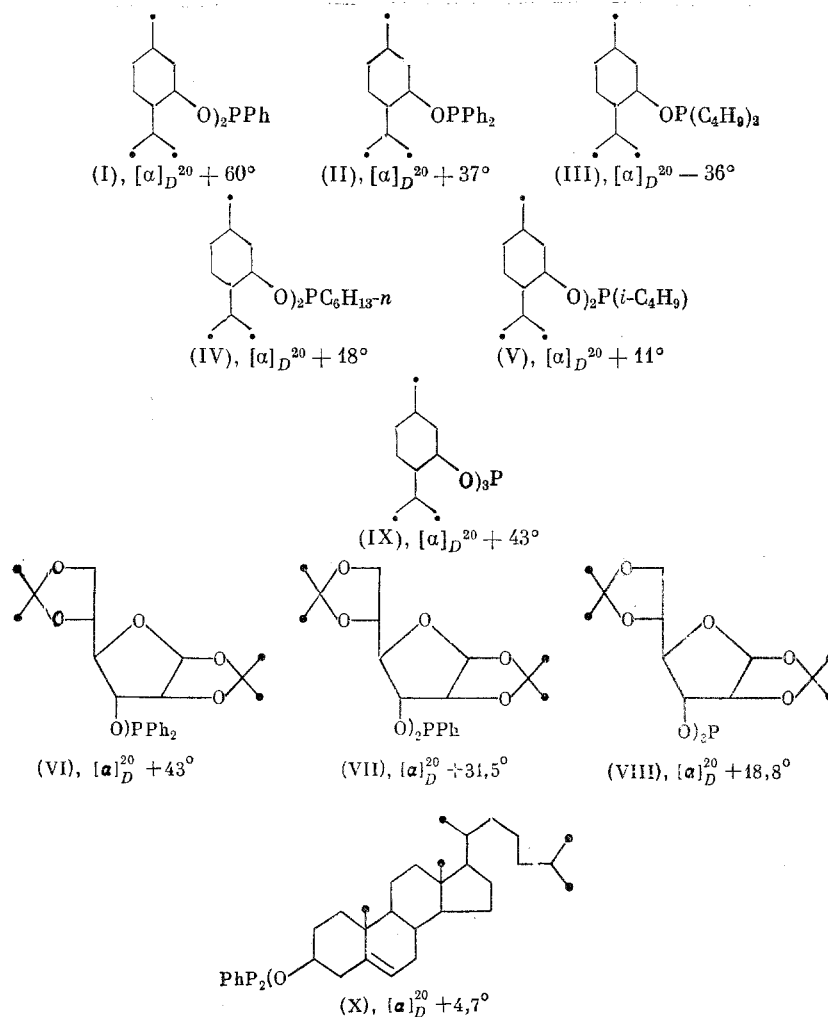


ASYMMETRIC AMINATION OF BUTADIENE BY SECONDARY AMINES, CATALYZED BY
LOW-VALENCE NICKEL CHIRAL COMPLEXES

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As a continuation of studying asymmetric induction in the amination reactions of conjugated dienes [1] we studied the reaction of butadiene with various secondary amines in the presence of homogeneous metal complex catalysts based on Ni compounds, activated by chiral phosphites and electron-acceptor additives. On the sample of aminating butadiene with pyrrolidine, piperidine, hexamethylenimine, morpholine, diethylamine, and dipropylamine using catalysts of type $\text{Ni}(\text{acac})_2 - \text{L}^* - \text{AlR}_3$ we studied the effect of the nature of the chiral ligand-activators, the structure of the amines, and the reaction conditions on the direction of amination and degree of asymmetric synthesis in these reactions. As the optically active ligand-activators we selected phosphites (I)-(X), which were obtained from halo-phosphines (PCl_3 , Bu_2PCl , Ph_2PCl , $i\text{-BuPCl}_2$, $n\text{-C}_6\text{H}_{13}\text{PCl}_2$ and PhPCl_2) and natural-occurring alcohols (L = menthol, D = 1,2;5,6-diisopropylidene-glucose, and L = cholesterol).

