

TABLE I
 TRICHLOROMETHYL ARENETHIOLSULFONATES, RSO₂SCCl₃

	Crude yield, %	Solvent ^a	M.p., ^b °C.	Formula	Sulfur, %	
					Calcd.	Found
C ₆ H ₅	58.5	..	Oil ^c	C ₇ H ₅ Cl ₃ O ₂ S ₂	22.0	22.0
4-CH ₃ C ₆ H ₄	46.5	A	67-68.5 ^d	C ₈ H ₇ Cl ₃ O ₂ S ₂	21.0	20.9
4-ClC ₆ H ₄	80	A	56-57.5 ^e	C ₇ H ₄ Cl ₄ O ₂ S ₂	19.7	19.6 ^f
3,4-Cl ₂ C ₆ H ₃	97	A	53-54.5	C ₇ H ₃ Cl ₅ O ₂ S ₂	17.8	18.1 ^g
3-NO ₂ C ₆ H ₄	79	A	65.5-66	C ₇ H ₄ Cl ₃ NO ₂ S ₂	19.1	19.3 ^h
4-NO ₂ C ₆ H ₄	37	A	92-93	C ₇ H ₄ Cl ₃ NO ₂ S ₂	19.1	19.1 ⁱ
2-Cl-5-NO ₂ C ₆ H ₃	88	B	118-119	C ₇ H ₃ Cl ₄ NO ₂ S ₂	17.3	17.2 ^j
4-Cl-3-NO ₂ C ₆ H ₃	63	A	67-68	C ₇ H ₃ Cl ₄ NO ₂ S ₂	17.3	17.7
4-CH ₃ OC ₆ H ₄	92.5	A	62.5-54	C ₈ H ₇ Cl ₃ O ₂ S ₂	21.0	20.8
2-C ₁₀ H ₇	47	..	Oil	C ₁₁ H ₇ Cl ₃ O ₂ S ₂	.. ^k	.. ^k
3-Cl ₃ CSSO ₂ -4-CH ₃ OC ₆ H ₃	33.6	C	125.5-127	C ₉ H ₅ Cl ₆ O ₃ S 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. Westerhuis³ reported a b.p. of 148-150° (2 mm.). ^d Reported⁸ m.p. 65.5-66.5°. ^e Reported⁸ 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 prepared⁸ are given in Table I.

Experimental⁹

The sodium benzene- and *p*-toluenesulfonates were purchased from Eastman Kodak Company. The other sodium arenethiolsulfonates were prepared by the reduction of the corresponding sulfonyl chloride with sodium sulfite or zinc dust.¹⁰ In most cases, the crude sulfonates 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 C₇H₆O₅S₂Na·H₂O: 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-

(6) For previous work on the formation of thiolsulfonates from sulfonyl chlorides and sulfonates, 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.

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 trichloromethanesulfonyl 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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O¹⁸ Exchange Reactions between Anhydrides and Carboxylic Acids^{1,2}

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In a search for a method for determination of the O¹⁸ concentration of the α -carboxyl oxygen atoms of α -amino acids, we have investigated the Dakin-West⁴ 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 CO₂ per mole of amino acid. When this reaction was carried out with phenylalanine containing 1.28 atom per cent. excess O¹⁸, the CO₂ produced contained but 0.12 atom per cent. excess O¹⁸. 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 CO₂ evolved contained no detectable excess O¹⁸.

A similar result was found when benzoic acid, containing 0.64 atom per cent. excess O¹⁸ was refluxed with acetic anhydride for one hour. Decarboxylation of the recovered benzoic acid pro-

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(2) The H₂O¹⁸ 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).

duced a CO₂ containing only 0.01 atom per cent. excess O¹⁸.

These results indicate that the oxygen atoms of carboxylic acids can exchange with those of acetic anhydride. This exchange is presumably due to reactions analogous to those involved in the formation of mixed anhydrides from acetic anhydride and other carboxylic acids at room temperature and their disproportionation on distillation.⁵ It also resembles that observed^{6,7} between acetic anhydride-1-C¹⁴ and acetyl chloride.

Experimental

Exchange Reactions of Phenylalanine.—Forty mg. of L-phenylalanine containing 1.28 atom per cent. excess O¹⁸ was added to 4 ml. of acetic anhydride and 2 ml. of pyridine and the mixture refluxed. After 2 to 4 minutes the phenylalanine went into solution. The system was flushed with oxygen-free nitrogen. When evolved CO₂ was being collected for O¹⁸ analysis the gases leaving the reaction vessel were passed through a trap cooled by CO₂-acetone and then into a trap cooled by liquid nitrogen. The CO₂ condensed in the latter trap was transferred to the gas manifold of a mass spectrometer by warming the trap to -80°. No contaminating gases were observed in the mass spectrometer.

In test experiments it was found that CO₂ began to be evolved about 7 minutes after the mixture was brought to reflux and the decarboxylation was completed in 15 minutes. These experiments show that the reaction is quantitative; from 98 to 101% of the theoretical was found for evolved CO₂.

When the phenylalanine was refluxed with acetic anhydride for 1 hour before addition of pyridine the amino acid went into solution but no CO₂ was formed until the pyridine was added.

Thirty mg. of the phenylalanine was added to 5 g. of benzoic anhydride and 2 ml. pyridine. The mixture was heated to reflux and the evolved CO₂ collected and analyzed as above. It contained 0.12 atom per cent. excess O¹⁸.

