

Note

Pinacol coupling of carbonyl compounds by using Al-NaOH/MeOH under microwave irradiation

Mohsen Mazaheri Tehrani* & Jila Asghari

College of Science, Gorgan University of Agricultural Sciences and Natural Resources, Gorgan, 49165-386, Iran

E-mail: mmazaheritehrani@gau.ac.ir

Received 2 September 2004; accepted (revised) 12 May 2005

Reductive coupling of aromatic aldehydes and ketones to the corresponding 1,2-diols has been achieved in 59-98% yields using aluminium powder in aqueous sodium hydroxide and methanol medium under microwave irradiation for 5-12 min. The notable advantage of this method seems to be negligible formation of small amounts of reduced product of the carbonyls i.e. alcohols and the formation of side product olefins via McMurry coupling. The reaction rate is fast and the purity of products is compared to the existing methods. The potential Pinacol rearrangement of the reductive coupling products greatly extends their synthetic utility.

Keywords: Reductive coupling, Pinacol coupling, microwave irradiation, enantioselectivity

IPC: Int.Cl.⁷ C 07 C

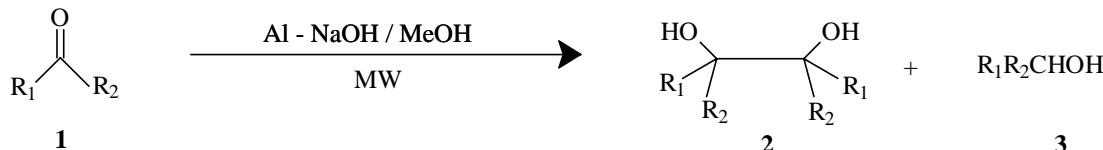
The reductive coupling of carbonyl compounds which leads to vicinal diols one of the important methods for the formation of carbon-carbon bonds¹. Various metals such as, Mg², Zn³, Mn⁴ have already been used to mediate the Pinacol coupling reaction in aqueous media. Recently, the Pinacol coupling of aromatic aldehydes and ketones has been reported for the synthesis of 1,2-diols using Al⁵⁻⁷ in the presence of potassium hydroxide and sodium hydroxide, Mg⁸ in aqueous NH₄Cl, Zn-Cu⁹ or In¹⁰ under ultrasound irradiation and TiCl₃/Al-EtOH under microwave irradiation¹¹. More recently, several chiral ligands including TiCl₄-Zn chiral diamines¹², titanium complex of the tetradeятate schiff base¹³ and TiCl₄(THF)₂/Zn with tartaric ester¹⁴, have been used to improve the enantioselectivity.

Results and Discussion

Microwave irradiation^{15,16} has been recently used to accelerate organic reaction, by increasing heating efficiency to give remarkable rate enhancements and dramatic reductions in reaction times. In continuation of our interest in performing the reactions in microwave¹⁷, we wish to describe herein a new method for Pinacol coupling reactions of aromatic aldehydes and ketones using aluminium in aqueous NaOH-MeOH under microwave irradiation. **Table I** shows the results of Pinacol coupling of aromatic aldehydes and ketones and the products were obtained in high yields. Pinacol coupling of benzaldehyde **1a**, *p*-methoxybenzaldehyde **1h**, *p*-methylbenzaldehyde **1g**, *p*-chlorobenzaldehyde **1e** and *m*-chlorobenzaldehyde **1f** proceeded smoothly within short time (5-12 min) and resulted into good yields (90-95%) of products. Cyclic ketones such as cyclopentanone, cyclohexanone, cycloheptanone and aliphatic acyclic ketones and aldehyde did not give the product under the same reaction conditions. Thus, it appears that the steric hindrance around the carbonyl group inhibits the coupling reaction and 2, 4-dichlorobenzaldehyde and benzophenone give only 59-60% Pinacols, under the same reaction conditions. To show the dramatic acceleration in the rate of reaction due to microwave irradiation, under the same experimental conditions several aldehydes and ketones were heated in an oil-bath by conventional heating under reflux condition. However, only low yield of Pinacol coupling products were obtained in very long reaction time, e.g. Pinacol coupling of 4-chlorobenzaldehyde (5-10%, 60°C, 5 min) (79%, 60°C, 3hr) and benzophenone (7-15 %, 60°C, 8 hr).

