of the reasonable assumption of continuity between these two "zones" of β_{nuc} values, one should expect a correlation between the extent of electron transfer and the value of β_{nuc} as was suggested by Shaik and Pross.[12b] Thus, as the magnitude of the α effect depends on the extent of the electron transfer at the transition state and this on the other hand is correlated with β_{nuc} value, the α effect should be directly related to the value of β_{nuc}. Indeed, for a series of hydrazines reacting with various substrates the magnitude of the α effect was found to be directly related to the β_{nuc} value,[3i] confirming our aforementioned proposal. Formally, one can also expect that the increase in the degree of electron transfer upon going from an LL substrate to a substrate with a lower LUMO will also increase the magnitude of the α effect. An example of such a behavior is found in nucleophilic reactions with $ArXSO_2Ph$ where SO_2Ph is the leaving group and X varies from SO_2 to SO to S.[16] The changes in X are accompanied by a parallel decrease of the α effect, giving the respective ratios: 7.3:2.4:1 for HO_2^- and 9.7:48:1 for $AcNHO^-$. However, it should be noted that the drastic change from an HL substrate such as methyl chloride to an LL substrate such as a carbonyl group gives rise to a relatively small change (about 2 kcal/mol) in the activation energy of an α nucleophile compared to a non α nucleophile. Therefore, a variation of the substrate within the LL family is likely to induce a much smaller effect which might be easily masked by other effects resulting from the structural changes.

In conclusion, the extra stabilization of the transition state in the reaction of α nucleophiles with LL substrates results from the partial radical character that the nucleophile acquires at the transition state. As the magnitude of this radical character increases, so should the size of the α effect.

Acknowledgment. Helpful discussions with Professor H. Basch, Dr. S. S. Shaik, and Professor J. F. Bunnett are gratefully acknowledged.

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Reaction of 3-Nitroso-2-phenylimidazo[1,2-*a*]pyridine with Triethyl Phosphite. A Revised Structure for the Product

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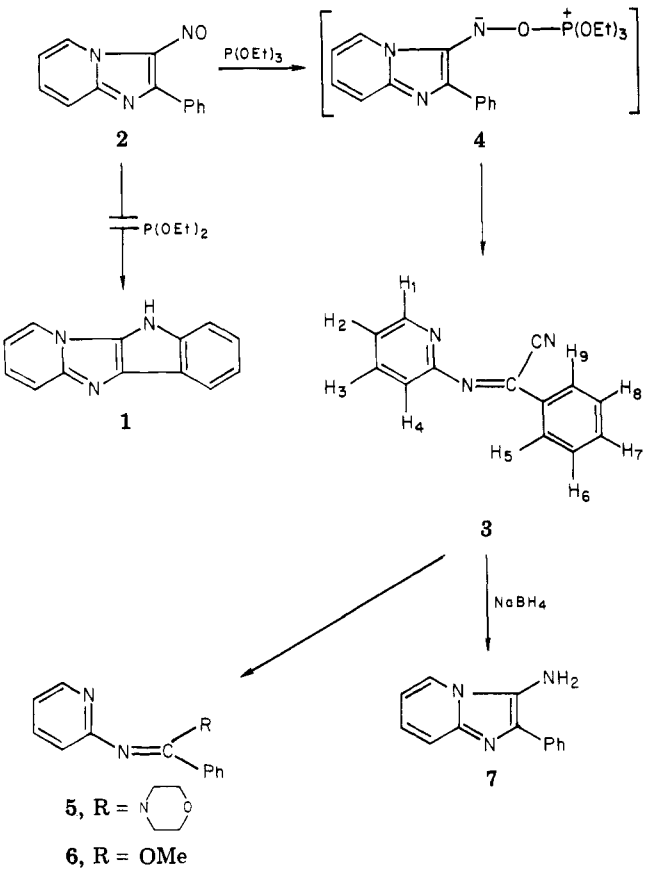
During an investigation of the effects of various antihypertensive agents on prostacyclin and thomboxane A_2 production we required a sample of pyridino[1,2-*a*]-imidazo[5,4-*b*]indole (**1**), which has recently been shown to possess potent hypotensive activity in spontaneously hypertensive rats.[1,2] The tetracycle **1** was reported to be formed by the triethyl phosphite reduction of the readily available 3-nitroso-2-phenylimidazo[1,2-*a*]pyridine (**2**,[3] Scheme I).

