

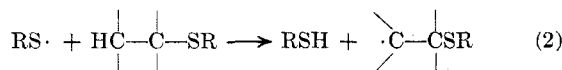
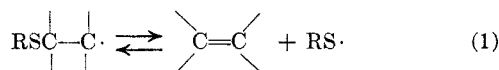
Free-Radical Cleavage of β -Hydroxy Thio Ethers to Ketones and Mercaptans¹EARL S. HUYSER AND RICHARD M. KELLOGG²

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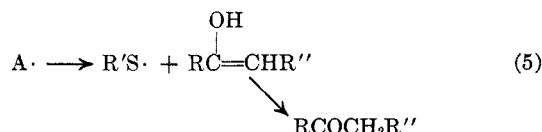
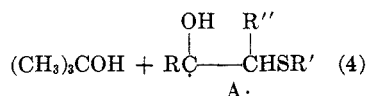
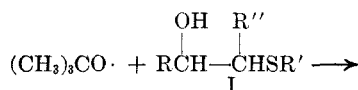
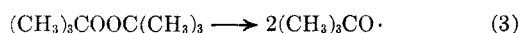
Certain β -hydroxy thio ethers ($RCHOHCH_2SR'$) have been found to undergo a facile cleavage yielding ketones and mercaptans in *t*-butyl peroxide induced reactions at 125°. A free-radical chain mechanism involving a β elimination of an alkanethiyl radical from an α -hydroxy- β -alkanethioalkyl radical ($RCHOHCH_2SR'$) which is produced by abstraction of a β hydrogen from the β -hydroxy thio ether by the eliminated thiyl radical is proposed for these reactions. In the case of 1-methanethio-2-propanol, the conversion to acetone and methyl mercaptan is essentially quantitative. With higher homologs, the reaction is complicated by the formation of thio-ketals from the products of the peroxide-induced reaction.

The reversibility of the addition of alkanethiyl radicals to unsaturated linkages³ suggests that formation of β -alkanethioalkyl radicals from thio ethers by abstraction of a β hydrogen might lead to cleavage of thio ethers. If an eliminated thiyl radical were the hydrogen abstractor, the over-all reaction would be the reverse of the familiar free-radical addition of a



mercaptan to an unsaturated linkage yielding a thio ether.⁴ In order to achieve the cleavage of a thio ether by such a free-radical chain path it would be necessary to have the β hydrogen of the thio ether specifically reactive toward abstraction by the eliminated thiyl radical. Furthermore, it would be advantageous if the unsaturated compound produced in the elimination step were less reactive toward readdition of the thiyl radical than the parent thio ether is toward abstraction of the β hydrogen by the eliminated thiyl radical.

Such a system is found in β -hydroxy thio ethers. *t*-Butyl peroxide induced reactions result in cleavage of such thio ethers yielding carbonyl-containing compounds and mercaptans as the major reaction products *via* the chain sequence 5 and 6. The chain-carrying radical $A \cdot$ is introduced into the system by abstraction of a hydrogen from the hydroxy-bonded carbon by

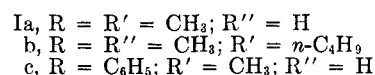
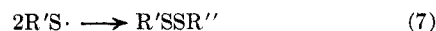
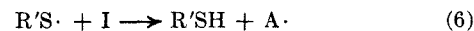


(1) This work was supported by a grant (GP-739) from the National Science Foundation.

(2) The work described was taken from the thesis of R. M. K. submitted in partial fulfillment of the requirements for the Ph.D. degree from the University of Kansas, 1965.

(3) C. Sivertz, W. Andrews, W. Eldsen, and K. Graham, *J. Polymer Sci.*, **19**, 587 (1956); C. Walling and W. Helmreich, *J. Am. Chem. Soc.*, **81**, 1144 (1959); E. S. Huyser and J. D. Taliaferro, *J. Org. Chem.*, **28**, 1676 (1963).

(4) For discussion of these reactions, see F. W. Stacey and J. F. Harris, Jr., *Org. Reactions*, **13**, 165 (1963).



a *t*-butoxyl radical. β elimination of the thiyl radical from $A \cdot$ (reaction 5) yields an enol which tautomerizes rapidly to the ketone precluding readdition of the eliminated thiyl radical. Abstraction of hydrogens from the hydroxy-bearing carbon of alcohols by thiyl radicals (reaction 6) have been reported previously.⁵ The reverse of the hydrogen atom abstraction, namely reaction of $A \cdot$ with the mercaptan, undoubtedly also occurs. However, the unimolecular elimination reaction of the thiyl radical from $A \cdot$ apparently competes favorably with the bimolecular hydrogen abstraction reaction of $A \cdot$ with the mercaptan.

