

This article was downloaded by:

On: 27 January 2011

Access details: *Access Details: Free Access*

Publisher *Taylor & Francis*

Informa Ltd Registered in England and Wales Registered Number: 1072954 Registered office: Mortimer House, 37-41 Mortimer Street, London W1T 3JH, UK



Phosphorus, Sulfur, and Silicon and the Related Elements

Publication details, including instructions for authors and subscription information:

<http://www.informaworld.com/smpp/title~content=t713618290>

Efficient, Simple Synthesis of Stable Phosphorus Ylides Derived from 4-Aryl Urazoles

Mehdi Adib^a; Moharram Omid^a; Hamid Reza Bijanzadeh^b

^a School of Chemistry, University College of Science, University of Tehran, Tehran, Iran ^b Department of Chemistry, Tarbiat Modarres University, Tehran, Iran

Online publication date: 02 August 2010

To cite this Article Adib, Mehdi, Omid, Moharram and Bijanzadeh, Hamid Reza(2010) 'Efficient, Simple Synthesis of Stable Phosphorus Ylides Derived from 4-Aryl Urazoles', *Phosphorus, Sulfur, and Silicon and the Related Elements*, 185: 8, 1732 – 1738

To link to this Article: DOI: 10.1080/10426500903251357

URL: <http://dx.doi.org/10.1080/10426500903251357>

PLEASE SCROLL DOWN FOR ARTICLE

Full terms and conditions of use: <http://www.informaworld.com/terms-and-conditions-of-access.pdf>

This article may be used for research, teaching and private study purposes. Any substantial or systematic reproduction, re-distribution, re-selling, loan or sub-licensing, systematic supply or distribution in any form to anyone is expressly forbidden.

The publisher does not give any warranty express or implied or make any representation that the contents will be complete or accurate or up to date. The accuracy of any instructions, formulae and drug doses should be independently verified with primary sources. The publisher shall not be liable for any loss, actions, claims, proceedings, demand or costs or damages whatsoever or howsoever caused arising directly or indirectly in connection with or arising out of the use of this material.

EFFICIENT, SIMPLE SYNTHESIS OF STABLE PHOSPHORUS YLIDES DERIVED FROM 4-ARYL URAZOLES

Mehdi Adib,¹ Moharram Omid,¹ and Hamid Reza Bijanzadeh²

¹School of Chemistry, University College of Science, University of Tehran, Tehran, Iran

²Department of Chemistry, Tarbiat Modarres University, Tehran, Iran

Crystalline phosphorus ylides are obtained in nearly quantitative yields from the 1:1:1 addition reaction between triphenylphosphine, dialkyl acetylenedicarboxylates, and 4-aryl urazoles.

Keywords Acetylenic esters; 4-aryl urazoles; phosphoranes; triphenylphosphine

INTRODUCTION

Among a large variety of nitrogen-containing heterocyclic compounds, those containing a urazole moiety are of interest because they constitute an important class of natural and non-natural products, many of which exhibit useful biological activities.¹ Some urazole derivatives have been shown to possess anticonvulsant,² fungicidal,³ antineoplastic,⁴ hypolipidemic,⁵ antiinflammatory,⁶ and antidepressant⁷ activities as well as catalytic activity in radical polymerization.⁸

Phosphorus ylides are reactive intermediates that take part in many valuable reactions in organic synthesis.^{9–22} Several methods have been developed for the preparation of phosphorus ylides. These ylides are usually prepared by treatment of a phosphonium salt with a base, and phosphonium salts are usually prepared from the phosphine and an alkyl halide.^{9–11} Phosphonium salts are also prepared by Michael addition of phosphorus nucleophiles to activated olefins among other methods.⁹

Recently, there are many reports in literature on the synthesis of phosphorus ylides by three-component reaction of electron-deficient acetylenic compounds and triphenylphosphine in the presence of various organic N-H, O-H, C-H, and S-H acids.²³

