Tetrahedron 66 (2010) 2928–2935

Contents lists available at ScienceDirect

Tetrahedron

journal homepage: www.elsevier.com/locate/tet

Cyclopropylmethyl- and cyclobutylmethyllithium by an arene-catalyzed lithiation. Stability and reactivity

Itziar Peñafiel, Isidro M. Pastor *, Miguel Yus *

Departamento de Química Orgánica, Facultad de Ciencias and Instituto de Síntesis Orgánica (ISO), Universidad de Alicante, Apdo. 99, 03080 Alicante, Spain

ARTICLE INFO

Article history:
Received 2 February 2010
Received in revised form
23 February 2010
Accepted 24 February 2010
Available online 1 March 2010

Keywords:
Cyclopropylmethyllithium
Cyclobutylmethyllithium
Homoallyllithium
Bishomoallyllithium
DTBB and naphthalene catalyzed lithiation
S_E reaction
Lithium

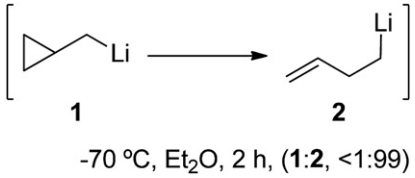
ABSTRACT

The reaction of (chloromethyl)cyclopropane **5** and (bromomethyl)cyclobutane **8** with lithium and a substoichiometric amount of DTBB, in the presence of different carbonyl compounds as electrophiles, in THF at −78 °C leads, after hydrolysis, to the corresponding cycloalkyl alcohols **6** and **9**, respectively. However, when the same starting materials are lithiated using naphthalene as catalyst in diethyl ether and at higher temperature (0 or 25 °C), and then react with the same electrophiles, the final hydrolysis yields the corresponding unsaturated alcohols **7** and **10**, respectively.

1. Introduction

The formation of carbon–carbon bonds constitutes a key step during the synthesis of many organic products, and organometallic reagents are versatile reagents for carrying out this transformation.[1] Among organometallic compounds, functionalized organolithium compounds constitute a unique class due to their characteristic reactivity.[1c,2] Regarding the lithiation agent employed for the preparation of organolithium intermediates, two different methodologies can be considered.[3] The first one consists in the use of another organolithium reagent, and the second is the reductive lithiation using lithium metal. For the latter, the use of a substoichiometric amount of an arene to facilitate the electron transfer from the lithium to the substrate has shown to be very useful under different reaction conditions and for several types of starting materials.[4]

The intramolecular carbolithiation of carbon–carbon double bonds is an interesting procedure to prepare functionalized carbocyclic and heterocyclic compounds.[5] Thus, the carbanionic cyclization reaction of different alk-5-enyllithium intermediates has been extensively studied.[6–8] Bailey et al. reported a very interesting methodology employing a catalytic amount of phenyllithium that allowed the cycloisomerization of different alkenyl primary, secondary, tertiary, and aryl iodides to the corresponding cyclic isomer iodides, and the mechanism of this procedure being substrate dependent.[6] Our laboratory reported the intramolecular cyclization of different hex-5-enyllithium derivatives prepared by chlorine/lithium exchange employing lithium metal.[8a,b] On the other hand, organolithium intermediates having in α-position a small cycloalkane (three- or four-membered rings) undergo rapidly a transformation to the more stable homoallyl- or bishomoallyllithium intermediates. Thus, cyclopropylmethyllithium **1** is an unstable intermediate even at low temperature, giving the corresponding homoallyllithium **2** with less than 1 h half-life time (Scheme 1).[9] Intermediates of type **1** and **2** have been prepared employing: (a) an organolithium reagent by iodine–lithium exchange,[9,10] selenium–lithium exchange,[11] or silicon–lithium exchange (involving a Brook-type process),[12] and (b) lithium metal in a mercury–lithium transmetallation process.[13] Regarding the stability of the cyclobutylmethyllithium intermediate



Scheme 1.

* Corresponding authors. Fax: +34 965 903549; e-mail addresses: ipastor@ua.es (I.M. Pastor), yus@ua.es (M. Yus).

0040-4020/$ – see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.tet.2010.02.090

3, which rearranges to the bishomoallyllithium intermediate **4** (Scheme 2), it has been less considered. Thus, organolithium **3** has been prepared by bromide–lithium[14] or iodine–lithium exchange[15] using *t*-BuLi or *n*-BuLi, respectively. Cyclobutylmethyllithium intermediate has shown lower stability than the corresponding magnesium derivatives.[16]

-50 °C, isooctane/Bu_2O, 1 h: (**3**:**4**, 95:5)
25 °C, benzene, 1 h: (**3**:**4**, 7:93)

Scheme 2.

Recently, we have preliminary reported that the arene-catalyzed lithiation methodology allowed the selective generation either the intermediate type **1** or type **2** from the same starting material.[17] Herein, we describe the study of the lithiation reaction of (chloromethyl)cyclopropane and (bromomethyl)cyclobutane by means of the mentioned arene-catalyzed lithiation reaction, the stability of the generated organolithium intermediates being also studied under these reaction conditions.

2. Results and discussion

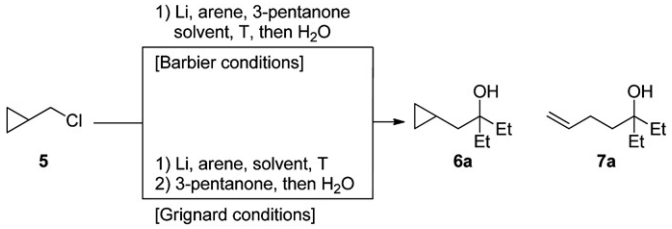
2.1. Lithiation of (chloromethyl)cyclopropane

The lithiation of (chloromethyl)cyclopropane **5** was performed employing a slight excess of lithium powder and a substoichiometric amount of an arene [i.e., 4,4′-di-*tert*-butylbiphenyl (DTBB) or naphthalene; 5 mol %] in the presence (Barbier-type conditions)[18] or absence (Grignard-type conditions) of 3-pentanone as the electrophile. Different reaction conditions were assayed giving after hydrolysis a mixture of the corresponding alcohols **6a** and **7a** resulting from the S_E reaction of the intermediates **1** and **2**, respectively (Table 1).

The cyclopropyl derivative **6a** was exclusively formed performing the reaction at −78 °C, in THF as solvent, under Barbier-type conditions (Table 1, entries 1 and 3). The use of DTBB as electron carrier gave better yield of the product **6a** than using naphthalene (Table 1, compare entries 1 and 3). Any change in the temperature (Table 1, entry 2) or solvent (Table 1, entry 4) gave poorer results. In contrast, the best yield for obtaining exclusively the unsaturated alcohol **7a** was observed by working under Grignard-type conditions at 0 °C in diethyl ether and using naphthalene as electron carrier (Table 1, entry 14). This result was not improved by performing the reaction at lower temperatures (Table 1, entries 6–9, 11 and 16), using DTBB as electron carrier (Table 1, entries 6–12) or employing other solvents (Table 1, entries 6–13 and 15). Additionally, we investigated the importance of using an arene in the selective preparation of either organolithium intermediate **1** or **2**, and there was no formation of the final products when performing the reaction under the optimal conditions but in the absence of the arene (Table 1, entries 5 and 17). The use of *n*-butyllithium, instead of the combination lithium/arene to perform the chlorine–lithium exchange, gave neither of the expected alcohols (**6a** and/or **7a**), but the alcohol derived from the addition of butyllithium to the 3-pentanone.

To investigate the scope of the process, different carbonyl compounds were subjected to the optimal conditions for obtaining exclusively either the cyclopropyl alcohol **6** or the unsaturated alcohol **7** (Table 2). Thus, compounds **6** were isolated

Table 1
Arene-catalyzed lithiation of (chloromethyl)cyclopropane and S_E reaction with 3-pentanone[a]

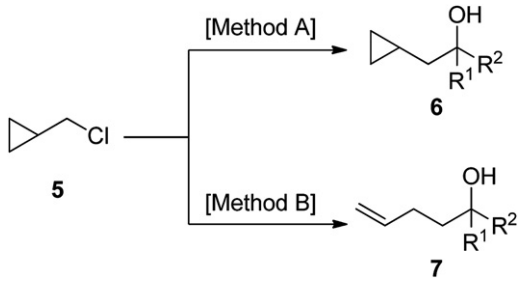


Method	Entry	*T* (°C)	Time[b] (min)	Arene	Solvent	Yield[c] (%)		
						6a	**7a**	Total
Barbier-type conditions	1	−78	60	DTBB	THF	87	0	87
	2	0	60	DTBB	THF	4	85	89
	3	−78	60	Naphthalene	THF	65	0	65
	4	−78	60	Naphthalene	Et_2O	1	0	1
	5[d]	−78	60		THF	0	0	0
Grignard-type conditions	6	−78	60+30	DTBB	THF	19	53	72
	7	−78	90+30	DTBB	THF	3	66	69
	8	−78	180+30	DTBB	THF	1	50	51
	9	−45	60+30	DTBB	THF	4	90	94
	10	0	60+30	DTBB	THF	0	84	84
	11	−78 to 0	60+30	DTBB	THF	0	87	87
	12	0	60+30	DTBB	THP	7	44	51
	13	0	60+30	Naphthalene	THF	0	54	54
	14	0	60+30	Naphthalene	Et_2O	0	97	97
	15	0	60+30	Naphthalene	THP	0	51	51
	16	−78	60+30	Naphthalene	Et_2O	2	3	5
	17[d]	0	60+30		Et_2O	0	6	6

[a] Reactions performed with (chloromethyl)cyclopropane (2 mmol), Li (7.1 mmol), arene (0.1 mmol), solvent (10 mL), and 3-pentanone (2.2 mmol).
[b] Under Grignard conditions the given times correspond to the two steps (lithiation and reaction with the electrophile).
[c] Yields of compounds **6a** and **7a** were calculated by GLC using an internal standard (1-decanol).
[d] The starting material was recovered.

with satisfactory yields performing the lithiation reaction, with 5 mol % of DTBB, under Barbier-type conditions at −78 °C in THF as solvent, the corresponding alcohols **7** being not detected in any case (Table 2, Method A). However, carrying out the reaction under the optimal conditions for generating the intermediate **2** (naphthalene, Grignard-type conditions, 0 °C, Et_2O) the process gave exclusively, after S_E (electrophilic substitution) and hydrolysis, compounds **7** with satisfactory yields (Table 2, Method B).