Heating 1-methanethio-2-propanol (Ia) at 125° for 18 hr with 5 mole % *t*-butyl peroxide resulted in complete consumption of the thio ether. Gas chromatographic analysis showed that an essentially quantitative yield of acetone was produced as a reaction product. In addition to methyl mercaptan, which was allowed to distil from the reaction mixture, small quantities of dimethyl disulfide were also produced indicating that coupling of methanethiyl radicals (reaction 7) was the termination reaction of the chain sequence. Evidence supporting the free-radical chain character of the reaction comes from the effect of the amount of peroxide on the kinetic chain length of the reaction.⁶ Table I shows that the kinetic chain length increases as the initial amount of initiator is decreased. Such an increase in kinetic chain length would be expected for a chain reaction involving termination by a bimolecular reaction of chain-carrying

TABLE I

EFFECT OF PEROXIDE CONCENTRATION ON KINETIC CHAIN LENGTH OF DECOMPOSITION OF 1-METHANETHIO-2-PROPANOL

1-Methanethio-2-propanol, mmoles	<i>t</i> -Butyl peroxide, ^b mmole	Kinetic chain length
Initial	After reaction ^a	
2.424	0.078	10.8
2.419	0.175	15.0
2.379	0.614	21.5
2.458	0.162	31.8

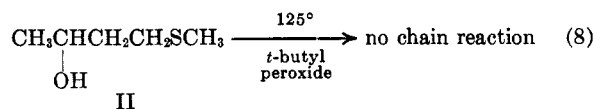
^a 17.5 hr at 125°. ^b Peroxide was completely consumed at the end of the reactions.

(5) S. G. Cohen and W. V. Sherman, *J. Am. Chem. Soc.*, **85**, 1642 (1963).

(6) Kinetic chain length is defined here as the number of moles of product formed per mole of initiator fragments produced. In this case, 2 moles of *t*-butoxyl radicals are produced per mole of initiator.

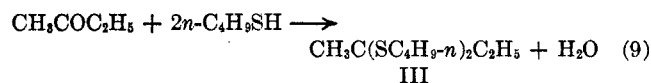
intermediates since decreasing initiator concentration would lower the concentration of chain-carrying species and hence the rate of termination.

After 18 hr of heating at 125° in the presence of 5 mole % *t*-butyl peroxide, 1-methanethio-3-butanol (II)



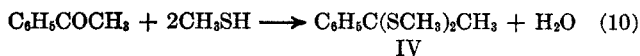
was recovered unchanged. The fact that no detectable amounts of mercaptan or 2-butanone were found in this reaction indicates that the hydrogen abstraction must occur at such a position that the radical produced is capable of a β elimination of the thiyl radical.

The *t*-butyl peroxide induced (10 mole %) reaction of 3-*n*-butylthio-2-butanol (Ib) resulted in approximated 70% reaction of the β -hydroxy thio ether. However, only half of the expected 2-butanone could be detected. Examination of the reaction mixture by thin layer chromatography indicated the presence of a high molecular weight material which was identified as 2,2-di(*n*-butylthio)butane (III), the thioketal formed by the reaction of the 2-butanone and *n*-butyl mercaptan produced in the free-radical reaction.

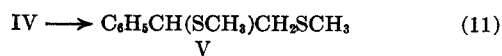


Support for this suggestion comes from the fact that small drops of water were observed in the reaction mixture.⁷ Gas chromatographic analysis of the reaction mixture indicated the presence of di-*n*-butyl disulfide in the reaction mixture.

