Sensitizers were commercial materials carefully purified by chromatography on alumina followed by sublimation and/or recrystallization.

Solvents. Hexane was spectro grade used without further purification. Benzene was reagent grade purified by the method of Hammond.[9]

Photolyses were performed on 10 ml of 3% by weight (0.07 *M*) solutions of the azides in benzene (except for a control run in hexane). In the sensitized reactions, sufficient sensitizer (0.05 to 0.5 g) was added to ensure that >95% of the light absorbed was absorbed by the sensitizer. All solutions were degassed with two freeze–pump–thaw cycles and sealed under vacuum in Kimex tubes. The samples were then photolyzed for 16 hr with a Hanovia 679A medium-pressure mercury vapor lamp (Engelhard Hanovia, Inc., Newark, N. J.), using a Pyrex filter to minimize direct photolysis of the azides. The work-up procedure was essentially that of Saunders and Caress,[3] except that the solution was added to the sulfuric acid at 155–160° at such a rate as to avoid accumulation of nonvolatilized benzene, and the ether extracts were neutralized with sodium bicarbonate solution (neutralization necessarily preceded extraction with the products from (*p*-dimethylaminophenyl)diphenylmethyl azide). Analysis was by gas chromatography on a 5 ft × 0.125 in. column of 3% Apiezon L on Chromosorb G at 230–245°.

Control Experiments. Corrections were made by the method of Saunders and Caress[3] to the migration aptitudes for the *ca.* 2% of acid-catalyzed rearrangement suffered by the unreacted azides during the work-up. The small yield of rearranged products from the treatment of the azides with acid (most of the product is triarylcarbinol) rendered independent determination of the migration aptitudes imprecise, so the figures of Tietz and McEwen[10] for the benzhydryl azides were used. They do not give a result for the *p*-dimethylaminophenyl group, and we therefore determined its migration aptitude to be approximately 10. Corrections ran 2–12%, mostly below 10%, of the observed migration aptitudes. In one photolysis of triphenylmethyl azide, 0.1 g of (*p*-nitrophenyl)diphenylcarbinol was added as an internal standard. The mixture was worked up and analyzed as usual on a gas-chromatographic column calibrated with synthetic mixtures of benzophenone, triphenylcarbinol, and (*p*-nitrophenyl)diphenylcarbinol. Assuming no loss or decomposition of the internal standard, over 95% of the azide appeared as benzophenone plus triphenylcarbinol. Finally, photolysis of 0.1 g of benzophenone phenylimine in 10 ml of benzene resulted in no decomposition, as judged by a gas chromatogram showing a single peak corresponding to an authentic sample of the imine in retention time.

Attempted Study of Emission Spectra. Samples were prepared as described by Hammond.[11] Solutions containing 0.001 *M* triphenylmethyl azide in 3-methylpentane or 5:1 methylcyclohexane–isopentane gave clear glasses at 77°K. The light source was a 3130 mercury PEK lamp with a B and L monochromator. The detecting system consisted of a Jarrell-Ash scanning monochromator and a 1P28 RCA photomultiplier (good to 6000 A only). Neither fluorescent nor phosphorescent emission was observed.

Acknowledgment. We thank Dr. George C. Nieman and Mr. George F. Hatch for the use of their equipment and their time in the attempted determination of emission spectra.

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[9] G. S. Hammond, J. Saltiel, A. A. Lamola, N. J. Turro, J. S. Bradshaw, D. O. Cowan, R. C. Counsell, V. Vogt, and C. Dalton, *J. Am. Chem. Soc.*, **86**, 3197 (1964).

[10] R. F. Tietz and W. E. McEwen, *ibid.*, **77**, 4007 (1955).

[11] W. G. Herkstroeter, A. A. Lamola, and G. S. Hammond, *ibid.*, **86**, 4537 (1964).

Reactions of Aryl(trichloromethyl)carbinols with Sulfur Nucleophiles. Formation and Proof of Zwitterionic Structure of Iminothiazolidinones

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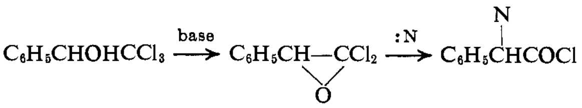
Contribution from the Chemistry Department, University of Maryland,
College Park, Maryland 20740. *Received September 29, 1966*

