TABLE I

Substance	Used, g.	Cu-(OAc)$_2$, g.	NH$_4$-NO$_3$, g.	80% Acetic acid, cc.	Di-ke-tone, M. p., °C.[a]	Yield, %
Benzoin	10.6	0.1	5.0	35.0	95	100
Anisoin	2.04	.015	0.75	7.5	132	97
o-Veratroin	1.66	.1	0.5	10.0	146	98
Furoin	1.92	.2	1.0	30.0	165	91

[a] All melting points are of the products as formed without further purification, and corrected for the emergent stem.

not affect the benzoin. To 2.00 g. of a mixture of equal quantities of benzil and benzoin dissolved in 45 cc. of ethanol, a solution of 0.1 g. of sodium cyanide in 5 cc. of water is added, and shaken for ten minutes. Five grams of sodium bisulfite dissolved in 50 cc. of water is then added and the precipitated benzoin filtered and dried; recovered, 1.00 g., m. p. 135° (cor.).

Anisil and *o*-veratril (2,3,2′3′-tetramethoxybenzil) were checked by sodium cyanide cleavage. The acids that formed showed no melting point depression when mixed with corresponding acids obtained by oxidation of the aldehydes. Furil showed no melting point depression when mixed with furil obtained by another method.[8]

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Summary

1. A convenient method is described for the oxidation of α-hydroxy ketones to diketones by the use of catalytic amounts of copper, iron, nickel and cobalt salts, which are regenerated continuously by means of ammonium nitrate.

2. The ammonium nitrite formed is decomposed by the acetic acid allowing pure diketones to crystallize.

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[CONTRIBUTION FROM THE ORGANIC LABORATORY OF THE WYETH INSTITUTE OF APPLIED BIOCHEMISTRY]

Reaction of Mercaptans with Unsaturated Compounds

BY J. LESTER SZABO AND ERIC T. STILLER[1]

In recent articles by Rapoport, Smith and Newman[2] and Hurd and Gershbein[3] the addition of mercaptans to unsaturated compounds is reported. We wish to report (Table I) work of a similar nature carried out in this Laboratory over the past few years. We have found this reaction to be generally applicable to the facile preparation of a wide variety of unsymmetrical sulfides.

Comparing catalysts for the addition of benzyl mercaptan to ethyl acrylate in dioxane as solvent, aqueous and methanolic sodium hydroxide solutions were found unsatisfactory since gels formed before all of the acrylate had been added (yields 75 and 78%, respectively). Triton B[4] gave the best yield (94%) followed closely by anhydrous potassium carbonate and tetra-(2-hydroxyethyl)-ammonium hydroxide.

Comparing solvents with triton B catalyst, benzene was more satisfactory than dioxane as the catalyst could be washed out with small amounts of water (yield 90%). Ethanol was also tried but was inferior (yield 62%).

The addition of mercaptans to unsaturated aldehydes may take at least two courses. In the case of ethyl mercaptan and crotonaldehyde addition took place at the double bond. However, the reaction between benzyl mercaptan and cinnamaldehyde took a different course. The first fraction on distillation proved to be cinnamaldehyde dibenzyl mercaptal. This was shown by the fact that it did not yield a dinitrophenylhydrazone and on distillation in the presence of traces of acid it yielded benzyl mercaptan; the large residue was not identified.

A dioxane solution of octene and octyl mercaptan in the presence of triton B[4] at room temperature gave only a small yield of dioctyl sulfide in a two-hour reaction period. The reaction was not further studied but the yield can undoubtedly be improved by raising the temperature and increasing the time. Isosafrole behaved similarly.

The authors are grateful to Dr. William F. Bruce of this Laboratory for aiding in the preparation of this paper.

Experimental

Triton B, acrylonitrile, methyl and ethyl acrylates were obtained through the courtesy of Dr. E. H. Riddle, Rohm & Haas Co., to whom we are grateful. The methyl vinyl ketone was obtained through the courtesy of du Pont. The thioglycol and tetra-(2-hydroxyethyl)-ammonium hydroxide were obtained from Carbide and Carbon, while the other compounds were Eastman Kodak Co. products. All were used without purification or removal of antioxidants.

