Application of Directed Orthometalation Toward the Synthesis of Aryl Siloxanes

W. Michael Seganish and Philip DeShong

*Department of Chemistry and Biochemistry, University of Maryland
College Park, Maryland 20742*

SUPPORTING INFORMATION

Table of Contents	Page
General Experimental	S2
Synthesis of starting materials for metalation experiments	S3-S4
References	S4
¹ H NMR spectrum for 2-(triethoxysilyl) anisole	S5
¹ H NMR spectrum for 2-(triethoxysilyl) methoxymethoxybenzene	S6
¹ H NMR spectrum for 2-(triethoxysilyl) O- <i>N,N</i> -diethylcarbamoyl benzene	S7
¹ H NMR spectrum for 2-(triethoxysilyl) pivalanilide	S8
¹ H NMR spectrum for 2-(triethoxysilyl) <i>N-tert</i> -butoxycarbonyl aniline	S9
¹ H NMR spectrum for 2-diethylcarbamoyl benzophenone	S10
¹ H NMR spectrum for <i>N,N</i> -diethyl- <i>o</i> -toluamide	S11
¹ H NMR spectrum for 2-methoxybiphenyl	S12
¹ H NMR spectrum for 4-methoxy-2-(<i>N,N</i> -diethyl-O-carbamoyl)biphenyl	S13
¹ H NMR spectrum for 2-methoxymethoxybiphenyl	S14
¹ H NMR spectrum for 2-pivalanilinebiphenyl	S15
¹ H NMR spectrum for 2-(<i>N-tert</i> -butoxycarbonyl)biphenyl	S16
¹ H NMR spectrum for 4-methoxy-2'-methoxybiphenyl	S17
¹ H NMR spectrum for methoxymethoxybenzene	S18
¹ H NMR spectrum for O-phenyldiethylcarbamate	S19
¹ H NMR spectrum for pivalaniline	S20
¹ H NMR spectrum for <i>N,N</i> -diethylbenzamide	S21
¹ H NMR spectrum for <i>tert</i> -butyl- <i>N</i> -phenyl carbamate	S22

General Experimental

Thin-layer chromatography (TLC) was performed on 0.25 mm Merck silica gel coated plates treated with a UV-active binder with compounds being identified by one or more of the following methods: UV (254 nm), iodine, or vanillin/sulfuric acid charring. Flash chromatography was performed using thick walled columns and medium pressure silica gel (Whatman 200-425 mesh), with column length and diameter being determined by the method of Still.¹

Melting points were taken in Kimax soft glass capillary tubes using a Thomas-Hoover Uni-Melt capillary melting point apparatus (Model 6406K) equipped with a calibrated thermometer.

IR band positions are reported in reciprocal centimeters (cm^{-1}) and relative intensities are listed as br (broad), s (strong), m (medium), or w (weak). Nuclear magnetic resonance (^1H , ^{13}C NMR) spectra were recorded on a 400 MHz spectrometer. Chemical shifts are reported in parts per million (δ) relative to tetramethylsilane (TMS). Coupling constants (J values) are reported in hertz (Hz), and spin multiplicities are indicated by the following symbols: s (singlet), d (doublet), t (triplet), q (quartet), and m (multiplet).

Low resolution mass spectrometry (LRMS) and high resolution mass spectrometry (HRMS) data are reported in the form of m/z (intensity relative to base peak = 100). The matrix used for fast atom bombardment (FAB) was ethylene glycol.

Tetrahydrofuran and diethyl ether were distilled from sodium/benzophenone ketyl. Methylene chloride, and tetraethylorthosilicate, were distilled from calcium hydride. Dimethylformamide was distilled under reduced pressure from calcium sulfate. Ethanol was fractionally distilled from calcium chloride.

Palladium (II) acetate ($\text{Pd}(\text{OAc})_2$) and tetrabutyl ammonium fluoride (1M solution in THF) were purchased from Acros and used as received. Triphenylphosphine was purchased from Aldrich and recrystallized from hexanes prior to use. All glassware used in these reactions was either oven dried at 120 °C for 12 hours or flame dried prior to use. All reactions were conducted under an atmosphere of argon.

All compounds were determined to be >95% pure by ^1H NMR or GC analysis, unless otherwise noted. Previously reported compounds were characterized *via* ^1H and ^{13}C NMR and IR and compared to literature values. All new compounds were fully characterized using ^1H NMR, ^{13}C NMR, IR, low resolution and high resolution mass spectrometry.

