

chloric acid solution which was then extracted with two 75-ml portions of ether. The combined ether extract was washed with two 25-ml portions of water, dried with anhydrous sodium sulfate, and evaporated under reduced pressure to give 3.14 g of a liquid residue. Analysis of this liquid by glpc⁸ revealed that it contained only isopropyl phenyl ether except for a little isopropyl iodide and that the yield of ether was 100%. Product purified by preparative glpc gave a refractive index of n_D^{25} 1.4946 (lit.¹¹ n_D^{25} 1.4944) and an infrared spectrum identical with that of an authentic sample.

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Registry No.—1, 51310-59-9; 2, 5342-31-4; 3, 5947-49-9; 4, 1231-74-9; diethyl malonate, 105-53-3; malonic acid, 141-82-2; ethyl iodide, 75-03-6; ethyl triphenylacetate, 5467-22-1; triphenylacetic acid, 595-91-5; 2-ethylbutanoic acid, 88-09-5; dibromomethane, 74-95-3; benzoic acid, 65-85-0; methyl iodide, 74-88-4; isopropyl phenyl ether, 2741-16-4; phenol, 108-95-2; isopropyl iodide, 75-30-9.

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A New Method for Preparation of Alkyl and Aryl Isothiocyanates Using Amines, Butyllithium, and Carbon Disulfide

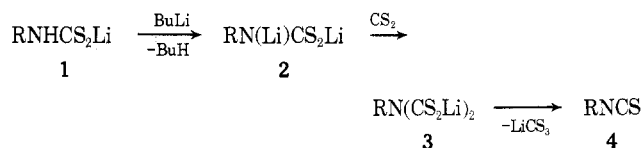
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Alkyl and aryl isothiocyanates are usually prepared in several steps from amines *via* dithiocarbamate derivatives.¹⁻⁴ We now describe a convenient alternative approach involving the amine, carbon disulfide, and butyllithium, which lead to isothiocyanates in good yields from alkyl- or arylamines which do not contain groups that react with butyllithium.

The amines are treated with an equimolar amount of butyllithium followed by carbon disulfide to give the lithium dithiocarbamate 1. Treatment with additional butyllithium and carbon disulfide leads *via* the dithio derivative 2 to the complex 3. The formation of 3 is indicated by the absence of characteristic ir bands for carbon disulfide at 1520 and 2230 cm^{-1} . After the reaction mixture was for 2 hr at the temperature indicated in Table I, the inorganic lithium salt had precipitated, and the solution showed the ν_{NCS} band at about 2150 cm^{-1} . Isothiocyanate 4 was obtained in good yield by distillation of the reaction mixture, as shown in Table I.



Successive additions of butyllithium and carbon disulfide to form intermediate 3 are essential for the formation of isothiocyanate in good yield. For example, phenyl isothiocyanate was formed quantitatively in the reaction *via* the intermediate 3 (R = Ph) at 80°, while it was obtained only in 46 and 11% yields by thermal decompositions (150°) of lithium *N*-lithio-*N*-phenyldithiocarbamate, 2 (R = Ph), and of lithium *N*-phenyldithiocarbamate, 1 (R = Ph), respectively. When the reaction product formed by treatment of aniline with 2 equiv of butyllithium was allowed to react with 2 equiv of carbon disulfide for 4 hr at 70°, *N,N*-diphenylthiourea was obtained in good yield, accompanied by the formation of a trace amount of phenyl isothiocyanate.

Experimental Section

All melting and boiling points were uncorrected. The ir and nmr spectra were determined with a JASCO Model IR-S spectrometer and a Hitachi Perkin-Elmer Model R-20 spectrometer, respectively. Solvents and amines were dried by common methods.

Standard Method for Preparation of Isothiocyanate. A. Butyl Isothiocyanate. Butylamine (4.39 g, 60 mmol) was dissolved in dry tetrahydrofuran (50 ml) under dry nitrogen in a flask equipped with a mechanical stirrer, a condenser, a dropping funnel, and a nitrogen inlet, and treated with butyllithium (66 mmol in 53 ml of petroleum ether) at 0°. After stirring for 30 min at room temperature, carbon disulfide (5.01 g, 66 mmol) in 5 ml of tetrahydrofuran was added dropwise at 0° to form the dithiocarbamate salt 1 (R = Bu). The solution of 1 thus prepared *in situ* was treated again with butyllithium (66 mmol) at 0° and was stirred for 30 min at room temperature, followed by the addition of carbon disulfide (66 mmol), to form the intermediate 3 (R = Bu). After the reaction mass was stirred for 30 min at room temperature, the inorganic lithium salt had precipitated and the characteristic band of isothiocyanate at 2170 cm^{-1} appeared in the ir spectrum of the reaction mixture. The mass was stirred for 2 hr at 60° and filtered to remove the salt. Tetrahydrofuran was evaporated *in vacuo* and butyl isothiocyanate was distilled: yield 5.5 g (80%); bp 47-48° (10 mm); ir (CHCl₃) ν_{NCS} 2170 cm^{-1} . The ir and nmr spectra were in good agreement with those of the authentic sample prepared by the published method.¹

B. Other Isothiocyanates. The intermediates 3 were prepared *in situ* from the respective amines, analogously to the case of butylamine, and were heated for 2 hr at the temperature indicated in Table I. The isothiocyanates formed were isolated by distillation. Their yields and boiling points are summarized in Table I. Their ir and nmr spectra were the same as those of authentic samples prepared by the literature method.¹

Among the isothiocyanates shown in Table I, α -naphthyl isothiocyanate was obtained by pyrolytic distillation of the reaction mixture.

