pounds[1a] and then subjected them to ^1H NMR studies in CD_3OD (Table I).[3] An analysis of the spin–spin coupling constants reveals that both pyranose rings exist in chair-like conformations. The ^1H NMR data for the C1′ and Cα protons firmly establishes that the *C*-glycosidic bond adopts the predicted conformation for both **1b** and **2b**. Most importantly, in contrast to the reported results for **1a** and **2a**, where a mixture of conformers or a single twisted conformer around the nonglycosidic bond was detected, the vicinal spin–spin coupling constants observed for **1b** and **2b** confirm the anticipated single conformation around the C.4–Cα bond.

As previously pointed out,[1d] the carbon analogue **3a** of α-D-galactopyranosyl-D-galactopyranose, a structural unit of human blood group determinants,[4] possesses one unique conformer **3a**-A, which is free from 1,3-diaxial-like interactions around the nonglycosidic bond. Thus, we anticipate that **3a**[2] exists predominantly in the ideal staggered conformer **3a**-A. Indeed, the ^1H NMR data supports this prediction. Moreover, this analysis suggests that this conformational preference should be disturbed by changing the configuration of the C4 hydroxyl group. Indeed, the ^1H NMR data of **3b**[2] supports this prediction as well.

In summary, we have shown that an analysis of the steric factors primarily around the nonglycosidic bond, as illustrated by use of a diamond lattice, enables us to predict the conformational preference of *C*-dissacharides. The conformational similarity between *C*-disaccharides and their oxygen counterparts will be discussed in a forthcoming paper.

Acknowledgment. Financial support from the National Institutes of Health (NS 12108) is gratefully acknowledged.

Supplementary Material Available: Schemes for the synthesis of **1b**, **2b**, **3a**, and **3b** and the complete table listing chemical shifts and spin–spin coupling constants (6 pages). Ordering information is given on any current masthead page.

(3) We observed a temperature effect; for example, $J_{4,\alpha(pro\text{-}R)}$ and $J_{4,\alpha(pro\text{-}S)}$ of **2b** were 3.4 and 9.2 Hz at 44 °C, 3.1 and 9.5 Hz at 23 °C, 2.8 and 10.0 Hz at −3 °C, 2.4 and 10.4 Hz at −13 °C, and 1.5 and 10.5 Hz at −35 °C.

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Yuan Wang, Peter G. Goekjian
David M. Ryckman, Yoshito Kishi*
Department of Chemistry
Harvard University
12 Oxford Street
Cambridge, Massachusetts 02138
Received March 1, 1988

Reactivity of Phosphacarbamates: Transfer of the Carbamate Group Promoted by Metal Assisted Electrophilic Attack at the Carbon Dioxide Moiety

Summary: Phosphacarbamates have been used in an unprecedented reaction as a source of carbamate group in the synthesis of organic carbamates via a metal assisted electrophilic attack at the carbon dioxide moiety.

Sir: Phosphacarbamates of of formula $Z_xP(OOCNR_2)_{2-x}$ (Z = halogen, alkyl-, dialkylamino; x = 1, 2) can be prepared via an easy carbon dioxide insertion into the P–N bond of the corresponding aminophosphines in the absence[1,2] or presence[3] of metal ions. The rate of insertion depends on the nature of substituent Z at the phosphorus atom, the solvent used, the temperature, and the metal complexes bearing the aminophosphine as ligand.[3] The reactivity of phosphacarbamates has been also studied by several authors who have shown that in the presence of amines they undergo a nucleophilic attack at the carbamic carbon[4] to afford ureas (eq 1).

$$(R_2N)_2POC(O)NR_2 \xrightarrow{H_2NR'} R'HNC(O)NR_2 + (R_2N)_2PHO \quad (1)$$

We report here an unprecedented electrophilic attack at the carboxylic function of phosphacarbamates that induces the carbamate group transfer to an organic halide (R′X) to afford carbamates of formula R_2NCOOR'.

