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A novel pseudo-seven-component diastereoselective synthesis of λ^5-phosphanylidene bis(2,5-dioxotetrahydro-1*H*-pyrrole-3-carboxylates) via binucleophilic systems

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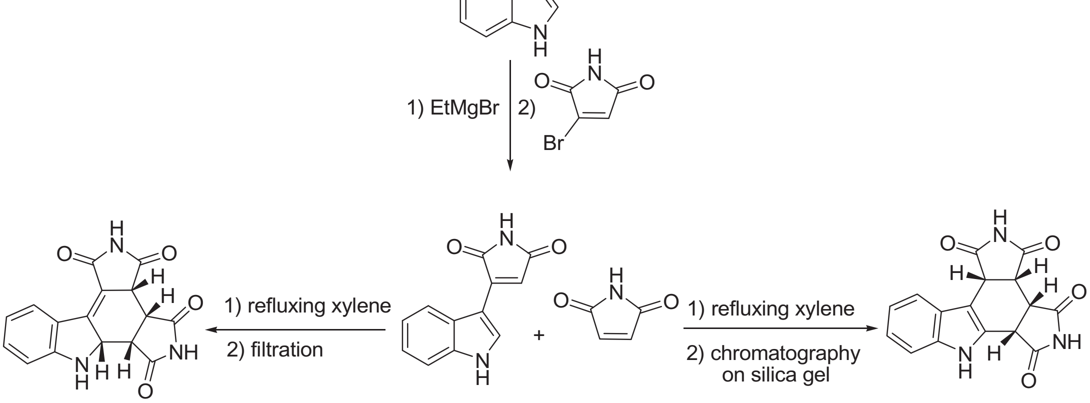
ABSTRACT

The unusual 1:2 intermediate, generated by the addition of triphenylphosphine (TPP) to dialkyl acetylenedicarboxylates (DAAD) was trapped during the reaction of a $Ph_3P/RN = C$/DMAD binucleophilic system with TFA as an initial proton source in a pseudo-seven-component (7-CR) diastereoselective reaction to give λ^5-phosphanylidene bis(2,5-dioxotetrahydro-1*H*-pyrrole-3-carboxylates) with three stereogenic centers and a phosphorane group in good yields.

Substituted pyrrolidines and maleimide frameworks are frequently included in many substances of biological and industrial interests.[1] Bismaleimide derivatives, their analoges, and related polycondensed compounds are known to have antitumor properties. These important biological properties have led to the continued investigations on their synthesis, and the development of protocols to obtain bispyrrolidines of complex structures.[2]

The synthesis of bispyrrolidines has also been widely examined[2] and a variety of non-catalytic[2a] and catalytic[2c] approaches have been described in the literature. Recent methods are limited



Scheme 1. Preparation of substituted decahydro-1*H*-dipyrrolo[3,4-*a*:3,4-*c*]-carbazole-1,3,4,6-tetraone via a multistep pathway.

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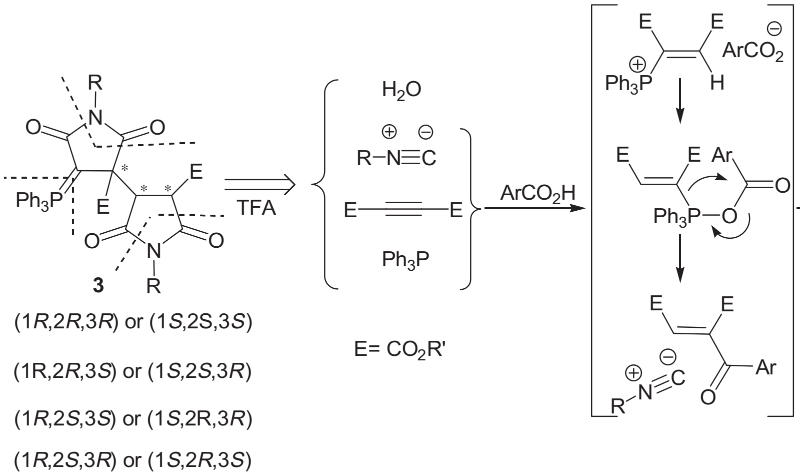
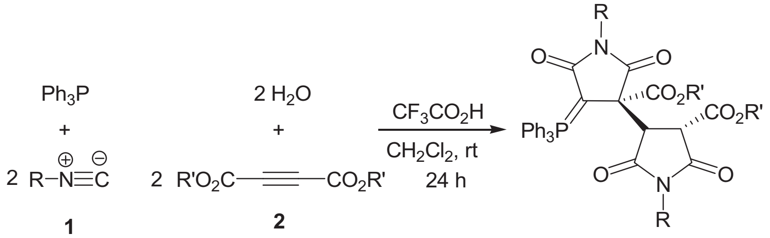


Scheme 2. Synthesis of bispyrrolidines **3** by reaction between Ph_3P, DAAD and TFA in the presence of an isocyanide and H_2O.