Table 2
Preparation of cyclopropyl alcohols **6** and unsaturated alcohols **7**



Entry	Method[a]	R^1	R^2	Product	Yield[b] (%)
1	A	Et	Et	**6a**	67
2	A	*n*-Pr	*n*-Pr	**6b**	61
3	A	*c*-C_3H_5	*c*-C_3H_5	**6c**	53
4	A	$(CH_2)_5$		**6d**	71
5	A	Ph	Me	**6e**	63
6	A	*t*-Bu	H	**6f**	53
7	A	*i*-Pr	H	**6g**	52
8	A	Ph	H	**6h**	62
9	B	Et	Et	**7a**	77
10	B	*n*-Pr	*n*-Pr	**7b**	70
11	B	*c*-C_3H_5	*c*-C_3H_5	**7c**	51
12	B	$(CH_2)_5$		**7d**	65
13	B	Ph	Me	**7e**	63
14	B	*t*-Bu	H	**7f**	51
15	B	*i*-Pr	H	**7g**	63
16	B	Ph	H	**7h**	50

[a] Method A: (a) (chloromethyl)cyclopropane, Li (1.8 equiv), DTBB (5 mol %), electrophile (1.1 equiv), THF, −78 °C, 60 min; (b) H_2O. Method B: (a) (chloromethyl)cyclopropane, Li (1.8 equiv), naphthalene (5 mol %), Et_2O, 0 °C, 60 min; (b) electrophile (1.1 equiv), 0 °C, 30 min; (c) H_2O.
[b] Isolated yield of pure (>95%) products **6** and **7** after column chromatography (silica gel, hexane/ethyl acetate).

2.2. Lithiation of (bromomethyl)cyclobutane

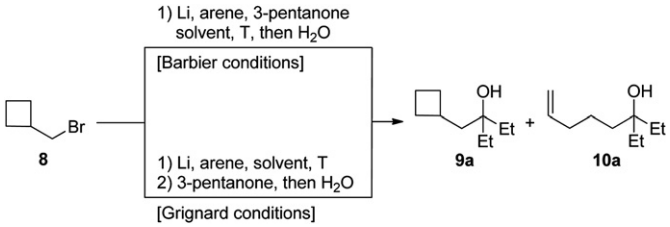
Then we studied the arene-catalyzed lithiation of (bromomethyl)cyclobutane **8**, trying to find reaction conditions for the selective generation of the intermediate **3** or **4** (Scheme 2). Thus, commercially available compound **8** was treated with an excess of lithium metal and a substochiometric amount of an arene (DTBB or naphthalene; 5 mol %) under Barbier-type or Grignard-type conditions, and employing 3-pentanone as electrophile. Different reaction conditions were tested and, after hydrolysis, the mixture of the corresponding alcohols **9a** and **10a** was obtained from the reaction of the intermediates **3** and **4**, respectively (Table 3). As previously observed for the cyclopropyl derivatives, the alcohol **9a** was exclusively obtained performing the reaction under Barbier-type conditions at −78 °C in THF and using DTBB as electron carrier (Table 3, entry 1). The optimal conditions to obtain exclusively the alcohol **10a** were performing the reaction under Grignard-type conditions at room temperature, using naphthalene as electron carrier, in diethyl ether (Table 3, entry 3).

The scope of the reaction was studied employing different carbonyl compounds under the optimal conditions for the exclusive generation of intermediate **3** (i.e., DTBB, THF, −78 °C and Barbier-type conditions), and also for the exclusive generation of **4** (i.e., naphthalene, Et_2O, 25 °C and Grignard-type conditions). Both procedures are general for aldehydes and ketones giving the corresponding alcohols (**9** or **10**, respectively) in satisfactory isolated yields and as the only reaction products (Table 4).

2.3. Stability of cyclopropylmethyl- and cyclobutyl methyllithium intermediates

Finally, we studied the stability of cyclopropylmethyllithium **1** and cyclobutylmethyllithium **3** under the lithiation reaction conditions employed. For that purpose, the silane derivatives **11** and **12** were prepared by means of the optimal conditions described previously employing $PhMe_2SiCl$ as electrophile

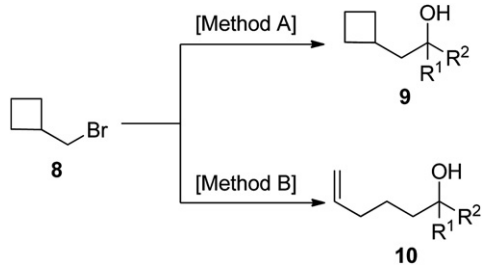
Table 3
Arene-catalyzed lithiation of (bromomethyl)cyclobutane and S_E reaction with 3-pentanone[a]



Method	Entry	*T* (°C)	Time[b] (min)	Arene	Solvent	Yield[c] (%)		
						9a	**10a**	Total
Barbier-type conditions	1	−78	60	DTBB	THF	88	0	88
	2	0	60	DTBB	THF	44	34	78
Grignard-type conditions	3	25	60+30	Naphthalene	Et_2O	0	89	89
	4	0	90+30	Naphthalene	Et_2O	0	78	78
	5	0	60+30	DTBB	THF	13	35	48
	6	0	60+30	Naphthalene	THF	7	34	41

[a] Reactions performed with (bromomethyl)cyclobutane (2 mmol), Li (7.1 mmol), arene (0.1 mmol), solvent (10 mL), and 3-pentanone (2.2 mmol).
[b] Under Grignard conditions the given times correspond to the two steps (lithiation and reaction with the electrophile).
[c] Yields of compounds **9a** and **10a** were calculated by ^1H NMR using an internal standard (benzene).

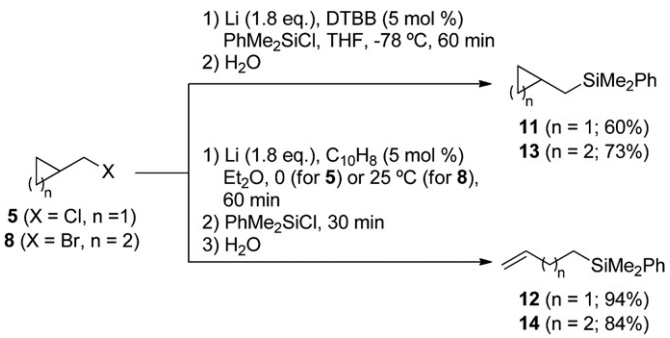
Table 4
Preparation of cyclobutyl alcohols **9** and unsaturated alcohols **10**



Entry	Method[a]	R^1	R^2	Product	Yield[b] (%)
1	A	Et	Et	**9a**	74
2	A	*n*-Pr	*n*-Pr	**9b**	58
3	A	*c*-C_3H_5	*c*-C_3H_5	**9c**	52
4	A	$(CH_2)_5$		**9d**	70
5	A	Ph	Me	**9e**	49
6	A	*t*-Bu	H	**9f**	46
7	A	*i*-Pr	H	**9g**	47
8	A	Ph	H	**9h**	70
9	B	Et	Et	**10a**	59
10	B	*n*-Pr	*n*-Pr	**10b**	69
11	B	*c*-C_3H_5	*c*-C_3H_5	**10c**	49
12	B	$(CH_2)_5$		**10d**	62
13	B	Ph	Me	**10e**	28
14	B	*t*-Bu	H	**10f**	55
15	B	*i*-Pr	H	**10g**	60
16	B	Ph	H	**10h**	35

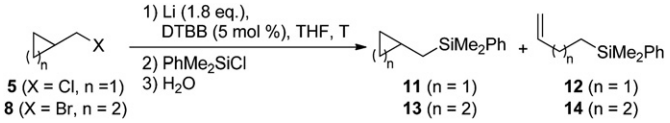
[a] Method A: (a) (bromomethyl)cyclobutane, Li (1.8 equiv), DTBB (5 mol %), electrophile (1.1 equiv), THF, −78 °C, 60 min; (b) H_2O. Method B: (a) (bromomethyl)cyclobutane, Li (1.8 equiv), naphthalene (5 mol %), Et_2O, 25 °C, 60 min; (b) electrophile (1.1 equiv), 0–25 °C, 30 min; (c) H_2O.
[b] Isolated yield of pure (>95%) products **9** and **10** after column chromatography (silica gel, hexane/ethyl acetate).

(Scheme 3). Subsequently, a set of lithiation reactions of compound **5** were quenched at different times with $PhMe_2SiCl$ producing mixtures of products **11** and **12** (Table 5). The rearrangement of cyclopropylmethyllithium **1** showed to be very rapid at low temperature, the ratio **11**/**12** being 86:14 in just 5 min (Table 5, entry 1). Additionally, we observed that in 30 min the intermediate **1** was almost completely converted into the homoallyllithium **2** (Table 1, entry 5). In the same way, the silyl derivatives **13** and **14**, which were prepared from (bromomethyl)cyclobutane as described above, were used in the study of the stability of intermediate **3** (Scheme 3, Table 5). As expected, intermediate **3** probed to be very stable at low temperature, rearrangement of the organolithium being not observed after 30 min at −78 °C (Table 5, entries 6–8). Then, higher temperatures were needed to detect certain transformation of intermediate **3** into **4** (Table 5, entries 9–14).



Scheme 3.

