

GENERATION OF DIENONE AND TRIENONE DIANION DERIVATIVES

DOUBLE DEPROTONATION AS A ROUTE TO LUMO-FILLED π -SYSTEMS^{1,2}

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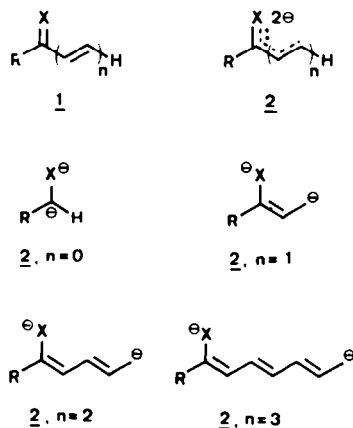
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Abstract—Conjugated unsaturated carbonyl compounds and their analogues **1** are $a^{1,3,5,\dots}$ -reagents. An umpolung of this intrinsic reactivity can be achieved by generation of the dianions **2**, LUMO filled π -systems, from hydrogenated precursors, see schemes 1 and 2. The preparation of the allylated ketones **3a–d**, of the acid derivatives **3e–h**, **9**, **10**, **12** as well as of the dienones **11** is described. Their double deprotonation (\rightarrow **14**, **18**, **26**, **30**, **33**, **36**, and **40**) is carried out by sequential treatment with potassium hydride and *s*-butyllithium/tetramethylethylene diamine (TMEDA) in THF. The decisive role of potassium in the second deprotonation step is demonstrated (Table 1 and eqn (6)). The brightly colored suspensions or solutions of these Li/K-dianions were quenched with the electrophile benzophenone. The products (**15**, **20**, **27**, **31**, **34**, **37**, **41**) result *exclusively* from ω -reactivity (d^5 - and d^7 -reactivity) of the ambident dianionic nucleophiles (*cf* formulae **2**, $n = 2, 3$).

Conjugated unsaturated carbonyl derivatives and their vinylogues **1** show electrophilic or *acceptor* (a) reactivity and are widely used as a^{2n+1} -reagents.⁴ Although highly desirable from the synthetic viewpoint, the vinylogous reactivities (a^3 - or *Michael*-addition, a^5 , a^7 , ...) are often difficult to realize selectively. If the lowest unoccupied orbital of **1** could be filled with two electrons, a dianion derivative **2** would result in which the acceptor properties of **1** are reversed (redox-umpolung). In principle, the *donor* system **2** might exhibit d^1 -, d^3 -, d^5 -, ... reactivity. It was, however, to be expected that charge repulsion and thermodynamic stability of the monoanion formed upon electrophile attack would strongly favour ω -reactivity as indicated in the accompanying formulae **2** for $n = 0$ –3. Thus, if available on a preparative scale, derivatives of dianions **2** (LUMO filled π -systems) might provide an umpolung of reactivity as well as remote reactivity.

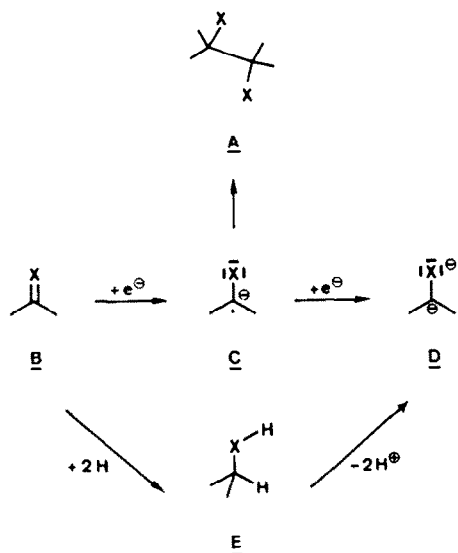
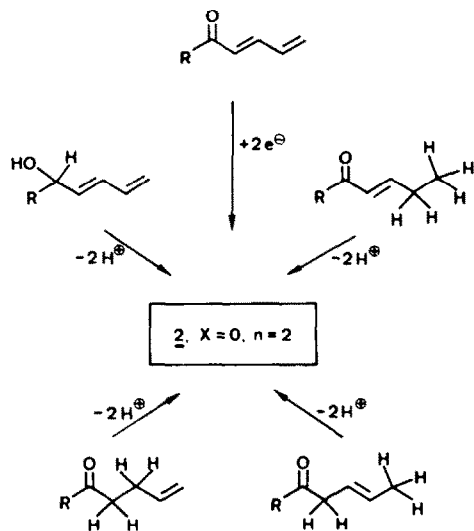
Since it is not reasonable to expect that the reduction **1** \rightarrow **2** could be achieved directly with alkali metals or electrochemically, conditions which are known to lead to coupling products^{5,6} (for instance **B** \rightarrow **C** \rightarrow **D** vs **B** \rightarrow **C** \rightarrow **A** in Scheme 1), we chose a different approach: hydrogenation of one of the double bonds of the π -system and subsequent double deprotonation lead to the same result as addition of two electrons. This is shown in Scheme 1 for the most simple system **1**, $n = 0$, see **B** \rightarrow **E** \rightarrow **D**. In previous papers, we have described the generation of Li- and Mg-derivatives **2**, $n = 0$ and **1**, $X = 0$ and S^4 (*cf.* also the doubly deprotonated nitroalkanes⁷). The subject of the present publication^{2b} is the system **2**, $n = 2$ and **3**. For oxygen as heteroatom X and $n = 2$, the potential precursors are assembled in Scheme 2, the most promising starting material being the γ , δ -unsaturated carbonyl compound because it should be most readily accessible



by an allylation and because the second deprotonation step is expected to be more facile than in all the other cases.⁸

A. Preparation of starting materials

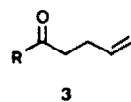
Except for the commercially available allylacetone (**3a**) and 4-pentenoic acid (**3e**), from which the ester **3f** and the amides **3g** and **3h** were obtained by conventional methods, the ketones **3b**, **c** and **d** were prepared through the corresponding *N*, *N*-dimethylhydrazones **4a**, **4c**, and **4d**, respectively. Direct allylation of the lithium enolates of pinacolone and acetophenone was complicated by double allylation, while the Li- enehydrazinates⁹ of **4a** and **4d** were cleanly monoallylated (\rightarrow **4b**, **4e**) and subsequently hydrolyzed to the ketones **3b** and **3d**, respectively. The overall yield of **3c** from **4c** according to eqn (1a)—without isolation of intermediates—was 80-

Scheme 1. Two routes to *LUMO* filled π -systems.Scheme 2. Possible precursors of the generation of a dianion derivative **2**, $n = 2$.

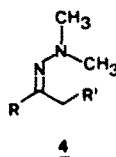
86%, while the dithiane route¹⁰ (1b) gave only *ca.* 50% of the same product.¹¹ The β , γ - and the α , β -unsaturated ketones **5** were obtained from **3b** as indicated in eqn (2a). The dienone **7** and the corresponding alcohol **8** were also prepared from **3b** by thiolation¹² (\rightarrow 6), sulfoxide elimination (\rightarrow 7) and DIBAH reduction (\rightarrow 8). The α -thiolated ester **9** and the malonates **10** are available by allylation of the corresponding precursors. The ketone **11a** and the hydroxyketone **11b** could be synthesized just like the analogues with one less double bond using 5-bromo-1,3-pentadiene instead of allyl bromide. In order to also include sulfur analogues in this investigation, the dithiopentenoic esters **12a** and **12b** were made from the homoallyl *Grignard* reagent as shown in eqn (3).

B. Polydeprotonation studies

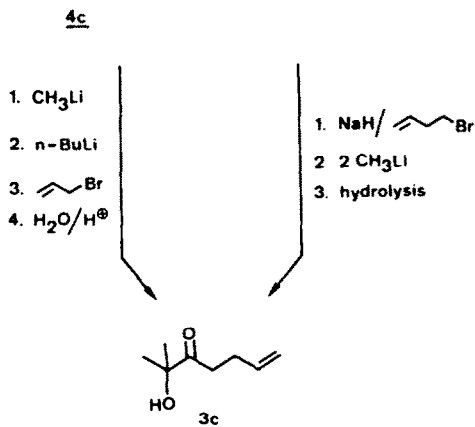
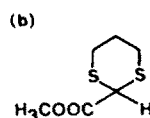
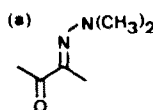
The precursors described in the previous section were treated with bases and base combinations under various



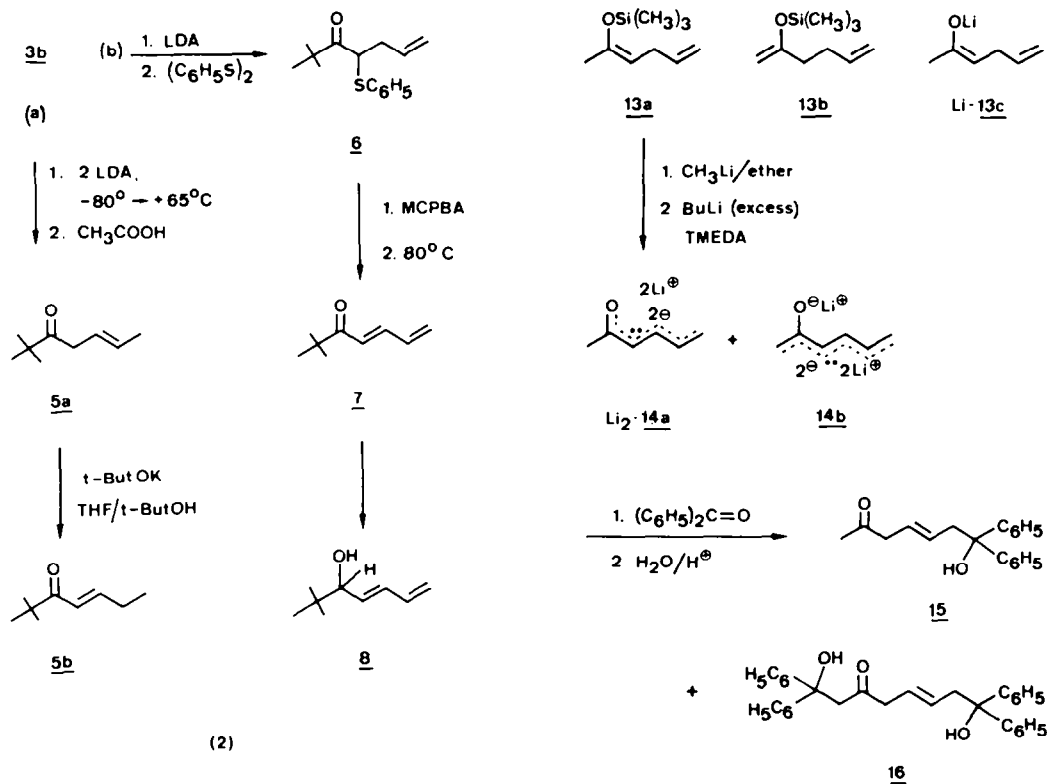
	R	3	R
3a	CH ₃	3e	OH
b	C(CH ₃) ₃	f	OCH ₃
c	C(OH)(CH ₃) ₂	g	N(CH ₂) ₄
d	C ₆ H ₅	h	NHC ₆ H ₅



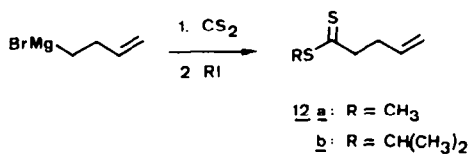
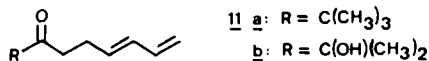
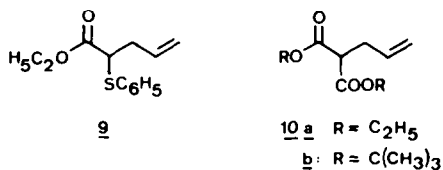
	R	R'
4a	C(CH ₃) ₃	H
b	C(CH ₃) ₃	CH ₂ -CH=CH ₂
c	COCH ₃	H
d	C ₆ H ₅	H
e	C ₆ H ₅	CH ₂ -CH=CH ₂