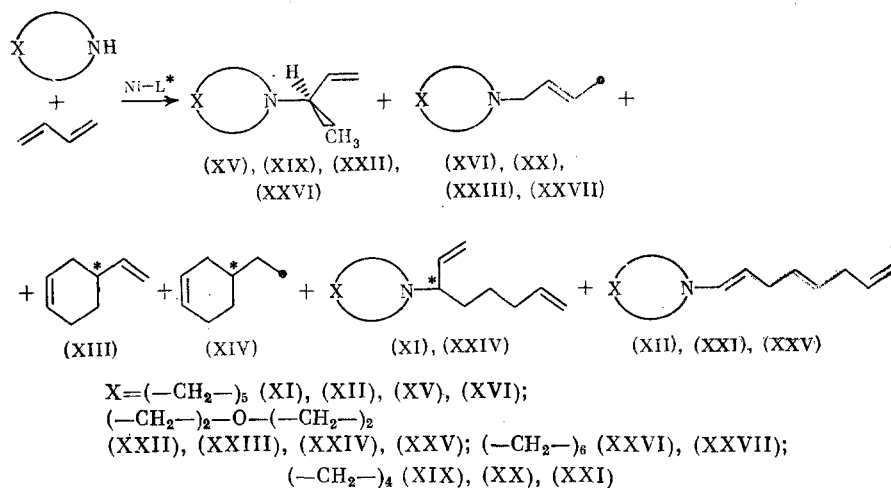


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The amination of butadiene with piperidine (-8°C , 30 days) in the presence of the catalytic system $\text{Ni}(\text{acac})_2 - (\text{I}) - \text{Et}_3\text{Al}$ (1:3:4) in anhydrous benzene gives a mixture of unsaturated amines and butadiene cyclodimers, composed of 3-piperidyl-1,7-octadiene (XI) (12%), 1-piperidyl-2,7-octadiene (XII) (71%), and 4-ethylcyclohexene (XIII) (17%). The overall yield of (XI)-(XIII) was $\sim 38\%$. Compounds (XI) and (XIII), isolated by fractional distillation through a Widmer column, had specific angles of rotation of -10.4 and $+10.4^{\circ}$, respectively. When the optically active ligand (I) in the catalytic complex was replaced by phosphite (II) the overall yield of amines (XI) (15%) and (XII) (85%) rises to 52%, but here the specific angle of rotation decreases noticeably (XI, $[\alpha]_D^{20} -3.6^{\circ}$). The butadiene cyclodimers are not formed in these experiments. The use of phosphite (III) as chiral component of the catalytic system not only permits realizing a marked increase in the overall yield of amines (XI) and (XIII) ($\sim 96\%$), but also in obtaining the (+)-enantiomer of (XI), which has a specific angle of rotation of $+5.3^{\circ}$. The amount of amines (XI) and (XII) in the reaction mixture is 18 and 82%.

The direction of aminating butadiene with piperidine changes noticeably when phosphites (IV)-(VI) are used, which, besides (XI) and (XII), also facilitate the formation of butenyl derivatives (XV) and (XVI). In particular, the reaction of butadiene with piperidine (2:1) in the presence of the catalytic system $\text{Ni}(\text{acac})_2 - (\text{V}) - \text{Et}_3\text{Al}$ (-8° , 30 days) leads to 3-piperidyl-1-butene (XV), 1-piperidyl-2-butene (XVI), and cyclodimers (XIII) and (XIV), in an overall yield of 21%. The amount of oligomers of the optically active amine (XV), $[\alpha]_D^{20} -0.41^{\circ}$, (P $\sim 52\%$)[†] in the mixture, is at least 49%. When ligand-activator (VI) was added to the catalyst the isolated (XV) had $[\alpha]_D^{20} +0.63^{\circ}$ (P $\sim 78\%$). In the experiments with (VII) a substantial portion of the piperidine and butadiene is converted to (XII) (85%), while the amounts of (XV), $[\alpha]_D^{20} +0.21^{\circ}$ (P 26%), and (XVI) are respectively 13 and 2%. It should be mentioned that phosphites (VIII), (IX), and (X) completely block the amination process. Apparently, the bulky molecules of the indicated phosphites prevent the approach and activation of the starting monomers to the central atom of the catalyst. The obtained results permitted the conclusion that phosphites (I), (II), and (III) direct the amination process toward the formation of the piperidine octadienyl derivatives (XI)-(XII), while phosphites (IV), (V), (VI), and (VII) facilitate the formation of butenyl derivatives (XV)-(XVI).