Table 5
Formation of silyl derivatives **11**–**14** under different reaction conditions[a]



Entry	Substrate	*T* (°C)	Time (min)	Products	Ratio[b]
1	**5**	−78	5	**11**/**12**	86:14
2	**5**	−78	10	**11**/**12**	33:67
3	**5**	−78	15	**11**/**12**	26:74
4	**5**	−78	20	**11**/**12**	9:91
5	**5**	−78	30	**11**/**12**	5:95
6	**8**	−78	10	**13**/**14**	>99:1
7	**8**	−78	20	**13**/**14**	>99:1
8	**8**	−78	30	**13**/**14**	>99:1
9	**8**	−50	10	**13**/**14**	91:9
10	**8**	−50	20	**13**/**14**	86:14
11	**8**	−50	30	**13**/**14**	75:25
12	**8**	0	10	**13**/**14**	76:24
13	**8**	0	20	**13**/**14**	66:34
14	**8**	0	30	**13**/**14**	58:42

[a] (Chloromethyl)cyclopropane or (bromomethyl)cyclobutane (1 mmol), Li (1.8 equiv), DTBB (5 mol %), THF, then $PhMe_2SiCl$ (1.1 equiv).
[b] Ratio was determined by GLC.

3. Conclusions

In summary, we have described herein that the arene-catalyzed lithiation is an effective methodology for the selective generation of cyclopropylmethyllithium **1** or but-3-enyllithium **2** intermediates as well as cyclobutylmethyllithium **3** or pent-4-enyllithium **4** intermediates, by a chlorine–lithium exchange. In all cases, these organolithiums react with different carbonyl compounds affording the expected alcohols. The cycloalkylmethyllithium intermediates have to be generated under milder reaction conditions [thus low temperatures and an arene with high reduction potential (i.e., DTBB)] than for the corresponding acyclic systems. In any case, intermediates **1** and **3**, even under these mild conditions, have a short life time and give better results reacting immediately with the corresponding electrophiles present in the reaction medium (Barbier-type conditions). Additionally, in a comparative experiment we have shown that cyclopropylmethyllithium is less stable than the corresponding cyclobutylmethyllithium, the former suffering almost complete rearrangement in 30 min at −78 °C.

4. Experimental section

4.1. General

All lithiation reactions were carried out under argon atmosphere in oven-dried glassware. All commercially available reagents (Acros, Aldrich, Fluka) were used without further purification, except in the case of liquid electrophiles, which were used freshly distilled. Commercially available anhydrous THF (99.9%, water content ≤0.006%, Fluka) was used as solvent in all the lithiation reactions. Lithium powder was commercially available (MEDALCHEMY S.L.). IR spectra were measured with a Nicolet Impact 400 D-FT Spectrometer. NMR spectra were recorded on a Bruker Avance 300 and Bruker Avance 400 (300 and 400 MHz for ^1H NMR, and 75 and 100 MHz for ^{13}C NMR) using, except otherwise stated, $CDCl_3$ as solvent and TMS as internal standard; chemical shifts are given in δ (ppm) and coupling constants (J) in hertz. Mass spectra (EI) were obtained at 70 eV on an Agilent 5973 spectrometer, fragment ions in m/z with relative intensities (%) in parenthesis and High Resolution Mass Spectra (HRMS) analyses were

carried out on a Finnigan MAT95S spectrometer. The purity of volatile and the chromatographic analyses (GLC) were determined with an Agilent 6890 N instrument equipped with a flame ionization detector and a 30 m capillary column (0.25 mm diameter, 0.25 μm film thickness), using nitrogen (2 mL/min) as carrier gas, $T_{injector}$=275 °C, T_{column}=60 °C (3 min) and 60–270 °C (15 °C/min); retention times (t_R) are given in minutes under these conditions. Thin layer chromatography was carried out on TLC plastic sheets with silica gel 60 F_{254} (Merck).

4.2. General procedure for the preparation of the alcohols 6

(Chloromethyl)cyclopropane (0.38 mL, 4 mmol) and the electrophile (4.4 mmol) were added to a suspension of lithium powder (100 mg, 14.2 mmol) and DTBB (53.2 mg, 0.2 mmol) in dry THF (15 mL) at −78 °C. The mixture was stirred for 60 min at the same temperature. The reaction mixture was hydrolyzed with water (10 mL), extracted with ethyl acetate (3×10 mL), and the organic phase was dried over anhydrous magnesium sulfate. After removing the solvent, under reduced pressure (15 Torr), the resulting crude was purified by column chromatography (pH=6.7–7.3 silica gel, mixtures of hexane and EtOAc). Yields are given in Table 2; analytical, physical and spectroscopic data, as well as literature references for known compounds, follow.

*4.2.1. 3-(Cyclopropylmethyl)pentan-3-ol (**6a**).* Colorless oil; t_R 7.12; R_f 0.31 (hexane/EtOAc 10:1); ν (film) 3301 cm^{-1} (OH); δ_H 0.08 (2H, m, CH_2 ring), 0.6 (2H, m, CH_2 ring), 0.70 (1H, m, CH ring), 0.87 (6H, t, J=7.5, 2×CH_3), 1.37 (2H, d, J=6.7, CH_2COH), 1.41 (1H, s, OH), 1.55 (4H, m, 2×CH_2CH$_3$); δ_C 4.1 (2×CH_2 ring), 5.5 (CH ring), 7.9 (2×CH_3), 31.0 (2×CH_2CH_3), 42.9 (CH_2COH), 75.4 (COH); m/z 113 (M^+−Et, 17%), 87 (100), 69 (15), 57 (83), 55 (10); HRMS calcd for $C_7H_{13}O$ 113.0966, found 113.0984.

*4.2.2. 3-(Cyclopropylmethyl)heptan-4-ol (**6b**).* Colorless oil; t_R 9.59; R_f 0.33 (hexane/EtOAc 10:1); ν (film) 3397 (OH), 3076 cm^{-1} (cyclopropyl); δ_H 0.05 (2H, m, CH_2 ring), 0.43 (2H, m, CH_2 ring), 0.65 (1H, m, CH ring), 0.90 (6H, t, J=9.5, 2×CH_3), 1.30, 1.47 (6H and 5H, 2m, CH_2COH, 2×CH_2CH_2CH$_3$); δ_C 4.1 (2×CH_2 ring), 5.6 (CH ring), 14.7 (2×CH_3), 16.8, 41.7 (2×CH_2CH_2CH$_3$), 43.9 (CH_2COH), 75.2 (COH); m/z 152 (M^+−H_2O, 24%), 123 (24), 115 (40), 109 (51), 95 (37), 91 (26), 82 (18), 81 (100), 79 (40), 77 (21), 71 (33), 69 (38), 68 (17), 67 (57), 55 (75), 53 (19); HRMS [M^+−H_2O] calcd for $C_{11}H_{20}$ 152.1565, found 152.1549.

*4.2.3. 1,1,2-Tricyclopropylethanol (**6c**).* Yellow oil; t_R 9.26; R_f 0.38 (hexane/EtOAc 10:1); ν (film) 3486 (OH), 3078 cm^{-1} (cyclopropyl); δ_H 0.11 (2H, m, CH_2 ring), 0.36 (8H, m, 4×CH_2 ring), 0.46–0.51 (2H, m, CH_2 ring), 0.93 (3H, m, 3×CH ring), 1.13 (1H, s, OH), 1.51 (2H, d, J=6.9, CH_2COH); δ_C −0.6 (2×CH_2 ring), 0.8 (2×CH_2 ring), 4.4 (2×CH_2 ring), 6.0 (CH ring), 18.7 (2×CH ring), 47.2 (CH_2COH), 71.4 (COH); m/z 166 (M^+, 0.05%), 148.0 (10), 120 (26), 117 (22), 115 (15), 111 (33), 107 (13), 105 (16), 103 (10), 92 (29), 91 (100), 79 (67), 78 (19), 77 (40), 69 (21), 65 (17), 55 (10), 53 (11), 51 (11).

*4.2.4. 1-(Cyclopropylmethyl)cyclohexanol (**6d**).* Colorless oil; t_R 10.53; R_f 0.29 (hexane/EtOAc 10:1); ν (film) 3386 (OH), 3073 cm^{-1} (cyclopropyl); δ_H 0.07 (2H, m, CH_2cyiclopropyl), 0.48 (2H, m, CH_2 cyclopropyl), 0.77 (1H, m, CH cyclopropyl), 1.38 (2H, d, J=6.87, CH_2COH), 1.21–1.31, 1.47–1.63, 1.68–1.77, 1.82–1.91, 2.32–2.36 (1H, 7H, 1H, 1H, and 1H, 5m, respectively, 5×CH_2 cyclohexyl and OH); δ_C 4.1 (2×CH_2 cyclopropyl), 5.3 (CH cyclopropyl), 22.2 (2×CH_2 cyclohexyl), 25.9 (CH_2 cyclohexyl), 37.5 (2×CH_2 cyclohexyl), 47.1 (CH_2COH), 72.3 (COH); m/z 154 (M^+, 0.13%), 136 (44), 121 (28), 108 (17), 107 (40), 100 (42), 95 (56), 94 (37), 93 (62), 91 (35), 81 (64), 79 (100), 77 (32), 67 (52), 55 (35), 53 (19). HRMS [M^+−H_2O] calcd for $C_{10}H_{18}$ 154.1358, found 154.1352.

