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## Reductive Olefination of Aldehydes via Chromium-Brook Rearrangement

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### Abstract

The combination of CrCl<sub>2</sub> and silyl chlorides converts aryl and conjugated aldehydes into olefinic adducts in good to excellent yields. When constrained by structural features, the intermediate *vic*-diol can be isolated. Available data are consistent with a novel chromium-Brook rearrangement.

The inter- and intramolecular reductive coupling of carbonyls to generate olefins is popularly known as the McMurry reaction.<sup>1</sup> It is most often conducted using low-valent titanium, although other metals have been utilized.<sup>2</sup> Mechanistically, the carbonyl forms a transient ketyl that dimerizes on or near the metal surface.<sup>3</sup> The resultant metallopinacolate undergoes stepwise cleavage of the C-O bonds resulting in formation of an alkene. Carbenoid intermediates may also be involved depending upon reaction conditions and/or structural features.<sup>4</sup> The geometry of the newly formed double bond is controlled principally by thermodynamic factors. Comparable reductions of carbonyls by chromium(II), on the other hand, typically lead to pinacols.<sup>5</sup> In contrast, we have observed that the combination of CrCl<sub>2</sub> and silyl chlorides generally converts aryl and conjugated aldehydes into olefinic adducts in good to excellent yields.<sup>6</sup> Consequently, we initiated a study to define the scope of the reaction and mechanistic *raison d'être* for the differences in outcomes.

The olefination was optimized using benzaldehyde (**1**) which furnished *trans*-stilbene (**2**) (Table 1).<sup>7</sup> The best yield and fastest reaction time were obtained with trichlorosilane and CrCl<sub>2</sub> in THF at reflux (entry 1). EtOAc was also satisfactory (entry 2), whereas THF/DMF (1:1) generated *threo*-dihydrobenzoin (58%) and benzyl alcohol (36%) only.<sup>8</sup> Repetition of the reaction described in entry 1, but utilizing catalytic CrCl<sub>2</sub> (10 mol %) regenerated by Mn<sup>9</sup> (4 equiv), also led to a mixture of *threo*-dihydrobenzoin and benzyl alcohol. Control experiments confirmed both trichlorosilane and CrCl<sub>2</sub> were necessary for olefin formation.

A variety of other chlorosilanes in THF likewise afforded olefinated adducts, *inter alia*, methyl trichlorosilane (entry 3), ethyl trichlorosilane (entry 4), phenyl trichlorosilane (entry 5), dimethyl dichlorosilane (Entries 6 and 7), trimethyl chlorosilane (entry 8), and 1,3-dichloro-1,1,3,3-tetraisopropyldisiloxane (entry 9). The outcomes of these reactions broadly followed the overall reactivity of the chlorosilanes toward chromium.

Aldehydes bearing an electron withdrawing substituent (**3**, entry 10),<sup>10,11</sup> electron donating group (**5**, entry 11),<sup>12</sup> and fused aromatic (**7**, entry 12)<sup>13</sup> gave generally similar results.

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Importantly, many functional groups were well tolerated, e.g., bromide (**9**, entry 13),<sup>14</sup> methylenedioxy (**11**, entry 14),<sup>15,16</sup> benzyl/methyl ethers (**13**, entry 15),<sup>17</sup> and, surprisingly, an unprotected phenol (**15**, entry 16).<sup>18</sup> The conjugated aldehyde cinnamaldehyde (**17**) was also well behaved and led to triene **18** (entry 17).<sup>19</sup> However, aliphatic aldehydes and unhindered ketones principally afforded aldol products under the same reaction conditions. The intramolecular condensation of dialdehyde **19** gave rise unexpectedly to *trans*-diol **20** (entry 18),<sup>20</sup> presumably because it could not close to form the cyclic chromium-diester necessary for elimination (*vide infra*).

While the details must be confirmed, we favor a mechanism whereby the silyl anion, formed via successive one electron transfers from Cr(II),<sup>21</sup> adds to the aldehyde to give  $\alpha$ -hydroxysilane **21** which undergoes chromium-Brook rearrangement to organochromium **22** (Figure 1). Numerous other metals and non-metals are known to undergo similar transformations.<sup>22</sup> Subsequent addition of **22** to a second equivalent of aldehyde furnishes pinacol **23**. The isolation of *trans*-diol **20** as the sole product in entry 18 suggests cyclic chromate ester **24**, which cannot form in this case, is the obligate intermediate for elimination to olefin **25**. As would be anticipated from this mechanistic hypothesis, heating the aldehyde and CrCl<sub>2</sub> or silyl chloride together for several hours prior to addition of the remaining ingredients does not yield olefinic adducts. But, good yields of adduct are obtained when the silyl chloride and CrCl<sub>2</sub> are heated together for several hours followed by addition of the aldehyde.

These data reveal a novel entry into an otherwise unattainable class of functionalized-chromium anions. Efforts to exploit them as reagents for organic synthesis will be detailed elsewhere.

## Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

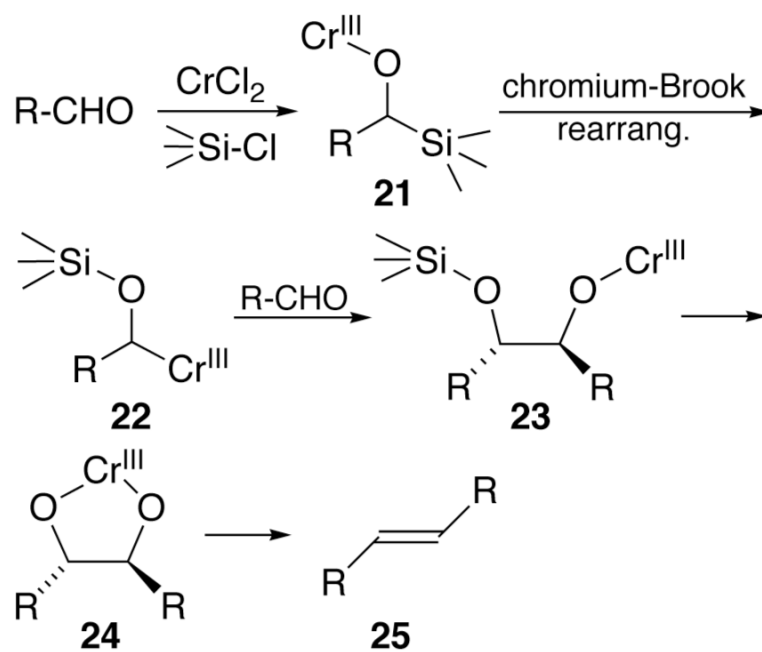
## Acknowledgment

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## References

- (1)(a). Reviews: Moser WH. Tetrahedron 2001;57:2065. (b) McMurry JE. Chem. Rev 1989;89:1513.
- (2). Fürstner, A. Transition Metals for Organic Synthesis. 2nd Edition. Beller, M.; Bolm, C., editors. 1. Wiley-VCH Verlag; Weinheim: 2004. p. 449
- (3). Hodgson, DM.; Boulton, LT. Preparation of Alkenes. Williams, JMJ., editor. Oxford University Press; Oxford: 1996. p. 81
- (4). Ephritikhine M. Chem. Commun 1998:2549.
- (5)(a). Svatos A, Boland W. Synlett 1998:549. (b) Fürstner A, Shi N. J. Am. Chem. Soc 1996;118:12349. and cited references.
- (6). Contrast with the reductive deoxygenations observed with chlorotrimethylsilane and zinc: Banerjee AK, Sulbaran De Carrasco MC, Frydrych-Houge CSV, Motherwell WB. J. Chem. Soc., Chem. Commun 1986:1803.
- (7). General procedure: The aldehyde (1 mmol) and silyl chloride (5 mmol) were added to a stirring suspension of anhydrous CrCl<sub>2</sub> (3-4 mmol) under an argon atmosphere in the solvent (15 mL) indicated in Table 1. After heating under reflux for the indicated time, the reaction mixture was cooled to room temperature, quenched with water (10 mL), extracted with ether (3 × 10 mL), and the combined organic extracts were washed with brine, dried, and evaporated. The residue was purified by SiO<sub>2</sub> column chromatography to furnish adducts in the yields stated (Table 1).