(1)

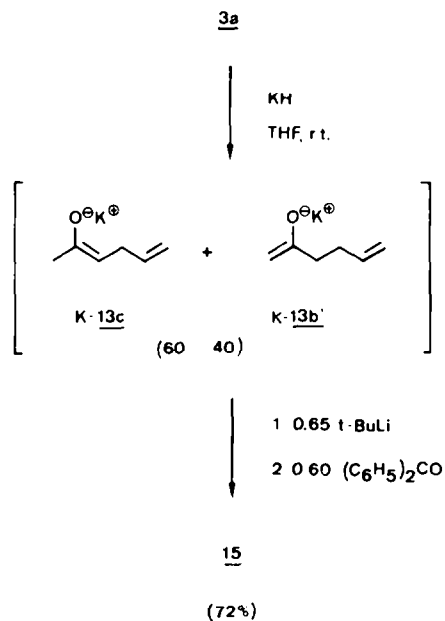


(2)



(3)

through a spinning band column. Sequential treatment of an ether solution of **13a** with methyl lithium (\rightarrow Li-**13c**), excess butyllithium (brown solution), and benzophenone gave the mono- and the diadduct **15** and **16**, respectively (yield 45%, ratio 1:2). This result indicated that both the di- and trilithioderivatives **14a** and **14b** had been formed and that both reacted at the ω -position with the electrophile. It was not possible to cleanly deprotonate the lithium enolate Li-**13c** to Li₂-**14a** under a variety of conditions [ether, THF as solvents, with and without tetramethyl ethylene diamine (TMEDA), n-, sec-,



conditions in order to generate dianion derivatives of type 2. The optimizations were carried out with benzophenone as the electrophile. Other reactions will be dealt with in subsequent papers.^{2b}

(a) *5-Hexen-2-one* (*Allylacetone*) is the most simple and at the same time the most crucial precursor for this reaction because of the presence of two enolizable α -positions. We first prepared a mixture of the two silyl enol ethers **13a** and **13b** from which the desired isomer could be separated in low yield by fractional distillation

and *t*-BuLi, -80° to 0°). We therefore turned to the use of potassium hydride¹³ as the first base. It converts allyl acetone to a 3:2 mixture of the thermodynamic and the kinetic enolate **K-13c** and **-13b'** as shown by quenching with chlorotrimethylsilane (\rightarrow **13a** + **13b**). *t*-BuLi reacts selectively¹⁴ with **K-13c** to give a dianion derivative **LiK-14a** (brown soln) which of course is much more reactive than the simultaneously present monoenolate **13b'**. Thus, it was possible to use just the amount of *t*-BuLi corresponding to the "right" enolate **K-13c** and prepare the d^5 -product **15** in high yield calculated from the electrophile benzophenone. Besides **15** no other adduct could be isolated by careful chromatography. The use of potassium hydride is far superior to the method which we checked first, (a) because it avoids the necessity of preparing the silyl enol ether **13a** and (b) since the potassium enolate **K-13c** is deprotonated much more readily than its Li-analogue.

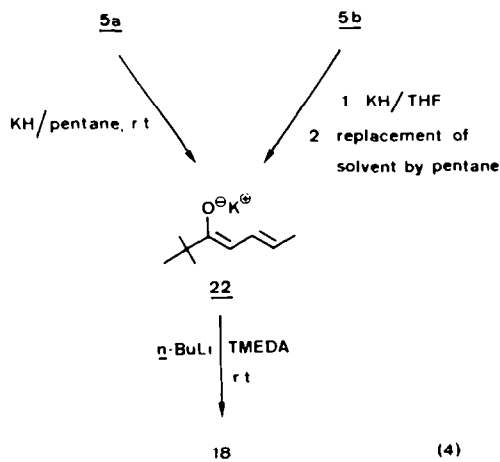
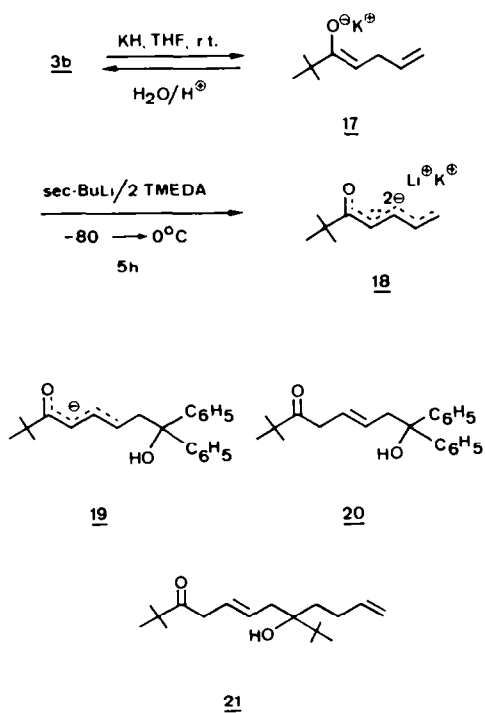
(b) *2,2-Dimethyl-6-hepten-3-one* (*Allylpinacolone*) does not have two acidic α -positions and therefore avoids the complication encountered with the methyl ketone above. When treated with potassium hydride in THF at room temperature until hydrogen evolution ceases, the enolate **17** is formed from **3b** without double bond migration: addition of acetic acid leads to quantitative recovery of **3b**. Addition of two equivalents of TMEDA and of one equivalent of *s*-BuLi to the solution of the potassium enolate at -78° and warming to 0° generates an orange-yellow suspension of the doubly metalated ketone **18**: Quenching with acetic acid gives 85% of the β , γ -unsaturated isomer **5a** of the allyl ketone **3b**, reaction with benzophenone furnishes a 59–80% yield of d^5 -product **20**. Obviously, both electrophiles combine with the dianion derivative exclusively at the ω -position to give dienolates (such as **19**) which are known to be kinetically protonated in the α -position¹⁵ (see **19** \rightarrow **20**). The position and configuration of the double bond can be unambiguously derived from the ^1H - and ^{13}C -NMR-

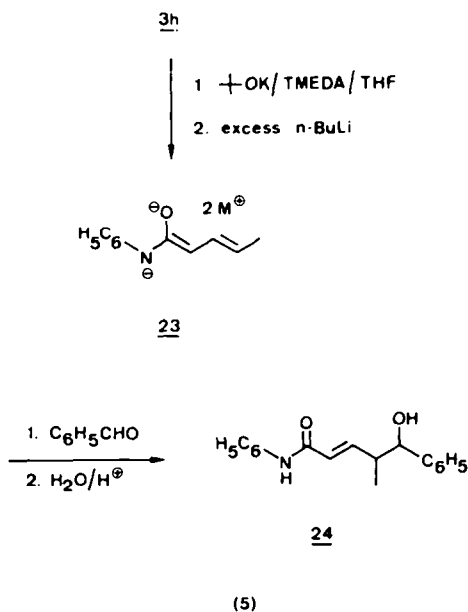
as well as from the IR spectra, see Experimental and discussion in a subsequent paper.^{2b} We conclude from these and other reactions with a variety of electrophiles (Section C) that **18** is formed to an extent of ca. 80%. Besides starting ketone **3b**, β , γ -isomer **5a**, and the hydroxy-ketone **20**, the "dimer" **21** was present in the crude reaction mixture (see Section B.a), above, and.^{2b}

Generation of the Li/K-derivative **18** was also tested with other potential precursors (see Scheme 2): (a) direct reduction of the dienone **7** with lithium naphthalenide or with sodium metal in THF leads to the expected mixture of products after hydrolysis, no enone **5a**, which would be indicative of dianion formation, could be detected (b) Treatment of the carbinol **8** with an excess of metalating reagents under a variety of conditions does not lead to the familiar orange-yellow suspension or any hydrolysis product with carbonyl absorption in the IR spectrum (c) Both ketones **5a** and **5b** are converted to the dienolate **22** with potassium hydride in THF, but subsequent deprotonation with *s*-BuLi/2 TMEDA (-78° to 0°) leads only to traces of dianion derivative **18**. This confirms the expectation⁸ that the non-conjugated enolate **17** is more readily deprotonated than its conjugated isomer **22**. If the solvent THF is replaced by pentane as indicated in eqn (4), a slow room temperature (R.T.) conversion of **22** to **18** is possible as evident from additions to benzophenone (\rightarrow 44% **20**) or benzaldehyde (\rightarrow 69% adduct^{2b}).

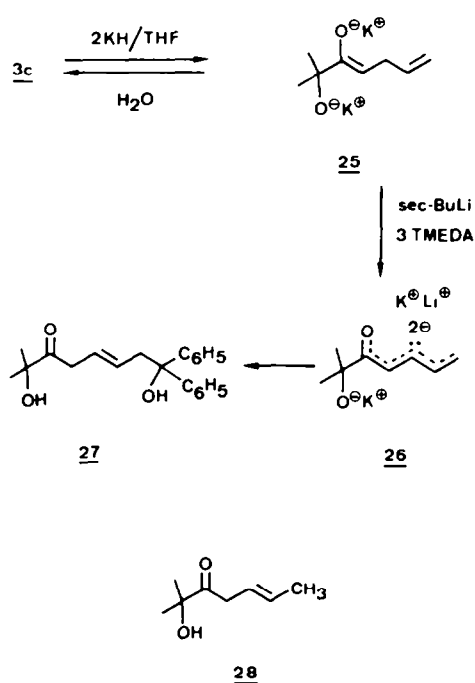
(c) *Pentenoic acid derivatives, and hydroxyketone 3c*. For a potential synthetic application of LUMO-filled π -systems of type **2**, the group R must be variable. The numerous functional group transformations of carboxylic acid derivatives would render polydeprotonations of the acid **3e**, of the esters **3f**, **9** and **10**, or of the amides **3g** and **3h** most useful. Unfortunately, all our attempts with these compounds have completely failed. In no case did we isolate any of the desired d^5 -products after treatment of the precursors with excess base and electrophiles. In addition to starting materials, double bond isomers, decomposition products or aldole-type products were obtained with carbonyl electrophiles. In the case of the anilide **3h**, the sequence of reactions given in equation (5) leads to the formation of 58% of the d^4 -product **24**, suggesting that double rather than triple deprotonation had occurred with double bond shift and that the resulting **23** has been intercepted by the electrophile benzaldehyde.¹⁶

Since the double metalation of homoallylketones had been successful, we looked for another group R in **3**,





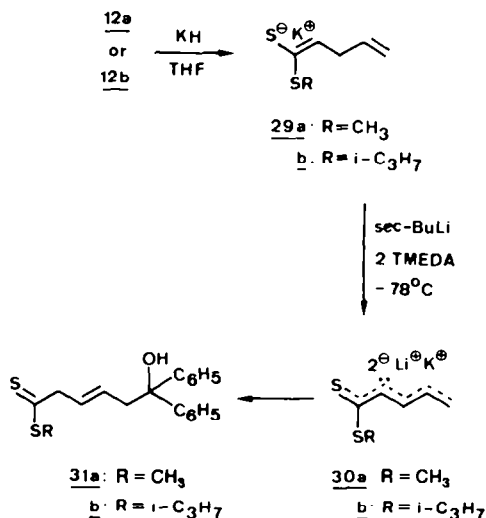
which ought to be readily converted to a carboxylic acid functionality and be concomitantly compatible with the strong bases (= nucleophiles) necessary for polydeprotonation. α -Hydroxyketones undergo facile oxidative cleavage;^{11,17} we therefore investigated the possibility of removing three protons from **3c**. Treatment with 2 equivalents of potassium hydride in THF afforded a suspension of the alkoxide enolate **25** (deduced from the quantitative recovery of **3c** or its α -D-derivative with H_2O and D_2O , respectively). Subsequent addition of $s\text{-BuLi}$ in the presence of three equivalents of TMEDA gave a red suspension of the trianion derivative **26**, which reacted with benzophenone at -78° to furnish a 48% yield of the d^5 -adduct **27**, from which unreacted **3c** and its isomer **28** could be easily separated. Other con-