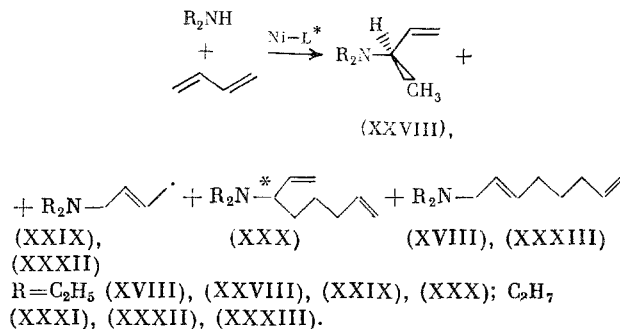
In order to increase the overall yield of the optically active amines (XI) and (XV), we added tributylphosphine to the catalytic system $\text{Ni}(\text{acac})_2 - \text{L}^* - \text{Et}_3\text{Al}$, which, according to [2], raises the activity of the indicated catalysts substantially in the amination of conjugated dienes. On the model reaction of aminating butadiene with piperidine we studied the effect of the (L*): PBu_3 ratio on the degree of asymmetric synthesis. As it proved, the yield of amines (XI) and (XII) increases with increase in the amount of Bu_3P in the $\text{Ni}(\text{acac})_2 - (\text{L}^*) - \text{Bu}_3\text{P} - \text{Et}_3\text{Al}$ catalyst, but the degree of asymmetric synthesis decreases (Table 1). Evidently, the enantioselectivity of the amination catalyst decreases with decrease in the amount of the chiral component (L*) in the catalytically active nickel complex.



[†]P = optical purity.

TABLE 1. Effect of L*:PBu₃ Ratio on Degree of Asymmetric Synthesis in Amination of Butadiene with Piperidine

L* : Bu ₃ P mole ratio	Overall yield of amines, %	Compositions of amination products, %				
		(XI)	$[\alpha]_D^{20}$	(XII)	(XIV)	$[\alpha]_D^{20}$
2 : 1	82	24	-0,12	56	20	+88
1 : 2	85	37	-0,09	59	4	+73
1 : 3	98	43	-	57	-	-



Next we studied the amination of butadiene with diethylamine, pyrrolidine, hexamethylenimine, and morpholine in the presence of the catalytic system Ni(acac)₂ - (V) - AlEt₃ (-8°, 30 days), which made it possible to obtain predominantly 3-piperidyl-1-butene (XV). Diethylamine gives with a high selectivity 1-diethylamino-2,7-octadiene (XVIII) (yield $\leq 9\%$). Branched amines are not formed here. From pyrrolidine under analogous conditions we obtained 3-pyrrolidyl-1-butene (XIX) (8%), 1-pyrrolidyl-2-butene (XX) (3%), and 1-pyrrolidyl-2,7-octadiene (XXI) (89%) in an overall yield of ~70%. The specific angle of rotation of (XIX) is equal to -0.1°. The reaction with morpholine proceeds quite easily and leads to a mixture of unsaturated amines (XXII)-(XXV), in which the amount of (XXII), $[\alpha]_D^{20} +1.8^\circ$ (P 58%) and (XXIV), $[\alpha]_D^{20} -2.74^\circ$ (P 37.4%) is equal to 8 and 30%, respectively. In contrast to the mentioned amines, hexamethylenimine reacts with butadiene only at 20° to give only the butenyl derivatives (XXVI) (11%), $[\alpha]_D^{20} +2.12^\circ$ (P 77.5%) and (XXVII) (49%) in an overall yield of ~22%.