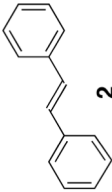
















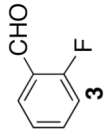
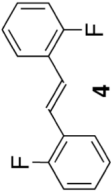
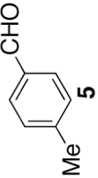
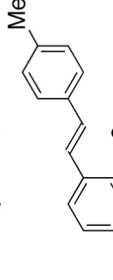
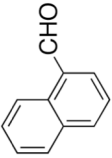
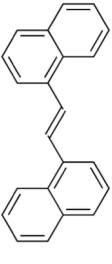
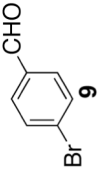
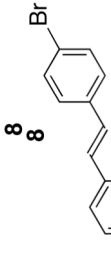
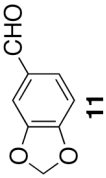
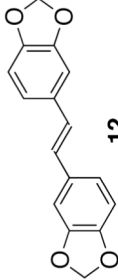
- (8). Satisfactory spectral data consistent with literature values or by comparison with commercial samples were obtained for all products using chromatographically homogeneous material.
- (9). Alois Fürstner A, Shi N. J. Am. Chem. Soc 1996;118:1239.
- (10). 2,2'-(*E*)-Difluorostilbene:Dunne EC, Coyne EJ, Crowley PB, Gilheany DG. Tetrahedron Lett 2002;43:2449.
- (11). 2,2'-(*Z*)-Difluorostilbene:Aitken RA, Hodgson PKG, Morrison JJ, Oyewale AO. J. Chem. Soc., Perkin Trans. 1 2002:402.
- (12). 4,4'-(*E*)-Dimethylstilbene:Grasa GA, Singh R, Stevens ED, Nolan SP. J. Organomet. Chem 2003;687:269.
- (13). 1,1'-(*E*)-1,2-Ethenediyl-bis-naphthalene:Sato T, Hanaki N, Yamada N, Asano T. Tetrahedron 2000;56:6223.
- (14). 2,2'-(*E*)-Dibromostilbene:Barman DC, Thakur AJ, Prajapati D, Sandhu JS. Synlett 2001:515.
- (15). 1,1'-Bis(3,4-methylenedioxy)-(E)-stilbene:Ali RS, Jagtap PG. Synthetic Commun 1991;21:841.
- (16). 1,1'-Bis(3,4-methylenedioxy)-(Z)-stilbene:Jiang Q, He L, He G, Zheng S.-l. Hecheng Huaxue 2004;12:267.
- (17). 1,1'-Bis-(3-methoxy-4-benzyloxy)-(E)-stilbene:Brezny R, Pufflerova A. Coll. Czech. Chem. Commun 1978;43:3263.
- (18). 4,4'-(*E*)-Dihydroxystilbene:Ali MA, Kondo K, Tsuda Y. Chem. Pharm. Bull 1992;40:1130.
- (19). 1,6-Diphenyl-(*E,E,E*)-1,3,5-hexatriene:Doyle MP, Yan M. J. Org. Chem 2002;67:602. [PubMed: 11798339]
- (20). *trans*-9,10-Dihydro-9,10-phenanthrenediol:Mori K, Ohtaka S, Uemura S. Bull. Chem. Soc. Jpn 2001;74:1497.
- (21)(a). Kochi JK, Davis DD. J. Am. Chem. Soc 1964;86:5264. (b) Kochi JK, Singleton DM. J. Am. Chem. Soc 1968;90:1582.
- (22). (a) Stanna-Brook:Paleo MR, Calaza MI, Grana P, Sardina F. Org. Lett 2004;6:1061. [PubMed: 15012100](b) Phospha-Brook:El Kaim L, Gaultier L, Grimaud L, Dos Santos A. Synlett 2005;15:2335.(c) Lithium-Brook:Nakazaki A, Nakai T, Tomooka K. Angew. Chem., Int. Ed 2006;45:2235.

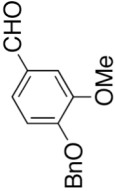
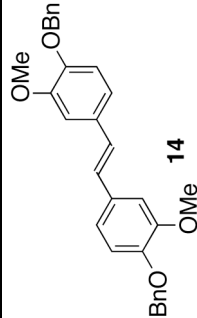
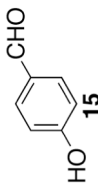
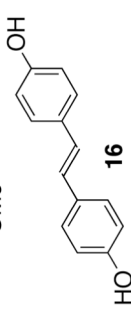
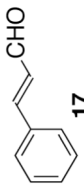
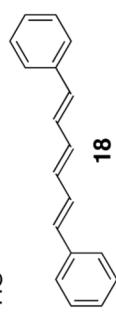
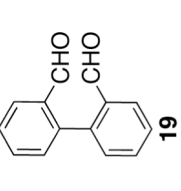
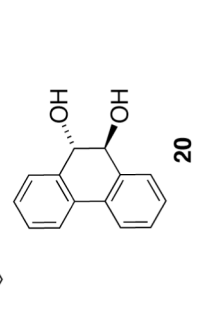


**Figure 1.**  
Proposed chromium-Brook rearrangement.

Table 1

Reductive Olefination of Aldehydes using  $\text{CrCl}_2/\text{Silyl Chlorides}$ 

entry	aldehyde	olefin	silane	solvent temp (°C)/ time (h)	yield(%)
1			$\text{HSiCl}_3$	THF, 67/8	95
2			$\text{HSiCl}_3$	EtOAc, 76/14	82
3			$\text{MeSiCl}_3$	THF, 65/24	72
4			$\text{EtSiCl}_3$	THF, 65/24	65
5			$\text{PhSiCl}_3$	THF, 65/24	68
6			$\text{Me}_2\text{SiCl}_2$	THF, 65/12	76
7			$\text{Me}_2\text{SiCl}_2$	EtOAc, 76/12	74
8			$\text{Me}_3\text{SiCl}$	THF, 65/12	62
9			$[(\text{tPr})_2\text{ClSiO}]_2$	THF, 65/12	45
10			$\text{HSiCl}_3$	THF, 65/12	74 <sup>d</sup>
11			$\text{HSiCl}_3$	THF, 65/8	87
12			$\text{HSiCl}_3$	THF, 65/8	90
13			$\text{HSiCl}_3$	THF, 65/12	65
14			$\text{HSiCl}_3$	THF, 65/8	84 <sup>b</sup>

entry	aldehyde	olefin	silane	solvent temp (°C)/ time (h)	yield(%)
15			HSiCl <sub>3</sub>	THF, 65/8	92
16			HSiCl <sub>3</sub>	THF, 65/8	82
17			HSiCl <sub>3</sub>	THF, 65/8	83
18			HSiCl <sub>3</sub>	THF, 65/12	95

<sup>a</sup> 8:92 *cis/trans* by GC analysis.

<sup>b</sup> 35:65 *cis/trans* by GC analysis.