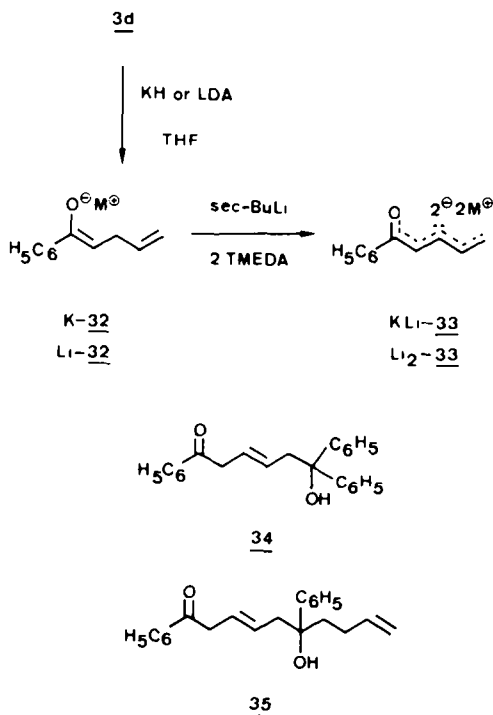


ditions for the third deprotonation (higher temperature, absence of TMEDA, t - instead of $s\text{-BuLi}$, HMPT as cosolvent) prove unsatisfactory, primarily because of a double bond shift in **25** which leads to the formation of **28**. The alkoxide dienolate isomer of **25** is obviously not further lithiated, see above.

(d) *Dithioesters 12a and 12b*. In light of the well documented ability of sulfur to stabilize anions, these two carboxylic acid derivatives should behave quite differently from their oxygen analogues which could not be doubly deprotonated. In fact, the dithioesters are smoothly converted to dienone dianion derivatives **30** by sequential treatment with potassium hydride (0°) and $s\text{-BuLi}/2$ TMEDA (-78°) in THF; **30a** forms an orange suspension, **30b** a red-brown solution. Both combine with benzophenone at their terminal carbon atoms to give high yields of the adducts **31**. To our knowledge, this is the first reported case of a sulfur-substituted, conjugated anion system exclusively¹⁰ reacting with an electrophile in the ω -position: even the dilithioderivative **2**, $n = 1$, $X = \text{S}$, $R = \text{H}$, in which the two formal negative charges reside on only four atoms, gives α,γ -mixtures.¹⁸ Unfortunately, we have not yet been able to desulfurize products of type **31** to "normal" carboxylic acid derivatives (*cf* previous section).

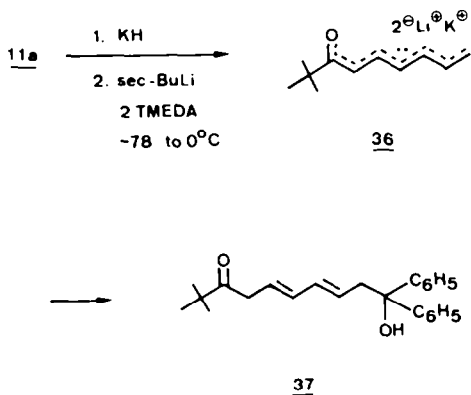
(e) *1-Phenyl-4-penten-1-one (3d)*. This ketone was considered to be especially amenable to dianion formation: it lacks α' -protons, and the phenyl substituent would be expected to exert a conjugative stabilization by extending the π -system. However, ortho-metalation of the benzene ring is one process which could compete with the desired second side chain deprotonation. The enolates, $\text{Li}^\oplus\text{-32}$ and $\text{K}^\oplus\text{-32}$ can be generated with one equivalent of lithium diisopropylamide (LDA) or with one equivalent of potassium hydride, respectively (up to 98% α -deuterio-**3d** with D_2O). Both the LiK - and the Li_2 -derivative **33**, the latter one after evaporative removal of diisopropyl amine (experimental), can be generated with $s\text{-BuLi}/2$ TMEDA from $\text{K}^\oplus\text{-32}$ and from $\text{Li}^\oplus\text{-32}$, respectively (*deep red-violet* soln). They yield 40–65% of the d^5 -adduct **34** with equimolar amounts of benzophenone. The ketone **3d**, the β,γ -unsaturated isomer of **3d**, and the "dimer" **35** (5–15%) are the only other compounds isolated chromatographically from the crude mixture. In view of the quantitative enolate for-





mation we do not understand how **35** arises: the process is definitely not benzophenone induced, since quenching of the LiK-**33** solution with acetic acid also leads to the isolation of up to 10% of **35**.

(f) The dienone **11a** and the hydroxydienone **11b** should form the more extended π -system, consisting of 8 atoms, much more readily than the enones dealt with in the previous sections. It was especially interesting to investigate whether they would still show ω -(d^7)-reactivity. Double deprotonation of **11a** in the usual way resulted in a red THF-suspension, which contained the LiK-derivative of the desired LUMO-filled π -system **36** as demonstrated by the isolation of the hydroxy-ketone **37** with benzophenone. Besides a ca. 54% yield of this product, careful chromatography gave no indication that any of the other conceivable isomeric d^3 - or d^5 -adducts had been formed: there was some starting ketone and its β , γ , δ , ϵ -dienone isomer (10–15%), the rest of the material balance consisted of highly polar material, from which no pure compound could be obtained or identified. With hydroxyketone **11b**, we encountered a severe isomerisation problem: deprotonation to the alkoxide

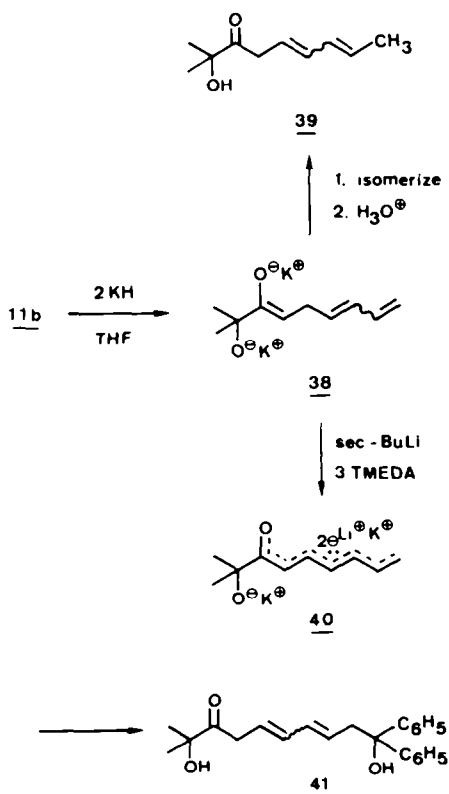


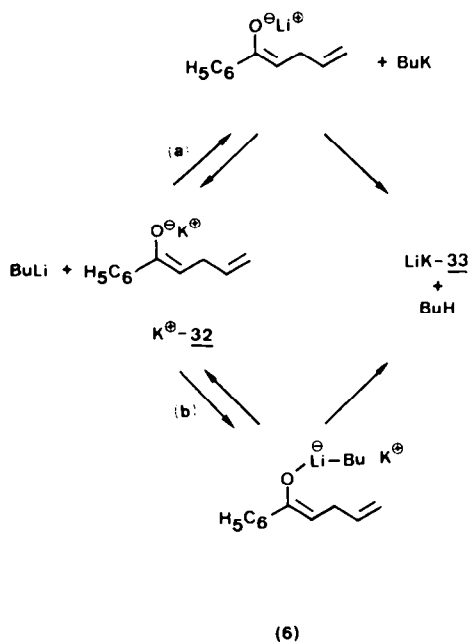
enolate **38** with two equivalents of potassium hydride in THF at temperatures above 0° was accompanied by an extensive double bond shift. Quenching with acetic acid gave up to 75% of the β , γ , δ , ϵ -doubly unsaturated ketone **39**. Although this could be avoided by carrying out the reaction at -12° for 30 min (deuterolysis → 95% α -deutero-**11b**), it occurred again during the third deprotonation with *s*-BuLi (with and without TMEDA) under a variety of conditions (temp, reaction time). With benzophenone, the ω -product **41** was obtained in yields ranging from 23 to 48% determined by ¹H-NMR. Thus, the trianion derivative **40** must have been present. The main product was always the ketone **39**, and only traces of starting material **11b** were recovered. Addition of the BuLi/TMEDA to **38** apparently causes a rapid 1,5-hydrogen shift which competes with the desired deprotonation.

These experiments show, that d^7 -reactions are possible with **36** and **40**, but that they are complicated by the formation of as yet unidentified polar side products in the first case and by double bond migrations in the second. Attempts with other electrophiles lead to similar results.

DISCUSSION

The optimum conditions for α,β -double deprotonations of γ,δ -unsaturated ketones have been found to be the employment of potassium hydride for the first step followed by *s*-BuLi/TMEDA for the second step. The use of Li enolates as intermediates for the second deprotonation is inferior for several reasons. (i) LDA-generated enolates are accompanied by diisopropyl amine which must be removed in our case prior to the second deprotonation. (ii) The silyl enol ether route to Li enolates is more cumbersome (iii) Potassium hydride





converts the γ, δ -unsaturated ketones into enolates in a short period of time under mild conditions and without self condensation or double bond migration. (iv) The most important reason, however, for using potassium enolates is the decisive role they play in the second deprotonation step: the Li enolate Li-13c did not undergo this crucial step with *s*-BuLi/TMEDA at all. In addition, we were able to show in the case of allyl acetophenone enolate that the potassium derivative was converted into the dianion much faster than its Li-analogue under otherwise identical conditions (Table 1). This effect is reminiscent of the activation of alkyllithium compounds by potassium *t*-butoxide^{19,20} and can be explained by either one of the equilibria (a) or (b) illustrated in eqn (6), i.e. formation of highly reactive alkylpotassium²⁰ or of ate-complexes.²¹

The present paper shows that dienone dianion derivatives are accessible by double deprotonation of γ, δ -unsaturated (i.e. α -allylated) ketones and dithioesters and that they react with benzophenone exclusively in the δ -position (ω - or d^5 -reactivity). Although not very likely in view of the drastic conditions necessary to generate the dianion system, it is conceivable that benzophenone furnishes the d^5 -products in a thermodynamically controlled process (reversible d^3 -reaction!).²² The subsequent paper^{2b} will show that "irreversible" electrophiles

behave just like benzophenone and that d^5 -reactivity is intrinsic to the dienone dianions. Finally, it is interesting to note that our dianion systems are formal exceptions to *Hauser's rule*²³ which states that a dianion reacts preferentially at the site from which the second proton was abstracted during its formation.

EXPERIMENTAL

IR spectra were recorded on a Perkin-Elmer 297, 283 or 225 IR spectrometer. ¹H-NMR were measured with Varian Associates EM-390 (90 MHz) and Jeol Minimar 100 spectrometers and are reported in ppm from the internal standard TMS (on the δ scale). Data are listed in the following order: chemical shift, multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, br = broad) and coupling constant (Hz). ¹³C-NMR spectra were determined on a Varian CFT 20 spectrometer. Mass spectra were taken with a Varian MAT GC-MS-System Hitachi. M.ps were determined with a Büchi 510 m. p. apparatus and are uncorrected. Boiling points correspond to the oil bath temps for short path distillations.

