

## Silica Chloride Mediated Alkylation of Electron-rich Aromatics by Benzyl or *tert*-Butyl Chloride

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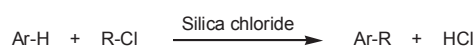
Formation of C-C bond is one of the most fundamental and useful reactions in organic chemistry. There are several methods for this purpose. Among the chemical reactions, Fridel-Crafts reaction<sup>1</sup> is widely used in organic synthesis for alkylation of aromatic rings. Many reagents and methodologies are developed for Fridel-Crafts alkylation reactions.<sup>2-7</sup>

The new environmental legislation pushes for the replacement of all liquid acids by solid acid catalysts which are environmentally more friendly catalysts and which lead to minimal pollution and waste.<sup>8</sup> Also, in the recent years, the use of reagents and catalysts on solid supports has received significant attention.<sup>9</sup> Silica gel is one of the extensively used surface material supports for different chemical transformations in organic chemistry.<sup>10</sup> One such modified silica is silica chloride which has been reported to be an efficient reagent for the synthesis of many organic compounds.<sup>11</sup> The efficiency of silica chloride, under operationally simple conditions, has prompted us to explore the possibility of this catalyst for the alkylation of aromatic rings.

Silica chloride could be prepared conveniently from inexpensive silica gel and thionyl chloride.<sup>12</sup> We have discovered that silica chloride acts as catalyst for alkylation of electron-rich aromatic compounds by benzyl and *tert*-butyl chloride (Scheme 1).

The procedure is simple and straightforward. The aromatic compound (0.01 mol) was added to a suspension of silica chloride (3 g) and alkyl halide (0.01 mol). The reaction mixture was stirred at 70 °C. TLC monitored the progress of reaction. After completion of the reaction, the mixture was diluted with ethyl acetate and filtered. The solution was washed with sodium carbonate (5% in water) and water. The organic layer separated and evaporated. The residue was applied to a silica gel column. Elution with CCl<sub>4</sub> gave pure product. We also tried a similar reaction in the presence of silica gel and HCl (gas) without using silica chloride. The reaction was not successful and the starting materials remained intact.

However, we found that this method was applicable for preparation of alkyl aromatic compounds from reaction of *tert*-butyl chloride and structurally and electronically diverse benzyl



R = benzyl, *tert*-butyl

**Scheme 1.** Reaction of aromatics with benzyl or *tert*-butyl chloride

chloride with aromatic rings substituted with electron-donating groups (Table 1, entries 2-11 and 13-15). The presence of electron-donating groups in aromatics is necessity for progress of

**Table 1.** Reaction of alkyl halides with aromatic compounds in the presence of silica chloride

Entry	Aromatics	Alkyl halide	Product	Time <sup>a</sup> (h)	Yield <sup>b</sup> (%)	Ratio	
						p	o
1			-- <sup>c</sup>	10	--	-	-
2				8	61	62	37
3				3	60	56	44
4				3	72	-	-
5				3	65	59	41
6				8	61	64	36
7				5	83	72	28
8				8	53	68	32
9				8	65	87	13
10				3	75	81	19
11				3	77	89	11
12			-- <sup>c</sup>	10	--	-	-
13				3	75	-	-
14				3	80	-	-
15				3	82	-	-

<sup>a</sup>The course of reaction was checked by TLC and the ratio of isomers was determined by GC. <sup>b</sup>Based on aromatic compound. <sup>c</sup>No reaction.

reaction, for example, benzene does not react with benzyl chloride (Table 1, entry 1).

Saturated primary and secondary alkyl halides do not react with aromatics in the presence of this reagent and remain mostly intact after the typical reaction times (Table 1, entries 12 and 15).

In conclusion we would like to reiterate that the method is a simple and efficient one, not requiring special equipment or harsh conditions. The respectable yields in these reactions also make it a viable method for the substitution of benzyl or *tert*-butyl group on aromatic rings.

