Tetrahedron Vol. 47, No. 28, pp. 5295-5308, 1991
Printed in Great Britain

0040-4020/91 $3.00+.00

Synthesis and Properties of Some Rh(I) Catalytic Complexes with Dinitrogen Ligands Derived from 5-Pyrido-1,4-benzodiazepin-4-ones

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(*Received in UK* 27 *March* 1991)

Key Words: 5-Pyrido-1,4-benzodiazepin-2-ones (N-N), [Rh(I) NBD (N-N)] ClO_4 complexes, stability, hydrogenation, σ-donor effect

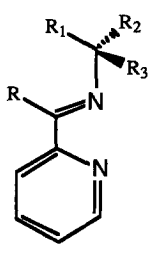
Abstract.A series of bidentate nitrogen ligands (**3-8**), and their [Rh (I) (NBD) (N-N)] ClO_4 complexes **11-14** (NBD-norbornadiene, N-N-dinitrogen ligand) were prepared. Conformational properties and stability of **4** and its catalytic complex **12** were reported Catalytic activity of complexes **11** and **12** in hydrogenation of cyclohexane is compared with **22**, a complex that contains 2,2'-bipyridyl as the "standard" ligand. Chiroptical data of chiral ligands **5,6** and their Rh(I) complexes **13,14** are reported.

INTRODUCTION

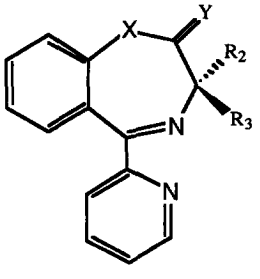
Nitrogen contaning ligands (aza-ligands), as chemically stable organic bases, apear promissing in catalyticaly active organometallic complexes for large-scale application. Although donor-acceptor properties of nitrogen atom, lacking d-orbitals, are less pronounced then those of phosphorous atom, bidentate nitrogen ligands form complexes with transition metals like Pt, Rh, Ir and Ru, which are stable enough to undergo the additional binding of the unsaturated substrate, and the activation of hydrogen by oxidative addition. To promote this step of the catalytic cycle, sufficiently strong *trans*- electron withdrawing effect, mainly *via* back-donation,[1,2] is required from the donor atom of the "spectator" ligand. This effect is most pronounced for ligands with phosphorous atom as the donor, it should be less strong for the sp^2-nitrogen ligands, and the weakest for the sp^3 nitrogen ligands. One would therefore expect the reverse order of catalytic activity of their complexes in hydrogenation. This is, however, not the case since some dinitrogen ligands form the catalitically active complexes[3,4] which are sometimes superior to the Wilkinson-type catalysts[5,6]. This may also be an indication that catalytic complexes of these two types of ligands operate *via* different mechanisms.

The mechanism of hydrogenation catalysed by organometallic complexes of mono- and diphosphines is well understood, mainly due to the work of Halpern[7,8], and Brown[9]. Little is known about the catalytic cycle of hydrogenation with molecular hydrogen (dihydrogen) by organometallic complexes with dinitrogen ligands. In particular, it is not clear to what extent d-π back donation is operative in binding of both, the ligand and the dihydrogen. In this context it is interesting to note that there are examples of catalytic hydrogenation[4] and hydrogen transfer[11] by complexes of bidentate nitrogen ligands with both nitrogens being sp^3. Other examples of hydrogenation catalysts refer either to sp^2-sp^3 or to sp^2-sp^2 dinitrogen ligands, whereas relative positions of donor atoms are 1,3-[4,10], 1,4-[11-14], or 1,5-[15,16] The 1,4-type dinitrogen ligands are the most numerous, and usually comprise 2,2'-bipyridyl and phenantroline derivatives[12,13], as well as similar structures with extended Π–conjugation[14]. 1,3-Dinitrogen sp^2-sp^3 ligands belong to amidines. Their Rh(I) complexes were examined as hydrogenation catalysts by Prucznik et al.[3,4] and Brunner et al.[10] Former authors reported high catalytic activity for achiral complexes with cyclohexene as the substrate, whereas the latter achieved rather low enantioselectivities with complexes of chiral amidines. They also made an interesting observation concerning the stability of the Schiff bases **I**, derived from pyridine aldehyde or pyridine ketones[17]. Ligands with R=H , derived from ketones, turned to be unstable when bound to the metal, and split their alkyl or aryl group R during preparation of the complexes.

This observation, as well as our previous studies of conformational and chiroptical properties of chiral 5-phenyl-1,4-benzodiazepin-2-ones[18-20], prompted us to prepare and study the stability, the conformational and catalytic properties of the Rh(I) complexes of 5-pyrid-2'-yl-1,4-benzodiazepin-2-ones **II**.(X=NH(NR), Y=O). We expected that the cyclic structure of the ketimine subunit in **II** will not only preclude splitting of the C-C(=N) single bond on complexation with Rh(I), but would also render the conformation of the ligand more rigid. The larger group (R_2 or R_3 = H) in the chiral ligands should be forced into *pseudo-equatorial* position of the seven-membered ring, which is known to regularly adopt a boat-like conformation.



I



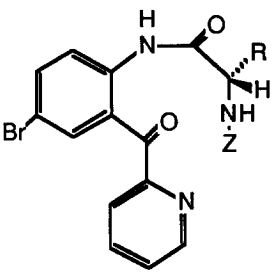
II

RESULTS AND DISCUSSION

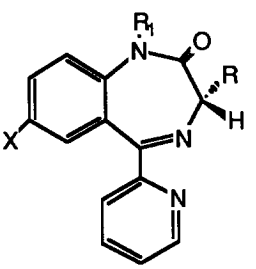
Synthesis.- Our synthetic goal was to prepare a series of 5-pyrido-1,4-benzodiazepines **3-8**, and their Rh(I) complexes **11-14**. The achiral ligand **3** is already well known compound

(bromazepam)[21,22]. The intermediates **1** and **2** were obtained by DCC-catalyzed acylation of the known aminoketone with Z-L-Ala and Z-L-Phe. An attempt to enhance the yield by the addition of 4-dimethylaminopyridine failed. Lower N-H acidity of Z-protected amino acids presumably precluded N-deprotonation by the intermediary enolate anion of the N-substituted urea derivative, since.this method was successful with N-tosylated aminoacids[23]

Deprotection of Z-derivatives **1** and **2** was achieved most conveniently with trifluoroacetic acid in the presence of anisole[24], and the intermediary amines were cyclised without isolation into **5** and **6.** Hydrogenolysis of **1** with Pd/C, used in deprotection of Z-derivatives of some congeners[25,26], afforded substantial quantities of the side products **8** and **16.** Interestingly, hydrogenation of 2-amino-5-bromophenyl-pyrid-2'-yl ketone with the same catalyst afforded debrominated carbinol **15.** The first attempts at hydrogenation of **3** yielded a mixture of *sec.* amines **9** and **10**. Optimization of the conditions led to the compound **9** in 92% yield. Stereochemical identity of **9** was deduced from the ^{13}C- and ^{1}H-NMR spectra. We noticed 100% stereoselectivity on hydrogenation of the 6-membered chiral congeners[27], whereas Kajtar et al.[28] reported the same level of stereoselectivity on hydrogenation of some C(3) chiral 5-phenyl analogues of 1,4-benzodiazepines.