Solutions of $P(NR_2)_3$ (1) in THF at 273 K and 0.10 MPa of CO_2 insert carbon dioxide in to the P–N bond to afford $(R_2N)_2P(OOCNR_2)$ (**2**). The dicarbamate $(R_2N)P(OOCNR_2)_2$ (**3**) can be obtained at room temperature. Attempts to insert a third molecule of carbon dioxide failed with use of aminophosphine (1) with both R = methyl (ref 1 and this work) and R = ethyl (this work). It is worth noting that we have observed CO_2 insertion neither into the P–N bond of $O{=}P(NR_2)_3$ (R = methyl and ethyl) at 300 K and 5.2 MPa of CO_2 after 24 h nor in the P–N bond of phosphonium salts $(R_2N)_3PR'X$ at 300 K and 0.10 MPa of CO_2 after 48 h.

Conversely, aminophosphines coordinated to transition metal centers[3] have been shown to be able to insert carbon dioxide into the P–N bond at a lower reaction rate than the free ligand. These results suggest that both the coordination number and the oxidation number of phosphorus can play an important role in the insertion reaction.

When phosphacarbamates (**2**) and **3**) are treated with an organic halide R′X or ArX no reaction is observed. Conversely, if a metal salt MY (M = group I metal) or $L_nM'Y$ (M′ = transition metal; L = phosphorus or nitrogen ligand; Y = F, Cl, Br, I) is added to the reaction system the synthesis of the organic carbamate is accomplished (eq 2). The yield depends on several factors: the operative

$$(R_2N)_{3-x}P(OOCNR_2)_x + xR'X \xrightarrow[\text{or } L_nMY]{MY + CE} R_2NCOOR' + (R_2N)_{3-x}PY_x \quad (2)$$

conditions, the nature of the metal salt (both M, M′, and Y play an important role; group I metal ions require crown ethers), and of the organic halide. In this paper we shall focus on the case in which aliphatic halides are used in the presence of group I metal salts. Other cases will discussed in a forthcoming paper.[5]

The first step in the reaction of phosphacarbamates with metal ions, both in the presence and absence of R′X, is the formation of metal carbamate R_2NCOOM that can be isolated from the reaction mixture when noncoordinating solvents such as benzene and toluene are used. However, this finding suggested to us that metal carbamates prepared in whatever manner might be used in the synthesis of organic carbamates under our conditions. We have, therefore, investigated the role played by the metal salt and the organic halide in the transfer reaction of the carbamate group. Among Group I metal ions investigated (Li^+, Na^+, K^+), K^+ seems to be a particularly good transfer

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0022-3263/88/1953-4153$01.50/0

agent. This finding matches the fact that potassium ion is implied in biological systems in the processes related to synthesis[6] and transfer[7] of the carbamate group. Among MY salts, the most active and selective of the halide ions is fluoride (100% selective in the organic carbamate), while other halides can afford other products derived from nucleophilic attack at the carbon dioxide moiety. Iodide yields the carbamoyl halide (eq 3) (ca. 20% yield), which

$$(R_2N)_2P(OOCNR_2) + NaI + R'X \rightarrow R_2NC(O)I + (R_2N)_2POR' + NaX \quad (3)$$

can be easily separated from the carbamate owing to the difference in physical properties. We have found that there is a correlation between the energy of the P–Y bond formed and the yield in carbamate.

When phosphacarbamate (3) was treated with an organic halide R'X (X = Cl, Br, I) in the presence of KF and of the 18,6-crown ether[8] we have observed quantitative formation of the organic carbamate R_2NCOOR' and of $(R_2N)PF_2$, which was isolated from the reaction mixture and characterized by means of IR spectroscopy and of ^1H, ^{13}C, ^{19}F, and ^{31}P NMR techniques. This fluorophosphine was quite unreactive and could not be recycled to afford the starting tris(dimethylamino)phosphine. Conversely, other halophosphines R_2NPY_2 (Y = Br, I) could be transformed into the starting aminophosphine. This fact was of interest as it permitted synthesis of carbamates under very mild conditions from quite safe reagents (amines, organic halides, and carbon dioxide), phosphorus halides being only promoters used in the synthesis of reactive intermediates. As the crown ether was also recycled the whole process can be summarized by eq 4 which represents the overall synthesis of carbamates from the reagents.[9]

$$R_2NH + CO_2 + R'X \xrightarrow{\text{base}} R_2NCOOR' + BaseH^+Y^- \quad (4)$$