Abstract: Nucleophilic reagents react with aryl(trichloromethyl)carbinols to give α-substituted acids or derivatives. Thiourea is shown to act as a typical nucleophile in this reaction, with a subsequent ring closure giving an iminothiazolidinone. Thus, phenyl(trichloromethyl)carbinol is converted in one step to 2-imino-5-phenyl-4-thiazolidinone in 54% of the theoretical yield. This is a new approach to the synthesis of heterocyclic compounds. In like manner, 5-(3,4-dichlorophenyl)-2-imino-4-thiazolidinone and 2-imino-5-(*p*-methoxyphenyl)-4-thiazolidinone are obtained in yields of 28 and 18%, respectively. Nmr spectra, together with other evidence, allow the correct structure of the parent iminothiazolidinone to be chosen from the nine possible tautomeric forms. Potassium methyl xanthate also functions as a nucleophile in its reaction with phenyl(trichloromethyl)carbinol, but cyanide ion does not under the conditions employed. The relative nucleophilicities of the reagents tried are: thiourea ≫ xanthate > methoxide ≫ cyanide.

Phenyl(trichloromethyl)carbinol is known to react with methoxide ion in methanol to form α-methoxyphenylacetic acid,[2] and with potassium amide to form α-aminophenylacetic acid.[3] The reactions are thought to take place *via* the following mechanism in which :N is the nucleophile.



$$\mathrm{C_6H_5CHOHCCl_3 \xrightarrow{base} C_6H_5CH\underset{O}{\diagdown\!\diagup}CCl_2 \xrightarrow{:N} C_6H_5\overset{N}{\overset{|}{C}}HCOCl}$$

The acid chloride is converted under the basic reaction conditions to a salt of the α-substituted carboxylic acid.

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[1] National Science Foundation Cooperative Graduate Fellow, 1962–1963; Public Health Service Predoctoral Fellow, 1963–1964; abstracted in part from the doctoral thesis of Monica Nees, University of Maryland, 1965.

[2] (a) W. Reeve, J. P. Mutchler, and C. L. Liotta, *Can. J. Chem.*, **44**, 575 (1966); (b) W. Reeve and C. W. Woods, *J. Am. Chem. Soc.*, **82**, 4062 (1960); (c) C. Weizmann, M. Sulzbacher, and E. Bergmann, *ibid.*, **70**, 1155 (1948).

[3] W. Reeve and L. W. Fine, *J. Org. Chem.*, **29**, 1148 (1964).

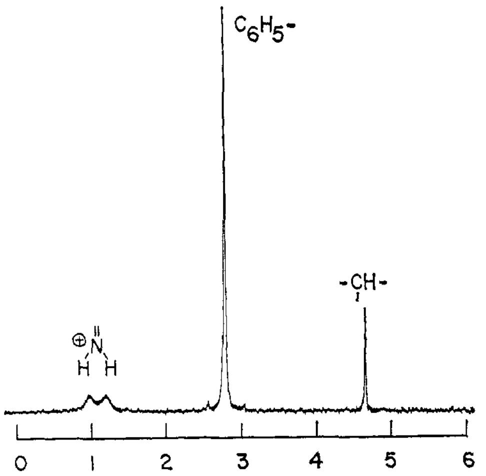
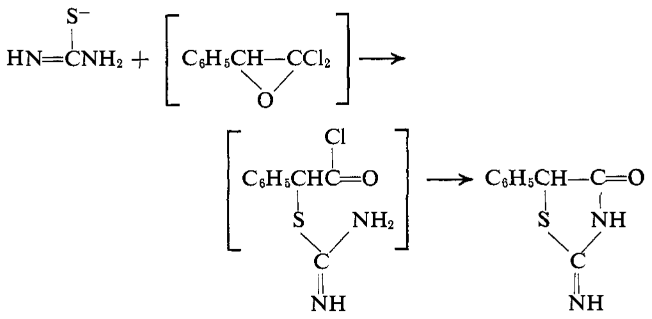


Figure 1. Nmr spectrum of 15% solution of 2-imino-5-phenyl-4-thiazolidinone in dimethyl sulfoxide; abscissa in τ units.

The purpose of the present work was to study a series of sulfur nucleophiles to see how well they would function in the above reaction. Positive results were obtained with thiourea and with potassium methyl xanthate but not with sodium sulfide or sodium thiosulfate. In an attempt to determine nucleophilicities of other reagents relative to the sulfur nucleophiles and methoxide ion (from the solvent), iodide ion and cyanide ion were also studied; they were such weak nucleophiles relative to methoxide ion that only the α-methoxyphenylacetic acid could be isolated.