Experimental Section

Solvents were used directly as obtained from the suppliers. Reagents were employed as purchased from Aldrich or Merck. Thin layer chromatography (TLC) was carried out using glass sheets precoated with



silica gel 60 F. Melting points were determined on a Electro thermal Gallen lamp apparatus and are uncorrected.

¹H NMR spectra were recorded on a Varian EM-340, and advance 500; and IR spectra on a Shimatzu IR-435 spectrometer. The microwave oven need was a domestic (2450 MHz) Butane model M-245. The characterization of the reaction products were determined by IR and ¹H NMR spectroscopy, and comparing the authentic samples.

Preparation of 1,2-diols 2. A mixture of aldehydes or ketones (1.2 mmoles), aluminium powder (0.12 g, 4.14 mmoles), 10% aqueous NaOH

(2 mL) and MeOH (3 mL) was mixed in unsealed glass vessels (pyrex). The reaction mixture was submitted to microwave irradiation at 100-200 W for 5-15 min.

After completion of the reaction (monitored by TLC) the mixture was quenched with 3 M HCl and extracted with ethyl acetate (3×10 mL). The combined organic layer was washed with saturated aqueous NaHCO₃ and dried over anhydrous MgSO₄. After filtration and removing the solvent and volatile materials under reduced pressure, coupling products were obtained as a white solid, which were further purified by crystallization from petroleum ether (b.p.

Table I—Pinacol coupling by using Al in aqueous NaOH / MeOH under microwave irradiation

Entry	Substrate	Reaction time (min)	Emitted Power (w)	Isolated yield (%)		d _l /meso
				2	3	
a		5	100	95	4	61:39
b		6	200	79	20	65:35
c		7	200	72	5	72:28
d		6	200	80	15	76:24
e		5	100	98	0	59:41
f		5	100	94	0	48:52
g		6	100	90	7	81:19
h		6	100	89	8	66:34
i		7	100	91	5	60:40
j		10	200	59	0	meso
k		12	200	60	8	-
l		10	200	70	10	62:22

Ratios of *d_l*/meso as calculated by ¹H NMR (500 MHz).

60-90°C) to get a mixture of diastereomers in good yields. The authenticity of the products was established by ^1H NMR and IR spectra. The residue obtained after the reaction contained a mixture of unreacted aluminium and aluminium hydroxide. The unreacted aluminium can be recycled after washing the residue with dil. HCl followed by water and drying. Moreover, the aluminium recovered after the reaction can be reused.

2a ^1H NMR (CDCl_3): δ 2.31 (s, 2H), 4.71, 4.80 (s, *dl*, *meso*, 2H), 7.1-7.3 (m, 10H); IR (KBr): 3350-3500 cm^{-1} .

2b ^1H NMR (CDCl_3): δ 1.47, 1.56 (s, *dl*, *meso*, 6H), 2.30 (s, 2H), 7.20 (s, 10H); IR (KBr): 3300-3450 cm^{-1} .

2c ^1H NMR (CDCl_3): δ 1.47, 1.58 (s, *dl*, *meso*, 6H), 2.21 (s, 2H), 3.75 (s, 6H), 6.90-7.25 (m, 8H); IR (KBr): 3300-3550 cm^{-1} .

2e ^1H NMR (CDCl_3): δ 2.89 (s, 2H), 4.59, 4.81 (s, *dl*, *meso*, 2H), 7.10-7.15 (m, 8H); IR (KBr): 3375-3410 cm^{-1} .

2f ^1H NMR (CDCl_3): δ 2.81 (s, 2H), 4.50, 4.71 (s, *dl*, *meso*, 2H), 7.15-7.20 (m, 8H); IR (KBr): 3270-3300 cm^{-1} .

2g ^1H NMR (CDCl_3): δ 2.30 (s, 6H), 2.49 (s, 2H), 4.69, 4.82 (s, *dl*, *meso*, 2H), 7.10-7.20 (s, 10H); IR (KBr): 3270-3380 cm^{-1} .

2h ^1H NMR (CDCl_3): δ 2.88 (s, 2H), 3.69, 3.81 (s, *dl*, *meso*, 6H), 4.62, 4.75 (s, *dl*, *meso*, 2H), 6.80-7.10 (m, 8H); IR (KBr): 3280-3400 cm^{-1} .

