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SHORT COMMUNICATION

Reaction between enaminones and acetylenic esters in the presence of triphenylphosphine: a convenient synthesis of alkyl 2(1-benzyl-2,4-dioxo-2,3,4,5,6,7-hexahydro-1*H*-indol-3-yl)acetates

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Abstract One-pot reaction between enaminocarbonyl compounds derived from six-membered 1,3-diketones and substituted benzylamines, and electron-deficient acetylenic esters in the presence of triphenylphosphine lead to alkyl 2-(1-benzyl-6,6-dimethyl-2,4-dioxo-2,3,4,5,6,7-hexahydro-1*H*-indol-3-yl)acetate derivatives in good yields.

Keywords β-Enaminones · Dialkyl acetylenedicarboxylates · Triphenylphosphine · One-pot reaction

Introduction

Enaminones are useful compounds which are used as intermediates in organic synthesis [1–8]. On the other hand, five-membered nitrogen-containing heterocycles, such as nonaromatic type of pyrrol-2-ones and indol-2-ones, exist in a wide range of biologically active organic compounds [9,10]. Also these compounds are important building blocks for the synthesis of new biologically active heterocycles [11,12]. In addition, the generation of 1,3-dipolar species and their trapping by suitable *H*-acids leading to heterocycles occupies an important position. Zwitterionic species often result from the addition of various nucleophiles to electron-deficient acetylenic compounds [13–18]. Trivalent phosphorus compounds have been the most studied nucleophilic species [19–23] and there are many studies on the reaction between activated alkynes and *NH*-acids in the presence of triphenylphosphine to produce numerous heterocycles [24–31]. In continuation of our interest in generation and trapping of various zwitterionic species by *H*-acids [32–38], we wish to report the one-pot reaction between dialkyl acetylenedicarboxylates and enaminones in the presence of triphenylphosphine to produce alkyl 2-(1-benzyl-6,6-dimethyl-2,4-dioxo-2,3,4,5,6,7-hexahydro-1*H*-indol-3-yl)acetate derivatives in good yields.

Results and discussion

The reaction of dialkyl acetylenedicarboxylates **1** with enaminocarbonyl compound **2** in the presence of triphenylphosphine in dichloromethane was complete within a few hours at room temperature. The progress of the reaction was monitored by TLC. After 10 h, the TLC of the mixture of the reaction clearly showed the presence of compound **3** and triphenylphosphine oxide. IR, ^{1}H NMR, ^{13}C NMR, mass spectra, and CHN data of the isolated products clearly support the formation of alkyl 2-(1-benzyl-6,6-dimethyl-2,4-dioxo-2,3,4,5,6,7-hexahydro-1*H*-indol-3-yl)acetate derivatives **3** (Scheme 1).

The structures of compounds **3a**–**e** were deduced from their elemental analyses and their IR, ^{1}H NMR, and ^{13}C NMR spectra. The mass spectrum of these compounds displayed molecular ion peaks at appropriate *m*/*z* value. The ^{1}H NMR spectrum of **3a** exhibited three sharp singlets, readily recognizable as arising from the methyl ($\delta = 0.82, 0.99$ ppm) and methoxy ($\delta = 3.67$ ppm) protons. The four methylene

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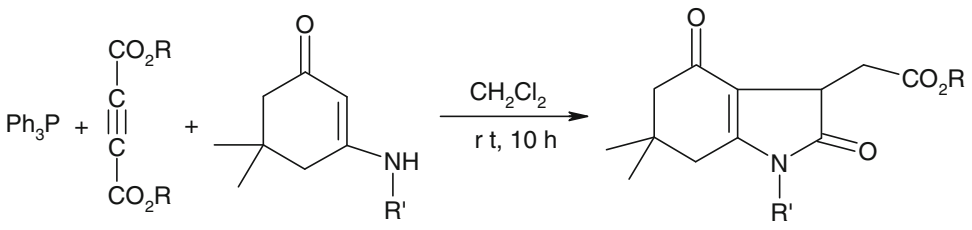