THF was freshly distilled from LAH under argon gas prior to use. *N, N, N', N'*-tetramethylethylenediamine (TMEDA) and hexamethylphosphoric triamide (HMPT) were distilled from CaH₂ and stored over molecular sieves. Diisopropylamine was distilled from NaH or CaH₂. *n*-BuLi, *s*-BuLi, MeLi, and *t*-BuLi were purchased from Metallgesellschaft AG and titrated before use. KH (about 50% or 20% suspension in oil) was purchased from Fluka AG, separation of KH from oil and necessary precautions are described elsewhere.¹³ Unless otherwise specified, all reactions were carried out under an atmosphere of argon (see also Ref. 24). Elemental analyses of the following compounds were determined and gave results within $\pm 0.4\%$ of the calculated values: **3b**, **3c**, **3d**, **4b**, **4c**, **4e**, **6**, **7**, **11a**, **11b**, **16**, **20**, **24**, **27**, **31a**, **31b**, **34**, **41**.

A. PREPARATION OF STARTING MATERIALS

3,3-Dimethyl-2-butanone N,N-dimethylhydrazone (4a). A mixture of pinacolone, (40 g; 400 mmol), *N, N*-dimethylhydrazine (35 ml; 440 mmol) and *p*-toluenesulfonic acid (90.5 g) in 300 ml benzene, was refluxed overnight with removal of water by means of a Dean-Stark trap (ca. 16 hr). After cooling, the mixture was diluted with pentane, washed twice with water and once with sat NaClq. The organic phase was dried over MgSO₄, filtered and the solvent was distilled off. The residue obtained was then distilled at 135–136°; yield 42.1 g (75%), $n_D^{25} = 1.4272$. IR (film): 2860, 2820, 2788, 1620, 1470, 1368, 1140, 1200, 1020, 990, 860 cm⁻¹. ¹H-NMR (CCl₄): δ 1.03 (s, 9 H, *t*-butyl), 1.83 (s, 3 H, CH₃C=C), 2.26 (s, 6 H, NMe₂).

Acetophenone N,N-dimethylhydrazone (4d). **4d** (29.37 g; 91%) obtained from acetophenone (24 g; 200 mmol) *N, N*-dimethylhydrazine (20 ml; 250 mmol) and *p*-toluenesulfonic acid (0.25 g) in 200 ml benzene using the procedure described above for the preparation of **4a**; b.p. 40–42°/0.08 torr. ¹H-NMR (CCl₄): δ 2.23 (s, 3 H, CH₃C=N), 2.46 (s, 6 H, NMe₂), 7.2 and 7.66 (m, 5 H, aromatic protons).

Table 1. Comparison of the metalation of K^{\ominus} -**32** and Li^{\ominus} -**32** in THF leading to the corresponding dianions $Li^{\ominus}K^{\ominus}$ -**33** and Li_2^{\ominus} -**33**, respectively. The formation of **33** was judged from the yield of benzophenone adduct **34** (after chromatography)

enolate	base combination	temp.	time (h)	% 34
Li^{\ominus} - 32	<i>s</i> -BuLi/2 TMEDA	-78° to 0°C	5	56
K^{\ominus} - 32	<i>s</i> -BuLi/2 TMEDA	-78° to 0°C	4	60
Li^{\ominus} - 32	<i>s</i> -BuLi or <i>t</i> -BuLi/2 TMEDA	-78°C	5	--
K^{\ominus} - 32	<i>t</i> -BuLi/2 TMEDA	-60°C	4	40
K^{\ominus} - 32	<i>s</i> -BuLi/20 % HMPT	-78°C	3	40

2,3-Butanedione mono N, N-dimethylhydrazone (4c). N, N-dimethylhydrazine (27 ml; 300 mmol) was added dropwise at 0° to a soln of 2,3-butanedione (26.3 ml; 300 mmol) in 250 ml absolute EtOH. After the completion of the addition, the mixture was stirred and allowed to warm up to room temp over night (15 hr). Anhyd. MgSO₄ (10 g) was added to the mixture, and EtOH was distilled from the mixture through a Vigreux-column. The residue obtained was further distilled through the same column at 52–54°/10 torr to yield 33.48 g (86%) of 4c as a clear yellow liquid. IR (film): 2960, 2870, 2830, 2780, 1675, 1575, 1445, 1355, 1250, 1110, 1010–1100, 930, 825, 780 cm⁻¹. ¹H-NMR (CCl₄): δ 1.92 (s, 3 H, CH₃C=N), 2.22 (s, 3 H, CH₃CO), 2.84 (s, 6 H, N(CH₃)₂).

2,2-Dimethyl-6-hepten-3-one N, N-dimethylhydrazone (4b). 4a (35 g; 250 mmol) was added at 0° to a soln of 250 mmol LDA prepared from diisopropylamine (35 ml; 250 mmol) and n-BuLi (156.3 ml; 250 mmol) (1.6 M soln in n-hexane) in 750 ml THF. The resulting mixture was vigorously stirred at this temp for 4–5 hr, during which a white suspension was formed. After cooling to –78°, 21.5 ml (250 mmol) of freshly distilled allyl bromide were slowly added giving a clear pale yellow soln. The mixture was slowly warmed up to room temp over night (ca. 12–16 hr), then poured into a water/pentane mixture. The aqueous phase was extracted with pentane, and the combined pentane extracts were washed twice with water, once with brine and dried over MgSO₄. The crude product obtained after removal of the solvent on a rotatory evaporator was distilled at 88°–90°/33 torr. 42.64 g (94%) of a pale yellow liquid 4b were obtained: n_D²⁰: 1.4440. IR (film): 2860, 2820, 2780, 1645, 1630, 1470, 1398, 1368, 1220, 1195, 1145, 1125, 1000, 960, 915 cm⁻¹. ¹H-NMR (CCl₄): δ 1.1 (s, 9 H, t-butyl), 2.3 (s, 6 H, N(CH₃)₂), 2.2–2.6 (m, 4 H, –CH₂CH₂–), 5.0 and 5.8 (m, 3 H, –CH=CH₂).

1-Phenyl-4-penten-1-one N, N-dimethylhydrazone (4e). A mixture obtained from 4d (24 g; 150 mmol) and LDA (150 mmol) in 300 ml THF was treated with allylbromide (12.7 mmol) as described for the preparation of 4b to afford 4e (26.04 g; 86%) as a yellow liquid after distillation at 72°–75°/0.5 torr (bath temp 120°). IR (film): 1650, 1620, 1580, 1500, 1450, 1370, 1320, 1275, 1030, 925, 775, 700 cm⁻¹. ¹H-NMR (CCl₄): δ 2.46 (s, 6 H, N(CH₃)₂), 2.26 (m, 2 H, –CH₂C=C), 2.85 (m, 2 H, CH₂C=N), 4.95 and 5.7 (m, 2 H, –CH=CH₂), 7.3 and 7.65 (m, 5 H, aromat. H).

2,2-Dimethyl-6-hepten-3-one (3b). Conc HCl (150 ml) was added dropwise at 0° to a soln of 4c (42.64 g; 234.3 mmol) in 100 ml pentane. After complete addition, the mixture was stirred at RT for 30 min, subsequently diluted with water and extracted with 3 × 150 ml pentane. The combined extracts were washed once with water, once with brine and then dried over MgSO₄. Distillation of the crude product at 70°–72°/30 torr gave 29.8 g (91%) of 3b as a colorless liquid. n_D²⁰: 1.4293. IR (film): 3080, 2880, 1710, 1640, 1480, 1370, 1000, 925 cm⁻¹. ¹H-NMR (CCl₄): δ 1.1 (s, 9 H, t-butyl), 2.06–2.6 (m, 4 H, –CH₂CH₂–), 5.0 and 5.71 (m, 3 H, –CH=CH₂).

1-Phenyl-4-penten-1-one (3d). The crude product obtained in the same manner as 3b (16 g; 100%) from a mixture of 4e (20.2 g; 100 mmol) and 100 ml conc HCl was distilled at 50–52°/0.03 torr to yield 3d (15.29 g; 95%) as a yellow liquid: n_D²⁰: 1.5320. IR (film): 1690, 1645, 1640, 1600, 1585, 1370, 1215, 920, 750, 700 cm⁻¹. ¹H-NMR (CCl₄): δ 2.46 (m, 2 H, –CH₂C=C), 2.97 (m, 2 H, CH₂CO), 4.93 and 5.72 (m, 3 H, –CH=CH₂), 7.3 and 7.78 (m, 5 H, aromatic protons).

2-Hydroxy-2-methyl-6-hepten-3-one (3c from 4c). To a cooled (–78°) yellow soln of 4c (12.8 g; 100 mmol) in 200 ml THF was added 65 ml (107 mmol) of a 1.65 M soln of MeLi in ether. The resulting pale yellow soln was stirred at –78° for 1 hr and at 0° for 30 min and then recooled to –78°. 62.5 ml (100 mmol) of a 1.6 M soln of n-BuLi in hexane were added. The resulting yellow soln was stirred at –78° for 1 hr and for an additional hr at 0°, after which a white suspension was formed. Freshly distilled allyl bromide (9 ml, 105 mmol) was added to the cooled (–78°) suspension, and the clear yellow soln obtained was stirred and warmed to room temp over 16 hr and hydrolysed with 150 ml 1.5 HCl at 0°. The mixture was diluted with water and extracted with three 150 ml portions ether. The combined organic phases were washed once with water and brine, then dried over MgSO₄ and concentrated to give 16.32 g crude product, which yielded 3c

(12.54 g; 88%) as a pale yellow liquid after distillation through a 30 cm Vigreux column at 65–67°/10 torr. IR (film): 3470, 3080, 2980, 2930, 1710, 1640, 1465, 1440, 1405, 1360, 1170, 1065, 998, 965, 915 cm⁻¹. ¹H-NMR (CCl₄): δ 1.3 (s, 6 H, (CH₃)₂C=O), 2.13–2.7 (m, 4 H, –CH₂CH₂CO), 3.33 (s, 1 H, OH), 5.0 and 5.72 (m, 3 H, –CH=CH₂).

2-Hydroxy-2-methyl-6-hepten-3-one (3c) from methyl 1,3-dithiane-2-carboxylate. A soln of methyl 1,3-dithiane-2-carboxylate²⁵ (17.8 g; 100 mmol) and 4-bromo-1-butene (15.07 g; 110 mmol) in 100 ml DMF was added slowly to a well-stirred suspension of NaH (2.64 g; 110 mmol) in 50 ml THF cooled to 0°–5°. The mixture was stirred at 0°–5° for 1 hr, at room temp for 18 hr, and subsequently diluted with 250 ml water and extracted with three 150 ml portions pentane. The combined extracts were washed several times with water and once with brine, dried over MgSO₄, filtered and concentrated to give 23.02 g of a pale yellow liquid. The crude product was then dissolved in 250 ml THF and cooled to –78°, at this temp a 1.65 M solution of MeLi (125 ml; 206 mmol in ether) was added. The resulting mixture was stirred at –78° for 1 hr and at room temp for an additional 2 hr. It was then added to ca. 200 ml brine and extracted with 3 × 150 ml ether. The combined extracts were dried (MgSO₄) and concentrated. The 22.01 g of pale yellow oil were treated with MeI (30 ml) CaCO₃ (33.48 g; 334.8 mmol) in a soln of 200 ml acetonitrile, 200 ml water and 100 ml THF. The mixture was refluxed for 16 hr, diluted after cooling with 200 ml ether and extracted with 3 × 200 ml ether. The combined extracts were washed once with brine, dried over MgSO₄, and concentrated. Distillation of the yellow oil (10.5 g) at 65°–66°/10 torr gave 6.9 g (49%) of a colorless liquid, whose spectral properties were identical with those of 3c described in the preceding procedure.

