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CATALYTIC DEHYDROGENATION OF SECONDARY AMINES WITH COBALT SCHIFF BASE COMPLEX-OXYGEN SYSTEM

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Summary: Catalytic oxidation of secondary aromatic amines using Co(salen)/O_2 in ethanol at 60 °C leads to dehydrogenation of the amines affording the corresponding imines in high yield. A mechanism involving electron transfer from the substrate to cobalt(III) species is suggested.

Oxygenation reactions using cobalt Schiff base complexes [Co(SB)] provide topics in bioinorganic chemistry.[1] Of particular interest is that Co(SB), in catalytic oxygenations, mimic the hem complex which catalyzes in living cells the different type of oxidations: dioxygenations, monooxygenations, and dehydrogenations. For example, Co(SB) promote not only dioxygenations of phenols, indoles, and flavonols in aprotic solvents[2] but also monooxygenations of phenols,[3] hydrazones,[4,5] and olefins[6] in protic media. Recently, the Co(SB)/O_2 system has been found to be effective for the dehydrogenation of hydrazones leading to the formation of diazo compounds[7] and alkenylcobalt(III) Schiff base complexes.[8] We wish to report here that N,N-ethylenebis(salicylideneiminato)cobalt(II), Co(L^1), catalyzes efficiently the oxidation of secondary aromatic amines with O_2 in ethanol at 60 °C to give imines in high yield. Since little has been known about dehydrogenation of secondary amines by catalytic oxidation with O_2,[9] the present system provides a new route to the synthesis of imines and heteroaromatic compounds.

To a solution of N-benzylaniline (**1a**) (2 mmol) in ethanol (30 ml) was added Co(L^1) (0.02 mmol). The resulting suspension was heated at 60 °C with stirring under an atmospheric pressure of oxygen for 24 h (conversion; 77%)(a clear solution was obtained in 10 min). The mixture was evaporated under a reduced pressure and the residue obtained was dissolved in a small volume of dichloromethane and filtered through a short column of Florisil to remove the metal complex. Evaporation of the organic solution gave N-benzylideneaniline (**2a**) and benzaldehyde (**3a**) in 87% and 9% yield, respectively. Table 1 summarizes the results obtained in the Co(L^1) catalyzed dehydrogenation of substituted benzylanilines (**1**).

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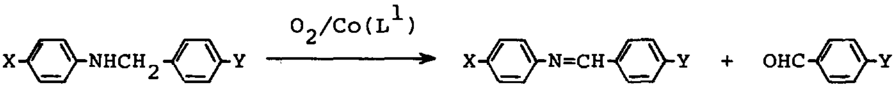
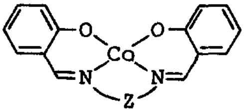
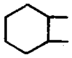
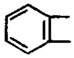


1 **2** **3**

a; X = Y = H **b**; X = H, Y = OMe **c**; X = H, Y = Me
d; X = H, Y = Cl **e**; X = H, Y = NO_2 **f**; X = OMe, Y = H
g; X = Me, Y = H **h**; X = Cl, Y = H **i**; X = Y = MeO
j; X = Y = Me **k**; X = Y = Cl



$Co(L^1)$; Z = CH_2CH_2 $Co(L^2)$; Z =  $Co(L^3)$; Z = 

$Co(L^4)$; Z = $(CH_2)_3$ $Co(L^5)$: Z = $(CH_2)3\underset{H}{N}(CH_2)_3$ $Co(L^6)$: Z = $=(CH_2)_3\underset{Me}{N}(CH_2)_3$

Table 1. Dehydrogenation of N-Benzylamines (1) using $O_2/Co(L^1)$ system[a]