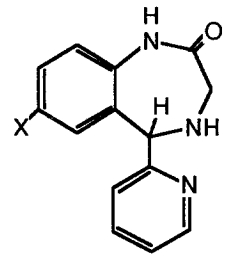
	R
1	CH_3
2	CH_2Ph

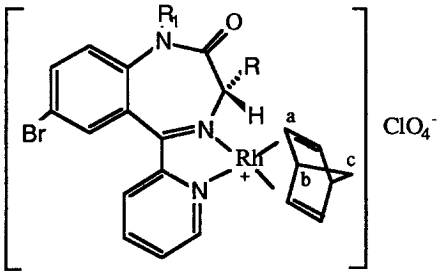


	R	R_1	X
3	H	H	Br
4	H	CH_2Ph	Br
5	CH_3	H	Br
6	CH_2Ph	H	Br
7	CH_3	CH_2Ph	Br
8	CH_3	H	H

Benzodiazepines **3** and **6** were benzylated to **4** and **7** by the modified literature method[25]. In view of the anticipated benzylation of these ligands on binding to chloromethylstirene-divinyl benzene solid support[29], this reaction should be improved.

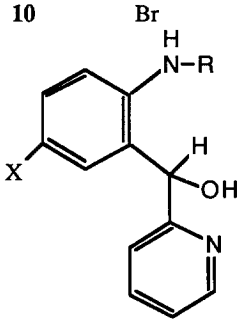
Rh(I)NBD complexes **11-14** were prepared according to the method of Brunner et al.[17] At variance with ligands **I**, all representatives of **II** form stable complexes which could be chromatographed on the silica gel column without decomposition. They move as a red band on the column, which on elution under nitrogen and evaporation, affords deep-blue to black crystalline products. These complexes, either in solution or as the solids, change the colour to red-brown when exposed to air, indicating the binding of oxygen, as already observed by Mestroni et al.[12].





	X
9	H
10	Br

	R	R_1
11	H	H
12	H	CH_2Ph
13	CH_3	H
14	CH_2Ph	H



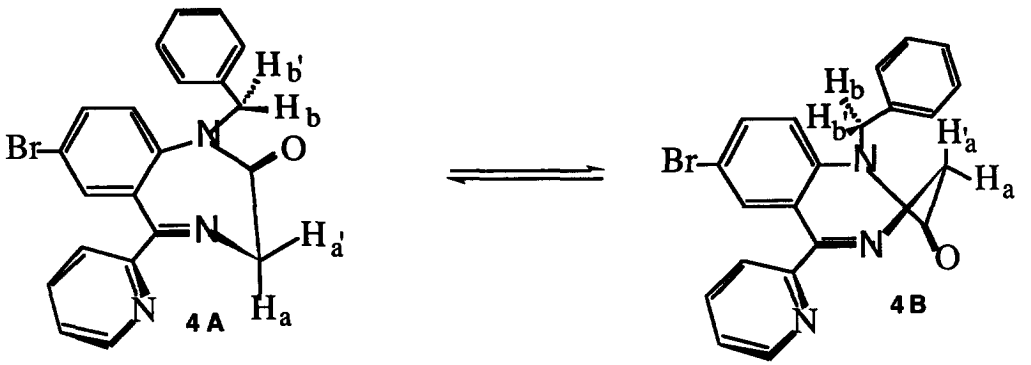
	R	X
15	H	H
16	$COCHCH_3$ | NH-BOC	Br

Conformational properties - Catalytic behaviour of Rh(I) complexes with dinitrogen ligands should depend on their stereoelectronic properties[30,31], i.e. on how easy the central metal ion exchanges ligands, binds the substrate, activates the hydrogen, and releases the products. These interactions are governed by the "spectator" ligands[32], *i. e.* the stereoselectivity of hydrogen transfer is controlled by the conformational properties of the chiral ligands.[20,30] With this in mind we examined conformational and dynamic properties of some ligands **II** and their Rh(I) complexes.

COSY and relayed NOSY experiments allowed the unequivocal assignment of all proton signals in **4**. The intramolecular proton-proton connectivities deduced from the respective n O.e. values observed in the NOESY contour plot indicate that space-distance between non-bonded C(9)H and C(2")H atoms is less than 0.45 nm. This effect indicates restricted rotation of the phenyl ring of the benzyl group. The additional evidence of this restriction is a large, temperature dependent magnetic nonequivalence of the benzylic protons C(1')Hb,Hb' ($\Delta\delta$ = 0 32 ppm).

Conformational mobility of the 7-membered ring and N-benzyl group in **4** can be presented as in the Scheme 1. The line broadening in DMSO-d_6 is observed for C(1'")Hb,Hb' system at ca. 70°C, and for C(3)Ha,Ha' system at ca. 80°C. Coalescence temperature for the former AB system is found at ca. 105°C, for the latter at ca. 110-115°C.

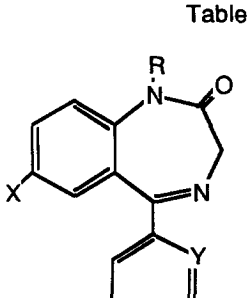
Scheme 1.



