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REACTION OF ISONITRILE WITH NITROALKENE[1]

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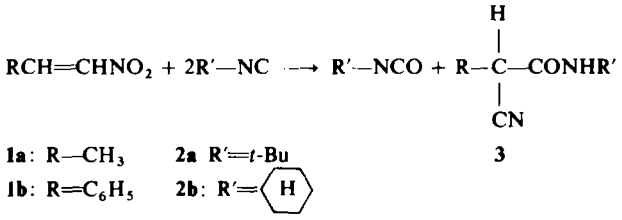
Abstract—The novel reaction of isonitrile (**2**) with nitroalkene (**1**) to produce isocyanate and α-cyano-α-substituted acetamide (**3**) is described. This involves the oxidation of **2** with **1**. In the reaction of **1b** and **2b**, the primary product **3bb** further reacted with **1b** to give the Michael adduct **4bb**.

IN THE reaction of isonitrile with nitro compounds, we found the abstraction of oxygen from nitrogen oxides by isonitrile producing isocyanate and molecular nitrogen.[2] We now report a new reaction of isonitrile with nitroalkene, such as 1-nitropropene (**1a**) and ω-nitrostyrene (**1b**), both of which have a hydrogen attached to the carbon atom and to the nitro group. The new reaction also involves the oxidation of isonitrile.

RESULTS AND DISCUSSION

Isonitrile reacts with nitroalkene to produce isocyanate and α-cyano-α-substituted acetamide (**3**) as shown by the following Eq 1.

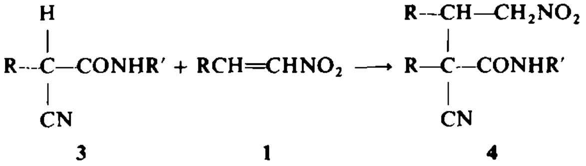


$$\mathrm{RCH{=}CHNO_2 + 2R'{-}NC \longrightarrow R'{-}NCO + R{-}\overset{\displaystyle H}{\underset{\displaystyle CN}{C}}{-}CONHR'} \qquad (1)$$

1a: R—CH_3 **2a** R'=*t*-Bu **3**

1b: R=C_6H_5 **2b**: R'=

The product (**3**) has an acidic hydrogen and reacts further with nitroalkene to form α-cyano-α,β-disubstituted γ-nitrobutyramide (**4**) in a mode of the Michael reaction.



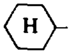
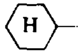
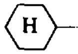
$$\mathrm{R{-}\overset{\displaystyle H}{\underset{\displaystyle CN}{C}}{-}CONHR' + RCH{=}CHNO_2 \longrightarrow R{-}\overset{\displaystyle R{-}CH{-}CH_2NO_2}{\underset{\displaystyle CN}{C}}{-}CONHR'} \qquad (2)$$

3 **1** **4**

Some results are shown in Table 1.

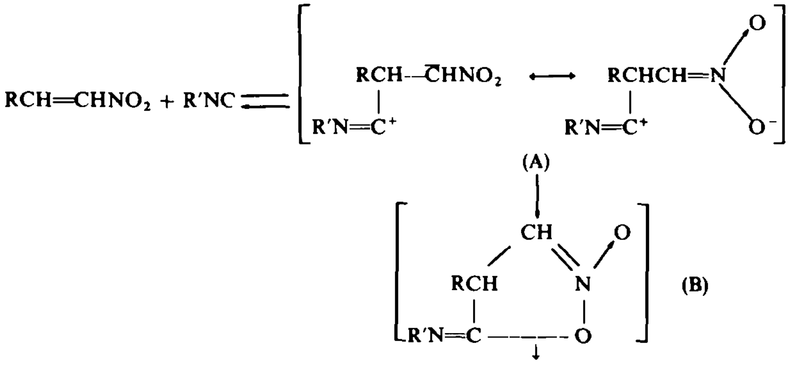
In the reactions of 1-nitropropene, no Michael addition products were detected under the conditions given in Table 1. On the other hand, ω-nitrostyrene gave two products, **3** and **4**. Reaction of equimolar amounts of **1b** and **2b** produced

