nitrophenyl-1-mesyloxy-2-benzamido-3-benzoyloxypropane by mild alkaline hydrolysis and the product cyclized with potassium acetate in ethanol to yield L-*erythro*-2-phenyl-4-hydroxymethyl-5-*p*-nitrophenyl-Δ^2-oxazoline.

We have also employed the mesylation procedure on L-*threo*-N,O-diacetyl-*p*-nitrophenylserinol to effect the *threo*- to *erythro*-conversion. The final product was isolated as L-*erythro*-chloramphenicol. In this case, the intermediates were all syrups and furnished no evidence that the conversion was through an intermediate oxazoline.

We also attempted the use of the tosylate of the N,O-dibenzoyl-*p*-nitrophenylserinol but found that tosylation gave considerably lower yields than did mesylation.

The elimination of the sulfonates with neighboring group participation has been recognized principally by Winstein, *et al.*[4] An entirely analogous inversion with participation of the benzamido group was reported[5] in the preparation of the *trans*-oxazoline from the appropriate *allo*-threonine derivative.

We are indebted to Dr. George Rieveschl, Jr., for his interest in this problem. Infrared data were obtained by R. B. Scott and Ernest Schoeb. Microanalyses are from the Parke, Davis and Co. microanalytical laboratory under the direction of Charles Childs.

Experimental

L-*threo*-1-*p*-Nitrophenyl-1-mesyloxy-2-benzamido-3-benzoyloxypropane.—By the usual method with methanesulfonyl chloride and pyridine, 75% yield, m.p. 112°, from ethanol.

Anal. Calcd. for $C_{24}H_{22}O_8N_2S$: C, 57.8; H, 4.44. Found: C, 57.27; H, 4.73.

In some preparations of the mesylate, a by-product (up to 30% yield), L-*erythro*-O,O'-dibenzoyl-*p*-nitrophenylserinol methanesulfonic acid salt, m.p. 191–192°, was obtained.[6]

Anal. Calcd. for $C_{24}H_{24}O_9N_2S$: C, 56.06; H, 4.70. Found: C, 56.40; H, 4.56.

On treatment with alkali this salt was converted to L-*erythro*-N,O-dibenzoyl-*p*-nitrophenylserinol, m.p. 185°.

L-*erythro*-2-Phenyl-4-benzoyloxymethyl-5-*p*-nitrophenyl-Δ^2-oxazoline.—The mesylate, 7 g., in 250 ml. of abs. ethanol was treated with 15 g. of freshly fused potassium acetate and heated at reflux for four hours. Precipitation occurred during the first hour. The mixture was cooled and filtered. The filtrate was evaporated to a thick sirup, taken into ethyl acetate and washed with water. The ethyl acetate solution was dried and evaporated *in vacuo* to leave a viscous sirup.

Infrared measurements showed C=N at 6.04 μ; benzoate ester at 5.79, 7.86 and 8.98 μ. No amide II band was discernible nor any other ester carbonyl.

L-*erythro*-O,O'-Dibenzoyl-*p*-nitrophenylserinol Hydrochloride.—The oxazoline was taken into ethyl acetate and treated with concd. HCl to precipitate the salt; 50% yield, m.p. 209°.

Anal. Calcd. for $C_{23}H_{21}O_6N_2Cl$: C, 60.6; H, 4.6. Found: C, 60.37, 60.23; H, 4.91, 4.86.

L-*erythro*-N,O-Dibenzoyl-*p*-nitrophenylserinol.—A sample of the oxazoline sirup was treated with acid and then with NaOH in alcohol. Concentration crystallized a white solid, m.p. 183°; recryst. from alcohol–water, m.p. 185°, 81% yield.

Anal. Calcd. for $C_{23}H_{20}O_6N_2$: C, 65.6; H, 4.79. Found: C, 65.44; H, 4.79.

L-*erythro*-N-Benzoyl-*p*-nitrophenylserinol.—A sample (13 g.) of the dibenzoyl derivative was warmed with sodium hydroxide in ethanol–water and separated crystals on dilution with water, m.p. 215°, 9.5 g., 97% yield; recryst. from methanol, m.p. 217°, $[\alpha]^{26}D$ +114° in dimethylformamide.

