

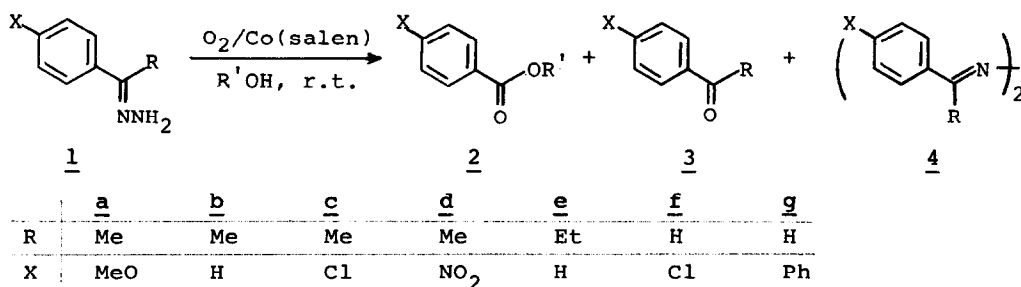
NOVEL OXIDATIVE CLEAVAGE OF CARBON-CARBON BOND IN HYDRAZONES
BY OXYGENATION WITH COBALT SCHIFF BASE COMPLEX

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Summary: Oxygenation of aromatic ketone hydrazones with Co(salen) in methanol resulted unexpectedly in oxidative degradation to give methyl benzoate derivatives. A mechanism involving nucleophilic attack by methanol on a diazo intermediate is discussed.

Oxygenations of organic compounds catalyzed by metal complexes which are capable of binding dioxygen are received much attention in connection with biological oxidations and organic synthesis.^{1,2} In aprotic solvents, cobalt(II) Schiff base complexes bind dioxygen reversibly, providing synthetic oxygen carriers,^{3,4} while function as model dioxygenases when organic compounds such as phenols, flavonols, and indoles are put in the reversible dioxygen binding system.^{5,6} These cobalt(II) Schiff base complexes are, on the other hand, oxidized irreversibly with molecular oxygen in alcohols giving rise to hydroxo- and alkoxo-cobalt(III) complexes depending on the acidity of the alcohol used.⁷ Recently, we reported that the reversible dioxygen binding system using five coordinate cobalt(II) Schiff base complexes was effective for dehydrogenation of aromatic ketone hydrazones, providing a convenient method for the synthesis of aryl diazoalkanes.⁸ In this communication, we wish to report that the oxygenation of aromatic ketone hydrazones with *N,N'*-ethylenebis(salicylideneiminato)cobalt(II), [Co(salen)], a planar four coordinate cobalt(II) Schiff base complex in alcohols, where the complex is irreversibly oxidized, results unexpectedly in oxidative cleavage of the C-C bond giving rise to alkyl benzoate derivatives. Few reports are available with reference to such oxidative carbon-carbon bond breakdown of hydrazones.⁹

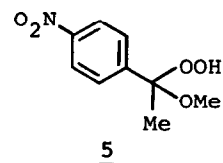
In a typical experiment, a suspension of Co(salen) (2 mmol) in methanol (30 ml) was stirred under an oxygen atmosphere at room temperature until a clear solution of Co^{III}(salen)(OH)⁷ was obtained (usually for 30 min). To the resulting solution with stirring was added dropwise a solution of hydrazone 1 (1 mmol) in methanol (20 ml) in 1 h at room temperature. After evaporation of the solvent, the resulting residue was dissolved in a small volume of dichloromethane and filtered through a short silica gel column to remove the metal complex. The organic products thus obtained was separated by silica gel layer chromatography to give derivatives of methyl benzoate 2, ketone 3, and azine 4. Ratio of the products depended on the reaction conditions (Table 1). As seen from Table 1, in methanol the slow addition of 1 as well as the higher

Table 1. Oxygenation of Hydrazones 1 by Co(salen)^a

<u>1</u>	[Co]/[<u>1</u>]	Addition rate of <u>1</u> (mmol/h)	Solvent (R'OH)	Product/%		
				<u>2</u>	<u>3</u>	<u>4</u>
<u>1a</u>	0.0	^b	MeOH	0	0	100
<u>1a</u>	0.1	1.0	MeOH	10	56	27
<u>1a</u>	0.5	1.0	MeOH	36	56	6
<u>1a</u>	1.0	1.0	MeOH	56	38	1
<u>1a</u>	1.0	^c	MeOH	39	48	8
<u>1a</u>	2.0	1.0	MeOH	64	32	-
<u>1a</u>	2.0	0.5	MeOH	70	28	-
<u>1a</u>	2.0	0.5	EtOH	30	60	-
<u>1a</u>	2.0	0.5	i-PrOH	3	81	10
<u>1a</u>	2.0	0.5	t-BuOH	3	66	27
<u>1b</u>	2.0	0.5	MeOH	73	25	2
<u>1c</u>	2.0	0.5	MeOH	63	24	-
<u>1d</u>	2.0	0.5	MeOH	80	15	-
<u>1d</u>	0.5	1.0	MeOH	63	32	<u>5</u> (5%)
<u>1e</u>	2.0	0.5	MeOH	55	33	-
<u>1f</u>	2.0	0.5	MeOH	69	19	-
<u>1g</u>	2.0	0.5	MeOH	13	^d	^d