### Experimental Section

$^1\text{H}$ -NMR spectra were recorded on a Jeol JNM-PMX 60SI NMR spectrometer using tetramethylsilane as the internal standard. IR spectra were taken on a Perkin-Elmer 267 spectrophotometer. Thin layer chromatography was performed on silica gel (Maceray-Nagel Co., plygram Sil G/uv). GC analyses were performed on Philips PU 4500.

All organic solutions were dried over  $\text{MgSO}_4$  or  $\text{Na}_2\text{SO}_4$  and solvents were removed under reduced pressure on a Buchi evaporator. All alkylation products are known compounds, they were identified by comparison of their spectral (IR, NMR) and physical data with those of authentic samples.

**Preparation of silica chloride.** Into a flask equipped with a reflux condenser and calcium chloride tube, silica gel (12 g) and thionyl chloride (100 mL) were charged. The reaction mixture was refluxed under stirring with a magnetic stirrer for 18 h, and the untreated thionyl chloride was removed by distillation. The silica chloride was dried in vacuum at  $90^\circ\text{C}$  and the resulting grayish powder was stored in a desiccator under vacuum. The chlorosilyl groups on silica surface (0.9 mmol of  $\text{Cl}/\text{g}$  silica) were determined by suspension or reagent (1 g) in  $\text{NaHCO}_3$  solution (0.005 M, 100 mL). The resulting chloride ion was titrated with silver nitrate solution (0.01 M, 90 mL) using potassium chromate solution as indicator.

**Reaction of toluene with benzyl chloride, typical procedure.** Toluene (0.92 g, 0.01 mol) was added to a suspension of silica chloride (3 g) and benzyl chloride (1.26 g, 0.01 mol). The reaction mixture was stirred at  $70^\circ\text{C}$ , under dried atmosphere, for 8 h. TLC monitored the progress of reaction. After completion of the reaction, the mixture was diluted with ethyl acetate (25 mL) and filtered. The solution was washed with sodium carbonate (5% in water) and water. The organic layer separated and evaporated. The residue was applied to a silica gel column. Elution with  $\text{CCl}_4$  gave mixture of isomers (1.24 g, 68%). The ratio of isomers was determined by GC (tubular column, 150 ft, coated with *m*-bis(*m*-phenoxyphenoxy)benzene modified with 20% Apiezon).<sup>13-14</sup> A hydrogen flame-ionization detector with helium carrier gas of 30 psi was used, columns being operated at  $125^\circ\text{C}$ , with detector temperature of  $185 - 190^\circ\text{C}$  and injector block temperature of  $310 - 320^\circ\text{C}$ . Retention times of 2-methyl-, and 4-methyldiphenylmethane were respectively 111.1 min and 118.9 min.

**4-Methyldiphenylmethane:**  $^1\text{H}$  NMR (60 MHz,  $\text{CDCl}_3$ )  $\delta$  7.0-7.2 (m, 9H, ArH), 3.8 (s, 2H,  $\text{CH}_2$ ), 2.3 (s, 3H,  $\text{CH}_3$ ).

**2-Methyldiphenylmethane:**  $^1\text{H}$  NMR (60 MHz,  $\text{CDCl}_3$ )  $\delta$  6.9-7.3 (m, 9H, ArH), 3.7 (s, 2H,  $\text{CH}_2$ ), 2.4 (s, 3H,  $\text{CH}_3$ ).

**4-Hydroxydiphenylmethane:**  $^1\text{H}$  NMR (60 MHz,  $\text{CDCl}_3$ )  $\delta$  3.9 (s, 2H,  $\text{CH}_2$ ), 4.9 (br. s, 1H, OH), 6.7-7.1 (dd, 4H, ArH), 7.2 (s, 5H, ArH). mp  $85 - 87^\circ$  (lit.<sup>15</sup>  $86^\circ$ )

**2-Hydroxydiphenylmethane:**  $^1\text{H}$  NMR (60 MHz,  $\text{CDCl}_3$ )  $\delta$  4.0 (br. s, 2H,  $\text{CH}_2$ ), 4.9 (s, 1H, OH), 6.6-7.2 (m, 9H, ArH). mp  $48.5 - 51^\circ$  (lit.<sup>15</sup>).