Coalescence temperature of C(3)Ha,Ha' system in the complex **12,** at ca. 90°C, is significantly lower than that of the free ligand, indicating that the complexation to Rh(I) lowers the conformational barrier for the inversion of the 7-membered ring in **4**. Unexpectedly, coalescence temperature of the C(1''')Hb,Hb' system increases on complexation to ca. 125-130°C. ΔG# for ring inversion and benzylic group free rotation were estimated as 18.9 kcal/mol and to 20.2 kcal/mol, respectively, using the known equation.[33]

The above data can be compared with those obtained earlier for some 5-phenyl congeners of **4** (Table 1.). Conformational stability of **19**, 1,4-benzodiazepin-2-one with $C(3)H_2$ group is in the case of N-*tert* -butyl derivative high enough to allow its isolation in the conformationally pure form, and determination of the crystal structure[36]. Polarimetrically determined activation energy of **21** was considerably lower (ΔG# 13.3 kcal/mol), but none-the less single conformer with **P** absolute conformation, as determined by the single crystal structure analysis,[37] crystallized from the equilibrium mixture. It is important to note, however, that the conformers of **17-20** are enantiomers, whereas that of **21** are diastereomers.

Table 1.Inversion Barriers for 5-Aryl-1,4-benzodiazepin-2-ones



	X	Y	R	$\Delta G^{\neq}$	Ref.
1	Br	N	CH_2Ph	18.9	this work
17	Cl	CH	H	12.3	40,41
18	Cl	CH	CH_3	17.6	40
19	Cl	CH	$C(CH_3)_3$	>24	42
20	Cl	CCl	$C(CH_3)_3$	>24	42
21	Cl	CH	$CH(CH_3)Ph$	13.3	43

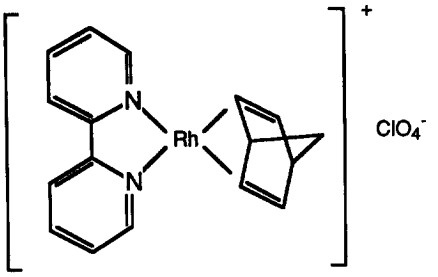
Stability of the complexes.-Stability to solvent exchange of some complexes with di- and tri-nitrogen ligands was already studied. It was observed that Pd(II) bis-2-bipyridyl-silane complexes are stable in Me_2CO-d_6 and MeCN-d_3, but in Py-d_5 only the signals corresponding to the free ligand were observed after 30 min, indicating unexpected liability of this class of ligands[38]. Tridentate nitrogen ligands derived from 2,6-disubstituted pyridine form Cu(II) complexes which are stable in MeCN, but decomposing in strong donor solvents like DMF or DMSO[39].

To get more insight into the stability of the precatalytic complex $[Rh(NBD)_2]ClO_4$ and the catalytic complex **12**, their liability to solvent exchange, and the stability under reductive hydrogen atmosphere was studied by ^{1}H-NMR. In the first series of experiments the exchange of diene ligand NBD in the catalytic complex $[Rh(NBD)_2]ClO_4$ for DMSO-d_6 was followed in $CHCl_3$-d. Intensive line broadening for Ha and Hb protons of NBD in $[Rh(NBD)_2]ClO_4$ on addition of DMSO-d_6 was observed first. No signal of the unbound NBD was noticed up to 5.6:1 DMSO/complex molar ratio. At higher molar ratios of DMSO the exchange of one mole of NBD takes place. Line broadening of the free ligand indicates fast ligand exchange, and the change of Rh spin state. On dissolution of $[Rh(NBD)_2]ClO_4$ in DMSO-d_6, immediate relase of ca. 1 mole of NBD can be noticed, however. Signals of the free NBD appeared at 6.74 ppm for Ha, at 3.56 ppm for Hb, and at 1.98 ppm for Hc. Presumably, DMSO-d_6 first coordinates to the 5th and 6th position of Rh(I) in $[Rh(NBD)_2]ClO_4$, changing the spin, and increasing formal oxidation number. This result is interesting also in wiev of the Brunner's reaction[40], where precatalytic species $[Rh(COD)Cl]_2$ reacts in DMSO with diphosphine ligand, and triethylammonium formate as the hydrogen source, affording catalytic species for hydrogen transfer.

When **12**, prepared *in situ* from $[Rh(NBD)_2]ClO_4$ and **4** was titrated analogously with DMSO-d_6, no ligand exchange was observed on 90 MHz instrument, confirming higher stability of the Rh(I) complex with dinitrogen ligand.

Stability to hydrogenation (reductive decomposition) of the precursor $[Rh(NBD)_2]ClO_4$ and catalytic complex **12**, parallels their liability to the ligand exchange. When $[Rh(NBD)_2]ClO_4$, was dissolved in MeOH under hydrogen, it decomposed quickly, whereas GLC control reveals simultaneous reduction of NBD to norbornane. The addition of potassium hydroxide, otherwise used as the promotor of hydrogenation by Rh(I) complexes with dinitrogen ligands,[12-14] did not preclude the decomposition of the complex, but only decreased the rate of norbornane formation. This could be explained by partial formation of metal oxides, along with the catalyticaly active amorphous metal. Under the hydrogen atmosphere, in the presence of hydroxide, complex **12** proved stable for at least 24 hrs.

Catalytic activity.-To establish catalytic activity of Rh(I) complexes of 5-pyrid-2'-yl-1,4-benzodiazepines, hydrogenation rate of cyclohexene was studied with the achiral complexes **11** and **12** and compared with the catalytic activity of the "standard" complex **22**, of Π-symmetric ligand 2,2'-bipyridine.



First, it was observed that **11** and **12**, the complexes with π-asymmetric ligand, exhibit somewhat lower activity than **22** (Fig. 1.). Both types of complexes reacted rather sluggishly at ca, 1-1.5 barr of hydrogen, but their activity increases notably with pressure (Fig. 2.). They also require the presence of hydroxy ions to exert significant activity (Fig. 3), as was already noticed by Mestroni et al.[12-14a] for other dinitrogen complexes. This finding might be an indication that complexes with nitrogen ligands activate hydrogen *via* heterolytic mechanism (Scheme 2.).Heterolytic route implies the activation of hydrogen by the catalytic species which coordinates, besides diaza ligand, one strong σ-donor ligand[32]. As one of the preliminary tests we examined the effect of methoxy ion, another σ-donor of similar basicity, on hydrogenation rate,.and noticed an effect similar to that of hydroxy ions (Fig. 4.).