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Scheme 3. Synthesis of λ^5-phosphanylidene bispyrrolidines by reaction between Ph_3P, DAAD and TFA in the presence of an isocyanide and H_2O.

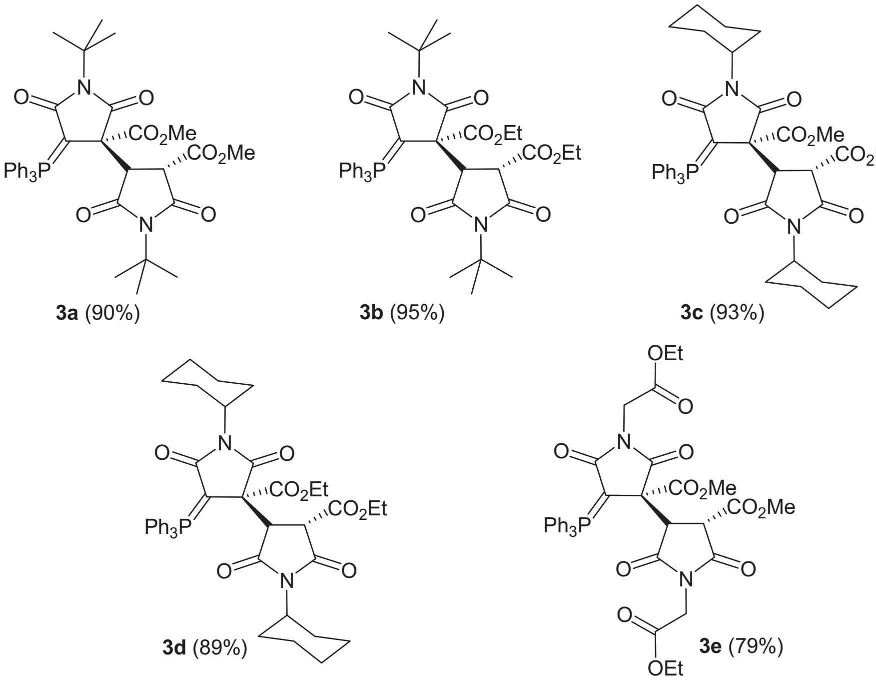
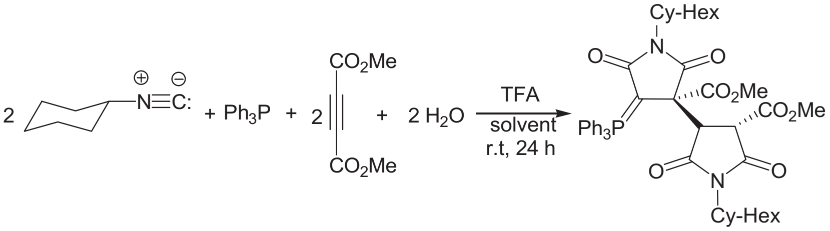


Figure 1. Structures of products **3a–e** [(1*R*,2*S*,3*R*) or (1*S*,2*R*,3*S*)] stereoisomers.

by the requirement of highly reactive functional groups in the substrates. However, all the reported methods rely on multistep reactions or their yields are low, and the reaction times are long. For example, decahydro-1*H*-dipyrrolo[3,4-*a*:3,4-*c*]-carbazole-1,3,4,6-tetraone was synthesized via a multistep pathway, as illustrated in Scheme 1.[2d,e] Thus, the development of new synthetic methods for bispyrrolidines remains an attractive goal.

We have recently reported the interception of zwitterionic species with carboxylic acids, resulting in a facile synthesis of 2-aminofurans via a novel binucleophilic system (Scheme 2).[3]

Table 1
Screening of solvents[a]



Solvent	Et_2O	CH_2Cl_2	THF	CH_3CN	H_2O
Yield (%)	72	95	77	65	Trace

[a] Reaction conditions: solvent (4 mL), Cy-HexNC (2 mmol), Ph_3P (1 mmol), DMAD (2 mmol), H_2O (2 mmol) and TFA (2 mmol) at room temperature.

