15 hr to give 16.5 g of product, mp 92–99°[8] (resolidifies and remelts at 166–168°). Recrystallization from an acetone–water mixture gave 15.5 g (53.4%) of the pure carbinol II, as white prisms, mp 167.5–169°.

Anal. Calcd for $C_{19}H_{18}N_2O$: C, 78.59; H, 6.25; N, 9.65. Found: 78.90; H, 6.04; N, 9.59.

The methylene chloride solution obtained from the separation of the mixture of products was washed with water, dried, and evaporated. Recrystallization of the residue from a mixture of dichloromethane and hexane gave 8.6 g (43.7%) of pure 4-(phenacyl)pyridine (I) as white prisms, mp 113–115°.[2]

Acknowledgment.—We are indebted to Dr. A. Steyermark and his staff for the microanalyses and to Mr. S. Traiman for the determination of infrared spectra.

[8] The compound is polymorphic and melting points of 117–118° and 126–127° have also been observed. Recrystallization from acetone however raises the melting point to 167.5–169°.

1,3-Dipolar Cycloaddition of Carbon Disulfide to a Nitrile Oxide[1]

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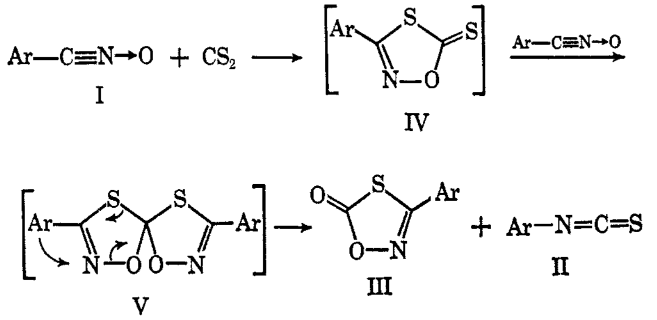
Reports on the reactions of nitrile oxides with thiocarbonyl functions[2] have not heretofore included carbon disulfide. We have found that 2,4,6-trimethylbenzonitrile oxide[3] (I) reacts with carbon disulfide at 80–90° to form mesityl isothiocyanate (II) and 3-mesityl-1,4,2-oxathiazoline-5-one (III). The latter compound is analogous to the 5,5-disubstituted (alkyl, alkoxyl, or alkylthio) 1,4,2-oxathiazolines which have been obtained using other thiocarbonyl compounds.[2] See Scheme I.

SCHEME I



Ar = 2,4,6-$(CH_3)_3C_6H_2$

These products could arise by prior formation of the thione (IV) by a conventional 1,3-dipolar cycloaddition, followed by rapid reaction of the thione with a second mole of nitrile oxide to give the spiro intermediate (V),[4] and thermal decomposition of V to form the observed products. A "thionecarbonate" such as IV would be expected[2] to react with a nitrile oxide under much milder conditions than were required to cause reaction of I with carbon disulfide. The isothiocyanate is a well-known compound and has been observed[2,5] as a product in reactions of nitrile oxides with various sulfur compounds. The oxathiazoline-5-one has infrared absorption at 1796 cm^{-1}, which is characteristic of a "carbonate" carbonyl group in a five-membered ring,[6] and shows no absorption above 3100 cm^{-1}. This compound decomposes above 150° with evolution of an odorless gas and forms mesityl isothiocyanate.

An attempt to obtain the same heterocycle using carbon oxysulfide in toluene under the same reaction conditions returned only the starting mesitonitrile oxide. Anthracene-9-nitrile oxide[3] under the same reaction conditions with carbon disulfide gave only the isothiocyanate.

Production of mesityl isothiocyanate from the nitrile oxide and thiocyanate ion as recently reported[5] has been verified. Use of buffered solutions at pH 5–7 in our case gave the same result.

Compounds I and III will be screened for radioprotective activity, since they possess reactive functions that should readily combine with cellular thiols.

Experimental Section

Melting points were determined in capillaries on a Mel-Temp aluminum block. Infrared spectra were obtained from a Perkin-Elmer Infracord 137B with sodium chloride optics. Evaporations were carried out with a rotary evaporator and water aspirator. Analyses were done by Carol K. Fitz, Needham Heights, Mass.

