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The reactions of phenyldimethylsilyllithium with nitriles [1]

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Abstract

Phenyldimethylsilyllithium reacts with nitriles by several substantially different pathways depending upon the structure of the nitrile. The products include the acylsilane **2** from pivalonitrile (**1**), cumylsilane **5** from 2-phenylisobutyronitrile (**4**), the α-anion from phenylacetonitrile (**9**), and a mixture of benzil (**15**) and 2,4,5-triphenylimidazole (**17**) from benzonitrile (**13**).

Keywords: Silicon; Lithium; Nitriles; Brook rearrangement; Acylsilane

1. Introduction

Carboxylic acid derivatives react with several silylmetal reagents to give acylsilanes. These include acid chlorides with silyl-copper or cuprate reagents [1], acid chlorides and acylthiopyridines with silyl-alu minates [2], acid chlorides with some rather special silyllithium reagents [3], acid chlorides with disilanes in the presence of palladium catalysts [4], trifluoroacetic anhydride with triphenylsilyllithium [5], and esters and amides with silyllithium reagents [6]. Some related reactions include that of carbon monoxide with a silylzirconium reagent [7], and the reductive silylation of acylimidazoles, imino chlorides, and esters with magnesium and trimethylsilyl chloride [8].

Missing from this l ist is the possibility of using nitriles, where hydrolysis of the intermediate adduct might reasonably be expected to give acylsilanes. The nearest set of reactions bearing on this omission are the reductive couplings of trimethylsilyl chloride with various nitriles in the presence of magnesium or lithium, studied by the Bordeaux group [9]. These reactions give α-silylated amines and, in the case of aromatic compounds, reductive silylation of the aromatic ring. These products are unlikely to be pr oduced from a silyllithium reagent, and indeed we do not find them among the products from the reactions which actually take place between phenyldimethylsilyllithium and several different nitriles. In place of the straightforward reaction that we expected, we find a bewildering variety of things that can go wrong, and almost none of the nitriles is of any use in the synthesis of acylsilanes.

2. Results and discussion

The privilege of giving an acylsilane is accorded only to the reaction with pivalonitrile (**1**), which does give the acylsilane **2**, but in indifferent yield after many tries under a variety of conditions (Scheme 1). The reaction is slow, and after 4 h at 0 °C there was still enough starting material left for us typically to be able to isolate pivalamide (**3**) after the hydrolytic work-up. This is in contrast to the reaction with amides, which takes place within minutes at −78 °C [6]. The low level of reactivity of nitriles did not augur well.

Attempting to make the isolation of an acylsilane easier, we used the phenyl-containing tertiary nitriles **4** and **6**, and obtained quite different and surprising products, the silanes **5** and **7** respectively, products of what looks like nucleophilic displacement of the nitrile group by the silyl nucleophile (Scheme 2). The latter was obtained only in low yield because of the ease with which the silyl group was displaced from the benzylic position during work-up, as shown by the isolation also of diphenylethane (**8**). We have no evidence for the mechanism of this reaction, but a quite plausible mecha-

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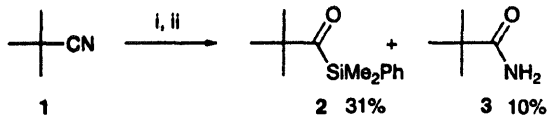


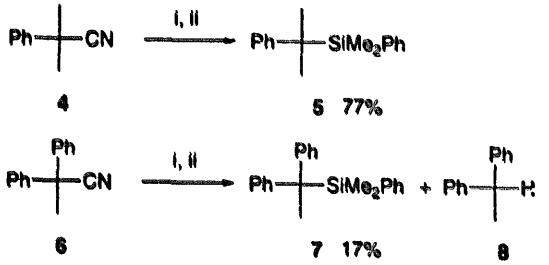
Scheme 1. Reagents: (i) $PhMe_2SiLi$, THF, 0 °C, 2 h; (ii) HCl, H_2O, r.t., 3 h.

nism would be initiated by the expected attack on the nitrile group, followed by displacement of the cumyl anion, and subsequent silylation by the silyl cyanide. An alternative mechanism might involve initial electron-transfer, but it is least likely to be the S_N2 displacement it looks like.