Methyl 4-pentenoate (3f).²⁶ A mixture of commercially available (3e) (10 g, 100 mmol), MeOH (10 g), p-toluenesulfonic acid (0.5 g) and 30 ml CCl₄ was refluxed for 10 hr. After cooling, the mixture was diluted with CH₂Cl₂ and washed with sat NaHCO₃ aq. The organic phase was dried over MgSO₄, filtered and then distilled through a short Vigreux column to give 3f (8.91 g; 78%) as a colorless liquid: b.p. 122°–125° (lit.²⁶ b.p. 120–122°). IR (film): 1735, 1640, 1436, 1355, 1255, 1195, 1170, 990, 915 cm⁻¹. ¹H-NMR (CCl₄): δ 2.3 (m, 4 H, –CH₂–CH₂–), 3.6 (s, 3 H, OCH₃), 5.0 and 5.8 (m, 3 H, –CH=CH₂).

4-Pentenoic acid pyrrolidide (3g).²⁶ 4-pentenoic acid (5 g, 50 mmol) was added to freshly distilled SOCl₂ (9 g) at room temp. The resulting mixture was then heated at 80–100° for 5 hr. Distillation through a Vigreux column yielded 5 g (83%) of the acid chloride as a colorless liquid (b.p. 120–123°), a THF soln of which was added to a cooled (0°) soln of pyrrolidine (3.5 g; 50 mmol) in 50 ml THF. The mixture was vigorously stirred at RT for 1–2 hr, then poured into water, and extracted with ether. The extracts were washed with a dil HCl aq and once with brine and dried over MgSO₄. Short path distillation at 110°/0.7 torr yielded 3g (5.8 g; 76%) as a colorless liquid. IR (film): 3030, 2960, 2860, 1640, 1435, 1340, 1225, 1192, 1170, 990, 915 cm⁻¹. ¹H-NMR (CCl₄): δ 1.84 (m, 4 H, –CH₂CH₂–), 2.22 (m, 4 H, CH₂CH₂CO), 3.29 (m, 4 H, –CH₂NCH₂–), 5.0 and 5.8 (m, 3 H, –CH=CH₂).

N-phenyl-4-pentenamide (3h).²⁶ A soln of the acid chloride (5.9 g; 50 mmol) in 15 ml THF was added at 0° to a well stirred soln of freshly distilled aniline (6 g, 65 mmol) in 50 ml THF. After stirring for 30 min, the mixture was poured into water, and extracted with ether (3 × 100 ml). The combined extracts were washed with NaHCO₃ aq, dried over MgSO₄, and concentrated *in vacuo* to give a crude product. Recrystallization from ether afforded 3h (5 g; 57%) m.p. 90°–91°. IR (nujol): 3310, 1660 cm⁻¹. ¹H-NMR (CDCl₃): δ 2.43 (m, 4 H, CH₂CH₂CO), 5.1 and 5.83 (m, 3 H, –CH=CH₂), 6.95–7.66 (m, 6 H, NH and aromatic protons).

2,2-Dimethyl-5-hepten-3-one (5a). To a cooled (–78°) soln of 100 mmol of LDA [prepared from 14 ml (100 mmol) of diisopropylamine and 62.5 ml (100 mmol) of a 1.6 M soln of n-BuLi in n-hexane] in 100 ml THF was added allylpinacolone 3b (7 g, 50 mmol). It was stirred at –78° for 1 hr, then warmed to RT, refluxed for 6 hr and quenched with 6 ml AcOH at –78°. After the addition of water, it was extracted with pentane. The combined extracts were washed with water and brine, dried over MgSO₄, filtered and concentrated. The crude product was distilled at

57–58°/10 torr to give **5a** (6.29 g; 89%) as a colorless oil. IR (film): 1710, 1650, 1480, 1395, 1365, 1315, 1220, 1110, 1070, 980, 845, 780, 680 cm^{-1} . $^1\text{H-NMR}$ (CCl_4): δ 1.14 (s, 9H, t-butyl), 1.6 (d, $J = 5$ Hz, 3H, $\text{CH}_3\text{C}=\text{C}$), 3.14 (d, $J = 5$ Hz, 2H, $-\text{CH}_2\text{CO}$), 5.5 (m, 2H, $-\text{CH}=\text{CH}-$).

2,2-Dimethyl-4-hepten-3-one (5b). A mixture of **5a** (3 g) and a catalytic amount of t-BuOK (ca. 20 mg) in 40 ml THF and 30 ml t-BuOH was stirred at RT overnight (16 hr), then poured into water and extracted with three 60 ml portions pentane. The combined extracts were washed several times with water and once with brine, and dried over MgSO_4 . The residue obtained after concentration was distilled at 65°/10 torr to yield **5b** (1.0 g; 33%). IR (film): 2980, 2880, 1690, 1625, 1480, 1460, 1400, 1370, 1340, 1300, 1140, 1080, 1000, 980, 865, 790 cm^{-1} . $^1\text{H-NMR}$ (CCl_4): δ 1.1 (s, 9H, t-butyl), 1.1 (t, $J = 7$ Hz, 3H, CH_2CH_2-), 2.2 (m, 2H, $-\text{CH}_2\text{C}=\text{C}$), 6.4 (d, $J = 16$ Hz, 1H, $-\text{CH}=\text{CHCO}$), 6.9 (d × t, $J = 6, 16$ Hz, 1H, $-\text{CH}=\text{CHCO}$).

2,2-Dimethyl-4-phenylthio-6-hepten-3-one (6). **3b** (3.2 g, 20 mmol) was added dropwise to a cooled (-78°) soln of 40 mmol LDA [from 5.6 ml (40 mmol) diisopropylamine and 25 ml (40 mmol) of a 1.6 M soln of n-BuLi in n-hexane] in 60 ml THF, and the resulting soln was stirred for 1 hr prior to being siphoned via a teflon tubing into a room temp soln of diphenyldisulfide (5.23 g; 24 mmol) in 20 ml HMPT. After stirring at RT for 1 hr., the mixture was diluted with water/ether and extracted with 3×100 ml ether. The combined extracts were washed several times with water and once with brine, dried over MgSO_4 and concentrated *in vacuo* to yield a yellow oil. The crude product was chromatographed on 200 g silica gel (2% ether in pentane) to give 4.58 g (92%) of an almost colorless oil which was distilled at 80°/0.006 torr ($n_D^{25} = 1.5369$). IR (film): 3080, 2970, 2870, 1700, 1640, 1580, 1475, 1440, 1395, 1370, 1330, 1070, 1030, 980, 920, 750, 690 cm^{-1} . $^1\text{H-NMR}$ (CCl_4): δ 1.16 (s, 9H, t-butyl), 2.4 (m, 2H, $-\text{CH}_2\text{C}=\text{C}$), 2.85 (m, 1H, CHS), 4.96 and 5.6 (m, 3H, $-\text{CH}=\text{CH}_2$), 7.46 (m, 5H, aromatic protons).

2,2-Dimethyl-4,6-heptadien-3-one (7): A soln of **6** (3.72 g; 15 mmol) in 150 ml CH_2Cl_2 was cooled to -78° , and a soln of 85% *m*-chloroperbenzoic acid (3.0 g; 15 mmol) in 50 ml CH_2Cl_2 was added dropwise. After stirring for 40 min, the cold mixture was poured into a separatory funnel containing 200 ml CH_2Cl_2 , and washed with 10% $\text{Na}_2\text{S}_2\text{O}_3$ aq. The organic phase was separated, washed twice with sat NaHCO_3 aq, dried over MgSO_4 and concentrated *in vacuo*. The crude sulfoxide was then dissolved in 60 ml CCl_4 , and the resulting soln was heated to reflux for 3 hr. After removal of the solvent and chromatography on 30 g silica gel (10% ether in pentane) 1.76 g of **7** were obtained and distilled at 58–60°/9 torr to give 1.52 g (73%) of a pale yellow liquid ($n_D^{25} = 1.4839$). IR (film): 2970, 2870, 1685, 1620, 1590, 1480, 1395, 1365, 1315, 1280, 1240, 1175, 1080, 1010, 920, 870, 785 cm^{-1} . $^1\text{H-NMR}$ (CCl_4): δ 1.13 (s, 9H, t-butyl), 5.53 (m, 2H), 6.4 (m, 2H), 7.16 (m, 1H).

2,2-Dimethyl-4,6-heptadien-3-ol (8). 30 ml of a 1 M soln of diisobutylaluminum hydride (DIBALH, 30 mmol) in n-hexane were added to a cooled (0°) soln of **7** (3.45 g; 25 mmol) in 80 ml dry benzene. The mixture was stirred at 0° for 1.5 hr, and 30 ml MeOH was added, which caused Al salt precipitation. After filtration, the soln was washed twice with 10% HCl aq and once with water and brine, dried over MgSO_4 and concentrated. Chromatography (100 g of SiO_2 , 20% ether in pentane) of the crude product yielded 2.62 g of **8** which was distilled at 85–90°/6 torr to give 2.21 g (63%) of an almost colorless oil. $n_D^{25} = 1.4757$. IR (film): 3400, 3080, 3040, 2960, 2870, 1650, 1600, 1480, 1460, 1360, 1300, 1240, 1220, 1190, 1100, 1040, 1000, 950, 900, 760 cm^{-1} . $^1\text{H-NMR}$ (CCl_4): δ 0.86 (s, 9H, t-butyl), 1.43 (br., 1H, OH), 3.46 (d, $J = 6$ Hz, 1H, CHO), 5.06, 5.7 and 6.2 (m, 5H, olefinic protons).

Ethyl 2-phenylthio-4-pentenoate (9). A soln of ethyl α -phenylthioacetate (5.88 g; 30 mmol) in 10 ml THF was added dropwise to a cooled (-78°) soln of 30 mmol of LDA (prepared from 4.2 ml (30 mmol) diisopropylamine and 18.75 ml (30 mmol) of a 1.6 M soln of n-BuLi in n-hexane) in 50 ml THF. The resulting soln was stirred at -78° for 1 hr, and then allyl bromide (2.6 ml, 30 mmol) was added. The mixture was stirred and allowed to warm to room temp over a period of 18 hr then poured

into H_2O and extracted with 3×100 ml pentane. The combined extracts were washed with brine soln, dried over MgSO_4 and concentrated *in vacuo* to give a pale yellow liquid which was distilled at 88°/0.06 torr to give **9** (5.2 g; 73%). IR (film): 3080, 2980, 1735, 1640, 1583, 1480, 1440, 1370, 1335, 1260, 1155, 1025, 920, 860, 750, 695 cm^{-1} . $^1\text{H-NMR}$ (CCl_4): δ 1.16 (t, $J = 7$ Hz, 3H, CH_2CH_2-), 2.5 (m, 2H, $-\text{CH}_2\text{C}=\text{C}$), 3.53 (m, 1H, CHS), 4.05 (q, $J = 7$ Hz, 2H, $-\text{CH}_2\text{CH}_3$), 5.08 and 5.8 (m, 3H, $-\text{CH}=\text{CH}_2$), 7.3 (m, 5H, aromatic protons).

