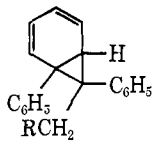

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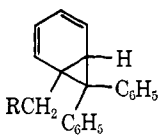

15

type of reactivity extends to all of the triphenylmethane derivatives **1–5**.

It is worthwhile to consider the possible formation of the norcaradienes **14** and **15** as intermediates in the transformations of **1–5**. Compound **14** would be the "normal" di-π-methane rearrangement product[2] while both **14** and **15** would be the products of concerted $_{\pi}2_{a}+{}_{\sigma}2_{a}$ cycloaddition.[7] Since no evidence exists for formation of these molecules from compounds **1–5**,[8] they were not included in the proposed reaction mechanism (Scheme I). It is conceivable, however, that they (**14** and **15**) are intermediates in these reactions since their photochemical decomposition could yield the same products as the rearrangement of **11** and **12**.[9] Supporting this possibility is the fact that **14** and **15** should be indirectly excited by energy transfer with ease,[10] thus allowing their facile further reaction. Unfortunately, the question of the intermediacy of norcaradienes in the photochemical reactions of phenyl-substituted methanes does not appear to be answerable from study of the substituted triphenylmethanes **1–5**. We are continuing to explore this question as part of an effort to further understand the relationship between the various possible reaction pathways (di-π-methane, 1,2 shift, $\sigma + \pi$ addition) available to excited aromatic systems attached to the same atom.

Acknowledgment. The authors wish to express their appreciation to Dr. Thomas W. Flechtner for his stimulating discussion of this work.

(7) R. B. Woodward and R. Hoffmann, *Angew. Chem., Int. Ed. Engl.*, **8**, 820 (1969).

(8) The nmr spectra of the crude reaction mixtures from photolyses of **1–5** were examined for the presence of olefinic absorptions not present in the starting materials or in **10**. None were detected.

(9) This type of reaction has been observed in similar systems. See: (a) T. Toda, M. Nitta, and T. Mukai, *Tetrahedron Lett.*, 4401 (1969); (b) M. Pomerantz and G. W. Gruber, *J. Amer. Chem. Soc.*, **89**, 6798 (1967); (c) D. B. Richardson, L. R. Darret, J. M. Martin, Jr., W. E. Putnam, S. C. Slaymaker, and I. Dvoretsky, *J. Amer. Chem. Soc.*, **87**, 2763 (1965).

(10) The triplet energy of compounds similar to **1–5** is 82 kcal/mol (ref 1d) while the norcaradiene system would be expected to have a triplet energy in the 50–60 kcal/mol range.[11]

(11) (a) D. F. Evans, *J. Chem. Soc.*, 1735 (1960); (b) R. S. H. Liu, N. J. Turro, and G. S. Hammond, *J. Amer. Chem. Soc.*, **87**, 3406 (1965).

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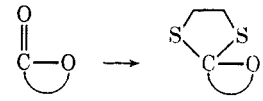
A Method for the Protection of Lactones and Esters against Nucleophilic Attack

Sir:

The direct application to lactones and esters of protecting groups which prevent attack at these sites by nucleophilic reagents (*e.g.*, RLi, AlH_4^-, OH^-) has not previously been part of synthetic practice, in contrast to the very widespread usage of ketal, thioketal, and acetal protection of ketones and aldehydes.[1] The need to effect such protection of a lactone function in connection with a synthetic program under way in these laboratories coupled with the inadequacy of existing methods for the conversion of lactones to suitable derivatives[2,3] led to the search for a mild and generally useful new method. This communication records a practical solution to the problem.