Although heating 2-methanethio-1-phenylethanol (Ic) with di-*t*-butyl peroxide resulted in complete consumption of the thio ether, only 60% of the theoretical amount of acetophenone could be detected. The presence of water in the reaction mixture was indicative of the formation of the thioketal of acetophenone and methyl mercaptan, 1,1-di(methanethio)-1-phenylethane (IV). Distillation of the reaction mixture yielded a



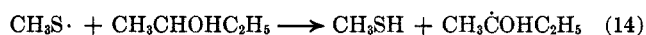
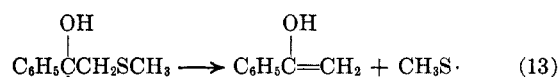
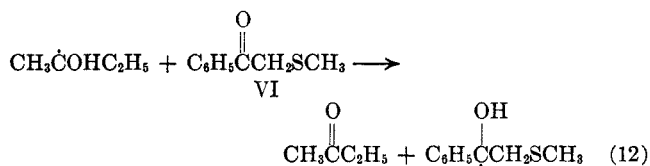
high-boiling fraction which consisted largely of IV. Thin layer chromatographic analysis showed that this fraction consisted of two components which were barely separable. One of the components had characteristics identical with those of an authentic sample of IV. The other component, although not definitely identified as such, may be 1,2-di(methanethio)-1-phenylethane (V), a material reported to result from thermal rearrangement of IV.⁸



(7) Distillation of a reaction mixture obtained from heating Ia with *t*-butyl peroxide resulted in isolation of only 40% of the expected acetone. A higher boiling product produced during the distillation was shown to have thin layer chromatographic properties identical with those of 2,2-di(methanethio)propane, the thioketal of acetone and methyl mercaptan, and was most likely formed from these products during the distillation.

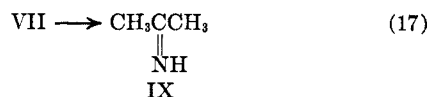
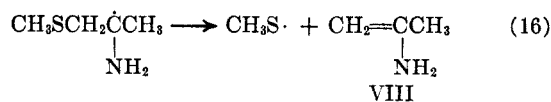
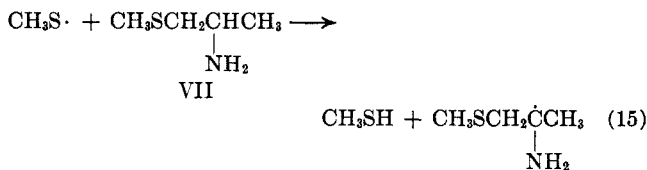
(8) R. Kh. Freidlina, A. B. Terent'ev, and R. G. Petrova, *Dokl. Akad. Nauk. SSSR*, **151**, 866 (1963).

ω -Methanethioacetophenone (VI) was reduced to acetophenone and methyl mercaptan by 2-butanol in a peroxide-induced reaction. This reduction of the keto thio ether probably occurs *via* the chain sequence in eq 12-14. The α -hydroxy- β -alkanethio alkyl radi-



cal is produced by hydrogen atom transfer of the oxygen-bonded hydrogen of the α -hydroxyalkyl radical to the carbonyl oxygen of the keto thio ether. Reductions of the carbonyl function of acetophenone by α -hydroxyalkyl radicals has been reported previously.⁹ The α -hydroxyalkyl radical required for the reaction with the keto thio ether is formed by abstraction of the α hydrogen from the 2-butanol by the eliminated thiyl radical. Again, as in the reaction of 2-methanethio-1-phenylethanol, only about half of the acetophenone expected on the basis of the thio ketone that had reacted was found. The rest may have been converted to the thioketal, a product which was detected by thin layer chromatographic analysis of the reaction mixture.

The α hydrogens of amines show a reactivity similar to that displayed by the α hydrogens of secondary alcohols toward abstraction by various free radicals.¹⁰ For that reason, β -amino thio ethers might be expected to undergo decomposition in a free-radical chain reaction in a manner analogous to the β -hydroxy thio ethers. 1-Methanethio-2-aminopropane (VII) would be expected to yield methyl mercaptan and isopropenylamine (VIII) in the chain sequence in eq 15 and 16 and tautomerization of VIII to acetone imine (IX) might be expected to occur. Heating VII with di-*t*-butyl peroxide at 125° for 30 hr resulted in complete reaction of the β -amino thio ether but, although formation of methyl mercaptan and some ammonia was evident, no isolable amounts of VIII and IX were found. Hydrolysis of the reaction mixture produced ammonia but only a trace of acetone could be detected in the