Anal. Calcd. for $C_{16}H_{16}O_5N_2$: C, 60.7; H, 5.10. Found: C, 60.95, 60.74; H, 5.01, 5.11.

L-*erythro*-*p*-Nitrophenylserinol.—The N-benzoyl derivative (6 g.) was heated for one hour at reflux in 200 ml. of 6 *N* HCl. The solution was cooled, filtered and evaporated *in vacuo*. The residual solid was taken into 50 ml. of water and made basic with NH_4OH. The solution was extracted with methyl ethyl ketone, the extract dried over Na_2SO_4 and evaporated. The residue was crystallized from ethylene dichloride. Crystallization was very slow. The yield was 0.8 g., m.p. 112–113°, $[\alpha]^{26.5}D$ −2.5° in ethanol.

Reaction of the residual sirup from the crystallization with methyl dichloroacetate in methanol gave 2.0 of L-*erythro*-chloramphenicol, m.p. 176°, $[\alpha]^{26}D$ +12.5° in ethanol.

L-*threo*-1-Nitrophenyl-1-mesyloxy-2-benzamido-3-propanol.—L-*threo*-1-*p*-Nitrophenyl-1-mesyloxy-2-benzamido-3-benzoyloxypropane (34 g.) was suspended in one liter of methanol and treated with 75 ml. of 1 *N* NaOH. After two hours, the yellow precipitate was separated, 15.4 g., m.p. 146–147°, 58% yield.

Anal. Calcd. for $C_{17}H_{18}O_7N_2S$: C, 51.77; H, 4.60. Found: C, 51.68; H, 4.64.

L-*erythro*-2-Phenyl-4-hydroxymethyl-5-*p*-nitrophenyl-Δ^2-oxazoline.—The mesylate amide (above), 3.93 g., in 100 ml. of abs. ethanol was treated with 2 g. of freshly fused potassium acetate, refluxed four hours and let stand overnight. The potassium mesylate was separated and the filtrate evaporated *in vacuo*. The yellow product was crystallized from ether, 1.3 g., m.p. 179°, 43% yield.

Anal. Calcd. for $C_{16}H_{14}O_4N_2$: C, 64.5; H, 4.73; N, 9.38. Found: C, 64.54; H, 5.11; N, 9.48.

Infrared spectra support this assignment by showing O–H at 2.97 μ; C=N at 6.07 μ with the absence of N–H and of amide II.

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(5) J. Attenburrow, D. F. Elliott and G. F. Penny, *J. Chem. Soc.*, 310 (1948).

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Trichloromethyl Arenethiolsulfonates

BY CHIEN-PEN LO, HAROLD F. WILSON AND W. J. CROXALL

RECEIVED NOVEMBER 30, 1953

Trichloromethanesulfenyl chloride reacts with a variety of compounds, the primary reaction being the replacement of a reactive hydrogen or its equivalent by a Cl_3CS- group. Such reactions with hydroxy[1] or sulfhydryl[2] compounds, amines,[3] imides[4] and others[5] have been reported in the literature. We have found that trichloromethanesulfenyl chloride reacts with sodium arenesulfinates

(1) J. M. Connolly and G. M. Dyson, *J. Chem. Soc.*, 679 (1935); 827 (1937).

(2) (a) R. S. Hawley and A. R. Kittleson, U. S. Patent 2,553,777 (1951); (b) R. S. Hawley, U. S. Patent 2,553,778 (1951); (c) H. J. Backer and E. Westerhuis, *Rec. trav. chim.*, **71**, 1065 (1952).

(3) (a) B. Rathke, *Ann.*, **167**, 211 (1873); (b) T. B. Johnson and E. E. Hemingway, THIS JOURNAL, **38**, 1860 (1916); (c) J. M. Connolly and G. M. Dyson, *J. Chem. Soc.*, 822 (1934); 827 (1937); (d) R. S. Hawley, U. S. Patent 2,553,774 (1951).