Scheme I



On repetition of the published procedure for the preparation of **1** a compound with an identical melting point and ^1H NMR spectrum was obtained. The IR spectrum of our product, however, showed none of the reported bands at 3410, 3080, or 2580 cm^{-1} but displayed strong bands at 1500 and 1540 cm^{-1} and a weak absorption at 2220 cm^{-1}. The latter band was indicative of a nitrile group. The reduction product gave a ^1H NMR spectrum identical with that reported by Adhikary, but none of the nine protons exchanged with D_2O. This failure to detect signals characteristic of the NH group in either the IR or the NMR spectra of the phosphite reduction product coupled with mechanistic considerations led us to postulate the alternative imidoyl cyanide structure **3**. The cyanide would be the expected product following the loss of triethyl phosphate from the intermediate **4**. A detailed examination of the proton NMR spectrum lent support to the postulated structure **3**, and these assignments were confirmed by decoupling experiments (see Experimental Section).

Chemical studies on the phosphite reduction product provided evidence which also supported the assignment of structure **3**. Reaction with morpholine gave the amidine **5** whereas treatment with sodium hydroxide in methanol furnished a mixture of 2-(benzoylamino)pyridine and the iminoether **6**. Reduction with sodium borohydride gave rise to 3-amino-2-phenylimidazo[1,2-*a*]pyridine (**7**), an initial reduction of the imine function followed by cyclization occurring.[4] None of these reactions could be explained by the tetracyclic structure **1**.

Final confirmation of the correctness of the assignment of structure **3** to the phosphite reduction product was

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(4) Strecker reactions between 2-aminopyridine and aldehydes give 3-aminoimidazo[1,2-*a*]pyridines. McCapra, F.; Wrigglesworth, R. *Chem. Commun.* **1968**, 1256.

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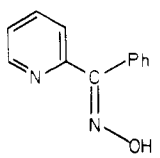
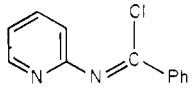
provided by the unequivocal synthesis of *N*-(2-pyridyl)-benzimidoyl cyanide. Treatment of *syn*-phenyl 2-pyridyl ketoxime (8) with thionyl chloride gave the hydrochloride



8



9

of the imidoyl chloride[5] **9**. Initial attempts to convert the hydrochloride of **9** to **3** with triethylamine and sodium cyanide under a variety of conditions failed. Zinc cyanide which has been recently used to synthesize α-cyano enamines from imidoyl chlorides[6] was also ineffective. However, when the hydrochloride of **9** was refluxed in dioxane with triethylamine and cuprous cyanide, the required nitrile **3** was obtained. This imidoyl cyanide was identical with the product obtained by the reaction of 3-nitroso-2-phenylimidazo[1,2-*a*]pyridine with triethyl phosphite.

Experimental Section

All melting points are uncorrected. IR spectra were recorded on a Perkin-Elmer 197 spectrophotometer. Proton magnetic resonance spectra were obtained on a Varian EM390 instrument or in the case of the decoupling experiments on a Perkin-Elmer R34 instrument. Mass spectral data was taken on an EMI MS9-02 spectrometer. All flash chromatography was done by using Merck 60 silica (230–400 mesh).

Reaction of 3-Nitroso-2-phenylimidazo[1,2-*a*]pyridine with Triethyl Phosphite. The reaction was carried out as described by Adhikary et al.[1] The crude product was flash chromatographed with EtOAc/toluene (3:20) as the solvent. Recrystallization from hexane gave a 63% yield of **3** as yellow prisms: mp 77–78 °C; mass spectrum, *m/e* 207 (M^+), 206 (M – H), 181 (M– CN), 179 (206 – HCN); ^1H NMR ($CDCl_3$; see structure **3** for numbering) δ 8.55 (dd, H_1), 8.25 (m, H_5 or H_9), 8.20 (m, H_5 or H_9), 7.80 (td, H_3), 7.50 (m, H_6, H_7 and H_8), 7.20 (m, H_2 and H_4). Irradiation at the H_1 proton caused the H_3 proton resonance to collapse to a triplet and the H_2 and H_4 multiplet to simplify whereas irradiation at the H_3 proton prompted the H_1 proton resonance to collapse to a doublet and the H_2 and H_4 multiplet to simplify.

1-[*N*-(2-Pyridyl)benzimidoyl]morpholine (5). A solution of **3** (1.035 g, 0.005 mol) and morpholine (0.5 mL, 0.00625 mol) in toluene (10 mL) was stirred at room temperature for 16 h. The solvent was evaporated under vacuum, and the residue was flash chromatographed with $CHCl_3$/MeOH (20:1) as the solvent. The resultant oil slowly solidified and was recrystallized from hexane/anhydrous Et_2O to afford 0.98 g (75%) of **5**: colorless prisms; mp 81–82 °C; ^1H NMR ($CDCl_3$) δ 8.15 (dd, 1 H, pyridine C(6) proton), 7.20 (m, 6 H, aryl protons and pyridine C(4) proton), 6.60 (m, 1 H, pyridine C(5) proton), 6.30 (d, 1 H, pyridine C(3) proton), 3.75 (m, 4 H, O–CH_2), 3.4 (m, 4 H, CH_2–N). Anal. Calcd for $C_{16}H_{17}N_3O$: C, 71.9; H, 6.4; N, 15.7. Found: C, 71.5; H, 6.1; N, 15.5.

