

# A fast and convenient coupling reaction of terminal alkynes

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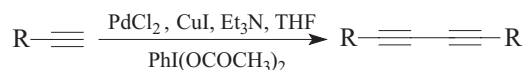
A fast and convenient coupling reaction of terminal alkynes was achieved using (diacetoxyiodo)benzene as an oxidant in the absence of palladium catalysts, providing a simple method for the synthesis of diynes in good yields in short time.

**Keywords:** coupling reaction, diyne, (diacetoxyiodo)benzene

As a powerful tool in molecular construction, acetylenic homocoupling has been extensively studied since Glaser's pioneering work in 1869.<sup>1–3</sup> Dienes may be synthesised in a number of ways, in which the Glaser coupling (oxidative coupling) of terminal alkynes in the presence of CuCl<sub>2</sub> and O<sub>2</sub> is without question the best-known reaction.<sup>4</sup> There are several Pd (0)–Cu (I) catalysed coupling reactions: coupling of terminal alkynes in the presence of chloroacetone,<sup>5</sup> ethyl bromoacetate,<sup>6</sup> ally bromide<sup>7</sup> and iodine,<sup>8</sup> coupling of terminal alkynyl halides with terminal alkynes.<sup>9</sup> Fairlamb also reported the preparation of diynes under standard Sonogashira cross-coupling conditions in the absence of an obvious oxidant.<sup>10</sup> Yan *et al.* recently investigated the coupling of terminal alkynes using (diacetoxyiodo)benzene as oxidant under palladium-catalysed conditions, they found that this reaction was conveniently carried out in the presence of catalytic amounts of PdCl<sub>2</sub> and CuI in THF, and diynes were prepared in good yields in a short period of time at room temperature (Scheme 1).<sup>11</sup> It is interesting because (diacetoxyiodo)benzene (DIB) is an important commercially available hypervalent iodine compound, with chemical properties and reactivity similar to those of Hg (II), Tl (III) and Pb (IV), but without the toxic and environmental problems of these heavy metal congeners.<sup>13–17</sup>

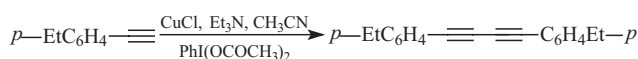
Herein we report a new method for the formation of diynes using DIB, which can be performed in the absence of a palladium-catalyst condition. In order to extend the application of DIB, we initially repeated the coupling<sup>9</sup> of terminal alkynes in the absence of a palladium-catalyst, and found that the reaction also can occur when CuI was used, but the yield was lower and the reaction time was longer than using a catalyst PdCl<sub>2</sub>. Then we checked other cuprous salts and found that the reaction was fast and with a good yield when CuCl was used in placed of CuI. Using (4-ethylphenyl)acetylene as the representative acetylene, we mixed it with DIB, CuCl and Et<sub>3</sub>N (2.0 equiv.) in CH<sub>3</sub>CN for coupling reaction. We found that the yields of the coupling mainly depended on the amounts of DIB and CuCl (Table 1). When the amounts of DIB and CuCl reached to 0.6 and 1.0 molar ratio of (4-ethylphenyl)acetylene respectively, the coupling was finished in 10 min at room temperature, providing the desired diyne in 88% yield. Under N<sub>2</sub>, the coupling reaction also gave the same result.

Under the optimum reaction conditions, the homocoupling of a series of terminal alkynes in the absence of palladium catalysts was investigated, the good results are summarised in Table 2. It is notable that the coupling of all terminal alkynes was fast and convenient, providing diynes in good to excellent yields. The coupling reaction of terminal aromatic alkynes which with electron-donating substituents in phenyl ring (entries 2–4) usually gave higher yields than that aromatic alkynes with electron-withdrawing substituents in the phenyl (entry 5); while when aliphatic alkynes were used, the yields were somewhat lower (entries 6 and 7) compared with



**Scheme 1**

**Table 1** The results of the coupling reaction of (4-ethylphenyl)acetylene



| Entry | DIB/equiv. | CuCl/equiv. | Time/min | Yield/% <sup>a</sup> |
|-------|------------|-------------|----------|----------------------|
| 1     | 1.0        | 0.1         | 30       | 5                    |
| 2     | 1.0        | 0.2         | 30       | 8                    |
| 3     | 1.0        | 0.5         | 30       | 10                   |
| 4     | 1.0        | 1.0         | 10       | 88                   |
| 5     | 0.5        | 1.0         | 10       | 82                   |
| 6     | 0.6        | 1.0         | 10       | 88                   |
| 7     | 0.6        | 1.0         | 60       | 10                   |
| 8     | 1.0        | 0           | 10 (h)   | 0                    |

<sup>a</sup>Isolated yield.