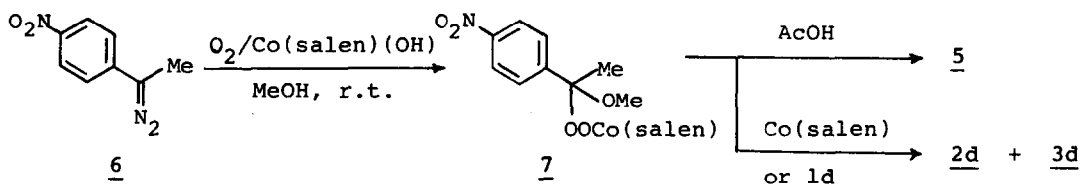
^a A solution of 1 in MeOH(20 ml) was added dropwise to a solution of Co(salen)(OH)(2 mmol) in MeOH(30 ml) under O₂ at r.t. Conv. 100% otherwise noted. ^b Conv. 7% in 72 h. ^c Hydrazone 1a was added at once. ^d Not determined.

anol resulted also in the predominant formation of 3. Interestingly, when 1d was oxygenated with a half amount of Co(salen)(OH) at a higher addition rate, hydroperoxide 5¹⁰ was obtained in 5% yield, and further the oxygenation of 1a without Co(salen)(OH) was quite slow to give only compound 4 (Table 1). These results therefore suggest that the nucleophilicity of the solvent and coordinately unsaturated Co^{III}(OH) species are essential for the present oxidative C-C bond cleavage reaction. Furthermore, oxygen bubbling through a solution of 1-(4-nitrophenyl)-1-diazoethane (6)⁸ in methanol containing an equimolar amount of Co(salen)(OH) at room temperature for a few minutes followed by



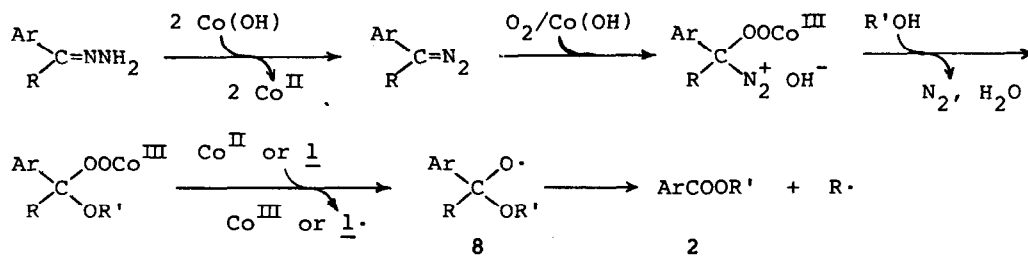
ratio [Co]/[1] resulted in the higher yield of 2, and the substituent X did not affect much the product ratio. The yield of 2 also depended on the nature of the solvent. Thus, with alcohols other than methanol the formation of the parent ketone 3 predominated. No oxidative C-C bond cleavage of 1 was observed in aprotic solvents such as dichloromethane and DMF, where 3 was formed along with a small amount of 4. The use of six coordinate Co(salpr)(OH)⁷ in place of Co(salen)(OH) in meth-

pouring the mixture into water gave peroxocobalt(III) complex 7 as yellow fine crystals (84% yield),¹¹ which gave hydroperoxide 5 upon treatment with acetic acid or silica gel. In methanol, the diazo compound 6 was stable without Co(salen)(OH), whereas with the cobalt complex under nitrogen was obtained a complex mixture but not a simple product in which methanol was incorporated. On the other hand, compound 6 was oxygenated readily in the presence of Co(salen)(OH) in acetonitrile to give 3d in 94% yield. Therefore, it may be clear that the formation of 7 results from the dioxygen incorporation into 6 in preference to the methanol addition. The peroxo complex 7 was stable against Co(salen)(OH) in methanol, but decomposed immediately when Co(salen) or hydrazone 1d was added to a solution of 7 in methanol under nitrogen to give 2d (80%) and 3d (20%), indicating that 7 is susceptible to one-electron reduction. From these observations and the fact that 6 is formed from 1d at