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(5) (a) G. Sanna and S. Stefano, *Gazz. chim. ital.*, **72**, 305 (1942); (b) H. Britzinger, K. Pfannatiel, H. Koddebusch and K. E. Kling, *Ber.*, **83**, 87 (1950).

TABLE I

TRICHLOROMETHYL ARENETHIOLSULFONATES, RSO_2SCCl_3

	Crude yield, %	Solvent[a]	M.p.,[b] °C.	Formula	Sulfur, % Calcd.	Found
C_6H_5	58.5	..	Oil[c]	$C_7H_5Cl_3O_2S_2$	22.0	22.0
4-$CH_3C_6H_4$	46.5	A	67–68.5[d]	$C_8H_7Cl_3O_2S_2$	21.0	20.9
4-ClC_6H_4	80	A	56–57.5[e]	$C_7H_4Cl_4O_2S_2$	19.7	19.6[f]
3,4-$Cl_2C_6H_3$	97	A	53–54.5	$C_7H_3Cl_5O_2S_2$	17.8	18.1[g]
3-$NO_2C_6H_4$	79	A	65.5–66	$C_7H_4Cl_3NO_4S_2$	19.1	19.3[h]
4-$NO_2C_6H_4$	37	A	92–93	$C_7H_4Cl_3NO_4S_2$	19.1	19.1[i]
2-Cl-5-$NO_2C_6H_3$	88	B	118–119	$C_7H_3Cl_4NO_4S_2$	17.3	17.2[j]
4-Cl-3-$NO_2C_6H_3$	63	A	67–68	$C_7H_3Cl_4NO_4S_2$	17.3	17.7
4-$CH_3OC_6H_4$	92.5	A	52.5–54	$C_8H_7Cl_3O_2S_2$	21.0	20.8
2-$C_{10}H_7$	47	..	Oil	$C_{11}H_7Cl_3O_2S_2$	..[k]	..[k]
3-Cl_3CSSO_2-4-$CH_3OC_6H_3$	33.6	C	125.5–127	$C_9H_6Cl_6O_5S_4$	24.0	24.3

[a] Solvents for recrystallization: A, petroleum ether (boiling range, 55–110°); B, ethylene dichloride; C, benzene + petroleum ether. [b] Uncorrected. [c] H. J. Backer and E. Westerhuis[8] reported a b.p. of 148–150° (2 mm.). [d] Reported[8] m.p. 65.5–66.5°. [e] Reported[8] m.p. 56–56.5°. [f] Calcd.: Cl, 43.6. Found: Cl, 43.5. [g] Calcd.: Cl, 49.2. Found: Cl, 48.9. [h] Calcd.: N, 4.2. Found: N, 3.8. [i] Calcd.: N, 4.2. Found: N, 3.8. [j] Calcd.: N, 3.8. Found: N, 3.8. [k] Calcd. Cl, 31.1. Found: Cl, 30.9.

to yield well-defined trichloromethyl arenethiolsulfonates.[6,7] The physical properties and yields of the eleven trichloromethyl arenethiolsulfonates thus prepared[8] are given in Table I.

Experimental[9]

The sodium benzene- and *p*-toluenesulfinates were purchased from Eastman Kodak Company. The other sodium arenesulfinates were prepared by the reduction of the corresponding sulfonyl chloride with sodium sulfite or zinc dust.[10] In most cases, the crude sulfinates were used without further purification. The preparation of the hitherto unknown sodium anisole-2,4-disulfinate is described as follows.

Sodium Anisole-2,4-disulfinate.—Anisole (162 g.) was added to chlorosulfonic acid (1440 g.) with stirring and cooling. The mixture was stirred at room temperature overnight and then poured onto an ice–water mixture. The gummy product was taken up in carbon tetrachloride and washed with water. After the solvent was removed by distillation under reduced pressure, the anisole-2,4-disulfonyl chloride was obtained as a white solid (115 g.), m.p. 90–94°.