All reactions were carried out under conditions similar to those used in the reaction of aryl(trichloromethyl)carbinols with methoxide ion.[2a] The aryl(trichloromethyl)carbinol together with the nucleophile were dissolved in methanol and to this solution, maintained at 50°, was added an excess of methanolic potassium hydroxide over a 1-hr period. After stirring for an additional hour at 50°, the reaction mixture was worked up in an appropriate manner. Under these conditions, the nucleophile used was in competition with methoxide ion from the solvent and had to be more nucleophilic than methoxide ion for the desired reaction to be successful.

With thiourea, the product-determining reaction is the attack of the nucleophilic sulfur atom on the α-carbon atom; this is followed by a ring closure to form the 5-aryl-2-imino-4-thiazolidinone (I). Ring closure occurs under the strongly alkaline reaction conditions, rather than during the later neutralization step, as shown by the fact that small amounts of the iminothiazolidinone can be obtained by extraction of the strongly alkaline reaction mixture with ether. Thiourea is potentially an ambident nucleophile, but no evidence was obtained to indicate attack by nitrogen. The iminothiazolidinone from phenyl(trichloromethyl)carbinol was formed in 54% of the theoretical yield. The by-products consisted primarily of a mixture of sulfur-containing acidic compounds which could not be identified.

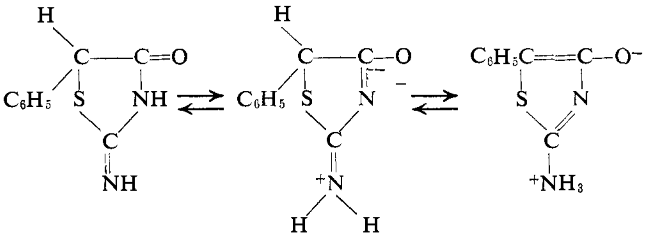


I

With 3,4-dichlorophenyl(trichloromethyl)carbinol, the yield of the substituted thiazolidinone decreased to 28%, presumably because the ring chlorines were attacked by the base; with p-methoxyphenyl(trichloromethyl)carbinol, the yield was 18%. It is well known that arylaldehydes with electron-releasing groups in the *meta* or *para* positions are less susceptible to nucleophilic attack, and the low yield in the p-methoxy case may be ascribed to a related phenomenon.

Nine tautomeric forms, including four inner salts, can be proposed as structures for the 5-aryl-2-imino-4-thiazolidinones. In the absence of any experimental evidence, the classical formula of iminothiazolidinones (*i.e.*, formula Ia) has been generally used. Recently, with no consideration of possible zwitterionic forms, there were two studies of amino–imino tautomerism but the results were contradictory.[4,5] Both involved an empirical comparison of the ultraviolet spectrum with the spectra of various model compounds in order to determine whether the carbon–nitrogen double bond was exo- or endocyclic.

The determination of the correct structure can better be accomplished by determining the position of the three protons associated with the heterocyclic ring and the cationic character of any nitrogen–hydrogen groups. The use of nmr spectra, in conjunction with other evidence, allows this to be done, at least with respect to the compound as it exists dissolved in a neutral solvent. In this work, a 15% solution of 2-imino-5-phenyl-4-thiazolidinone (I) in dimethyl sulfoxide was studied; this is the only neutral solvent in which it has any appreciable solubility.



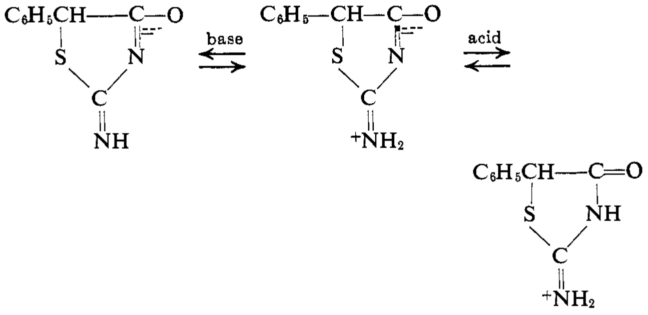
Ia Ib Ic

Evidence for formula Ib is as follows. (1) The substance is a zwitterion. This follows from its limited solubility in organic solvents such as ether and alcohols. Although insoluble in water, it is readily soluble in both 1 *N* HCl and in 1 *N* NaOH solutions. As would be expected for a salt-like structure, the melting point, 229°, is 100° higher than that of nonzwitterionic 5-phenyl-2,4-thiazolidinedione (II). In the nmr spectra (Figure 1), two of the hydrogen atoms appear at τ 0.92 and 1.15. This is characteristic of deshielded protons such as those associated with a positively charged nitrogen atom. The peaks are broad, as is often characteristic of nitro-

[4] H. Najer, R. Giudicelli, C. Morel, and J. Menin, *Bull. Soc. Chim. France*, 1018 (1963).