Reaction of 2,4,6-Trimethylbenzonitrile Oxide with Carbon Disulfide.—A 250-ml conical flask was charged with 8.05 g of 2,4,6-trimethylbenzonitrile oxide[3] (0.05 mole) and 100 ml of dry carbon disulfide,[7] capped with aluminum foil and sealed in a 1000-ml Parr bomb. The bomb was placed in a water bath preheated to 80°, maintained at 80–90° for 22 hr, then cooled to room temperature before opening. The light yellow solution was freed of carbon disulfide on a water bath, and the clear oil remaining was taken up in 50 ml of hexane and cooled overnight at −15° to complete crystallization. The large, white prisms were recrystallized from 50 ml of hexane to give **3-mesityl-1,4,2-oxathiazoline-5-one (III)**: 1.71 g (31%); mp 72–73.5°; $\nu_{\text{min}}^{\text{Nujol}}$ 1796, 1741, 1052, 900, 857, and 725 cm^{-1}. Five recrystallizations from hexane gave the analytical sample: mp 75–76°; dec pt 150°.

Anal. Calcd for $C_{11}H_{11}NO_2S$: C, 59.8; H, 5.0; N, 6.3. Found: C, 60.0; H, 5.2; N, 6.3.

Heating a sample in a 200° oil bath for a few seconds produced **mesityl isothiocyanate**: mp 59–61° (lit. 63°,[8] 61–62°[5]).

The hexane liquors were combined and concentrated to about 20 ml, cooled, and seeded. This yielded 0.40 g of **mesityl isothiocyanate**, mp 57–59°; a second crop of less pure material comprised 4.78 g. The crude material (6 g) was recrystallized twice from hexane and once from methanol giving 1.75 g of large, white spars, mp 60–62°.

Anal. Calcd for $C_{10}H_{11}NS$: C, 67.8; H, 6.2; N, 7.9. Found: C, 67.3; H, 6.2; N, 8.1.

Reaction of Anthracene-9-nitrile Oxide with Carbon Disulfide.—The above reaction conditions were applied to 1.1 g of anthracene-9-nitrile oxide.[3] There was obtained 1.3 g of yellow solid, mp 125–136°, $\nu_{\text{min}}^{\text{CHCl}_3}$ 2090 cm^{-1}, characteristic of isothiocyanates, and a sodium fusion test for sulfur was strongly

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[1] Part of a project supported by grant RH 00297 from the Division of Radiological Health, Bureau of State Services, U. S. Public Health Service, Bethesda, Md.

[2] R. Huisgen, W. Mack, and E. Anneser, *Angew. Chem.*, **73**, 656 (1961).

[3] C. Grundmann and J. M. Dean, *J. Org. Chem.*, **30**, 2809 (1965).

[4] A stable spiro adduct has been obtained from the reaction of a nitrilimine with carbon disulfide: R. Huisgen, R. Grashey, M. Seidel, H. Knupfer, and R. Schmidt, *Ann.*, **658**, 169 (1962).

[5] C. Grundmann and H.-D. Frommeld, *J. Org. Chem.*, **31**, 157 (1966).

[6] N. B. Colthup, L. H. Daly, and S. E. Wiberley, "Introduction to Infrared and Raman Spectroscopy," Academic Press, Inc., New York, N. Y., 1964, p 255.

[7] L. F. Fieser, "Experiments in Organic Chemistry," 3rd ed, D. C. Heath and Co., Boston, Mass., 1955, pp 282–283.

[8] G. M. Dyson and R. F. Hunter, *J. Soc. Chem. Ind.*, **45**, 81T (1926).

positive. Recrystallization did not sharpen the melting point of this product which was concluded to be **anthracene 9-isothiocyanate.**

Anal. Calcd for $C_{15}H_9NS$: C, 76.7; H, 3.8; N, 5.96. Found: C, 76.0; H, 4.1; N, 5.95.

Asymmetric Induction in a 1,4-Cycloaddition Reaction. Influence of Variation of Configuration of the Asymmetric Center

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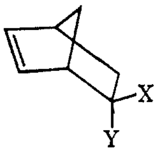
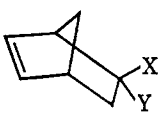
Partial asymmetric syntheses have been achieved in 1,4-cycloaddition reactions.[1-3] With the application of Lewis acid catalysis to promote reaction rate acceleration came the discovery of greatly enhanced asymmetric synthesis. Walborsky, Barash, and Davis presented an effective rationale for the steric course of a particular cycloaddition reaction and examined solvent, temperature, and catalyst effects.[2]

We wish to report our investigation of a system well suited for the study of the effect of variation of substituents about the influencing asymmetric center. This system consists of the reaction between 1,3-cyclopentadiene and acrylic acid esters. The four possible products are represented by I and II. In particular the reaction of esters derived from (*R*)-(−)-menthol, (*S*)-(+)-2-octanol, and (*S*)-(+)-2-butanol were studied. Both catalytic and noncatalytic additions were run. Anhydrous stannic chloride was employed as the Lewis acid catalyst because homogeneous reaction solutions were obtained. The ester adducts were reduced with lithium aluminum hydride to the corresponding alcohols and their rotations were measured. The absolute rotations and configurations of the alcohols derived from the reduction of esters I and II have been assigned.[4] The alcohol obtained from Ia has the *S* configuration and in 95% alcohol the absolute [α]D −76.6°. Our results are summarized in Table I.