Starting from metal carbamates R_2NCOOM (M = Li, Na, K) prepared by other routes, the organic carbamate could also be isolated in particularly good yield (>85%) when M = K^+ in the presence of 18,6-crown ether. Utilization of the coordinating crown ethers thus allows transfer of the carbamate group in high yield and represses nucleophilic attack at the carbon atom which yields ureas.

This transfer reaction appears to be of interest in a cyclic or a flow system. It represents one of the very few examples of an electrophilic attack at the carbon dioxide moiety mediated by a metal ion and the first example of a carbamate moiety transfer from a phosphacarbamate. It is relevant to other similar reactions in which the carbamate group is involved,[10-12] and may help in the understanding of common features.

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(8) 18,6-Crown ether is 1,4,7,10,13,16-hexaoxacyclooctadecane.

(9) NMR data for $P(NMe_2)_3$ and its carbamate derivatives (mono and di) agree with those reported in the literature.[1-3] ^1H and ^{13}C data are referred to TMS, ^{31}P are referred to H_3PO_4, and ^{19}F data are referred to $(CF_3)_2CO$(hydrated). All spectra were run in CD_2Cl_2 at 273 K with a Varian XL 200 instrument. $P[N(CH_2CH_3)_2]_3$: ^1H NMR 2.74 (m, ^3J(H–P) = 8.47 Hz, CH_2), 0.84 ppm (t, ^3J(H–H) = 7.1 Hz, CH_3); ^{13}C NMR 38.94 (tdq, ^1J(C–H) = 133.7 Hz, ^2J(C–H) = 4.4 Hz, ^2J(C–^{31}P) = 19.3 Hz, CH_2), 13.57 ppm (qt, ^1J(C–H) = 125.0 Hz, ^2J(C–H) = 5.0 Hz, CH_3). $^{31}P\{^1H\}$ NMR 116.5 ppm. $P[N(CH_2CH_3)_2]_2$ [$OOCN(CH_2CH_3)_2$]: $^{13}C\{^1H\}$ NMR amino groups 39.67 (d, ^2J(C–^{31}P) = 20.2 Hz, CH_2), 13.78 ppm (s, CH_3); carbamate group 154.38 (d, ^2J(C–^{31}P) = 8.2 Hz, C(O)O), 41.43 (br s, CH_2), 14.57–14.50 ppm (s, CH_3). The two signals for the methyl groups show that the free rotation is restricted. This is true also at 300 K; $^{31}P\{^1H\}$ NMR 127.15 ppm. $P[N(CH_2CH_3)_2][OOCN(CH_2CH_3)_2]_2$: $^{13}C\{^1H\}$ NMR amino group 38.82 (d, ^2J(C–^{31}P) = 23.0 Hz, CH_2), 13.18 ppm (CH_3); carbamate groups 153.42 (d, ^2J(C–^{31}P) = 8.4 Hz), 41.81 (CH_2), 14.40 ppm (CH_3); $^{31}P\{^1H\}$ NMR 125.82 ppm. $(CH_3)_2NCOOCH_2CH{=}CH_2$: IR 1705 cm^{-1} (neat); *m/e* 129; ^1H NMR 5.48 (m, J(H–H_{trans}) = 17.25 Hz, J(H–H_{cis}) = 10.45 Hz, CH=), 4.82–4.72 m, J(H_{gem}) = 1.58 Hz, $=CH_2$), 4.10 (dt, J(H–C*H*=) = 5.41 Hz J(H–CH_2=) = 1.43 Hz, CH_2), 2.46 ppm (s, CH_3); ^{13}C NMR 155.97 (s, C(O)O), 133.03 (d, ^1J(C–H) = 152.4 Hz, C=), 116.69 (t, ^1J(C–H) = 156.6 Hz, $=CH_2$), 65.59 (t, ^1J(C–H) = 152.4 Hz, CH_2), 36.08 (q, ^1J(C–H) = 136.4 Hz, CH_3), 35.52 ppm (q, ^1J(C–H) = 136.8 Hz, CH_3). Yield, 95%. $(CH_3CH_2)_2NCOOCH_2(CH_2)_6CH_3$: IR 1695 cm^{-1}; *m/e* ^{13}C NMR 155.97, (t, ^3J(C–H) = 3.9 Hz, C(O)O), 64.94 (tt, ^1J(C–H) = 145.5 Hz, ^2J(C–H) = 3.8 Hz, OCH_2), 41.30, (t, ^1J(C–H) = 137.7 Hz, CH_2N), 31.78, 29.41, 29.17, 28.98, 25.88, 22.53 (m, CH_2), 13.90 (q, ^1J(C–H) = 122.8 Hz, CH_3N), 13.62 ppm (q, ^1J(C–H) = 126.0 Hz, CH_3). Yield, 98%. $(CH_3)_2NCOOCH_2C_6H_5$: IR 1700 cm^{-1} (neat); *m/e* 179; ^1H NMR 7.20 (m, phenyl protons), 5.00 (s, CH_2), 2.75 ppm (s, CH_3); ^{13}C NMR 156.36 (s, C(O)O), 66.92 (t, ^1J(C–H) = 147.0 Hz), 35.82 (q, ^1J(C–H) = 137.6 Hz), 36.36 (q, ^1J(C–H) = 137.9 Hz), 137.0 (s, C-1 phenyl), 127.35 (d, ^1J(C–H) = 159.2 Hz, C-2 and C-6 phenyl), 128.37 (d, ^1J(C–H) = 159.1 Hz, C-3 and C-5 phenyl), 127.83 ppm (d, ^1J(C–H) = 159.2, C-4 phenyl). Yield, 97%, based on the organic halide used in stoichiometric amounts. $(CH_3)_2NPF_2$: IR 1308, 990, 800, 740, 710 cm^{-1}; ^{19}F NMR 19.1 ppm (d, J(F–P) = 1193.7 Hz), ^{31}P NMR 154.2 ppm (doublet).