Scheme 2.

$$[M^+A^-] + H_2 \longrightarrow [MH] + H^+ + A^-$$

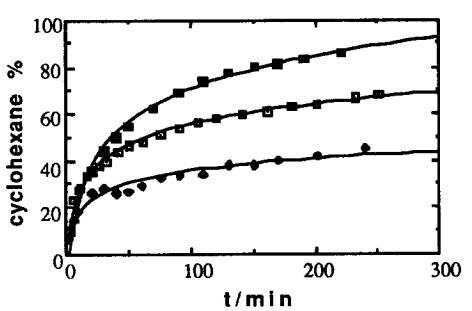


Fig 1 Progress curves for hydrogenation of cyclohexene with **11** (▫), **12** (◆), and **22** (■), at 10 Barr, and c_{NaOH} 0 024 M

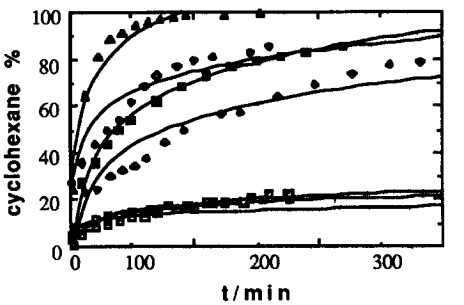


Fig.2.Progress curves for hydrogenation of cyclohexene with **11** (▫) and **12** (■) at 1 Barr, and with **22** at (▫) 1 Barr, (◆) 5 Barr, (■) 10 Barr, (◆) 20 Barr, and (▲) 40 Barr, c_{NaOH} 0.024M

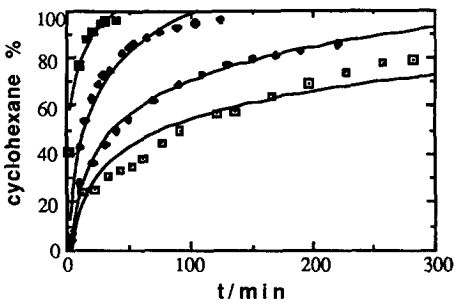


Fig 3. Effect of c_{OH} on hydrogenation rate with **22** at 5 Barr (□ 0.024 M, ◆ 0.24 M) and 10 Barr (◇ 0.024 M, ■ 0.24 M)

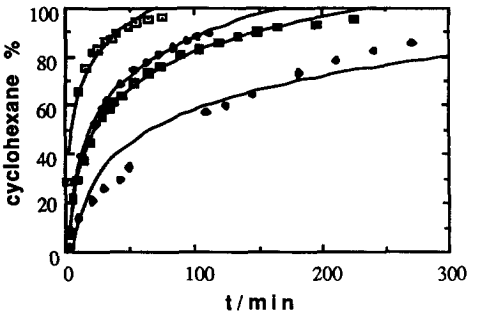


Fig.4. Effect of c_{MeO} on hydrogenation with **22** at 5 Barr (◇ 0.024 M, ■ 0.24 M and 10 Barr (◆ 0.024 M, □ 0.24 M)

Chiral ligands.-Chiral C(3) derivatives **5,6** exhibit much lower conformational mobility. On heating up to 150°C in DMSO-d_6 no signals of the diastereomeric conformer can be observed. It is therefore reasonable to expect the same (high) conformational stability of C(3)-*S* chiral ligands **5-8** within their Rh(I) complexes.

The CD spectra of **5,6**, and of their Rh(I) complexes **13,14** are presented in the Figs 5. and 6. The CD spectra of the free ligands relate to those observed with their 5-phenyl 7-chloro analogues, for which the **M** absolute conformation of the 7-membered ring, and pseudo-equatorial position of the larger group on the C(3)-*S* -chiral centre were established by rigorous analysis of the chromophore[19]. Less conformational informations can at present be deduced from the CD spectra of their Rh(I) complexes **13,14**. A larger series of their congeners needs to be examined, and their temperature and solvent dependent spectra should be determined before any rigorous analysis of the chiroptical properties of such complexes.

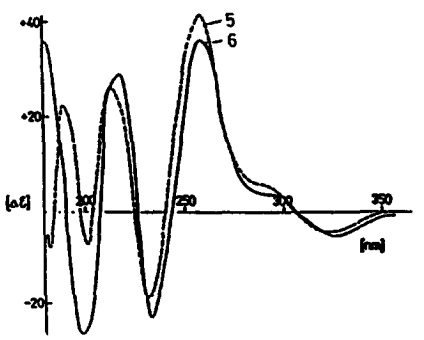


Fig.5. CD Spectra of compounds **5** and **6** (in acetonitrile).

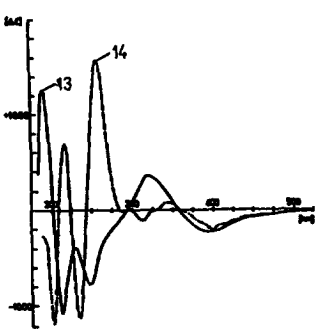


Fig. 6. CD Spectra of complexes **13** and **14** (in acetonitrile)

In the preliminary hydrogenation experiments performed in relation to our study[41] of the enantioselective preparation of *S*-3(3-hydroxyphenyl)-1-propylpyperidine (*S*-3-PPP, an agonist of the central dopamine receptor), the reduction of some prochiral precursors proceeded with low enantioselectivity (e.e's.≤20%). Since the hydrogenation of prochiral substrates regularly required the elevated hydrogen pressures to achive acceptable rates, low enantioselectivities can in part be explained by this inconvenience. The work in progress is oriented towards a broader range of prochiral substrates, in particular those with more reactive, non-shielded double bonds, and to the use of the complexes of these ligands in some other catalytic reactions[42]

Acknowledgement.- The authos are indebted to Prof. G. Snatzke, Ruhruniversity Bochum, for providing the CD spectra, to Prof. G. Mestroni, University of Trieste, and to Prof. H. Brunner, University of Regensburg, for communicating the preliminary results on enantioselectivity of hydrogen transfer and hydrosilylation, respectively.

EXPERIMENTAL

Melting points were determined on Buchi mp apparatus, and are not corrected. IR spectra were obtained for KBr pellets, on a Perkin Elmer M 137 spectrometer. TLC was performed on Merck's DC-alufolien with Kieselgel $60F_{254}$. Organic extracts during usual work-up were dried over Na_2SO_4 and evaporated *in vacuo*. Flash column chromatography was performed with dry nitrogen as pressurazing gas, using silica gel Merck, 0.040-0.063 mm (230-400 mesh ASTM). Solvents for flash chromatography were dried and prior to use deaerated by continous flushing with dry nitrogen for 20 min.