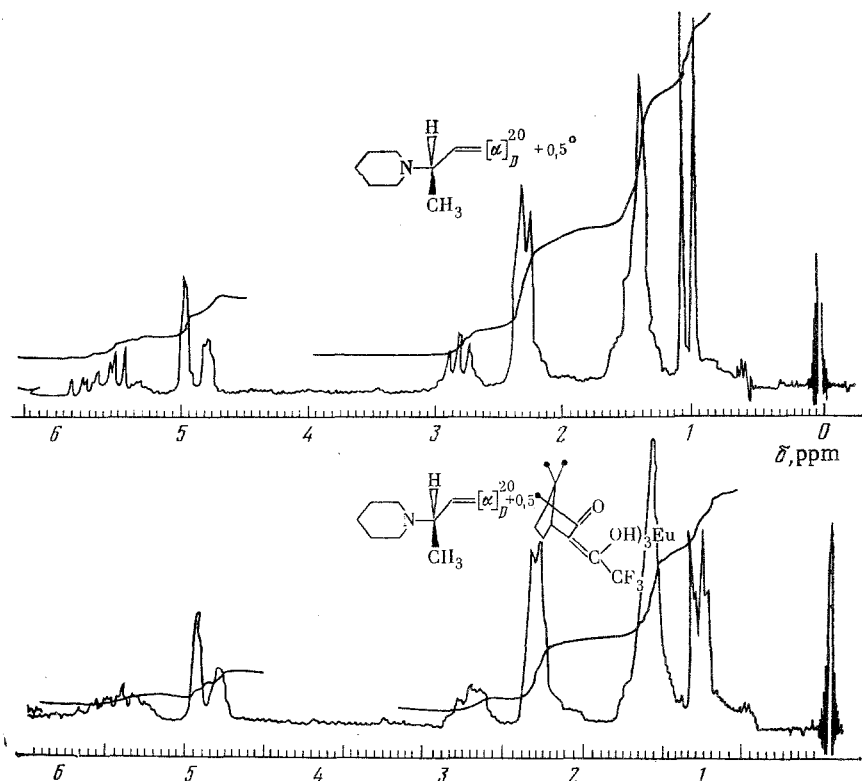


Fig. 1

TABLE 2. Effect of Optically Active Electron-Acceptor Additives and $\text{CF}_3\text{CO}_2\text{H}$ on Asymmetric Amination of Butadiene by Amines of Variable Structure (0.002 mole $\text{Ni}(\text{acac})_2$, 0.006 mole PBu_3 , 0.008 mole $\text{Al}(\text{C}_2\text{H}_5)_3$, 20 ml C_6H_6 , -8° , 720 h)

Amine	Additive	Total yield, %	Catalyze composition, %						
			$\text{Alk}_2\text{N}-\text{F}$	$[\alpha]_D^{20}$	P, %	$\text{Alk}_2\text{N}-\text{U}$	$[\alpha]_D^{20}$	$\text{Alk}_2\text{N}-\text{V}$	$[\alpha]_D^{20}$
Piperidine	L-Proline	92	36	+0.05	6.3	29	+0.59	4	31
»	L-Histidine	91	21	+0.03	3.8	26	+0.27	6	47
»	D-Tartaric acid	66	30.3	-0.1	1.2	29.4	-0.3	3.5	36.9
»	D-Campharic acid	90	27	-0.2	2.5	34	-0.32	-	39
»	L-Ascorbic acid	64	43	-0.36	4.5	16	-0.92	4	38
»	D-Trifluoroacetylcamphor	98	82	-0.36	4.5	-	-	18	-
»	Ditto	96	79	-0.48	17.7	-	-	21	-
Hexamethylenimine	»	98	84	-0.15	4.8	-	-	16	-
Morpholine	»	98	83	-0.27	-	4	-	8	5
Diethylamine	»	98	78	-0.42	-	-	-	12	10
Dipropylamine	$\text{CF}_3\text{CO}_2\text{H}$	29	45	-0.61	75.7	-	-	13	36
Piperidine	$\text{CF}_3\text{CO}_2\text{H}$	68	27	+0.25	31.6	-	-	73	-
Morpholine*	$\text{CF}_3\text{CO}_2\text{H}$	22	48	+1.8	58	-	-	30	22

*We used (IX) as the chiral ligand-activator. In the experiment with piperidine the catalyze contains (XIV), $[\alpha]_D^{20} +97.4^\circ$.

†We used (VIII) as the chiral ligand-activator.

TABLE 3. Optical Purity (P)* of Obtained Unsaturated Amines

Amine	[α] _D ²⁰		P, %
	experiment	calculated	
(XV)	+0,63	+0,79	78
(XV)	-0,61	-0,79	75,7
(XXII)	+1,8	+3,1	58
(XXII)	-0,15	-3,1	4,8
(XXVI)	+2,12	+2,7	77,5
(XXVI)	-0,48	-2,7	18
(XXIV)	-2,74	-7,35	37,4

$$* P = \frac{[\alpha]_{D}^{20}{}_{\text{expt}}}{[\alpha]_{D}^{20}{}_{\text{calc}}} \cdot 100\%$$

A substantial portion of the butadiene is converted to (XIV), whose specific angle of rotation is +42.3°.