The ideal derivative for lactone protection appeared to be the corresponding 1,3-dithiolane structure. This type of unit is more stable to weakly acidic reagents



than the highly labile ortho ester (oxygen) analog and can be removed by a variety of highly specific reagents under nearly neutral[4] conditions. It appeared possible that the lactone → 1,3-dithiolane conversion might be effected under mild nonacidic reaction conditions using a reagent of the type $MetSCH_2CH_2SMet$, in which Met represents a metallic unit having a larger affinity for oxygen than for sulfur substituents. Of the various candidates Met = dialkylaluminum was selected for initial studies. It was soon ascertained that such reagents performed the desired function and that the dimethylaluminum reagent (I) possessed superior reactivity.[5]

Bis(dimethylaluminum) 1,2-ethanedithiolate (I) can be generated from trimethylaluminum (as a *ca.* 1.7 *M* solution in toluene as obtained from Texas Alkyls, Inc.) and ethanedithiol (molar ratio 2:1) in toluene–methylene chloride at −78° initial temperature with gradual warming to room temperature.[6] Reaction of I (1.05 equiv) with the unsaturated lactone II[7] in methylene chloride (at *ca.* 0.25 *M* reactants) first at −20° was com-

(1) For a review of such protection see J. F. W. McOmie, *Advan. Org. Chem.*, **3**, 191 (1963); J. F. W. McOmie, "Protective Groups in Organic Chemistry," Plenum Press, London, 1973.

(2) For background information see R. H. De Wolfe, "Carboxylic Ortho Acid Derivatives," Academic Press, New York, N. Y., 1970, Chapters 1 and 6.

(3) Two methods for the conversion of lactones to ortho esters have been described by the Meerwein school: (a) the reaction with boron trifluoride and an oxirane to give 1,3-dioxolane derivatives [K. Bodenbenner, *Justus Liebigs Ann. Chem.*, **623**, 183 (1959)], and (b) the reaction with a trialkyloxonium salt followed by treatment with an alkoxide salt [H. Meerwein, P. Borner, O. Fuchs, H. J. Saase, H. Schrodt, and J. Spille, *Chem. Ber.*, **89**, 2060 (1967)]. The former method requires the use of a strongly acidic reagent and affords at best only moderate yields; the latter suffers from limitations of scope and efficiency.

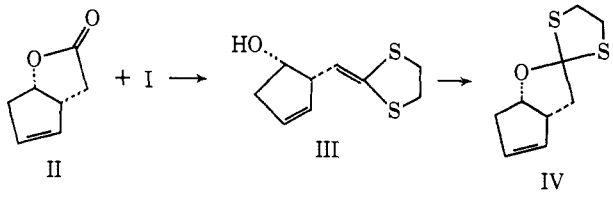
(4) A number of methods which are applicable to thioketals (*e.g.*, 1,3-dithianes) can be mentioned in this regard including Hg^{2+}–HgO or *N*-halosuccinimide [E. J. Corey and B. W. Erickson, *J. Org. Chem.*, **36**, 3553 (1971); E. Vedejs and P. L. Fuchs, *ibid.*, **36**, 366 (1971)], chloramine-T [D. W. Emerson and H. Wynberg, *Tetrahedron Lett.*, 3445 (1971)], Ce(IV) [T.-L. Ho, H. C. Ho, and C. M. Wong, *J. Chem. Soc., Chem. Commun.*, 791 (1972)], and CH_3I or FSO_3CH_3 [M. Fetizon and M. Jurion, *ibid.*, 382 (1972)].

(5) Reagents based on other metals, *e.g.*, boron or titanium, have not been studied thus far.

(6) All operations involving organoaluminum reagents were conducted in an atmosphere of dry argon or nitrogen using oxygen-free, dry solvents. In a typical preparation of I, 15 ml of a cooled solution of trimethylaluminum (1.67 *M* in toluene) was diluted with 10 ml of dry methylene chloride, further cooled to −78°, and treated dropwise with 1.06 ml (12.5 mmol) of dry ethanedithiol (distilled from Linde 4A Molecular Sieve) to afford a colorless precipitate (*strongly exothermic* reaction). After warming to 25° over *ca.* 30 min, the partially soluble reagent (I) is ready for use *in situ*. Alternatively, the mixture may be concentrated to dryness to yield I as a colorless solid which may be stored under nitrogen and used for reactions as needed with methylene chloride as the preferred solvent.

