

Patchanee Charoenying, Karl Hemming, Darren M^cKerrecher
and Richard J. K. Taylor*

Department of Chemistry, University of York, Heslington, York, YO1 5DD, U.K.

Received January 25, 1996

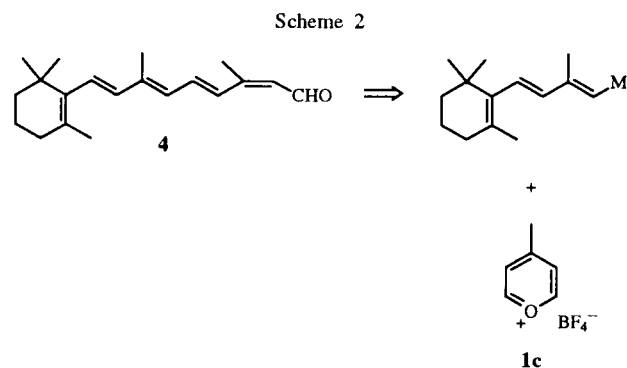
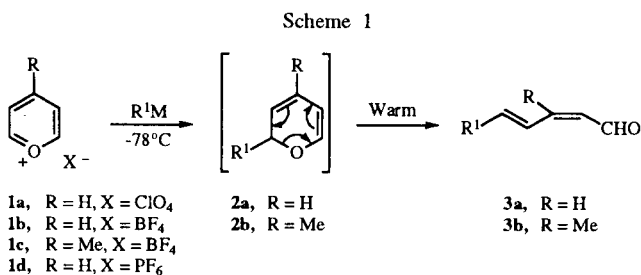
Revised March 11, 1996

The unsubstituted pyrylium nucleus is shown to undergo reaction with cuprate or secondary Grignard organometallic reagents to give intermediate 4-substituted pyrans which are converted into the corresponding 4-substituted pyrylium salts (7 examples) in fair to good overall yield. The synthetic utility of the 4-substituted pyrylium heterocycles is demonstrated by their reaction with organolithium reagents to give 3,5-disubstituted dienals in a highly stereospecific manner (7 examples) *via* electrocyclic ring opening of the intermediate 2-substituted pyrans.

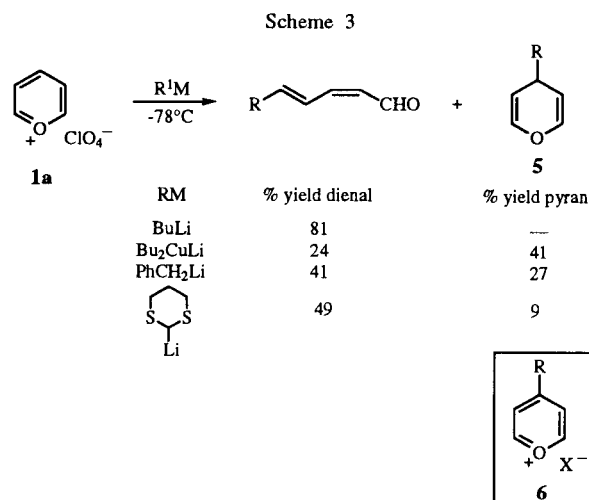
J. Heterocyclic Chem., 33, 1083 (1996).

Introduction.

We have previously shown that the unsubstituted pyrylium salts pyrylium perchlorate **1a** [1] and pyrylium tetrafluoroborate **1b** [2] undergo organometallic addition followed by electrocyclic ring opening of the intermediate 2*H*-pyran **2a** to give 2*Z*,4*E*-dienals **3a** in a stereocontrolled manner (Scheme 1). These dienals have been employed for the synthesis of a number of bioactive natural products [3]. More recently we described the preparation of 4-methylpyrylium tetrafluoroborate **1c** and showed that it underwent a similar transformation on treatment with organolithium reagents giving rise to 3-methyl-2*Z*,4*E*-dienals **3b**. This chemistry provided the cornerstone of a new approach to retinal *via* its 13*Z* isomer **4** as shown in Scheme 2 [4].