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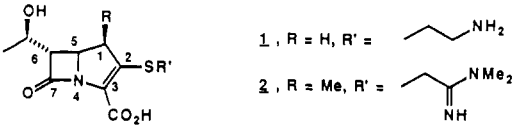
Michele Aresta,* Eugenio Quaranta
Dipartimento di Chimica
Campus Universitario
70126 Bari, Italy
Received February 9, 1988

Enantioselective Synthesis of the 1β-Methylcarbapenems via Cycloaddition of 3-Siloxypentadiene and 4-Acetoxyazetidinone

Summary: The cycloaddition of a 3-siloxy-1,3-pentadiene and the 4-acetoxyazetidinone **3** followed by ring contraction and phosphorylation leads to the key precursor of 1β-methylcarbapenems (**11**) in a five-step process in 27% overall yield.

Sir: The huge success, both financially and medically, for thienamycin (**1**; Primaxin) since its introduction in 1985[1] has spawned considerable interest in analogues with either enhanced activity or greater stability. In 1984, the Merck group reported[2] the synthesis of the 1β-methyl analogue **2**, which exhibited greater stability and resistance to deactivation by renal dipeptidase-1 (DHP-1) and still retained the excellent broad spectrum antibacterial activity.



The 1α-methyl analogue, however, exhibited a marked decrease in antibacterial activity.[3] Furthermore, due to the concave environment in **2**, the β-methyl derivative is

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