*4.2.5. 1-Cyclopropyl-2-phenylpropan-2-ol (**6e**).* Yellow oil; t_R 10.06; R_f 0.32 (hexane/EtOAc 10:1); ν (film) 3407 (OH), 3076 cm^{-1} (cyclopropyl); δ_H 0.01 (1H, m, CH*H* ring), 0.09 (1H, m, C*H*H ring), 0.40 (2H, m, CH_2 ring), 0.56 (1H, m, CH ring), 1.53 (1H, m, C*H*HCOH), 1.58 (3H, s, CH_3), 1.97 (1H, dd, J=14.2, 5.62, CH*H*COH), 2.27 (1H, s, OH), 7.23, 7.35, 7.48 (1H, 2H and 2H, 3m, 5×ArH); δ_C 4.4 (2×CH_2 ring), 6.0 (CH ring), 29.8 (CH_3), 48.5 (CH_2COH), 75.4 (COH), 124.8, 126.4, 128.0, 148.3 (6×ArC); m/z 176 (M^+, 0,03%), 158 (27), 143 (100), 141 (18), 129 (48), 128 (76), 127 (17), 121 (25), 115 (41), 91 (17), 77 (22); HRMS [M^+−H_2O] calcd for $C_{11}H_{14}$ 158.1095, found 158.1095.

*4.2.6. 1-Cyclopropyl-3,3-dimethylbutan-2-ol (**6f**).* Colorless oil; t_R 8.2; R_f 0.29 (hexane/EtOAc 10:1); ν (film) 3407 (OH), 3076 cm^{-1} (cyclopropyl); δ_H 0.01, 0.13, 0.43, 0.52 (1H, 1H, 1H and 1H, 4m, 2×CH_2 ring), 0.83 (1H, m, CH ring), 0.88 (9H, s, 3×CH_3), 1.29 (2H, t, J=4.8, CH_2CHOH), 1.76 (1H, s, OH), 3.36 (1H, t, J=4.8, C*H*OH); δ_C 3.3, 5.1 (2×CH_2 ring), 8.6 (CH ring), 25.7 (3×CH_3), 34.5 (*C*CHOH), 36.4 (CH_2CHOH), 80.4 (CHOH); m/z 142 (M^+, 0.15%), 124 (22), 109 (54), 95 (25), 91 (13), 87 (52), 86 (10), 85 (43), 84 (24), 83 (21), 82 (15), 81 (47), 70 (23), 69 (57), 57 (78), 57 (100), 56 (37), 55 (79), 53 (22).

*4.2.7. 1-Cyclopropyl-3-methylbutan-2-ol (**6g**).* Colorless oil; t_R 10.29; R_f 0.29 (hexane/EtOAc 10:1); ν (film) 3431 cm^{-1} (OH); δ_H 0.01 (1H, m, C*H*H ring), 0.11 (1H, m, CH*H* ring), 0.45 (2H, m, CH_2 ring), 0.75 (1H, m, CH ring), 0.89 (6H, d, J=6.8, 2×CH_3), 1.33 (2H, m, CH_2CHOH), 1.68 (1H, m, C*H*CHOH), 1.73 (1H, br s, OH), 3.46 (1H, m, C*H*OH); δ_C 3.5, 4.6 (2×CH_2 ring), 7.8 (CH ring), 17.2, 18.8 (2×CH_3), 33.2 (*C*HCHOH), 38.9 (CH_2CHOH), 69.8 (CHOH); m/z 110 (M^+−H_2O, 8%), 95 (42), 91 (24), 85 (26), 81 (18), 77 (20), 73 (87), 72 (21), 70 (17), 69 (28), 67 (54), 57 (32), 56 (44), 55 (100), 54 (27), 53 (24); HRMS [M^+−H_2O] calcd for C_8H_{14} 110.1095, found 110.1102.

*4.2.8. 2-Cyclopropyl-1-phenylethanol (**6h**)[19].* Yellow oil; t_R 9.23; R_f 0.32 (hexane/EtOAc 10:1); ν (film) 3364 (OH), 3076 cm^{-1} (cyclopropyl); δ_H 0.01, 0.11, 0.44, 0.68 (1H, 1H, 2H and 1H, 2×CH_2 ring and CH ring), 1.58–1.72 (2H, m, CH_2CHOH), 2.17 (1H, s, OH), 4.76 (1H, dd, J=7.5, 5.8, C*H*OH), 7.25, 7.33 (1H and 4H, 2m, 5×ArH); δ_C 3.9, 4.4 (2×CH_2 ring), 7.6 (CH ring), 44.1 (CH_2CHOH), 74.9 (CHOH), 125.8, 127.4, 128.3, 144.6 (6×ArC); m/z 162 (M^+, 6.57%), 144 (29), 143 (24), 142 (21), 141 (23), 129 (65), 128 (47), 115 (34), 107 (100), 105 (28), 79 (51), 77 (51), 51 (21).

4.3. General procedure for the preparation of the alcohols 7

(Chloromethyl)cyclopropane (0.38 mL, 4 mmol) was added to a suspension of lithium powder (100 mg, 14.2 mmol) and DTBB (53.2 mg, 0.2 mmol) in THF (15 mL) at 0 °C. The mixture was stirred for 60 min and then, the corresponding carbonyl compound (4.4 mmol) was added, continuing the stirring for 45 min at the same temperature. The reaction mixture was hydrolyzed with water (10 mL), extracted with ethyl acetate (3×10 mL), and the organic phase was dried over anhydrous magnesium sulfate. After removing the solvent, under reduced pressure (15 Torr), the resulting crude was purified by column chromatography (pH=6.7–7.3 silica gel, mixtures of hexane and EtOAc). Yields are given in Table 2; analytical, physical and spectroscopic data, as well as literature references for known compounds, follow.

*4.3.1. 3-Ethylhept-6-en-3-ol (**7a**)[20].* Colorless oil; t_R 8.30; R_f 0.40 (hexane/EtOAc 10:1); ν (film) 3437 (OH), 3077 cm^{-1} (C=CH): δ_H 0.92 (6H, t, J=7.5, 2×CH_3), 1.56 (4H, c, J=7.5, 2×CH_2CH_3), 1.59–1.63 (2H, m, CH_2COH), 1.90 (1H, s, OH), 2.09–2.17 (2H, m, CH_2CH=CH_2), 4.98–5.12 (2H, m, CH=CH_2), 5.94 (1H, ddt, J=17.1,

10.5, 6.3, C*H*=CH_2); δ_C 8.2 (2×CH_3), 28.4 (CH_2CH=CH_2), 31.3 (2×CH_2CH_3), 37.8 (CH_2COH), 75.0 (COH), 114.6 (CH_2=CH), 139.6 (CH_2=*C*H); *m*/*z* 142 (M^+, 0.02%), 124 (16), 95 (76), 87 (19), 67 (32), 57 (34), 55 (100).

*4.3.2. 4-Propyloct-7-en-4-ol (**7b**).* Colorless oil; t_R 10.18; R_f 0.4 (hexane/EtOAc 10:1); ν (film) 3394 (OH), 3077 cm^{-1} (C=CH); δ_H 0.92 (6H, t, *J*=7.0, 2×CH_3), 1.25–1.46, 1.51 (8H and 2H, respectively, 2m, 2×$CH_2CH_2CH_3$ and CH_2COH), 2.07 (2H, m, CH_2CH=CH_2), 5.00 (2H, m, CH=CH_2), 5.84 (1H, ddt, *J*=16.9, 10.1, 6.5, C*H*=CH_2); δ_C 15.3 (2×CH_3), 17.4 (2×CH_2CH_3), 28.9 (CH_2CH=CH_2), 39.0 (CH_2COH), 42.2 (2×CH_2 CH_2CH_3), 75.0 (COH), 114.9 (CH_2=CH), 139.7 (CH_2=CH); *m*/*z* 158 (M^+, 0.01%), 152 (19), 127 (13), 123 (28), 115 (21), 110 (56), 109 (57), 95 (19), 82 (23), 81 (54), 79 (22), 77 (14), 71 (33), 69 (100), 67 (80), 55 (87), 53 (15); HRMS [M^+-H_2O] calcd for 152.1565, found 152.1481.

*4.3.3. 1,1-Dicyclopropylpent-4-en-1-ol (**7c**).* Yellow oil; t_R 10.72; R_f 0.31 (hexane/EtOAc 10:1); ν (film) 3382 (OH), 3073 cm^{-1} (C=CH); δ_H 0.26–0.43 (8H, m, 4×CH_2 ring), 0.80 (2H, m, 2×CH ring), 0.92 (1H, s, OH), 1.64 (2H, m, CH_2COH), 2.27 (2H, m, CH_2CH=CH_2), 5.01 (2H, m, CH_2CH=CH_2), 5.87 (1H, ddt, *J*=17.0, 10.4, 6.4, C*H*=CH_2); δ_C 0.6 (2×CH_2 ring), 0.7 (2×CH_2 ring), 18.5 (2×CH ring), 28.3 (CH_2CH=CH_2), 41.5 (CH_2COH), 70.7 (COH), 114.1 (CH_2=CH), 139.4 (CH_2=CH); *m*/*z* 166 (M^+, 0.05%), 148 (25), 111 (20), 107 (16), 105 (44), 92 (18), 91 (90), 79 (100), 78 (15), 77 (41), 69 (14), 65 (18); HRMS [M^+-H_2O] calcd for $C_{11}H_{16}$ 148.1252, found 148.

*4.3.4. 1-(But-3-enyl)cyclohexanol (**7d**)*[21]. Yellow oil; t_R 8.10.20; R_f 0.30 (hexane/EtOAc 10:1); ν (film) 3423 cm^{-1} (OH); δ_H 1.32–1.42, 1.44–1.60 (4H and 8H, 2 m, 5×CH_2 cyclohexyl and CH_2COH), 2.12 (2H, m, CH_2CH=CH_2), 5.00 (2H, m, CH=CH_2), 5.86 (1H, ddt, *J*=17.0, 10.3, 6.6, C*H*=CH_2); δ_C 22.1, 25.8, 37.4 (5×CH_2 ring), 27.4 (CH_2CH=CH_2), 41.9 (CH_2COH), 71.3 (COH), 114.2 (CH_2=CH), 139.3 (CH_2=CH); *m*/*z* 154 (M^+, 0.07%), 136 (44), 121 (26), 107 (24), 99 (27), 95 (100), 94 (33), 93 (34), 91 (24), 81 (32), 80 (17), 79 (52), 77 (24), 67 (70), 55 (36).