(9) E. S. Huyser and D. C. Neckers, *J. Am. Chem. Soc.*, **85**, 3641 (1963)
 (10) W. H. Urry, F. W. Stacey, E. S. Huyser, and O. O. Juveland, *ibid.*, **76**, 450 (1954); E. S. Huyser, C. Bredeweg, and R. VanScoy, *ibid.*, **86**, 4148 (1964).

hydrolysis mixture. The ambiguous nature of the products formed in the peroxide-induced reaction of VII may not be surprising in view of the chemistry of the proposed products of this reaction. Isopropenylamine has been reported to polymerize readily.¹¹ If tautomerization of some of the isopropenylamine did occur, the resulting acetone imine could condense with unreacted amine,¹² a reaction that could account for the ammonia produced in the reaction. Furthermore, the mercaptan could undergo Markovnikov addition to the imine producing an α -amino thio ether.¹³

Djerassi and co-workers¹⁴ reported that the Raney nickel desulfurization of certain β -mercaptoethanols to the corresponding alcohols is often accompanied by the formation of ketone. Since there is evidence for free-radical intermediates in Raney nickel desulfurizations,¹⁵ it seems quite possible that the free-radical chain sequence proposed for the β -hydroxy thio ethers is responsible for the dehydrosulfurization observed in the reactions of β -mercaptoethanols.

Experimental Section¹⁶

1-Methanethio-2-propanol.—1-Methanethio-2-propanone was prepared by reaction of 1-chloro-2-propanone with sodium methyl sulfide in refluxing methanol. Reduction of this ketone (26.0 g, 0.25 mole) with lithium aluminum hydride in dry ether yielded 21.4 g (0.206 mole, 82% of theory) of 1-methanethio-2-propanol, bp 61° (15 mm) [lit.¹⁷ bp 67° (20 mm)].

2-Methanethio-1-phenylethanol.— ω -Methanethioacetophenone, bp 155° (10 mm), was prepared in 86% yield by reaction of phenacyl chloride with sodium methyl sulfide in methanol. Reduction of the ketone (16.6 g, 0.10 mole) with lithium aluminum hydride in the manner described by Reisner¹⁸ yielded 12.5 g (75% of theory) of 2-methanethio-1-phenylethanol, bp 100° (0.5 mm), melting point of the 3,5-dinitrobenzoate of the alcohol, 107–108°.

Anal. Calcd for C₁₅H₁₄N₂O₅S: C, 53.03; H, 3.90; N, 7.73; S, 8.85. Found: C, 52.72; H, 4.22; N, 7.98; S, 9.02.

3-*n*-Butanethio-2-butanol.—3-Chloro-2-butanone was prepared in the manner described previously¹⁹ which consisted of hydrolysis and decarboxylation of ethyl α -chloro- α -methylacetate which was obtained from the reaction of ethyl α -methylacetate with sulfur chloride. Reaction of the chloro ketone (18.5 g, 0.19 mole) in a mixture of methanol and ethanol containing 15.6 g (0.174 mole) of *n*-butyl mercaptan and 4.0 g (0.174 mole) of sodium yielded 21.7 g (0.136 mole, 78% of theory) of 3-*n*-butanethio-2-butanol, bp 80–85° (7 mm). Reduction of this ketone (21.7 g, 0.136 mole) with lithium aluminum hydride yielded 14.8 g (0.088 mole, 65% of theory) of 3-*n*-butanethio-2-butanol, bp 94–95°.

Anal. Calcd for C₈H₁₈OS: C, 59.19; H, 11.20; S, 19.76. Found: C, 59.35; H, 11.50; S, 19.65.

1-Methanethio-3-butanol.—A mixture of α -methyl alcohol (5.0 g, 0.0695 mole) and methyl mercaptan (5.2 g, 0.108 mole) was sealed in a Pyrex tube and illuminated with a 275-w sunlamp at 35° for 48 hr. The resulting reaction mixture was washed with aqueous sodium hydroxide and then with water and dried over magnesium sulfate. Distillation yielded 3.3 g (0.0276 mole, 40% of theory) of 1-methanethio-3-butanol, bp 66–72° (2 mm).

(11) A. T. Blomquist, W. J. Tapp, and J. R. Johnson, *J. Am. Chem. Soc.*, **67**, 1519 (1945).

(12) V. Grignard and R. Escourrow, *Compt. Rend.*, **180**, 1883 (1925).

