TABLE I

REDUCTION OF SULFOXIDES BY TRIPHENYLPHOSPHINE AND CARBON TETRACHLORIDE

Sulfoxide	M.p. °C.	Lit. m.p., °C.	Sulfide Yield, %	Sulfide M.p., °C.	Sulfide Lit. m.p., °C.
Dimethyl[a]			82	157.5–163.5[b]	150–151[b]
Di-*p*-tolyl	94–95	92[c]	100	54–57.5	57.3[d]
Di-*p*-hydroxyphenyl	195–196	195[e]	27	135.5–147.5	151–151.5[f]
Di-*p*-methoxyphenyl	95–96	93–94[g]	90	38.5–42.5	46[f]
Di-*p*-bromophenyl	154–155	153[h]	94	114.5–115.5	112[i]
Di-*p*-nitrophenyl	182–187	178–180[j]	83	150–153	158–160[k]
Phenoxathiin-10-oxide	154–155	158–159[l]	91	51.5–55	57.5–58[m]

[a] Matheson Coleman and Bell product redistilled *in vacuo*. [b] Mercuric chloride complex reported in ref. 4. [c] H. C. Parker, *Ber.*, **23**, 1845 (1890). [d] E. Fischer, *ibid.*, **48**, 96 (1915). [e] S. Smiles and A. W. Bain, *J. Chem. Soc.*, **91**, 1119 (1907). [f] G. Tassinari, *Gazz. chim. ital.*, **17**, 83 (1887). [g] S. Smiles and A. Le Rossignol, *J. Chem. Soc.*, **93**, 755 (1908). [h] J. Boesecken, *Rec. trav. chim.*, **29**, 315 (1910). [i] K. W. Rosenmund and H. Harns, *Ber.*, **53**, 2234 (1920). [j] H. H. Szmant and J. J. McIntosh, *J. Am. Chem. Soc.*, **73**, 4356 (1951). [k] C. C. Price and G. W. Stacy, *Org. Syn.*, **28**, 82 (1948). [l] H. D. K. Drew, *J. Chem. Soc.*, 511 (1928). [m] C. M. Suter and Ch. E. Maxwell, "Organic Syntheses," Coll. Vol. II, John Wiley and Sons, Inc., New York, N. Y., 1943, p. 485.

While the mechanism of this reaction is currently under study, it is very likely that the reduction of the sulfoxides is brought about by the dichloromethylidene derivative of the triphenylphosphine produced[5] according to this equation.

$$2Ph_3P + CCl_4 \longrightarrow Ph_3P{=}CCl_2 + Ph_3PCl_2$$

Furthermore, one is tempted to suggest that the ylide reacts subsequently with the sulfoxide to give an intermediate sulfur ylide, similar to the known reaction of carbonyl compounds.[5]

$$Ph_3P{=}CCl_2 + R_2SO \longrightarrow Ph_3PO + (R_2S{=}CCl_2)$$

Although the fate of the $=CCl_2$ moiety is not clear, the following possibility is suggested at this time.

$$(R_2S{=}CCl_2) + Ph_3PCl_2 \longrightarrow R_2S + CCl_4 + Ph_3P$$

In favor of this suggestion is the observation that a nearly theoretical yield of di-*p*-bromophenyl sulfide is obtained when equimolar quantities of the sulfoxide and triphenylphosphine are allowed to react.

We wish to add that a large-scale experiment employing dimethyl sulfoxide failed to provide evidence for the formation of tetrachloroethylene. This would indicate that the dichlorocarbene, a possible decomposition product of the sulfur ylide, is either not produced or efficiently scavenged[6,7] by triphenylphosphine.

(5) R. Rabinowitz and R. Marcus, *J. Am. Chem. Soc.*, **84**, 1312 (1962).
(6) G. Wittig, *et al.*, *Angew. Chem.*, **72**, 324, 4.7 (1960).
(7) D. Seyferth, S. O. Grim, and T. O. Read, *J. Am. Chem. Soc.*, **82**, 1510 (1960).

Solutions of Organic Compounds in Fused Alkali Thiocyanates

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Received November 12, 1964

The number of reports of reactions between organic compounds and fused salts is increasing.[1] These reactions, understandably, involve a gas in contact with the high-temperature melt. Homogeneous reactions are rare, though some interesting current research makes use of fused tetra-*n*-alkylammonium nitrates.[2]

The melting points of potassium thiocyanate (177°) and of a 3:1 mixture by weight of KSCN and NaSCN (about 130°) are low enough to permit the study of organic compounds in the fused salts. While investigating organic reactions in these media, we observed the high solubility of a number of polyhydroxy compounds. At 150° in fused KSCN–NaSCN, pentaerythritol, hydroquinone, ethylene glycol, methanol, and water are very soluble and sucrose, glucose, and *p*-nitroaniline are fairly soluble, glucose being recoverable as the osazone. The carbohydrate solutions begin to turn yellow after 10 min. at 150°. Triphenylmethyl chloride, triphenylcarbinol, hexyl bromide, phenol, borneol, *p*-toluidine, and pyridine are relatively insoluble. Benzoic acid is soluble and can be sublimed unchanged from the melt, but some decomposition of the thiocyanate occurs, probably due to the formation of HSCN.