*4.3.5. 2-Phenylhex-5-en-2-ol (**7e**).* Colorless oil; t_R 11.60; R_f 0.30 (hexane/EtOAc 10:1); ν (film) 3405 (OH), 3062 cm^{-1} (C=CH); δ_H 1.54 (3H, s, CH_3), 1.89, 2.03 (3H and 1H, 2m, CH_2CH_2), 2.57 (1H, s, OH), 4.93 (2H, m, CH=CH_2), 5.77 (1H, m, CH_2C*H*=CH_2), 7.21, 7.31, 7.43 (1H, 2H and 2H, 3m, 5×ArH); δ_C 28.4 (CH_2CH=CH_2), 30.2 (CH_3), 42.9 (CH_2COH), 74.5 (COH), 114.0 (CH_2=CH), 126.4, 128.2, 128.6, 147.6 (6×ArC), 138.6 (CH_2=*C*H); *m*/*z* 176 (M^+, 0.16%), 158 (43), 143 (100), 141 (19), 130 (20), 129 (65), 128 (84), 127 (16), 11 (24), 117 (13), 116 (13), 115 (61), 103 (13), 91 (31), 77 (24); HRMS calcd for $C_{12}H_{16}O$ 176.1201, found 176.1273.

*4.3.6. 2,2-Dimethylhept-6-en-3-ol (**7f**)*[22]. Colorless oil; t_R 7.76; R_f 0.44 (hexane/EtOAc 10:1); ν (film) 3386 (OH), 3072 cm^{-1} (C=CH); δ_H 0.89 (9H, s, 3×CH_3), 1.36 (1H, m, C*H*HCHOH), 1.61 (1H, m, CH*H*CHOH), 1.79 (1H, s, OH), 2.10 (1H, m, C*H*HC*H*=CH_2), 2.32 (1H, m, CH*H*C*H*=CH_2), 3.20 (1H, m, C*H*OH), 5.02 (2H, m, CH=CH_2), 5.85 (1H, ddt, *J*=17.1, 10.3, 6.7, C*H*=CH_2); δ_C 25.7 (3×CH_3), 30.7, 31.2 (CH_2CH_2), 34.9 (*C*CHOH), 79.3 (CHOH), 114.7 (CH_2=CH), 138.9 (CH_2=*C*H); *m*/*z* 130 (M^+, 0.01%), 109 (29), 87 (27), 85 (69), 84 (30), 83 (29), 81 (18), 71 (19), 70 (34), 69 (27), 68 (14), 67 (90), 57 (100), 56 (20), 55 (53).

*4.3.7. 2-Methylhept-6-en-3-ol (**7g**)*[23]. Colorless oil; t_R 7.03; R_f 0.33 (hexane/EtOAc 10:1); ν (film) 3382 (OH), 3073 cm^{-1} (C=CH); δ_H 0.87 (6H, d, *J*=9.2, 2×CH_3), 1.38–1.67 (4H, m, CH_2CHO*H*C*H*), 2.00–2.24 (2H, m, CH_2CH=CH_2), 3.33 (1H, m, C*H*OH), 4.99 (2H, m, CH=CH_2), 5.80 (1H, ddt, *J*=17.0, 10.1, 6.7, C*H*=CH_2); δ_C 17.2, 18.7 (2×CH_3), 31.1, 33.8 (CH_2CH_2), 34.2 (*C*HCHOH), 76.1 (CHOH), 115.3 (CH_2=CH), 139.4 (CH_2=*C*H); *m*/*z* 118 (M^+, 0.04%), 109 (29), 87 (27), 85 (69), 84 (30), 83 (29), 81 (18), 71 (19), 70 (34), 69 (27), 68 (14), 67 (90), 57 (100), 56 (20), 55 (53).

*4.3.8. 2-Methylhept-6-en-3-ol (**7h**)*[24]. Yellow oil; t_R 11.5; R_f 0.31 (hexane/EtOAc 10:1); ν (film) 3348 (OH), 3064 cm^{-1} (C=CH); δ_H 1.78 (2H, m, CH_2CHOH), 2.08 (2H, m, CH_2CH=CH_2), 2.50 (1H, s, OH), 4.59 (1H, t, *J*=5.8, C*H*OH), 5.02 (2H, m, CH=CH_2), 5.79 (1H, ddt, *J*=17.0, 10.3, 6.6, CH_2C*H*=CH_2), 7.22–7.30 (5H, m, 5×ArH); δ_C 29.9, 37.9 (CH_2CH_2), 73.8 (CHOH), 114.8 (CH_2=CH), 125.8, 127.4, 128.3, 144.5 (6×ArC), 138.1 (CH_2=*C*H); *m*/*z* 162 (M^+, 0.35%), 144 (39), 143 (22), 129 (100), 128 (56), 127 (14), 115 (38), 107 (22), 91 (17), 79 (14), 77 (17), 65 (14).

4.4. General procedure for the preparation of the alcohols 9

(Bromomethyl)cyclobutane (0.34 mL, 3 mmol) and the electrophile (3.3 mmol) were added to a suspension of lithium powder (100 mg, 14.2 mmol) and DTBB (53.2 mg, 0.2 mmol) in THF (15 mL) at −78 °C. The mixture was stirred for 60 min at the same temperature. The reaction mixture was hydrolyzed with water (10 mL), extracted with ethyl acetate (3×10 mL), and the organic phase was rinsed with brine solution (10 mL) and dried over anhydrous magnesium sulfate. After removing the solvent under reduced pressure (15 Torr), the resulting crude was purified by column chromatography (pH=6.7–7.3 silica gel, mixtures of hexane and EtOAc). Yields are given in Table 4; analytical, physical and spectroscopic data, as well as literature references for known compounds, follow.

*4.4.1. 3-(Cyclobutylmethyl)pentan-3-ol (**9a**).* Yellow oil; t_R 7.12; R_f 0.31 (hexane/EtOAc 10:1); ν (film) 3457 (OH), 3060 cm^{-1} (cyclobutyl); δ_H 0.84 (6H, t, *J*=7.4, 2×CH_3), 1.35 (1H, s, OH), 1.42 (4H, m, 2×CH_2CH_3), 1.52 (2H, d, *J*=6.7, CH_2COH), 1.65–1.90, 2.01 (4H and 2H, 2m, 3×CH_2 ring), 2.44 (1H, m, CH ring); δ_C 7.8 (2×CH_3), 19.4 (CH_2 ring), 29.7 (CH_2), 31.3 (2×CH_2), 31.9 (CH), 45.5 (CH_2), 75.2 (C); *m*/*z* 138 (M^+-H_2O, 17%), 127 (29), 87 (100), 69 (14), 57 (55), 55 (23).

*4.4.2. 4-(Cyclobutylmethyl)heptan-4-ol (**9b**).* Colorless oil; t_R 10.5; R_f 0.33 (hexane/EtOAc 10:1); ν (film) 3452 (OH), 2954 cm^{-1} (cyclobutyl); δ_H 0.90 (6H, t, *J*=9.3, 2×CH_3), 1.12 (1H, s, OH), 1.24–1.38 (8H, m, 2×$CH_2CH_2CH_3$), 1.54 (2H, d, CHCH_2COH), 1.66–1.79, 1.83–1.92, 2.01–2.08 (3H, 1H and 2H, 3 m, 3×CH_2 ring), 2.44 (CH ring); δ_C 14.6 (2×CH_3), 16.8 (2×CH_2CH_3), 19.3 ($CH_2CH_2CH_2$ ring), 30.11 (2×CH_2 ring), 31.9 (CH ring), 41.8 (2×$CH_2CH_2CH_3$), 46.5 (CH_2COH), 74.9 (COH); *m*/*z* 166 (M^+-H_2O, 11%), 141 (15), 138 (15), 123 (14), 115 (46), 109 (16), 97 (15), 96 (16), 95 (100), 91 (10), 82 (13), 81 (45), 79 (21), 77 (27), 69 (20), 67 (58), 55 (79), 53 (18).

*4.4.3. 2-Cyclobutyl-1,1-dicyclopropylethanol (**9c**).* Yellow oil; t_R 9.26; R_f 0.38 (hexane/EtOAc 10:1); ν (film) 3206 (OH), 3087 cm^{-1} (cyclobutyl); δ_H 0.23–0.28, 0.31–0.40 (2H and 6H, 2m, 4×CH_2 cyclopropyl), 0.72–0.79 (2H, m, 2×CH cyclopropyl), 0.87 (1H, s, OH), 1.67 (2H, d, *J*=5.2, CH_2COH), 1.70–1.84, 1.86–1.91, 2.03–2.11 (3H, 1H and 2H, 3 m, 2×CH_2 cyclobutyl), 2.65 (1H, m, *J*=5.8, CH cyclobutyl); δ_C −0.7 (2×CH_2 cyclopropyl), 0.8 (2×CH_2 cyclopropyl), 18.5 (2×CH cyclopropyl), 19.09 (CH_2 cyclobutyl), 30.1 (2×CH_2 cyclobutyl), 31.9 (CH cyclobutyl), 49.7 (CH_2COH), 71.0; (COH); *m*/*z* 162 (M^+-H_2O, 2.6%), 134 (45), 119 (32), 111 (43), 106 (21), 105 (32), 91 (100), 79 (26), 78 (20), 77 (38), 69 (24), 65 (16); HRMS [M^+−OH] calcd for $C_{12}H_{19}$ 163.1486, found 163.1479.

