Microwave-assisted coupling of carbonyl compound: an efficient synthesis of olefin

M.M.V. Ramana*, B.K.D. Singh and J.A. Parihar

Department of Chemistry, University of Mumbai, Vidyanagari, Santacruz (E), Mumbai-400098, India

Self-coupling of various ketones and aldehyde as well as mixed coupling of ketones employing $TiCl_4$/ Zn under microwave irradiation has been carried out to afford the corresponding olefins.

Keywords: carbonyl coupling, olefins, $TiCl_4$, zinc, microwave

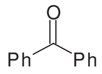
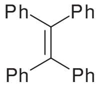
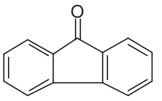
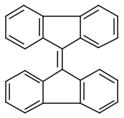
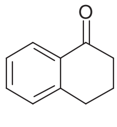
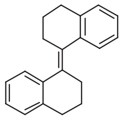
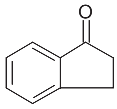
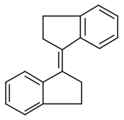
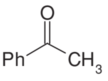
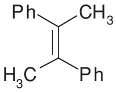
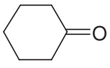
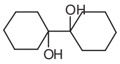
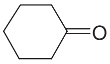
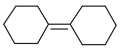
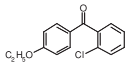
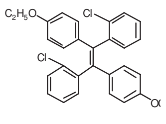
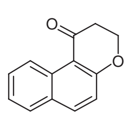
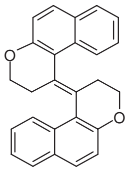
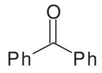
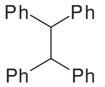
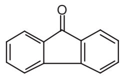
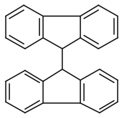
The efficiency of microwave irradiation for promoting organic reactions has been widely documented.[1]

Titanium induced coupling of carbonyl compounds to give olefins has been utilised for the syntheses of several strained olefins,[2] unusual molecules[3] and natural products.[4] A survey of the literature revealed that $TiCl_3$ or $TiCl_4$ along with a suitable redox system are commonly used for the synthesis of pinacols and or olefins by the reductive coupling of carbonyl compounds. Of these, $TiCl_3$ along with a variety of redox system such as $LiAlH_4$, K, Li, and Zn–Cu (MaMurry's reagent)[5a,5b] work efficiently for the intermolecular as well as intramolecular coupling of aromatic and aliphatic compounds to yield their corresponding olefins. An excellent review by Ephritkhine[5c] focussing on the most recent developments was published in 1998. Though $TiCl_4$/Zn (Mukaiyama's reagent) works efficiently for benzophenone, benzaldehyde and acetophenone to give the corresponding olefins[6] and uses relatively inexpensively chemicals, surprisingly many carbonyl compounds have not yet been studied using this reagent system. In the case of aliphatic carbonyl compounds it gives predominantly pinacols with a negligible or low yield of olefins[6]. The mixed coupling of carbonyl compounds (to the best of our knowledge) has not yet been studied. These observations led us to investigate the feasibility of carbonyl coupling for the formation of olefins employing $TiCl_4$/ Zn (Mukaiyama's reagent) under microwave irradiation.

First, benzophenone was reacted with $TiCl_4$/Zn in dioxan under microwave irradiation to give the required olefin in 97% yield in only 5 minutes. Encouraged by this result, other ketones (see Table 1) were subjected to reductive coupling under the microwave irradiation. Cyclohexanone gave successfully the corresponding olefin in 65 % yield in 10 minutes (entry 7) under microwave irradiation. Benzophenone and fluorenone when reacted with 2 equivalents of low valent titanium reagent gave the corresponding saturated analogs (entries 10, 11). Several aldehydes were then reacted with the low valent titanium reagent under the microwave irradiation (see Table 2). All the aromatic aldehydes gave the corresponding olefins in good yields. However, citral did not give the corresponding olefin but gave the corresponding pinacol in 76 % yield (entry 6). Finally the mixed coupling, which has not yet been studied employing Mukaiyama's reagent, was investigated under microwave irradiation. The mixed reductive coupling of acetone with benzophenone gave the corresponding olefin in 52 % yield along with 31 % of the self-coupling product of benzophenone. Unfortunately the mixed coupling of flavanone with acetone gave only 10 % of the corresponding olefin along with 62 % of the self-coupling product of flavanone after column chromatographic purification (silica gel, hexane) (Table 3).