In connection with these studies in the retinal area we required a synthesis of other 4-substituted pyrylium salts to allow ready access to a variety of novel retinal analogues. There are a number of approaches to pyrylium salts in the literature [2,5] but we have found that the treatment of 4*H*-pyrans with tritylium salts is usually the preferred method. In earlier work [1], we have shown that 4*H*-pyrans **5** are often formed as by-products from organometallic additions to pyrylium salt **1a** (Scheme 3), a result of competing attack of the nucleophile at the 2 and 4 positions of the pyrylium nucleus.



We decided to try to optimise organometallic attack at C-4 and then to utilise the resulting pyrans **5**, *via* treatment with tritylium salts, to prepare novel 4-substituted pyrylium salts **6** for use in diene synthesis.

This route to 4-substituted pyrans, and subsequently to 4-substituted pyrylium salts is novel. However, the reaction of 2,6-dimethyl [6], 2,4,6-trimethyl, and 2,4,6-triphenyl [7,8] pyrylium salts with Grignard reagents, and the reaction of 2,4,6-trimethyl pyrylium salts with

organocuprates [9], to give the corresponding polysubstituted pyrans *via* C-4 addition are well documented in the literature. Also well known is the corresponding reaction of *N*-substituted pyridinium salts with Grignard reagents [10] and organocuprates [11,12] to give 1,4-dihydropyridines and, *via* oxidation, 4-substituted pyridines.

Results and Discussion.

(a) Organocuprate Additions to Unsubstituted Pirylium Salts.

The unsubstituted pyrylium salts **1b,d** were employed as starting materials and were prepared by established procedures [2] from glutaric dialdehyde. Treatment of pyrylium salts **1b** or **1d** with lithium or magnesium dialkylcuprates (generated from organolithium or Grignard reagents and copper(I) iodide), resulted in exclusive or predominant attack of the nucleophile at the 4-position of the pyrylium ring to give the 4-substituted pyrans **5a-e** (Scheme 4) in the yields shown. It should be noted that dienals resulting from attack at C-2 were not detected in most of the cases examined. The 4-substituted pyrans were usually unstable, and could not normally be fully characterised (except as the corresponding pyrylium salt - see section (c), below). Purification was effected by rapid filtration through a plug of aluminium oxide or silica. Instant analysis by tlc and 60 or 270 MHz ¹H nmr spectroscopy confirmed the purity of the pyrans.

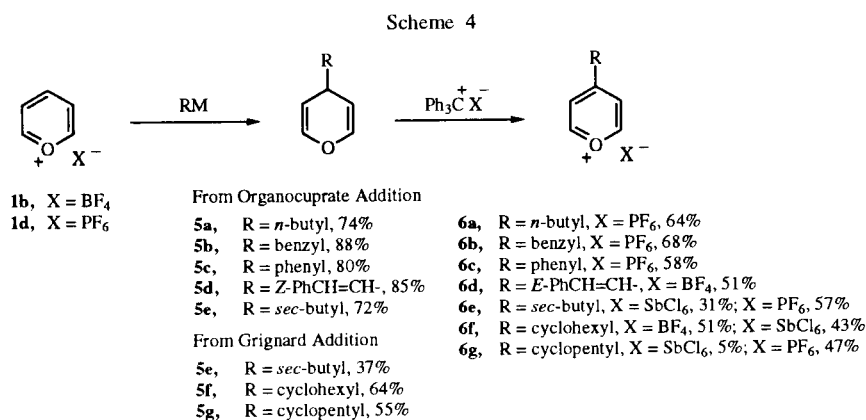
nantly at C-4 to give the desired 4-substituted pyrans **5e-g** (Scheme 4, above) in fair yields.

Our results show, for the first time, the predominant C-4 attack at the unsubstituted pyrylium nucleus of secondary Grignard reagents to give the 4-substituted pyrans **5e-g** (Scheme 4). Dreux, Reyer and co-workers [5,7] had already established the following sequence of increasing softness of various Grignard reagents towards 2,4,6-trimethylpyrylium salts: methylmagnesium halides < primary magnesium halides \cong tertiary magnesium halides < secondary magnesium halides. Our results with the unsubstituted pyrylium salts **1b,d** bear out this sequence.