The compounds described here were prepared as follows: one mole of the mercaptan was dissolved in 200 cc. of solvent and 10 g. of the catalyst was then added. To this mixture one mole of the unsaturated compound was then added with stirring in small portions so as to control the temperature. In the case of methyl and ethyl mercaptans, the temperature was kept below the boiling point of the mercaptan. In the addition of ethyl mercaptan to ethyl acrylate and to vinyl acetate, the temperature reached 55 and 45°, respectively, so rapidly that difficulty was experienced in cooling the reaction unless it was precooled, while with benzyl mercaptan the temperature was kept below

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[1] Present address: Squibb Institute for Medical Research, New Brunswick, New Jersey.

[2] Rapoport, Smith and Newman, THIS JOURNAL, 69, 693 (1947); see references 2 and 3 for a brief bibliography.

[3] Hurd and Gershbein, *ibid.*, 69, 2328 (1947).

[4] An approximately 35% solution of benzyltrimethylammonium hydroxide.

TABLE I

ADDITION OF MERCAPTANS TO UNSATURATES

	Unsaturate[a]	Products	Yield,[b] %	B. p. (uncor.) °C.	mm.	n^t_D	t	Sulfur,[c] % Calcd.	Found
1	Vinyl acetate	Thiodiglycol	20[d]	80–89	34	1.4628	26	26.22	26.80
		Thiodiglycol monoacetate	40[d]	120–121	34	1.4728	26	19.52	19.70
2	Vinyl acetate	β-Benzylthioethanol[e]	73	70.5	1	1.5542	26	19.06	18.95
3	Allyl alcohol	α-Benzylthiopropanol	51.5[f]	119.5	1	1.5711	21	17.58	17.50
4	Ethyl acrylate	Ethyl β-benzylthiopropionate[g]	94	134–136	1.7	1.5329	20	14.27	14.34
5	Acrylonitrile	β-Benzylthiopropionitrile[h]	95	131[i]	0.9	1.5655	20	18.06	18.46
6	Maleic anhydride	*dl*-Benzylthiomalic anhydride[j]	74	232–235	4				
		dl-Benzylthiomalic acid						13.33	13.32
7	Allyl isothiocyanate	α-Benzylthiopropyl isothiocyanate[k]	87	102–105	0.2	1.5770	22	28.70	28.40
8	Cinnamaldehyde	Cinnamaldehyde dibenzyl mercaptal	43.5	178–181	4	1.6071	29	17.69	17.47
9	Methyl vinyl ketone	4-Benzylthio-2-butanone[l]	71	131.5	1.8	1.5490	26	16.50	16.50
10	Acrylonitrile	β-Methylthiopropionitrile[m]	74	100–106	22	1.4813	28	31.69	31.52
11	Methyl acrylate	Methyl β-methylthiopropionate[n]	84	77–78	4	1.4600	32		
12	Ethyl acrylate	Ethyl β-methylthiopropionate	95	88	18				
13	Crotonaldehyde	β-Ethylthiobutyraldehyde	30	160–180	2	1.5291	27	24.23	24.8
14	Ethyl acrylate	Ethyl β-ethyl thiopropionate	93	95–97	18	1.4575	26	19.77	19.80