NMR Spectroscopy - One- and two dimensional spectra at room temperature were obtained on a Varian Gemini 300 spectrometer operating at 300 MHz, and the spectra were referenced to residual DMSO (2.51 ppm). Each one-dimensional spectrum was collected using a single 30° pulse, 2 s relaxation delay time, and a total sweep width of 3000 Hz sampled with 16 K points. Data processing employed a Lorentz line broadening factor of 0.2 to 0.5 Hz.Temperature dependent NMR spectra at temperature range from 298 to 408°K were obtained on a JEOL FX90 FT spectrometer operating at 89.55 MHz with total sweep width of 1000 Hz sampled with 8 K points. Titration of samples dissolved in $CHCl_3$-d was performed with $CHCl_3$-d/DMSO-d_6 solution (4:1 vol., 3.50 M in DMSO-d_6).

Two-dimensional COSY[44,45] and relayed COSY spectra[46,47] were obtained in the magnitude mode. Each spectrum had 1024 points in the F2 dimension and 256 slices in F1, which were zero filled to 1024 points. Each slice was obtained using 16 averages, a relaxation delay of 1.5 s, and spectral width of 3000 Hz. Resolution of the F2 domain was 3.0 Hz/point. The delay for relay transfer of magnetization was adjusted to 60 ms to optimize sensitivity for coupling constants of interest (8 Hz). NOESY spectra[48] were obtained in the phase sensitive mode, and

employed a mixing time of 800 ms. The number of points in both dimensions, the zero-filling, the pulse recovery time, and the number of averages per slice were the same as in the relayed COSY experiment.

Preparations - Starting 2-amino-5-bromophenyl-pyrid-2'-yl ketone, and compound **3** are prepared as described[21,22] Z-L-Ala and Z-L-Phe were prepared according to the standard procedure.

2-(N-Carbobenzoxy-S-alanyl)amino-5-bromophenyl-pyrid-2'yl ketone (1).

To a solution of dicyclohexylcarbodiimide (DCC, 0.85 g, 0.41 mmol) in dichloromethane (40 ml) Z-L-Ala, (1.0 g, 4.5 mmol) and 2-amino-5-bromophenyl-pyrid-2'-yl ketone (1.03 g, 3,74 mmol) were added. Stirring at ambient temperature was continued for 5 days, in the meantime additional quantities of Z-L-Ala (0.5 g, 50% mol excess) and DCC (0.5 g, 60% mol excess) were added portionwise. Dicyclohexylurea (DCU) was removed by filtration, organic solution was washed with dill. aqueous bicarbonate, dried, evaporated and residual oil purified by chromatography on silica gel column (100 g), eluting with ether-light petroleum (5:1). It was obtained 1.92 g of pure **1**, mp. 131-133°C, from MeOH-H_2O (6:1). IR max: 3320, 1695, 1680, 1510, 1265, 1240 cm^{-1}. ^{1}H-NMR ($CHCl_3$-d): 1.46 (s, CH_3), 4.4 (m, C(3)-H), 5.12 (s, 2H), 5.72 (d, Cbo-NH), 6.9-7.3 (m, 10H), 8.54 (d, J=4.7 Hz C(3')-H), 8.69 (d, J=4.7 Hz C(6')-H), 11.39 (s, NH). ^{13}C-NMR ($CHCl_3$-d): 18.23, 52.09, 66.99, 114.84, 122.70, 123.82, 124.66, 126.36, 127.94, 128.33, 136.23, 136.80, 155.92, 171.67, 195.15. Anal. for $C_{23}H_{20}N_3O_4Br$ (482.13) Calcd.. C 57.27, H 4.18, N 8.71, Found: C 57.54, H 4.33, N 8.88 %

2-(N-Carbobenzoxy-S-phenylalanyl)amino-5-bromophenyl-pyrid-2'-yl ketone (2)

This compound was prepared as described for **1**, starting from Z-L-Phe (6.0 g, 20 mmol). Crude product was purified by crystallization from dichlorometane-light petroleum to afford 5.72 g (76.5%) of pure **2**, mp. 118-120°C. IR max: 3300,1695,1680, 1510, 1260, 750 cm^{-1}. ^{1}H-NMR ($CHCl_3$-d): 2.2 (d, CH_2Ph), 3.16 (m, C(3)H), 5.09 (s, CH_2-Cbo), 5.58 (1H, NH-Cbo), 7.1-7.9 (m, 15H), 8.20 (d, C(3")-H), 8.61 (d, C(6")-H), 11.2 (s, N(1)-H). ^{13}C-NMR ($CHCl_3$-d): 38.32 (t, CH_2Ph), 57.56 [d, C(3)], 67.04 (t, CH_2 in Cbo), 115.07, 122.80, 124.04, 124.72, 126.36, 126.87, 127.94, 128.33, 128.61, 129.12, 136.01, 136.12, 136.69, 136.97, 173.08, 139.06, 148.47, 154.69, 155.81, 170.21, 194.75. Anal for $C_{29}H_{24}NO_4Br$ (530.20) Calcd.: C 62.37, H 4.33, N 7.52 Found: C 62.60, H 4.40, N 7.26%

1-Benzyl-7-bromo-1,3-dihydro-5-(pyrid-2'-yl)-2H-1,4-benzodiazepin-2-one (4)

To a stirred suspension of 2.0 g (6.3 mmol) of **3** in dry toluene (30 ml), sodium methoxide (0.34 g, 6.3 mmol) was added at. 80°C. After refluxing for few minutes solvent was distilled off until methanol was removed, then benzyl chloride (0.72 ml, 6.3 mmol), sodium iodide (60 mg), and acetonitrile (12.5 ml) were added. After 20 hr reflux, fresh quantities (30% of the initial) of sodium methoxide and benzyl chloride, and 12.5 ml of acetonitrile were added. After 2.hr reaction mixture was concetrated *in vacuo*, dilluted with water and made neutral with 3N HCl. Organic phase was separated, dryed and evaporated, affording an oily product, which was purified by chromatography with $CHCl_3$-THF-conc aq. ammonia (9:1:2 drops). This product (1.23 g, 47.9%) was crystallized from dichloromethane or ethanol to aford analytical sample, m p. 130-132°C IR

max.: 1680(CO), 1610(C=N), 1405, 1340, 1190, 800, 740, 700 cm^{-1}. ^{1}H-NMR($CHCl_3$-d): 5.32-8.0(m, 4H, Ph$\underline{CH_2}$), 7.13-7.97(m, 12H), 8.62(d, C(6')-H. ^{13}C-NMR ($CHCl_3$-d): 50.74(t, CH_2), 57.11(t, Ph$\underline{CH_2}$), 75.68, 77.09, 78.50, 117.27, 123.59, 123.71, 124.72, 126.87, 127.26, 128.61,130.48, 133.19, 134.14, 136.63, 141.82, 148.87, 155.42, 167.95, 168.57(CO).