*4.4.4. 1-(Cyclobutylmethyl)cyclohexanol (**9d**).* Colorless oil; t_R 10.75; R_f 0.29 (hexane/EtOAc 10:1); ν (film) 3138 (OH), 2934 cm^{-1} (cyclobutyl); δ_H 1.21 (2H, m, CH_2 ring), 1.32–1.40 (2H,

m, CH_2 ring), 1.46 (4H, m, 2×CH_2 ring), 1.56 (4H, m, 2×CH_2 ring), 10.66–1.84, 1.86–1.93 (3H and 1H, 2m, 2×CH_2 ring), 2.06 (2H, def d, CH_2COH); δ_C 19.4 (CH_2 cyclobutyl), 22.1 (2×CH_2 cyclohexyl), 25.7 (CH_2 cyclohexyl), 30.2 (2×CH_2 cyclobutyl), 31.6 (CH cyclobutyl), 37.5 (2×CH_2 cyclohexyl), 49.9 (CH_2COH), 72.0 (COH); *m*/*z* 168 (M^+, 0.18%), 101 (23), 99 (100), 98 (10), 81 (50), 79 (13), 55 (30); HRMS [M^+-H_2O] calcd for $C_{11}H_{18}$ 150.1409, found 150.1372.

*4.4.5. 1-Cyclobutyl-2-phenylpropan-2-ol (**9e**).* Yelow oil; t_R 12.11; R_f 0.30 (hexane/EtOAc 10:1); ν (film) 3439 cm^{-1} (OH); δ_H 1.50 (4H, m, OH and CH_3), 1.55–1.85 (6H, m, 3×CH_2 ring), 1.82 (2H, m, *J*=6.7, CH_2COH), 2.30 (1H, m, CH ring), 7.18–7.25, 7.40–7.46 (2H and 3H, 2m, 5×ArH); δ_C 19.3 (CH_3), 24.8 (2×CH_2 ring), 29.7 (CH_2 ring), 32.7 (CH ring), 51.4 (CH_2CHOH), 78.8 (CHOH), 124.7, 127.3, 128.0, 143.4 (6×ArC); *m*/*z* 176 (M^+, 0,08%), 122 (10), 105 (12), 121 (100), 78 (15), 77 (23).

*4.4.6. 1-Cyclobutyl-3,3-dimethylbutan-2-ol (**9f**).* Yellow oil; t_R: 9.34; R_f 0.31 (hexane/EtOAc 10:1); ν (film) 3411 cm^{-1} (OH); δ_H 0.88 (9H, s, 3×CH_3), 1.01 (1H, s OH), 1.7, 1.5, 1.67, 1.77–1.94 (1H, 2H, 1H, 2H, m, 3×CH_2 ring), 2.03–2.12 (2H, m, CH_2CHOH), 2.44–2.54 (1H, m, CH ring), 3.16 (1H, m, *CH*OH); δ_C 18.6 (CH_2 ring), 25.6 (3×CH_3), 28.0 (2×CH_2 ring), 29.5 (CH ring), 34.7 (*C*HCHOH), 38.7 (CH_2CHOH), 78.3 (CHOH); *m*/*z* 156 (M^+, 0.01%), 99 (47), 95 (6), 87 (60), 81 (100), 71 (14), 70 (36), 69 (30), 57 (36), 55 (53).

*4.4.7. 1-Cyclobutyl-3-methylbutan-2-ol (**9g**).* Colorless oil; t_R 10.29; R_f 0.29 (hexane/EtOAc 10:1); ν (film) 3383 cm^{-1} (OH); δ_H 0.88 (6H, d, *J*=7.2, 2×CH_3), 1.45–1.58, 1.66–1.72, 1.73–1.79 (2H, 2H and 2H, 3m, 3×CH_2 ring), 1.83–1.92 (2H, m, CH_2CHOH), 1.94–2.07 (1H, m, *CH*CHOH), 2.4–2.7 (1H, m, CH ring); δ_C 18.5, 18.8 (2×CH_3), 20.21, 31.4, 31.8 (3×CH_2 ring), 34.4 (CH ring), 34.6 (*C*HCHOH), 43.0 (CH_2CHOH), 70.2 (CHOH); *m*/*z* 142 (M^+, 11%), 141 (100), 97 (37), 95 (13), 81 (16), 71 (45), 70 (45), 67 (12), 55 (39); HRMS [M^+-H] calcd for $C_9H_{17}O$ 141.1274, found 141.1280.

*4.4.8. 2-Cyclobutyl-1-phenylethanol (**9h**)*[19]. Yellow oil; t_R 13.7; R_f 0.29 (hexane/EtOAc 10:1); ν (film) 3358 (OH), 3029 cm^{-1} (cyclobutyl); δ_H 1.54–2.07 (9H, m, 3×CH_2 ring, CH ring, and C*H*HCHOH), 2.57 (1H, s, OH), 2.31 (1H, m, CH*H*CHOH), 4.55 (1H, t, *J*=6.9, C*H*OH), 7.21–7.32 (5H, m, CHAr); δ_C 18.6 (CH_2 ring), 28.3 (2×CH_2 rin), 32.6 (CH ring), 46.2 (CH_2CHOH), 72.9 (CHOH), 125.8, 127.2, 128.2, 144.8 (6×ArC); *m*/*z* 176 (M^+, 3.81%), 107 (100), 79 (37), 77 (20), 51 (21); HRMS calcd for $C_{12}H_{16}O$ 176.1196, found 176.1197.

4.5. General procedure for the preparation of the alcohols 10

(Bromomethyl)cyclobutane (0.34 mL, 3 mmol) was added to a suspension of lithium powder (100 mg, 14.2 mmol) and DTBB (53.2 mg, 0.2 mmol) in THF (15 mL) at 0 °C. The mixture was stirred for 60 min and then, the corresponding carbonyl compound (3.3 mmol) was added, continuing the stirring for 45 min at the same temperature. The reaction mixture was hydrolyzed with water (10 mL), extracted with ethyl acetate (3×10 mL), and the organic phase was dried over anhydrous magnesium sulfate. After removing the solvent, under reduced pressure (15 Torr), the resulting crude was purified by column chromatography (pH=6.7–7.3 silica gel, mixtures of hexane and EtOAc). Yields are given in Table 4; analytical, physical and spectroscopic data, as well as literature references for known compounds, follow.

*4.5.1. 3-Ethyloct-7-en-3-ol (**10a**).* Colorless oil; t_R 8.57; R_f 0.32 (hexane/EtOAc 10:1); ν (film) 3365 (OH), 3068 cm^{-1} (C=CH); δ_H 0.86 (6H, t, *J*=7.5, 2×CH_3), 1.17 (1H, s, OH), 1.40–1.50 (8H, m, 2×CH_2CH_3 and CH_2CH_2CHOH), 2.06 (2H, CH_2CH=CH_2), 5.00 (2H, m, CH_2CH=CH_2), 5.81 (1H, ddt, *J*=17.2, 10.3, 6.5, CH_2CH=CH_2); δ_C 7.7 (2×CH_3), 22.7 (2×CH_2CH_3), 31.0 (CH_2CH_2COH), 34.2 (CH_2CH=CH_2), 37.6 (CH_2COH), 74.5 (COH), 114.5 (CH_2=CH), 138.7 (CH_2=CH); *m*/*z* 156 (M^+, 0,03%), 127 (28), 87 (96), 86 (11), 69 (15), 57 (19); HRMS [M^++H] calcd for $C_{10}H_{21}O$ 157.1586, found 157.1580.

*4.5.2. 4-Propylnon-8-en-4-ol (**10b**).* Yellow oil; t_R 10.53; R_f 0.30 (hexane/EtOAc 10:1); ν (film) 3468 cm^{-1} (OH); δ_H 0.91 (6H, t, *J*=5.4, 2×CH_3), 1.27–1.37, 1.42 (4H and 8H, 2m, 2×$CH_2CH_2CH_3$ and 2×CH_2CH_2COH), 2.05 (2H, m, CH_2CH=CH_2), 4.98 (2H, m, CH=CH_2), 5.83 (1H, ddt, *J*=12.6, 7.8, 5.1, CH=CH_2); δ_C 14.7 (2×CH_3), 16.7 (2×CH_2CH_3), 22.8 (2×$CH_2CH_2CH_3$), 34.2 (CH_2CH=CH_2), 38.7 ($CH_2CH_2CH_2$), 41.6 (CH_2COH), 74.4 (COH), 114.5 (CH=CH_2), 138.8 (CH=CH_2); *m*/*z* 166 [M^+-H_2O] (4.4%), 141 (23), 123 (22), 115 (55), 110 (24), 95 (27), 91 (12), 84 (24), 83 (26), 82 (18), 81 (58), 79 (26), 77 (17), 71 (66), 69 (62), 67 (58), 55 (100), 53 (27); HRMS [M^+−Et] calcd for $C_{10}H_{19}O$ 155.1435, found 155.1430.

*4.5.3. 1,1-Dicyclopropylhex-5-en-1-ol (**10c**).* Yellow oil; t_R 10.73; R_f 0.29 (hexane/EtOAc 10:1); ν (film) 3488 cm^{-1} (OH); δ_H 0.24–0.31, 0.33–0.45 (3H and 5H, 2m, 4×CH_2 ring),0.81 (2H, m, 2×CH ring), 0.90 (1H, s, OH), 1.58 (2H, m, CH_2COH), 2.07 (2H, m, CH_2CH=CH_2), 4.98 (2H, m, CH_2CH=CH_2), 5.84 (1H, ddt, *J*=17.0, 10.1, 6.7, CH=CH_2); δ_C −0.7 (2×CH_2 ring), 0.7 (2×CH_2 ring), 18.4 (2×CH ring), 23.1 ($CH_2CH_2CH_2$), 34.3 (CH_2CH=CH_2), 42.1 (CH_2COH), 70.7 (COH), 114.3 (CH_2=CH), 138.9 (CH_2=CH); *m*/*z* 162 [M^+-H_2O] (3%), 121 (57), 111 (60), 105 (17), 93 (53), 92 (10), 91 (67), 80 (12), 79 (100), 78 (16), 77 (60), 69 (39), 67 (88), 65 (25), 55 (36); HRMS [M^+-H_2O] calcd for $C_{12}H_{18}$ 162.1409, found 162.1447.