The above crude anisole-2,4-disulfonyl chloride (130 g.) was added to a stirred and cooled solution of sodium sulfite (164 g.) in water (500 ml.). The mixture was stirred at room temperature for two hours during which time it was kept slightly alkaline by the addition at intervals of small portions of 50% sodium hydroxide solution. The solid which separated upon cooling was collected by filtration. The sodium anisole-2,4-disulfinate, after two recrystallizations from water, was obtained as a white solid which weighed 105 g.

Anal. Calcd. for $C_7H_6O_5S_2Na\cdot H_2O$: S, 21.5. Found: S, 21.8.

The method of preparation of the trichloromethyl arenethiolsulfonates is illustrated by the following example.

Trichloromethyl 4-Chloro-3-nitrobenzenethiolsulfonate.—A mixture of potassium 4-chloro-3-nitrobenzenesulfonate (229 g.) and chlorosulfonic acid (232 g.) was heated at 135–140° for three hours. The mixture was poured onto ice and the oil was taken up in carbon tetrachloride. After the solvent was removed by distillation, the 4-chloro-3-nitrobenzenesulfonyl chloride was obtained as a viscous oil (119 g.). This was reduced by sodium sulfite (110 g.) as above. The solid sodium 4-chloro-3-nitrobenzenesulfinate was collected and dissolved in water (800 ml.). To this stirred solution was added a solution of trichloromethanesulfenyl chloride (74 g.) in carbon tetrachloride (150 ml.). The mixture was stirred for three hours. The organic layer was separated and concentrated *in vacuo* to give 94 g. of trichloromethyl 4-chloro-3-nitrobenzenethiolsulfonate.

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(6) For previous work on the formation of thiolsulfonates from sulfenyl chlorides and sulfinates, see, for example: (a) T. Zincke and F. Farr, *Ann.*, **391**, 72 (1912); (b) C. J. Miller and S. Smiles, *J. Chem. Soc.*, 224 (1925); (c) R. Child and S. Smiles, *ibid.*, 2702 (1926).

(7) For a summary of the discussion of the structure of thiolsulfonates, see R. Connor, Gilman's "Organic Chemistry," second ed., Vol. I, John Wiley and Sons, Inc, New York, N. Y., 1943, p. 912.

(8) An article by H. J. Backer and E. Westerhuis has recently appeared (*Rec. trav. chim.*, **71**, 1082 (1952)) in which the preparation of three of our compounds by the same method was reported.

(9) We are indebted to Dr. W E Craig for a generous supply of sodium 4-chloro- and 3,4-dichlorobenzenesulfinate and to Mr. T. P. Callan and his staff for chemical analyses.

(10) Adaptation of the method of F. C. Whitmore and F. H. Hamilton, "Organic Syntheses," Coll. Vol. I, John Wiley and Sons, Inc., New York, N. Y., 1944, p. 492.

O^{18} Exchange Reactions between Anhydrides and Carboxylic Acids[1,2]

BY L. PONTICORVO AND D. RITTENBERG[3]

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In a search for a method for determination of the O^{18} concentration of the α-carboxyl oxygen atoms of α-amino acids, we have investigated the Dakin-West[4] reaction. In this reaction the α-amino acid is warmed in a mixture of acetic anhydride and pyridine. Under these conditions α-amino acids yield 1 mole of CO_2 per mole of amino acid. When this reaction was carried out with phenylalanine containing 1.28 atom per cent. excess O^{18}, the CO_2 produced contained but 0.12 atom per cent. excess O^{18}. A similar result was obtained when benzoic anhydride replaced acetic anhydride. When the phenylalanine was kept in boiling acetic anhydride for one-half hour before addition of the base, the CO_2 evolved contained no detectable excess O^{18}.

A similar result was found when benzoic acid, containing 0.64 atom per cent. excess O^{18} was refluxed with acetic anhydride for one hour. Decarboxylation of the recovered benzoic acid pro-

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(2) The H_2O^{18} employed in these experiments was obtained by allocation of the Atomic Energy Commission.

(3) On leave 1953–1954, at The Institute for Advanced Study, Princeton, N. J.

(4) H. D. Dakin and R. West, *J. Biol. Chem.*, **78**, 91 (1928); **78**, 757 (1928).