[a] Mercaptans used: 1, thioglycol; 2 to 9, benzyl mercaptan; 10 to 12, methyl mercaptan; 13 and 14, ethyl mercaptan. Dioxane used as solvent except in 13 and 14, where benzene was used, while triton B was used as catalyst. [b] In most cases the reaction was exothermic and where low yields were encountered, they were often traced to the loss of readily volatile reactants. [c] In some cases considerable difficulty was experienced in obtaining satisfactory analyses for sulfur unless the products were carefully fractionated through an efficient column. As examples ethyl β-benzylthiopropionate and 4-benzylthio-2-butanone gave, respectively, 15.15 and 14.46% sulfur when distilled through a modified Vigreux column as against the theoretical 14.27 and 16.50%. One distillation through a Todd column gave 14.34 and 16.50%, respectively. These results may be due to small quantities of by-products since in some cases solid crystalline residues remained in the still pot. The authors are grateful to Mr. Thomas McCrea for the analyses reported here. [d] If recovered thioglycol is taken into account, the yield is practically quantitative. [e] Only the alcohol could be isolated. We believe that by keeping the temperature lower hydrolysis could be largely avoided. [f] The yield reported here was obtained only after an eight-hour heating period on the steam-bath. [g] Sulfone, m. p. 97–99°. S, calcd. 12.5, found 12.5 (prepared by permanganate oxidation in acetone). Mercurichloride, m. p. 95–98°. S, calcd. for $C_{12}H_{16}O_2S{\cdot}HgCl_2$ 6.48; found, 6.80. [h] Compounds 5, 10 and 11 were previously prepared by the same method in reference 3. Sulfone, m. p. 116–118°. S, calcd. 15.31, found 15.80; reference 3 gives m. p. 117–117.5°. [i] Reference 3 gives b. p. 152–153° at 2 mm., $n^{20}D$ 1.5625. [j] The anhydride was not further characterized except as the acid, m. p. 192° after crystallization from ethyl acetate. Andreasch, *Monatsh.*, **18**, 87 (1897), gives m. p. 181. Neutral equiv., calcd. 248, found 247. [k] Mercurichloride, dec. 210°. S, calcd. for $C_{11}H_{13}NS_2{\cdot}2HgCl_2$ 8.14. found 8.7. [l] Mercurichloride, m. p. 92°. [m] A reaction temperature of 0 to −10° was maintained and the reaction was stopped after two hours. Mercurichloride, m. p. 103.5–104.5°. Reference 6 gives b. p. 101–104° at 24 mm., and mercurichloride m. p. 102–103.5°; reference 3 gives b. p. 97° at 15 mm., $n^{20}D$ 1.4840. [n] Reference 3 gives b. p. 80.5° at 15 mm., $n^{20}D$ 1.4646; mercurichloride m. p. 88.5–89°. The ester was converted to the free acid and had b. p. 125° at 12 mm., $n^{31}D$ 1.4839. The mercurichloride, fine crystals from alcohol, m. p. 165–167° (*cf.*, references 3, 5 and 6). [o] Reference 5 gives b. p. 95° at 20 mm., 192° at 760 mm.

60°. If the unsaturated compound was a solid it was dissolved in the same solvent as was used for the mercaptan, if liquid it was added without solvent.

When water soluble solvents were used the reaction mixtures were diluted with water, extracted with ether or benzene, the extract washed with water or dilute sodium hydroxide followed by water, dried, the solvent removed and the residue fractionated. With water insoluble solvents the catalyst was washed out with small amounts of water, the solvent removed and the residue fractionated.

β-Methylthiopropionyl Chloride.[3]—B. p. 66–69° (2 mm.), melted below room temperature and was obtained in 54% yield by warming the acid with thionyl chloride at 50° for two hours. The acyl cyanide was prepared from the chloride and cuprous cyanide crystallized in large plates from isopropanol and had m. p. 66–66.5° but was not analyzed. Its 2,4-dinitrophenylhydrazone had m. p. 155–155.5°.

β-Benzylthiopropionic Acid.[3]—The ethyl ester, 50 g., was refluxed for two hours with 60 cc. of 20% hydrochloric acid. The oily layer was extracted with benzene, the benzene removed and the residue fractionated. The product, b. p. 147° at 0.5 mm., solidified to a crystalline solid, m. p. 81°; yield *ca.* 90%.

Anal. Calcd. for $C_{10}H_{12}O_2S$: S, 16.3; neutral equivalent, 196. Found: S, 16.6; neutral equivalent, 202.

Summary

1. The addition of various mercaptans to ten different unsaturated compounds bearing functional groups was found to proceed smoothly and rapidly in the presence of selected alkaline catalysts.

2. In general, excellent yields were obtained from commercially available reagents.

3. The reaction is a general one and can be used to prepare a large number of unsymmetrical sulfides.

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(5) Barger and Coyne, *Biochem. J.*, **22**, 1417 (1928).

(6) Akabori, Kaneko and Mochizuki, *J. Chem. Soc. Japan*, **59**, 1135 (1938).