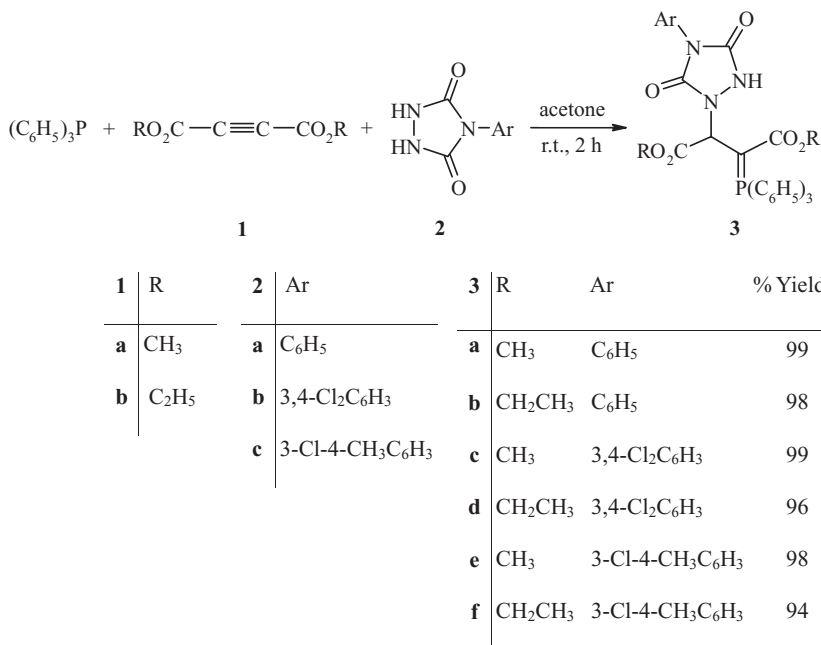
Received 9 June 2009; accepted 11 August 2009.

This research was supported by the Research Council of the University of Tehran as a research project (6102036/1/03).

Address correspondence to Mehdi Adib, School of Chemistry, University College of Science, University of Tehran, PO Box 14155-6455, Tehran, Iran. E-mail: madib@khayam.ut.ac.ir

RESULTS AND DISCUSSION

As part of our current studies on the development of efficient and facile methods for the preparation of organic compounds,²⁴ we report in this article an efficient synthetic route to phosphorus ylides derived from 4-aryl urazoles. Thus, a mixture of triphenylphosphine, a dialkyl acetylenedicarboxylate **1**, and a 4-aryl urazole **2** underwent a one-pot, three-component reaction to afford the corresponding phosphorus ylides **3** in nearly quantitative yields (Scheme 1).



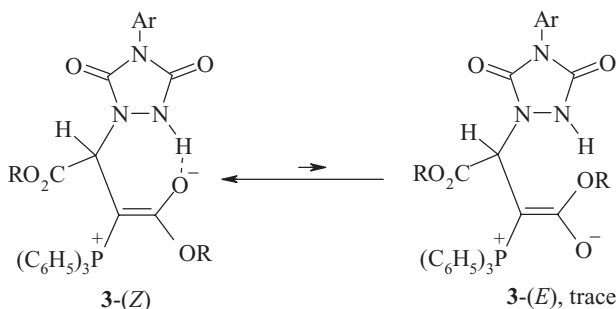
Scheme 1

The reaction of triphenylphosphine with dialkyl acetylenedicarboxylates in the presence of 4-aryl urazoles proceeded spontaneously at room temperature in acetone, and was complete within 2 h. ¹H and ¹³C NMR spectra of the crude product clearly indicated the formation of the phosphoranes **3**. Any product other than **3** could not be detected by NMR spectroscopy.

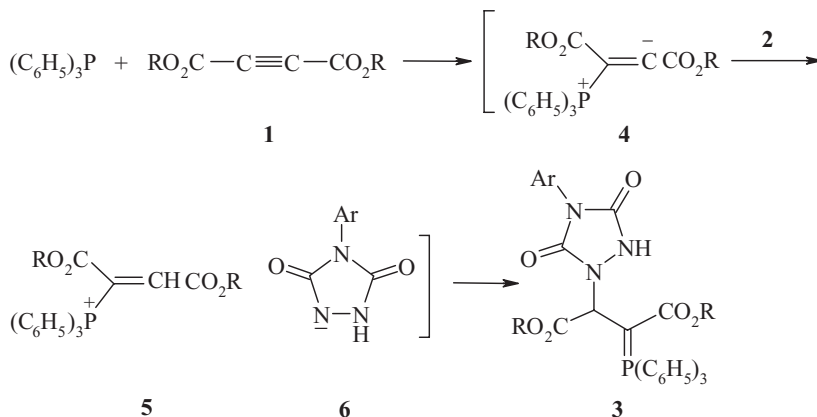
The structures of the isolated products **3a–f** were deduced on the basis of IR, ¹H, ¹³C, and ³¹P NMR spectroscopy, mass spectrometry, and elemental analysis. The nature of these compounds as 1:1:1 adducts was apparent from their mass spectra, which displayed molecular ion [M⁺] peaks at *m/z* = 581, 609, 650, 678, 630, and 658, respectively. Initial fragmentations involve loss from or complete loss of the side chains and scission of the heterocyclic ring system.

