Reaction of Trimethylsilylamines with α,β-Unsaturated Aldehydes: A Convenient Synthesis of 1,3-Bis[dialkylamino]-1-alkenes

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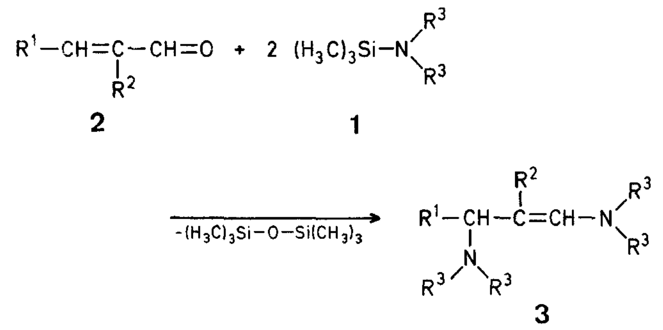
Trimethylsilyl derivatives of secondary amines **1**, mainly known as silylating agents[1], have been used as nucleophilic reagents in a few cases[1,2]. As part of a study of the nucleophilic addition on unsaturated carbonyl compounds (attempts to isolate silylated species and new functional aminoalkenes[3]), we have noticed that silylamines **1** do react with α,β-unsaturated aldehydes **2** to yield hexamethyldisiloxane and diamino derivatives, identified as 1,3-bis[dialkylamino]-1-alkenes **3**. Compounds **3** are γ-aminoenamines, a little known class of functional enamines: only three examples have been described from the direct reaction of secondary amines and aldehydes **2a–c**[4,5]; their preparation is however difficult to carry out in a reproducible way and all other aldehydes fail to give definite products[3,4].

In contrast, aldehydes **2a–d** react easily with two equivalents of **1** at room temperature and afford **3a–d**, with excellent yields; disappearance of **2** and formation of hexamethyldisiloxane being best monitored by ^{1}H-N.M.R. and G.L.C., respectively.



α-Substituted aldehydes **2e–f** are very poor reactants in these conditions; however, formation of **3** – although dramatically slowed – is still noticed. An increase in temperature (up to 80 °C) and use of catalytic amounts of an acid, such as *p*-toluenesulfonic acid, leads to reasonable reaction times and better yields in these cases.

Noteworthy is the fact that zinc chloride and trimethylsilyl trifluoromethanesulfonate (TMS triflate) can be used as catalysts, owing to the aprotic conditions. Thus, the highly oxophilic property of trimethylsilyl triflate[6] allows a fast reaction of all aldehydes **2** at room temperature with nearly quantitative formation of **3** (Table 1). Easy removal of the solvent and hexamethyldisiloxane affords pure aminoenamines **3** characterised by their physical[4,5] and chemical[3] properties, and their ^{1}H-N.M.R. data (see Table 2).

Sufficiently pure products are directly obtained in a number of cases (Table 1) after evaporation of the reaction mixture, as established from their analysis, mass and N.M.R. spectra (hexamethyldisiloxane is the sole detectable impurity) and quantitative chemical reactions[3] (100% formation of α,β-unsaturated iminium salts and reduction to corresponding amines).

The method described here provides a simple and efficient way to functional enamines **3**; it is of preparative interest since the reaction uses aprotic conditions and nearly ideal stoichiometry with formation of a single and easily removed by-product.

1,3-Bis[dialkylamino]-1-alkenes 3; General Procedure:

The reaction can be performed with pure reactants or in a inert solvent (5 ml diethyl ether, dichloromethane, benzene). Trimethylsilylamine **1** (200 mmol) is added to aldehyde **2** (100 mmol) at room temperature and under inert atmosphere. When needed, a drop of trimethylsilyl triflate is introduced just after the silylamine. After the time indicated in Table 1, including for **2a** and **2b** 10 min at 40 °C, the mixture is filtered when **3** is a solid, or evaporated under reduced pressure. If necessary solids can be washed with minimum pentane or recrystallised (pentane, hexane), liquids distilled in some cases (Table 1) or the reaction mixture can be submitted to flash chromatography (basic alumina, hexane/diethyl ether, 50/50).