**2-Benzylthiophene:**  $^1\text{H}$  NMR (60 MHz,  $\text{CDCl}_3$ )  $\delta$  7.2 (s, 5H, ArH), 7.0-7.1 (m, 1H, ArH), 6.7-6.9 (m, 2H, ArH), 4.1 (s, 2H,  $\text{CH}_2$ ). Yellow oil.

**4-Methoxydiphenylmethane:**  $^1\text{H}$  NMR (60 MHz,  $\text{CDCl}_3$ )  $\delta$  6.8-7.8 (m, 9H, ArH), 4.0 (s, 3H,  $\text{CH}_3$ ), 3.8 (s, 2H,  $\text{CH}_2$ ). mp  $20 - 21^\circ$  (lit.<sup>16</sup>  $20^\circ$ )

**2-Methoxydiphenylmethane:**  $^1\text{H}$  NMR (60 MHz,  $\text{CDCl}_3$ )  $\delta$  6.6-7.8 (m, 9H, ArH), 4.0 (s, 3H,  $\text{CH}_3$ ), 3.9 (s, 2H,  $\text{CH}_2$ ). mp  $38 - 40^\circ$  (lit.<sup>16</sup>  $39^\circ$ ).

**4-Chloro-4'-methyldiphenylmethane:**  $^1\text{H}$  NMR (60 MHz,  $\text{CDCl}_3$ )  $\delta$  7.0-7.3 (m, 8H, ArH), 3.9 (s, 2H,  $\text{CH}_2$ ), 2.3 (s, 3H,  $\text{CH}_3$ ). Colorless oil (lit.<sup>17</sup>)

**4-Chloro-2'-methyldiphenylmethane:**  $^1\text{H}$  NMR (60 MHz,  $\text{CDCl}_3$ )  $\delta$  7.0-7.5 (m, 8H, ArH), 3.8 (s, 2H,  $\text{CH}_2$ ), 2.4 (s, 3H,  $\text{CH}_3$ ). Colorless oil (lit.<sup>17</sup>).

**4-Methoxy-4'-methyldiphenylmethane:**  $^1\text{H}$  NMR (60 MHz,  $\text{CDCl}_3$ )  $\delta$  6.9-7.4 (m, 8H, ArH), 4.0 (s, 3H,  $\text{CH}_3$ ), 3.8 (s, 2H,  $\text{CH}_2$ ), 2.3 (s, 3H,  $\text{CH}_3$ ). Colorless oil (lit.<sup>18</sup>).

**4-Methoxy-2'-methyldiphenylmethane:**  $^1\text{H}$  NMR (60 MHz,  $\text{CDCl}_3$ )  $\delta$  6.8-7.7 (m, 8H, ArH), 4.0 (s, 3H,  $\text{CH}_3$ ), 3.9 (s, 2H,  $\text{CH}_2$ ), 2.4 (s, 2H,  $\text{CH}_2$ ). Colorless oil (lit.<sup>18</sup>).

**4-Nitro-4'-methyldiphenylmethane:**  $^1\text{H}$  NMR (60 MHz,  $\text{CDCl}_3$ )  $\delta$  7.1-7.5 (m, 8H, ArH), 4.0 (s, 2H,  $\text{CH}_2$ ), 2.5 (s, 3H,  $\text{CH}_3$ ). bp<sub>12</sub>  $195-6-8$  (lit.<sup>19</sup> bp<sub>12</sub>  $195-8^\circ$ ).

**4-Nitro-2'-methyldiphenylmethane:**  $^1\text{H}$  NMR (60 MHz,  $\text{CDCl}_3$ )  $\delta$  7.0-7.6 (m, 8H, ArH), 4.1 (s, 2H,  $\text{CH}_2$ ), 2.5 (s, 3H,  $\text{CH}_3$ ). Oil (lit.<sup>19</sup>).