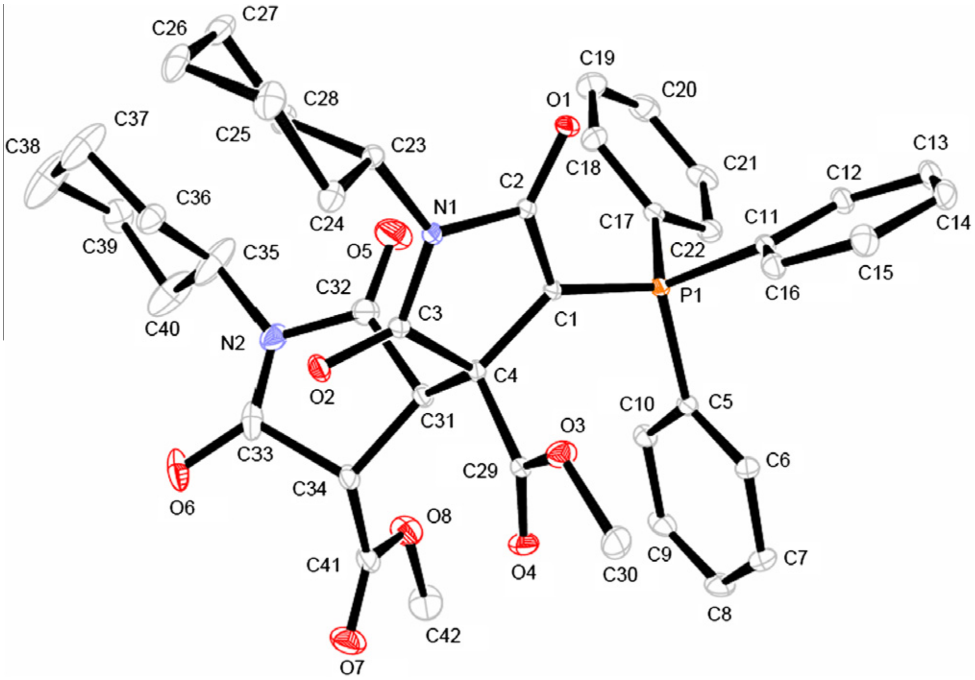


Figure 2. ORTEP diagram of **3c**.

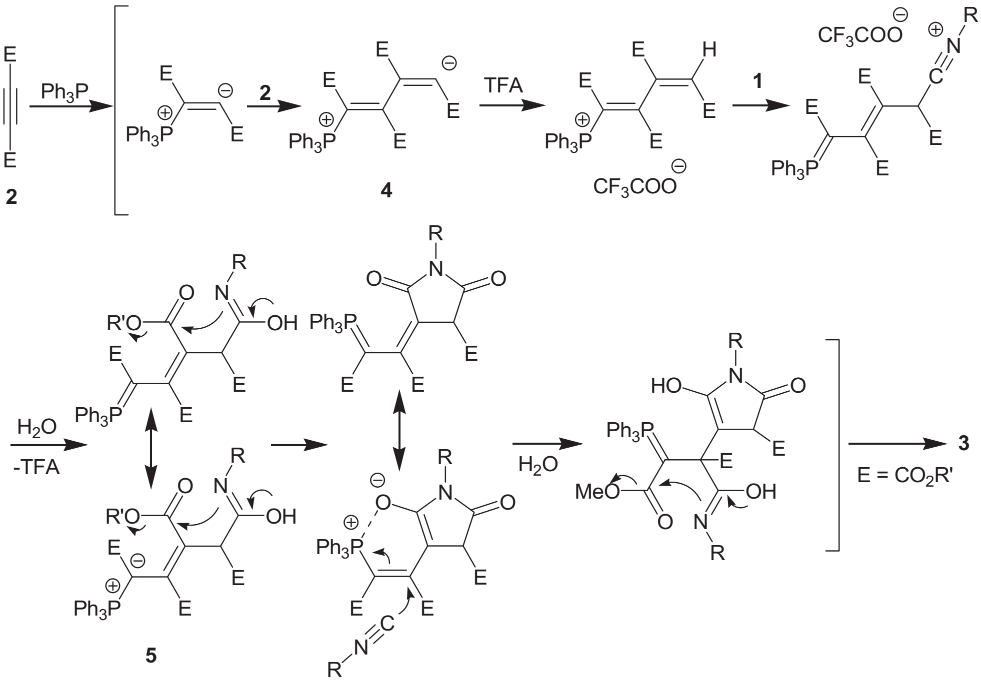
In this context, and in view of our interest in the multicomponent area,[4] we explored the use of trifluoroacetic acid as the third component in our reaction. Our initial aim was to synthesis fluorinated aminofurans and began with the reaction of a triphenylphosphine/dimethyl acetylenedicarboxylate adduct with isocyanides and TFA. To our surprise, the products were λ^5-phosphanylidene bis(dioxotetrahydro-1*H*-pyrrole-3-carboxylate) derivatives with three stereogenic centers and a phosphorane group.[5] This plan, however, was foiled by the TFA/H_2O (moisture) mixture (Scheme 3). Contemporaneous with the aforementioned investigations, for the preparation of the λ^5-phosphanylidene bis(dioxotetrahydro-1*H*-pyrrole-3-carboxylates) instead of fluorinated aminofurans with the influence of atmospheric moisture, we planned to react Ph_3P, dimethyl acetylenedicarboxylate (DMAD), cyclohexyl isocyanide, and H_2O in the presence of TFA (Scheme 3). The preliminary results of our investigations, which reveal some novel reactivity patterns of the zwitterions, form the subject of this paper.