Table 1. 1,3-Bis[dialkylamino-1-alkenes] 3 prepared

Aldehyde 2	R^1	R^2	Product	R^3	R^3	Yield [%][a]	Reaction Time [min]	b.p. [°C]/torr or m.p.	Molecular Formula[c] or Lit. Data
2a	H	H	**3a**	$-(CH_2)_2-O-(CH_2)_2-$		95	30[b]	115°/1	$C_{11}H_{20}N_2O_2$ (212.3)
			3a'	$-(CH_2)_5-$		97	30[b]	110°/2	150°/12[4]; 100°/0.5[5]
2b	CH_3	H	**3b**	$-(CH_2)_2-O-(CH_2)_2-$		98	30[b]	oil[f]	$C_{12}H_{22}N_2O_2$ (226.3)
			3b'	$-(CH_2)_5-$		97	30[b]	oil[f]	oil[4]
			3b''	$-(CH_2)_4-$		98	30[b]	oil[f]	$C_{12}H_{22}N_2$ (197.3)
2c	C_6H_5	H	**3c**	$-(CH_2)_2-O-(CH_2)_2-$		98	60[b]	100°	$C_{17}H_{24}N_2O_2$ (288.4)
			3c'	$-(CH_2)_5-$		90	60[b]	75	oil[4]
			3c''	$-(CH_2)_4-$		98	60[b]	oil[f]	$C_{17}H_{24}N_2$ (256.4)
			3c'''	CH_3	CH_3	98	30[b]	oil[f]	$C_{13}H_{20}N_2$ (204.3)
2d	n-C_3H_7	H	**3d**	$-(CH_2)_2-O-(CH_2)_2-$		95	40[b]	oil[f]	$C_{14}H_{26}N_2O_2$ (254.4)
			3d'	$-(CH_2)_5-$		94	50[b]	oil[f]	$C_{16}H_{30}N_2$ (250.4)
2e	C_2H_5	CH_3	**3e**	$-(CH_2)_2-O-(CH_2)_2-$		93	30[e]	oil[f]	$C_{14}H_{26}N_2O_2$ (254.4)
			3e'	$-(CH_2)_5-$		94	50[e]	oil[f]	$C_{16}H_{30}N_2$ (250.4)
2f	C_6H_5	CH_3	**3f**	$-(CH_2)_2-O-(CH_2)_2-$		70	5 days[b]	70	$C_{18}H_{26}N_2O_2$ (302.4)
						84	48 h[d]		
						95	4 h[e]		
			3f'	$-(CH_2)_5-$		96	4 h[e]	oil[f]	$C_{20}H_{30}N_2$ (298.5)
			3f''	$-(CH_2)_4-$		96	4 h[e]	oil[f]	$C_{18}H_{26}N_2$ (270.4)

[a] Yield after evaporation of the reaction mixture.

[b] In the absence of a catalyst; reaction time generally 5–10 min in the presence of trimethylsilyl triflate.

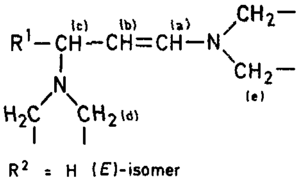
[c] Satisfactory microanalyses obtained: C ±0.35, H ±0.29, N ±0.39; exception: **3b'**, C − 0.69, H + 0.39, N − 0.50.

[d] Zinc chloride as catalyst.

[e] Trimethylsilyl triflate as catalyst.

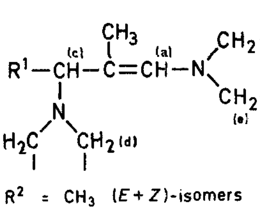
[f] Decomposed on attempted distillation[4,8].

Table 2. ^{1}H-N.M.R. (CCl_4/TMS_{int}) Data for Compounds 3



Product	δ [ppm], J [Hz]				
	H(a)	H(b)	H(c)	H(d)	H(e)
3a	5.85 (d, $J_{a,b} = 13$)	4.40 (2t, $J_{b,c} = 6$)	masked	2.35 (m)	2.80 (m)
3a'	5.80 (d, $J_{a,b} = 13$)	4.30 ($J_{b,c} = 6$)	masked	2.20 (m)	2.70 (m)
3b	5.80 (d, $J_{a,b} = 13$)	4.25 (2d, $J_{b,c} = 8$)	masked	2.30 (m)	2.65 (m)
3b'	5.70 (d, $J_{a,b} = 13$)	4.20 (2d, $J_{b,c} = 8$)	masked	2.35 (m)	2.70 (m)
3b''	6.15 (d, $J_{a,b} = 13$)	4.00 (2d, $J_{b,c} = 8$)	masked	2.50 (m)	3.00 (m)
3c	5.80 (d, $J_{a,b} = 13$)	4.30 (2d, $J_{b,c} = 9$)	masked	2.20 (m)	2.60 (m)
3c'	5.80 (d, $J_{a,b} = 13$)	4.30 (2d, $J_{b,c} = 9$)	3.50 (d)	2.35 (m)	2.70 (m)
3c''	6.35 (d, $J_{a,b} = 13$)	4.30 (2d, $J_{b,c} = 9$)	3.50 (d)	2.60 (m)	3.00 (m)
3c'''	5.90 (d, $J_{a,b} = 13$)	4.20 (2d, $J_{b,c} = 9$)	3.40 (d)	2.15 (s)	2.60 (s)
3d	5.80 (d, $J_{a,b} = 13$)	4.30 (2d, $J_{b,c} = 8$)	masked	2.30 (m)	2.60 (m)
3d'	5.80 (d, $J_{a,b} = 13$)	4.20 (2d, $J_{b,c} = 8$)	masked	2.35 (m)	2.80 (m)

Table 2. (Continued)



Product	δ [ppm], J [Hz]				Isomer Distribution [%]
	H(a)	CH_3	H(c)	H(d), H(e)	
3f (Z)[a]	5.75	1.60	masked	2.45–2.55	40
(E)[a]	6.30	1.90	3.1.		60
3f' (Z)[a]	5.80	masked	3.50	2.65	45
(E)[a]	6.30	1.95	3.15		55
3f''	6.00	(1.80) masked	3.40	2.50–3.00	–[b]
3e	5.70	1.50	masked	2.40–2.60	–[b]
3e'	5.40	masked	masked	2.40–2.60	–[b]

[a] Established according to Ref.[7].

[b] One isomer only (not definitely assigned).

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