(13) G. W. Stacey and R. J. Morath, *J. Am. Chem. Soc.*, **74**, 3885 (1952); G. W. Stacey, R. J. Day, and R. J. Morath, *ibid.*, **77**, 3869 (1955).

(14) C. Djerassi, M. Gorman, and J. A. Henry, *ibid.*, **77**, 4647 (1955).

(15) W. A. Bonner, *ibid.*, **74**, 1034 (1952).

(16) All melting points are uncorrected. Infrared analyses were performed on a Beckman IR-8 spectrophotometer and the nmr analyses were performed on a Varian Associates Model A-60 nuclear magnetic resonance spectrometer. Microanalyses were performed by Weiler and Strauss Microanalytical Laboratory, Oxford, England.

(17) M. Hunt and C. S. Marvel, *ibid.*, **57**, 1691 (1935).

(18) D. B. Reisner, *ibid.*, **78**, 2132 (1956).

(19) J. H. Curd and A. Robertson, *J. Chem. Soc.*, 714 (1933).

Anal. Calcd for C₅H₁₂OS: C, 49.94; H, 10.08; S, 26.67. Found: C, 50.10; H, 10.21; S, 26.61.

1-Methanethio-2-aminopropane.—1-Methanethio-2-propanone oxime (18.0 g, 0.15 mole) was reduced with a twofold excess of lithium aluminum hydride in ether followed by hydrolysis. The amine was recovered by continuous liquid-liquid extraction with ether of the hydrolysis mixture. Distillation of the ether extracts yielded 9.3 g (0.089 mole, 59% of theory) of 1-methanethio-2-aminopropane, bp 59° (22 mm), melting point of the benzamide, 76–76.5°.

Anal. Calcd for C₁₁H₁₅SNO: C, 63.11; H, 7.24; N, 6.69; S, 15.32. Found: C, 63.10; H, 7.31; N, 6.92; S, 15.67.

1-Methanethio-2-propanol and Di-*t*-butyl Peroxide.—A reaction mixture consisting of 0.498 g (4.68 mmoles) of 1-methanethio-2-propanol and 0.040 g (0.27 mmole) of di-*t*-butyl peroxide was heated at 125° in a sealed Pyrex tube for 18 hr. After cooling, the tube was opened and most of the methyl mercaptan allowed to distill out of the reaction mixture. Gas chromatographic analysis of the liquid portion indicated the following components: acetone, 4.45 mmoles; *t*-butyl alcohol, 0.55 mmole; and dimethyl disulfide, 0.39 mmole. The chromatogram showed no evidence of either of the original reactants. Another reaction mixture consisting of 2.00 g (18.9 mmole) of 1-methanethio-2-propanol and 0.16 g (1.09 mmole) of di-*t*-butyl peroxide was heated for 10 hr at 125°. Distillation of the resulting mixture from glass wool gave 1.00 g of acetone, bp 56–60°, melting point of 2,4-dinitrophenylhydrazone, 124° (lit.²⁰ mp 126°). The pot residue remaining after removal of the acetone was subjected to thin layer chromatographic analysis (silica gel G, three parts ethyl acetate to two parts cyclohexane as the eluting solvent). The main component in the pot residue had a flow rate the same as that of an authentic sample of 2,2-di(methanethio)propane, bp 40° (6 mm), the thioketal of acetone and methyl mercaptan.

Anal. Calcd for C₁₃H₁₈S₂: C, 44.06; H, 8.89; S, 47.06. Found: C, 43.97; H, 8.91; S, 47.34.

Kinetic Chain Length Determinations.—Accurately weighed samples of 1-methanethio-2-propanol and *t*-butyl peroxide in the ratios shown in Table I were sealed in Pyrex tubes. The tubes were heated at 125° for 17.5 hr. After cooling, a weighed amount of chlorobenzene was added to each tube to serve as an internal standard for the gas chromatographic analysis of the reaction mixtures. In each case, the analysis showed that all of the peroxide had reacted. The amount of unreacted 1-methanethio-2-propanol was determined by comparing its peak area with that of the internal standard. The kinetic chain length was calculated from the amount of 1-methanethio-2-propanol that had reacted and the amount of peroxide that was initially present.²¹