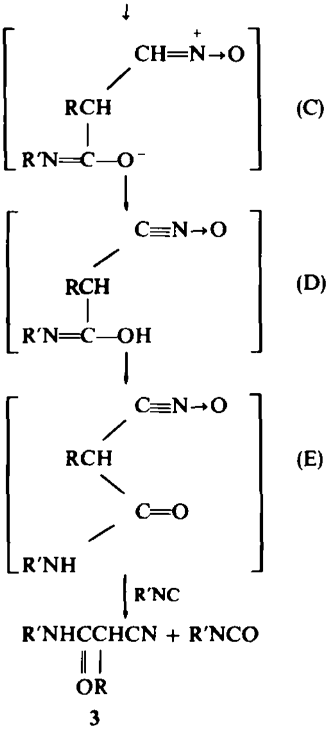
TABLE 1. REACTION OF NITROALKENE WITH ISONITRILE

R of $RCH{=}CHNO_2$ (mmol)	R' of R'—NC (mmol)	Solvent (ml)	Reaction conditions (°) (hr)	Product	(mmol)
CH_3 (**1a**) 20·0	*t*-Bu (**2a**) 40·0	—	60 3	t-BuNCO **3aa** ($R{=}CH_3$, R'=*t*-Bu)	10·7 11·0
CH_3 (**1a**) 10·0	(**2b**) 20·0	C_6H_6 3·0	60 3	-NCO **3ab** ($R{=}CH_3$, R'= )	7·0 7·3
C_6H_5 (**1b**) 10·0	 (**2b**) 30·0	$C_6H_5CH_3$ 10·0	100 5	-NCO[a] **3bb** ($R{=}C_6H_5$, R'= ) **4bb** ($R{=}C_6H_5$, R'= )	3·4 2·8 0·6
C_6H_5 (**1b**) 20·0	 (**2b**) 20·0	$C_6H_5CH_3$ 10·0	100 8	-NCO[a] **4bb** ($R{=}C_6H_5$, R'= )	6·2 5·8

[a] Isolated as N,N'-dicyclohexylurea.

exclusively the Michael addition product. The following scheme may be taken to explain the formation of **3**. The first step of the reaction is probably the nucleophilic attack of isonitrile on the β-carbon atom of **1** to form the 1,3-dipolar type intermediate (A), since it has been known that the nucleophilicity is the general feature of isonitrile reactions.[3] The intermediate (A) will be converted into an unstable ring intermediate





(B), whose ring opening reaction gives rise to the nitrile oxide species (E) through (C) and (D). The deoxidation of (E) with the second molecule of isonitrile will give the product 3. In this step, the second isonitrile molecule is converted into the corresponding isocyanate. The deoxidation of nitrile oxide by isonitrile has been established.[4]

The Michael addition of 3 to nitroalkene may have been catalyzed by isonitrile which has base character. In a separate experiment, the Michael addition of this combination was smoothly carried out in the presence of triethylamine catalyst, *i.e.*, a mixture of 10 mmol of **3bb** and 15 mmol of **1b** catalyzed by 1 mmol of triethylamine in toluene at 60° for 0·5 hr, gave **4bb** quantitatively.

EXPERIMENTAL

Materials. 1-Nitropropene (**1a**) was prepared by dehydration of 2-nitroisopropyl alcohol[5] with phthalic anhydride at reduced pressure.[6]

ω-Nitrostyrene (**1b**) was prepared[7] by dehydration of benzaldehyde and nitromethane with alkali, m.p. 57°. t-Butyl and cyclohexyl isocyanides were prepared according to Ugi *et al.*[8]

Reaction of 1-*nitropropene* (**1a**) *and t-butyl isocyanide* (**2a**). A mixture of **1a** (1·74 g: 20 mmol) and **2a** (3·32 g; 40 mmol) was heated at 60° for 3 hr. After the reaction, t-butyl isocyanate (0·86 g; 8·7 mmol) was trapped by distillation at reduced pressure, and its structure was determined by comparing its IR spectrum with that of an authentic sample. The distillation residue was extracted with hot ligroin to give **3aa** (1·70 g: 11·0 mmol), m.p. 85–86° (from ligroin). Compound **3aa** was identified by IR and NMR spectra as well as elemental analysis. The IR spectrum showed bands at ν_{max} 3250 (s), 2280 (w) and 1650 (vs): NMR (in $CDCl_3$) peaks appeared at τ 8·62 (9H, singlet, t-Bu), 8·44 (3H, doublet, CH_3—CH(CN)), 6·68 (1H, quartet, CH_3—CH(CN)) and 3·8–4·3 (1H, broad, NH). (Found: C, 62·01: H, 9·15: N, 18·02. Calcd for $C_8H_{14}N_2O$: C, 62·30: H, 9·15: N, 18·17).