2j m.p. 128-131°C; ^1H NMR (CDCl_3): δ 2.89 (s, 2H), 5.50 (s, *meso*, 2H), 7.12-7.20 (m, 6H); IR (KBr): 3315-3380 cm^{-1} .

2k m.p. 183-185°C (lit.¹⁸ m.p. 185-186°C); ^1H NMR (CDCl_3): δ 2.71 (s, 2H), 7.45-7.98 (m, 8H); IR (KBr): 3450-3500 cm^{-1} .

2o ^1H NMR (CDCl_3): δ 2.10 (s, 2H), 5.00, 5.04 (s, *dl*, *meso*, 2H), 6.63 (m, 2H), 7.26 (m, 1H); IR (KBr): 3230-3280 cm^{-1} .

Conclusion

It was observed that the aluminium in NaOH/MeOH under microwave irradiation was favourable for the reduction of aromatic ketones and aldehydes to the corresponding pinacols. The percentage and the time of reaction by microwave irradiation (100-200 w) were compared with those

achieved by classical methods^{19a-e}. The easy experimental operations and work-up, mild reaction conditions, purity of coupled products, low cost and less toxic materials compared to many reagents can make this procedure a useful and attractive method.

Acknowledgement

This work is financially supported by Gorgan University of Agricultural Sciences and Natural Resources, Gorgan, Iran.

References

- (a) Wirth T, *Angew Chem Int Ed Engl*, **35**, **1996**, 61.
- (b) Gansauer A, *Chem Commun*, **5**, **1996**, 457.
- 2 Zhang W-C & Li C-J, *J Org Chem*, **64**, **1999**, 3230.
- 3 Wang L, Sun X-H & Zhang Y-M, *J Chem Research (5)*, **1998**, 336.
- 4 Rieke R D & Kim S H, *J Org Chem*, **63**, **1998**, 5232.
- 5 Khurana J M & Sehgal A, *J Chem Soc, Chem Commun*, **1994**, 571.
- 6 Khurana J M, Sehgal A, Gogia A, Manian A & Maikap G C, *J Chem Soc, PerkinTrans 1*, **1996**, 2213.
- 7 Bhar S & Panja C, *Green Chemistry*, **1999**, 253.
- 8 Li J T, Bian Y J, Zang H J & Li T S, *Synthetic Commun*, **32** (4), **2002**, 547.
- 9 Li C-J, Meng Y, Yi X-H, Ma J & Chan T-H, *J Org Chem*, **63**, **1998**, 7498.
- 10 Lim H J, Keum G, Kang S B, Chung B Y & Kim Y, *Tetrahedron Lett*, **39**, **1998**, 4367.
- 11 Li J T, Lin Z P, Qi N & Li T S, *Synth Commun*, **34**, **2004**, 4349.
- 12 Li Y-G, Jiang C-S, Tian Q-S, Ke Y-P & You T-P, *Chin J Chem*, **21**, **2003**, 1369.
- 13 Chatterjee A, Bennur T H & Joshi N N, *J Org Chem*, **68**, **2003**, 5668.
- 14 Li Y-G, Jiang C, Zhao J, Tian Q-S & You T-P, *Chin J Chem*, **22**, **2004**, 950.
- 15 Loupy A, *Microwave in Organic Synthesis*, (Wiley-VCH Verlag GmbH & Co. KgaA, Weinheim), **2002**.
- 16 Yamamoto Y, Haltori R, Miwa T, Nakagai Y, Kubota T, Yamamoto C, Okamoto Y & Itah K, *J Org Chem*, **88** (11), **2001**, 3865.
- 17 Ghiasi M & Asghari J, *Synthetic Commun*, **30** (21), **2000**, 3865.
- 18 Prasad K R K & Joshi N N, *J Org Chem*, **61**, **1996**, 3888.
- 19 (a) Svatos A & Boland W, *Synlett*, **1998**, 549.
 - (b) Zhang W-C & Li C-J, *J Chem Soc, Perkin Trans 1*, **1998**, 3131.
 - (c) Li C J, Meng Y, Yi X- H, Ma J & Chan T- H, *J Org Chem*, **63**, **1998**, 7498.
 - (d) Lim H J, Keum G, Kang S B, Chung B Y & Kim Y, *Tetrahedron Lett*, **39**, **1998**, 4367.
 - (e) Villiers C & Ephritikhine M, *Chem Eur J* **7**, **2001**, 3043.