The obtained results permit the conclusion that, independent of the structure of the starting secondary amines, when the latter are telomerized with butadiene the main products are unsaturated straight-chain amines, while the total amount of branched amines does not exceed 30%.

To increase the yield of the optically active branched unsaturated amines we added chiral electron-acceptor components to the achiral catalytic system Ni(acac)₂ - Bu₃P - AlEt₃, which noticeably increase the yield of butenyl derivatives when butadiene is aminated with secondary amines: D-campharic, L-ascorbic, and D-tartaric acids, L-proline, L-histidine, and D-trifluoroacetylcamphor. Based on the data of the preliminary experiments, among the tested electron-acceptor additives the greatest activating ability is shown by trifluoroacetylcamphor, which makes it possible to obtain the optically active unsaturated amines (XV), (XXV), (XXII), (XXVIII), and (XXXI) in high yields (Table 2).

Besides the optically active acids, we used CF₃CO₂H when butadiene was aminated by secondary amines on the catalyst Ni(acac)₂ - L* - (C₂H₅)₃Al, which, according to [2], substantially increases the activity of the catalytic system. In particular, when butadiene is reacted with piperidine or morpholine using Ni complexes, activated by phosphites (VIII) or (IX) and CF₃CO₂H, we obtained the corresponding optically active amines (XV) and (XXII). As can be seen from Table 3, the complex catalysts Ni(acac)₂ - L* - Et₃Al, activated by CF₃CO₂H, chiral acids or trifluoroacetylcamphor, can be successfully used to obtain optically active unsaturated amines in high yields.

The optical yields are given for amines (XV), (XXII), (XXIV), and (XXVI), whose yields are practically quite high in each experiment. The optical purity of the obtained unsaturated amines (XV), (XXII), (XXVI), (XXIV) were determined via PMR spectroscopy using Eu trifluoroacetylcamphorate as the shift reagent [3], which exerts a noticeable effect on the chemical shifts of the methyl protons in diastereomeric complexes. The ratio of the areas of the signals of the diastereomeric methyl protons corresponds to the ratio of the (+)- or (-)-enantiomeric unsaturated amines (Fig. 1).

As follows from Table 3, the three- and four-component Ni-containing metal complex catalysts proposed by us, activated by chiral electron-donor and electron-acceptor additives, have a high enantioselectivity when butadiene is aminated, reaching 75-78%.

EXPERIMENTAL

In the study we used butadiene, piperidine, hexamethylenimine, morpholine, pyrrolidine, diethylamine, dipropylamine, D-tartaric, D-campharic, and L-ascorbic acids, L-proline, and L-histidine that were ~99.8% pure. Trifluoroacetylcamphor and Eu₃-trifluoroacetylcamphorate were obtained as described in [4]. The chiral phosphites (I)-(X) were obtained as described in [5]. The PMR spectra were recorded on a Tesla BS-480B instrument (CCl₄, internal standard = HMDS), and the IR spectra were taken on a UR-20 spectrophotometer as a thin layer. The GLC analysis of the mixed oligomers was run on a Chrom-41 chromatograph, equipped with a flame-ionization detector and a 2.4 m × 3 mm column packed with 15% PM 1322/300 deposited on Chromosorb GAW-DMCS (60-80 mesh), and using helium as the carrier gas at a flow rate of 40

ml/min. A Perkin-Elmer-141 polarimeter was used to determine the specific angles of rotation. The mass spectra were taken on an MX-13-06 instrument. The energy of the ionizing electrons was 70 eV and the temperature of the ionization chamber was 200°.

General Method for Amination of Butadiene. To a solution of 0.002 mole of Ni(acac)₂, 0.006 mole of the appropriate phosphite, and 10 ml of butadiene in 20 ml of benzene, in an argon stream, at -5°, was added 0.008 mole of Al(C₂H₅)₃ and the mixture was stirred for 20 min. The catalyst solution was transferred in an argon stream to a 150-ml glass ampul, into which had previously been loaded 0.6 mole of butadiene, 0.3 mole of the amine, and, when necessary, 0.01 mole of the electron-acceptor additive, and the mixture was kept at the given temperature. At the end of reaction the catalyzed mixture was fractionally distilled through a column. The results of the experiments are given in Tables 1-3.