**Table 2** The results of the coupling of alkynes

$$\text{R}-\text{C}\equiv\text{CH} \xrightarrow[\text{PhI}(\text{OCOCH}_3)_2]{\text{CuCl}, \text{Et}_3\text{N}, \text{CH}_3\text{CN}} \text{R}-\text{C}\equiv\text{C}-\text{C}\equiv\text{C}-\text{R}$$

| Entry | Alkyne/R                                                                                      | Diyne     | Time/min | Yield/% <sup>a</sup> |
|-------|-----------------------------------------------------------------------------------------------|-----------|----------|----------------------|
| 1     | C <sub>6</sub> H <sub>5</sub><br><b>1a</b>                                                    | <b>2a</b> | 10       | 85                   |
| 2     | <i>p</i> -CH <sub>3</sub> C <sub>6</sub> H <sub>4</sub><br><b>1b</b>                          | <b>2b</b> | 10       | 88                   |
| 3     | <i>p</i> -C <sub>2</sub> H <sub>5</sub> C <sub>6</sub> H <sub>4</sub><br><b>1c</b>            | <b>2c</b> | 10       | 90                   |
| 4     | <i>p</i> - <i>n</i> -C <sub>3</sub> H <sub>7</sub> C <sub>6</sub> H <sub>4</sub><br><b>1d</b> | <b>2d</b> | 10       | 83                   |
| 5     | <i>o</i> -CF <sub>3</sub> C <sub>6</sub> H <sub>4</sub><br><b>1e</b>                          | <b>2e</b> | 20       | 78                   |
| 6     | <i>n</i> -C <sub>4</sub> H <sub>9</sub><br><b>1f</b>                                          | <b>2f</b> | 40       | 70                   |
| 7     | <i>n</i> -C <sub>8</sub> H <sub>17</sub><br><b>1g</b>                                         | <b>2g</b> | 40       | 71                   |

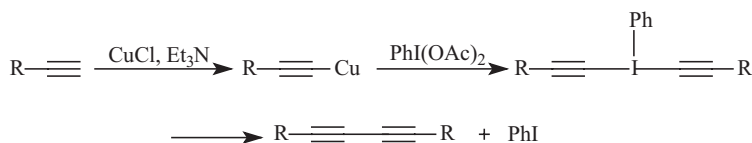
<sup>a</sup>Isolated yield.

aromatic alkynes. It needed prolonged reaction time due to the weaker acidity of the acetylenic proton.<sup>18</sup>

The proposed mechanism for the coupling of alkynes is shown in Scheme 2, which is different with the report.<sup>11</sup> It probably involved first a nucleophilic substitution of acid radical of iodane by the anion of alkyne, followed an intramolecular coupling reaction was accompanied to yield the corresponding diyne.

In summary, a rapid and convenient method for coupling of terminal alkynes is afforded in the absence of palladium catalysts conditions. It is simple, fast and affording good to excellent yield for synthesis of diynes. Furthermore, the useful range of DIB for homocoupling of alkynes could be extended.

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Scheme 2

## Experimental

M.p.s were determined on a digital m.p. apparatus and were not corrected. IR spectra were recorded on a FT-170 SX instrument,  $^1\text{H}$  NMR spectra were measured on a VARAIN-400 spectrometer, and Mass spectra were determined on MS-EI instrument (FINNIGAN Trace DSQ) mass spectrometer. All terminal alkynes are commercially available.