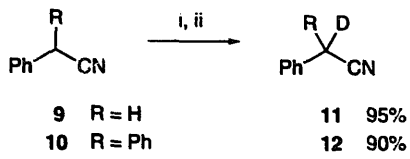
Acetonitrile, isobutyronitrile, and nonanonitrile gave no identifiable products, and we surmised that the silyllithium reagent had simply acted as a base and removed the α-proton. This is not common with this reagent which usually shows high nucleophilicity towards carbonyl groups, and little tendency towards enolate formation. Nitriles seemed to be rather exceptional, and we confirmed that this pathway is reasonable with phenylacetontrile (**9**) and phenylpropionitrile (**10**). Treatment with phenyldimethylsilyllithium and quenching with deuterium oxide gave the deuterated products **11** and **12**, and, significantly in the case of phenylacetonitrile (**9**), the mono-deuterated product **11** (Scheme 3).

The last class of nitriles that we investigated, aromatic nitriles, gave completely different products. Benzonitrile (**13**) initially gave a mixture of products, of which only benzil (**15**) was identifiable. Subsequently, by incorporating a fairly vigorous acidic hydrolysis in the work-up, we were able to isolate two major products, the first being benzil, as before, and the second proving to be 2,4,5-triphenylimidazole (**17**) (Scheme 4). To make sure that all three phenyl groups came from the benzonitrile, we repeated this reaction with *p*-tolunitrile (**14**) and obtained the corresponding benzil **16** and the tri-*p*-tolylimidazole (**18**).

We neither know the mechanism in detail, nor do we know how much of the imidazole-forming reaction takes place during the work-up. Nevertheless, we can say that this reaction must involve a combination of an intermediate **19**, nucleophilic at the nitrile carbon by virtue of a Brook-like rearrangement, with another



Scheme 2. Reagents: (i) $PhMe_2SiLi$, THF, 0 °C, 4 h; (ii) HCl, H_2O, r.t., 1 h.



Scheme 3. Reagents: (i) $PhMe_2SiLi$, THF, 0°C, 30 min; (ii) AcOD, 0°C; (iii) HCl, H_2O, r.t., 30 min.

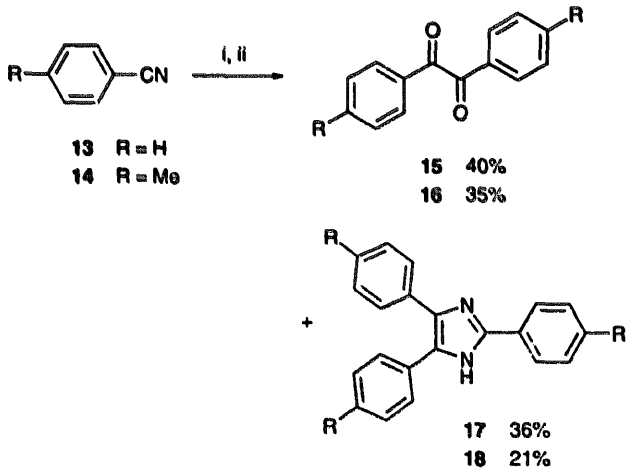
molecule of benzonitrile to give a benzil-type intermediate **20** (Scheme 5). Some of this must survive to be hydrolysed to benzil, and the rest could attack another molecule of benzonitrile to give an intermediate **21**. This intermediate is still at too high an oxidation level, and a possible pathway by which it is reduced is attack by another silyllithium molecule, leading to an intermediate **22** capable of an aza-Peterson elimination to give the imidazole. There are several other possibilities, such as attack by the silyllithium reagent on the benzil-type intermediate **20**, effectively achieving the reduction at this stage to give the intermediate **23**, before the third equivalent of benzonitrile is attacked, conceivably during the work-up, and either before or after the loss of the most recently introduced silyl group.

In conclusion, we find that nitriles are not good substrates for attack by silyllithium reagents; reaction takes place rather slowly compared with attack on carbonyl groups, and the several pathways followed are unusually dependent upon the structure of the nitrile.