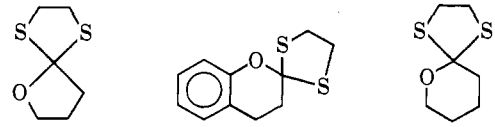
(7) E. J. Corey, Z. Arnold, and J. Hutton, *Tetrahedron Lett.*, 307 (1970).

plete after warming to 25° and storage at that temperature for 12 hr. Removal of solvent under reduced pressure, addition of ether followed by a few grams of moist sodium sulfate, filtration, and concentration of the ethereal filtrate afforded the pure ketene thioacetal III as a colorless oil in 94% yield.[8] Conversion of III to the dithiolane ortho lactone IV occurred quantitatively upon storage for 15 min at 25° in chloroform solution (probably catalyzed by a trace of acid) or in methylene chloride solution containing a trace of *p*-toluenesulfonic acid at 0° for a few min. It was found that the ketene thioacetal III is not produced from the dithio ortho lactone IV by the action of I under conditions for the conversion of II to III, thus demonstrating that IV cannot be an intermediate in the formation of III.



II III IV

Analogously the 1,3-dithiolane derivatives V[8] and VI[8] were obtained in 94 and 81% yields, respectively, from γ-butyrolactone and dihydrocoumarin and the reagent I (*via* the corresponding ketene thioacetals). The 1,3-dithiolane derivative of δ-valerolactone (VII)



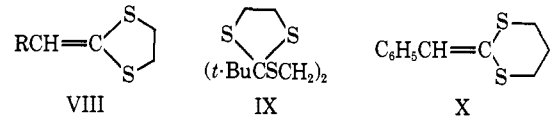
V VI VII

could be prepared in 91% yield even starting from the solid polyester of δ-hydroxyvaleric acid.

A study of the stability of these 1,3-dithiolanes was made using IV as the test substrate. This substance was stable to a 5:3:2 mixture of acetic acid–water–tetrahydrofuran at 25° for 1 hr, to KOH (1.5 equiv) in aqueous methanol at 25° for 12 hr, to lithium aluminum hydride (3.8 mol) in ether at 25° for 3 hr, or to methyllithium (1.0 equiv) in ether at 25° for 2 hr. The conversion of the 1,3-dithiolane IV to the corresponding lactone II was effected cleanly, however, using neutral, aqueous mercuric ion or mercuric oxide (2.1 equiv) and boron trifluoride etherate (2.1 equiv) in 15% aqueous tetrahydrofuran at 25° for 40 min.

In summary, the above data demonstrate the following useful features of the new technique reported here: (1) the reagent is readily available, (2) the conditions for protection and deprotection are mild, (3) the yields are high, and (4) the protected lactone is rendered inert to a variety of common nucleophilic reagents.

Reagent I has also been applied to the protection of esters. Reaction of methyl stearate with 1.12 equiv of I in methylene chloride initially at −10° and then at 25° for 40 hr yielded the ketene thioacetal VIII, R = n-$C_{16}H_{33}$,[8] in 93% yield. Similarly, methyl phenylacetate afforded VIII, R = C_6H_5,[8] in 98% yield after 12 hr at 25° with 1.08 equiv of I. In general, the ketene thioacetals are fairly stable to reagents such as CH_3OH–KOH, $LiAlH_4$–Et_2O, or aqueous acetic acid. Cleavage

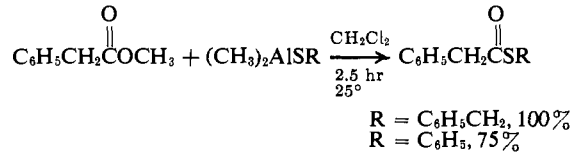


VIII IX X

of the ketene thioacetals VIII to afford carboxylic acids can be effected by the 1:1 mercuric oxide–boron trifluoride reagent in aqueous tetrahydrofuran at 60° for 4 hr.

Esters which do not possess an α hydrogen and which cannot form ketene thioacetals react with I in novel and more complex ways. Thus, reaction of methyl benzoate with 1.25 equiv of I in methylene chloride, initially at −10° and then at 25° for 36 hr, produced the dithioethylene ketal of acetophenone in 66% yield. On the other hand, methyl pivalate afforded the crystalline trithioortho ester IX,[8] mp 135–136°, in 86% yield.