In conclusion, the present method provides an excellent approach for the synthesis of olefins by reductive carbonyl coupling. Reductive coupling of aliphatic ketones like

Table 1 Reductive coupling of the ketones using $TiCl_4$/Zn under microwave irradiation

Entry	Ketones	Product	Time /min	MP[a] /°C	Yield /%	Lit. (^{1}H NMR)[b]
1			5	222[7]	97	8
2			5	189[7]	94	9
3			5	143[10]	89	9
4			5	142[10]	74	11
5			8	80	90 (7:3)[c]	7, 8
6			10	125[12]	89	8
7[d]			10	52[8]	65	8
8			10	212	81	
9			10	>300	75	
10[d]			5	209[7]	90	7
11[d]			5	246[7]	93	7, 9

[a] Melting points are un-corrected.

[b] PMR spectral data of the compound was in agreement with the literature data.

[b] Ration of trans and cis.

[c] 2 equivalents of Zn/TiCl4 was used.

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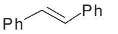
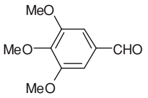
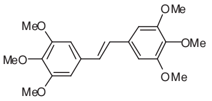
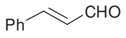
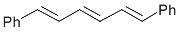
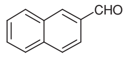
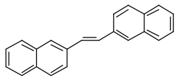
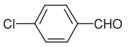
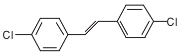
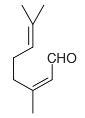
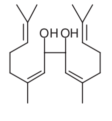
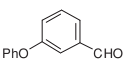
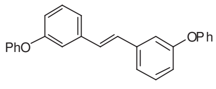
* Correspondence. E-mail: mmvramana@indiatimes.com

Table 2 Reductive coupling of the aldehydes using $TiCl_4$/Zn under microwave irradiation

Entry	Aldehydes	Product	Time /min	MP[a] /°C	Yield /%	Lit. (^1H NMR)[b]
1	Ph–CHO		7	127[8]	92	8
2			8	213[13]	95	13
3			5	199[10]	83	14
4			5	213[15]	82	15
5			5	178[16]	80	16
6			5	-	76	
7			10	204	80	

[a]Melting points are un-corrected.
[b]PMR spectral data of the compound was in agreement with the literature data.

cyclohexanone to give the corresponding olefin and the mixed coupling of ketones, has been successfully carried out under microwave irradiation.

Experimental

Reductive coupling of benzophenone: To a well-stirred suspension of $TiCl_4$ (3.79 g, 0.02 mole) in dioxan maintained at –5°C to–10°C under N_2 were added Zn dust (1.30 g, 0.02 mole) and pyridine (1–2 drops). The resultant yellow suspension mixture was stirred vigorously at the same temperature until it turned black (*ca.* 30 min.). The formation of the black slurry indicated the formation of low valent titanium. Benzophenone in dioxan (3.64 g, 0.02 mole) was added and the resultant reaction mixture was subjected to microwave irradiation for 5 min in a conventional microwave oven (Samsung, Model C-945-G, 900 W) with 100% intensity. Heating was stopped momentarily every minute. The reaction mixture was quenched with 5% Na_2CO_3 (200 cm^3) and then extracted with ether (5 × 25 cm^3). The combined ether extracts were washed with water (2 × 25 cm^3) and then dried (anhyd. Na_2SO_4). The evaporation of solvent gave analytically pure white solid, which was further purified by column chromatography [silica gel, hexane] to furnish required olefin (m.p. 222 °C, 3.20 g, yield 97 %).

The same experimental procedure was followed for the other compounds.