In comparison to the pyrans **5e-g** synthesised from Grignard reagents, the pyrans **5a-e** synthesised from organocuprates are generally formed in higher yields. Indeed, when 4-*sec*-butyl-4*H*-pyran **5e** was prepared by the organocuprate route, a yield of 72% was obtained compared to 37% obtained with the Grignard route (Scheme 4). Thus organocuprates seem to be the reagent of choice for this transformation.

(c) Preparation of 4-Substituted Pirylium Salts From the Pyrans **5a-g**.

With the freshly purified pyrans **5a-g** in hand, they were immediately dissolved in dry, freshly distilled acetonitrile, cooled to a temperature of -30 to -40°, and treated with a solution of tritylium tetrafluoroborate,



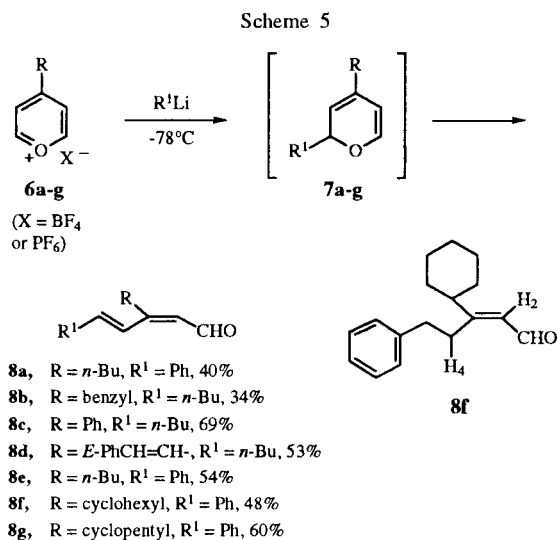
(b) Grignard Reagent Additions to Unsubstituted Pirylium Salts.

We also investigated the reaction of the unsubstituted pyrylium salts **1b,d** with a variety of Grignard reagents. Methylmagnesium bromide was found to give exclusively 2-addition [1], whereas other non-secondary Grignard reagents (for example *n*-butylmagnesium chloride [1]) showed little regioselectivity, giving mixtures of 4-substituted pyrans and dienals. To our surprise, and delight, we found that secondary Grignard reagents add predomi-

hexafluorophosphate or hexachloroantimonate in a dropwise manner. On precipitation with ice-cold ether, the 4-substituted pyrylium salts **6** were isolated as fully characterised, analytically pure, colored solids, in fair to good overall yields from the unsubstituted pyrylium salts **1b,d** as shown in Scheme 4. It should be noted that the *Z*-alkenyl-4*H*-pyran **5d** underwent isomerisation to the *E*-alkenylpyrylium salt **6d** during preparation of the pyrylium salt. Full spectral, analytical and other data for the pyrylium salts **6a-g** are given in the Experimental and are in full accord with the assigned structures.

(d) Organolithium Additions to 4-Substituted Pyrylium Salts **6**.

The 4-substituted pyrylium salts **6a-g** were next subjected to treatment with organolithium reagents (Scheme 5). Exclusive attack at the harder C-2 site was observed, giving the 3,5-disubstituted dienals **8**, via 2*H*-pyrans **7**, after warming to room temperature. Dienals **8** were obtained as unstable orange oils in fair to good yields as single isomers (Scheme 5). It should be noted that the hexachloroantimonate pyrylium salts **6e-g** gave no dienals, producing only unidentifiable tars. The 2*Z*,4*E* arrangement of the dienals was suggested by literature precedent [1,3,4,5] and confirmed by NOE studies. Thus, for example, 3-cyclohexyl-5-phenyl-2*Z*,4*E*-pentadienal **8f**, when irradiated at H-2 in an nmr difference NOE (DIFNOE) experiment, showed clear enhancement in the cyclohexyl ring protons but, importantly, no enhancement at H-4 (Scheme 5). These factors are indicative of a *cis* relationship between H-2 and the cyclohexyl ring.



We are currently applying this methodology in polyene natural product synthesis, especially in the area of novel retinoids [4].

Conclusions.