It should be noted that this is the first report on the synthesis of λ^5-phosphanylidene bis(dioxotetrahydro-1*H*-pyrrole-3-carboxylates) or pyrrolidine derivatives using multicomponent conditions, and this procedure represents a novel use of a multicomponent reaction strategy for the synthesis of pyrrolidine or bismaleimide derivatives.

In a pilot experiment, a solution of DMAD, H_2O, and TFA, in CH_2Cl_2 was treated with a mixture of a half-stoichiometric amount of triphenylphosphine and a stoichiometric amount of *tert*-butylisocyanide at room temperature. λ^5-Phosphanylidene bis(dioxotetrahydo-1*H*-pyrrole-3-carboxylates) **3** have three stereogenic centers, and therefore four diastereomers were expected (Scheme 2). The ^1H, ^{13}C and ^{31}P NMR spectra of the product confirmed the presence of one isomer, showing that these reactions proceed diastereoselectively. This procedure was next applied to the preparation of a series of λ^5-phosphanylidene bis(dioxotetrahydro-1*H*-pyrrole-3-carboxylates), the structures of which are shown in Figure 1.

We examined the preparation of **3c** under various conditions and orders of addition of the reagents. The reaction was also carried out in various solvents, including Et_2O, THF, CH_3CN, H_2O, and CH_2Cl_2 (Table 1), with CH_2Cl_2 proving to be the best.

Under these reaction conditions, fumarate and maleate are the by products. In all cases, reactants at −10 °C or at reflux gave similar products in varying yields. In this context, it is interesting to note that a stoichiometric quantity of TFA was required to protonate zwitterion **4**; when the reaction was carried out using less than the stoichiometric amount of TFA, fumarate, and maleate by products were formed, showing that TFA is the initial proton source.



Scheme 4. Proposed mechanism for the reaction.

The structures of products **3a–d** were assigned on the basis of spectroscopic analysis. The ^{1}H NMR spectrum of **3a** exhibited four sharp singlets due to the two tertiary butyl and two methoxy groups (δ = 1.53, 1.56 and 3.43, 3.59), and two sharp doublets for the vicinal protons (δ = 2.57 and 4.68, ^3J 4.7 Hz). The aryl moiety exhibited characteristic signals in the aromatic region of the spectrum. The ^{1}H-decoupled ^{13}C NMR spectrum of **3a** showed 20 distinct resonances in agreement with the assigned structure. The ^{1}H and ^{13}C-decoupled ^{31}P NMR spectrum of **3a** exhibited one sharp signal due to the phosphorane (11.64 ppm). Unambiguous evidence for the structure of **3c** was obtained from single crystal X-ray analysis (Fig. 2).

Although the precise mechanism of the reaction is not known, the following rationalization may be advanced to explain the product formation. Presumably, the zwitterion **4**, formed from triphenylphosphine and DAAD, was protonated[4,6] by TFA to furnish an ion paired intermediate, which was then attacked by the isocyanide and water to produce **5**. The latter then rearranges to give the final product via a proton shift (Scheme 4).

In conclusion, we have reported a binucleophilic system, (TPP/RN = C/DAAD) for a one-pot, pseudo-seven-component reaction as a simple procedure for the diastereoselective synthesis of potential pharmacologically and biologically interesting λ^5-phosphanylidene bis(dioxotetrahydro-1*H*-pyrrole-3-carboxylates). This multicomponent method affords, bis-maleimido phosphoranes with three stereogenic centers.

Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.tetlet.2010.07.027.