1 **2** **3**

R: Me, Et R': Bn, 2-Cl-Bn, 4-F-Bn

3	R	R'	Yield (%)
a	Me	Bn	65
b	Et	Bn	62
c	Me	2-Cl-Bn	61
d	Et	2-Cl-Bn	63
e	Et	4-F-Bn	65

Scheme 1 Synthesis of compounds **3**

protons in **3a** exhibit a complex pattern for the diastereotopic hydrogens. Two methylene protons of six-membered ring appear as a multiplets ($\delta = 2.25$–2.46 ppm). The methylene protons of CH_2CO_2Me substituent have different chemical shifts and show an AMX system ($\delta_A = 2.72$ ppm, $\delta_M = 3.13$ ppm, $J_{AM} = 16.5$ Hz, $J_{AX} = 7.5$ Hz, $J_{MX} = 2.3$ Hz). The methylene protons of benzyl group show an AX system ($\delta_A = 4.63$ ppm, $\delta_X = 5.12$ ppm, $J_{AX} = 16.5$ Hz). The methine proton appears as broad doublet ($\delta = 4.08$ ppm, $J = 7.5$ Hz) and aromatic protons appear as multiplets ($\delta = 7.11$–7.45 ppm). The ^{13}C NMR spectrum of compound **3a** showed eighteen distinct resonances in agreement with the proposed structure. The structural assignments made on the basis of the NMR spectra of compound **3a** were supported by its IR spectrum. The carbonyl groups in **3a** exhibited strong absorption bands at 1726, 1690, and 1650 cm^{-1}.

Although the mechanistic details of the above reactions are unknown, a possible explanation for this transformation is proposed in Scheme 2. It is conceivable that the reaction involves the initial formation of a zwitterionic intermediate **4** from the reaction between Ph_3P and the acetylenic compound [20–32], which protonated with **2** to produce intermediates **5** and **6**. Then, the positively charged ion **6** is attacked by the conjugated base of enaminone **5** to produce ylide intermediate **7**. Subsequently, the intramolecular annulation of this intermediate produce the ylide **8**. This ylide is attacked by water, and subsequent elimination of triphenylphosphine oxide [39] produce final product **3**.

Conclusions

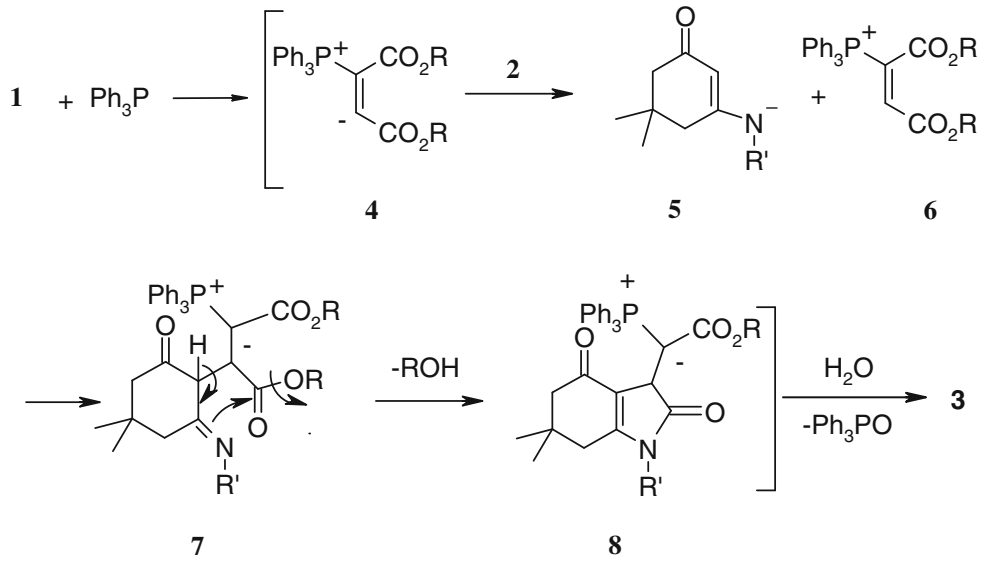
In summary, we have described a convenient route to alkyl 2-(1-benzyl-6,6-dimethyl-2,4-dioxo-2,3,4,5,6,7-hexahydro-1*H*-indol-3-yl)acetate derivatives from the one-pot reaction of enaminocarbonyl compounds and dialkyl acetylenedicarboxylates in the presence of triphenylphosphine.

