

Ytterbium Metal-promoted Novel Cross-coupling Reaction between Diaryl Ketones and Electrophiles

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In the presence of Yb metal, diaryl ketones react nucleophilically with octan-2-one, acetonitrile, epoxides, and CO₂ to give the corresponding unsymmetrical pinacols, α -hydroxy ketones, 1,3-diols, and α -hydroxy carboxylic acids, respectively.

We recently reported the ytterbium metal-mediated synthesis of symmetrical and unsymmetrical pinacols from carbonyl compounds, including the nucleophilicity of an intermediate derived from the reaction of benzophenone with Yb metal.¹ In a continuing study of this reaction we have found that diaryl

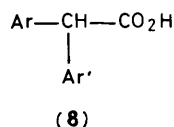
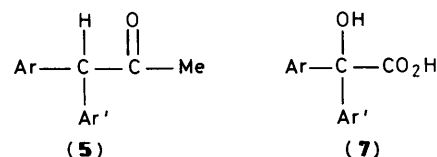
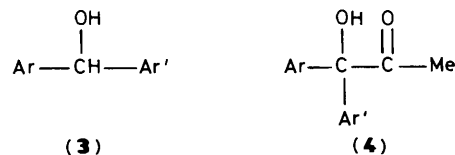
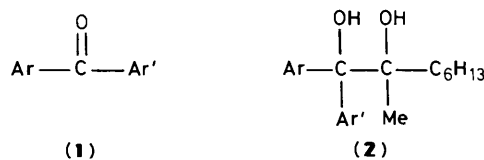
ketones, when treated with 1–2 equiv. of Yb metal, can be used as efficient nucleophiles towards not only ketones but also nitriles, epoxides, CO₂, *etc.*, and now report our results.

Typically,¹ to Yb powder (1 mmol) was added 1 drop of MeI by a micro-syringe under N₂, and the metal was then heated

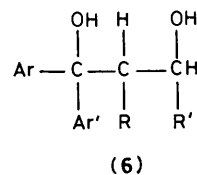
Table 1. Yb promoted reactions of diaryl ketones with electrophiles.^a

Run	Diaryl ketone	Electrophile	Product ^b	(Yield, % ^c)
1	(1a)	Octan-2-one ^d	(2a) (90)	(3a) (8)
2	(1b)	Octan-2-one ^d	(2b) (63)	(3b) (8)
3	(1c)	Octan-2-one ^d	(2c) (88)	(3c) (8)
4	(1a)	MeCN	(4a) (72)	(5a) (5) (3a) (6)
5	(1b) ^e	MeCN	(4b) (76)	(5b) (11) (3b) (6)
6	(1c)	MeCN	(4c) (53)	(5c) (—) (3c) (46)
7	(1a)	Cyclohexene oxide	(6a) (67)	(3a) (33)
8	(1b) ^e	Cyclohexene oxide	(6b) (77)	(3b) (19)
9	(1c)	Cyclohexene oxide	(6c) (58)	(3c) (24)
10	(1a)	Styrene oxide	(6d) (64)	(3a) (12)
11	(1b) ^e	Styrene oxide	(6e) (77)	(3b) (5)
12	(1c)	Styrene oxide	(6f) (61)	(3c) (16)
13	(1a)	CO ₂ ^f	(7a) (61)	(8a) (4) (3a) (12)
14	(1b) ^e	CO ₂ ^f	(7b) (68)	(8b) (8) (3b) (8)
15	(1c)	CO ₂ ^f	(7c) (61)	(8c) (15) (3c) (5)

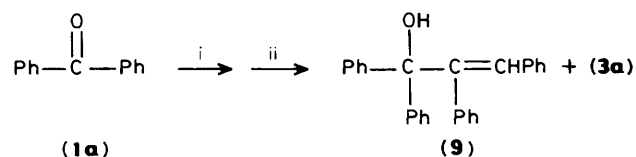
^a Reaction conditions: Yb : diaryl ketone : electrophile = 1 : 1 : 2 (mmol); THF (6 ml); HMPA (1 ml); room temp.; reaction times: octan-2-one and CO₂: 30 min, MeCN: 4 h, epoxide: 2 h. ^b All products gave satisfactory ¹H n.m.r., i.r., and mass spectra. ^c Isolated yields based on (1a–c). ^d 1 equiv. of octan-2-one used. ^e 2 equiv. of Yb used. ^f 1 atm.