Thermal Decomposition of Lithium *N*-Lithio-*N*-phenyldithiocarbamate, 2 (R = Ph). The solution of 2 (R = Ph) in tetrahydrofuran was prepared *in situ* analogously to the case of *N*-butyl dithiocarbamate, 2 (R = Bu), and was pyrolytically dis-

Table I
Yields of Isothiocyanates by the Reaction of the *N*-Lithio Carbamates 2 with Carbon Disulfide

Amine used (RNH ₂)	Registry no.	Reaction temp, °C	RNCS formed		Registry no.
			Bp, °C (mm)	Yield, %	
EtNH ₂	75-04-7	<i>a</i>	55 (50)	80	542-85-8
<i>n</i> -PrNH ₂	107-10-8	<i>a</i>	50-55 (20)	85	628-30-8
<i>n</i> -BuNH ₂	109-73-9	<i>a</i>	47-48 (10)	81	592-82-5
<i>t</i> -BuNH ₂	75-64-9	<i>a</i>	50-53 (22)	75	590-42-1
Cyclohexyl-NH ₂	108-91-8	<i>a</i>	109 (10)	74	1122-82-3
PhCH ₂ NH ₂	100-46-9	70-80	105-110 (10)	55	622-78-6
PhNH ₂	62-53-3	80	96-98 (15)	99	103-72-0
<i>p</i> -CH ₃ C ₆ H ₄ NH ₂	106-49-0	80	77-78 (0.2)	99	622-59-3
α -Naphthyl-NH ₂	134-32-7	<i>b</i>	109-112 (0.2)	71	551-06-4

^a Room temperature. ^b Distilled with decomposition.

tilled *in vacuo* (15 mm) at 150° to afford phenyl isothiocyanate in 46% yield.

Thermal Decomposition of Lithium *N*-Phenyldithiocarbamate, 1 (R = Ph). The solution of 1 (R = Ph) in tetrahydrofuran was evaporated to dryness *in vacuo* (15 mm). The residue was pyrolyzed at 150° to afford the mixture of *N,N'*-diphenylthiourea (mp 154-155°, main product) and phenyl isothiocyanate. The latter compound was isolated by filtration of the mixture in 11% yield.

One-Step Thiocarbonylation Reaction of Aniline. Aniline (2.79 g, 30 mmol) was dissolved in dry tetrahydrofuran (30 ml) and treated with butyllithium (66 mmol) under dry nitrogen at room temperature. To the resulting solution was added carbon disulfide (5.02 g, 66 mmol) at 0°. The mixture was refluxed for 4 hr and evaporated to eliminate the solvent. The residue was distilled *in vacuo* (15 mm) to afford crude *N,N'*-diphenylthiourea, contaminated with a trace amount of phenyl isothiocyanate. The crude thiourea was recrystallized from ethanol to give pure *N,N'*-diphenylthiourea, yield 2.80 g (82%), mp 154-155° (lit.⁵ mp 154°).

Registry No.—Butyllithium, 109-72-8; carbon disulfide, 75-15-0; *N,N'*-diphenylthiourea, 102-08-9.

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Synthesis of Racemic Globulol via Solvolysis-Cyclization of a 2,7-Cyclodecadien-1-ol Derivative

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We have previously shown that 2,7-cyclodecadien-1-ol derivatives undergo facile and stereoselective solvolysis-cyclization to give hydroazulenes in high yield.¹ The cyclodecadienols, in turn, are conveniently prepared from 9-methyl-5(10)-octalin-1,6-dione.² In this report we describe an application of this approach to the synthesis of racemic globulol (7), a tricyclic hydroazulene sesquiterpene found in eucalyptus.³

Our previous preparation of cyclodecadienol 3 involved treatment of the unsaturated keto methanesulfonate 1 with borane-tetrahydrofuran followed by methanolic sodium methoxide to effect the boronate fragmentation reaction.¹ Presumably carbonyl reduction precedes hydroboration, in which case the stereochemistry depicted in struc-

ture 3 would be expected.⁴ This presumption was confirmed in the present study by first reducing enone 1 with lithium tri-*tert*-butoxyaluminum hydride and then subjecting the resulting equatorial alcohol 2 to hydroboration-fragmentation. The cyclodecadienol 3 thus secured gave the identical crystalline *p*-nitrobenzoate derivative 4 with that obtained in the combined reduction-hydroboration-fragmentation sequence.⁵ Solvolysis of this *p*-nitrobenzoate in aqueous dioxane containing sodium bicarbonate as previously described yielded the hydroazulenol 5¹ (Chart I).

While simple hydroazulenes tend to show considerable conformational flexibility, thus rendering stereochemical predictions highly problematical, hydroazulene 5 projects a clear-cut picture upon examination of molecular models. The *trans*-fused cyclopentane ring tends to restrict cycloheptane pseudorotation and the double bond removes the most serious eclipsing interactions present in the idealized

Chart I