Experimental

Enaminones **2** were prepared based on reported procedures [40]. Other starting materials and solvents were obtained from Merck (Germany) and Fluka (Switzerland) and were used without further purification. Melting points were measured with an Electrothermal 9100 apparatus. Elemental analyses C, H, and N were performed using a Heraeus CHN-O-Rapid analyzer. IR spectra were measured with a Shimadzu IR-460 spectrometer. NMR spectra were recorded with a Bruker DRX-250 AVANCE instrument (250.1 MHz for ^1H and 62.9 MHz for ^{13}C) with $CDCl_3$ as solvent. Mass spectra were recorded with an Agilent-5975 C inert XL MSD mass spectrometer operating at an ionization potential of 70 eV.

General procedure

To a magnetically stirred solution of triphenylphosphine (2 mmol) and enaminone **2** (2 mmol) in dichloromethane (5 mL) was added dropwise a mixture of dialkyl acetylenedicarboxylate (2 mmol) in dichloromethane (2 mL) at 0 °C over 10 min. The reaction mixture was then allowed to warm up to room temperature and stirred for 10 h. The solvent was removed under reduced pressure and the residual was purified by silica gel (Merck 230–400 mesh) column chromatography.



Scheme 2 A proposed mechanism for the formation of compounds **3**

Methy1 2-(1-benzyl-6,6-dimethyl-2,4-dioxo-2,3,4,5,6,7-hexahydro-1*H*-indol-3-yl)acetate (**3a**)

Yellow oil, yield: 65 %. IR (KBr) (υ_{max}/cm^{-1}): 1726, 1690, 1650 (C=O). Anal. Calcd for $C_{20}H_{23}NO_4$ (341.4), C, 70.36; H, 6.79; N, 4.10. Found: C, 68.95; H, 6.68; N, 3.98. ^{1}H NMR (250.1 MHz, $CDCl_3$): δ_H 0.82 and 0.99 (6H, 2s, $2CH_3$), 2.25–2.46 (4H, m, $2CH_2$), 2.72 and 3.13 (2H, AMX system, $\delta_A = 2.72$ ppm, $\delta_M = 3.13$ ppm, $J_{AM} = 16.5$ Hz, $J_{AX} = 7.5$ Hz, $J_{MX} = 2.3$ Hz, $CH_2CO_2CH_3$), 3.67 (3H, s, OCH_3), 4.08 (1H, brd, $J = 7.5$ Hz, CH), 4.59 (2H, AX system, $\delta_A = 4.63$ ppm, $\delta_X = 5.12$ ppm, $J_{AX} = 16.5$ Hz, NCH_2), 7.11–7.45 (5H, m, CH–Ar) ppm. ^{13}C NMR (62.9 MHz, $CDCl_3$): $\delta_C = 27.3$, 28.7, 32.7, 33.6, 33.8, 40.1, 44.8, and 49.4 (8C), 52.4 (OCH_3), 112.8 (N–C=*C*), 126.0 (2CH–Ar), 127.5 (CH–Ar), 128.8 (2CH–Ar), 136.8 (C), 154.3 (N–*C*=C), 169.2 (C=O, lactam), 172.3 (C=O, ester), 194.9 (C=O) ppm. MS: *m*/*z* (%) = 341 (M^+, 22), 282 (48), 149 (50), 91 (100).