This methodology demonstrates a useful protocol for the conversion of the unsubstituted pyrylium nucleus into 4-substituted pyrylium salts *via* reaction with secondary Grignard reagents and organocuprates to give intermediate 4*H*-pyrans which are readily re-aromatised by tritylium-mediated hydride abstraction. The synthetic value of these 4-substituted pyrylium salts is highlighted by their reaction with organolithium reagents to give 3,5-disubstituted dienals in a highly stereospecific reaction.

EXPERIMENTAL

General Directions.

Proton nmr spectra were recorded using JEOL PMX 60 and JEOL EX 270 nmr spectrometers referencing to tetramethylsilane ($\delta = 0.00$) as internal standard or to residual protonated solvent. Proton nmr spectra were assigned using related literature data [1-4], homonuclear decoupling and/or COSY-45 experiments at 270 MHz, and DIFNOE experiments at 270 MHz. Carbon-13 nmr spectra were recorded using a JEOL EX 270 nmr spectrometer operating at 67.8 MHz referencing to the deuteriochloroform lock, and were assigned using DEPT or heteronuclear correlation experiments, or by reference to related literature compounds [1-4]. J values are in Hertz (Hz) and proton nmr data is reported in the form as (multiplicity, integration, J value, assignment).

Infra-red spectra were recorded on Perkin-Elmer FTIR 1720X or ATI Mattson Genesis Series FTIR spectrometers, and were run as neat films unless otherwise stated. Mass spectra were recorded on a Fisons Instruments VG Analytical Autospec Spectrometer system (low and high resolution electron impact (EI), fast atom bombardment (FAB) and chemical ionisation (CI) spectra). Light petroleum refers to the fraction of boiling range 40 to 60° and was redistilled before use. Tetrahydrofuran and ether were dried over sodium/benzophenone ketyl and distilled immediately before use. Triethylamine, acetonitrile, dichloromethane and toluene were dried by boiling over calcium hydride and distilled immediately before use. Ethyl acetate refers to hplc grade solvent and was used as purchased. Solutions of organolithium compounds were regularly titrated using diphenylacetic acid [13]. Solutions of organocuprates were prepared in the usual manner [14] by addition of a solution of the appropriate Grignard or organolithium reagent to a stirred suspension of high purity (99.999%, Aldrich) copper(I) iodide in tetrahydrofuran or ether under nitrogen. Solutions of Grignard reagents and other starting materials were used as purchased or prepared according to established literature procedures using references given in the text. Analytical tlc was performed on Merck 5554 aluminium-backed silica gel plates which were visualised using uv, and potassium permanganate-acetone or acidic ethanolic vanillin solutions. Column chromatography was carried out under flash conditions [15] using silica gel (Phase Separations Ltd Sorbsil C60 40/60H or ICN Biomedicals GmbH silica 32-63, 60Å) and the specified eluent. Plug filtrations were carried out using the same silica as above, or with aluminium oxide (Fluka, type 507C neutral; 100-125 mesh). Low temperature reactions were carried out in a Cryobath CB-80 cryocool bath. Melting points were recorded on an Electrothermal LA9100 digital melting point apparatus and are uncorrected. Micro-analyses were carried out at The University of East Anglia and are reported to one decimal place.

Preparation of 4-Substituted Pyrylium Salts.

General Procedure, Step 1: Preparation of 4-Substituted Pyrans.

The organometallic solution (1.0-1.5 equivalents) was cooled to ice temperature and added, *via* canula and under an atmosphere of dry nitrogen, to a stirred suspension of pyrylium tetrafluoroborate or hexafluorophosphate in dry tetrahydrofuran or ether at a temperature of -60 to -78° and the mixture stirred at

this temperature for 18 to 20 hours under an atmosphere of dry nitrogen. The solution was then warmed to room temperature over a period of 1 hour, stirred at this temperature for an additional hour, then quenched by the addition of a saturated solution of aqueous ammonium chloride. Extraction into ethyl acetate (4 x 50 ml), drying over sodium sulfate and concentration under reduced pressure gave the crude product as a yellow/orange oil. The crude product was purified by rapid passage through a 5 to 10 cm deep plug of aluminium oxide or silica using light petroleum as eluant. In this way the non-polar 4*H*-pyran was quickly obtained as a chromatographically (tlc) pure compound. The R_f values of the pyrans were between 0.6-0.8 with light petroleum as the eluent. Removal of the solvent under reduced pressure gave the pyran as a colorless to pale yellow mobile liquid which was noted to decompose rapidly in most cases. Rapid 60 or 270 MHz proton nmr spectroscopic analysis confirmed the presence of essentially pure 4*H*-pyrans **5** in all cases as evidenced by the distinctive signals for the 4*H*-pyran 2*H* protons at 6.50-7.00 ppm, for the 3*H* protons at 4.50-5.00 ppm, and for the 4*H* proton at 2.50-3.00 ppm. The 4*H*-pyrans **5** so obtained were generally too unstable to allow full characterisation and were used immediately in step 2.