[5] A. M. Comrie, *J. Chem. Soc.*, 3478 (1964).

gen–proton bonds, and two peaks are observed because of the *cis* and *trans* relationship of the two hydrogens to the rest of the molecule. Treatment of the dimethyl sulfoxide solution of Ib with sodium hydride changes the immonium nitrogen into the uncharged imine with a consequent shift of the proton signals to a singlet corresponding to one proton at τ 3.5. (For comparison purposes, the nitrogen protons of aniline hydrochloride dissolved in dimethyl sulfoxide resonate at τ −0.73; for the free base, the τ value is 5.0.)



Acceptance of the zwitterionic structure eliminates formula Ia and four other uncharged tautomeric forms.

(2) The third proton is attached to carbon; proof of this follows from an exchange experiment with heavy water. This proton signal is a singlet at τ 4.65 in anhydrous dimethyl sulfoxide and also in dimethyl sulfoxide containing 10% water. In dimethyl sulfoxide containing 10% heavy water, the proton signal slowly decreases over a period of several days. The exchange follows first-order kinetics with respect to the iminothiazolidinone and 36 hr is required for 50% exchange at room temperature. In contrast, the two protons on the nitrogen undergo virtually complete exchange before the spectra can be measured.

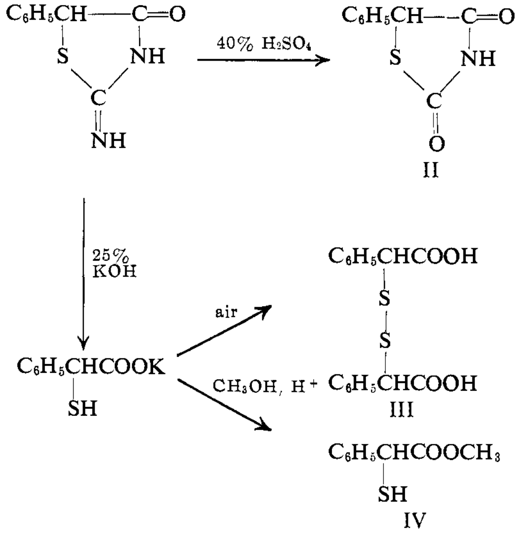
Acceptance of a carbon–hydrogen bond eliminates all structures such as Ic containing a carbon–carbon double bond in the heterocyclic ring. These structures undoubtedly account for the slow hydrogen–deuterium exchange observed, but evidently they do not make a significant contribution to the ground state of the molecule.

(3) The infrared spectra show strong broad bands around 3000 cm^{-1} and bands at 1750 cm^{-1} which are consistent with the above but cannot be assigned to any one structure.

(4) Electrometric titration curves of the thiazolidinone suggest that the zwitterion is derived from a strong acid and a strong base. Assignment of specific acidity values is complicated by the insolubility of the compound in the zwitterionic form, and the strong acid–strong base combination causes the titration curve to resemble that of a blank titration of sodium hydroxide with hydrochloric acid. The isoelectric point is 4.8.

(5) Finally, the negative charge in Ib is shown spread over the three-atom oxygen–carbon–nitrogen system rather than as localized on either the nitrogen or oxygen atoms because of the greater stability associated with a delocalized charge in an allyl-type system.

All of the iminothiazolidinones were converted in almost quantitative yield to thiazolidinediones (II) by refluxing several hours with 40% sulfuric acid.[6] The thiazolidinone ring is known to be opened by base.[7,8] Refluxing overnight with 25% potassium hydroxide solution converted the phenyl- and the *p*-methoxyphenyliminothiazolidinones to potassium salts of the corresponding mercaptophenylacetic acids; air oxidation of the latter gave the dithiobis(phenylacetic acids) (III) in 60% yield. α-Mercaptophenylacetic acid could be obtained only as an oil; therefore, it was esterified to the liquid methyl ester. The mercapto group of this compound is inert to air, and forms a crystalline silver salt (IV).



The reaction of phenyl(trichloromethyl)carbinol with potassium methyl xanthate at 50° was studied intensively. The xanthate was formed *in situ* from carbon disulfide and methanolic potassium hydroxide, and the reaction was carried out under an atmosphere of nitrogen to minimize uncontrolled oxidation of the desired mercapto acid. Acidification of the reaction mixture yielded a crude acid fraction in 80% yield, but the best yield of dithiobis(phenylacetic acid) (III) obtainable following air oxidation was 28% based on the starting carbinol.