Ethyl 2-(1-benzyl-6,6-dimethyl-2,4-dioxo-2,3,4,5,6,7-hexahydro-1*H*-indol-3-yl)acetate (**3b**)

Yellow oil, yield: 62 %. IR (KBr) (υ_{max}/cm^{-1}): 1722, 1697, 1618 (C=O). Anal. Calcd for $C_{21}H_{25}NO_4$ (355.4): C, 70.96; H, 7.09; N, 3.94. Found: C, 69.72; H, 6.92 %; N, 3.81. ^{1}H NMR (250.1 MHz, $CDCl_3$): δ_H 0.82 and 1.00 (6H, 2s, $2CH_3$), 1.2 (3H, t, $^3J_{HH} = 7.5$ Hz, OCH_2CH_3), 2.17–2.40 (4H, m, $2CH_2$), 2.72 and 3.15 (2H, AMX system, $\delta_A = 2.72$ ppm, $\delta_M = 3.15$ ppm, $J_{AM} = 16.5$ Hz, $J_{AX} = 7.8$ Hz, $J_{MX} = 1.8$ Hz, $CH_2CO_2C_2H_5$), 4.10 (2H, m, O CH_2CH_3), 4.12 (1H, brd, $J = 7.8$ Hz, CH), 4.13 (2H, q, $^3J_{HH} = 7.5$ Hz, O CH_2CH_3), 5.03 (2H, AX system, $\delta_A = 4.60$ ppm, $\delta_X = 5.45$ ppm, $J_{AX} = 16.5$ Hz, NCH_2), 7.11–7.40 (5H, m, CH–Ar) ppm. ^{13}C NMR (62.9 MHz, $CDCl_3$): δ_C 14.1 (OCH_2CH_3), 27.0, 28.9, 32.7, 33.6, 33.9, 40.1, 44.8, and 49.4 (8C), 61.4 (OCH_2CH_3), 112.9 (N–C=*C*), 126.0 (2CH–Ar), 127.4 (CH–Ar), 128.9 (2CH–Ar), 136.8 (C), 154.1 (N–*C*=C), 169.3 (C=O, lactam), 171.8 (C=O, ester), 195.0 (C=O) ppm. MS: *m*/*z* (%) = 355 (M^+, 46), 309 (15), 282 (85), 91 (100).

Methyl 2-(1-(2-chlorobenzyl)-6,6-dimethyl-2,4-dioxo-2,3,4,5,6,7-hexahydro-1*H*-indol-3 yl)acetate (**3c**)

Yellow oil, yield: 61 %. IR (KBr) (υ_{max}/cm^{-1}): 1730, 1700, 1650 (C=O). Anal. Calcd for $C_{20}H_{22}ClNO_4$ (375.8), C, 63.91; H, 5.90; N, 3.73. Found: C, 62.67; H, 5.78; N, 3.65. ^{1}H NMR (250.1 MHz, $CDCl_3$): δ_H 0.84 and 1.0 (6H, 2s, $2CH_3$), 2.29–2.34 (4H, m, $2CH_2$), 2.75, 3.13 (2H, AMX system, $\delta_A = 2.75$ ppm, $\delta_M = 3.13$ ppm, $J_{AM} = 16.5$ Hz, $J_{AX} = 8.0$ Hz, $J_{MX} = 0.0$ Hz, $CH_2CO_2CH_3$), 3.69 (3H, s, OCH_3), 4.09 (1H, brd, $J = 8.0$ Hz, CH), 4.88 (2H, AX system, $\delta_A = 4.90$ ppm, $\delta_X = 5.02$ ppm, $J_{AX} = 16.5$ Hz, NCH_2), 7.11–7.46 (4H, m, CH–Ar) ppm. ^{13}C NMR (62.9 MHz, $CDCl_3$): δ_C 27.2, 28.8, 32.8, 33.6, 33.9, 39.9, 42.7, and 49.4 (8C), 52.5 (OCH_3), 112.7 (N–C=*C*), 126.8, 127.3, 128.7, 129.6, 132.0, and 134.0 (6C–Ar), 154.0 (N–*C*=C), 169.1 (C=O, lactam), 172.4 (C=O, ester), 195.0 (C=O) ppm. MS: *m*/*z* (%) = 375 (M^+, 12), 340 (25), 316 (50), 125 (100).