We have reported^{25,26} the synthesis of several functionalized phosphoranes via one-pot, three-component reactions between triphenylphosphine, dialkyl acetylenedicarboxylates, and some NH-acids. Dynamic NMR effects were observed in the ¹H NMR spectra of the reported ylides and were attributed to restricted rotation around the carbon–carbon partial double bond resulting from conjugation of the ylide moiety with the adjacent carbonyl

group. However, the ^1H , ^{13}C NMR spectra of the ylides synthesized from 4-aryl urazoles **3a–f** are consistent with the presence of only one isomer, and the minor isomer is present in less than 3% (on the basis of ^{31}P NMR). In the *Z* geometrical isomer of these ylides, there is strong hydrogen bonding between O^- of the ylide moiety and the adjacent NH group, which could stabilize the *Z* isomer.



On the basis of the well established chemistry of trivalent phosphorus nucleophiles,^{9–22} it is reasonable to assume that phosphorus ylide **3** results from the initial addition of triphenylphosphine to the acetylenic ester and subsequent protonation of the zwitterionic intermediate **4** by the NH-acid **2**. Then the positively charged ion **5** is attacked by the conjugate base of the NH-acid **6** to form phosphorane **3** (Scheme 2).



Scheme 2

Functionalized phosphorus ylides **3a–f** may be considered as potentially useful synthetic intermediates.^{9,10} Excellent yields of the products and relatively short reaction times are the main advantages of this method. The reactions were performed under neutral and mild conditions, and the starting materials and reagents can be mixed without any activation or modification. The procedure described here may be an acceptable method for the preparation of phosphoranes with variable functionalities. The one-pot nature of the present procedure makes it an interesting alternative to multistep approaches.^{9–18} In view of widespread biological activities of urazole derivatives, the urazole-containing phosphorus

ylides prepared in the present study may find useful applications in synthetic organic and bioorganic chemistry.

EXPERIMENTAL

Dialkyl acetylenedicarboxylates and triphenylphosphine were obtained from Merck (Germany) and were used without further purification. 4-Aryl urazoles were prepared according to the procedure in the literature.²⁷ Melting points were measured on an Electrothermal 9100 apparatus. Elemental analyses for C, H, and N were performed using a Heraeus CHN-O-Rapid analyzer. Mass spectra were recorded on a Finnigan-MATT 8430 mass spectrometer operating at an ionization potential of 20 eV. ¹H, ¹³C, and ³¹P NMR spectra were measured (CDCl₃ solution) with a Bruker DRX-500 AVANCE spectrometer at 500.1, 125.8, and 202.5 MHz, respectively. IR spectra were recorded on a Shimadzu IR-460 spectrometer.

Preparation of Dimethyl 2-(4-Phenyl-3,5-dioxo-1,2,4-triazolin-1-yl)-3-(triphenylphosphoranylidene)butanedioate (3a)

