CHEMISTRY LETTERS, pp. 775-778, 1976. Published by the Chemical Society of Japan

CATALYTIC ENANTIOSELECTION BY CHIRAL TRANSITION-METAL COMPLEXES. II. DEHYDROGENATION OF RACEMIC 1-PHENYLETHANOL BY *in situ* PREPARED RhCl((+)-neomenthyldiphenylphosphine)$_3$ COMPLEX

Katsutoshi OHKUBO, Tsutomu OHGUSHI, and Kohji YOSHINAGA

Department of Synthetic Chemistry, Kumamoto University, Kumamoto 860

The magnitude of the enantioselection of racemic 1-phenylethanol by RhCl((+)-neomenthyldiphenylphosphine)$_3$ prepared *in situ* from (RhCl(CH_2=CH_2)$_2$)$_2$ and the chiral phosphine was the greatest around [phosphine]$_0$/[(RhCl(CH_2=CH_2)$_2$)$_2$]$_0$≃6 and was considerably elevated by the addition of unsaturated ketones and by lowering the reaction temperature.

Although the asymmetric hydrogenation of prochiral olefins by Rh(I) chiral phosphine complexes prepared *in situ* has recently been documented,[1] there are no reports on the enantioselective dehydrogenation of racemic alcohols by the chiral Rh(I) complexes with or without olefins. It has recently been observed in our laboratory that RhCl(NMDP)$_3$[2] (NMDP=(+)-neomenthyldiphenylphosphine) prepared *in situ* by the reaction of NMDP with Rh(I) dimer complex ((RhCl(CH_2=CH_2)$_2$)$_2$ or (RhCl-(norbornadiene))$_2$) or with Wilkinson complex (RhCl(PPh_3)$_3$) catalyzed the enantioselective dehydrogenation of racemic 1-phenylethanol, I, and that the enantioselective ability of the *in situ* prepared RhCl(NMDP)$_3$ complex was not affected by the preparation methods mentioned above.

When the dehydrogenation of I catalyzed by RhCl(NMDP)$_3$ was carried out at 160° - 190°C with or without olefins such as benzalacetone, the optical purity of unreacted I enriched in the S-(-) isomer increased monotonously with increasing conversion, obeying a pseudo-first-order rate law:

$$\begin{matrix} \text{R-(+)-I} \xrightarrow{k_R} \\ \text{S-(-)-I} \xrightarrow{k_S} \end{matrix} \text{dehydrogenation products} \qquad k_R/k_S = \ln\{[\text{R-I}]/[\text{R-I}]_0\}/\ln\{[\text{S-I}]/[\text{S-I}]_0\}$$

The dehydrogenation products consisted of acetophenone (AP) and racemic- or meso-bis(1-phenylethyl) ether (PEE) with small amounts of styrene and ethylbenzene, and, in the presence of olefins, the AP formation accompanied the quantitative saturation of olefins.

The enantioselectivity (defined by k_R/k_S), which was found to be very low but reproducible, varied with mole-ratio of NMDP and the Rh(I) complex added (chlorine-bridged dimer or Wilkinson complex), the olefin concentration, and with the structure of unsaturated additives. The results of a representative series of the experiments are shown in Fig. 1 and Table 1. The maximum selectivity found around [NMDP]$_0$/[(RhCl(CH_2=CH_2)$_2$)$_2$]$_0$≃6 may be related to the formation of an active chlorine-bridged dimer of (RhCl(NMDP)$_2$)$_2$[3] probably *via* the following equilibrium:

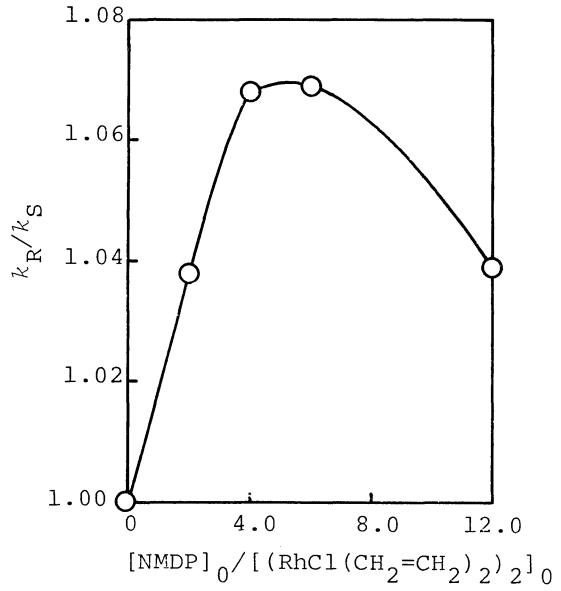


Fig. 1. The effect of NMDP concentration on the enantioselectivity ($[RhCl(CH_2=CH_2)_2)_2]_0$=5 and $[benzalacetone]_0/[I]_0$=0.84 at 180°C for 24 - 30 hr).

$$(RhCl(CH_2=CH_2)_2)_2 + nNMDP \longrightarrow (RhCl(NMDP)_2)_2 + (n-4)NMDP \rightleftharpoons 2RhCl(NMDP)_3 \quad (n\simeq 6)$$