Ethyl 2-(1-(2-chlorobenzyl)-6,6-dimethyl-2,4-dioxo-2,3,4,5,6,7-hexahydro-1*H*-indol-3 yl)acetate (**3d**)

Yellow oil, yield: 63 %. IR (KBr) (υ_{max}/cm^{-1}): 1722, 1680, 1657(C=O). Anal. Calcd for $C_{21}H_{24}ClNO_4$ (389.9), C, 64.70;

H, 6.20; N, 3.59. Found: C, 63.68; H, 6.07; N, 3.50. ^{1}H NMR (250.1 MHz, $CDCl_3$): δ_H 0.84 and 1.01 (6H, 2s, 2 CH_3), 1.22 (3H, t, $^3J_{HH}$ = 7.0 Hz, OCH_2CH_3), 2.21–2.42 (4H, m, $2CH_2$), 2.75 and 3.13 (2H, AMX system, δ_A = 2.75 ppm, δ_M = 3.13 ppm, J_{AM} = 16.5 Hz, J_{AX} = 7.8 Hz, J_{MX} = 1.8 Hz, $CH_2CO_2C_2H_5$), 4.12 (1H, brd, J = 7.8 Hz, CH), 4.10 (2H, m, OCH_2CH_3), 5.04 (2H, AX system, δ_A = 4.78, δ_X = 5.37 ppm, J_{AX} = 17.5 Hz, NCH_2), 7.11–7.45 (4H, m, CH–Ar) ppm. ^{13}C NMR (62.9 MHz, $CDCl_3$): δ_C 14.1 (OCH_2CH_3), 26.9, 29.0, 32.7, 33.6, 34.1, 39.9, 42.7, and 49.5 (8C), 61.4 (OCH_2CH_3), 112.8 (N–C=*C*), 126.7, 127.3, 128.7, 129.6, 131.9, 134.1 (6C–Ar), 153.8 (N–*C*=C), 169.2 (C=O, lactam), 171.9 (C=O, ester), 194.9 (C=O) ppm. MS: *m/z* (%) = 390 (M^+, 30), 354 (20), 316 (65), 125 (100).

Ethyl 2-(1-(4-fluorobenzyl)-6,6-dimethyl-2,4-dioxo-2,3,4,5,6,7-hexahydro-1*H*-indol-3-yl)acetate(**3e**)

Yellow oil, yield: 65 %. IR (KBr) (υ_{max}/cm^{-1}): 1731, 1695, 1649 (C=O). Anal. Calcd for $C_{21}H_{24}FNO_4$ (373.4), C, 67.55; H, 6.48; N, 3.75. Found: C, 66.41; H, 6.23; N, 3.68. ^{1}H NMR (250.1 MHz, $CDCl_3$): δ_H 0.84 and 1.01 (6H, 2s, $2CH_3$), 1.22 (3H, t, $^3J_{HH}$ = 7.5 Hz, OCH_2CH_3), 2.25–2.38 (4H, m, $2CH_2$), 2.68 and 3.12 (2H, AMX system, δ_A = 2.68 ppm, δ_M = 3.12 ppm, J_{AM} = 16.3 Hz, J_{AX} = 7.7 Hz, J_{MX} = 0.0 Hz, $CH_2CO_2C_2H_5$), 4.10 (2H, m, OCH_2CH_3), 4.15 (1H, brd, J = 7.7 Hz, CH), 4.52 (2H, AX system, δ_A = 4.55, δ_X = 5.40, J_{AX} = 16.5 Hz, NCH_2), 7.11–7.45 (4H, m, CH–Ar) ppm. ^{13}C NMR (62.9 MHz, $CDCl_3$): δ_C 14.1 (OCH_2CH_3), 27.1, 28.9, 32.7, 33.6, 34.0, 40.2, 44.2, and 49.5 (8C), 61.4 (OCH_2CH_3), 113.1 (N–C=*C*), 115.8 (d, $^2J_{CF}$ = 22.0 Hz, 2 CH–Ar), 127.8 (d, $^3J_{CF}$ = 7.0 Hz, 2 CH–Ar), 132.6 (C), 153.7 (N–*C*=C), 169.2 (C=O, lactam), 171.8 (C=O, ester), 194.7 (C=O) ppm. MS: *m/z* (%) = 373 (M^+, 10), 300 (20), 109 (100).

