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NICKEL(0)-CATALYZED REACTION OF t-BUTYL ISOCYANIDE WITH WATER AND METHANOL: A NOVEL PREPARATION OF 1,2-DI-AMINOETHYLENE DERIVATIVES

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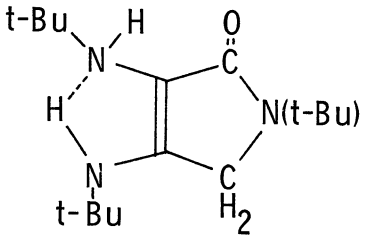
Nickel-catalyzed transformations of t-butyl isocyanide into cyclic 1,2-diaminoethylene derivatives, t-BuN-CH_2C(NH-t-Bu)=C(NH-t-Bu)CO and $[=C(NH\text{-}t\text{-}Bu)\text{-}C(=N\text{-}t\text{-}Bu)OCH_3]_2$ are described.

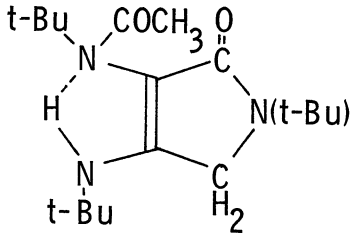
Potentiality of organic isocyanides in organic synthetic reactions receiving recent wide-spread attention[2)] owes to chemical activation of the isocyanides through complexation with transition metals. The observation of successive insertion of isocyanide into a nickel-alkyl bond[3)] prompted us to investigate catalytic reaction of isocyanides with protic reagents (HB) such as water, alcohols, acids etc. using nickel(0) or palladium(0) complexes as catalysts, expecting isocyanide insertion into a presumed metal-hydride intermediate derived from the oxidative addition of HB.

The reaction of t-butyl isocyanide in aqueous methanol(75%) in the presence of nickel(0) complexes, e.g. $Ni(t\text{-}BuNC)_4$, at 120°C for 24 hr under nitrogen in an ampoule or in an autoclave gave a complex mixture of products. Evaporation of the ether extract followed by chromatographic separation on silica gel and recrystallization of the benzene-ether eluate gave colorless crystals (1) mp 114~116°C, of molecular formula,[4)] $C_{16}H_{31}N_3O\cdot H_2O$, in 20% yield. Di-t-butyloxamide, t-BuNHCOCONH-t-Bu, (4% yield) and di-t-butylurea, t-BuNHCONH-t-Bu, (5% yield) were also isolated from the reaction mixture. Control experiments indicated that the presence of both zerovalent nickel complexes and a proton donor is essential for the catalysis. Nickelocene, nickel tetracarbonyl, and tetrakis(triphenylphosphine)nickel(0) may also be employed as catalysts. A proposed structure[4)] for 1 (shown below) is the only one which best accommodates all spectroscopic data; ir (Nujol) 3380 and 3300 cm^{-1} (νNH), 1660 and 1640 cm^{-1} (νC=O and νC=C); nmr ($CDCl_3$) in δ(TMS), sharp singlets

1.14, 1.32 and 1.45 ppm (t-butyl), broad singlets 2.91 and 4.65 ppm (NH exchangeable with added D_2O), singlet 3.98 ppm (CH_2); λ_{max}^{EtOH} 221 and 285 nm (ε 9,400 and 9,500). Alternative structures 1b~1d are excluded since the electronic spectrum lacks strong



1a



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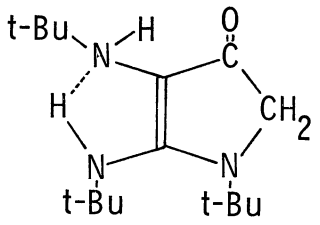
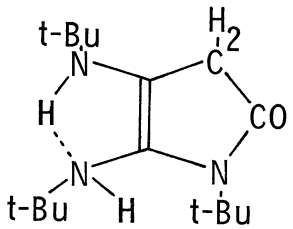
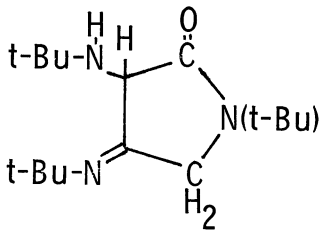
absorptions at 300~350 nm expected for a ketone 1b conjugated with a strongly electron donating triaminoethylene group and since the ir lacks a carbonyl band at 1700 1750 cm^{-1} region characteristic to a 5-membered lactam such as 1c or 1d.