Reaction of the Triethyl Phosphite Product 3 with Sodium Hydroxide in Methanol. The triethyl phosphite reaction product **3** (1.035 g, 0.005 mol) was added to a solution of sodium hydroxide (0.2 g, 0.005 mol) in 20 mL of H_2O/MeOH (1:1), and the resultant solution was stirred for 1 h at room temperature. The methanol was removed under vacuum and the residue extracted with toluene. The organic extract was dried and on evaporation under vacuum gave a sticky solid, which was flash chromatographed with toluene/EtOAc (4:1) as the solvent. The chromatography gave, in the order of elution, 2-(benzoylamino)pyridine [0.42 g; mp 82 °C (lit.[7] mp 82–83 °C)] and the imino ether **6**: 0.30 g; colorless oil; ^1H NMR ($CDCl_3$) δ 8.35 (dd, 1 H, pyridine C(6) proton), 7.35 (m, 6 H, aryl protons and pyridine C(4) proton), 6.90 (m, 1 H, pyridine C(5) proton), 6.55 (d, 1 H, pyridine C(3) proton), 4.05 (s, 3 H, OMe); mass spectrum, *m/e* 211 (M^+).

3-Amino-2-phenylimidazo[1,2-*a*]pyridine (7). Sodium borohydride (0.095 g, 0.005 mol) was added gradually to an ice-cooled, well-stirred solution of the triethyl phosphite reaction product **3** (1.035 g, 0.005 mol) in absolute ethanol (10 mL). After the addition the reaction mixture was stirred for 1 h at room temperature. The solvent was evaporated under vacuum and the residue extracted with 1 N hydrochloric acid (30 mL). The acid extract was made alkaline by utilizing 2 N sodium hydroxide solution, and the amine was extracted with ethyl acetate. The organic phase was separated and dried over $MgSO_4$, and the solvent was removed under vacuum to give crude **7**. Recrystallization from absolute EtOH/hexane furnished **7**: 0.57 g (55%); colorless prisms; mp 211 °C (lit.[1] mp 212–214 °C).

***N*-(2-Pyridyl)benzimidoyl Cyanide (3).** Triethylamine (0.88 g, 0.0088 mol) was added to a solution of the hydrochloride of **9**[5] (2.0 g, 0.0008 mol) in dry dioxane (15 mL), and the solution was stirred at room temperature for 30 min. Cuprous cyanide (2.2 g, 0.025 mol) was added, and the reaction mixture was refluxed for 2 h. The solvent was evaporated under vacuum and the residue extracted with three 50-mL portions of ether. The combined extracts were dried over $MgSO_4$ and evaporated. The residual gum was flash chromatographed with toluene/EtOAc (4:1) as the solvent to give, after recrystallization from hexane, 0.48 g (30%) of **3**, mp 77–78 °C. Anal. Calcd for $C_{13}H_9N_3$: C, 75.4; H, 4.3; N, 20.3. Found: C, 75.3; H, 4.2; N, 19.9.

Registry No. **2**, 3672-37-5; **3**, 82093-41-2; **5**, 82093-42-3; **6**, 82093-43-4; **7**, 3999-29-9; **8**, 14178-31-5; **9**·HCl, 82093-44-5; $P(OEt)_3$, 122-52-1; morpholine, 110-91-8; 2-(benzoylamino)pyridine, 4589-12-2.

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Preparation of 3-*C*-Methylene Sugars by Peterson Olefination

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Olefination of glycosides of 3-keto sugars is complicated by the ease with which these materials undergo elimination of the anomeric alkoxy group under the usual conditions of the Wittig reaction with unstabilized ylides. A careful study of the conversion of methyl 2-*O*-benzoyl-4,6-*O*-benzylidene-α-D-*ribo*-hexopyranosid-3-ulose (**1**) to methyl 4,6-*O*-benzylidene-3-deoxy-3-*C*-methylene-α-D-*ribo*-hexopyranoside (**3**) has been described[1] which testifies to the difficulty of effecting this seemingly straightforward transformation. An interest in branched-chain amino sugars required unsaturated carbohydrates as their potential synthetic precursors, and our experience with [(trimethylsilyl)methyl]magnesium reagents[2] encouraged us to believe that the Peterson olefination sequence[3] might be a superior method for the preparation of exocyclic methylene sugars. The present work, summarized in Scheme I, presents evidence that this is indeed the case.

Addition of the Grignard reagent from (chloromethyl)trimethylsilane to **1** gave methyl 2-*O*-benzoyl-4,6-*O*-benzylidene-3-[(trimethylsilyl)methyl]-α-D-allopyranoside (**2**, 90%).[4] Elimination of trimethylsiloxide

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