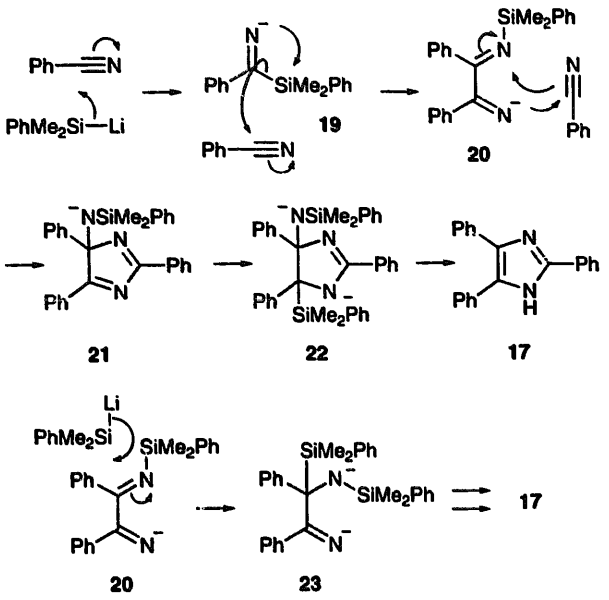
3. Experimental

3.1. The reaction of phenyldimethylsilyllithium with nitriles

Typically, dimethyl(phenyl)silyllithium [10] (9.9 ml of a 0.85 M solution, 8.4 mmol) was added slowly to



Scheme 4. Reagents: (i) $PhMe_2SiLi$, THF, 0 °C, 2 h; (ii) HCl, H_2O, reflux, 2 h.



Scheme 5.

the nitrile (8.3 mmol) in dry THF (30 ml) under argon at 0 °C, and the mixture kept for 0.5–4 h. Water (6 ml) and aqueous hydrochloric acid (12 ml of a 3 M solution) were added dropwise, and the mixture stirred at room temperature or at reflux for 0.5–2 h, after which the layers were separated. The aqueous layer was washed with ether (3 × 25 ml), the combined organic layers were washed with brine (50 ml), dried ($MgSO_4$), and evaporated under reduced pressure. The residue was purified by flash chromatography (SiO_2, EtOAc–hexane, 1:4) to give the neutral products. The aqueous layer was basified with a sodium hydroxide solution (10% until basic, litmus) and then washed with ethyl acetate (3 × 25 ml), the organic layer separated, dried ($MgSO_4$), and evaporated under reduced pressure to give the imidazoles. The following products were prepared by this method, with times and temperatures noted in the schemes.

3.2. Dimethyl(trimethylacetyl)(phenyl)silane (2) [6]

As an oil (31%), ν_{max} (film)/cm^{-1} 1631 (C=O), 1249 (SiMe), and 1109 (SiPh), δ_H (250 MHz, $CDCl_3$) 7.6 (2H, m, *o*-Ph), 7.4 (3H, m, *m*-, and *p*-Ph), 1.0 (9H, s, CMe_3), and 0.5 (6H, s, $SiMe_2$), δ_C ($CDCl_3$) 134.1, 129.6, 127.9, 49.4, 24.8, and −2.1.

3.3. Trimethylacetamide (3)

As needles (10%), m.p. 161–163 °C (Ref. [11], 155–156 °C), ν_{max} (Nujol)/cm^{-1} 3395 (NH) and 1651 (C=O), δ_H (250 MHz, $CDCl_3$) 6.0–5.7 (2H, broad s, NH_2) and 1.2 (9H, s, CMe_3).

3.4. Dimethyl(1-methyl-1-phenylethyl)(phenyl)silane (5)

As needles (77%), m.p. 73.5–74.5 °C (from EtOH), ν_{max} (Nujol)/cm^{-1} 1248 (SiMe) and 1112 (SiPh), δ_H (250 MHz, $CDCl_3$) 7.4–7.0 (10H, m, Ph and SiPh), 1.3 (6H, s, CMe_2), and 0.2 (6H, s, $SiMe_2$), δ_C ($CDCl_3$) 148.2, 136.9, 134.7, 128.9, 127.6, 127.3, 126.4, 124.2, 27.4, 24.2, and −5.8, *m/z* 254 (M^+), 239 (M − Me), and 135 ($PhMe_2Si$) (Found: C, 79.8; H, 8.7: M^+, 254.1490. $C_{17}H_{22}Si$. Calc.: C, 80.2; H, 8.7%; *M*, 254.1491).

3.5. Methyl(1,1-diphenylethyl)(phenyl)silane (7)

As an oil (17%), ν_{max} (film)/cm^{-1} 1250 (SiMe) and 1110 (SiPh), δ_H (250 MHz, $CDCl_3$) 7.4–7.1 (15H, m, Ph and SiPh), 1.8 (3H, s, CMe), and 0.3 (6H, s, $SiMe_2$), δ_C ($CDCl_3$) 148.4, 133.9, 129.2, 129.1, 128.9, 127.8, 127.3, 126.1, 25.9, 21.9, and −2.9 (Found: M^+, 316.1646. $C_{22}H_{24}Si$. Calc.: *M*, 316.1647).