To a magnetically stirred solution of triphenylphosphine (0.262 g, 1 mmol) and 4-phenyl urazole **2a** (0.177 g, 1 mmol) in acetone (6 mL), a solution of dimethyl acetylenedicarboxylate **1a** (0.148 g, 1 mmol) in acetone (2 mL) at -5°C was added dropwise over 10 min. The reaction mixture was then allowed to warm to room temperature and stirred for 2 h. The white precipitate was filtered and washed with cold acetone. The product **3a** was recrystallized from EtOAc/*n*-hexane (2:1) as colorless crystals, mp $149\text{--}151^{\circ}\text{C}$, yield 0.58 g, 99%. IR (KBr) ($\nu_{\text{max}}/\text{cm}^{-1}$): 3210 (NH), 1760 (shoulder), 1732 (shoulder), 1691 (C=O), 1647, 1610, 1489, 1423, 1301, 1230, 1130, 1100, 761, 712, 689, 536. MS, m/z (%): 581 (M^{+} , 25), 566 (20), 447 (10), 419 (75), 262 (100), 183 (46), 177 (45), 144 (29), 94 (20), 77 (10). Anal. Calcd. for $\text{C}_{32}\text{H}_{28}\text{N}_3\text{O}_6\text{P}$ (581.56): C, 66.09; H, 4.85; N, 7.23. Found: C, 66.4; H, 4.8; N, 7.0%. ¹H NMR: δ 3.15 and 3.75 (6 H, 2 s, 2 OCH₃), 4.74 (1 H, d, ³*J*_{PH} 16.6 Hz, P-C-CH), 7.34 (1 H, t, *J* 7.1 Hz, CH), 7.42 (2 H, t, *J* 8.0 Hz, 2 CH), 7.51 (2 H, d, *J* 7.8 Hz, 2 CH), 7.57–7.75 (9 H, m, 6 CH_{meta} and 3 CH_{para}), 7.81 (6 H, dd, *J* 8.1 Hz and *J* 12.3 Hz, 6 CH_{ortho}), 9.93 (1 H, br. s, NH). ¹³C NMR: δ 40.16 (d, ¹*J*_{PC} 128.2 Hz, P=C), 48.08 and 51.26 (2 OCH₃), 57.39 (d, ²*J*_{PC} 16.8 Hz, P-C-CH), 124.53 (CH), 124.95 (d, ¹*J*_{PC} 92.4 Hz, C_{ipso}), 126.21 and 127.53 (2 CH), 128.15 (d, ³*J*_{PC} 12.4 Hz, CH_{meta}), 131.66 (d, ⁴*J*_{PC} 2.9 Hz, CH_{para}), 131.78 (C), 132.62 (d, ²*J*_{PC} 9.9 Hz, CH_{ortho}), 150.77 and 151.03 (2 C=O, urea), 169.73 and 170.65 (2 d, ²*J*_{PC} 10.9 Hz and ³*J*_{PC} 12.5 Hz, 2 C=O ester). ³¹P NMR: δ 23.81 (Ph₃P⁺-C).

Diethyl 2-(4-Phenyl-3,5-dioxo-1,2,4-triazolin-1-yl)-3-(triphenylphosphoranylidene)butanedioate (3b)

Colorless crystals, mp $132\text{--}134^{\circ}\text{C}$, yield 0.59 g, 98%. IR (KBr) ($\nu_{\text{max}}/\text{cm}^{-1}$): 3195 (NH), 1761, 1732, 1696 (C=O), 1631, 1595, 1489, 1423, 1367, 1298, 1227, 1130, 1101, 1022, 771, 748, 710, 688, 548, 511. MS, m/z (%): 609 (M^{+} , 17), 490 (25), 462 (31), 262 (89), 183 (100), 177 (10), 77 (28). Anal. Calcd. for $\text{C}_{34}\text{H}_{32}\text{N}_3\text{O}_6\text{P}$ (609.62): C, 66.99; H, 5.29; N, 6.89. Found: C, 66.6; H, 5.2; N, 6.7%. ¹H NMR: δ 0.50 and 1.29 (6 H, 2 t, *J* 7.1 Hz, 2 OCH₂CH₃), 3.75 and 4.23 (4 H, 2 m, 2 OCH₂CH₃), 4.80 (1 H, d, ³*J*_{PH} 16.5 Hz, P-C-CH), 7.28 (1 H, t, *J* 7.4 Hz, CH), 7.39 (2 H, t, *J* 7.7 Hz, 2 CH), 7.48 (2 H, d, *J* 7.9 Hz,

2 CH), 7.53 (6 H, dt, J 2.5 Hz and J 7.5 Hz, 6 CH_{meta}), 7.62 (3 H, t, J 7.1 Hz, 3 CH_{para}), 7.72 (6 H, dd, J 7.7 Hz and J 12.5 Hz, 6 CH_{ortho}), 10.03 (1 H, s, NH). ¹³C NMR: δ 13.86 and 14.21 (2 OCH₂CH₃), 42.39 (d, ¹J_{PC} 128.4 Hz, P=C), 57.89 (d, ²J_{PC} 16.5 Hz, P-C-CH), 58.74 and 61.99 (2 OCH₂CH₃), 125.62 (d, ¹J_{PC} 92.7 Hz, C_{ipso}), 125.71, 127.53, and 128.90 (3 CH), 129.06 (d, ³J_{PC} 12.7 Hz, CH_{meta}), 132.14 (C), 132.65 (CH_{para}), 133.65 (d, ²J_{PC} 9.9 Hz, CH_{ortho}), 151.28 and 151.42 (2 C=O, urea), 170.37 and 172.11 (2 d, ²J_{PC} 10.2 Hz and ³J_{PC} 12.3 Hz, 2 C=O ester). ³¹P NMR: δ 23.00 (Ph₃P⁺-C).