3-Diethylamino-1-butene (XXVIII), $[\alpha]_D^{20} -0.27^\circ$, bp 66° (30 mm), $n_D^{20} 1.4637$. Infrared spectrum (ν , cm⁻¹): 920, 1000, 3080 (CH=CH₂), 1380, 1450 (CH₃). PMR spectrum (δ , ppm): 1.06 m (9H, CH₃), 2.3 m (4H, NCH₂), 2.8 m (1H, NCH), 4.87-5.66 m (3H, CH=CH₂), M⁺ 127.

1-Diethylamino-2-butene (XXIX), bp 68° (30 mm), $n_D^{20} 1.4673$. Infrared spectrum (ν , cm⁻¹): 975, 3030 (trans-CH=CH), 1380, 1450 (CH₃). PMR spectrum (δ , ppm): 1.05 m (6H, CH₃), 1.66 d (3H, CH₃C=C, J = 3 Hz), 2.27 m (4H, NCH₂), 2.79 m (2H, NCH₂C=C), 5.42 m (2H, CH=CH), M⁺ 127.

3-Diethylamino-1,7-octadiene (XXX), $[\alpha]_D^{20} -0.13^\circ$, bp 89° (6 mm), $n_D^{20} 1.4798$. Infrared spectrum (ν , cm⁻¹): 925, 1000, 3080 (CH=CH₂), 1380, 1450. PMR spectrum (δ , ppm): 1.05 m (6H, CH₃), 1.44 m (4H, CH₂), 1.97 (2H, CH₂C=C=), 2.35 m (4H, NCH₂), 2.56 m (1H, NCH), 4.82-5.03 (6H, CH=CH₂), M⁺ 181.

1-Diethylamino-2,7-octadiene (XVIII), bp 98° (6 mm), $n_D^{20} 1.4793$. Infrared spectrum (ν , cm⁻¹): 920, 1000, 3080 (CH=CH₂), 980, 3080 (trans-CH=CH), 1380, 1450 (CH₃). PMR spectrum (δ , ppm): 1.05 m (6H, CH₃), 1.5 m (2H, CH₂), 1.96 m (4H, CH₂C=C), 2.27 m (4H, NCH₂), 2.8 (2H, NCH₂C=C), 4.87 m (2H, C=CH₂), 5.4 (3H, CH=CH), M⁺ 181.

3-Dipropylamino-1-butene (XXXI), $[\alpha]_D^{20} -0.12^\circ$, bp 92° (30 mm), $n_D^{20} 1.4689$. Infrared spectrum (ν , cm⁻¹): 920, 1000, 3080 (CH=CH₂), 1380, 1450 (CH₃). PMR spectrum (δ , ppm): 1.06 m (9H, CH₃), 1.37 m (4H, CH₂), 2.3 m (4H, NCH₂), 2.8 m (1H, NCH), 4.87-5.66 m (3H, CH=CH₂), M⁺ 155.

1-Dipropylamino-2-butene (XXXII), bp 98° (30 mm), $n_D^{20} 1.4752$. Infrared spectrum (ν , cm⁻¹): 975, 3030 (trans-CH=CH), 1380, 1450 (CH₃). PMR spectrum (δ , ppm): 1.05 (6H, CH₃), 1.37 m, 1.6 d (3H, CH₃C=C, J = 3 Hz), 2.27 m (4H, NCH₂), 2.79 m (2H, NCH₂C=C), 5.42 m (2H, CH=CH), M⁺ 155.

1-Dipropylamino-2,7-octadiene (XXXIII), bp 98° (1 mm), $n_D^{20} 1.4739$. Infrared spectrum (ν , cm⁻¹): 920, 1000, 3080 (CH=CH₂), 980, 3080 (trans-CH=CH), 1380, 1450 (CH₃). PMR spectrum (δ , ppm): 1.06 m (6H, CH₃), 1.45 m (6H, CH₂), 1.96 m (4H, CH₂CH=C), 2.27 m (4H, NCH₂), 2.8 (2H, NCH₂C=C), 4.87 m (2H, C=CH₂), 5.4 m (3H, CH=CH), M⁺ 209.

Compounds (XI), (XII), (XVI), and (XIX-XXVI) were identified by comparing with authentic compounds [1, 2].

CONCLUSIONS

It was shown that it is theoretically possible to obtain optically active unsaturated amines by reacting butadiene with the simpler secondary amines in the presence of chiral Ni-containing metal complex catalysts.

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