3.6. 1,1-Diphenylethane (8) [12]

In va riable amounts, ν_{max} (film)/cm^{-1} 1599 (Ar), δ_H (250 MHz, $CDCl_3$) 7.1–7.3 (10H, m), 4.2 (1H, q, *J* 7 Hz), and 1.6 (3H, d, *J* 7 Hz), δ_C (400 MHz, $CDCl_3$) 133.8, 128.3, 127.8, 126.0, 44.7, and 21.8.

3.7. Phenylacetonitrile d-1 (11)

As an oil (95%), ν_{max} (film)/cm^{-1} 3031 (ArC–H), 2956 (benzylicC–H), 2249 (C≡N), and 2120 (C–D), δ_H (250 MHz, $CDCl_3$) 7.5–7.3 (5H, m, ArH) and 3.75 (1H, s, CHD), δ_C ($CDCl_3$) 129.9, 129.2, 1 28.9, 128.3, 128.1, 128.0, 118.0, and 23.2. The characteristic signals of dimethylphenylsilane at δ 4.5 (1H, septet, *J* 4.5, SiH) and 0.3 (6H, d, *J* 4.5, $SiMe_2$) were also evident in the ^{1}H NMR spectrum of the crude product from the reaction with acetonitrile, providing further evidence for the suggested pathway in this reaction.

3.8. Diphenylacetonitrile d-1 (12)

As needles (90%), m.p. 73–74 °C (from EtOH) (Ref. [13], 75–76 °C), ν_{max} (Nujol)/cm^{-1} 2238 (CN) and 2148 (CD), δ_H (250 MHz, $CDCl_3$) 7.3–7.4 (10H, m), δ_C ($CDCl_3$) 135.9, 129.2, 128.3, 127.7, 119.7, and 42.5.

3.9. Benzil (15)

As plates (40%), m.p. 94–95 °C (from EtOH) (Ref. [14], 94–95 °C), ν_{max} ($CHCl_3$)/cm^{-1} 1682 (C=O), δ_H (250 MHz, $CDCl_3$) 7.96 (4H, d, *J* 8.1 Hz, *o*-Ph) 7.65

(2H, t, *J* 7.4, *p*-Ph), and 7.53 (4H, t, *J* 7.5 Hz, *m*-Ph), δ_C ($CDCl_3$) 194.6, 134.9, 133.0, 130.4, 129.9, and 129.0.

3.10. 4,4'-Dimethylbenzil (16)

As plates (35%), m.p. 102–103 °C (from EtOH) (Ref. [15], 102–104 °C), ν_{max} (Nujol)/cm^{-1} 1702.7 (C=O), δ_H (250 MHz, $CDCl_3$) 7.85 (4H, d, *J* 10 Hz, H-2, H-2', H-6, and H-6'), 7.3 (4H, d, *J* 10 Hz, H-3, H-3', H-5, and H 5'), and 2.4 (6H, s, ArMe), δ_C ($CDCl_3$) 194.5, 146.1, 130.7, 130.0, 129.7, and 21.9.

3.11. 2,4,5-Triphenylimidazole (17)

As needles (36%), m.p. 272–274 °C (from Et_2O) (Ref. [16], 276.5 °C), ν_{max} (Nujol)/cm^{-1} 1600 (Ar), δ_H (400 MHz, d_6-DMSO) 12.7 (1H, s, NH), 8.1 (2H, d, *J* 7.4 Hz, *o*-Ph on C-2), and 7.2–7.7 (13H, m, Ph), δ_C (d_6-DMSO) 145.6, 137.2, 135.3, 131.2, 130.5, 128.8, 128.6, 128.3, 127.2, 126.6, and 125.3 (Found: C, 85.2; H, 5.4; N 9.5. $C_{21}H_{16}N_2$. Calc.: C, 85.1; H, 5.4; N, 9.5%).