**4-tert-Butyltoluene:**  $^1\text{H}$  NMR (60 MHz,  $\text{CDCl}_3$ )  $\delta$  7.0-7.3 (m, 4H, ArH), 2.3 (s, 3H,  $\text{CH}_3$ ), 1.3 (s, 9H, 3 $\text{CH}_3$ ). bp  $189 - 194^\circ$  (lit.<sup>20</sup>  $189 - 92^\circ$ ).

**2-tert-Butyltoluene:**  $^1\text{H}$  NMR (60 MHz,  $\text{CDCl}_3$ )  $\delta$  6.9-7.5 (m, 4H, ArH), 2.4 (s, 3H,  $\text{CH}_3$ ), 1.3 (s, 9H, 3 $\text{CH}_3$ ). bp<sub>743</sub>  $169 - 72^\circ$  (lit.<sup>20</sup>  $170 - 71^\circ$ ).

**4-tert-Butylphenol:**  $^1\text{H}$  NMR (60 MHz,  $\text{CDCl}_3$ )  $\delta$  6.4-7.3 (dd, 4H, ArH), 5.0 (br. s, 1H, OH), 1.3 (s, 9H, 3 $\text{CH}_3$ ). mp  $98 - 9^\circ\text{C}$  (lit.<sup>21</sup>  $99^\circ$ ).

**2-tert-Butylphenol:**  $^1\text{H}$  NMR (60 MHz,  $\text{CDCl}_3$ )  $\delta$  6.4-7.5 (m, 4H, ArH), 4.8 (br. s, 1H, OH), 1.4 (s, 9H, 3 $\text{CH}_3$ ). bp  $222 - 4^\circ$  (lit.<sup>22</sup>  $224^\circ$ )

**4-tert-Butylanisole:**  $^1\text{H}$  NMR (60 MHz,  $\text{CDCl}_3$ )  $\delta$  6.9-7.3 (dd, 4H, ArH), 3.9 (s, 3H,  $\text{CH}_3$ ), 1.3 (s, 9H, 3 $\text{CH}_3$ ). bp  $214 - 6^\circ$  (lit.<sup>21</sup>  $215-6$ ).

**2-tert-Butylanisole:**  $^1\text{H}$  NMR (60 MHz,  $\text{CDCl}_3$ )  $\delta$  6.8-7.5 (m, 4H, ArH), 3.9 (s, 3H,  $\text{CH}_3$ ), 1.4 (s, 9H, 3 $\text{CH}_3$ ). bp<sub>22</sub>  $102 - 106^\circ$  (lit.<sup>22</sup> bp<sub>22</sub>  $102.5 - 104.5^\circ$ ).

**2-tert-Butylthiophene:**  $^1\text{H}$  NMR (60 MHz,  $\text{CDCl}_3$ )  $\delta$  6.7-6.9 (m, 2H, ArH), 7.1-7.2 (m, 1H, ArH), 1.1 (s, 9H, 3 $\text{CH}_3$ ). bp<sub>0.2</sub>  $74 - 7^\circ$  (lit.<sup>23</sup> bp<sub>0.15</sub>  $75^\circ$ ).

**2-tert-Butylfuran:**  $^1\text{H}$  NMR (60 MHz,  $\text{CDCl}_3$ )  $\delta$  7.3 (s, 1H, ArH), 6.2-6.3 (m, 1H, ArH), 5.9-6.1 (m, 1H, ArH). bp  $114 - 6^\circ$  (lit.<sup>23</sup>  $115.5^\circ$ ).

**2-(2-Chloro-1-phenylethyl)thiophene:**  $^1\text{H}$  NMR (60 MHz,

$\text{CDCl}_3$ )  $\delta$  7.1-7.3 (br.s, 5H, Arh), 7.1-7.2 (m, 1H, ArH), 6.6-6.6.9 (m, 2H, ArH). Colorless liquid.