### A typical procedure for the coupling reaction of alkynes

To a mixture of phenylacetylene (1.0 mmol), DIB (0.6 mmol),  $\text{Et}_3\text{N}$  (2.0 mmol) and  $\text{CuCl}$  (1.0 mol),  $\text{CH}_3\text{CN}$  (5 ml) was added. The mixture was stirred at room temperature for 10 min and then separated by a silica gel plate using petroleum ether as developer, the product of diphenylbutadiyne (**2a**) was afforded in 85% yield.

**Diphenylbutadiyne (2a)**: M.p. 86–88°C (Lit.<sup>8</sup> 87–88°C);  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ),  $\delta$ : 7.32–7.36 (m, 6H), 7.50–7.55 (m, 4H); IR (KBr),  $\nu/\text{cm}^{-1}$ : 3049, 2978, 2145, 1261, 730; EIMS (70eV),  $m/z$  (%): 202 ( $\text{M}^+$ , 100).

**Bis(4-methylphenyl)butadiyne (2b)**: M.p. 137–139°C (Lit.<sup>18</sup> 138–140°C);  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ),  $\delta$ : 2.39 (s, 3H), 7.25 (d,  $J = 11.0$  Hz, 4H), 7.42 (d,  $J = 11.0$  Hz, 4H); IR (KBr),  $\nu/\text{cm}^{-1}$ : 3060, 2988, 2133, 1267, 751; EIMS (70eV),  $m/z$  (%): 230 ( $\text{M}^+$ , 100).

**Bis(4-ethylphenyl)butadiyne (2c)**: M.p. 97–99°C (Lit.<sup>19</sup> 98–99°C);  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ),  $\delta$ : 1.23 (t,  $J = 7.6$  Hz, 6H), 2.65 (q,  $J = 7.6$  Hz, 4H), 7.14 (d,  $J = 8.0$  Hz, 4H), 7.42 (d,  $J = 8.0$  Hz, 4H); IR (KBr),  $\nu/\text{cm}^{-1}$ : 3051, 2991, 2142, 1268, 743; EIMS (75eV),  $m/z$  (%): 258 ( $\text{M}^+$ , 100).

**Bis(4-propylphenyl)butadiyne (2d)**: M.p. 115–117°C (Lit.<sup>20</sup> 117–119°C);  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ),  $\delta$ : 0.90 (t,  $J = 7.2$  Hz, 6H), 1.76–1.52 (m, 4H), 2.51 (q,  $J = 7.6$  Hz, 4H), 7.01 (d,  $J = 8.0$  Hz, 4H), 7.35 (d,  $J = 8.0$  Hz, 4H); IR (KBr),  $\nu/\text{cm}^{-1}$ : 3058, 2995, 2141, 1269, 745; EIMS (75eV),  $m/z$  (%): 286 ( $\text{M}^+$ , 100).

**Bis(2-trifluoromethylphenyl)butadiyne (2e)**: M.p. 72–73°C (Lit.<sup>21</sup> 74–76°C);  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ),  $\delta$ : 7.47–4.50 (m, 2H), 7.2–7.56 (m, 2H), 7.68–7.72 (m, 4H); IR (KBr),  $\nu/\text{cm}^{-1}$ : 3060, 2988, 2133, 1267, 751; EIMS (75eV),  $m/z$  (%): 338 ( $\text{M}^+$ , 100).

**Dodeca-5,7-diyne (2f)**: Oil;  $^{22}\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ),  $\delta$ : 0.90 (t,  $J = 7.2$  Hz, 6H), 1.38–1.41 (m, 4H), 1.42–1.45 (m, 4H), 2.25 (t,  $J = 6.8$  Hz, 4H); IR (film),  $\nu/\text{cm}^{-1}$ : 2966, 2140, 1259, 736; EIMS (70eV),  $m/z$  (%): 162 ( $\text{M}^+$ , 100).

**Eicosa-9,11-diyne (2g)**: Oil;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ),  $\delta$ : 0.88 (t,  $J = 7.0$  Hz, 6H), 1.20–1.40 (m, 20H), 1.48–1.52 (m, 4H), 2.24 (t,  $J = 6.8$  Hz, 4H); IR (film),  $\nu/\text{cm}^{-1}$ : 2982, 2133, 1263, 741; EIMS (70eV),  $m/z$  (%): 274 ( $\text{M}^+$ , 100).

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