Methoxymethoxybenzene (Table 1, entry 2)

Phenol (1.88 g, 20.0 mmol) was dissolved in 15 mL of DMF. The solution was transferred *via* cannula to a suspension of NaH (0.768 g, 20.0 mmol) in 35 mL of DMF at 0 °C with significant evolution of gas. The reaction was allowed to warm to room temperature and was stirred for 15 min, then cooled to 0 °C. Chloromethylmethyl ether (3.04 mL, 40.0 mmol) was added and the reaction stirred for 5 min at 0 °C, then 15 min at room temperature. The cloudy white solution was diluted with 50 mL of ether and poured into 50 mL of water. The organic layer was washed with 1M KOH (50 mL), water (50 mL), dried (MgSO₄), and concentrated *in vacuo* to yield a pale yellow oil which was purified *via* column chromatography (19:1 hexanes/EtOAc, TLC R_f = 0.32) to give the title compound as a colorless oil (97%). The ¹H and ¹³C NMR and IR match that reported by LeBel.²

O-Phenyl diethylcarbamate (Table 1, entry 3)

Diethyl carbamoyl chloride (12.6 mL, 100 mmol) is added to a mixture of K₂CO₃ (13.8 g, 100 mmol) and phenol (6.31 g, 67.0 mmol) in 135 mL of MeCN. The reaction was refluxed for 3.5 h followed by the addition of 100 mL of water. The aqueous layer was extracted with ether (100 mL x3). The combined organic layers were washed with 100 mL of a 1M KOH solution followed by 100 mL of water. The ethereal solution was then dried (MgSO₄) and concentrated *in vacuo* to produce a yellow oil. Kugelrohr distillation (95 °C, 0.3 mm Hg) yielded a colorless oil (92%). ¹³C NMR (CDCl₃) δ 13.4, 14.2, 41.9, 42.2, 121.7, 125.0, 129.2, 151.6, 154.2. The ¹H NMR and IR match that reported by Snieckus.³

Pivalanilide (Table 1, entry 4)

Pivaloyl chloride (26.3 mL, 214 mmol) was added slowly to a vigorously stirred biphasic solution of Na₂CO₃ (22.7 g, 214 mmol) in 100 mL H₂O and aniline (9.78 mL, 107 mmol) in 100 mL of CH₂Cl₂. The reaction was refluxed for 1 h and diluted with 100 mL of CH₂Cl₂. The organic layer was extracted once with 100 mL of 1M NaOH, and twice with 100 mL of water, dried (MgSO₄) and concentrated to yield a slightly yellow crystalline solid. The solid was recrystallized from hexanes/EtOAc to produce white needles (96%) mp 133.1-133.5 °C (lit. 133.8-135.0 °C)⁴. IR (CCl₄) 3458 (s), 3064 (w), 3026 (w), 2964 (m), 2902 (w), 2871 (w), 1697 (s), 1597 (s), 1521 (s), 1435 (s), 1435 (s), 1314 (s), 1241 (m), 1148 (s). The ¹H and ¹³C NMR match that reported by Lappert.⁴

***tert*-Butyl *N*-phenylcarbamate (Table 1, entry 5)**

Di-*tert*-butyl dicarbonate (5.14 g, 23.5 mmol) was added in one portion to a stirred solution of aniline (1.96 mL, 21.4 mmol) in 25 mL of THF. The reaction was heated to reflux for 3 h. The solvent was removed *in vacuo* and the residue dissolved in 50 mL of EtOAc. The organic layer was washed twice with 1M HCl (50 mL), once with water (50 mL), dried (MgSO₄) and concentrated to yield a slightly yellow solid. Recrystallization (CH₂Cl₂) yielded white flakes (97%) mp 137.1-137.4 °C (lit. 136-137 °C)⁵. IR (CCl₄) 3451 (m), 3061 (w), 3029 (w), 3012 (w), 2978 (m), 2926 (w), 1735 (s), 1604 (m), 1521 (s), 1435 (s), 1366 (m), 1307 (m), 1162 (s). The ¹H and ¹³C NMR match that reported by Smith.⁵

***N,N*-Diethylbenzamide (Table 1, entry 6)**

To a stirred solution of benzoyl chloride (2.48 mL, 21.3 mmol) in 25 mL of THF at 0 °C is added 6.62 mL (64.0 mmol) of diethylamine. The reaction is heated at reflux for two hours, followed by evaporation of the solvent. The residue is dissolved in 50 mL of EtOAc and washed three times with 1M HCl (50 mL), twice with saturated NaHCO₃ (50 mL), and once with water (50 mL). The organic layer was then dried (MgSO₄) and concentrated to a yellow oil. Kugelrohr distillation (90 °C, 0.2 mm Hg) yielded a colorless oil (96%). The ¹H and ¹³C NMR and IR match that reported by Burke.⁶

REFERENCES

- (1) Still, W. C.; Kahn, M.; Mitra, A. *J. Org. Chem.* 1978, *43*, 2923-2925.
- (2) Agharahimi, M. R.; LeBel, N. A. *J. Org. Chem.* 1995, *60*, 1856-1863.
- (3) Sibi, M. P.; Chattopadhyay, S.; Dankwardt, J. W.; Snieckus, V. *J. Am. Chem. Soc.* 1985, *107*, 6312-6315.
- (4) Bezombes, J. P.; Hitchcock, P. B.; Lappert, M. F.; Merle, P. G. *J. Chem. Soc., Dalton Trans.* 2001, 816-821.
- (5) Moraczewski, A. L.; Banaszynski, L. A.; From, A. M.; White, C. E.; Smith, B. D. *J. Org. Chem.* 1998, *63*, 7258-7262.
- (6) Hans, J. J.; Driver, R. W.; Burke, S. D. *J. Org. Chem.* 2000, *65*, 2114-2121.

ppm Integral

8

0.9094

0.9279

7

0.9294

0.9985

6

5

4

6.0204

3.0586

3

2

1

8.9546

0