Numerous procedures in the literature for oxidizing the crude mercapto acid to the disulfide acid were tried, but all were quite unsatisfactory. These included the use of hydrogen peroxide, sodium hypochlorite, ferric chloride in acetic acid, iodine in acetic acid, and iodine in slightly alkaline solution. The best method was found to be a simple air oxidation of a 5% aqueous solution at pH 7.5 using a small amount (0.5% of the weight of the mercapto acid) of ferric chloride as catalyst. The initial purple solution changed to yellow green as all of the mercapto acid was oxidized. At room temperature, the reaction did not proceed beyond the disulfide stage, so exposure to an excess of air was practical.

Disulfide acids are reported to be quite easily destroyed by alkali[9] but dithiobis(phenylacetic acid) is highly atypical. It was recovered unchanged after warming for 15 min in ammonium hydroxide solution at 80°. After warming overnight at 50° in 15% methanolic potassium hydroxide solution, 65% was

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(6) A. Rahman, H. S. E. Gatica, and A. A. Khan, *Chem. Ind.* (London), 1422 (1962).

(7) N. M. Turkevich and B. I. Shvydkii, *Ukr. Khim. Zh.* **18**, 513 (1952).

(8) B. H. Nicolet and L. F. Bate, *J. Am. Chem. Soc.*, **49**, 2064 (1927).

(9) E. E. Reid, "Organic Chemistry of Bivalent Sulfur," Vol. III, Chemical Publishing Co., Inc., New York, N. Y., 1960, Chapter 7, p 375.

recovered unchanged. Likewise, most disulfides are easily reduced to mercaptans by zinc in acetic acid or zinc in ammonium hydroxide, but this disulfide acid was recovered unchanged in 80% yield after such treatment with no evidence for formation of the mercapto acid.

Relative Nucleophilicities. The nucleophiles tried can be qualitatively rated relative to each other and to the methoxide ion used as a base to form the intermediate dichloro epoxide. Cyanide ion does not compete with methoxide ion: α-methoxyphenylacetic acid was formed in 78% yield but no trace of either α-cyanophenylacetic acid or any of its hydrolysis products was isolated. However, methoxide ion in turn does not compete with thiourea: 2-imino-5-phenyl-4-thiazolidinone was formed in 54% yield but none of the methoxy acid could be detected. Xanthate and methoxide are of approximately equal nucleophilicity: α-mercaptophenylacetic acid resulting from xanthate attack and subsequent hydrolysis was prepared in 28% yield (based on the amount of the corresponding disulfide acid isolated after oxidation) and α-methoxyphenylacetic acid in approximately 30% yield (based on a methoxyl analysis, because the acid could not be isolated from the reaction mixture). In all of these reactions the methoxide ion was present in excess. From the above arguments, the following nucleophilicities are deduced.

$$HN{=}\overset{\overset{S^-}{|}}{C}NH_2 \gg {-}S\overset{\overset{S}{\|}}{C}OCH_3 > {}^-OCH_3 \gg CN^-$$

The result with thiourea is not surprising; sulfur nucleophiles are among the most effective known, but so is cyanide ion, and it is indeed surprising that it did not compete successfully with methoxide ion, usually considered a fairly weak nucleophile.

Experimental Section

All melting and boiling points are corrected. Analyses are by Dr. Franz J. Kasler. The infrared spectra were determined on a Beckman IR-5 using potassium bromide pellets for solids. The nmr spectra were recorded on a Varian A-60.

General Procedure for Preparation of Iminothiazolidinones. 2-Imino-5-phenyl-4-thiazolidinone (I). To a solution of 112 g (0.5 mole) of phenyl(trichloromethyl)carbinol[2a] and 76 g (1 mole) of thiourea in 500 ml of methanol at 50° was added dropwise over a period of 2 hr a methanolic potassium hydroxide solution prepared by dissolving 198 g of potassium hydroxide pellets (3 moles) in 500 ml of methanol. The temperature was maintained at 50–55° during the addition. After all of the base was added, the mixture was stirred an additional hour at 50°, then allowed to stand overnight while cooling to room temperature. The potassium chloride (104 g, 93% of theory) was filtered off and washed with methanol. The combined filtrates were diluted with an equal volume of water, the base-insoluble materials extracted with several large portions of ether, and the aqueous layer was slowly acidified to pH 6.9 with dilute hydrochloric acid. An immediate precipitate of 2-imino-5-phenyl-4-thiazolidinone formed and was filtered off after cooling the solution. The yield was 52 g (54% of theory), mp 226° dec. Two recrystallizations from ethanol raised the melting point to 229°; the literature values[7,10] range from 226 to 234°.[11] The infrared spectrum showed: $\nu_{\max}^{\mathrm{KBr}}$ 3200 and 3015 (N–H and C–H), 1670 (>C=N<), 1490 (C_6H_5), 1375, 1255, 1175, 1135, 800, 765, 725, and 693 cm^{-1}. The nmr spectrum (in τ) showed: $\nu_{\max}^{\mathrm{DMSO}}$ 0.92, singlet, and 1.15, singlet (1 proton each, $=N^+H_2$); 2.75, singlet (5 protons, C_6H_5); 4.65, singlet (1 proton, >C*H*).