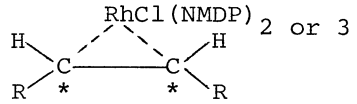
Notably, the variation in the selectivity mentioned above was in parallel with that in the ratio of the AP and PEE formed; that is, [AP]/[PEE] (k_R/k_S)=0.124(1.000), 1.704(1.067), 2.340(1.068), and 1.304(1.039). Thus, the side reaction of the PEE formation apparently decreased the magnitude of the selectivity through the consumption of I without any enantioselection, and this reaction seems to proceed *via* a rhodium alkoxide intermediate similar to the alkoxide intermediate formed from the Ru(II) complex and secondary carbinols:[4]

$$Ph(Me)CHOH + (Rh) \xrightarrow[-H^+]{} [Ph(Me)CHO\text{--}(Rh)] \longrightarrow Ph(Me)C{=}O + (Rh\text{-}H)$$

$$Ph(Me)CHOH + H^+ \longrightarrow Ph(Me)CHOH_2^+ \xrightarrow[-H_2O]{} [Ph(Me)CHO\text{--}(Rh)] \longrightarrow (Ph(Me)CH)_2O$$

where (Rh) denotes the Rh(I) complex, and the hydride complex, (Rh-H), is converted into (Rh) through the saturation of styrene or the evolution of H_2 in the absence of olefins.

The variation in the selectivity with the olefin concentration (Table 1) is also related to the above reaction channel. The increase in the olefin concentration depressed the PEE formation considerably with a monotonous elevation of the selectivity under the present reaction conditions. Interestingly, the change in the structures of unsaturated additives resulted in the change in the magnitude of the selectivity which is independent of the dehydrogenation rate. The effect of the additives on the enhancement of the selectivity follows the order, benzalacetophenone>benzalacetone>*trans*-stilbene>ethyl cinnamate>*n*-hexyl methacrylate, and this suggests the importance of the molecular asymmetry induced by the additives:[5]



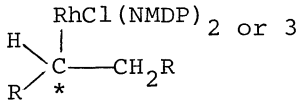


Table 1. The effect of concentration or structure of unsaturated additives on the enantioselective dehydrogenation of I (83.5 mmol) by $RhCl(NMDP)_3$ complex at 180° C for 30 hr

Olefin	(mmol)	Conversion (%)	$-[\alpha]_D^{23}$ [a] (deg.)	Optical purity (%)	$10^6 k_R$ (s^{-1})	$10^6 k_S$ (s^{-1})	k_R/k_S	AP (mmol)	PEE (mmol)
-----	(0)[b]	29.4	0.025	0.048	4.027	4.016	1.003	6.17	7.50
benzal-acetone	(34.2)	18.7	0.224	0.427	1.955	1.876	1.042	8.52	2.92
	(68.5)	18.4	0.354	0.675	1.950	1.825	1.068	7.82	3.43
	(102.7)	23.4	0.453	0.863	2.546	2.386	1.067	9.77	3.98
benzal-acetophenone	(68.5)	12.4	0.331	0.631	1.287	1.170	1.100	7.82	0.56
trans-stilbene	(68.5)	6.4	0.077	0.147	0.623	0.596	1.045	3.87	0.73
ethyl cinnamate	(68.5)	11.0	0.035	0.066	1.087	1.075	1.011	8.52	trace
n-hexyl methacrylate	(68.5)	23.2	0.031	0.059	2.454	2.443	1.005	16.78	1.37

a) $[\alpha]_D^{23}$ -52.5°, c 2.27 in CH_2Cl_2 (Ref. 7). b) Reaction time=24 hr.
The reaction conditions were $[(RhCl(CH_2{=}CH_2)_2)_2]_0$=5 mM and $[NMDP]_0/[(RhCl\text{-}CH_2{=}CH_2)_2)_2]_0$=6. The experimental error of $[\alpha]_D^{23}$, optical purity, or each rate constant was within ±0.002°, ±0.003%, or ±0.001 s^{-1}, respectively.

Table 2. The effect of reaction temperature on the enantioselective dehydrogenation of I by $RhCl(NMDP)_3$ ($[(RhCl(CH_2{=}CH_2)_2)_2]_0/[NMDP]_0$=1/6)

Run	Temp. (°C)	Time (hr)	Conversion (%)	$-[\alpha]_D^{23}$ (deg.)	Optical purity (%)	$10^6 k_R$ (s^{-1})	$10^6 k_S$ (s^{-1})	k_R/k_S	AP (mmol)	PEE (mmol)
1	170	30	12.1	0.070	0.133	1.210	1.185	1.021	4.01	2.44
2	190	22	45.1	0.048	0.091	7.571	7.548	1.003	6.39	10.14
3	160	36	7.9	0.274	0.512	0.677_0	0.596_6	1.135	2.17	0.67
4	170	30	10.9	0.322	0.613	1.130	1.016	1.112	6.10	1.29
5	180	30	18.5	0.390	0.743	1.961	1.823	1.076	9.74	2.52
6	190	20	22.5	0.434	0.827	3.648	3.419	1.067	13.13	2.38

$[(RhCl(CH_2{=}CH_2)_2)_2]_0$=5 mM and $[olefin]_0$=0 in Runs 1 and 2; $[(Rh(CH_2{=}CH_2)_2)_2]_0$=10 mM and $[benzalacetone]_0/[I]_0$=0.84 in Runs 3-6.