7-Bromo-1,3-dihydro-3(S)-methyl-5-(pyrid-2'-yl)-2H-1,4-benzodiazepin-2-one (5)

Compound **1** (1.0 g, 2.0 mmol) was dissolved in trifluoroacetic acid (3.6 ml) and anisole (0.36 ml) was added. Reaction solution was protected by $CaCl_2/P_2O_5$ tube, and heated under reflux for 2.5 hr. Solvent was evaporated *in vacuo*, crude amine was dissolved in aq. HCl (1:1), and solution extracted with dichlorometane (3x20 ml). Aqueos phase was made alkaline by sodium bicarbonate, solution, extracted with dichloromethane, organic extracts were dried, evaporated to dryness and crude product crystallized from dichloromethane-light petroleum affording 0.47 g (68.7 %) of the pure **5**, mp. 224-225°C. Analytical sample, obtained from dichloromethane-light petroleum melted at 233-237°C (decc.). IR max: 3060, 2940, 1690, 1625, 1480, 1470, 1435, 1390, 1320, 825, 800 cm^{-1}. ^{1}H-NMR ($CHCl_3$-d): 1.75 (d, CH_3), 3.80 (q, C(3)-H), 7.1-8.1 (m, 6H), 8.60 (d, C(6")-H, J=4.1 Hz), 9.77 N(1)-H. ^{13}C-NMR ($CHCl_3$-d): 16.55 (q,CH_3), 58.51 C(3), 115.52, 122.69, 123.87, 124.32, 127.94, 133.30, 134.20, 136.57, 137.42, 148.47, 155.70, 166.03, 172.01. Anal. for $C_{15}H_{12}N_3OBr$ (330.08) Calcd.: C 54.56, H 3.66, N 12.73. Found: C 54.31, H 3.86 N 12.69 %.

7-Bromo-1,3-dihydro-3-S-benzyl-5-(pyrid-2'-yl)-2H-1,4-benzodiazepine (6)

Compound **2** (9.17 g, 19.0 mmol) was dissolved in triflouroacetic acid (33 ml) and anisole (2.3 ml), and treated as described for **5.** Isolation of 6 was performed by addition of aq. bicarbonate to pH 9, extraction with dichloromethane, evaporation and trituration with diisopropylether. Crude product (5.8 g, 93.0 %) was crystallized from acetone-water affording analytical sample, mp. 204-206°C. IR max: 3060, 1690, 1615, 1485, 1465, 1330, 800, 750, 700 cm^{-1}. ^{1}H-NMR ($CHCl_3$-d): 3.53-3.95 (m 3H, CH-CH_2), 6.9-8.1 (m, 11H), 8.57 [d, C(6")-H, J=4.1 Hz], 9.25 N(1)-H. ^{13}C-NMR ($CHCl_3$-d): 37.42 (t, CH_2Ph), 65.18 (d, C(3)), 115.89, 122.97, 124.16, 126.24, 138.99, 148.59, 155.99, 166.48, 171.22. Anal. for $C_{21}H_{16}N_3OBr$ (406.14) Calcd.: C 62.08, H 3.97, N 10.34. Found· C 61.90, H 4.24, N 10 41%

1-Benzyl-7-bromo-1,3-dihydro-3(S)-benzyl-5-pyrid-2'-yl)-2H-1,4-benzodiazepin-2-one (7)

This compound was obtained from **6** in 34.4% yield, according to method described for **4.** IR max: 2915,1484, 1470, 1407, 1345, 1310, 1090, 795, 740, 705, 620 cm^{-1}. ^{1}H-NMR (CH_3OH-d_4): 1.64 (s, 2Ha), 4-25-4.28 (m, 4H, 2H+2H on C(3)), 4.74-4.79 (m, 4Hc), 5.58 (s, 2H, CH_2Ph), 7 12 (s, 5H, C_6H_5) 7.86 (m, 7H)

1,3-Dihydro-3(S)-benzyl-5-(pyrid-2'-yl)-2H-1,4-benzodiazepin (8)

Compound **1** (2.0 g, 50 mmol) was dissolved in ethanol-dioxane (2:1, 12 ml) and hydrogenolyzed during 24 h, in the presence of 10% Pd/C (0.17 g) at ambient hydrogen pressure. On filtration of the catalyst and evaporation of the solvent mixture *in vacuo*, crude product mixture was separated on the silica gel column (100 g) with ether-ethylacetate (1:5) + 2 drops of conc. ammonia. In the first fractions 0.57 g (41.6%) of **5** were obtained, in the second

fraction 74 mg (5%) of **8** were obtained on crystallization from MeOH-H_2O, mp. 182-184°C. IR max: 3060, 2940, 1690, 1615, 1470, 1435, 1315, 1250, 825, 800 cm^{-1}. ^{1}H-NMR ($CHCl_3$-d): 1.75 (d, CH_3), 3.80 (q, C(3)-H), 6.98-8.02 (m, 7H), 8.60 (d, C(6')-H, J=4.7 Hz), 9.76 N(1)-H. ^{13}C-NMR ($CHCl_3$-d): 16.65 (q, CH_3), 58.81 (d, C(3)), 115.52, 122.69, 123.87, 124.32, 127.94, 133.30, 134.20, 136.57, 137.42, 148.47, 155.70, 166.03, 172.01.