Supplementary Material

Supplementary data (^{1}H NMR and ^{13}C NMR spectra for compounds **3a**–**3e**) associated with this article can be found in the online version.

References

1. Riyadh SM (2011) Enaminones as building blocks for the synthesis of substituted pyrazoles with antitumor and antimicrobial activities. Molecules 16: 1834–1853. doi:10.3390/molecules16021834
2. Bezenšek J, Grošelj U, Stare K, Svete J, Stanovnik B (2012) Transformations of enaminones. A simple one-pot synthesis of imidazolone derivatives. Tetrahedron 68: 516–522. doi:10.1016/j.tet.2011.11.013
3. Hossaini Z, Rostami-Charati F, Soltani S, Mirzaei A, Berijani K (2011) Multicomponent reactions of ammonium thiocyanate, acyl chlorides, alkyl bromides, and enaminones: a facile one-pot synthesis of thiophenes. Mol Divers 15: 911–916. doi:10.1007/s11030-011-9322-5
4. Al-Mousawi SM, El-Apasery MA, Elnagdi MH (2010) Enaminones in heterocyclic synthesis: a novel route to tetrahydropyrimidines, dihydropyridines, triacylbenzenes and naphthofurans under microwave irradiation. Molecules 15: 58–67. doi:10.3390/molecules15010058
5. Teimouri MB, Abbasi T (2010) Facile synthesis of oxaspirobicyclic butenolides via a domino Michael addition/aldol reaction/γ-lactonization sequence. Tetrahedron 66: 3795–3800. doi:10.1016/j.tet.2010.03.058
6. Singh P, Sharma P, Bisetty K, Mahajan MP (2009) Cycloaddition reactions of cross-conjugated enaminones. Tetrahedron 65: 8478–8485. doi:10.1016/j.tet.2009.08.038
7. Ge H, Niphakis MJ, Georg GI (2008) Palladium(II)-catalyzed direct arylation of enaminones using organotrifluoroborates. J Am Chem Soc 130: 3708–3709. doi:10.1021/ja710221c
8. Nasiri F, Pourdavaie K (2007) A simple approach to the synthesis of highly functionalized 3-alkylidene-2,3-dihydro-1*H*-pyrrole-2-ol derivatives and related pyrroles. Mol Divers 11: 37–45. doi:10.1007/s11030-007-9055-7
9. Carpenedo R, Mannaioni G, Moroni F (1998) Oxindole, a sedative tryptophan metabolite, accumulates in blood and brain of rats with acute hepatic failure. J Neurochem 70: 1998–2003. doi:10.1046/j.1471-4159.1998.70051998.x
10. Strigacova J, Hudecova D, Mikulasova M, Varecka L, Lasikova A, Vegh D (2001) Novel oxindole derivatives and their biological activity. Folia Microbiol 46: 187–192. doi:10.1007/BF02818531
11. Egorova A, Timofeeva Z (2004) Reactivity of pyrrol-2-ones (review). Chem Heterocycl Compd 40: 1243–1261. doi:0009-3122/04/4010-1243
12. Galliford CV, Scheidt KA (2007) Pyrrolidinyl-spirooxindole natural products as inspirations for the development of potential therapeutic agents. Angew Chem Int Ed 46: 8748–8758. doi:10.1002/anie.200701342
13. Nair V, Nair JS, Vinod AU, Rath NP (1997) Triphenylphosphine promoted addition of dimethyl acetylenedicarboxylate to 1,2-benzoquinones: facile synthesis of novel γ-spirolactones. J Chem Soc Perkin Trans 1: 3129–3130. doi:10.1039/A706272I
14. Nair V, Rajesh C, Vinod AU, Bindu S, Sreekanth AR, Mathess JS, Balagopal L (2003) Strategies for heterocyclic construction via novel multicomponent reactions based on isocyanides and nucleophilic carbenes. Acc Chem Res 36: 899–907. doi:10.1021/ar020258p
15. Yavari I, Hossaini Z, Sabbaghan M (2006) Synthesis of functionalized 5-imino-2,5-dihydro-furans through the reaction of isocyanides with activated acetylenes in the presence of ethyl bromopyruvate. Mol Divers 10: 479–482. doi:10.1007/s11030-006-9034-4
16. Fan MJ, Li GQ, Liang YM (2006) DABCO catalyzed reaction of various nucleophiles with activated alkynes leading to the formation of alkenoic acid esters, 1,4-dioxane, morpholine, and piperazinone derivatives. Tetrahedron 62: 6782–6791. doi:10.1016/j.tet.2006.04.100
17. Yavari I, Hossaini Z, Sabbaghan M (2006) A synthesis of pyrrolo[2,1-*a*]isoquinolines through the reaction of activated acetylenes and isoquinoline in the presence of ethyl bromopyruvate. Tetrahedron Lett 47: 6037–6040. doi:10.1016/j.tetlet.2006.06.113
18. Esmaeili AA, Zangouei M, Hosseinabadi R, Fakhari AR (2012) Three-component reactions of isocyanides, dialkyl acetylenedicarboxylates, and trans-cinnamoyl chlorides for the synthesis of highly functionalized 2-vinyl furans. Mol Divers 16: 145–150. doi:10.1007/s11030-011-9341-2