3-*n*-Butanethio-2-butanol and *t*-Butyl Peroxide.—A mixture consisting of 3-*n*-butanethio-2-butanol (1.627 g, 10.03 mmoles) and *t*-butyl peroxide (0.136 g, 0.932 mmole) was sealed in Pyrex tube and heated at 125° for 18 hr. At the end of the heating there were droplets of water in the reaction mixture. The mixture was analyzed by gas chromatography and shown to consist of 2-butanone (3.56 mmoles), *t*-butyl alcohol (1.30 mmoles), di-*n*-butyl disulfide (0.63 mmole), a trace of *n*-butyl mercaptan, and unreacted 3-*n*-butanethio-2-butanol (2.72 mmoles). An authentic sample of 2,2-di(*n*-butanethio)butane, bp 114° (10 mm), the thioketal of 2-butanone and *n*-butyl mercaptan, was prepared in 45% yield from the ketone and mercaptan.

Anal. Calcd for C₁₂H₂₆S: C, 61.45; H, 11.20; S, 27.35. Found: C, 61.60; H, 11.11; S, 27.56.

The elevated temperatures required for gas chromatographic analysis of this thioketal resulted in extensive decomposition of the material on the column. However, thin layer chromatographic analysis of a portion of the β -hydroxy thio ether-peroxide reaction mixture showed the presence of a material with characteristics the same as those of the authentic sample of the thioketal. Isolation of this material from the thin layer chromatogram showed that it had infrared and nmr spectra essentially identical with those of the authentic sample of thioketal.

2-Methanethio-1-phenylethanol and *t*-Butyl Peroxide.—A reaction mixture consisting of 1.68 g (9.97 mmoles) of 2-methanethio-1-phenylethanol and 0.069 g (0.47 mmole) of *t*-butyl peroxide was heated in a sealed Pyrex tube at 125° for 18 hr.

(20) R. L. Shriner, R. C. Fuson, and D. Y. Curtin, "The Systematic Identification of Organic Compounds," John Wiley and Sons, Inc., New York, N. Y., 1956, p 316.

(21) See footnote 6.

Gas chromatographic analysis of the resulting mixture showed that all of the starting reagents had reacted and that 5.97 mmoles of acetophenone were formed. Distillation of another reaction mixture consisting of 6.72 g (39.9 mmole) of 2-methanethio-1-phenylethanol and 0.32 g (2.19 mmole) of *t*-butyl peroxide which had been heated for 18 hr at 125° yielded 1.6 g of material identified as acetophenone, collected over the boiling range 83–120° (8 mm) with the bulk distilling at 90° (8 mm). The nmr spectrum of the material was identical with that of acetophenone, melting point of 2,4-dinitrophenyl hydrazone, 245° (lit.¹⁸ mp 250°), melting point of the phenylhydrazone of the material, 102–104° (lit.¹⁸ mp 105°). After removal of the acetophenone, another distillation fraction [0.49 g, bp 120–142° (8 mm)] was collected. The infrared spectra of this material was essentially the same as that of an authentic sample of 1,1-di(methanethio)-1-phenylethane, bp 120° (0.4 mm), the thioketal obtained in 74% yield from acetophenone and methyl mercaptan.

Anal. Calcd for C₁₀H₁₄S₂: C, 60.54; H, 7.13; S, 32.33. Found: C, 60.57; H, 6.87; S, 32.55.

The nmr spectra of the authentic sample and the second distillation fraction however, were not the same. Thin layer chromatography on silica gel G of the second distillation fraction using a 2:1 mixture of ethyl acetate and cyclohexane gave a spot identical with that of the authentic sample of thioketal. However, a 10:1 mixture of cyclopentane and diethyl ether did resolve the second distillation fraction into two components, one of which was the same as that of the authentic sample of thioketal. The other component, on the basis of its infrared spectra being similar to that of the thioketal, has been tentatively identified as 1,2-di(methanethio)-1-phenylethane.

ω -Methanethioacetophenone, 2-Butanol, and *t*-Butyl Peroxide.

—A reaction mixture consisting of ω -methanethioacetophenone (0.474 g, 2.85 mmoles), 2-butanol (1.81 g, 24.5 mmoles), and *t*-butyl peroxide (0.150 g, 1.02 mmoles) was heated for 18 hr in a sealed Pyrex tube at 125°. Gas chromatographic analysis of the resulting reaction mixture indicated the following amounts

of material were present: unreacted ω -methanethioacetophenone, 2.27 mmoles; 2-butanone, 1.12 mmoles; and acetophenone 0.24 mmole. Thin layer chromatographic analysis of the reaction mixture on silica gel G using a 2:1 mixture of ethyl acetate and cyclohexane gave a spot identical with that of 1,1-di(methanethio)-1-phenylethane, the thioketal of acetophenone and methyl mercaptan.