3.12. 2,4,5-Tri-p-tolylimidazole (18)

As needles (21%), m.p. 235–236 °C (from Et_2O) (Ref. [17], 235 °C), ν_{max} (CH_2Cl_2)/cm^{-1} 3436 (NH), δ_H (250 MHz, CD_2Cl_2) 7.8 (2H, d, *J* 8 Hz, H-2 and H-6 on Ar on C-2), 7.4 (4H, d, *J* 8 Hz, H-2', H-2'', H-6', and H-6''), 7.25 (2H, d, *J* 8 Hz, H-3 and H-5), 7.15 (4H, d, *J* 8 Hz, H-3', H-3'', H-5', H-5''), and 2.4 (9H, s, ArMe), δ_C(CD_2Cl_2) 145.8, 139.0, 137.4, 129.8, 129.4, 127.8, 127.6, 125.2, 21.3, and 21.2.

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References

[1] N. Duffaut, J. Dunoguès, C. Biran, R. Calas and J. Gerval, *J. Organomet. Chem., 161* (1978) C23. A. Capperucci, A. Degl'Innocenti, C. Faggi and A. Ricci, *J. Org. Chem., 53* (1988) 3612. B.F. Bonini, F. Busi, R.C. de Laet, G. Mazzanti, J.-W.J.F. Thuring, P. Zani and B. Zwanenburg, *J. Chem. Soc. Perkin Trans. 1*, (1993) 1011. B.F. Bonini, M. Comes-Franchini, G. Mazzanti, U. Passamonti, A. Ricci and P. Zani, *Synthesis*, (1995) 92.

[2] J. Kang, J.H. Lee, K.S. Kim, J.U. Jeong and C. Pyun, *Tetrahedron Lett., 28* (1987) 5261. M. Nakada, S. Nakamura, S. Kobayashi and M. Ohno, *Tetrahedron Lett., 32* (1991) 4929.

[3] A.G. Brook, A. Baumegger and A.J. Lough, *Organometallics, 11* (1992) 310.

[4] K. Yamamoto, A. Hayashi, S. Suzuki and J. Tsuji, *Organometallics, 6* (1987) 974. A. Ricci, A. Degl'Innocenti, S. Chimichi, M. Fiorenza, G. Rossini and H.J. Bestmann, *J. Org. Chem., 50* (1985) 130.

[5] F. Jin, B. Jiang and Y. Xu, *Tetrahedron Lett., 33* (1992) 1221.

[6] I. Fleming and U. Ghosh, *J. Chem. Soc. Perkin Trans. 1*, (1994) 257.

[7] F.H. Elsner, H.-G. Woo and T.D. Tilley, *J. Am. Chem. Soc., 110* (1988) 313.

[8] J.-P. Picard, R. Calas, J. Dunoguès and N. Duffaut, *J. Organomet. Chem., 26* (1971) 183. P. Bourgeois, *J. Organomet. Chem., 76* (1974) C1. P. Bourgeois, J. Dunoguès and N. Duffaut, *J. Organomet. Chem., 80* (1974) C25. J.-P. Picard, R. Calas, J. Dunoguès, N. Duffaut, J. Gerval and P. Lapouyade, *J. Org. Chem., 44* (1979) 420. N. Kise, H. Kaneko, N. Uemoto and J. Yoshida, *Tetrahedron Lett., 36* (1995) 8839.

[9] R. Calas and J. Dunoguès, *J. Organomet. Chem. Libr., Organomet. Chem. Rev.: Organosilicon Rev., 2* (1976) 277. J.-P. Picard, S. Grelier, T. Constantieux, J. Dunoguès, J.M. Aizpurua, C. Palomo, M. Pétraud, B. Barbe, L. Lunazzi and J.-M. Léger, *Organometallics, 12* (1993) 1378.

[10] M.V. George, D.J. Peterson and H. Gilman, *J. Am. Chem. Soc., 82* (1960) 403.

[11] G.E. Philbrook, *J. Org. Chem., 19* (1954) 623.

[12] R. Anschütz, *Justus Liebigs Ann. Chem., 235* (1886) 299.

[13] K. Neure, *Justus Liebigs Ann. Chem., 250* (1888) 140.

[14] D.G. Markees, *J. Org. Chem., 23* (1958) 1490.

[15] M. Gomberg and W.E. Bachmann, *J. Am. Chem. Soc., 50* (1928) 2766.

[16] W.B. Leslie and G.W. Watt, *J. Org. Chem., 7* (1942) 73.

[17] A. Fürth, *Monatsh. Chem., 27* (1906) 839.