19. Trost BM, Li CJ (1994) Novel "umpolung" in C–C bond formation catalyzed by triphenylphosphine. J Am Chem Soc 116: 3167–3168. doi:10.1021/ja00086a074
20. Trost BM, Dake GR (1997) Nucleophilic α-addition to alkynoates. A synthesis of dehydroamino acids. J Am Chem Soc 119: 7595–7596. doi:10.1002/chin.199750097
21. Maghsoodlou MT, Hazeri N, Habibi-Khorassani SM, Saghatforoush L, Rofouei MK, Rezaie M (2006) Diastereoselective synthesis of phosphonato esters by reaction between triphenylphosphite and acetylenic esters in the presence of *NH*-acid compounds. ARKIVOC 13:117–123
22. Yavari I, Djahaniani H (2006) Synthesis of 4*H*-[1,3]dithiolo[4,5-*b*]pyrroles through the reaction of benzoyl isothiocyanate and dialkyl acetylenedicarboxylates in the presence of Ph_3P. Tetrahedron Lett 47: 2953–2956. doi:10.1016/j.tetlet.2006.02.097
23. Ramazani A, Kazemizadeh A, Ahmadi E, Noshiranzadeh N, Souldozi A (2008) Synthesis and reactions of stabilized phosphorus ylides. Curr Org Chem 12: 59–82. doi:10.2174/138527208783330055
24. Yavari I, Alizadeh A, Anary-Abbasinejad M (2002) Reaction between heterocyclic *NH*-acids and dibenzoylacetylene in the presence of triphenylphosphine. Simple synthesis of 1-3-furyl-1*H*-imidazole derivatives. Tetrahedron Lett 43: 9449–9452. doi:10.1016/S0040-4039(02)02259-1
25. Yavari I, Adib M, Sayahi MH (2002) Efficient synthesis of functionalized 3*H*-pyrrolo [1,2-*a*]indoles. J Chem Soc Perkin Trans 1: 1517–1519. doi:10.1039/b204433c
26. Yavari I, Nasiri F, Djahaniani H (2004) Synthesis of fluorinated dialkyl 1-aryl-4-alkoxy-5-oxo-2,5-dihydro-1*H*-pyrrole-2,3-dicarboxylates. Pol J Chem 78: 1871–1876. doi:10.1002/chin.200508110
27. Yavari I, Moradi L, Nasiri F, Djahaniani H (2005) Regioselective reaction of N^1-benzyl-N^2-(4-nitrophenyl)-ethanediamide and acetylenic esters. Monatsh Chem 136: 1757–1761. doi:10.1002/chin.200604103
28. Vicini P, Incerti M, Ferretti R, Zanardi F (2006) A one-pot entry to a novel 3-*H*-benzo[d]pyrazolo[1,5-*b*]isothiazole ring system. Mol Divers 10: 251–253. doi:10.1007/s11030-005-9011-3
29. Yavari I, Zabarjad-Shiraz N (2006) Three-component reaction between triphenylphosphine, dialkyl acetylenedicarboxylates and urea or *N*-methylurea. Mol Divers 10: 23–27. doi:10.1007/s11030-006-8696-2
30. Islami MR, Kalantari M, Hassani Z, Saidi K (2006) Synthesis of dimethyl 1-(trifluoromethyl)-3*H*-pyrrolizine-2,3-dicarboxylate using phosphorus compounds. ARKIVOC 10:55–62