*4.5.4. 1-(Pent-4-enyl)cyclohexanol (**10d**)*[25]. Yellow oil; t_R 10.12; R_f 0.28 (hexane/EtOAc 10:1); ν (film) 3392 cm^{-1} (OH); δ_H 1.28–1.38, 1.44–1.60 (2H and 12H, 2m, 5×CH_2 cyclohexyl, CH_2CH_2COH and CH_2COH), 2.05 (2H, m, CH_2CH=CH_2), 4.97 (2H, m, CH=CH_2), 5.81 (1H, ddt, *J*=17.0, 10.2, 6.6, CH=CH_2); δ_C 22.1, 25.8, 37.4 (5×CH_2 ring), 22.2 ($CH_2CH_2CH_2$), 34.2 (CH_2CH=CH_2), 41.8 (CH_2COH), 71.3 (COH), 114.4 (CH_2=CH), 138.8 (CH_2=CH); *m*/*z* 168 (M), 141 (18), 124 (11), 123 (23), 115 (41), 110 (34), 95 (28), 84 (33), 83 (36), 82 (19), 81 (57), 79 (22), 77 (14), 71 (50), 69 (73), 67 (58), 55 (100), 53 (22); HRMS [M^+−OH] calcd for $C_{11}H_{19}$ 151.1486, found 151.1488.

*4.5.5. 2-Phenylhept-6-en-2-ol (**10e**).* Colorless oil; t_R 11.77; R_f 0.30 (hexane/EtOAc 10:1); ν (film) 3405 (OH), 3062 cm^{-1} (C=CH); δ_H 1.18–1.42 (2H, m, $CH_2CH_2CH_2$), 1.53 (3H, s, CH_3), 1.79 (2H, m, CH_2CHOH), 1.98 (3H, m, CH_2CH=CH_2 and OH), 4.88–4.97 (2H, m, CH=CH_2), 5.65 (1H, ddt, *J*=17.1, 10.3, 6.7, CH=CH_2), 7.17–7.21, 7.22–7.36, 7.37–7.42 (1H, 1H and 3H, 3m, 5×ArH); δ_C 23.2 ($CH_2CH_2CH_2$), 33.8 (CH_2CH=CH_2), 43.5 (CH_2COH), 74.5 (CHOH), 114.5 (CH_2=CH), 138.5 (CH_2=CH), 124.7, 126.4, 128.0, 147.9 (6×ArC); *m*/*z* 176 (M^+, 0.06%), 144 (8), 131 (15), 121 (100), 115 (12), 105 (20), 91 (31), 77 (24); HRMS [M^+] calcd for $C_{13}H_{18}O$ 190.1358, found 190.1358.

*4.5.6. 2,2-Dimethyloct-7-en-3-ol (**10f**)*[22]. Colorless oil; t_R 8.25; R_f 0.32 (hexane/EtOAc 10:1); ν (film) 3420 (OH), 3064 cm^{-1} (C=CH); δ_H 0.89 (9H, s, 3×CH_3), 1.18–1.29, 1.40, 1.52, 1.66 (1H, 1H, 1H and 1H, 4m, CH_2CH_2CHOH), 2.01–2.13 (2H, m, CH_2CH=CH_2), 3.14–.3.19 (1H, m, *CH*OH), 5.83–5.04 (2H, m, CH=CH_2), 5.81 (1H, ddt, *J*=17.1, 10.5, 6.6, CH=CH_2); δ_C 25.6 (3×CH_3), 26.3 ($CH_2CH_2CH_2$), 30.8 (*C*CHOH), 31.2 (CH_2CHOH), 33.7 (CH_2CH=CH_2), 79.8 (CHOH), 114.5 (CH_2=CH), 138.8 (CH_2=CH); *m*/*z* 156 (M^+, 0.02%), 141 (49), 113 (12), 99 (50), 89 (48), 81 (100) 69 (43), 67 (41), 55 (53); HRMS [M^+-H_2O-H] calcd for $C_{10}H_{17}$ 137.1330, found 137.1337.

*4.5.7. 2,2-Dimethyloct-7-en-3-ol (**10g**)*[26]. Colorless oil; t_R 7.03; R_f 0.30 (hexane/EtOAc 10:1); ν (film) 3420 (OH), 2959 cm^{-1} (C=CH);

δ_H 0.91 (6H, d, J=5.3, 2×CH_3), 1.38–1.67 (4H, m, CH_2CHOHCH), 2.00–2.24 (2H, m, CH_2CH=CH_2), 3.33 (1H, m, CHOH), 4.99 (2H, m, CH=CH_2), 5.80 (1H, ddt, J=17.0, 10.1, 6.7, CH=CH_2); δ_C 17.2, 18.7 (2×CH_3), 31.1, 33.8 (CH_2CH_2), 34.2 (CHCHOH), 76.1 (CHOH), 115.3 (CH_2=CH), 139.4 (CH_2=CH); m/z 118 (M^+, 0.04%), 109 (29), 87 (27), 85 (69), 84 (30), 83 (29), 81 (18), 71 (19), 70 (34), 69 (27), 68 (14), 67 (90), 57 (100), 56 (20), 55 (53); HRMS [M^+] calcd for $C_9H_{18}O$ 142.1358, found 142.1357.

*4.5.8. 1-Phenylhex-5-en-1-ol (**10h**).* Yellow oil; t_R 11.5; R_f 0.30 (hexane/EtOAc 10:1); ν (film) 3368 (OH), 3063 cm^{-1} (C=CH); δ_H 1.32, 1.36–1.50, 1.52–1.81 (1H, 1H and 2H, 3m, CH_2CH_2CHOH), 1.98–2.07 (2H, m, CH_2CH=CH_2), 2.55 (1H, s, OH), 4.58 (1H, m, CHOH), 4.90–5.00 (2H, m, CH=CH_2), 5.75 (1H, ddt, J=17.1, 10.2, 6.6, CH_2CH=CH_2), 7.21–7.33 (5H, m, ArH); δ_C 33.5 ($CH_2CH_2CH_2$), 38.4 (CH_2CH=CH_2), 65.3 (CH_2CHOH), 74.7 (CHOH), 114.6 (CH_2=CH), 140.8 (CH_2=CH), 127.6, 128.4, 128.5, 144.9 (6×ArC); m/z 176 (M^+, 0.16%), 158 (43), 143 (100), 141 (19), 130 (20), 129 (65), 128 (84), 127 (16), 11 (24), 117 (13), 116 (13), 115 (61), 103 (13), 91 (31), 77 (24); HRMS [M^+] calcd for $C_{12}H_{16}O$ 176.1201, found 176.1209.

4.6. Preparation of the silyl compounds 11–14

Following the same procedures as described for the preparation of the alcohols the corresponding silyl derivatives **11–14** were prepared and isolated, employing $PhMe_2SiCl$ as electrophile. Yields are given in Scheme 3; analytical, physical and spectroscopic data, follow.

*4.6.1. (Cyclopropylmethyl)dimethyl(phenyl)silane (**11**).* Yield 60%; colorless oil; t_R 11.00; R_f 0.30 (hexane); ν (film) 3069 cm^{-1} (CH ring); δ_H 0.10 (1H, m, CHH ring), 0.33 (1H, m, CHH ring), 0.37 (2H, m, CH_2 ring), 0.42 (6H, s, 2×CH_3), 0.46 (1H, m, CH ring), 0.92 (2H, d, J=6.4, CH_2Si), 7.34–7.61 (5H, m, 5×ArH); δ_C 0.7 (2×CH_3), 0.82 (2×CH_2 ring), 6.1 (CH ring), 31.3 (CH_2Si), 126.6, 127.7, 133.0, 149.9 (6×ArC); m/z 190 (M^+, 2.3%), 175 (8), 136 (14), 135 (100), 121 (8), 107 (6), 105 (8), 91 (8).

*4.6.2. (But-3-en-1-yl)dimethyl(phenyl)silane (**12**).* Yield 94%; yellow oil; t_R 10.60; R_f 0.30 (hexane/EtOAc 10:1); ν (film) 2986 cm^{-1} (C=CH); δ_H 0.25 (6H, s, 2×CH_3), 0.85 (2H, m, CH_2Si), 2.06 (2H, m, CH_2CH=CH_2), 4.94 (2H, m, CH=CH_2), 5.86 (1H, ddt, J=17.0, 10.1, 6.2, CH_2CH=CH_2), 7.33, 7.50 (3H and 2H, 2m, 5×ArH); δ_C 0.8 (2×CH_3), 14.8 (CH_2Si), 27.9 (CH_2CH=CH_2), 112.8 (CH_2=CH), 127.7, 128.8, 132.9, 141.4 (6×ArC), 139.2 (CH_2=CH); m/z 190 (M^+, 5.4%), 175 (16), 162 (13), 136 (14), 135 (100), 121 (25), 105 (10).

*4.6.3. (Cyclobutylmethyl)dimethyl(phenyl)silane (**13**).* Yield 73%; colorless oil; t_R 10.60; R_f 0.27 (hexane); ν (film) 2955 cm^{-1} (CH ring); δ_H 0.25 (6H, s, 2×CH_3), 0.98 (2H, d, J=7.5, CH_2Si), 1.53–1.68 (2H, m, CH_2 ring), 1.7–1.8 (2H, m, CH_2 ring), 2.0–2.09 (1H, m, CH ring), 7.34, 7.45 (3H and 2H, 2 m, 5×ArH); δ_C 0.8 (2×CH_3), 18.5 (CH_2 ring), 24.8 (CH_2Si), 32.4 (CH ring), 32.8 (2×CH_2 ring), 127.6, 127.9, 133.5, 139.9 (6×ArC); m/z 204 (M^+, 0.05%), 176 (5), 161 (4), 136 (14), 135 (100), 107 (11), 105 (16), 91 (10); HRMS [M^+] calcd for $C_{13}H_{20}Si$ 204.1334, found 204.1321.