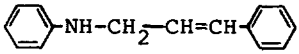
Run	1	$Co(L^1)$ (mol%)	Solvent	Reaction temp.(°C)	Reaction time (h)	Conversion (%)	Product (%)[b] 2	3
1	**1a**	0	EtOH	60	24	0	-	-
2	**1a**	1	EtOH	60	24	77	87	9
3	**1a**	2	EtOH	60	24	100	84	11
4	**1a**	2	EtOH	50	24	85	89	11
5	**1a**	2	MeOH	60	24	55	83	17
6	**1a**	2	i-PrOH	60	24	69	89	11
7	**1a**	20	DMF	60	24	41	79	21
8	**1a**	20	$ClCH_2CH_2Cl$	60	24	31	85	11
9	**1b**	2	EtOH	60	24	100	80	20
10	**1c**	2	EtOH	60	24	100	81	17
11	**1d**	2	EtOH	60	24	100	82	18
12	**1e**	2	EtOH	60	24	100	81	19
13	**1f**	2	EtOH	60	2	100	94	5
14	**1g**	2	EtOH	60	6	100	87	9
15	**1h**	2	EtOH	60	24	98	83	16
16	**1i**	2	EtOH	60	2	100	95	2
17	**1j**	2	EtOH	60	24	100	88	12
18	**1k**	2	EtOH	60	24	100	77	19

[a] Reaction conditions: a solution containing amine (1) (2 mmol) and $Co(L^1)$ in an appropriate solvent (30 ml) was warmed under oxygen (1 atm).

[b] Determined by ^1H NMR.

As seen from Table 1, the reaction depends on the reaction medium and temperature: the use of an alcohol as solvent at a higher temperature is important for the smooth reaction (Runs 2-8), and the best results are obtained in ethanol at 60 °C. Poor results are obtained in aprotic solvents (Runs 7, 8). The reactivity of **1** depends strongly on the nature of the substituent X but apparently independent of Y. The reaction is retarded by an electron-withdrawing group (Runs 3, 15), and no reaction took place with **1** (X = NO_2, Y = H) in 2 h, suggesting that the electronic state in the aniline moiety plays an important role. Treatment of N-benzylideneaniline (**2a**) with a catalytic amount of $Co^{III}(L^1)(OH)$ in ethanol at 60 °C under nitrogen resulted in the quantitative formation of benzaldehyde (**3a**) (conversion; 12% in 2 h). Since the imines (**2**) were stable without the cobalt complex, the aldehydes (**3**) must be the hydrolysates of **2** resulting from the catalysis by $Co^{III}(L^1)(OH)$.

Similarly, the $Co(L^1)$ catalyzed oxidation of the following amines **3**, **4**, **5**, and **6** with O_2 in ethanol at 60 °C for 24 h gave **7** (96%), **8** (89%), **9** (60%), and **10** (55%), respectively. In the case with **4**, the use of methanol at 60 °C in place of ethanol gave a better result (**9**; 81% yield). On the other hand, amines **11** - **14** were not reactive under the reaction conditions described above. Therefore, it seems likely that a sterically unhindered structure of the starting amine and a conjugated structure of the resulting imine are important factors for the reaction taking place.



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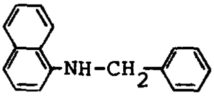

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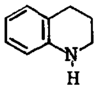

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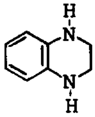

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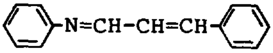

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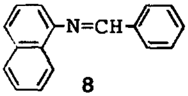

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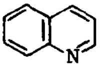

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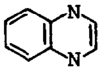

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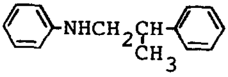

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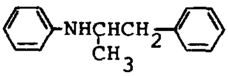

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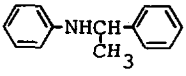

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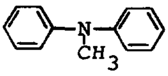