31. Alizadeh A, Sheikhi E (2007) One-pot synthesis of functionalized hydantoin derivatives via a four-component reaction between an amine, an arylsulfonyl isocyanate and an alkyl propiolate or dialkyl acetylenedicarboxylate in the presence of triphenylphosphine. Tetrahedron Lett 48: 4887–4890. doi:10.1016/j.tetlet.2007.05.061
32. Yavari I, Nasiri F, Djahaniani H (2004) Synthesis and dynamic NMR study of ketenimines derived from tert-butyl isocyanide, alkyl 2-arylamino-2-oxo-acetates, and dialkyl acetylenedicarboxylates. Mol Divers 8: 431–435. doi:10.1023/B:MODI.0000047510.22335.8c
33. Yavari I, Nasiri F, Moradi L, Djahaniani H (2004) A simple approach to the synthesis of dialkyl 5-tert-butylamino-[2,2′]bifuranyl-3,4-dicarboxylates. Tetrahedron Lett 45: 7099–7101. doi:10.1016/j.tetlet.2004.07.120
34. Nasiri F, Nazem F, Pourdavaie K (2007) Chemo- and stereoselective reaction between alkyl isocyanides and dimethyl 1,3-acetonedicarbocxylate in the presence of acetylenic esters. Mol Divers 11: 101–105. doi:10.1007/s11030-007-9064-6
35. Nasiri F, Pourdavaie K, Yosefdad S, Atashkar B (2007) Reaction between dialkyl acetylenedicarboxylates and six-membered 1,3-diketones in the presence of trialkylamines: a convenient synthesis of alkyl 2,5-dioxo-5,6,7,8-tetrahydro-2*H*-chromene-4-carboxylates. Mendeleev Commun 17: 352–353. doi:10.1016/J.mencom.2007.11.019
36. Nasiri F, Bidar M (2008) A facile synthesis of stable 1,4-diionic phosphorus compounds in aqueous media. Phosphorus Sulfur Silicon 183: 1344–1349. doi:10.1080/10426500701641346
37. Nasiri F, Atashkar B (2008) Trimethylamine catalyzed stereoselective reaction between dimethyl acetylenedicarboxylate and phenols. Monatsh Chem 139: 1223–1227. doi:10.1007/s00706-008-0919-z
38. Nasiri F, Malakutikhah D (2011) Stereoselective reaction between alkyl propiolates and phenols in the presence of sodium azide in tert-butyl alcohol. Monatsh Chem 142: 807–812. doi:10.1007/s00706-01105146
39. Nasiri F, Bidar M, Atashkar B (2009) Two intermediates in the reaction between dibenzoylacetylene and enol systems in the presence of triphenylphosphine in THF/H_2O. Monatsh Chem 140: 463–466. doi:10.1007/s00706-008-0075-5
40. McMurry JE (1988) A general synthesis of 4-isoxazolecarboxylic esters: ethyl 3-ethyl-5-methyl-4-isoxazolecarboxylate. Org Synth Coll 6:592–594