### References

1. Olah, G. A. *Friedel-Crafts Chemistry*; Wiley and Son: New York, 1973.
2. Olah, G. A.; Kobayashi, S.; Tashiro, M. *J. Am. Chem. Soc.* **1972**, *94*, 7448.
3. Khalaf, A. A.; Roberts, R. M. *J. Org. Chem.* **1970**, *35*, 3717.
4. Khalaf, A. A.; Raberts, R. M. *J. Org. Chem.* **1972**, *37*, 4227.
5. Wang, X.; Wang, Y.; Du, D. M.; Xu, J. *Journal of Molecular Catalysis A: Chemical* **2006**, *255*, 31.
6. Schaarschmidt, A.; Hermann, L.; Szemzo, B. *Ber.* **1925**, *58B*, 1914.
7. Roberts, R. M.; El-Khawaga, A. M.; Roengsumran, S. *J. Org. Chem.* **1984**, *49*, 3180.
8. Clark, J. H.; Cullen, S. R.; Barlow, S. J.; Bastock, T. W. *J. Chem. Soc. Perkin Trans 2* **1994**, 1117.
9. (a) McKillop, P. A.; Young, D. W. *Synthesis* **1979**, 401. (b) Cornelis, A.; Laszlo, P. *Synthesis* **1985**, 909. (c) Zhu, J. *Eur. J. Org. Chem.* **2003**, *2003*, 1133.
10. (a) Tal, D. M.; Keinan, E.; Mazur, Y. *Tetrahedron* **1981**, *37*, 4327. (b) Onofrio, F. D.; Scettri, A. *Synthesis* **1985**, 1159.
11. (a) Kamitori, Y.; Hojo, M.; Masuda, R.; Kimura, T.; Yoshida, T. *J. Org. Chem.* **1986**, *51*, 1427. (b) Ravindranath, N.; Ramesh, C.; Das, B. *Synlett* **2001**, 1777. (c) Sathe, M.; Kaushik, M. P. *Catalysis Communications* **2006**, 644. (d) Sathe, M.; Gupta, A. K.; Kaushik, M. P. *Tetrahedron Lett.* **2006**, *47*, 3107. (e) Mohanazadeh, F.; Momeni, A. R.; Ranjbar, Y. *Tetrahedron Lett.* **1994**, *35*, 6127.
12. Saunders, D. H.; Barford, R. A.; Magidman, P.; Olszewski, L. T.; Rothbart, H. L. *Anal. Chem.* **1974**, *46*, 834.
13. Walker, J. Q. *Anal. Chem.* **1963**, *35*, 2028.
14. Olah, G. A.; Olah, J. A. *J. Org. Chem.* **1967**, *32*, 1612.
15. Tarbell, D. S.; Petropoulos, J. C. *J. Am. Chem. Soc.* **1952**, *74*, 244.
16. Papa, D.; Schwenk, E.; Whitman, B. *J. Org. Chem.* **1942**, *7*, 587.
17. Darbeau, R. W.; White, E. H.; Song, F.; Darbeau, N. R.; Chou, J. *J. Org. Chem.* **1999**, *64*, 5966.
18. Lipshutz, B. H.; Tomioka, T.; Blomgren, P. A.; Sclafani, J. A. *Inorganica Chimica Acta* **1999**, *269*, 164.
19. Kliegl, A. *Ber.* **1908**, *41*, 1847.
20. Schlatter, M. J.; Clark, R. D. *J. Am. Chem. Soc.* **1953**, *75*, 361.
21. Bowman, R. S.; Stevens, D. R.; Baldwin, W. E. *J. Am. Chem. Soc.* **1957**, *79*, 87.
22. Goldsmith, E. A.; Schlatter, M. J.; Toland, W. G. *J. Org. Chem.* **1958**, *23*, 1871.
23. Cadogan, J. I. G.; Hey, D. H.; Sanderson, W. A. *J. Chem. Soc.* **1960**, 3203.
24. Shuikin, N. I.; Lebedev, B. L.; Nikolskil, V. G.; Korytina, O. A.; Kessenikh, A. V.; Prokofev, E. P. *Russ. Chem. Bull.* **1967**, *16*, 1561.