Diethyl allylmalonate (10a). Diethyl malonate (8.0 g; 50 mmol) was added to a soln of NaOEt prepared from Na (1.15 g; 50 mmol) in 150 ml abs EtOH. The resulting mixture was heated at 60° for 30 min, and then allyl bromide (5.04 ml, 60 mmol) was added. The mixture was refluxed for 10 hr, cooled to room temp, poured into water, acidified with dil HCl aq and extracted with pentane. The extracts were washed with water, dried over MgSO_4 and concentrated *in vacuo*. Distillation of the residue afforded **10a** (10.8 g; 54%); b.p. 100°/10 torr (lit.²⁸ 111°/10 torr). IR (film): 1740, 1640, 1445, 1370, 1335, 1240, 1155, 1035, 925, 860 cm^{-1} . $^1\text{H-NMR}$ (CCl_4): δ 1.3 (t, $J = 7$ Hz, 6H, $-\text{CH}_2\text{CH}_3$), 2.56 (br., t, $J = 7$ Hz, 2H, $-\text{CH}_2\text{C}=\text{C}$), 3.26 (t, $J = 7$ Hz, 1H, $-\text{CHCO}$), 4.16 (q, $J = 7$ Hz, 4H, $\text{CO}_2\text{CH}_2\text{CH}_3$), 5.06 and 5.75 (m, 3H, $-\text{CH}=\text{CH}_2$).

Di-*t*-butylallylmalonate (10b). Di-*t*-butylmalonate (4.32 g; 20 mmol) was added to a cooled (-78°) soln of 20 mmol of LDA. The resulting pale yellow soln was then stirred for 30 min, and then allylbromide (1.68 ml, 20 mmol) was added. While stirring was continued, the mixture was warmed to room temp over a period of 22 hr. Work-up was effected by pouring this mixture into water and extracting it with three 100 ml portions of pentane. The combined extracts were washed with H_2O and brine and dried over K_2CO_3 and concentrated yielding **10b** (2.41 g; 47%) by the distillation of the residue at 65°/0.08 torr. $^1\text{H-NMR}$ (CCl_4): 1.43 (s, 18H, t-butyl), 2.46 (br., t, 2H, $-\text{CH}_2\text{C}=\text{C}$), 3.06 (t, $J = 7.5$ Hz, 1H, CHCO), 5.03 and 5.74 (m, 3H, $-\text{CH}=\text{CH}_2$).

2,2-Dimethyl-6,8-nonadien-3-one (11a). A 1.54 M soln of n-BuLi (195 ml; 300.3 mmol) in n-hexane was added to a cooled (-78°) soln of **4a** (42.0 g; 300 mmol) in 500 ml THF. The resulting soln was stirred at -78° for 30 min, then warmed up to RT. Stirring was continued for 2 hr, during which time a white suspension formed. 5-Bromo-1,3-pentadiene²⁹ (48.5 g; 330 mmol) was added with stirring at -78° . The resulting clear pale yellow soln was slowly warmed to room temp (18 hr), then hydrolysed with 20% HCl aq (250 ml) and worked up in the manner described in the procedure for **3c**. The crude product (53.6 g) was purified by distillation through a Vigreux-column (30 cm) to give **11a** (28.64 g; 58%) as a colorless liquid, b.p. 42–43°/0.05 torr. IR (film): 3085, 2970, 2905, 2870, 1705, 1650, 1600, 1480, 1365, 1080, 1060, 1005, 980, 950, 900 cm^{-1} . $^1\text{H-NMR}$ (CCl_4): δ 1.1 (s, 9H, $(\text{CH}_3)_2\text{C}$), 2.15–2.6 (m, 4H, $-\text{CH}_2\text{CH}_2-$), 4.8–5.16 and 5.4–6.45 (m, 5H, olefinic protons).

2-Hydroxy-2-methyl-6,8-nonadien-3-one (11b). **11b** was prepared by the same procedure as described for **3c** from **4c** (38.4 g; 300 mmol) 195 ml (300 mmol) of a 1.54 M soln of MeLi in ether, 195 ml (300 mmol) of a 1.54 M soln of n-BuLi in n-hexane and 48.5 g (330 mmol) 5-bromo-1,3-pentadiene²⁹ in 500 ml THF. The yield of **11b** was 36.06 g (72%), b.p. 44–46°/0.02 torr. IR (film): 3480, 3090, 2980, 2940, 1700, 1650, 1605, 1455, 1440, 1405, 1360, 1110, 1240, 1075, 1005, 965, 905, 840, 790 cm^{-1} . $^1\text{H-NMR}$ (CCl_4): δ 1.3 (s, 6H, $(\text{CH}_3)_2\text{C}$), 2.2–2.7 (m, 4H, $-\text{CH}_2\text{CH}_2-$), 3.33 (br., s, 1H, OH), 4.85–6.7 (m, 5H, olefinic protons).

Methyl-4-pentendiothioate (12a). CS_2 (12 ml; 200 mmol) was added dropwise to a cooled (-10°) soln of 3-butenyl magnesium bromide (200 mmol) in 250 ml THF prepared by treatment of freshly distilled 4-bromo-1-butene (27 g, 200 mmol) with 5.0 g (0.208 atomic equivs) Mg turnings. The resulting clear brown soln was stirred at room temp for further 2 hr, and then MeI (13 ml, 206 mmol) was added. The resulting yellow suspension was vigorously stirred at room temp for 2 hr, poured into water and extracted with ether (3×200 ml). The combined extracts were washed once with sat NaCl aq, dried over MgSO_4 and concentrated *in vacuo* to give a crude yellow-orange liquid which was distilled at 43–45°/1 torr. 25.3 g (87%) of **12a** were obtained. IR (film): 3080, 2980, 2918, 1640, 1415, 1218, 918 cm^{-1} . $^1\text{H-NMR}$

(CCl₄): δ 2.6 (s, 3 H, SCH₃), 2.56 and 3.03 (m, 4 H, -CH₂CH₂-), 5.0 and 5.76 (m, 3 H, -CH=CH₂).

Isopropyl-4-pentanedithioate (12b). CS₂ (12 ml, 200 mmol) was added to a soln of 1-pentenyl magnesium bromide (200 mmol) at -10°. After stirring for 2 hr at room temp, 40 ml HMPT followed by 38 ml (224 mmol) isopropyl iodide were added. The resulting soln was then heated at 50–60° for 24 hr and worked up as described above. Distillation yielded 12b (28.06 g; 81%) as a yellow-orange liquid (b.p. 38–40°/0.6 torr). IR (film): 3080, 2960, 2925, 2865, 1640, 1460, 1440, 1385, 1365, 1215, 1180–1140, 990, 915 cm⁻¹. ¹H-NMR (CCl₄): δ 1.33 (d, J = 7 Hz, 6 H, (CH₃)₂CH), 2.53 and 2.96 (m, 4 H, -CH₂CH₂CS), 3.81 (sept, J = 7 Hz, 1 H, CHS), 5.0 and 5.78 (m, 3 H, -CH=CH₂).

B. GENERATION OF POLYANIONS AND THEIR REACTIONS WITH BENZOPHENONE

a. Polydeprotonation of 5-hexene-2-one (3a)

Preparation of 5-trimethylsilyloxy-1,4-hexadiene (13a) and 2-trimethylsilyloxy-1,5-hexadiene (13b). A mixture of 13a and 13b was prepared according for the procedure of House³⁰ from a mixture of (9.8 g; 100 mmol) trimethylsilyl chloride (16.2 g; 150 mmol), Et₃N (20.2 g; 300 mmol) and 30 ml DMF. Distillation at 76–79°/50 torr yielded 13a (12 g; 71%) and 13b in a ratio of 72:28. ¹H-NMR (CCl₄): δ 0.1 (s, 9 H, SiMe₃), 1.6 and 1.68 (2xs, CH₂-C=C), 2.05 (m, -CH₂-CH₂-), 2.6 (br., t, J = 6 Hz), 3.85 (br., s, CH₂=C), 4.3 (m, -CH=C-O), 4.7 (m, CH₂=C), 5.5 (m, -CH=CH₂). 4.8 g of pure 13a were obtained by distillative separation through a spinning band column. B.p. 77–78°/50 torr. n_D^{25} = 1.4336. IR (film): 3080, 2960, 1680, 1640, 1380, 1330, 1250, 1180, 1000, 840, 740 cm⁻¹. ¹H-NMR (CCl₄) (69:31 mixture of E/Z-stereoisomers): δ 0.1 (s, 9 H, SiMe₃), 1.6 and 1.68 (2xs), 3 H, CH₃-C=C), 2.6 (m, 2 H -CH₂-C=C), 4.45 (m, 1 H, -CH=C-O), 4.85 and 5.68 (m, 3 H, -CH=CH₂).

Generation of Li₂-14a and of 14b from 13a and reaction with benzophenone

7,7-Diphenyl-7-hydroxy-4-hepten-2-one (15a) and 1,8-dihydroxy-1,1,8,8-tetraphenyl-5-octen-3-one (16). To a cooled (0°) soln of 13a (0.43 g; 2.5 mmol) in 15 ml ether was added dropwise a 1.6 M soln of MeLi in ether (1.63 ml, 2.6 mmol). After stirring at room temp for 1.5 hr and cooling to -78° TMEDA (1.2 ml; 7.5 mmol) and a 1.6 M soln of n-BuLi (5.0 ml; 8 mmol) in n-hexane were added. The mixture was allowed to warm up to room temp and stirring was continued overnight, during which time a yellow-orange suspension formed. A soln of benzophenone (0.91 g; 5 mmol) in 10 ml THF was added to the cooled (-78°) suspension. After being stirred at -78° for 1 hr and for an additional hr at room temp it was quenched at -78° with 5 ml AcOH, diluted with water and extracted with three portions ether. The combined extracts were washed several times with water, once with brine soln and dried over MgSO₄. The crude product was chromatographed on silica gel (20% ether in pentane) yielding 15 (0.09 g; 14%) (m.p. = 53–56°, from 10% ether in pentane) and 16 (0.36 g; 31%) (m.p. = 145°–146°, from EtOAc).

Compound 15: IR (CCl₄): 3600–3200, 3060, 1705, 1640, 1600, 1490, 1445, 1355, 1230, 1170, 1060, 750, 700 cm⁻¹. ¹H-NMR (CDCl₃): δ 2.07 (s, 3 H, CH₃CO), 2.95 (br., s, 1 H, OH), 3.02 (br., d, J = 6 Hz, 2 H, -CH₂C=C), 3.16 (br., d, J = 6 Hz, 2 H, -CH₂CO), 5.6 (m, 2 H, -CH=CH-), 7.33 (m, 10 H, aromatic protons). -MS: m/e (%) = 43 (20), 77 (52.5), 105 (82.5), 183 (100), 203 (4), 219 (6), 262 (4).

Compound 16: IR (KI): 3500, 2965, 1660, 1490, 1390, 1370, 1225, 1170, 1050, 970, 770, 700 cm⁻¹. ¹H-NMR (CDCl₃): δ 2.46 (s, 1 H, OH), 3.06 (br., d, J = 6 Hz, 4 H, -CH₂CO and -CH₂-C=C), 3.3 (s, 2 H, -CH₂CO), 4.96 (s, 1 H, OH), 5.44 (m, 2 H, -CH=CH-), 7.33 (m, 20 H, aromatic protons).

Generation of LiK-14a from a mixture enolates K-13c and 13b, and reaction with benzophenone

Allyl acetone (0.98 g, 10 mmol) was added at room temp to a suspension of KH (0.44 g; 11 mmol) in 30 ml THF. The mixture was stirred for 30 min and cooled -78°. 1.65 M soln of t-BuLi (3.9 ml; 6.4 mmol) in pentane were added, and the resulting soln was stirred and allowed to warm up to 0° over a period of 5 hr. A soln of benzophenone (1.09 g; 6 mmol) in 5 ml THF was added to

the cooled (-78°) red-brown soln. After being stirred for 2 hr at -78°, it was quenched with AcOH, poured into water and extracted with pentane. The combined extracts were washed several times with H₂O, once with brine, dried over MgSO₄ and concentrated *in vacuo*. 2.2 g of crude product were chromatographed on 60 g of SiO₂ (20% ether in pentane) to give 15 (1.2 g; 72%) (m.p. = 53–56°) identical with the sample, obtained in the preceding procedure.