Dimethyl 2-[4-(3,4-Dichlorophenyl)-3,5-dioxo-1,2,4-triazolin-1-yl]-3-(triphenylphosphoranylidene)butanedioate (3c)

Colorless crystals, mp 145–147°C, yield 0.64 g, 99%. IR (KBr) ($\nu_{\max}/\text{cm}^{-1}$): 3150 (NH), 1762, 1736, 1697 (C=O), 1607, 1468, 1421, 1320, 1294, 1225, 1144, 1100, 747, 711, 688, 512. MS, m/z (%): 650 (M⁺, 8), 635 (7), 404 (14), 376 (61), 262 (97), 183 (100), 174 (24), 161 (16), 78 (25). Anal. Calcd. for C₃₂H₂₆Cl₂N₃O₆P (650.45): C, 59.09; H, 4.03; N, 6.46. Found: C, 59.3; H, 3.8; N, 6.4%. ¹H NMR: δ 3.20 and 3.78 (6 H, 2 s, 2 OCH₃), 4.79 (1 H, d, ³J_{PH} 16.2 Hz, P-C-CH), 7.46 (2 H, br., 2 CH), 7.55 (6 H, dt, J 2.3 Hz and J 7.4 Hz, 6 CH_{meta}), 7.64 (3 H, t, J 7.1 Hz, 3 CH_{para}), 7.70 (6 H, dd, J 7.8 Hz and J 12.5 Hz, 6 CH_{ortho}), 7.72 (1 H, br., CH), 10.08 (1 H, s, NH). ¹³C NMR: δ 42.59 (d, ¹J_{PC} 128.3 Hz, P=C), 50.10 and 53.20 (2 OCH₃), 57.78 (d, ²J_{PC} 17.0 Hz, P-C-CH), 124.43 (CH), 125.35 (d, ¹J_{PC} 92.6 Hz, C_{ipso}), 127.04 (CH), 129.19 (d, ³J_{PC} 11.7 Hz, CH_{meta}), 130.41 (CH), 131.28, 131.71, and 132.67 (3 C), 132.79 (CH_{para}), 133.57 (d, ²J_{PC} 9.8 Hz, CH_{ortho}), 150.09 and 150.43 (2 C=O, urea), 170.78 and 172.58 (2 d, ²J_{PC} 10.3 Hz and ³J_{PC} 12.3 Hz, 2 C=O ester). ³¹P NMR: δ 23.38 (Ph₃P⁺-C).

Diethyl 2-[4-(3,4-Dichlorophenyl)-3,5-dioxo-1,2,4-triazolin-1-yl]-3-(triphenylphosphoranylidene)butanedioate (3d)

Colorless crystals, mp 127–129°C, yield 0.65 g, 96%. IR (KBr) ($\nu_{\max}/\text{cm}^{-1}$): 3190 (NH), 1761, 1732 (shoulder), 1700 (C=O), 1628, 1594, 1469, 1426, 1368, 1305, 1232, 1129, 1100, 1021, 711, 689, 549, 511. MS, m/z (%): 678 (M⁺, 5), 649 (11), 432 (15), 404 (43), 245 (15), 262 (100), 183 (84), 174 (14), 161 (18), 77 (31). Anal. Calcd. for C₃₄H₃₀Cl₂N₃O₆P (678.51): C, 60.19; H, 4.46; N, 6.19. Found: C, 59.9; H, 4.5; N, 6.4%. ¹H NMR: δ 0.48 and 1.26 (6 H, 2 t, J 7.1 Hz, 2 OCH₂CH₃), 3.72 and 4.20 (4 H, 2 m, 2 OCH₂CH₃), 4.73 (1 H, d, ³J_{PH} 16.5 Hz, P-C-CH), 7.43 (2 H, br., 2 CH), 7.51 (6 H, dt, J 2.4 Hz and J 7.4 Hz, 6 CH_{meta}), 7.61 (3 H, t, J 7.0 Hz, 3 CH_{para}), 7.68 (6 H, dd, J 7.9 Hz and J 12.6 Hz, 6 CH_{ortho}), 7.69 (1 H, br., CH), 10.19 (1 H, s, NH). ¹³C NMR: δ 13.80 and 14.15 (2 OCH₂CH₃), 41.43 (d, ¹J_{PC} 128.4 Hz, P=C), 57.94 (d, ²J_{PC} 16.9 Hz, P-C-CH), 58.84 and 62.08 (2 OCH₂CH₃), 124.40 (CH), 125.48 (d, ¹J_{PC} 92.6 Hz, C_{ipso}), 126.99 (CH), 129.05 (d, ³J_{PC} 11.7 Hz, CH_{meta}), 130.34 (CH), 131.21, 131.70, and 132.62 (3 C), 132.68 (CH_{para}), 133.57 (d, ²J_{PC} 10.1 Hz, CH_{ortho}), 150.46 and 150.51 (2 C=O, urea), 170.08 and 172.20 (2 d, ²J_{PC} 10.3 Hz and ³J_{PC} 12.4 Hz, 2 C=O ester). ³¹P NMR: δ 23.02 (Ph₃P⁺-C).