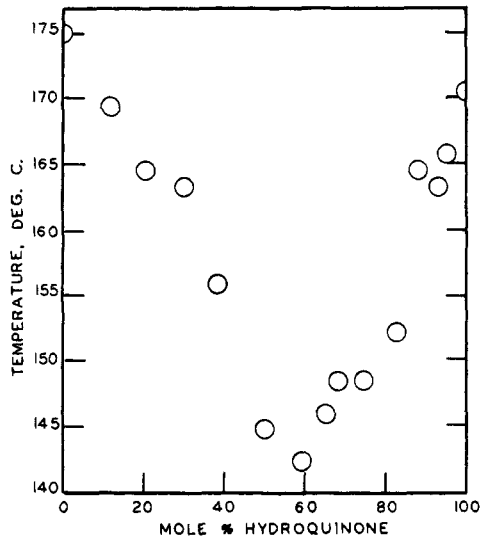

Figure 1.—Freezing point–composition plot for potassium thiocyanate–hydroquinone system.

The hydroxy compounds are apparently un-ionized in solution. Alizarin dissolves to form an orange solution and only when a trace of sodium hydroxide is added, does the deep blue color of the anion appear. The addition of solid benzoic acid changes the color back to yellow. The n.m.r. spectrum of pentaerythritol in KSCN–NaSCN at 150° shows two singlets, separated by 0.4 p.p.m. at 60 Mc.

The fused-salt solubility of the limited number of compounds observed shows some similarity to their water solubility. There are differences, for example ethanol is not miscible at 150°, though there is con-

(1) D. C. Coldiron, L. F. Albright, and L. G. Alexander, *Ind. Eng. Chem.*, **50**, 991 (1958); M. Fild, W. Sundermeyer, and O. Glemser, *Ber.*, **97**, 620 (1964); and earlier references.
(2) J. E. Gordon, *J. Am. Chem. Soc.*, **86**, 4492 (1964).

siderable mutual solubility in the two-phase system. Pyridine is insoluble, perhaps because of the impossibility of any hydrogen bonding, and sodium benzoate is not wet by fused potassium thiocyanate.

A rough freezing point–composition diagram (Figure 1), constructed from cooling curves for the system KSCN–hydroquinone, shows a minimum at about 140° and 60 mole % of hydroquinone. The organic compound (m.p. 171°) and the fused salt are completely miscible above 177°.

Experimental

Reagent grade potassium thiocyanate and sodium thiocyanate were oven dried at 150° for 6 hr. In the solubility tests, 0.1 g. of organic compound was stirred in a test tube with 10 g. of the molten solvent, 75% KSCN–25% NaSCN. Temperature was maintained at 150° by an aluminum-block thermostat containing recesses filled with silicone oil. The solubilities of methanol and ethanol in the fused thiocyanate were observed in sealed tubes behind a safety shield. The compounds classified above as insoluble are probably far below 0.1 g./10 g. in solubility.

Pentaerythritol (2.3 g.) easily dissolved in 10 g. of molten potassium thiocyanate, lowering the melting point to 156°. Certainly the solubility would be much higher at 176°.

The hydroquinone–KSCN mixtures were sealed into Pyrex tubes 12 × 120 mm., each with a 20-mm. well pushed into the lower end to accommodate a chromel–alumel thermocouple. The tubes were heated in a furnace to 200° and the cooling curves were obtained on a Sargent recorder.

The preliminary n.m.r. spectrum was obtained on a Varian A-60 spectrometer with variable-temperature probe.[3] The TMS standard is of course not feasible at 150° and no other was used.

Acknowledgment.—The authors wish to thank the U. S. Army Research Office (Durham) for support, and Mr. Murray Margolis and Mrs. Edna M. Luck[4] for assistance in the laboratory.

(3) We are indebted to Mr. Robert A. Pages for this determination.
(4) National Science Foundation summer research participant, 1959.

A Convenient Preparation of S-Benzhydryl- and S-Trityl-L-cysteine[1]

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Received December 10, 1964

In connection with our work on the synthesis of unsymmetrical cystine peptides, a simple, rapid method for the preparation of S-benzhydryl-(DPM-) (I) and S-trityl-L-cysteine (II) was desired. The method should give good yields and be readily adaptable to large-scale laboratory operations. The best published procedures[3] for the preparation of I and II, from L-cysteine hydrochloride or tosylate, suffer from the disadvantage of the rather low crude yields of I (53%) and II (75%).

In view of these limitations the present procedure was devised. The method involves the direct S-alkylation of L-cysteine hydrochloride using the appropriate alcohol and boron trifluoride etherate in acetic acid. The scheme provides high yields of pure products and, as illustrated in the synthesis of I, is applicable to large-scale synthesis. In this regard it should be noted that the present procedure for the preparation of I is superior both in yield and simplicity to the scheme classically used for the synthesis of S-benzyl-L-cysteine[4] (III).

