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A Radical Substitution on Sulfur of Thioester Group. Formation of β- and γ-Thiolactone[1)]

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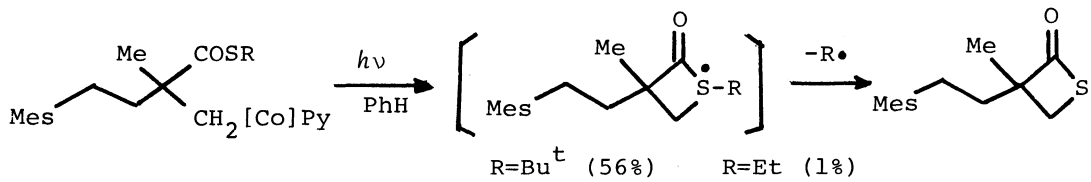
Alkyl radicals having (t-butylthio)carbonyl group on β- or γ-position gave β- or γ-thiolactones whereas the homologous radical did not give δ-thiolactone. These reactions involve intramolecular radical substitution on the sulfur atom of thioester group. Ethylthioesters have much less reactivity to the same substitution.

We have been concerned with the biomimetic radical rearrangement of thioester groups[2)] and have reported the formation of β-thiolactone on the photolysis of 2-(t-butylthio)carbonyl-4-mesityl-2-methylbutylcobaloxime (Eq. 1).[3)] This type of intramolecular radical substitution on sulfur of thioester has no precedent and we expanded the system from 2-(alkylthio)carbonyl-alkyl radical to 3- and 4-(t-butylthio)carbonyl-alkyl radical.

Four organocobaloximes, 2-(t-butylthio)carbonyl-2-methylpropylcobaloxime (1a),[4)] 2-(t-butylthio)carbonyl-2-ethoxycarbonyl-4-mesitylbutylcobaloxime (2a),[4)] 3-(t-butylthio)carbonyl-2,2-bis-ethoxycarbonylpropylcobaloxime (3a),[4)] and 4-(t-butylthio)carbonyl-2,2-bis-ethoxycarbonylbutylcobaloxime (4a),[4)] were synthesized from the corresponding bromides 1b - 4b and bis-dimethylglyoximato(pyridine)cobalt(I).[5)]

Cobaloximes 1a - 4a were photolyzed in benzene[6)] and bromides 1b - 3b were treated with tributylstannane/AIBN in benzene.[7)] The product ratio and the total yield of the products are shown in Eqs. 2 - 5.

The structures of products 5, 6,[8)] 8, 11, 13, and 14 were deduced by comparing the spectroscopic data of authentic samples. Product 7 was a mixture of S-t-butyl 3-methyl-2-butenethioate and S-t-butyl 3-methyl-3-butenethioate which were identified by comparing the gaschromatograph-mass data and H-NMR signals of authentic samples. Product 9 was deduced from IR absorptions at 1770 (β-thiolactone) and 1730 cm^{-1}(ester); H-NMR signals at 2.99 and 3.68 (each 1H, d, J=9, ring methylene), 2.12 and 2.69 (each 2H, t, J=7); mass m/z=306 (9%, M^+). Product 10 was characterized by an unsaturated ester group, 1720 cm^{-1}; 5.58 and 6.18 (each 1H, br. s); m/z=248 (41%, M^+).



R=Bu^t (56%) R=Et (1%) (1)

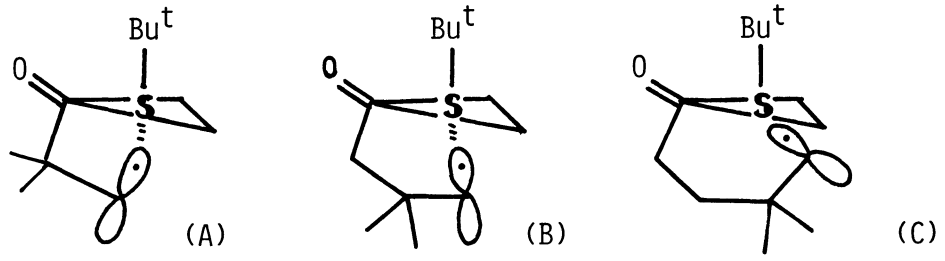
The structure of 12 was assigned from IR 1734 (ester) and 1725 cm^{-1}(thiolactone); H-NMR 3.00 and 3.78 (each 2H, s, two methylenes in thiolactone), and mass m/z=246 (28%, M^+). High volatility of the products 5 - 7 made it difficult to determine the yields though 30 - 40% total yields were obtained in a few runs.