Dimethyl 2-[4-(3-Chloro-4-methylphenyl)-3,5-dioxo-1,2,4-triazolin-1-yl]-3-(triphenylphosphoranylidene)butanedioate (3e)

Colorless crystals, mp 162–164°C, yield 0.62 g, 98%. IR (KBr) ($\nu_{\max}/\text{cm}^{-1}$): 3140 (NH), 1760, 1738, 1694 (C=O), 1609, 1489, 1421, 1322, 1293, 1224, 1145, 1100, 711,

689, 527. MS, m/z (%): 630 (M^+ , 21), 404 (16), 376 (29), 262 (100), 225 (54), 183 (79), 144 (19), 78 (10). Anal. Calcd. for $C_{33}H_{29}ClN_3O_6P$ (630.04): C, 62.91; H, 4.64; N, 6.67. Found: C, 62.6; H, 4.3; N, 6.6%. 1H NMR: δ 2.33 (3 H, s, CH_3), 3.17 and 3.76 (6 H, 2 s, 2 OCH_3), 4.76 (1 H, d, $^3J_{PH}$ 16.2 Hz, P-C-CH), 7.23 (1 H, d, J 8.2 Hz, CH), 7.28 (1 H, dd, J 8.2 Hz and J 1.2 Hz, CH), 7.48 (1 H, d, J 1.2 Hz, CH), 7.52 (6 H, dt, J 1.7 Hz and J 7.3 Hz, 6 CH_{meta}), 7.61 (3 H, t, J 7.4 Hz, 3 CH_{para}), 7.67 (6 H, dd, J 7.6 Hz and J 12.4 Hz, 6 CH_{ortho}), 9.84 (1 H, s, NH). ^{13}C NMR: δ 19.67 (CH_3), 42.55 (d, $^1J_{PC}$ 128.4 Hz, P=C), 49.96 and 53.09 (2 OCH_3), 57.63 (d, $^2J_{PC}$ 17.0 Hz, P-C-CH), 123.84 (CH), 125.42 (d, $^1J_{PC}$ 92.4 Hz, C_{ipso}), 126.17 (CH), 129.10 (d, $^3J_{PC}$ 12.5 Hz, CH_{meta}), 130.63 (C), 130.90 (CH), 132.67 (CH_{para}), 133.54 (d, $^2J_{PC}$ 9.9 Hz, CH_{ortho}), 134.32 and 135.57 (2 C), 150.46 and 150.91 (2 C=O, urea), 170.89 and 172.41 (2 d, $^2J_{PC}$ 10.3 Hz and $^3J_{PC}$ 12.6 Hz, 2 C=O ester). ^{31}P NMR: δ 22.96 (Ph_3P^+-C).