2-(N-Carbobenzoxy-S-alanyl)-amino-5-bromophenyl-pyrid-2'-yl carbinol (16)

When hydrogenation was repeated as described for **1**, and crude product mixture eluated with chloroform-methanol-conc. ammonia (9.0 : 0.5 + 1 drop), ca. 11% of **16** was isolated, which on crystallization from ethylacetate-diisopropylether had mp. 137-139°C. IR max: 3450-3550, 1690, 1655, 1535, 1270 cm^{-1}. ^{1}H-NMR (DMSO-d_6) 1.38 (d, CH_3), 3.57 (s, OH), 4.3 (m, C(3)-H), 5.08 (s, CH_2 in Cbo), 6.03 (d, CHOH), 6.60 (d, NH in Cbo), 7.15-7.83 (m, 10 H), 8.00 (d, C(3")-H), 8.37 [d, C(6")-H, J=4.4 Hz], 10.97 (s, NH). ^{13}C-NMR (DMSO-d_6) 17.66 (q, CH_3), 51.64 (d, C(3)), 66.03 (t, CH_2 in Cbo), 66.48, 70.49, 116.48, 119.25, 122.58, 125.45, 128.05, 128.22, 128.45. 128.73, 129.97, 134.48, 136.74, 137.87, 138.49, 148.19, 156.21, 163.26, 171.45.

Preparation of Rh(I)-[7-bromo-1,3-dihydro-5-(pyrid-2'-yl)-2H-1,4-benzodiazepin-2-one, norbornadien] perchlorates 11-14.-Compounds **3-5** (100 mg, ca. 0.3 mmol) were dissolved in dichloromethane (20 ml, dried over CaH_2), and solution of $[Rh(NBD)_2]ClO_4$ (122 mg, 0.32 mmol) in dichloromethane (10 ml) was added. After two hours stirring at ambient temperature solvent was evaporated to dryness and deep-brown to black crystalls were dried *in vacuo*. They were purified under nitrogen, on deaerated silicagel column using dichloromethane-methanol (88 : 12) as the eluant. Pure complexes form a deep-red zone on the column, which on evaporation and drying *in vacuo* afford analytically pure products.

Compund 11.- IR max: 1770, 1485, 1470, 1340, 1090, 600 cm^{-1}. ^{1}H-NMR (CH_2Cl_2-d_2): 1.56 (s, CH_2 gem in NBD), 3.81-3.87 (d, 2H, allylic in NBD), 4.18 (m, (C(3)-2H), 4.54-4.62 (m, 4H, vinylic in NBD) 9.06 (s, NH). Anal. for $C_{21}H_{18}N_3BrClO_5Rh$ (610.70.) Calcd.: C 41.30 H 2.97 N 6.88. Found: C 41.29 H 3.23 N 6.68%

Compound 12.-IR max 2915, 1485, 1470, 1407, 1345, 1310, 1090, 795, 740, 705, 620 cm^{-1}. ^{1}H-NMR (CH_3OH-d_4): 1.64 (s, 2H), 4.25-4.28 (m, 2Ha + 2Hb), 4.74-4.79 (m, 4Hc), 5.58 (s, 2H), 7.12 (s, 5H0, 7.86-8.01 (m, 7H).

Compound 13.- IR max: 2940, 1695, 1437, 1340, 1100, 625 cm^{-1}. ^{1}H-NMR (CH_3CN-d_3): 1.81 (s, 2H gem. in NBD), 1.88 (d, CH_3), 3.9 (s, 2H allylic in NBD), 4.07-4.33 (m, C(3)-H), 7.25-8.1 (m, 6H), 8.60 (d, C(6')-H), 8.95-8.99 (br. s, NH). Anal. for $C_{22}H_{20}N_3BrClO_5Rh$ (624.70). Calcd.: C 42.30 H 3.23 N 6.73 Found: C 42.43 H 3.42 N 6.48%

Compound 14.- IR max: 2920,1700, 1470, 1335, 1090, 750, 620 cm^{-1}. ^{1}H-NMR (CH_3CN-d_3): 1 93 (s, 2H gem. in NBD), 3.94 (m, CH_2Ph+2H vinyllic in NBD), 4.23 (m, C(3)-H), 7.34 (m, 6H), 7.8 (m, 6H). Anal for $C_{28}H_{24}N_3BrClO_5Rh$ (700.80) Calcd.: C 47.98 H 3.45 N 6.00. Found: C 47.77 H 3.56 N 6.30%.

Rh(I)-[2,2'-Bipyridyl, norbornadien] perchlorate (22)

This compound was prepared from 2,2'-bipyridyl (78.1 mg, 0.5 mmol), and $[Rh(NBD)_2]ClO_4$ (193.3 mg, 0.5 mmol), as described for **11-14**. Pure product was obtained in

quantitative yield. IR max: 3080, 3020, 1600, 1565, 1495, 1470, 1450, 1415, 1315, 1250, 1100 (broad), 770, 725, 620 cm^{-1}. ^{1}H-NMR: 1.34 (s, 2H), 3.91 (s, 2H), 4.11-4.19 (m, 4H), 7.7-8.6 (m, 8H). ^{13}C-NMR: 49.21, 54.68, 55.14, 61.17, 61.46, 123.19, 127.20, 140.18, 149.49, 154.91 ppm.

Hydrogenation Experiments - All experiments were performed in a Parr M 4561 minireactor, maintaining constant stirring, either at ambient temperature or at the temperatures controlled by a Parr M 4841 temperature controller. Catalytic complexes **11**, **12**, and **21** (0.02 mmol), were dissolved in MeOH (100 ml), and the solution of sodium hydroxide or methoxide in MeOH was added. The activation of the catalytic system was performed by stirring under working pressure of hydrogen for 60 min. On addition of cyclohexane (10 mmol, 1.0 ml), hydrogenation was followed by GLC. Analysis of the samples taken at regular time intervals was performed on a Hewlett-Packard 5890 II instrument, equipped with HP 3396A integrator, and HP-1 column (25 mx 0.2 mm, 0.5 μm film thickness, crosslinked methyl silicone gum), at constant temperature.of 80°C. Callibration curves for cyclohexene and cyclohexane were obtained for the authentic samples