The reaction of esters with reagents derived from monothiols and trimethylaluminum (ratio 1:1) leads to the formation of thio esters; for example



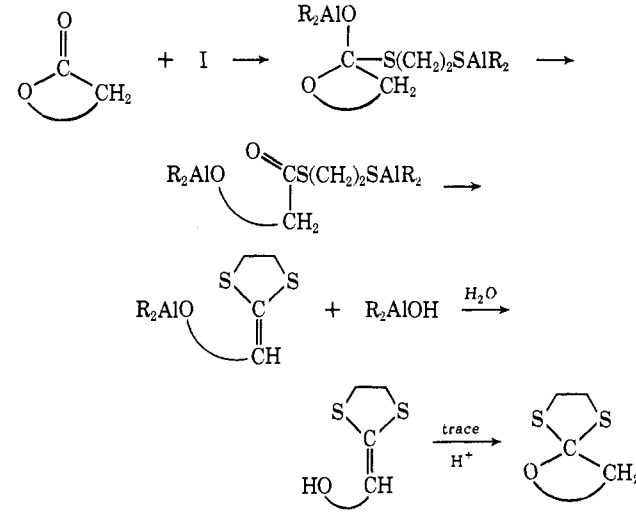
$C_6H_5CH_2COCH_3 + (CH_3)_2AlSR \xrightarrow[2.5\ hr,\ 25°]{CH_2Cl_2} C_6H_5CH_2CSR$

R = $C_6H_5CH_2$, 100%
R = C_6H_5, 75%

This process represents a uniquely simple procedure for the generation of thio esters and represents in essence a new method for one-step carboxyl activation starting from an ester. An expanded report on this process will be made elsewhere.

Although the reagent I has proved to be highly satisfactory for lactone or ester protection, some variation in the reagent is possible, *e.g.*, the use of the propane-1,3-dithiol–trimethylaluminum (ratio 1:2) derived reagent with methyl phenylacetate produced the ketene thioacetal X in 86% yield. Triethylaluminum and triisobutylaluminum have also been used as the organoaluminum component; however, the reagent I appears to possess higher reactivity and greater selectivity in some cases.

Studies on the application of reagents such as I to synthesis are continuing. Although mechanistic detail has not been investigated, the following sequence would seem to be consistent with the facts now available for the reaction of I with lactones.



Acknowledgment. This work was assisted financially

(8) Satisfactory infrared, proton magnetic resonance, and high resolution mass spectral data were obtained for this substance.

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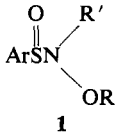
N-Alkoxybenzenesulfinamides. Evidence for an Alkylation Reaction

Sir:

We wish to report on some unusual chemical properties of the *N*-alkoxybenzenesulfinamides (**1**). The nature of their reactions is strongly dependent upon the substituent, R′, on nitrogen. If R′ is hydrogen, a novel N → S alkoxy group migration readily occurs. When R′ is alkyl, a facile fragmentation of the sulfinyl–nitrogen bond occurs. On the other hand, little reaction is evident at elevated temperatures when nitrogen has an acyl substituent.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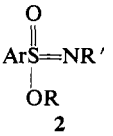
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The N-unsubstituted alkoxysulfinamides (**1**, R′ = H) are particularly noteworthy because they represent a new class of alkylating agents. Our results indicate that the alkylating properties result from rearrangement of **1** (R′ = H) to an *O*-alkylsulfonimidate intermediate **2**, which is structurally analogous to the sulfonate ester alkylating agents.[1]

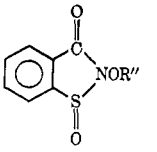
The synthesis of some *N*-alkoxyalkanesulfinamides has been reported by Zinner and Ritter,[2] but very little information concerning their chemical properties was provided. We have synthesized a variety of previously unknown *N*-alkoxybenzenesulfinamides (**1**)[3] from the appropriate sulfinyl chlorides and alkoxyamines in recrystallized yields ranging from 30–70% (Table I).

N-Methoxybenzenesulfinamide (**1a**) was observed to rearrange to *N*-methylbenzenesulfonamide (30%) on standing neat at room temperature for about 2 weeks.[4] A complicated mixture of other products such as benzenesulfonamide, ammonium benzenesulfinate, ammonium benzenesulfonate, phenyl disulfide, and phenyl benzenethiolsulfonate were also obtained. Decomposition of **1a** in an alcohol results in the formation of benzenesulfonamide and alkylation of the alcohol to give an ether. These results suggest that **1a** rearranges to a sulfonimidate ester intermediate (**2a**), which in turn alkylates itself (perhaps intermolecularly) or alkylates the alcohol (Scheme I).