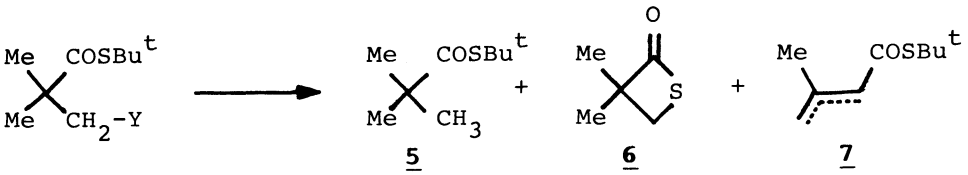
Both processes, photolysis and tributylstannane treatment, give organo-radicals.[10] The latter process gives the radical in the presence of tributyl-stannane, an effective radical scavenger, and the reactions of 1b and 2b result in the formation of 5 and 8 as main products. The radicals from organocobaloxime 1a and 2a, however, gave a thioester-rearranged product 7 and a thioester-eliminated product 10, respectively, in addition to β-thiolactones and hydrogen abstraction products. The photolysis of 3a gave only a γ-thiolactone 12 and it is noteworthy that the same radical intermediate from bromide 3b gave mainly 12 even in the presence of tributylstannane. This result indicates that the radical substitution of the intermediate from 3b is much faster than the hydrogen abstraction from tri-butylstannane. On the other hand, the formation of δ-thiolactone from 4a was not seen but the prolonged irradiation of 4a gave a degradation product 14.

The ethylthio-esters corresponding to 1a, 1b, and 2b gave no thiolactone and the ethylthio-esters corresponding to 2a, 3a, and 3b gave a β-thiolactone 9 and a γ-thiolactone 12 but in much less yield. The radical substitution on the sulfur atom of ethylthio-ester, therefore, is much less feasible than the substitution on t-butylthio-ester. This difference in reactivity is accounted for by the stability of a leaving alkyl radical R∘.

Radical substitutions on sulfur are accumulating[11, 12] and are understood by apical attack of a radical and apical rupture of a leaving group.[13] The rupture of t-butyl radical must facile and the attacking step of a radical species is con-dered to be a rate determining process. The apical attack is practical for radical A and B, in which a radical center and the σ*-orbital of S-Bu^t bond can be nearly colinear but the radical center is hardly colinear with S-Bu^t bond in radical C.

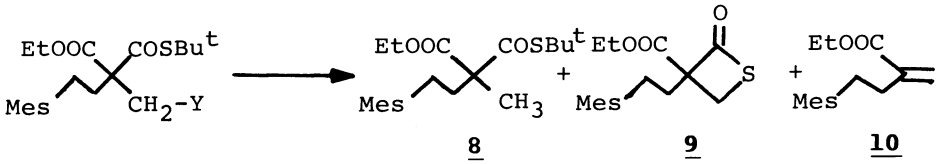
The results recorded in this letter provide a new method to prepare β-thio-lactone and γ-thiolactone and also show the strong interaction between alkyl radi-cals and the sulfur atom of thioester group when those are in a proper molecular geometry. The latter concept must be taken into account when we discuss the bio-mimetic radical rearrangement of thioester groups.





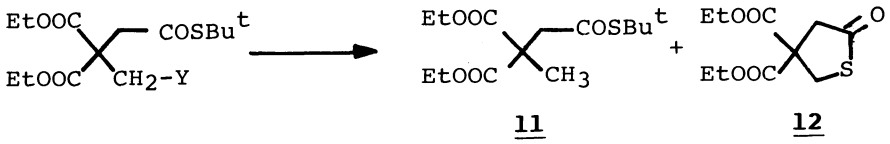
(2)

1a (Y=[Co]Py) $h\nu$ (12 : 55 : 33) (Yield)
1b (Y=Br) Bu_3SnH (82 : 18 : 0) See text



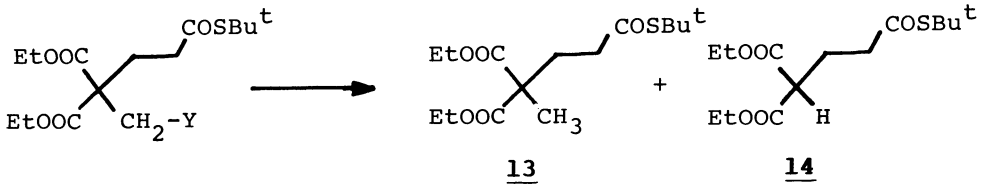
(3)