1b

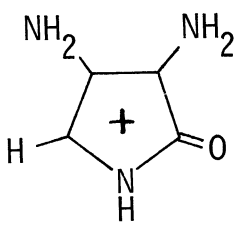


1c

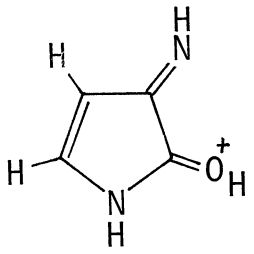


1d

The mass spectrum of 1a shows a strong molecular ion peak at m/e 281 and very strong fragment peaks at m/e 225, 168, and 112 by successive loss of three C_4H_8 groups. Metastable peaks corresponding to the above fragmentation route were observed at m/e 178.5, 127.0 and 75.5. Further, very strong peaks corresponding to the species (a) or (b) indicate the presence of a resonance-stabilized cyclic structure of the fragment ion. The mono-N-acetyl derivative (2) shows a similar fragmentation pattern except some peaks due to the presence of an acetyl group.



(a) m/e 112

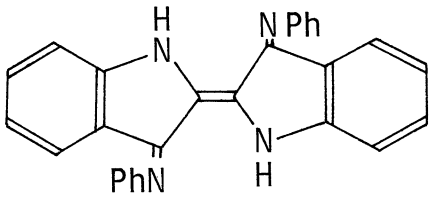


(b) m/e 97

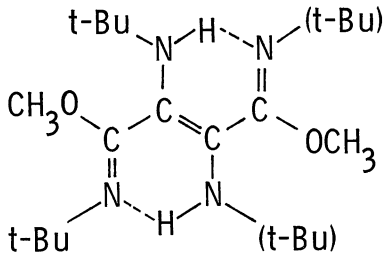
The proposed structure (1a) is further confirmed by preparation of a mono-

N-acetyl derivative (2). Of the two amino-groups of 1a the α-amino group (A) is expected to be more susceptible to acetylation on the ground of its electron density higher compared to the other. Even when a large excess of acetic anhydride was employed at room temperature for 18 hr only a monoacetyl derivative (2)[4] mp 142-143°C, M^+ at m/e 323, was obtained selectively. The nmr showed a new singlet (δ 1.85 ppm, $COCH_3$) in place of the signal of NH at δ 2.91 ppm observed for 1. The ir has only one NH frequency (3320 cm^{-1}) together with a strong band at 1655 cm^{-1} (N-acetyl). The electronic spectra of 1a and 2 are similar and both consistent with the presence of a conjugated β-aminoester chromophore.

When anhydrous methanol is used as a solvent, a somewhat different catalytic reaction of the isocyanide with methanol takes place at 120°C in the presence of $Ni(t\text{-}BuNC)_4$. The orange yellow solution obtained after the reaction for 24 hr gives upon distillation (200°C/5 mmHg) pale yellow needles admixed with yellow liquid products. The needles were recrystallized from anhydrous methanol to give an analytically pure colorless sample (3)[4], mp 126~128°C, M^+ at m/e 396, which is very air-sensitive in solution. A considerable loss during the purification is inevitable due to the instability of 3 reducing the yield to ca. 10%. On the basis of its relatively simple nmr and ir patterns, the following symmetrical structure 3 is proposed. Thus, two different t-butyl groups (at δ 1.20 and 1.44 ppm), equivalent NH and OCH_3 groups (at δ 5.87 and 3.75 ppm) are indicated by the nmr spectrum ($CDCl_3$). Presence of NH (3310 cm^{-1}), C=N (1625 cm^{-1}), and OCH_3 (1062 cm^{-1}) groups are confirmed by the ir spectrum. The di(iminoacyl)diaminoethylene structure of 3 interestingly reminds us formation of "Indigodianil" from thermal oligomerization of PhNC.[5] The mass spectral pattern is also interpretable with this structure 3 (m/e 396(M^+)). Several stable heterocyclic intermediate fragments observed are due to the elimination of some of the t-butyl and methoxy groups. The electron-rich unsaturation of 3 is responsible for the susceptibility to air-oxidation which can be detect-



Indigodianil



3

ed by the disappearance of the NH proton signal. The electronic absorption maximum (EtOH) at 321 nm with a considerable tail into 360 nm region supports the structure. 1a and 3 slowly reduces aqueous silver nitrate to the metal at room temperature. The reducing property apparently owes to the diaminoethylene part.

Although many other complexes of low-valent nickel or cobalt triad elements were tried as a catalyst under similar conditions, none has been found effective for preparation of 1a or 3 except Ni(0) complexes. Thus catalytic synthesis provides an important preparative route to the heretofore difficulty accessible diaminoethylenes which are interesting in view of the current importance of "reducton" in biological chemistry.

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