Preparation of Benzoic Acid-O¹⁸.—Ten cc. of benzotrichloride and 20 cc. of O¹⁸ labeled water were refluxed for 48 hours. The contents of the flask was chilled, normal water added, the benzoic acid filtered off and washed with cold water. The wet crystalline mass was dissolved with the aid of a minimum of 1 N NaOH and precipitated by acidification. The benzoic acid was promptly filtered off and washed with cold water. It was dried *in vacuo*; yield 5.0 g.; m.p. 121.6–122°. The silver salt was prepared, dried *in vacuo* and thermally decarboxylated in an evacuated Y tube (see Fig. 2 of ref. 8). The O¹⁸ concentration was 0.64 atom per cent. excess.

Exchange of Benzoic Acid-O¹⁸.—Two hundred and fifty mg. of the benzoic acid-O¹⁸ and 20 ml. of acetic anhydride were refluxed for 1 hour. The acetic anhydride was removed by vacuum distillation, the residue dissolved in 1 N NaOH and 30 minutes later the benzoic acid precipitated by addition of nitric acid. The benzoic acid was immediately removed by filtration, washed with cold water and dried *in vacuo*; yield 85 mg. Forty-five mg. of this benzoic acid was neutralized and dissolved with 1 N NaOH. AgNO₃ was added and the precipitated silver benzoate filtered, washed and dried *in vacuo* at 90°. The silver salt was thermally decarboxylated in an evacuated Y tube. It contained 0.01 atom per cent. excess O¹⁸.

Repetition of the above experiment with the addition of 1 ml. of acetic acid to the acetic anhydride gave a benzoic acid containing 0.00 atom per cent. excess O¹⁸.

When benzoic acid-O¹⁸ was dissolved in acetic anhydride and kept at room temperature for 90 minutes the O¹⁸ concentration in the benzoic acid was reduced to 0.52 atom per cent. excess. In this experiment the isolation was so conducted that all operations took place at room temperature or lower.

(5) W. Autenrieth, *Ber.*, **34**, 168 (1901).

(6) G. L. Curran, *J. Biol. Chem.*, **191**, 775 (1950).

(7) E. A. Evans, J. L. Huston and T. H. Norris, *THIS JOURNAL*, **74**, 4985 (1952).

(8) D. B. Sprinson and D. Rittenberg, *J. Biol. Chem.*, **180**, 707 (1949).

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The Reaction of Raney Nickel with Organoselenium Compounds

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As part of our work in determining the orientation of substitution reactions of dibenzoselenophene, we have tested the applicability of a reaction analogous to the Mozingo desulfurization reaction.¹ Mozingo used Raney nickel to remove sulfur from organosulfur compounds with a variety of sulfur-containing functional groups. Our modification of the desulfurization reaction applies to the removal of selenium from at least one member of each of the following classes of compounds: diarylselenides, arylheterocyclic selenides, diaryldiselenides, diarylselenium dichlorides, diarylselenones, arylselenocyanates and arylseleninic acids. The yields are generally fair except in cases where separations of the products are difficult. The weight of Raney nickel used was approximately 20 times the weight of sample. The usual desulfurization solvent, dilute ethanol, gave low yields. However, a mixture of alcohol and benzene greatly improved the process. Consequently, all other experiments were carried out in 10–20% by volume solution of ethanol in benzene. It is conceivable that better yields would result from variations of refluxing time, weight of nickel used, and solvent composition; but extended search for optimum conditions in this reaction was not carried out.

The compounds undergoing deselenization are listed in Table I. Most of our substances were chosen to yield biphenyl in view of the ease of iso-

TABLE I
COMPOUNDS UNDERGOING DESELENIZATION

Compounds deselenized	Reflux time, hr.	Product	Yield, %
Dibenzoselenophene ²	2.5	Diphenyl	87
<i>p,p'</i> -Diethoxydiphenylselenium	5	Phenetole	79
Di-(<i>o</i> -biphenyl) diselenide	3	Diphenyl	76
<i>p,p'</i> -Diethoxydiphenylselenium dichloride	4	Phenetole	43
2-Selenocyanobiphenyl	7	Diphenyl	84
Dibenzoselenophene oxide ²	5	Diphenyl	72
Dibenzoselenophene dichloride	5	Diphenyl	72
<i>p</i> -Selenocyanoaniline	5.5	Aniline	79
<i>o</i> -Biphenylseleninic acid ³	5.5	Diphenyl	62
<i>p,p'</i> -Dimethoxydiphenylselenone	5.5	Anisole	25
<i>p</i> -Selenocyanato- <i>N,N</i> -dimethylaniline	4.5	Dimethylaniline (as picrate)	14
Diphenyl diselenide	4	Benzene	0 ^a
Dibenzothiophene	3	Diphenyl	66 ^{a, 4}

^a Solvent was ethanol.

(1) R. Mozingo, D. Wolf, S. Harris and K. Folkers, *THIS JOURNAL*, **65**, 1013 (1943).

(2) J. D. McCullough, T. W. Campbell and E. S. Gould, *ibid.*, **72**, 5753 (1950).

(3) J. D. McCullough and E. S. Gould, *ibid.*, **71**, 674 (1949).

(4) F. F. Blicke and D. K. Sheets, *ibid.*, **71**, 4010 (1949).

(5) H. Gilman and D. L. Esmay, *ibid.*, **75**, 2947 (1953).