A part of t-butyl isocyanate was converted to N,N′-di-t-butylurea (1·0 mmol), which was isolated from the extract of ligroin by recrystallization.

Reaction of 1-nitropropene (**1a**) *and cyclohexyl isocyanide* (**2b**). A mixture of **1a** (0·87 g; 10 mmol) **2b** (2·18 g; 20 mmol) and 3 ml of benzene (solvent) was heated at 60° for 3 hr. Vacuum distillation of the mixture gave 3·7 g of distillate boiling at 30–76° (40 mm), which was analyzed by GLPC to contain cyclohexyl isocyanate (0·87 g; 7·0 mmol). The distillation residue was extracted several times with chloroform-ligroin to give crude **3ab** (1·31 g; 7·3 mmol), m.p. 80–81° (from ligroin).

The IR spectrum of **3ab** showed bands at ν_{max} 3260 (s), 2270 (w) and 1650 (vs); NMR (in $CDCl_3$) showed peaks at τ 8·42 (3H, doublet, $CH_3CH(CN)$), 7·9–9·1 (10H, broad, $-(CH_2)_5-$), 6·62 (1H, quartet, $CH_3CH(CN)$), 6·0–6·6 (1H, broad, $N-CH<$), and 3·6–4·1 (1H, broad, NH—). (Found: C, 66·83; H, 9·14; N, 15·26. Calcd for $C_{10}H_{16}N_2O$: C, 66·64; H, 8·95; N, 15·54).

Reaction of ω-nitrostyrene (**1b**) *and cyclohexyl isocyanide* (**2b**). To a mixture of **1b** (1·49 g; 10 mmol) and **2b** (3·27 g; 30 mmol) 10 ml toluene was added as solvent and the mixture was heated at 100° for 5 hr. After the reaction, a small amount of wet ligroin was added to the mixture and kept standing at room temp for one day. A crystalline material precipitated out and collected by filtration. On recrystallization, two crystalline compounds were obtained. One was shown to be N,N′-dicyclohexylurea (1·7 mmol) by its IR spectrum and identified as the reaction product of cyclohexyl isocyanate and water. The other crystalline (0·68 g), m.p. 118°, was identified as **3bb** (2·8 mmol) by IR and NMR spectra as well as elemental analysis. The IR spectrum showed ν_{max} 3260 (s), 2280 (w) and 1650 (vs); NMR (in $CDCl_3$) peaks appeared at τ 7·9–9·0 (10H, broad, $-(CH_2)_5-$), 6·1–6·6 (1H, broad, $N-CH<$), 5·33 (1H, singlet, CH(CN)), 3·6–4·0 (1H, broad, —NH—), and 2·57 (5H, singlet, C_6H_5-). (Found: C, 74·57; H, 7·63; N, 11·51. Calcd for $C_{15}H_{18}NO$: C, 74·35; H, 7·49; N, 11·56.)

Addition of light petroleum ether to the filtrate gave the third crystalline compound, which was identified as **4bb** (0·6 mmol), m.p. 154–155° (from ligroin), by IR and NMR spectra, elemental analysis and molecular weight. The IR spectrum showed bands at ν_{max} 3360 (s), 2280 (w), 1690 (vs), 1530 (vs), and 1370 (s); NMR (in $CDCl_3$) peaks appeared at τ 7·8–9·0 (10H, broad, $-(CH_2)_5-$), 6·0–6·5 (1H, broad, $N-CH<$), 5·35 and 5·55 (1H, two doublets, $-CH(C_6H_5)-CH_2NO_2$), 4·98 and 4·87 (2H, two doublets, $CH-CH_2-NO_2$), 3·8–4·2 (1H, broad, NH—), and 2·98 and 2·73 (10H, two singlets, C_6H_5-CH and $C_6H_5-C(CN)$); molecular weight (VPO in benzene). (Found: 391·5. Calcd for **4bb**: 391·5. (Found: C, 70·35; H, 6·26; N, 10·75. Calcd for $C_{23}H_{25}N_3O_3$: C, 70·57; H, 6·44; N, 10·74. A large quantity of tarry materials was obtained after the extraction.

The reaction of **1b** (2·98 g; 20 mmol) with **2b** (2·18 g; 20 mmol) in 10 ml toluene at 100° for 8 hr, gave 3·1 mmol of N,N′-dicyclohexylurea and 5·8 mmol of **4bb**. A large amount of tarry materials was also formed in this case.

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