Anal. Calcd for $C_9H_8N_2OS$: C, 56.25; H, 4.16; N, 14.58; S, 16.69. Found: C, 56.29; H, 4.35; N, 14.43; S, 16.40.

5-(3,4-Dichlorophenyl)-2-imino-4-thiazolidinone. 3,4-Dichlorophenyl(trichloromethyl)carbinol[2a] (60 g, 0.2 mole), 30 g (0.4 mole) of thiourea, 200 ml of methanol, and 79 g (1.2 moles) of potassium hydroxide dissolved in 250 ml of methanol were allowed to react as above, except that the reaction mixture was worked up 1 hr after addition of base was completed. After filtering off the potassium chloride and adding an equal volume of water to the alkaline filtrate, an ether extraction gave 9.9 g of crude **α,β,β,3,4-pentachlorostyrene**, mp and mmp 46–47°, following crystallization from ethanol (lit.[2a] mp 48°). This material is formed from 1,2-dichloro-4-(1,2,2,2-tetrachloroethyl)benzene present as an impurity in the starting carbinol to the extent of approximately 17%. On acidifying the aqueous layer to pH 7, **5-(3,4-dichlorophenyl)-2-imino-4-thiazolidinone** precipitated and was filtered off after standing at 0° overnight. There was obtained 14.7 g (28% of theory), mp 238° dec; several crystallizations from ethanol raised the melting point to 251° dec.

Anal. Calcd for $C_9H_6N_2OSCl_2$: C, 41.39; H, 2.32; N, 10.73; S, 12.28; Cl, 27.16. Found: C, 41.72; H, 2.50; N (Kjeldahl), 10.36; S, 12.32; Cl, 27.10.

2-Imino-5-(*p*-methoxyphenyl)-4-thiazolidinone. From 65 g of *p*-methoxyphenyl(trichloromethyl)carbinol,[2a] there was obtained in like manner 10.6 g (18% yield) of 2-imino-5-(*p*-methoxyphenyl)-4-thiazolidinone, mp 223° dec. Recrystallization from ethanol–water raised the melting point to 234° dec.

Anal. Calcd for $C_{10}H_{10}N_2O_2S$: C, 54.05; H, 4.54; N, 12.61; S, 14.40. Found: C, 54.15; H, 4.35; N, 12.41; S, 14.23.

Formation of the Thiazolidinediones. 2-Imino-5-phenyl-4-thiazolidinone (I), 5 g, was refluxed overnight with 150 ml of 40% sulfuric acid. Diluting with water and cooling gave a semisolid mass which crystallized completely on trituration with cyclohexane. There was obtained 4.9 g (98% yield) of **5-phenyl-2,4-thiazolidinedione** (II), mp 122–126°. Recrystallization from ethanol–water raised the melting point to 129°. Literature values are from 126[12] to 130°.[13] The infrared spectrum showed two bands at 1665 and 1740 cm^{-1} in the carbonyl region. Other bands occurred at $\nu_{\max}^{\mathrm{KBr}}$ 3075, 2755, 1495, 1450, 1395, 1315, 1300, 1200, 1150, 1075, 1035, 1005, 933, 910, 865, 795, 758, 725, 697, and 670 cm^{-1}. The nmr spectrum (in τ) showed: $\nu_{\max}^{\mathrm{acetone}}$ −0.9, very broad singlet (1 proton, >N*H*), 2.6, singlet (5 protons, C_6H_5), and 4.4, singlet (1 proton, >C*H*).

From 2 g of 5-(3,4-dichlorophenyl)-2-imino-4-thiazolidinone after refluxing 3 hr with 40 ml of 40% sulfuric acid, there was likewise obtained 1.9 g (96% yield) of **5-(3,4-dichlorophenyl)-2,4-thiazolidinedione**, mp 149–153°. Recrystallization from ethanol–water raised the melting point to 156–157°.