(1) Supported in part by Grant A-3416 from the Institute of Arthritis and Metabolic Diseases of the National Institutes of Health, U. S. Public Health Service.
(2) Shell Chemical Corp. Fellow, 1963–1964.
(3) L. Zervas and I. Photaki, *J. Am. Chem. Soc.*, **84**, 3887 (1962).

Experimental[5]

S-Benzhydryl-L-cysteine (I).—Into a 2-l. erlenmeyer flask were placed 157.6 g. (1 mole) of L-cysteine hydrochloride[6] and 1 l. of glacial acetic acid. The mixture was heated on a steam bath with occasional swirling until the temperature reached 60°, whereupon 184.2 g. (1 mole) of benzhydrol was added and the temperature was again brought to 60°. Then was added in one portion 140 ml. (a 10% excess) of boron trifluoride etherate, and the mixture was heated and swirled for another 15 min. while the temperature rises to 80°. The thick mixture was transferred to a 4-l. beaker with the aid of 1500 ml. of ethanol, 500 ml. of water was added, and the mixture was stirred until homogeneous. The solution was treated with 300 g. of anhydrous, powdered sodium acetate, added in one portion with rapid stirring. The mixture was cooled to 10° and filtered, and the product was washed successively (and thoroughly) with water, absolute ethanol, and ether. The product was dried *in vacuo* over phosphorus pentoxide and sodium hydroxide and appeared as 259 g. (90%) of white, odorless solid: m.p. 206–207° dec., unchanged on one recrystallization[3] (86% recovery); $[\alpha]^{22}D$ +15.2° ± 0.3° (*c* 1.7, 0.1 *N* ethanolic HCl); reported[3] m.p. 202–203°, $[\alpha]^{25}D$ +16.9° (*c* 2.9, 0.1 *N* ethanolic HCl).

Thin layer chromatography of I ("crude") on silica gel G shows (ninhydrin or iodine vapor) one spot. With silica gel GF_{254} one spot is revealed under ultraviolet light. Ascending paper chromatography (Whatman No. 1) shows (ninhydrin) one spot, R_f 0.92, and a faint trace, R_f 0.12. After the one recrystallization the compound was chromatographically homogeneous.

Anal. Calcd. for $C_{16}H_{17}NO_2S$: C, 66.86; H, 5.96; N, 4.87; S, 11.16. Found (for "crude"): C, 66.48; H, 5.84; N, 4.87; S, 11.28. Found (for recrystallized): C, 66.78; H, 5.63; N, 4.57; S, 11.42.

S-Trityl-L-cysteine (II).—By the procedure previously described for the preparation of I, 1.58 g. (0.01 mole) of L-cysteine hydrochloride and 2.60 g. (0.01 mole) of trityl alcohol in 10 ml. of glacial acetic acid were treated with 1.40 ml. (a 10% excess) of boron trifluoride etherate. The mixture was warmed 30 min. on a steam bath, kept at room temperature for 45 min., and transferred to a beaker with 15 ml. of ethanol. The solution was treated with 5 ml. of water and 3 g. of powdered, anhydrous sodium acetate. The addition of 40 ml. of water provided a gum which solidified when triturated with cold water. After successive washings with water, acetone, and ether, the product was dried *in vacuo* over phosphorus pentoxide and sodium hydroxide and appeared as 3.08 g. (85%) of II, m.p. 181–182° dec. One recrystallization from N,N-dimethylformamide–water raised the melting point to 183.5° dec., $[\alpha]^{24}D$ +114 ± 2° (*c* 0.832, 0.04 *N* ethanolic HCl); reported[3] m.p. 181–182°, $[\alpha]^{24}D$ +108° (*c* 1.45, 0.04 *N* ethanolic HCl).

Anal. Calcd. for $C_{22}H_{21}NO_2S$: C, 72.69; H, 5.82; N, 3.85; S, 8.82. Found: C, 72.20; H, 5.97; N, 3.99; S, 8.96.

Thin layer chromatography of the "crude" material (m.p. 181–182°) revealed one spot, as did paper chromatography of the recrystallized material, R_f 0.92.

(4) Conditions for the removal of the S-benzhydryl (DPM) group from I using either sodium in liquid ammonia or refluxing trifluoroacetic acid are described in ref. 3.
(5) Melting points are uncorrected and were taken in capillary tubes. Elemental analyses were performed by the Triangle Chemical Laboratories, Chapel Hill, N. C. Optical rotations were taken with a Rudolph polarimeter, Model 80, equipped with a Model 200 photoelectric attachment. All chromatographic procedures were carried out in the 1-butanol–acetic acid–water (4:1:5) system. The L-cysteine hydrochloride was obtained as the C.P. monohydrate from the Mann Research Laboratories, New York, N. Y.
(6) M. Bergmann and G. Michalis [*Ber.*, **63**, 987 (1930)] describe the conversion of the monohydrate to the anhydrous form.