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Chinese Chemical Letters 22 (2011) 1195–1198
CHINESE CHEMICAL LETTERS
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# $FeBr_3$-catalyzed dibromination of alkenes and alkynes

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Received 21 January 2011
Available online 18 July 2011

**Abstract**

The dibromination of alkenes and alkynes with bromosuccinimide and sodium bromide catalyzed by $FeBr_3$ under mild conditions has been developed. The *trans*-dibromo compounds were exclusively obtained with excellent yields.
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*Keywords:* Dibromination; Alkenes and alkynes; Iron catalyst

Bromo derivatives are very important intermediates in organic synthesis, because the bromine group can easily be transformed into other functionalities [1]. In addition, they have found wide applications as pharmaceuticals, agrochemicals and other speciality chemicals [2].

The dibromination of alkenes and alkynes has received significant interest in recent years. The classical bromination involves the use of elemental bromine that is difficult to manipulate due to its toxicity and high vapor pressure [3]. Alternative brominating agents, perbromide ($Br_3^-$), such as tetrabutylammonium tribromide ($TBABr_3$), pyridinium tribromide ($PyHBr_3$) and pentylpyridinium tribromide, are commercially available and safer to handle [4]. Nevertheless, their preparation still involves direct contact with elemental bromine. A possible solution to avoid this reagent is oxidative bromination where metal bromide or hydrobromic acid is used in combination with a suitable oxidant, such as hydrogen peroxide, ceric ammonium nitrate, sodium metaperiodate, and so on [5]. However, these reactions suffer from the major drawbacks that are the occurrence of side reactions, low selectivity and the limitation of substrates. Ross and Shi reported two independent sources of $Br^+$ and $Br^-$ (NBS/$Bu_4NBr$, NBS/LiBr) were used in the system for the dibromination of carbon–carbon unsaturated bonds, respectively [6]. Although the mechanism was not yet clear, they believed that molecular $Br_2$ generated in situ was the real brominating agent. The development of more convenient and effective Lewis acid mediators for the addition of electrophiles to alkynes and alkenes is desirable. Wang and co-workers developed an effective and mild $FeX_3$-promoted strategy for the synthesis of alkenyl halides by the addition of benzylic alcohols to aromatic alkynes [7]. Iron complexes have recently emerged as promising catalysts in various transformations, as they are inexpensive, easily available and nontoxic [8]. Herein, we wish to report an iron-catalyzed dibromination of alkenes and alkynes with *N*-bromosuccinimide (NBS) and sodium bromide under mild conditions.

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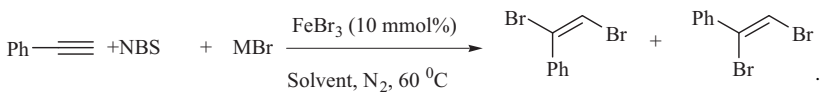
doi:10.1016/j.cclet.2011.05.005

Table 1
Optimization of $FeBr_3$-catalyzed dibromination of phenylacetylene **1a**.[a]




**1a** **2a** **3a**

| Entry | MBr | Solvent | Yield (%)[e] | **2a/3a**[f] |
|---|---|---|---|---|
| 1 | NaBr | PhMe | Trace | / |
| 2 | NaBr | DCE | 26 | 12:1 |
| 3 | NaBr | MeCN | 88 | 19:1 |
| 4 | NaBr | THF | 53 | 13:1 |
| 5 | NaBr | Dioxane | 37 | 10:1 |
| 6 | NaBr | DMF | 43 | 10:1 |
| 7 | KBr | MeCN | 65 | 17:1 |
| 8 | LiBr | MeCN | 70 | 18:1 |
| 9 | *n*-$Bu_4NBr$ | MeCN | 63 | 16:1 |
| 10[b] | NaBr | MeCN | 36 | 12:1 |
| 11[c] | – | MeCN | 25 | 15:1 |
| 12[d] | NaBr | MeCN | Trace | / |

[a] Unless otherwise noted, the reaction conditions are as follows: **1a** (0.3 mmol), NBS (1.5 equiv.), MBr (1.5 equiv.), $FeBr_3$ (0.1 equiv.), solvent (3 mL), 60 °C, under $N_2$.
[b] Without $FeBr_3$.
[c] Without NaBr.
[d] Without NBS.
[e] Isolated yield.
[f] Ratio determined by $^1H$ NMR.