2a (Y=[Co]Py) $h\nu$ (3 : 82 : 15) 61%
2b (Y=Br) Bu_3SnH (100 : 0 : 0) 90%



(4)

3a (Y=[Co]Py) $h\nu$ (0 : 100) 81%
3b (Y=Br) Bu_3SnH (2 : 98) 94%



(5)

4a (Y=[Co]Py) $h\nu$ (18 : 82) 36%

References

1) This study was supported by The Annual Project Organized by Waseda University and by The Mishima Kaiun Foundation.
2) M. Tada, K. Inoue, K. Sugawara, M. Hiratsuka, and M. Okabe, Chem. Lett., 1985, 1821; M. Tada, K. Inoue, and M. Okabe, ibid., 1986, 703.
3) M. Tada, T. Nakamura, and M. Matsumoto, Chem. Lett., 1987, 409.
4) 1a, mp 196-197 °C(dec); IR($CHCl_3$): 2970, 1665, 1560 cm^{-1}; NMR($CDCl_3$): 1.12(6H, s), 1.42(9H, s), 1.87(2H, s), 2.15(12H, s), 7.38(2H, t, J=7), 7.80(1H, t, J=7), 8.68(2H, d, J=7), 18.1(2H, br. s). Anal. C. H. N.
2a, mp 135-136 °C(dec); IR($CHCl_3$): 2950, 1722, 1660, 1560 cm^{-1}; NMR($CDCl_3$): 1.05-1.85(4H, m), 1.32(3H, t, J=7), 1.46(9H, s), 1.93(6H, s), 1.98(6H, s),

2.00-2.50(2H, m), 2.20(3H, s), 2.31(6H, s), 4.07-4.33(2H, m), 6.75(2H, s), 7.12-7.45(2H, m), 7.63(1H, t, J=7), 8.44(2H, d, J=7), 18.1(2H, br. s). Anal. C, H, N.

3a, mp 158-159 °C(dec); IR($CHCl_3$): 2985, 1725, 1690, 1562 cm^{-1}; NMR($CDCl_3$): 1.17(6H, t, J=7), 1.40(9H, s), 2.01(2H, s), 2.09(12H, s), 3.12(2H, s), 4.05(4H, q, J=7), 7.11-7.43(2H, m), 7.70(1H, t, J=7), 8.45(2H, d, J=7), 18.1(12H, br. s). Anal. C, H, N.

4a, mp 137-138 °C(dec); IR($CHCl_3$): 2985, 1720, 1685, 1560 cm^{-1}; NMR($CDCl_3$): 1.20 (6H, t, J=7), 1.43(9H, s), 1.80-2.50(6H, m), 2.15(12H, s), 4.11(4H, q, J=7), 7.13-7.43(2H, m), 7.77(1H, t, J=7), 8.48(2H, d, J=7), 18.1(2H, br. s).

5) G. N. Schrauzer, "Inorganic Syntheses," McGraw-Hill, New York (1968), Vol. 11, p. 65.

6) One of the organocobaloximes 1a-4a (20-200 mg) in 10-80 ml of benzene was irradiated with a 400W high pressure mercury lamp through a Pyrex filter. The irradiation was continued until disappearance of the starting organocobaloxime (4-30 h). The irradiation time does not mean the relative reactivity since deterioration of the reaction solution reduced the transparency. The reaction mixture was condensed and separated by preparative TLC. In the case of 1a, the products were volatile and collected by bulb to bulb transfer under reduced pressure. Product ratios were determined by gas chromatography using silicone SE-30 as a stationary phase.

7) One of the bromides 1b-3b (20 mg) in benzene ($2X10^{-2}$mol/l) was treated with tributylstannane ($2.2X10^{-2}$mol/l) and catalytic amount of AIBN (1 mg), and the mixture was refluxed for 4-10 h.

8) P. Y. Johnson and G. A. Berchtold, J. Org. Chem., 35, 584 (1970); P. Y. Johnson, Tetrahedron Lett., 1972, 1991.

9) Authentic samples of 5, 8, 11, and 13 were synthesized by α-methylation (iodomethane/LDA) of the corresponding t-butylthio-esters which were used for the syntheses of bromides 1b-4b.

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