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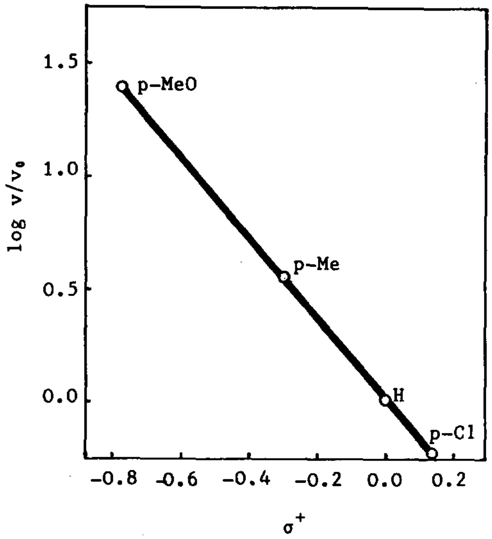

Fig. 1. Effect of substituent X in **1** (Y = H) on the reaction rate determined by competitive consumption of the substrates.

The dehydrogenation is also influenced by the structure of Co(SB). In the oxidation of **1a** with O_2 in ethanol at 60°C for 24 h in the presence of Co(L^2) (2 mol%), Co(L^3) (2 mol%), Co(L^4) (20 mol%), Co(L^5) (20 mol%), or Co(L^6) (20 mol%), the conversion of the substrate was 66%, 67%, 18%, 6%, and 7%, respectively. These results suggest that a planar four coordinate ligand is essentially required for the catalysis of the cobalt complex.

The plot of relative reactivity of 4-substituted N-benzylanilines (**1**; Y = H), determined by a competitive reaction, vs. σ_p^+ value gave a linear correlation with a value of $\rho = -1.8$ (Fig. 1), although no linear correlation was obtained with the σ_p value. Therefore, the transition state may involve an electron transfer from the aniline moiety.

Since $Co^{II}(L^1)$ is rapidly oxidized to $Co^{III}(L^1)(OH)$ in alcohols,[10] the electron accepting reactive species should be the hydroxocobalt(III) species. The resulting substrate cation radical intermediate may undergo deprotonation from the NH group followed by further oxidation to the imine product, and the Co^{II} species formed is reoxidized with dioxygen to the active Co^{III} species, although the reoxidation of the Co^{II} species may also be possible to take place by a some other oxidizable species that may be produced when the benzylphenylaminyl radical intermediate undergoes further oxidation with dioxygen. Detailed studies on the mechanism is currently investigated.

References

(1) E. C. Niederhoffer, J. H. Timmons, A. E. Martell, Chem. Rev., **84**, 137 (1984). T. Matsuura, Tetrahedron, **33**, 2869 (1977).

(2) A. Nishinaga, H. Tomita, J. Mol. Catal., **7**, 179 (1980). A. Nishinaga, H. Ohara, H. Tomita, T. Matsuura, Tetrahedron Lett., **24**, 213 (1983).

(3) A. Nishinaga, H. Tomita, T. Matsuura, Tetrahedron Lett., **21**, 1261 (1980);

(4) A. Nishinaga, S. Yamazaki, T. Matsuura, Tetrahedron Lett., **25**, 5805 (1984).

(5) A. Nishinaga, S. Yamazaki, T. Matsuura, Tetrahedron Lett., **27**, 2649 (1986).

(6) A. Zombeck, D. E. Hamilton, R. S. Drago, J. Am. Chem. Soc., **104**, 6782 (1982).

(7) A. Nishinaga, S. Yamazaki, T. Matsuura, Chem. Lett., **1986**, 505.

(8) A. Nishinaga, S. Yamazaki, T. Matsuura, Tetrahedron Lett., **28**, 6309 (1987).

(9) Stoichiometric dehydrogenation of secondary amines to imines by oxidants has well been documented: R. V. Hoffman, A. Kumar, J. Org. Chem., **49**, 4011 (1984). S. -I. Murahashi, T. Naota, H. Taki, J. Chem. Soc. Chem. Commun., **1985**, 613.

(10) A. Nishinaga, T. Kondo, T. Matsuura, Chem. Lett., **1985**, 905.

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