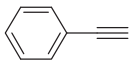
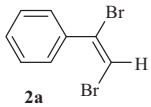
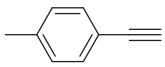
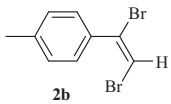
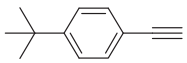
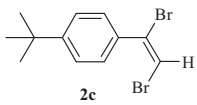
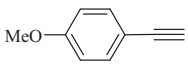
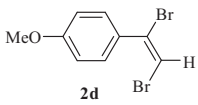
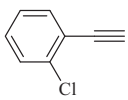
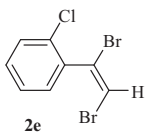
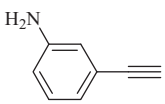
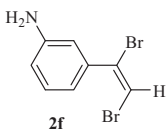
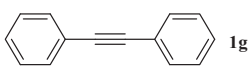
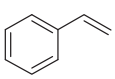
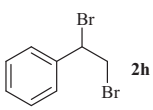
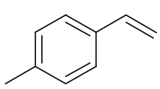
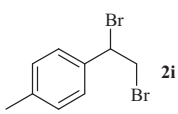
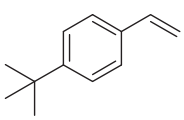
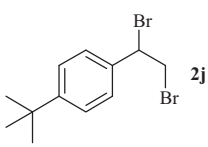
On the outset of this investigation, we used phenylacetylene **1a** as model substrate with bromosuccinimide and sodium bromide to screen suitable reaction conditions. The results are summarized in Table 1. When $FeBr_3$ was used as catalyst, the reaction was found to proceed more efficiently in a polar solvent than in nonpolar solvent (Table 1, entries 1–6). The *trans*-dibromo compound (**2a**) was exclusively obtained with good yield in MeCN (Table 1, entry 3), whereas the reaction gave in moderate yields and the ratios of **2a** to **3a** significantly decreased in DCE, THF, dioxane and DMF (Table 1, entries 2, 4–6). Other metal bromides, such as KBr, LiBr and *n*-$Bu_4NBr$ resulted in diminished yields and the ratios of **2a** to **3a** dropped slightly (Table 1, entries 7–9). Several control experiments demonstrated that dibromo compounds were obtained in 36% and 25% yields in the absence of $FeBr_3$ or NaBr, and the ratio of **2a** to **3a** decreased (Table 1, entries 10 and 11). Only a trace amount of desired product could be detected by GC–MS, when the reaction was carried out without bromosuccinimide (Table 1, entry 12).

Under the optimized conditions, the substrate scope of this reaction was investigated. The results are summarized in Table 2. Aromatic terminal alkynes with either electron-donating or electron-withdrawing functional groups, such as methyl, *tert*-butyl, methoxy and chloro groups, smoothly converted to the *trans*-dibromo compounds in good yields under the standard conditions (Table 2, entries 1–5). However, for amino-substituted aromatic alkynes, only small amount of the desired product was detected by GC–MS (Table 2, entry 6). For internal alkynes, 1,2-diphenylethyne did not afford the dibromo compound under the optimized conditions (Table 2, entry 7). In addition, the reaction was also suitable for the dibromination of alkenes and gave high yields (Table 2, entries 8–10).

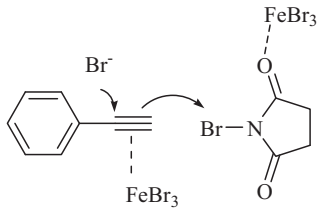
Although the detailed mechanism for this process awaits further investigation, a dual activation of both the carbon–carbon unsaturated bonds and NBS by Lewis acid ($FeBr_3$) might greatly enhance the reactivity (Scheme 1), which is similar to the gold-catalyzed halogenation of aromatics with *N*-halosuccinimides reported by Wang [9].

In summary, we have developed an efficient iron-catalyzed dibromination of alkenes and alkynes with NBS and NaBr under mild conditions. This methodology represents an efficient, straightforward, and safer alternative to the hazardous molecular $Br_2$ protocols. Further investigation of the detailed mechanism and the scope of substrates is currently underway in our lab.

Table 2
$FeBr_3$-catalyzed dibromination of alkenes and alkynes **1**.[a]

| Entry | Alkynes and alkenes (**1**) | Major product (**2**) | Yield (%)[b] | **2/3**[c] |
|---|---|---|---|---|
| 1 |  **1a** |  **2a** | 88 | 19:1 |
| 2 |  **1b** |  **2b** | 92 | >19:1 |
| 3 |  **1c** |  **2c** | 84 | >19:1 |
| 4 |  **1d** |  **2d** | 93 | >19:1 |
| 5 |  **1e** |  **2e** | 78 | >19:1 |
| 6 |  **1f** |  **2f** | Trace | / |
| 7 |  **1g** | / | / | / |
| 8 |  **1h** |  **2h** | 88 | / |
| 9 |  **1i** |  **2i** | 92 | / |
| 10 |  **1j** |  **2j** | 90 | / |

[a] Unless otherwise noted, the reaction conditions are as follows: **1** (0.5 mmol), NBS (1.5 equiv.), NaBr (1.5 equiv.), $FeBr_3$ (0.1 equiv.), solvent (3 mL), 60 °C, under $N_2$.
[b] Isolated yield.
[c] Ratio determined by $^1H$ NMR.




Scheme 1. Mechanistic rationale.

## Acknowledgment

We are grateful for the financial support by Lishui University Opening Foundation for advanced talents.

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