Ia, X = H; Y = COOR
b, X = COOR; Y = H



IIa, X = H; Y = COOR
b, X = COOR; Y = H

Reactions with stannic chloride catalysis were run at 4–8° because at much lower temperatures the catalytic effect on enhancement of optical purity appears to diminish. Walborsky[2] obtained a 75% optical yield for the reaction of 1,3-butadiene with (−)-dimenthyl fumarate using $SnCl_4$ catalysis in toluene at 25°, but at −70° the catalyst was ineffective.

TABLE I

REACTION OF CYCLOPENTADIENE WITH $CH_2{=}CHCOOR$

R	Solvent	Yield,[a] %	endo[a] %	endo[a] $[\alpha]^{25}D$, deg	Optical yield, %
(*R*)-(−)-Menthyl	0.6 *M* in toluene[b] and 1 equiv of $SnCl_4$	76	89	+31.4	41
(*S*)-(+)-2-Octyl		78	92	−11.1	15
(*S*)-(+)-2-Butyl		77	94	−18.4	24
(*R*)-(−)-Menthyl	Neat[c]	77	69	+6.1	8[d]
(*S*)-(+)-2-Octyl	Neat	77	71	−2.3	3
(*S*)-(+)-2-Butyl	Neat	70	74	−4.2	5

[a] Determined by glpc. [b] Temperature maintained at 4–8° for 0.5 hr. [c] Temperature maintained at 24–26° for 6 hr. [d] Agrees with ref 3.

It is noted that for a given acrylate there is a large difference in the amount of *endo* isomer formed in the catalytic and noncatalytic reactions. This gives further support to the contention[2] that the bulky Lewis acid catalyst participates in close coordination with the carboxyl group during cyclization as its steric requirement would result in a higher *endo* yield.[5a] Sauer and Kredel[5b] have reported similar results in a study of solvent and catalyst effects on the *endo–exo* product ratio of the (*R*)-(−)-menthyl acrylate reaction.

It is also seen that the (*R*)-acrylate gives an adduct with excess *R* configuration, and (*S*)-acrylates give adducts of excess *S* configuration. If one attempts to predict the configuration of the adducts from a consideration of diene steric approach control exerted by a dienophile of Cram–Prelog design, it is found that the (*R*)-acrylate should yield an excess of *S* isomer and the (*S*)-acrylate an excess of *R*. Walborsky[2] postulates that the (*R*)-(−)-methyl group exerts a steric control force in a manner deviating from that predicted because of the steric influence of substituents on the menthyl moiety which are not directly attached to the asymmetric carbon. The (*R*)-(−)-menthyl group, he argues, behaves as if the groups about the asymmetric carbon were of *S* configuration. Our data for the (*R*)-acrylate reactions are thus seen to agree with similar results obtained by Walborsky.[2] It is not feasible from the available evidence to rationalize the unexpected observations of the (*S*)-acrylates.

Experimental Section

Materials.—*l*-Menthol, *d*-2-octanol, and acrylyl chloride were purchased from Aldrich Chemical Co. Rotations of the alcohols conformed with literature values.[6] Optically pure *d*-2-butanol was prepared by brucine resolution of the acid phthalate.[7] Cyclopentadiene was freshly distilled before each use. Anhydrous stannic chloride employed was Baker Analyzed reagent. Boiling points are uncorrected.

Preparation of the Optically Active Acrylates.—To an ice-cooled solution of 19.0 g (0.21 mole) of acrylyl chloride and 21.3 g (0.21 mole) of triethylamine in 100 ml of anhydrous ether was added dropwise with stirring to a solution of 0.20 mole of alcohol in 100 ml of anhydrous ether. Triethylammonium hydrochloride precipitated. The addition was controlled to maintain mild reflux and then heated at reflux for an additional 0.5 hr. The ether solution was filtered from the hydrochloride precipitate and washed with 10% aqueous sodium bicarbonate. The ether layer was dried over anhydrous sodium sulfate and the ether was

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