1-Methanethio-3-butanol and *t*-Butyl Peroxide.—A reaction mixture consisting of 1-methanethio-3-butanol (0.606 g, 5.04 mmoles) and *t*-butyl peroxide (0.037 g, 0.025 mmole) was heated in a sealed Pyrex tube at 125° for 18 hr. On opening the tube, no odor of mercaptan was evident. Gas chromatographic analysis of the reaction mixture showed that 4.75 mmoles of the starting hydroxy sulfide had not reacted.

1-Methanethio-2-aminopropane and *t*-Butyl Peroxide.—A mixture of 1-methanethio-2-aminopropane (2.01 g, 19.13 mmoles) and *t*-butyl peroxide (0.15 g, 1.01 mmoles) was heated at 125° for 30 hr in a sealed tube. Both methyl mercaptan and ammonia were detected by their odors when the tube was opened. Examining the mixture by gas chromatography indicated that all of the starting amine was consumed. *t*-Butyl alcohol and dimethyl disulfide were identified from the chromatographic analysis as reaction products by comparison of their retention times with those of authentic samples of these materials. Addition of water to the reaction mixture resulted in evolution of ammonia. Gas chromatographic analysis of the hydrolysis mixture indicated the presence of acetone.

The hydrolysis mixture was dissolved in dioxane and dried, and after the dioxane had been evaporated in a stream of nitrogen, a viscous, red liquid remained. Sulfur was detectable in this material (sodium fusion). Thin layer chromatography on silica gel G using a 2:3 mixture of methanol and chloroform containing a few drops of ammonium hydroxide resolved this mixture into six components, none of which corresponded to that of the starting amine. No further investigations were made of the products of this reaction.

Trichloroacetoacetates. I. Synthesis and Reactions of Ethyl and β,β,β -Trifluoroethyl Trichloroacetoacetates

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A study of the reaction of chloral and ethyl diazoacetate as a potential source of ethyl trichloroacetoacetate (1) showed that the main product of this reaction was ethyl 3-(trichloromethyl)glycidate (2). The reaction of trichloroacetyl chloride, ketene, and an alcohol in liquid sulfur dioxide was found to be an excellent method to prepare trichloro- β -keto esters. The acid hydrolysis of 1 yielded α,α,α -trichloroacetone, but this reaction could not be utilized as a general synthetic route to trichloromethyl ketones because alkylation of the ester could not be accomplished. The reactions of 1 with amines were studied and the products formed depended on the basicity and structure of the amine. Ammonia reacted with the ester to form ethyl malonamate. Primary aliphatic amines yielded malonamides and secondary amines formed amine salts. Aromatic amines did not react with 1 under similar conditions, but in the presence of polyphosphoric acid they gave 2-trichloromethyl-4-quinolones. These compounds could be hydrolyzed to kynurenic acids, thus providing a new synthetic route to these compounds. The condensation of 1 with *o*-phenylenediamine, under neutral conditions, yielded 4-(trichloromethyl)-1H-1,5-benzodiazepin-2(3H)-one.

While the reactions of ethyl trifluoroacetoacetate have been investigated by several authors³ the same is not true of the corresponding trichloroacetoacetate (1) which is not commercially available.

The Synthesis of 1.—Schlotterbeck first reported to have synthesized 1 by the reaction of chloral with ethyl

diazoacetate.⁴ Arndt and co-workers prepared the same ester by oxidation of ethyl 4,4,4-trichloro-3-hydroxybutanoate with chromium trioxide.⁵ These authors established that the Schlotterbeck method gave a mixture. They attempted to separate the mixture but could not obtain acceptable analytical data for any other product than the acetoacetate. Smrt, Beránek, and Šorm, while studying the reactions of activated acid chlorides with ketene, prepared 1 by treating ketene with trichloroacetyl chloride.⁶ We

(1) Abstracted in part from the Ph.D. dissertation of D. K. Wald, University of Pennsylvania, 1965.

(2) Recipient of E. F. Smith Memorial Scholarships, 1962–1964.

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