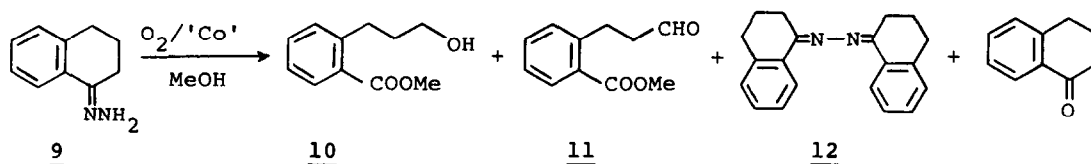
the expense of two equivalents of Co(salen)(OH),⁸ the present oxidative cleavage of the C-C bond in 1 is rationalized to proceed by the following mechanism involving the diazo intermediate (Scheme 1). Actually, in an early stage of

Scheme 1

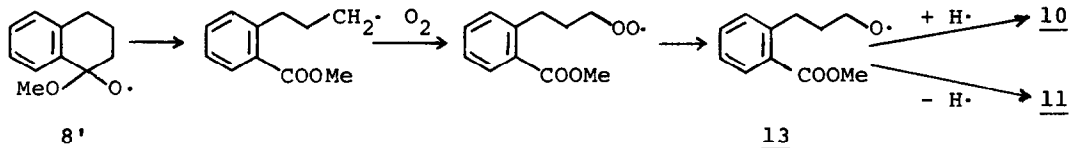


the oxygenation of 1, transient appearance of red color due to the diazo intermediate was generally observed.

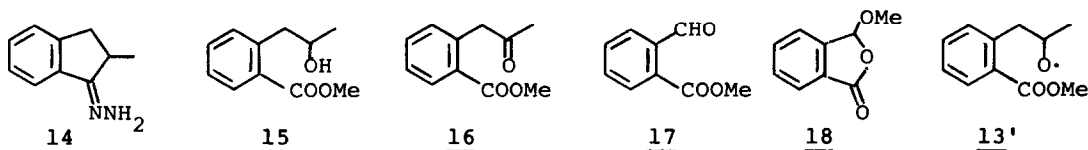
The fate of radical $R\cdot$ in the final step in Scheme 1 under the oxygenation conditions was clearly demonstrated by the oxygenation of cyclic ketone hydrazones. Thus, the oxygenation of 1-tetralone hydrazone (9) with two equivalents of Co(salen)(OH) in methanol gave compounds 10 (27%), 11 (27%), 12 (3%), and the parent ketone (27%).¹² Since compound 11 was not formed from



10 under the reaction conditions, these products should be formed independently from a common intermediate 13 resulting from breakdown of 8' (refer to 8 in Scheme 1) and dioxygen incorporation followed by reductive or associative decomposition.¹³ Similarly, the oxygenation of 2-methyl-1-indanone hydrazone



(14) gave compounds 15, 16, 17, 18, and the parent ketone in 12%, 16%, 15%, 34%, and 10% yield, respectively.¹² The formation of 17 and 18 is rational-



ized by assuming the breakdown of alkoxy radical intermediate 13' leading to a more stable benzyl radical species followed by the further oxidation.

The present oxygenolysis of hydrazones is characteristic for those of aromatic ketones, whereas aliphatic ketone hydrazones exhibit different reactivity in the oxygenation. The details are under current investigation.

References and Notes

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- 10) Hydroperoxide 5: m.p. 56-57 °C. ¹HNMR(CDCl₃) δ 1.58 (s, 3H), 3.40 (s, 3H), 7.66 (d, 2H, J = 9Hz), 8.17 (d, 2H, J = 9Hz), 8.33 (brd s, 1H, OH). Anal. C₉H₁₁NO₅: C, ±0.26%; H, ±0.02%; N, ±0.02%.
- 11) Complex 7: Anal. C₂₅H₂₄N₃O₇·Co·H₂O: C, ±0.28%; H, ±0.07%; N, ±0.02%.
- 12) Isolated yield. The ¹HNMR(CDCl₃) for the products are in good agreement with the structures: 10; 1.59-2.13 (m, 2H), 2.43 (brd s, 1H, OH), 3.02 (t, 2H, J = 7Hz), 3.57 (t, 2H, J = 6Hz), 3.84 (s, 3H), 6.97-7.97 (m, 4H). 11; 2.76 (m, 2H), 3.25 (m, 2H), 3.88 (s, 3H), 7.0-8.0 (m, 4H), 9.72 (t, 1H, J = 1Hz). 12; 1.3-2.1 (m, 4H), 2.5-2.9 (m, 8H), 7.0-7.4 (m, 6H), 8.0-8.4 (m, 2H). 15; 1.26 (d, 3H, J = 6Hz), 3.05 (d, 2H, J = 8Hz), 3.89 (s, 3H), 4.00 (m, 1H), 7.0-8.0 (m, 5H). 16; 2.23 (s, 3H), 3.85 (s, 3H), 4.07 (s, 2H), 7.0-7.5 (m, 3H), 7.8-8.1 (m, 1H). 18; 3.57 (s, 3H), 6.24 (s, 1H), 7.3-7.9 (m, 4H).
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(Received in Japan 6 March 1986)