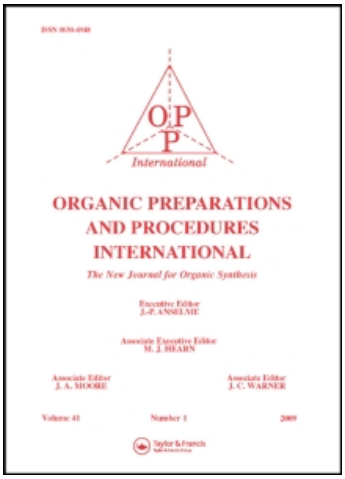

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SYNTHESIS OF ALKYL ISOTHIOCYANATES FROM PRIMARY ALKYL AMINES USING DICYANDIAMIDE AS A DEHYDROSULFURIZING AGENT†

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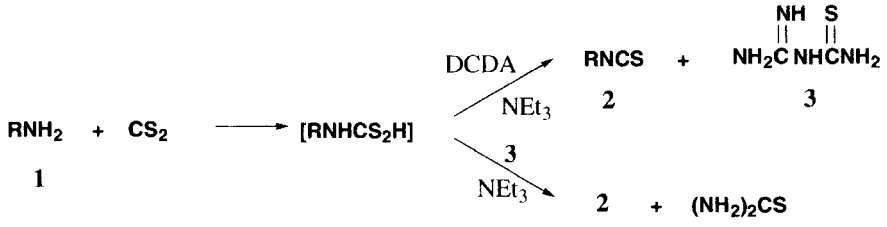
Isothiocyanates have been prepared mainly (a) by the reaction of primary amines with thiophosgene,[1] (b) the decomposition of 1,3-disubstituted thiourea with acid,[2] (c) by the decomposition of dithiocarbamates from primary amines and carbon disulfide in the presence of heavy metal salts,[3] or *N,N'*-dicyclohexylcarbodiimide (DCC).[4] The method using DCC is an effective and convenient route to isothiocyanates in a non-aqueous system.[5] In the previous paper,[6] cyanamide (CA), a tautomer of carbodiimide, was shown to be a useful agent for the dehydrosulfurization of dithiocarbamic acids (or their salts) to isothiocyanates. Since the tautomeric form of dicyandiamide (DCDA) is also a carbodiimide, it might also be useful for such a purpose. The present paper describes an efficient synthesis of alkyl isothiocyanates using DCDA as that reported using CA with the exception of aryl isothiocyanates.



a) R = C_6H_{13} b) R = C_3H_7 c) R = C_4H_9 d) *c*-C_6H_{11}
e) R = $PhCH_2CH_2$ f) $(MeO)_3Si(CH_2)_3$ g) $(EtO)_3Si(CH_2)_3$

Thus, *n*-hexylamine (**1a**) was converted to the corresponding dithiocarbamic acid by the reaction with 2.5 fold molar quantity of carbon disulfide to **1a** in tetrahydrofuran (THF) and the dithiocarbamic acid was treated with 1.5 fold molar quantity of DCDA to **1a** in the presence of catalytic amount of triethylamine. Work-up of the reaction mixture gave hexyl isothiocyanate (**2a**) in 89% yield. In a similar manner, other alkyl and substituted alkyl isothiocyanates listed in Table 1 were obtained in high yields. However, dehydrosulfurization of triethylammonium aryl (phenyl and 4-methylphenyl)dithiocarbamates with DCDA was unsuccessful as it was the case with CA.[6]

In each dehydrosulfurization of alkyl dithiocarbamic acids, guanylthiourea (**3**) was obtained nearly quantitatively. The use **3** for the dehydrosulfurization of hexyl dithiocarbamic acid resulted in the formation of **2a** in a 90% yield and this suggests that *one* molecule of DCDA consumes *two* molecules of hydrogen sulfide. Actually, **2a** was obtained in a 73% yield when the

precursor dithiocarbamic acid was treated with 0.6 fold molar quantity of DCDA to **1a** (step 2 was carried out at 40° for 12 hrs). Although the reaction failed for the preparation of aryl isothiocyanates, the present procedure may be convenient and economical route to alkyl, arylalkyl, allyl and, especially, water-sensitive isothiocyanates.

EXPERIMENTAL SECTION

Melting and boiling points are uncorrected. The IR spectra were recorded as neat samples on a Shimadzu IR-435 spectrophotometer and ^{1}H NMR spectra on a JEOL JNM-PMX60 spectrometer for $CDCl_3$ solution using TMS as an internal standard. DCDA (from Tokyo Kasei Kogyo Co., Ltd.) was used after dehydration. All primary amines (from Tokyo Kasei Kogyo Co., Ltd.) and solvents were used after drying.