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5. Typical procedure for the preparation of methyl (3*R*)-1-(*tert*-butyl)-3-[methyl(3*S*,4*R*)-1-(*tert*-butyl)-2,5-dioxotetrahydro-1*H*-pyrrole-3-carboxylate-3-yl]-2,5-dioxo-4-(1,1,1-triphenyl-λ^5-phosphanylidene)tetrahydro-1*H*-pyrrole-3-carboxylate (**3a**): To a stirred solution of dimethyl acetylenedicarboxylate (0.28 g, 2 mmol), H_2O (0.036 g, 2 mmol), and TFA (0.228 g, 2 mmol) in CH_2Cl_2 (5 mL) was added dropwise a solution of *tert*-isocyanide (0.116 g, 2 mmol) and Ph_3P (0.262 g, 1 mmol) in CH_2Cl_2 (4 mL) at room temperature over 10 min. The reaction mixture was then allowed to stir for 24 h under the same conditions. The solvent was removed under reduced pressure, and the residue was purified by silica gel (Merck 230–240 mesh) column chromatography using hexane–EtOAc as the eluent. Yield: 0.62 g (90%); colorless crystals, mp = 90–92 °C. IR (KBr) (ν_{max}/cm^{-1}): 1729 (C=O of CO_2Me), 1698 and 1636 [CO of $N(CO)_2$], 1470 and 1400 (Ar), 1429, 1106 and 1010 (Ph-P), 1258 and 1185 (C–O). ^{1}H NMR (500.13 MHz, $CDCl_3$): δ = 1.53 (9H, s, *t*-Bu), 1.56 (9H, s, *t*-Bu), 2.57 (1H, d, $^3J_{H-H}$ = 4.7 Hz, CH), 3.43 (3H, s, OCH_3), 3.59 (3H, s, OCH_3), 4.68 (1H, d, $^3J_{H-H}$ = 4.7 Hz, CH), 7.50 (6H$_{meta}$, td, $^3J_{H-H}$ = 7.5 Hz and $^4J_{P-H}$ = 3.0 Hz, 3 × 2CH of Ph), 7.60 (3H$_{para}$, td, $^3J_{H-H}$ = 7.5 Hz and $^5J_{P-H}$ = 1.8 Hz, 3 × 1CH of Ph), 7.72 (6H$_{ortho}$, dd, $^3J_{H-H}$ = 7.3 Hz and $^3J_{P-H}$ = 12.9 Hz, 3 × 2CH of Ph). ^{13}C NMR (125.75 MHz, $CDCl_3$): δ = 28.19 and 29.00 (2 × *t*-Bu), 44.08 (d, $^2J_{P-C}$ = 142.0 Hz, $Ph_3P{=}C$), 45.23 and 51.91 (2 × CH of maleimide), 52.17 and 52.52 (2 × OMe), 57.30 and 58.60 (2 × NC of *t*-BuN), 59.93 (d, $^4J_{P-C}$ = 8.6 Hz, C^q), 124.47 (3C-P, d, $^1J_{P-C}$ = 92.4 Hz, 3C$_{ipso}$ of P-Ph), 128.81 (6CH, d, $^3J_{P-C}$ = 12.7 Hz, 6CH$_{meta}$ of P-Ph), 132.53 (3CH, d, $^4J_{P-C}$ = 2.9 Hz, 3CH$_{meta}$ of P-Ph), 134.16 (6CH, d, $^3J_{P-C}$ = 10.6 Hz, 6CH$_{ortho}$ of P-Ph), 169.00 (C^{4}ON), 171.33 (C^{1}ON), 172.51 (d, $^2J_{P-C}$ = 14.2 Hz, C^{5}ON), 172.65 (CO_2Me), 174.66 (d, $^3J_{P-C}$ = 14.5 Hz, C^{7}ON), 175.46 (CO_2Me). ^{31}P NMR (202.45 MHz, $CDCl_3$): δ = 11.64 ppm. MS: *m*/*z* (%) = 605 (2), 604 (3), 279 (36), 277 (100), 199 (18), 183 (15), 77 (24), 57 (11). Anal. Calcd for $C_{38}H_{41}N_2O_8P$: C, 66.66; H, 6.04; N, 4.09. Found: C, 67.10; H, 6.10; N, 4.20. Compound (**3b**): Ethyl (3*R*)-1-(*tert*-butyl)-3-[ethyl(3*S*,4*R*)-1-(*tert*-butyl)-2,5-dioxotetrahydro-1*H*-pyrrole-3-carboxylate-3-yl]-2,5-dioxo-4-(1,1,1-triphenyl-λ^5-phosphanylidene)tetrahydro-1*H*-pyrrole-3-carboxylate. Yield: 0.66 g (95%); yellow viscous liquid. IR (KBr) (ν_{max}/cm^{-1}): 1742 (C=O of CO_2Et), 1710 [CO of $N(CO)_2$], 1505 and 1470 (Ar), 1463, 1103 and 929 (Ph-P), 1271 and 1037 (C–O). ^{1}H NMR (500.13 MHz,