General Procedure, Step 2: Preparation of 4-Substituted Pyrylium Salts From 4-Substituted Pyrans.

The freshly prepared 4*H*-pyran **5** was dissolved in dry, freshly distilled acetonitrile (5 ml) and cooled to -30 to -40° under an atmosphere of dry nitrogen. To this solution was added, dropwise during 30 minutes, a solution of tritylium tetrafluoroborate, hexafluorophosphate or hexachloroantimonate in the minimum volume of dry, freshly distilled acetonitrile. The solution was allowed to warm to ice temperature during 1 hour, stirred at this temperature for 2 hours, and then at room temperature for an additional 2 hours. The solution was then recooled to ice temperature and ice-cold, freshly distilled, dry ether (500 ml) added dropwise to the stirring mixture over 1 hour. The solid so precipitated was collected and washed with cold ether (2 x 50 ml). The crude product was redissolved in the minimum volume of acetonitrile (10 ml) at room temperature, and celite (0.5-1.0 g) and decolorising carbon (0.5-1.0 g) added. The mixture was stirred for 5 minutes, filtered, cooled to 0° and ice-cold dry ether (500 ml) was added dropwise to the slowly stirring mixture over 1 hour. The precipitated solid was collected on a filter paper, washed with cold, dry ether and dried under vacuum (0.1 mm Hg) to give the analytically pure salt as a colored solid.

4-*n*-Butylpyrylium Hexafluorophosphate **6a**.

This procedure was carried out as described above for step 1, using *n*-butylmagnesium chloride, 2.0*M* in ether (3.50 ml, 7.00 mmoles), copper(I) iodide (667 mg, 3.50 mmoles) and pyrylium hexafluorophosphate (715 mg, 3.16 mmoles) to give 4-*n*-butyl-4*H*-pyran **5a** (321 mg, 74%) as a pale yellow oil.

The pyrylium salt was prepared as described above for step 2, using tritylium hexafluorophosphate (903 mg, 2.33 mmoles) and 4-*n*-butyl-4*H*-pyran **5a** (321 mg, 2.33 mmoles) to give 4-*n*-butylpyrylium hexafluorophosphate **6a** (418 mg, 64%) as a purple solid, mp 91-92°; ir (Nujol): ν 3139, 3087, 1627, 1010, 839, 727; ^1H nmr (270 MHz, acetonitrile- d_3): δ 1.11-1.17 (t, 3H, $J = 7.0$ Hz, $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2$), 1.54-1.65 (m, 2H, $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2$), 1.87-1.98 (m, 2H, $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2$), 3.24-3.30 (m, 2H, $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2$), 8.33-8.35 (m, 2H, H-3 and H-5) and 9.48-9.50 (m, 2H, H-2 and H-6); ^{13}C nmr (67.8 MHz, acetonitrile-

d_3): δ 13.3 ($\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2$), 22.4 ($\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2$), 31.1 ($\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2$) 37.3 ($\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2$), 126.7 (C-3 and C-5), 166.3 (C-2 and C-6) and 181.8 (C-4); hrms: Calcd. for $\text{C}_9\text{H}_{13}\text{PF}_6\text{O}$: 137.0966. Found (FAB): M^+ (cation), 137.0969.

Anal. Calcd. for $\text{C}_9\text{H}_{13}\text{PF}_6\text{O}$: C, 38.3; H, 4.6. Found: C, 38.6; H, 4.7.

4-Benzylpyrylium Hexafluorophosphate **6b**.