Diethyl 2-[4-(3-Chloro-4-methylphenyl)-3,5-dioxo-1,2,4-triazolin-1-yl]-3-(triphenylphosphoranylidene)butanedioate (3f)

Colorless crystals, mp 125–127°C, yield 0.62 g, 94%. IR (KBr) (ν_{max}/cm^{-1}): 3210 (NH), 1759, 1729, 1697 (C=O), 1632, 1489, 1423, 1366, 1299, 1228, 1134, 1101, 690. MS, m/z (%): 658 (M^+ , 11), 629 (8), 432 (20), 404 (52), 262 (100), 183 (84), 174 (12), 141 (36), 78 (15). Anal. Calcd. for $C_{35}H_{33}ClN_3O_6P$ (658.09): C, 63.88; H, 5.05; N, 6.39. Found: C, 63.4; H, 4.9; N, 6.5%. 1H NMR: δ 0.41 and 1.21 (6 H, 2 t, J 7.0 Hz, 2 OCH_2CH_3), 2.23 (3 H, s, CH_3), 3.67 and 4.18 (4 H, 2 m, 2 OCH_2CH_3), 4.73 (1 H, d, $^3J_{PH}$ 16.5 Hz, P-C-CH), 7.15 (1 H, d, J 8.2 Hz, CH), 7.25 (1 H, dd, J 8.2 Hz and J 1.2 Hz, CH), 7.40–7.48 (7 H, m, CH and 6 CH_{meta}), 7.53 (3 H, t, J 7.3 Hz, 3 CH_{para}), 7.66 (6 H, dd, J 7.6 Hz and J 12.4 Hz, 6 CH_{ortho}), 10.15 (1 H, s, NH). ^{13}C NMR: δ 13.77 and 14.19 (2 OCH_2CH_3), 19.60 (CH_3), 41.89 (d, $^1J_{PC}$ 127.8 Hz, P=C), 58.12 (d, $^2J_{PC}$ 17.0 Hz, P-C-CH), 58.72 and 61.94 (2 OCH_2CH_3), 123.80 (CH), 125.50 (d, $^1J_{PC}$ 92.1 Hz, C_{ipso}), 126.05 (CH), 129.00 (d, $^3J_{PC}$ 12.6 Hz, CH_{meta}), 130.77 (C), 130.84 (CH), 132.64 (CH_{para}), 133.60 (d, $^2J_{PC}$ 9.8 Hz, CH_{ortho}), 134.16 and 135.36 (2 C), 150.10 and 151.18 (2 C=O, urea), 170.24 and 171.95 (2 d, $^2J_{PC}$ 10.2 Hz and $^3J_{PC}$ 12.4 Hz, 2 C=O ester). ^{31}P NMR: δ 23.08 (Ph_3P^+-C).

REFERENCES

1. (a) X. Lei, N. Zaarur, M. Y. Sherman, and J. A. Porco Jr., *J. Org. Chem.*, **70**, 6474 (2005); (b) A. Kiriazis, T. Ruffer, S. Jantti, H. Lang, and J. Yli-Kauhaluoma, *J. Comb. Chem.*, **9**, 263 (2007); (c) P. D. Boatman, J. Urban, M. Nguyen, M. Qabar, and M. Kahn, *Bioorg. Med. Chem. Lett.*, **13**, 1445 (2003); (d) V. M. Kolb, J. P. Dworkin, and S. L. Miller, *J. Mol. Evol.*, **38**, 549 (1994); (e) R. A. Izydore, J. A. Bernal-Ramirez, and P. Singh, *J. Org. Chem.*, **55**, 3761 (1990).
2. C. R. Jacobson, A. D'Adamo, and C. E. Cosgrove, US Patent 3,663,564 (1972).
3. T. Shigematsu, M. Tomita, T. Shibahara, M. Nakazawa, and S. Munakata, Jpn. Patent 52,083,562 (1977).
4. I. H. Hall, O. T. Wong, R. Simlot, M. C. Miller, and R. A. Izydore, *Anticancer Res.*, **12**, 1355 (1992).
5. R. Simlot, R. A. Izydore, O. T. Wong, and I. H. Hall, *J. Pharm. Sci.*, **83**, 367 (1994).
6. I. H. Hall, R. Simlot, and R. A. Izydore, *Arch. Pharm.*, **328**, 5 (1995).
7. R. F. Mayol and G. M. Luke, EP Patent 568,437 (1993).
8. E. Baumgartner, U. Blumenstein, R. Bueschl, and N. Reieber, EP Patent 390,026 (1990).
9. D. E. C. Corbridge, *Phosphorus: An Outline of the Chemistry, Biochemistry and Uses*, 5th ed. (Elsevier, Amsterdam, 1995).