Anal. Calcd for $C_9H_5NO_2SCl_2$: C, 41.22; H, 1.92, N, 5.34; S, 12.23; Cl, 27.05. Found: C, 41.50; H, 2.20; N, 5.30; S, 11.98; Cl, 27.17.

From 2 g of 2-imino-5-(*p*-methoxyphenyl)-4-thiazolidinone under similar conditions there was obtained a 90% yield of crude **5-(*p*-methoxyphenyl)-2,4-thiazolidinedione**, mp 102–103°, after recrystallizing from ethanol–water.

Anal. Calcd for $C_{10}H_9NO_3S$: C, 53.79; H, 4.06; N, 6.28; S, 14.37. Found: C, 53.95; H, 4.10; N, 6.00; S, 14.60.

Disulfide Acids from Iminothiazolidinones. An aqueous solution of potassium α-mercaptophenylacetate was prepared from 2.5 g of 2-imino-5-phenyl-4-thiazolidinone (I) and 10 g of potassium hydroxide in 40 ml of water by refluxing overnight. The pH was adjusted to 7.6 and 3 drops of a 5% ferric chloride solution was added as catalyst; a deep purple color developed. Air was blown through the mixture at room temperature for 3 hr at which time the purple color was discharged and the nitroprusside test for mercaptans was also negative. After filtering, the solution was acidified and extracted with ether. Evaporation of the ether gave a viscous oil which solidified when seeded. The pulverized crystalline mass was leached with benzene; 1.3 g (60% of theory) of **dithiobis(phenylacetic acid)** (III), mp 206–211° dec, was obtained. Recrystallization from methanol–water raised the melting point to 210–212°. Literature melting points[14] are from 198 to 218°, but are on poorly

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[10] P. N. Rylander and E. Campaigne, *J. Org. Chem.*, **15**, 249 (1950).

[11] These are capillary melting points (with decomposition) determined in a liquid bath. Using a Fisher–Jones melting point block (R. M. Dodson and H. W. Turner, *J. Am. Chem. Soc.*, **73**, 4517 (1951)) or a Maquenne block,[4] values range from 244 to 257°.

[12] H. L. Wheeler, *Am. Chem. J.*, **26**, 345 (1901); F. J. Wilson and R. Burns, *J. Chem. Soc.*, **123**, 799 (1923).

[13] F. A. Eberly and F. B. Dains, *J. Am. Chem. Soc.*, **58**, 2544 (1936).

[14] Y. Iskander and R. Tewfik, *J. Chem. Soc.*, 2393 (1961); C. Ulpiani and G. Chieffi, *Atti Accad. Lincei*, [5] **15** (II), 516 (1906), from

characterized products. The infrared spectrum showed: ν_{max}^{KBr} 2940, 1695, 1495, 1450, 1410, 1285, 1215, 1180, 1160, 933, 740, 695, and 672 cm^{-1}. The nmr spectrum (in τ) showed: ν_{max}^{DSMO} −0.6, singlet (2 protons, COO*H*); 2.73, singlet (10 protons of 2 phenyl rings); and 5.32, slightly split singlet (2 protons, >C*H*).

Anal. Calcd for $C_{16}H_{14}O_4S_2$: C, 57.44; H, 4.25; S, 19.17. Found: C, 57.45; H, 4.48; S, 18.90.

From 2 g of 2-imino-5-(*p*-methoxyphenyl)-4-thiazolidinone under the same conditions, there was obtained 1.2 g (65% of theory) of dithiobis(*p*-methoxyphenylacetic acid), mp 201° dec.

Anal. Calcd for $C_{18}H_{18}O_6S_2$: C, 54.79; H, 4.60; S, 16.26. Found: C, 54.37; H, 4.85; S. 16.60.

Methyl α-Mercaptophenylacetate. An aqueous solution of potassium α-mercaptophenylacetate, prepared as previously described, was acidified to give α-mercaptophenylacetic acid as a yellow oil. After the crude acid was refluxed overnight with twenty volumes of methanol and a few drops of sulfuric acid, there was obtained 7 g (62% of theory) of **methyl α-mercaptophenylacetate**, bp 96–98° (0.8 mm). Analysis by glpc (2-m glycol succinate column programmed from 175 to 275°) showed the ester to be 80% pure.