General procedure for generation of the LiK-dianion derivative 18 from allyl pinacolone 3b.

8-Hydroxy-2,2-dimethyl-8,8-diphenyl-5-octen-3-one (20). 3b (0.7 g, 5 mmol) was added to a suspension of KH (0.24 g; 6 mmol) in 2 ml THF at room temp. The resulting mixture was stirred for 40–60 min, cooled to -78°, and then TMEDA (1.6 ml; 10 mmol) and a 1.0 M solution of s-BuLi (6 ml; 6 mmol) in isopentane were added consecutively. The resulting brown soln was slowly warmed up to 0° (5 hr), during which time a yellow-orange suspension formed. A soln of benzophenone (0.91 g; 5 mmol) in 5 ml THF was added to the cooled (-78°) suspension. After being stirred at -78°, the mixture was quenched with excess AcOH, poured into water and extracted with ether. The combined ether extracts were thoroughly washed with water and brine, dried over MgSO₄ and concentrated *in vacuo*. The crude product was purified by chromatography on 50 g silica gel (10% ether in pentane) to yield 20 (m.p. 88.5°–90° from ether/pentane). The yields ranged from 59–80%, depending on the reaction time and temp as shown in the following list.

Cosolvent added with the benzophenone (equiv.)	Temperature (°C) and time (hr) of reaction with benzophenone	Amount of 20 isolated (% yield)
—	-78/1	0.94 g (59)
—	-78/2	1.06 g (66)
HMPT (2)	-78/2	1.15 g (72)
—	-78 to +25/16	1.29 g (80)

IR (CCl₄): 3580–3320, 3090, 3060, 3030, 2980, 2910, 2880, 1950, 1880, 1800, 1705, 1650, 1600, 1490, 1480, 1450, 1395, 1345, 1310, 1170, 1060, 1020, 960, 915, 890, 700 cm⁻¹. ¹H-NMR (CDCl₃): δ 1.15 (s, 9 H, t-C₄H₉), 3.04 (br., d, J = 6 Hz, 2 H, -CH₂C=C), 3.27 (br., d, J = 6 Hz, 2 H, -CH₂CO), 3.3 (br., s, 1 H, OH), 5.33–5.83 (m, 2 H, -CH=CH-), 7.3 (m, 10 H, aromatic protons).

Generation of the LiK-dianion 18 from 5a and its reaction with benzophenone

Compound 5a (0.7 g, 5 mmol) was treated with a suspension of KH (0.22 g; 5.5 mmol) in 15 ml pentane. Stirring at room temp was continued for 1 hr, and then TMEDA (1.6 ml; 10 mmol) and a 1.6 M soln of n-BuLi (3.75 ml) in n-hexane were added to the cooled (0°) and stirred mixture. Stirring at room temp was continued for 20–24 hr, during which time a yellow-orange suspension formed. 15 ml THF were added after cooling to -78°, followed by a soln of benzophenone (0.91 g; 5 mmol) in THF. After being stirred for 2 hr, the mixture was hydrolyzed at -78° with AcOH and worked up as described above. The crude product was chromatographed on 60 g SiO₂ (10% ether in pentane) to yield 20 (0.69 g; 44%) of 20.

Preparation of the dianion derivative 18 from 5b and its reaction with benzophenone. After treatment of 5b (0.7 g, 5 mmol) with KH (0.22 g; 5.5 mmol) in 15 ml THF for 1 hr, THF was removed *in vacuo*. The residue was suspended in TMEDA (1.6 ml; 10 mmol) and 15 ml pentane, and then a 1.6 M soln of n-BuLi (3.56 ml; 5.7 mmol) in n-hexane were added dropwise at 0°. The resulting mixture was kept stirred at room temp for 20 hr. A soln of benzophenone (0.91 g; 5 mmol) in 10 ml THF was added to the cooled (-78°) yellow-orange suspension. After stirring for 1 hr, it was quenched with AcOH and then worked up in the manner as described above. The crude product was

chromatographed on SiO₂ (60 g, 10% ether in pentane) to give **20** (0.61 g; 38%) of **20**.

Preparation of 5-hydroxy-4-methyl-N, 5-diphenyl-2-pentenamide (24). To a cooled (0°) mixture of **3h** (0.44 g; 2.5 mmol), t-BuOK (0.84 g; 7.5 mmol) and TMEDA (0.8 ml, 5 mmol) in 15 ml THF, a 1.6 M soln of n-BuLi in n-hexane (5.6 ml; 9 mmol) was added, after which a dark red soln containing a ppt was obtained. It was kept stirred at 0° for 6 hr (brown soln with ppt), cooled to -78°, and then benzaldehyde (0.26 ml; 2.6 mmol) was added. The resulting mixture was stirred at -78° for 2 hr, quenched with an excess AcOH and worked up as described. Purification of the crude product by preparative (50% ether in pentane) afforded **24** (0.41 g; 58% as a white solid (m.p. 141–143°, from ether/EtOAc). IR (KBr): 3350, 3060, 3025, 2980, 2880, 2850, 1660, 1620, 1595, 1525, 1495, 1440, 1330, 1240, 1190, 1125, 990, 968, 945, 900, 740, 700, 685 cm⁻¹. ¹H-NMR (acetone-d₆): δ 1.07 (d, J = 7 Hz, 3H, -CHCH₃), 2.7 (m, 3H, -CHC=C), 4.26 (m, 1H, OH), 4.7 (br., d, J = 6 Hz, 1H, CHO), 5.97 (d, J = 16 Hz, 1H, COCH=CH-), 6.96 (d x d, J = 16 and 7.5 Hz, 1H, COCH=CH-), 7.3 and 7.73 (m, 10H, aromatic protons).

General procedure for the generation of the trianion derivative **26** and its reaction with benzophenone

Preparation of 2,8-dihydroxy-8,8-diphenyl-2-methyl-5-octen-3-one (27): Treatment of **3c** (1.42 g; 10 mmol) with KH (0.88 g; 20 mmol) at 0° or at room temp for 30 min gave a suspension of **25**. TMEDA (4.8 ml; 30 mmol) was added to the cooled (-78°) suspension followed by a 1.2 M soln of s-BuLi in isopentane (14 ml; 11.6 mmol). The resulting mixture was then kept stirred at -50 to -30° for 4 hr, during which time a red suspension formed. A soln of benzophenone in 8 ml THF (1.82 g; 10 mmol) was added to the cooled (-78°) suspension. After being stirred for 1 hr, it was quenched with 5 ml AcOH, poured into water and extracted with three 80 ml portions pentane. The combined extracts were washed several times with H₂O, once with brine, dried over MgSO₄ and concentrated *in vacuo*. 2.9 g of crude product were chromatographed on 100 g SiO₂ (30% ether in pentane) to afford 1.28 g of a mixture of benzophenone, **3c**, and its isomer **28**, and 1.55 g (48%) of **27** as viscous material. IR (film): 3450, 3060, 3030, 2980, 1710, 1600, 1492, 1448, 1365, 1150–1200, 1058, 965, 755, 740, 700 cm⁻¹. ¹H-NMR (CDCl₃): δ 1.26 (s, 6H, (CH₃)₂C), 2.83 (br., s, 2H, OH), 2.95 (br., d, J = 6 Hz, 2H, -CH₂C=C), 3.26 (br., d, J = 6 Hz, 2H, CH₂CO), 5.26–5.75 (m, 2H, -CH=CH-), 7.03–7.5 (m, 10H, aromatic protons).

Procedure for the generation of the LiK-derivative **30a** and its reaction with benzophenone

Methyl 6-hydroxy-6, 6-diphenyl-β-hexenedithioate (31a): 12a (0.73 g; 5 mmol) was added at 0° to a suspension of KH (0.22 g; 5.5 mmol) in 20 ml THF. After being stirred at 0° for 20–30 min, the resulting red-brown soln was cooled to -90°, at which point TMEDA (1.6 ml; 10 mmol) and a 1.0 M soln of s-BuLi in isopentane (5.5 ml; 5.5 mmol) was added. The resulting mixture was kept stirred at -78° for 4 hr, during which time a yellow-orange suspension formed. A soln of benzophenone in 5 ml of THF (0.91 g; 5 mmol) was added. The mixture was stirred at -78° for 2 hr, quenched with AcOH, poured into water and extracted with pentane. The combined pentane extracts were washed several times with water, once with brine, dried over MgSO₄ and concentrated. The crude product was purified by chromatography on 60 g silica gel (10% ether in pentane) to yield **31a** (1.18 g; 71%) as a yellow solid (m.p. = 64–66%). IR (KBr): 3450, 3080, 2940, 2920, 1600, 1490, 1448, 1415, 1400, 1345, 1240, 1162, 1050, 970, 900, 850, 775, 750, 705, 700, 635 cm⁻¹. ¹H-NMR (CDCl₃): δ 2.58 (s, 3H, SCH₃), 2.46 (s, 1H, OH), 3.03 (br., d, J = 7 Hz, 2H, -CH₂C=C), 3.61 (br., d, J = 7 Hz, 2H, CH₂CS), 5.2–6.0 (m, 2H, -CH=CH-), 7.1–7.53 (m, 10H, aromatic protons). MS; *m/e* (%) = 47 (53), 48 (43), 77 (15), 91 (16), 105 (37), 115 (14), 148 (37), 165 (20), 180 (100), 193 (9), 204 (28), 222 (15), 310 (2.5), 328 (0.9).

Procedure for the generation of the LiK-derivative **30b** and its reaction with benzophenone

Isopropyl-6, 6-diphenyl-6-hydroxy-3-hexenedithioate (31b): 12b

(0.87 g; 5 mmol) was added at 0° to a suspension of KH (0.22 g; 5.5 mol). Stirring was continued for 30 min, and the resulting mixture was cooled to -90°. TMEDA (1.6 ml; 10 mmol) and a 1.0 M soln of s-BuLi in isopentane (6.5 ml; 5.5 mmol) was added: it was then kept stirred at -78° for 4–5 hr, during which time a red-brown soln was observed. Benzophenone (0.91 g; 5 mmol) in 5 ml THF was added dropwise at -78°, and the resulting mixture was stirred for 2 hr, quenched with AcOH, poured into water and extracted with pentane. The combined pentane extracts were washed extensively with water, once with brine, dried over MgSO₄ and concentrated *in vacuo* to give 1.8 g of crude product. Chromatography on 100 g silica gel (15% ether in pentane) yielded **31b** (1.51 g; 84%) as a yellow solid (m.p. 53–55°, from pentane). IR (KBr): 3440, 3070, 3030, 2930, 1650, 1600, 1490, 1450, 1350, 1235, 1160, 1050, 970, 895, 850, 770, 742, 700 cm⁻¹. ¹H-NMR (CCl₄): δ 1.35 (d, J = 7 Hz, 6H, -CH(CH₃)₂), 2.53 (s, 1H, OH), 2.95 (br., d, J = 6 Hz, 2H, CH₂C=C), 3.5 (br., d, J = 6 Hz, 2H, CH₂C=S), 3.86 (sept, J = 7 Hz, 2H, CHS), 5.13–5.96 (m, 2H, -CH=CH-), 7.0–7.5 (m, 10H, aromatic protons). MS; *m/e*(%) = 43 (47), 77(41), 105 (100), 134 (37), 183 (93), 204 (21), 356 (1).

Procedure for generation of the LiK-derivative **33** from potassium enolate K[⊖]-32.