REFERENCES AND NOTES

1. G. Henrici-Olive, S. Olive, *Coordination and Catalysis*, Verlag Chemie, Weinheim-New York, **1977.**
2. C. Masters, *Homogeneous Transition-Metal Catalysis*, Chapman and Hall, London- New York,**1981** pp.12-25.
3. M. Zuber, B. Banas, F. Pruchnik, *J. Mol. Catal.* **1981,** *10* , 143.
4. M. Zuber, A. Zuberla, F. Pruchnik, *J. Mol. Catal.* **1986,***38* , 309.
5. B. Bosnich (Ed.), *Asymmetric Catalysis,* NATO ASI Series, Martinus Nijhoff Publ., Dordrecht, **1986.**
6. J. D. Morrison (Ed.), *Asymmetric Synthesis, Vol. V.*, Chiral Catalysis, Chapters *1-4*, Academic Press, New York **1985.**
7. J. Halpern, *Science,* **1982**, 401.
8. C.R. Landis, J. Halpern, *J. Am. Chem. Soc.*, **1987,***109* , 1746.
9. J.M. Brown, P.J. Meddox, *J.C.S. Chem. Commun.* **1987**, 1276, ibid., **1987,** 1278.
10. H. Brunner, G. Agrifoglio, *Monatsh. Chem.* **1980,***111,* ,275.
11. R. Uson, L.Oro, R. Sariego, M.A Esteruelas, *J. Organomet. Chem.* **1981**, *214* , 399.
12. G. Zassinovich, A. Camus, G. Mestroni, *Inorg. Nucl. Chem. Lett.* **1976,** *2,* 865.
13. G. Zassinovich, G. Mestroni, A. Camus. *J. Mol. Catal.,* **1977,** *2* , 63.
14 (a) G. Zassinovich, G. Mestroni, *J. Organomet. Chem.* **1987** *42, 81.* ; (b) V. Šunjić, Z. Raza, B. Klaić, DŠepac, VII International Symposium on Homogeneous Catalysis, Lyon-Villeurbanne, France, Sept. 3-7, **1990**, Book of Abstr. 439, P-151.
15 H. Fritsch, U. Leutenegger, K.Siegmann, A. Pfaltz, W. Keller, C. Kratky, *Helv. Chim. Acta,* **1988,** *71,* 1541
16. H. Fritsch, U. Leutenegger, A. Pfaltz, *Helv. Chim. Acta,* **1988,** *71,* 1553.
17. H. Brunner, B. Reiter, G. Riepl, *Chem. Ber.* **1984,** *117,* 1330.
18. E. Decorte, R. Toso, T. Fajdiga, A. Sega, V.šunjić, A. Lisini, *J. Heterocycl. Chem..* **1983,** *20* , 1321.
19 G. Snatzke, A. Konowal, A. Sabljić, N. Blažević, V. Šunjić, *Croat. Chem. Acta* **1982**, *55* , 435.
20. V. Sunjić, M. Oklobdžija, A. Lisini, A. Sega, F. Kajfež, D. Srzić, L. Klasinc, *Tetrahedron* **1979,***35,* 2531.
21. *US Pat.* 3,886141 **1975**; *Chem. Abstr.* **1975** *83* , 193407h.
22. T. Kovač, B. Belin, T. Fajdiga, V. Šunjić, *J. Heterocycl. Chem.* **1981,** *18,* 59.
23. D. Tanner, P. Somfai, *Tetrahedron* **1988,** *44,* 613.
24. F. Weigand, W. S. Teglich, *Z. Naturforsch..* **1959***B 14* , 472.

25. L.H. Sternbch, E. Reeder, *J. Org. Chem.*, **1961**,*26*, 4936.
26 V. Šunjić, F. Kajfež, I. Štromar, N. Blažević, D. Kolbah, *J. Heterocycl. Chem.* **1973**, *10*, 591
27. V. Čaplar, A. Lisini, F. Kajfež, D. Kolbah, V. Šunjić, *J. Org. Chem.* **1978**, *43*,1355
28. M. Kajtar, J. Kajtar, J. Rohricht, J.G. Angyan, *Croat. Chem. Acta* **1989**, *62*, 245.
29. K. Soai, S. Niwa, M. Watanabe, *J. Org. Chem.* **1988**, *53*, 927.
30. H. Brunner, *Top. Stereochem.* **1988**, *18*, 129.
31. M.E. Wright, S.A. Svejda, M.-Jong Jin, M.A. Peterson, *Organometallics* **1990**, *9*, 136, and papers cited therein.
32. A. Yamamoto, *Organotransition Metal Chemistry*, J. Wiley Co. Sons, **1986**, pp. 49-92.
33. J. Sandstroem, *Dynamic NMR Spectroscopy*, Academic Press, **1982**, pp. 77-92.
34. J.M. Lehn, P. Linscheid, *Bull.Soc. Chim. Fr.*, **1967**, 992.
35. W. Sadee, *Arch. Farm. (Weinheim)* **1969**,*302*, 769.
36. N. W. Gilman, P. Rosen. J.V. Early, C. Cook, L.J. Todaro, *J. Am. Chem. Soc.* **1990**, *12*, 3969.
37. E. Decorte, R. Toso, A. Sega, V. Šunjić, Z. Ružić-Toroš, B. Kojić-Prodić, N. Bresciani-Pahor, G. Nardin, L. Randaccio, *Helv. Chim. Acta*, **1981**, *64*, 1145.
38. M.E. Wright, C.K. Lowe-Ma, *Organometallics* **1990**, *9*, 347
39. C. Piguet, B.Boquet, E. Muller, A.F. Williams, *Helv. Chim. Acta*, **1989***72*, 323.
40 H. Brunner, E. Graf, W. Leitner, K. Wutz, *Synthesis* ,**1989**, 743.
41. Z. Raza, S. Đaković, I. Habuš, V. Šunjić, *Croat. Chem. Acta*, **1991**, *63*, in press.
42. Ir complex of **5** was tested according to ref. 13 in enantioselective hydrogen transfer 2-propanol-phenyl-*tert.*-butyl ketone (11.2% e.e.), whereas the Rh(I) complex of the same ligand exhibited 24.6% enantioselectivity in hydrosilylation of acetophenone, according to ref. 43.
43. H. Brunner, U. Obermann, *Chem. Ber.* **1989**, *122*, 499.
44. G. Bodenhausen, R.I. Vold, R.R. Vold, *J. Magn. Res.* **1980**, *37*, 93.
45. E. T. Olejniczak, J,C, Hoch, C.M. Dobson, F.M. Poulsen, *J. Magn. Res.* **1985**, *64*, 199.
46. G. Wagner, *J. Magn. Res.* **1983**, *55*, 151.
47 D. Neuhaus, G. Wagner, N. Vasak, J.H.R. Kaglund, K. Wutrich, *Eur. J. Biochem.* **1985**, *151*, 257.
48. D.J. States, R.A. Haberkorn, D.J. Ruben, *J. Magn, Res.* **1982**, *48*, 286.