10. R. Engel, *Synthesis of Carbon–Phosphorus Bonds* (CRC Press, Boca Raton, FL, 1988).
11. J. I. G. Cadogan, *Organophosphorus Reagents in Organic Synthesis* (Academic Press, New York, 1979).
12. A. W. Johnson, *Ylides and Imines of Phosphorus* (Wiley, New York, 1993).
13. A. W. Johnson, *Ylide Chemistry* (Academic Press, New York, 1966).
14. O. I. Kolodiazhyi, *Russ. Chem. Rev.*, **66**, 225 (1997).
15. H. J. Bestmann and R. Zimmermann, *Top. Curr. Chem.*, **20**, 88 (1971).
16. H. J. Bestmann and O. Vostrowsky, *Top. Curr. Chem.*, **109**, 85 (1983).
17. B. E. Maryano and A. B. Reitz, *Chem. Rev.*, **89**, 863 (1989).
18. K. M. Pietrusiewicz and M. Zablocka, *Chem. Rev.*, **94**, 109 (1994).
19. R. A. Aitken, H. Herion, A. Janosi, N. Karodia, S. V. Raut, S. Seth, I. J. Shanon, and F. C. Smith, *J. Chem. Soc., Perkin Trans. 1*, 2467 (1994).
20. E. Zbiral, *Synthesis*, 775 (1974).
21. P. Ferrer, C. Avendo, and M. Sollhuber, *Liebigs Ann. Chem.*, 1895 (1995).
22. K. B. Becker, *Tetrahedron*, **36**, 1717 (1980).
23. (a) M. Anary-Abbasinejad, H. Anaraki-Ardakani, and H. Hosseini-Mehdiabad, *Phosphorus, Sulfur, and Silicon*, **183**, 1440 (2008); (b) R. Heydari, M. T. Maghsoodlou, and R. N. Yami, *Phosphorus, Sulfur, and Silicon*, **183**, 2578 (2008); (c) A. R. Kazemizadeh, A. Ramazani, and B. Ganjei, *Phosphorus, Sulfur, and Silicon*, **183**, 1935 (2008); (d) A. Jafari, E. Ahmadi, and A. Ramazani, *Phosphorus, Sulfur, and Silicon*, **183**, 1489 (2008); (e) I. Amini, A. Ramazani, and H. Ahankar, *Phosphorus, Sulfur, and Silicon*, **183**, 1994 (2008); (f) M. Adib, E. Sheibani, M. Mostofi, K. Ghanbary, and H. R. Bijanzadeh, *Phosphorus, Sulfur, and Silicon*, **180**, 2701 (2005).
24. (a) M. Adib, E. Sheibani, H. R. Bijanzadeh, and L. G. Zhu, *Tetrahedron*, **64**, 10681 (2008); (b) M. Adib, M. H. Sayahi, H. Ziyadi, L. G. Zhu, and H. R. Bijanzadeh, *Synthesis*, 3289 (2008); (c) M. Adib, E. Sheibani, L. G. Zhu, and H. R. Bijanzadeh, *Synlett*, 2941 (2008); (d) M. Adib, B. Mohammadi, and H. R. Bijanzadeh, *Synlett*, 3180 (2008); (e) M. Adib, B. Mohammadi, and H. R. Bijanzadeh, *Synlett*, 177 (2008); (f) M. Adib, M. H. Sayahi, H. Ziyadi, H. R. Bijanzadeh, and L. G. Zhu, *Tetrahedron*, **63**, 11135 (2007); (g) M. Adib, S. Aali Koloogani, A. Abbasi, and H. R. Bijanzadeh, *Synthesis*, 3056 (2007); (h) M. Adib, E. Sheibani, A. Abbasi, and H. R. Bijanzadeh, *Tetrahedron Lett.*, **48**, 1179 (2007); (i) M. Adib, E. Sheibani, M. Mostofi, K. Ghanbary, and H. R. Bijanzadeh, *Tetrahedron*, **62**, 3435 (2006); (j) M. Adib, M. Mahdavi, N. Mahmoodi, H. Pirelahi, and H. R. Bijanzadeh, *Synlett*, 1765 (2006).
25. I. Yavari, M. Adib, F. Jahani-Mogaddam, and M. H. Sayahi, *Phosphorus, Sulfur, and Silicon*, **177**, 545 (2001).
26. I. Yavari and M. Adib, *Tetrahedron*, **57**, 5873 (2001).
27. E. H. Huntress, T. E. Lesslie, and J. Bornstein, *Org. Synth. Coll. Vol. IV*, 329 (1963).