General Procedure for Isothiocyanation of Alkyl Amines.- To a stirred solution of alkylamine **1** (30 mmol) in 20 mL of THF was added dropwise 45 mmol of carbon disulfide at 0-5°. After stirring at this temperature for 3 hrs, 45 mmol of finely powdered DCDA, 1 mmol of triethylamine and 20 mL of THF were added into the solution containing the dithiocarbamic acid at room temperature. After stirring at 40° for 3 hrs, the solvent was evaporated under reduced pressure. The residue was extracted with ether (4 x 10 mL) and the combined ethereal extract was evaporated to give the corresponding isothiocyanate **2** as oily residue. Purification was carried out by distillation under atmospheric or reduced pressure. The insoluble solid left from ethereal extraction was purified by recrystallization from methanol to give colorless crystals of guanylthiourea (**3**), mp. 169-171°, lit.[7] 170-172°.

Hexyl Isothiocyanate (2a), oil, 89% yield, bp. 98° /27 mm, lit.[8a] 210°. IR: 2170-2090 cm^{-1} (NCS). NMR: δ 0.85 (t, 3H, *J* = 4.0 Hz), 1.1-2.0 (m, 8H), 3.49 (t, 2H, *J* = 6.0 Hz).

Propyl Isothiocyanate (2b), oil, 88% yield, bp. 152-153°, lit.[8a] 153°. IR:[9a] 2190-2080 cm^{-1} (NCS). NMR: δ1.03 (t, 3H, *J* = 7.3 Hz), 1.47-2.01 (m, 2H), 3.50 (t, 2H, *J* = 7.3 Hz).

Butyl Isothiocyanate (2c), oil, 90% yield, bp. 164-165°, lit.[8a] 166°. IR:[9b] 2190-2080 cm^{-1} (NCS). NMR:[11a] δ 0.98 (t, 3H,*J* = 5.9 Hz), 1.1-1.9 (m, 4H), 3.55 (t, 2H, *J* = 6.3 Hz).

c-Hexyl Isothiocyanate (2d), oil, 71% yield, bp 125°/35 mm, lit.[8b] 219° /746 mm. IR:[9c] 2200-2050 cm^{-1} (NCS). NMR: δ 1.2-2.1 (m, 10H), 3.6-4.0 (m, 1H).

2-Phenylethyl Isothiocyanate (2e), oil, 79% yield, bp. 124-126°/20 mm, lit.[8c] 247.5°. IR:[9d] 2180-2070 cm^{-1} (NCS). NMR: δ 2.81 (t, 2H, *J* = 6.6 Hz), 3.55 (t, 2H, *J* = 6.6 Hz), 7.25 (s, 5H).

Allyl Isothiocyanate (2f), oil, 60% yield, bp. 149-150°, lit.[8d] 151.9°. IR: 2160-2080 cm^{-1} (NCS). NMR:[10c] δ 3.98-4.03 (m, 2H), 5.10-5.16 (m, 1H), 5.18-5.29 (m,1H), 5.63-5.78 (m,1H).

3-(Trimethoxysilyl)propyl Isothiocyanate (2g), oil, 87% yield, bp. 109-111°/7 mm, lit.[6] 109-111°/7 mm. IR:[6] 2190-2100 cm^{-1} (NCS); NMR:[6] δ 0.6-0.9 (m, 2H), 1.60-2.20 (m, 2H), 3.64 (t, 2H, *J* = 8.9 Hz), 3.66 (s, 9H).

3-(Triethoxysilyl)propyl Isothiocyanate (2h), oil, 91% yield, bp. 121-123°/10 mm, lit.[6] 121-123°/10 mm. IR: 2170-2060 cm^{-1} (NCS). NMR:[6] δ 0.5-0.8 (m, 2H), 1.19 (t, 9H, *J* = 7.0 Hz), 1.5-2.1 (m, 2H), 3.52 (t, 2H, *J* = 6.7 Hz), 3.81 (q, 6H, *J* = 7.0 Hz).

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AN IMPROVED SYNTHESIS OF 9-CHLORO-1,8-*p* -MENTHADIENE†

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During a recent study, 4R-(+)-9-chloro-1,8-*p*-menthadiene (**1**) was required. A review of the literature indicated that this allylic chloride had been previously described as a side-product of the