*4.6.4. (Dimethyl)pent-4-en-1-yl(phenyl)silane (**14**).* Yield 84%; yellow oil; t_R 11.60; R_f 0.29 (hexane/EtOAc 10:1); ν (film) 2958 cm^{-1} (C=CH); δ_H 0.32 (6H, s, 2×CH_3), 0.83 (2H, m, CH_2Si), 1.47 (2H, m, $CH_2CH_2CH_2$), 2.12 (2H, m, CH_2CH=CH_2), 5.01 (2H, m, CH=CH_2), 5.82 (1H, m, CH_2CH=CH_2), 7.39, 7.55 (3H and 2H, 2m, 5×ArH); δ_C 3.1 (2×CH_3), 15.3 (CH_2Si), 23.4 ($CH_2CH_2CH_2$), 37.5 (CH_2CH=CH_2), 114.5 (CH_2=CH), 127.7, 128.7, 133.5, 139.5 (6×ArC), 138.8 (CH_2=CH); m/z 204 (M^+, 0.04%), 161 (9), 136 (14), 135 (100), 126 (14), 121 (25), 105 (8); HRMS [M^+−Me] calcd for $C_{12}H_{17}Si$ 189.1100, found 189.1122.

Acknowledgements

This work was generously supported by the Spanish Ministerio de Educación y Ciencia [CTQ2004-01261, CTQ2007-65218, and CONSOLIDER INGENIO 2010 (CSD2007-00006)], the Generalitat Valenciana (GRUPOS 03/135, GV05/52, GV/2007/036, GVPRE/2008/278 and PROMETEO 2009/039) and the Universidad de Alicante. I.P. thanks the Spanish Ministerio de Educación y Ciencia for a predoctoral fellowship. We also thank Medalchemy S.L. for a gift of chemicals, especially lithium powder.

References and notes

1. (a) Boudier, A.; Bromm, L. O.; Lotz, M.; Knochel, P. *Angew. Chem., Int. Ed.* **2000**, *39*, 4414–4435; (b) Knochel, P.; Hupe, E.; Dohle, W.; Lindsay, D. M.; Bonnet, V.; Queguiner, G.; Boudier, A.; Kopp, F.; Demay, S.; Seidel, N.; Calaza, M. I.; Vu, V. A.; Sapountzis, I.; Bunlaksananusorn, T. *Pure Appl. Chem.* **2002**, *74*, 11–17; (c) Yus, M.; Foubelo, F. In *Handbook of Functionalized Organometallics*; Knochel, P., Ed.; Wiley-VCH: Weinheim, 2005.
2. (a) Nájera, C.; Yus, M. *Trends Org. Chem.* **1991**, *2*, 155–181; (b) Nájera, C.; Yus, M. *Org. Prep. Proced. Int.* **1995**, *27*, 383–457; (c) Nájera, C.; Yus, M. *Recent Res. Dev. Org. Chem.* **1997**, *1*, 67–96; (d) Yus, M.; Foubelo, F. *Rev. Heteroat. Chem.* **1997**, *17*, 73–107; (e) Nájera, C.; Sansano, J. M.; Yus, M. *Tetrahedron* **2003**, *59*, 9255–9303; (f) Nájera, C.; Yus, M. *Curr. Org. Chem.* **2003**, *7*, 867–926; (g) Chinchilla, R.; Nájera, C.; Yus, M. *Chem. Rev.* **2004**, *104*, 2667–2722; (h) Chinchilla, R.; Nájera, C.; Yus, M. *Tetrahedron* **2005**, *61*, 3139–3176; (i) Nájera, C.; Yus, M. *Tetrahedron* **2005**, *61*, 3125–3450; (j) Brandsma, L.; Zwikker, J. W. *Sci. Synth.* **2006**, *8a*, 243–252; (k) Foubelo, F.; Yus, M. *Chem. Soc. Rev.* **2008**, *37*, 2620–2633.
3. Tomooka, K.; Ito, M. In *Main Group Metals in Organic Synthesis*; Yamamoto, H., Oshima, K., Eds.; Wiley-VCH: Weinheim, 2004; pp 1–34.
4. (a) Yus, M. *Chem. Soc. Rev.* **1996**, *25*, 155–161; (b) Ramón, D. J.; Yus, M. *Eur. J. Org. Chem.* **2000**, 225–237; (c) Yus, M. *Synlett* **2001**, 1197–1205; (d) Ramón, D. J.; Yus, M. *Rev. Cubana Quim.* **2002**, *14*, 75–115; (e) Yus, M.; Ramón, D. J. *Latv. J. Chem.* **2002**, 79–92; (f) Yus, M. In *The Chemistry of Organolithium Compounds*; Rappoport, Z., Marek, I., Eds.; J. Wiley & Sons: Chichester, UK, 2004; pp 647–747.
5. Mealy, M. J.; Bailey, W. F. *J. Organomet. Chem.* **2002**, *646*, 59–67.
6. (a) Bailey, W. F.; Carson, M. W. *J. Org. Chem.* **1998**, *63*, 9960–9967; (b) Bailey, W. F.; Carson, M. W. *J. Org. Chem.* **1998**, *63*, 361–365; (c) Bailey, W. F.; Carson, M. W. *Tetrahedron Lett.* **1999**, *40*, 5433–5437; (d) Bailey, W. F.; Mealy, M. J.; Wiberg, K. B. *Org. Lett.* **2002**, *4*, 791–794; (e) Bailey, W. F.; Jiang, X. *Tetrahedron* **2005**, *61*, 3183–3194.
7. (a) Tomooka, K.; Komine, N.; Sasaki, T.; Shimizu, H.; Nakai, T. *Tetrahedron Lett.* **1998**, *39*, 9715–9718; (b) Hoffmann, R. W.; Koberstein, R.; Harms, K. *J. Chem. Soc., Perkin Trans. 2* **1999**, 183–192; (c) Krief, A.; Remacle, B.; Mercier, J. *Synlett* **2000**, 1443–1446; (d) Deng, K.; Bensari, A.; Cohen, T. *J. Am. Chem. Soc.* **2002**, *124*, 12106–12107.
8. (a) Yus, M.; Ortiz, R.; Huerta, F. F. *Tetrahedron Lett.* **2002**, *43*, 2957–2960; (b) Yus, M.; Ortiz, R.; Huerta, F. F. *Tetrahedron* **2003**, *59*, 8525–8542; (c) Yus, M.; Ortiz, R. *Eur. J. Org. Chem.* **2004**, 3833–3841; (d) Yus, M.; Ortiz, R. *Lett. Org. Chem.* **2004**, *1*, 365–368; (e) Ortiz, R.; Yus, M. *Tetrahedron* **2005**, *61*, 1699–1707.
9. (a) Lansbury, P. T.; Pattison, V. A. *J. Am. Chem. Soc.* **1963**, *85*, 1886–1887; (b) Lansbury, P. T.; Pattison, V. A.; Clement, W. A.; Sidler, J. D. *J. Am. Chem. Soc.* **1964**, *86*, 2247–2251.
10. Charette, A. B.; Naud, J. *Tetrahedron Lett.* **1998**, *39*, 7259–7262.
11. Hoffmann, R.; Koberstein, R. *J. Chem. Soc., Perkin Trans. 2* **2000**, 595–602.
12. Clayden, J.; Watson, D. W.; Chambers, M. *Tetrahedron* **2005**, *61*, 3195–3203.
13. Maercker, A.; Bsata, M.; Buchmeier, W.; Engelrn, B. *Chem. Ber.* **1984**, *117*, 2547–2554.
14. Hill, E. A.; Richey, H. G., Jr.; Rees, T. C. *J. Org. Chem.* **1963**, *28*, 2161–2162.
15. Bailey, W. F.; Punzalan, E. R.; Della, E. W.; Taylor, D. K. *J. Org. Chem.* **1995**, *60*, 297–300.
16. (a) Hill, E. A.; Davidson, J. A. *J. Am. Chem. Soc.* **1964**, *86*, 4663–4669; (b) Hill, E. A.; Ni, H.-R. *J. Org. Chem.* **1971**, *36*, 4133–4134; (c) Hill, E. A. *J. Organomet. Chem.* **1975**, *91*, 123–271; (d) Hill, E. A. *Adv. Organomet. Chem.* **1977**, *16*, 131–165; (e) Hill, E. A.; Hallade, M. W. *J. Organomet. Chem.* **1988**, *352*, 263–272.
17. Pastor, I. M.; Peñafiel, I.; Yus, M. *Tetrahedron Lett.* **2008**, *49*, 6870–6872.
18. For a review on Barbier-type reactions, see: Alonso, F.; Yus, M. *Recent Res. Dev. Org. Chem.* **1997**, *1*, 397–436.
19. Christoffers, J.; Kauf, T.; Werner, T.; Rössle, M. *Eur. J. Org. Chem.* **2006**, 2601–2608.
20. Kondo, T.; Tsunawaki, F.; Sato, R.; Ura, Y.; Wada, K.; Mitsudo, T. *Chem. Lett.* **2003**, *32*, 24–25.
21. Hon, Y.-S.; Liu, Y.-W.; Hsich, C.-H. *Tetrahedron* **2004**, *60*, 4837–4860.
22. Hay, M. B.; Hardin, A. R.; Wolfe, J. P. *J. Org. Chem.* **2005**, *70*, 3099–3107.
23. Taillier, C.; Hameury, T.; Bellosta, V.; Cossy, J. *Tetrahedron* **2007**, *63*, 4472–4490.
24. Chatgilialoglu, C.; Ferreri, C.; Ballestri, M.; Mulazzani, Q. G.; Landi, L. *J. Am. Chem. Soc.* **2000**, *122*, 4593–4601.
25. Hu, N. X.; Aso, Y.; Otsubo, T.; Ogura, F. *J. Org. Chem.* **1989**, *54*, 4391–4397.
26. Meyer, C.; Marek, I.; Courtemanche, G.; Normant, J. *Tetrahedron* **1994**, *50*, 11665–11692.