To establish the scope and pursue the mechanism of the alkylation reaction, we investigated the reactions of **1** with different alcohols. *N*-Benzyloxybenzenesulfinamides **1c**, **1e**, and **1g** were completely converted on heating at 50° in dry methanol for 48 hr to benzenesulfonamides, benzyl methyl ether, and benzyl alcohol (Table II). Reaction of **1a** with benzyl alcohol at the same temperature also gave benzyl methyl ether. Reaction of **1c** with water in dioxane at 50° gave benzyl alcohol. But more significantly, reaction of **1c** with 1-butanol gave the alkylated cross-product dibutyl ether.

The mechanism (Scheme II) suggested by these results involves a dissociative rearrangement process from **1** to **2**, whereby the migrating alkoxy group can exchange with the alcohol solvent. The sulfonimidate intermediates (**2** and **2′′**) then alkylate the solvent. A delocalized nitrenium ion[5] intermediate (**3**), which is stabilized by the nonbonded sulfinyl electron pair, is

Table I. *N*-Alkoxybenzenesulfinamides, *p*-$XC_6H_4SN(R')OR$

Compd no.	X	R	R′	% yield	Mp, °C
1a	H	CH_3	H	20–40	48–51
1b	H	$C_6H_5CH_2$	H	45	91–92
1c	CH_3	$C_6H_5CH_2$	H	71	71–72
1d	Cl	CH_3	H	50	117–118
1e	Cl	$C_6H_5CH_2$	H	38	116–117
1f	NO_2	CH_3	H	28	126–127
1g	NO_2	$C_6H_5CH_2$	H	65	137–138
1h	H	CH_3	CH_3	94	Liquid[a]
1i	H	C_2H_5	C_2H_5	97	Liquid[a]
1j	NO_2	CH_3	CH_3	64	62–63
1k	Cl	CH_3	CH_3	50	35–39
4a	R′′ = CH_3			40	122–123
4b	R′′ = $CH_2C_6H_5$			20	110–111

[a] Decomposes on attempted vacuum distillation.

Scheme I

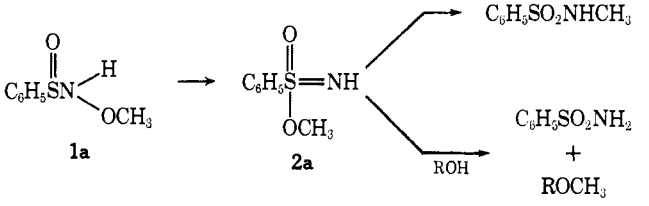


Table II

		X =	% yield[a] CH_3	Cl	NO_2
p-$XC_6H_4SNHOCH_2C_6H_5$	50°, 48 hr, CH_3OH	*p*-$XC_6H_4SO_2NH_2$	65	58	39
		$C_6H_5CH_2OCH_3$	20	26	10
		$C_6H_5CH_2OH$	52	42	58

[a] Average of duplicate runs.

(1) (a) G. C. Barrett in "Organic Compounds of Sulfur, Selenium, and Tellurium," Vol. 1; D. H. Reid, Ed., The Chemical Society, Burlington House, London, 1970, pp 95–97; (b) J. A. Montgomery, T. P. Johnston, and Y. F. Shealy in "Medicinal Chemistry," 3rd ed, Part I, A. Burger, Ed., Wiley-Interscience, New York, N. Y., 1970, p 698.

(2) G. Zinner and W. Ritter, *Arch. Pharm. (Weinheim)*, **296**, 681 (1963).

(3) Satisfactory elemental analyses were obtained for all of the compounds or for their sulfonamide oxidation products; ir and nmr spectra were consistent with their proposed structures.

(4) T. J. Maricich, Abstracts, 157th National Meeting of the American Chemical Society, Minneapolis, Minnesota, April 1969, ORGN-122.

(5) For a recent review of nitrenium ion chemistry, see P. G. Gassman, *Accounts Chem. Res.*, **3**, 26 (1970).