- a; Ar = Ar' = Ph
b; Ar = Ph, Ar' = 2-naphthyl
c; Ar, Ar' = biphenyl-2,2'-diyl



- a; Ar = Ar' = Ph, R = R' = [CH₂]₄
b; Ar = Ph, Ar' = 2-naphthyl, R = R' = [CH₂]₄
c; Ar, Ar' = biphenyl-2,2'-diyl, R = R' = [CH₂]₄
d; Ar = Ar' = Ph, R = Ph, R' = H
e; Ar = Ph, Ar' = 2-naphthyl, R = Ph, R' = H
f; Ar, Ar' = biphenyl-2,2'-diyl, R = Ph, R' = H



Scheme 1. Reagents: i, (1a) (1 mmol), Yb (1 mmol), THF (4 ml), HMPA (1 ml), room temp., 20 min; ii, PhC≡CPh (1 mmol), THF (2 ml), room temp., 5 h.

slightly by a dryer to activate the Yb metal.† Addition of tetrahydrofuran (THF; 2 ml) gave a coloured slurry (pale yellow) to which hexamethylphosphoric triamide (HMPA; 1 ml) was introduced. Benzophenone (1 mmol) in THF (2 ml) was then added and the solution immediately turned dark blue. The mixture was then stirred at room temperature for 20 min and a purple solution was finally obtained. After addition of octan-2-one (1 mmol) the mixture was stirred at room

† If the Yb metal was not treated with MeI, benzopinacol was formed as the main product, which shows that the Yb metal (surface) must be activated for high reactivity. See also: Z. Hou, H. Taniguchi, and Y. Fujiwara, *Chem. Lett.*, 1987, 305; and ref. 1.

temperature for 30 min and the colour changed from purple to brown. Usual work-up followed by chromatography on silica gel gave the cross-coupling product (2a) [281 mg, 90%, *m/z* 294 (*M*⁺ – 18)]. Results are given in Table 1. In the case of epoxides, since they can react with Yb metal to give unidentified products, the diaryl ketone–ytterbium mixture was transferred by a cannula to another vessel to obviate the influence of unchanged Yb metal, and the epoxides were then added (Table 1, runs 7–12). It is clear from Table 1 that besides benzophenone (1a), phenyl 2-naphthyl ketone (1b) and fluoren-9-one (1c) also show high reactivity towards a variety of electrophiles in the presence of Yb metal. The reactions with octan-2-one give the corresponding unsymmetrical pinacols (2a–c) in high yields and no deoxygenation products were found.^{1,2} In the case of acetonitrile, the corresponding coupling products, the α-hydroxy ketones (4a–c), are formed in fair to high yields with some of the deoxygenated products (5a–c) (runs 4–6). The reaction with

epoxides gives the coupling products, 1,3-diols, in good yields (runs 7—12), and it is also interesting that in the case of styrene oxide (runs 10—12), C—C bond formation occurs on the more substituted carbon atom. Bubbling CO₂ through the reaction mixture of diaryl ketones (**1a—c**) and Yb metal gives the corresponding carboxylation products (**7a—c**) in good yields (runs 13—15).

The intermediate of the reaction of benzophenone with Yb metal also reacts with diphenylacetylene to give the corresponding product (**9**) in 22% yield, together with (**3a**) (78%) (Scheme 1).

To the best of our knowledge, this cross-coupling reaction is

the first example, of its kind,^{1—3} and it should have synthetic importance.

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