$CDCl_3$): δ = 1.20 (3 H, dd, $^{3}J_{H-H}$ = 7.1 Hz, $^{3}J_{H-H}$ = 7.1 Hz, OCH_2CH_3), 1.33–1.45 (3H, m, OCH_2CH_3), 1.55 (9H, s, *t*-Bu), 1.58 (9H, s, *t*-Bu), 2.60 (1H, br, CH), 3.82–3.83, 3.95–4.03, 4.10–4.14 and 4.20–4.35 (4H, m, $2OCH_2CH_3$), 4.05 (1H, d, $^{3}J_{H-H}$ = 4.4 Hz, CH), 7.46–7.54 ($6H_{meta}$, m, 3 × 2CH of Ph), 7.57–7.70 ($3H_{para}$, m, 3 × 1CH of Ph), 7.76 ($6H_{ortho}$, dd, $^{3}J_{H-H}$ = 7.3 Hz and $^{3}J_{P-H}$ = 12.8 Hz, 3 × 2H of Ph). ^{13}C NMR (125.75 MHz, $CDCl_3$): δ = 13.78 and 14.00 (2 × OCH_2CH_3), 28.15 and 28.95 (2 × *t*-Bu), 44.29 (d, $^{2}J_{P-C}$ = 140.65 Hz, $Ph_3P{=}C$), 45.03 and 52.08 (2 × CH of maleimide), 52.08 (OCH_2CH_3), 57.30 and 58.46 (2 × NC of *t*-BuN), 60.01 (d, $^{4}J_{P-C}$ = 9.9 Hz, C^{q}), 61.42 (d, $^{4}J_{P-C}$ = 13.6 Hz, OCH_2CH_3), 124.48 (3C–P, d, $^{1}J_{P-C}$ = 93.0 Hz, $3C_{ipso}$ of P-Ph), 128.58 and 128.65 [6H, d, $^{3}J_{P-C}$ = 12.3 Hz and d, $^{3}J_{P-C}$ = 12.6 Hz, 3 × $2CH_{meta}$ of P-Ph], 132.18 and 132.55 [3 × CH, d, $^{3}J_{P-C}$ = 9.6 Hz and br, $3CH_{meta}$ of P-Ph], 134.22 (6CH, d, $^{3}J_{P-C}$ = 10.6 Hz, $6CH_{ortho}$ of P-Ph), 168.58 ($C^{4}ON$), 170.76 ($C^{1}ON$), 172.60 (d, $^{2}J_{P-C}$ = 15.3 Hz, $C^{5}ON$), 172.80 (CO_2Et), 174.79 (d, $^{3}J_{P-C}$ = 13.20 Hz, $C^{7}ON$), 175.69 (CO_2Et). ^{31}P NMR (202.45 MHz, $CDCl_3$): δ = 11.38 ppm. MS: *m*/*z* (%) = 350 (1), 277 (15), 201 (3), 77 (9), 46 (100), 41 (9). Anal. Calcd for $C_{40}H_{45}N_2O_8P$: C, 67.40; H, 6.36; N, 3.93. Found: C, 67.60; H, 6.40; N, 4.10. Compound (**3c**): Methyl (3*R*)-1-cyclohexyl-3-[methyl(3*S*,4*R*)-1-cyclohexyl-2,5-dioxotetrahydro-1*H*-pyrrole-3-carboxylate-3-yl]-2,5-dioxo-4-(1, 1,1-triphenyl-λ^{5}-phosphanylidene)tetrahydro-1*H*-pyrrole-3-carboxylate. Yield: 0.70 g (93%); colorless crystals, mp = 87–89 °C. IR (KBr) (ν_{max}/cm^{-1}): 1724 (C=O of CO_2Me), 1697 and 1635 [CO of $N(CO)_2$], 1534 and 1470 (Ar), 1428, 1095 and 1009 (Ph-P), 1260 and 1165 (C–O). ^{1}H NMR (500.13 MHz, $CDCl_3$): δ = 1.16–1.28, 1.48–1.65, 1.74–1.80 and 1.99–2.16 (20H, m, 2Cy-Hex), 2.62 (1H, d, $^{3}J_{H-H}$ = 4.3 Hz, CH), 3.43 (3H, s, OCH_3), 3.60 (3H, s, OCH_3), 3.82–3.90 (2H, m, 2NHCy-Hex), 4.11 (1H, d, $^{3}J_{H-H}$ = 4.3 Hz, CH), 7.52 ($6H_{meta}$, td, $^{3}J_{H-H}$ = 7.6 Hz and $^{4}J_{P-H}$ = 2.9 Hz, 3 × 2CH of Ph), 7.62 ($3H_{para}$, td, $^{3}J_{H-H}$ = 6.9 Hz and $^{5}J_{P-H}$ = 1.5 Hz, 3 × 1CH of Ph), 7.73 ($6H_{ortho}$, dd, $^{3}J_{H-H}$ = 7.5 Hz and $^{3}J_{P-H}$ = 12.9 Hz, 3 × 2CH of Ph). ^{13}C NMR (125.75 MHz, $CDCl_3$): δ = 25.08, 25.28, 25.81, 25.99, 26.01, 28.37, 28.60, 28.79 and 29.14 ($10CH_2$ of 2Cy-Hex), 43.74 (d, $^{2}J_{P-C}$ = 140.45 Hz, $Ph_3P{=}C$), 44.76 and 50.62 (2CH of maleimide), 51.44 and 52.10 (2OMe), 52.28 and 52.62 (2NCH of Cy-Hex), 59.55 (d, $^{4}J_{P-C}$ = 8.9 Hz, C^{q}), 124.11 (3C-P, d, $^{1}J_{P-C}$ = 92.4 Hz, $3C_{ipso}$ of P-Ph), 128.92 (6CH, d, $^{3}J_{P-C}$ = 12.7 Hz, $6CH_{meta}$ of P-Ph), 132.73 (3CH, d, $^{4}J_{P-C}$ = 2.8 Hz, $3CH_{meta}$ of P-Ph), 134.17 (6CH, d, $^{3}J_{P-C}$ = 10.6 Hz, $6CH_{ortho}$ of P-Ph), 168.55 ($C^{4}ON$), 170.56 (d, $^{2}J_{P-C}$ = 14.1 Hz, $C^{5}ON$), 171.18 ($C^{1}ON$), 171.72 (CO_2Me), 173.75 (d, $^{3}J_{P-C}$ = 13.8 Hz, $C^{7}ON$), 174.46 (CO_2Me). ^{31}P NMR (202.45 MHz, $CDCl_3$): δ = 11.29 ppm. MS: *m*/*z* (%) = 625 (1), 277 (100), 199 (13), 77 (12), 51 (7). Anal. Calcd for $C_{42}H_{45}N_2O_8P$: C, 68.47; H, 6.16; N, 3.80. Found: C, 68.50; H, 6.20; N, 4.10. X-ray data for compound **3c**: Empirical formula, $C_{42}H_{45}N_2O_8P$, formula weight = 736.77, orthorhombic, space group = $P2_12_12_1$, *a* = 11.9662(9) Å, *b* = 16.3396(12) Å, *c* = 19.3850(14) Å, α = 90°, β = 90°, γ = 90°, *V* = 3790.21(5) $Å^3$, *Z* = 4, D_c = 1.291 Mg/m^3, λ = 0.71073 Å, μ = 0.129 mm^{-1}, *F*(0 0 0) = 1564, *T* = 295 (2) K, crystal dimensions 0.20 × 0.20 × 0.25 mm. CCDC 652093 contains the supplementary crystallographic data for this compound. Compound (**3d**): Ethyl (3*R*)-1-cyclohexyl-3-[ethyl(3*S*,4*R*)-1-cyclohexyl-2,5-dioxotetrahydro-1*H*-pyrrole-3-carboxylate-3-yl]-2,5-dioxo-4-(1, 1,1-triphenyl-λ^{5}-phosphanylidene)tetrahydro-1*H*-pyrrole-3-carboxylate. Yield: 0.68 g (89%); yellow viscous liquid. IR (KBr) (ν_{max}/cm^{-1}): 1744 (C=O of CO_2Et), 1710 and 1646 [CO of $N(CO)_2$], 1588 and 1479 (Ar), 1452, 1101 and 912 (Ph-P), 1273 and 1024 (C–O). ^{1}H NMR (500.13 MHz, $CDCl_3$): δ = 1.18 (3H, t, $^{3}J_{H-H}$ = 7.1 Hz, OCH_2CH_3), 1.20 (3H, t, $^{3}J_{H-H}$ = 7.0 Hz, OCH_2CH_3), 1.26–1.28 and 1.53–2.17 (20H, m, 2Cy-Hex), 2.60 (1H, d, $^{3}J_{H-H}$ = 3.9 Hz, CH), 3.74–3.80 and 4.11–4.17 (2H, m, 2 NHCy-Hex), 3.84–3.93 and 3.96–4.04 (4H, m, $2OCH_2CH_3$), 4.08 (1H, d, $^{3}J_{H-H}$ = 3.9 Hz, CH), 7.53 ($6H_{meta}$, m, 3 × 2CH of Ph), 7.63 ($3H_{para}$, td, $^{3}J_{H-H}$ = 7.3 Hz, 3 × 1CH of Ph), 7.76 ($6H_{ortho}$, dd, $^{3}J_{H-H}$ = 7.3 Hz and $^{3}J_{P-H}$ = 12.8 Hz, 3 × 2CH of Ph). ^{13}C NMR (125.75 MHz, $CDCl_3$): δ = 13.77 and 14.01 (2 × OCH_2CH_3), 25.10, 25.28, 25.83, 26.03, 28.32, 28.58, 28.70, 29.11, 30.84 and 33.06 (10 × CH_2 of 2Cy-Hex), 43.81 (d, $^{1}J_{P-C}$ = 140.20 Hz, $Ph_3P{=}C$), 44.66 and 50.57 (2 × CH of maleimide), 51.65 and 52.03 (2 × NCH of Cy-Hex), 53.37 (OCH_2CH_3), 59.66 (d, $^{4}J_{P-C}$ = 8.9 Hz, C^{q}), 61.54 (d, $^{4}J_{P-C}$ = 13.4 Hz, OCH_2CH_3), 124.24 (3C-P, d, $^{1}J_{P-C}$ = 92.3 Hz, $3C_{ipso}$ of P-Ph), 128.85 (6CH, d, $^{3}J_{P-C}$ = 12.7 Hz, $6CH_{meta}$ of P-Ph), 132.68 (3CH, d, $^{4}J_{P-C}$ = 2.8 Hz, $3CH_{meta}$ of P-Ph), 134.22 (6CH, d, $^{3}J_{P-C}$ = 10.6 Hz, $6CH_{ortho}$ of P-Ph), 168.19 ($C^{4}ON$), 170.67 (d, $^{2}J_{P-C}$ = 14.3 Hz, $C^{5}ON$), 170.68 ($C^{1}ON$), 171.95 (CO_2Et), 173.87 (d, $^{3}J_{P-C}$ = 14.1 Hz, $C^{7}ON$), 174.68 (CO_2Et). ^{31}P NMR (202.45 MHz, $CDCl_3$): δ = 10.33 ppm. MS: *m*/*z* (%) = 709 (3), 611 (3), 277 (100), 199 (24), 83 (17), 45 (12). Anal. Calcd for $C_{44}H_{49}N_2O_8P$: C, 69.10; H, 6.46; N, 3.66. Found: C, 69.07; H, 6.47; N, 4.00. Compound (**3e**): Methyl (3*R*)-1-(2-ethoxy-2-oxoethy)-3-[methyl(3*S*,4*R*)-1–(2-ethoxy-2-oxoethyl)-2,5-dioxotetrahydro-1*H*-pyrrole-3-carboxylate-3-yl]-2,5-dioxo-4-(1,1,1-triphenyl-λ^{5}-phosphanylidene)tetrahydro-1*H*-pyrrole-3-carboxylate. Yield: 0.59 g (79%); colorless crystals, mp = 80–82 °C. IR (KBr) (ν_{max}/cm^{-1}): 1745 (C=O of CO_2Me and CO_2Et), 1709 [CO of $N(CO)_2$], 1592 and 1483 (Ar), 1450, 1102 and 913(Ph-P), 1273 and 1024 (C–O). ^{1}H NMR (500.13 MHz, $CDCl_3$): δ = 1.24 (3H, t, $^{3}J_{H-H}$ = 7.0 Hz, OCH_2CH_3), 1.27 (3H, t, $^{3}J_{H-H}$ = 7.0 Hz, OCH_2CH_3), 2.89 (1H, d, $^{3}J_{H-H}$ = 3.7 Hz, CH), 3.48 (3H, s, OCH_3), 3.64 (3H, s, OCH_3), 4.12–4.28 [8H (d, $^{3}J_{H-H}$ = 3.9 Hz, and m) $2NCH_2$ and $2OCH_2CH_3$], 4.39 (1H, d, $^{3}J_{H-H}$ = 3.7 Hz, CH), 7.47–7.69 (9H, m, 3 × $2CH_{meta}$ of Ph and 3 × $1CH_{para}$ of Ph), 7.79 ($6H_{ortho}$, dd, $^{3}J_{H-H}$ = 7.7 Hz and $^{3}J_{P-H}$ = 12.7 Hz, 3 × 2CH of Ph). ^{13}C NMR (125.75 MHz, $CDCl_3$): δ = 13.99 and 14.11 (2 × OCH_2CH_3), 39.44 and 40.09 (2 × NCH_2), 43.88 (d, $^{2}J_{P-C}$ = 142.0 Hz, $Ph_3P{=}C$), 45.66 and 51.17 (2 × CH of maleimide), 52.50 and 52.77 (2 × OMe), 61.12 (d, $^{4}J_{P-C}$ = 8.5 Hz, C^{q}), 61.56 and 61.63 (2 × OCH_2CH_3), 123.54 (3C-P, d, $^{1}J_{P-C}$ = 92.4 Hz, $3C_{ipso}$ of P-Ph), 128.51, 128.96 and 129.12 [6 × CH, (d, $^{3}J_{P-C}$ = 12.2 Hz, $^{3}J_{P-C}$ = 12.6 Hz and $^{3}J_{P-C}$ = 13.0 Hz), $6CH_{meta}$ of P-Ph], 132.00, 132.11 and 132.91 [3 × CH, (d, $^{4}J_{P-C}$ = 2.3 Hz, $^{4}J_{P-C}$ = 10.0 Hz and $^{4}J_{P-C}$ = 2.6 Hz, $3CH_{para}$ of P-Ph], 133.91 and 134.58 [6 × CH, (d, $^{3}J_{P-C}$ = 11.31 Hz and $^{3}J_{P-C}$ = 10.6 Hz, $6CH_{ortho}$ of P-Ph)], 166.14 ($C^{4}ON$), 167.45 and 167.48 ($2CO_2Et$), 169.02 (d, $^{2}J_{P-C}$ = 14.4 Hz, $C^{5}ON$), 170.62 ($C^{1}ON$ and CO_2Me), 172.93 (d, $^{3}J_{P-C}$ = 13.8 Hz, $C^{7}ON$), 172.92 (CO_2Me). ^{31}P NMR (202.45 MHz, $CDCl_3$): δ = 10.37 ppm. MS: *m*/*z* (%) = 745 [M^{+}+1], 277 (44), 262 (100), 199 (0), 183 (92), 168 (59), 108 (51), 77 (16), 53 (32). Anal. Calcd for $C_{38}H_{37}N_2O_{12}P$: C, 61.29; H, 5.01; N, 3.76. Found: C, 61.30; H, 5.20; N, 4.00.

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