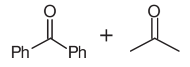
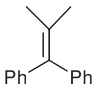
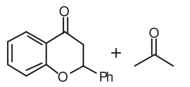
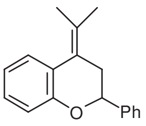
1-[(E)-1,2-bis(4-ethoxyphenyl)-2-(3-chlorophenyl)vinyl]-3-chlorobenzene: IR (KBr) ν: 1510, 1580, 1610 cm^{-1}; ^1H NMR ($CDCl_3$, 60 MHz) δ: 1.33 (t, J = 7 Hz, 6H, CH_3), 3.85 (q, J = 7 Hz, 4H, OCH_2), 6.50–7.18 (m, 16H, Ar–H); UV ($CHCl_3$) λ_{max}, nm (log ε): 226 (6.28), 242 (7.23); Anal. calcd for $C_{30}H_{26}O_2Cl_2$: C 73.62, H 5.35, Cl 14.49. Found C 73.51, H 5.38, Cl 14.55.

4-[2,3-dihydro-4H-naphtho(1,2-b)pyran-9-ylidene]-2,3-dyhydro-4H-naphtho(1,2-b)pyran: IR (KBr) ν: 1510, 1590, 1610 cm^{-1}; ^1H NMR ($CDCl_3$, 60 MHz) δ: 2.40 (t, J = 7 Hz, 4H, CH_2), 4.00 (t, J = 7 Hz, 4H, OCH_2), 7.25–7.60 (m, 8H, Ar–H), 8.00–8.25 (m, 4H, Ar–H); UV ($CHCl_3$) λ_{max}, nm (log ε): 243 (7.69), 288 (6.84), 353 (6.98); Anal. calcd for $C_{26}H_{20}O_2$: C 85.69, H 5.53. Found C 85.56, H 5.59.

2,6,11,15-Tetramethylhexadeca-2,6,10,14-tetraene-8,9-diol: IR (oil film) ν: 1640, 3450 cm^{-1}; ^1H NMR ($CDCl_3$, 60 MHz) δ: 1.95–2.52 (m, 26 H), 2.85–3.00 (br s, 2H, OH), 4.48–4.60 (m, 2H, O-CH), 5.42–5.55 (m, 4H, C=C-H), 8.00–8.25 (m, 4H, Ar–H); UV ($CHCl_3$) λ_{max}, nm (log ε): 242 (6.71), 269 (6.58), 291 (6.75); Anal. calcd for $C_{20}H_{34}O_2$: C 78.38, H 11.18. Found C 78.25, H 11.24.

1-phenoxy-3-[(E)-2-(3-phenoxyphenyl)vinyl]benzene: IR (KBr) ν: 1500, 1580, 1610 cm^{-1}; ^1H NMR ($CDCl_3$, 200 MHz) δ: 6.81–7.02 (m, 14H, Ar–H), 7.28–7.39 (m, 6H, Ar–H); UV ($CHCl_3$) λ_{max}, nm (log ε): 243 (7.35), 320 (7.10); Anal. calcd for $C_{26}H_{20}O_2$: C 85.69, H 5.53. Found C 85.57, H 5.60.

Table 3 Mixed reductive coupling of the ketones using $TiCl_4$/Zn under microwave irradiation

Entry	Ketones	Product	Time /min	MP[a] /°C	Yield /%	Lit. (^1H NMR)[b]
1			10	Oil	52	8
2			10	Oil	10	

[a]Melting points are un-corrected.
[b]PMR spectral data of the compound was in agreement with the literature data.

4-(1-methylethylidene)-2-phenylchromane: IR (KBr): 1510, 1580, 1600 cm^{-1}; ^1H NMR ($CDCl_3$, 60 MHz) δ: 1.90–2.25 (m, 8H), 5.50 (t, J = 5 Hz, 1H), 6.80–7.25 (m, 9H, Ar–H); MS (EI, *m*/*z*): 250 (38%, M^+), 235 (30), 159 (100), 146 (25), 131 (27), 115 (20), 107 (10), 91 (30); UV ($CHCl_3$) λ_{max}, nm (log ε): 243 (7.15), 305 (7.45); Anal. calcd for $C_{18}H_{18}O$: C 86.36, H 7.25. Found C 86.21, H 7.32.

One of the authors (BKS) is thankful to the G.D. Gokhale Charitable Trust for the financial assistance.

Received 13 June 2004; accpted 28 September 2004
Paper 04/2575

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