Treatment of the crude ester in ethanol with ethanolic silver nitrate yielded a white precipitate which melted and then dissolved when the solution was warmed. The silver salt of **methyl α-mercaptophenylacetate** (IV) precipitated on cooling. Leaching with hot ethanol yielded an almost white material, mp 138°.

Anal. Calcd for $C_9H_9O_2SAg$: C, 37.38; H, 3.18; S, 11.09; OCH_3, 10.73. Found: C, 37.43; H, 3.20; S, 11.10; OCH_3, 10.58.

Disulfide Acid by the Xanthate Method. To 45 g (0.2 mole) of phenyl(trichloromethyl)carbinol and 23 g (0.3 mole) of freshly distilled carbon disulfide in 150 ml of methanol at 50° under a nitrogen atmosphere, there was added over a period of 75 min a solution of 104 g (1.6 moles) of potassium hydroxide pellets dissolved in 300 ml of methanol. The temperature was maintained near 50° during the addition; the reaction mixture was stirred 1 hr more at this temperature, and then allowed to cool to room temperature while standing overnight. After the solution was diluted with an equal volume of water and the negligible neutral fraction extracted with ether, the pH was adjusted to 1 and the acid fraction extracted with ether. There was obtained 29 g of crude α-mercaptophenylacetic acid, a yellow oil which gave a strong test for the mercapto group with sodium nitroprusside. Air oxidation of an aqueous solution of its sodium salt by the previously described procedure gave **dithiobis(phenylacetic acid)** (III), mp 197–201° dec, in 28% yield from the carbinol. Recrystallization from methanol–water raised the melting point to 210–212°.

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Optical Rotatory Dispersion Studies. CVII.[1] Factors Governing the Relative Stability of Hydrindanones. Syntheses of 17-Alkyl-15-keto Steroids[2]

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Abstract: New syntheses of 17-alkyl-15-keto steroids from readily available 17-keto steroids are described, the key step being the base-catalyzed addition of benzyl alcohol to Δ^{15}-5α-androsten-17-one (VII). The pure 14α and 14β epimers were prepared, and the position of their base-catalyzed equilibrium was established by optical rotatory dispersion measurements yielding the results presented in Table I. The importance of nonbonded steric interaction between a 17β-alkyl substituent and the C-18 angular methyl group in 15-keto steroids is emphasized. A number of 14α- and 14β-Δ^{16}-15-ketones have been prepared, and their stereospecific catalytic hydrogenation is noted. Optical rotatory dispersion measurements on these α,β-unsaturated ketones demonstrated that the sign of their Cotton effect is controlled by the stereochemistry at C-14.

One of the complications in conformational analysis lies in the variation of the relative stabilities of *cis*- and *trans*-hydrindanone systems when incorporated into more complicated structures such as the steroids.[4] The contrast between 5α-cholestan-3β-ol-15-one[5] and 5α-androstan-15-one (XXXII)[4g] may be cited as an example, the former being more stable[6] with a *trans* C/D ring juncture while the latter is more stable (85–87% 14β) with a *cis* C/D ring fusion. The only variable responsible for this difference is the substituent at C-17.

The relative stabilities of *cis*- and *trans*-steroidal hydrindanone systems have been studied by numerous workers,[4a,7] and the variations observed had led to

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[1] Paper CVI: C. Djerassi, R. Records, C. Ouannes, and J. Jacques, *Bull. Soc. Chim. France*, 2378 (1966).

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[3] Taken from part of the Ph.D. dissertation of A. R. V., Stanford University, 1966.

[4] (a) For a detailed summary of literature citations see N. L. Allinger, R. B. Hermann, and C. Djerassi, *J. Org. Chem.*, **25**, 922 (1960); see also (b) H. Linde and K. Meyer, *Helv. Chim. Acta*, **42**, 807 (1959); (c) F. L. Weisenborn and H. E. Applegate, *J. Am. Chem. Soc.*, **81**, 1960 (1959); (d) N. L. Allinger and S. Greenberg, *J. Org. Chem.*, **25**, 1399 (1960); (e) H. Ishii, T. Tozyo, and D. Satoh, *Chem. Pharm. Bull.* Tokyo), **11**, 576 (1963); (f) T. Wada and D. Satoh, *ibid.*, **13**, 308 (1965); (g) C. Djerassi, G. von Mutzenbecher, J. Fajkos, D. H. Williams, and H. Budzikiewicz, *J. Am. Chem. Soc.*, **87**, 817 (1965).

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[6] This was later verified by optical rotatory dispersion measurements. See C. Djerassi, R. Riniker, and B. Riniker, *J. Am. Chem. Soc.*, **78**, 6362 (1956).