Table 3. Activation parameters

Species	$\Delta H^{\ddagger}$ (kcal/mol)	$\Delta\Delta H^{\ddagger}$ (kcal/mol)	$\Delta S^{\ddagger}$ (e.u.)	$\Delta\Delta S^{\ddagger}$ (e.u.)
R-(+)-I	21.49(36.50)	0.87(0.36)	-37.99(-4.05)	1.76(0.78)
S-(-)-I	22.36(36.86)		-36.23(-3.27)	

Values in parentheses, which were roughly estimated, are those for the reaction in the absence of olefins. The standard deviations of $\Delta H^{\ddagger}$ and $\Delta S^{\ddagger}$ for the system involving the olefin were ±0.18 kcal/mol and ±0.40 e.u. respectively.

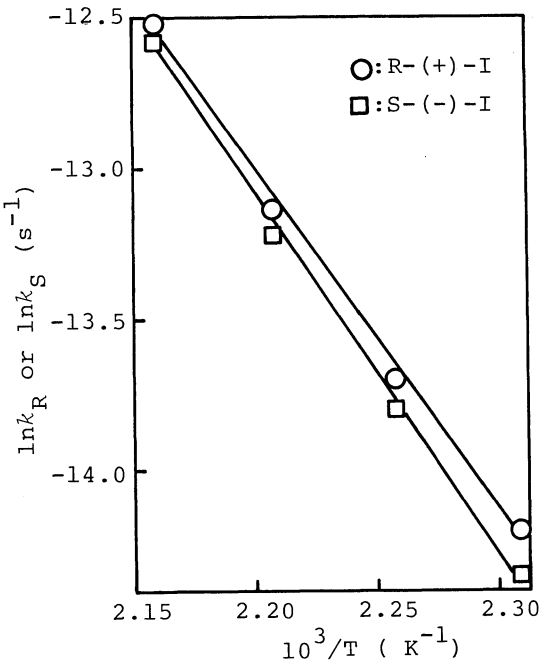


Fig. 2. Arrhenius plots of $\ln k_R$ (or $\ln k_S$) *vs.* 1/T (T=absolute temperature).
([$(RhCl(CH_2=CH_2)_2)_2$]$_0$=10 mM, [NMDP]$_0$/[$(RhCl(CH_2=CH_2)_2)_2$]$_0$=6, and [benzalacetone]$_0$/[I]$_0$=0.84.)

The remarkable effect of the unsaturated ketones is probably due to a bulky ligand (phosphobetaine) formation from the ketone and the chiral ligand,[6] and the phosphobetaine ($R'_3\overset{+}{P}CH(Ph)CH=C(R)\bar{O}$) acts as an optically effective ligand in stead of NMDP. In this respect, the detailed investigation is now in progress. The enantioselectivity was also dependent on the reaction temperature and substantially decreased with elevating the temperature in spite of an increase in the conversion of I without any considerable change in the product distribution (Table 2). The two linear Arrhenius plots indicated apparent activation energies of 22.38±0.18 kcal/mol for R-(+)-I and 23.25±0.18 kcal/mol for S-(-)-I in the presence of benzalacetone (Fig. 2). The activation-energy difference of 0.87 kcal/mol is undoubtedly larger than that (0.36 kcal/mol) in the absence of the olefin. The contribution of the olefin to the present reaction is also reflected in the entropy of activation, $\Delta S^{\ddagger}$, listed in Table 3; that is, the olefin increases the difference in the $\Delta S^{\ddagger}$ value, $\Delta\Delta S^{\ddagger}$, between the isomers.

References

1) R.E.Hormon, S.K.Gupta, and J.Brown, *Chem.Rev.*, 73, 21 (1973), and references therein.
2) Strictly speaking, the structure of the complex is uncertain.
3) C.A.Tolman, P.Z.Meakin, D.L.Lindner, and J.P.Jesson, *J.Am.Chem.Soc.*, 96, 2762 (1974).
4) Y.Sasson and J.Blum, *Chem.Comm.*, 309 (1974).
5) G.A.Paiaro and A.Pannunzi, *J.Am.Chem.Soc.*, 86, 5148 (1964); A.Pannunzi and G.A. Paiaro, *J.Am.Chem.Soc.*, 88, 4843 (1966).
6) L.Marko and B.Heil, *Catalysis Rev.*, 8, 269 (1973); K.Ohkubo, K.Hirata, and K.Yoshinaga, *Chem.Lett.*, in press.
7) U.Nagai, T.Shishido, R.Chiba, and H.Mitsuhashi, *Tetrahedron*, 21, 1701 (1965).

(Received May 10, 1976)