Preparation of 6-hydroxy-1, 6, 6-triphenyl-3-hexen-1-one (34). A cooled (-78°) soln of K[⊖]-32, prepared by the reaction of **3d** (0.8 g; 5 mmol) and KH (0.22 g; 5 mmol) in 20 ml of THF at 0° for 30–45 min, was treated with a 1.0 M soln of s-BuLi in isopentane (6 ml; 6 mmol) in the presence of TMEDA (1.6 ml; 10 mmol). The resulting mixture was allowed to warm up to 0° over a period of 4–5 hr. HMPT (0.87 ml; 5 mmol) was added to the cooled (-78°) deep red-violet soln followed by a soln of benzophenone in 5 ml of THF (0.91 g; 5 mmol). The resulting mixture was allowed to warm up to room temp within 3 hr, it was combined, at -78° with AcOH, poured into water and extracted with ether. The combined extracts were washed several times with water, once with brine, dried MgSO₄ and concentrated *in vacuo*. Chromatography of the crude product (1.7 g) on 80 g silica gel (15% ether in pentane) afforded **34** (1.10 g; 65%) as white crystals. (Thin layer R_f = 0.36, 40% ether in pentane; m.p. = 111–112°). IR (KI): 3470, 1680, 1670, 1600, 1580, 1490, 1450, 1410, 1330, 1220, 1050, 980, 780, 750, 700 cm⁻¹. ¹H-NMR (CDCl₃): δ 2.8 (br., s, 1H, OH), 3.1 (br., d, J = 6.5 Hz, 2H, -CH₂C=C), 3.65 (br., d, J = 6.5 Hz, 2H, CH₂CO), 5.6 and 5.9 (m, 2H, -CH=CH-), 7.2 and 8.0 (m, 15H, aromatic protons).

Generation of the Li₂-derivative **33** and its reaction with benzophenone

Compound **3d** (0.8 g; 5 mmol) was treated with LDA (5.5 mmol) in 20 ml THF at -78° for 2 hr. After removal of THF and di-isopropyl amine *in vacuo* (0.002 torr, room temp), the residue was dissolved in 20 ml THF. The resulting soln was cooled to -78°, and treated with a 1 M soln of s-BuLi in isopentane (6 ml; 5.5 mmol) in the presence of TMEDA (1.6 ml; 10 mmol). After being allowed to warm up to 0° over a period of 4 hr, the deep red-violet soln was recooled to -78° and treated with a soln of benzophenone in 5 ml THF (0.91 g; 5 mmol). The resulting mixture was kept stirred at -78° for 2 hr, quenched with AcOH and then worked up as described. Chromatography of the crude product (1.76 g) on 100 g SiO₂ yielded **34** (0.95; 56%).

Generation of the dianion derivative **36** and its reaction with benzophenone

Preparation of 2,2-dimethyl-10,10-diphenyl-10-hydroxy-5,7-decadien-3-one (37): 11a (0.83 g; 5 mmol) was treated with a suspension of KH (0.22 g; 5.5 mmol) in 30 ml THF at room temp for 1 hr. The resulting mixture was cooled to -78°, and then TMEDA (1.6 ml; 10 mmol) followed by s-BuLi (6.5 ml; 5.9 mmol) was added. The temp was gradually raised to -10° over a period of 4 hr, during which time a red suspension formed. A soln of benzophenone in 5 ml THF (0.91 g; 5 mmol) was added at -78°. Stirring was continued for 2 hr at this temp, and then the mixture was quenched with 4 ml AcOH, poured into water and extracted with ether. The combined ether extracts were washed several

times with H₂O, once with brine, dried (MgSO₄) and concentrated *in vacuo*. Chromatography of the crude product (1.85 g) afforded **37** (0.95 g; 54%), a mixture of benzophenone (0.51 g) **11a** and its isomer and a mixture of highly polar, slow moving substances. (0.26 g). Compound **37**. IR (film): 3650–3200, 3020, 2960, 2860, 1695, 1595, 1490, 1475, 1445, 1390, 1360, 1220, 1175, 1065, 1000, 910, 845, 755, 700 cm⁻¹. ¹H-NMR (CCl₄): δ 1.06 and 1.1 (2 × s, 9H, t-butyl), 2.23 (br., s, 1H, OH), 2.9–3.36 (m, 4H, CH₂CO and –CH₂C–O), 5.2–6.46 (m, 4H, olefinic protons), 7.03–7.5 (m, 10H, aromatic protons).

Generation of the trianion derivative **40**

*Preparation of 2,10-dihydroxy-10,10-diphenyl-2-methyl-5,7-decadien-3-one (41): Compound **11b** (1.68 g; 10 mmol) was added to a cooled (–12°) THF suspension (40 ml) of KH (0.88 g; 20 mmol). After being stirred at –12° to –10° for 30 min, the mixture was cooled to –78° and TMEDA (4.8 ml; 30 mmol) followed by a 1.1 M soln of s-BuLi in isopentane (12 ml; 10.9 mmol) was added. It was kept stirred at –50° to –30° over a period of 4 hr, during which time a dark brown suspension formed. A soln of benzophenone in 10 ml THF (1.82 g; 10 mmol) was added to the cooled (–78°) mixture. After stirring for 2 hr, it was quenched with AcOH, poured into water and extracted with ether. The combined extracts were washed several times with H₂O, once with brine, dried (MgSO₄) and concentrated *in vacuo*. 3.8 g of crude product were chromatographed on 120 g SiO₂ (50% ether in pentane) to give 1.1 g of benzophenone (60% recovery), **39** (0.86 g; 51%), traces of **11b**, and 1.2 g (34% or 85% from unrecovered ketone) of **41** (m.p. 106–109°). IR (KBr): 3400, 3060, 3030, 2980, 2940, 1708, 1600, 1492, 1450, 1390, 1365, 1190, 1138, 1095, 1068, 1055, 1030, 1000, 980, 960, 830, 800, 780, 745, 700, 695 cm⁻¹. ¹H-NMR (CDCl₃): δ 1.4 (s, 6H, (CH₃)₂C), 2.43 and 3.45 (br., s, 2H, OH), 3.12 and 3.2 (2 × br., d, J = 7.5 Hz, 2H, –CH₂C=C), 3.42 (br., d, J = 7.5 Hz, 2H, CH₂CO), 5.3–6.5 (m, 4H, –CH=CH–CH=CH–), 7.35 (m, 10H, aromatic protons). MS: *m/e* (%) = 59 (24), 77 (31), 105 (65), 183 (100), 205 (3), 291 (1.8), 332 (2), 350 (3).*

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REFERENCES

- ¹In part from the Ph.D. thesis of M. Pohmakotr, Universität Giessen (1978).
- ^{2a}For preliminary communications describing part of this work see M. Pohmakotr and D. Seebach, *Angew. Chem.* **89**, 333 (1977); *Ibid.* Int. Ed. Engl. **16**, 320 (1977); *Tetrahedron Letters* 2271 (1979); *Helv. Chim. Acta* **62**, 843 (1979); ^bSee also subsequent papers: D. Seebach, M. Pohmakotr, B. Weidmann, R. S. Mali and S. Pohmakotr, *Helv. Chim. Acta* **64** (1981), and *Liebigs Ann.* in press.
- ³Recipient of a DAAD stipend, 1975–1978; present address: Department of Chemistry, Faculty of Science, Mahidol University, Rama VI Road, Bangkok 4, Thailand.
- ⁴Review: D. Seebach, *Angew. Chem.* **91**, 259 (1979); *Ibid.* Int. Ed. Engl. **18**, 239 (1979) and Refs. cited.
- ⁵Review: V. Kalyamaran and M. V. George, *J. Organomet. Chem.* **47**, 225 (1973) and Refs. cited.
- ⁶Reviews: F. Beck, *Elektroorganische Chemie*, Verlag Chemie, Weinheim (1974); A. J. Fry: *Synthetic Organic Electrochemistry*. Harper & Row, New York (1972).
- ⁷Review: D. Seebach, E. W. Colvin, F. Lehr, and T. Weller, *Chimia* **33**, 1 (1979).
- ⁸It is for instance well known that 1,4-pentadiene is deprotonated much more readily than the 1,3-isomer: R. B. Bates, D. W. Gosselink and J. A. Kaezyski, *Tetrahedron Letters* 199 (1967).
- ⁹E. J. Corey and D. Enders, *Chem. Ber.* **111**, 1337, 1362 (1978).
- ¹⁰Review: B. Gröbel and D. Seebach, *Synthesis* 357 (1977).
- ¹¹An alternative method of preparing α,α-dimethyl-α-hydroxy ketones starts from propionaldehyde cyanohydrin (Stork method of carbonyl umpolung): C. H. Heathcock and C. T. Buse, *J. Am. Chem. Soc.* **99**, 8109 (1977).
- ¹²D. Seebach and M. Teschner, *Chem. Ber.* **109**, 1601 (1976); B. M. Trost, T. N. Salzman and K. Hiroi, *J. Am. Chem. Soc.* **98**, 4887 (1976).
- ¹³C. A. Brown, *J. Org. Chem.* **39**, 3913 (1974).
- ¹⁴Obviously, the β-methylene group of K[⊖]-**13c** is more acidic than the α-Me group, see footnote⁸.
- ¹⁵cf I. Fleming, *Frontier Orbitals and Organic Chemical Reactions*. Wiley (1976).
- ¹⁶cf J. A. Oakleaf, M. T. Thomas, A. Wu, and V. Snieckus, *Tetrahedron Letter* 1645 (1978).
- ¹⁷K. B. Wiberg, *Oxidation in Organic Chemistry*, Part A. Academic Press, New York (1965); R. L. Augustine, *Oxidation*. Marcel Dekker, New York (1969).
- ¹⁸K. -H. Geiss, D. Seebach and B. Seuring, *Chem. Ber.* **110**, 1833 (1977); M. Pohmakotr, K. -H. Geiss and D. Seebach, *Ibid.* **112**, 1420 (1979).
- ¹⁹L. Lochmann, J. Pospisil and D. Lim, *Tetrahedron Letter* 257 (1966); M. Schlosser, *J. Organomet. Chem.* **8**, 9 (1967); M. Schlosser and J. Hartmann, *Angew. Chem.* **85**, 544 (1973); *Ibid.* Int. Ed. Engl. **12**, 508 (1973) and Refs. cited.
- ²⁰B. Renger, H. Hügel, W. Wykypiel and D. Seebach, *Chem. Ber.* **111**, 2630 (1978).
- ²¹W. Tochtermann, *Angew. Chem.* **78**, 355 (1966); *Ibid.* Int. Ed. Engl. **5**, 351 (1966); M. Schlosser: *Struktur und Reaktivität polarer Organometalle*. Springer, Heidelberg (1973).
- ²²B. Renger and D. Seebach, *Chem. Ber.* **110**, 2334 (1977); R. Henning, Dissertation, Universität Giessen (1978).
- ²³E. M. Kaiser, J. D. Petty and P. L. A. Knutson, *Synthesis* 509 (1977).
- ²⁴D. Seebach and D. Enders, *Chem. Ber.* **108**, 1293 (1975).
- ²⁵E. L. Eliel and A. A. Hartmann, *J. Org. Chem.* **37**, 505 (1972); D. Seebach, H. F. Leitz and V. Ehrig, *Chem. Ber.* **108**, 1924 (1975).
- ²⁶See *Organikum*, VEB Deutscher Verlag der Wissenschaften, Berlin (1976).
- ²⁷H. K. Hall, Jr., J. P. Schaefer and R. J. Spangord, *J. Org. Chem.* **37**, 3069 (1972).
- ²⁸H. Normant and Th. Cuvigny, *Bull. Soc. Chim. Fr.* 1881 (1965).
- ²⁹C. Prevost, P. Miginiac and L. Miginiac-Groizeleau, *Ibid.* 2485 (1964).
- ³⁰H. O. House, L. J. Czuba, M. Gall and H. D. Olmstead, *J. Org. Chem.* **34**, 2324 (1969).