This procedure was carried out as described above for step 1, using benzylmagnesium chloride, 2.0*M* in tetrahydrofuran (7.96 ml, 15.92 mmoles), copper(I) iodide (1.52 g, 7.98 mmoles) and pyrylium hexafluorophosphate (1.80 g, 7.96 mmoles) to give 4-benzyl-4*H*-pyran **5b** (1.20 g, 88%) as a yellow oil.

The pyrylium salt was prepared as described above for step 2, using tritylium hexafluorophosphate (1.69 g, 4.37 mmoles) and 4-benzyl-4*H*-pyran **5b** (751 mg, 4.36 mmoles) to give 4-benzylpyrylium hexafluorophosphate **6b** (935 mg, 68%) as a dark brown solid, mp 205-208°; ir (Nujol): ν 3138, 3081, 1624, 1603, 1511, 1213, 942, 841; ^1H nmr (270 MHz, acetonitrile- d_3): δ 4.56 (m, 2H, CH_2 (benzyl)), 7.41-7.56 (m, 5H, 5 x PhH), 8.23 (dd, 2H, $J = 1.7, 3.8$ Hz, H-3 and H-5), 9.43 (dd, 2H, $J = 1.7, 3.8$ Hz, H-2 and H-6); ^{13}C nmr (67.8 MHz, acetonitrile- d_3): δ 43.1 (CH_2 (benzyl)), 126.9 (C-3 and C-5), 128.8 (Ph), 130.2 (Ph), 130.5 (Ph), 135.5 (q-Ph), 167.2 (C-2 and C-6) and 179.1 (C-4); hrms: Calcd. for $\text{C}_{12}\text{H}_{11}\text{PF}_6\text{O}$: 171.0810. Found (FAB): M^+ (cation), 171.0815.

Anal. Calcd. for $\text{C}_{12}\text{H}_{11}\text{PF}_6\text{O}$: C, 45.6; H 3.5. Found: C, 45.5; H, 3.5.

4-Phenylpyrylium Hexafluorophosphate **6c**.

This procedure was carried out as described above for step 1, using phenyllithium, 1.8*M* in cyclohexane-ether (8.9 ml, 16.0 mmoles), copper(I) iodide (1.60 g, 8.4 mmoles) and pyrylium hexafluorophosphate (1.20 g, 5.3 mmoles) to give 4-phenyl-4*H*-pyran **5c** (0.67 g, 80%) as a pale yellow oil.

The pyrylium salt was prepared as described above for step 2, using tritylium hexafluorophosphate (1.40 g, 3.63 mmoles) and 4-phenyl-4*H*-pyran **5c** (574 mg, 3.61 mmoles) to give 4-phenylpyrylium hexafluorophosphate **6c** (630 mg, 58%) as a pale tan solid, mp 147-149°; ir (Nujol): ν 3133, 3077, 1626, 1600, 1510, 1219, 956, 845; ^1H nmr (270 MHz, acetonitrile- d_3): δ 7.66-7.72 (m, 2H, 2 x PhH), 7.79-7.86 (m, 1H, 1 x PhH), 8.12-8.14 (m, 2H, 2 x PhH), 8.50 (dd, 2H, $J = 4.0, 1.7$ Hz, H-3 and H-5), 9.32 (dd, 2H, $J = 4.0, 1.7$ Hz, H-2 and H-6); ^{13}C nmr (67.8 MHz, acetonitrile- d_3): δ 122.6 (C-3 and C-5), 130.9 (Ph), 131.2 (Ph), 132.1 (q-Ph), 137.4 (Ph), 166.9 (C-2 and C-6) and 168.7 (C-4); ms: m/z (FAB) 157 (M^+ , cation).

Anal. Calcd. for $\text{C}_{11}\text{H}_9\text{PF}_6\text{O}$: C, 43.7; H, 3.0. Found: C, 43.5; H, 2.9.

4-(2'*E*-Phenylethenyl)pyrylium Tetrafluoroborate **6d**.

This procedure was carried out as described above for step 1, using 2*Z*-phenylethenyllithium [16] (generated from *cis*- β -bromostyrene (2.00 g, 10.99 mmoles) and a 1.7*M* solution of *tert*-butyllithium in pentane (12.90 ml, 21.93 mmoles) in tetrahydrofuran:ether (25 ml, 4:1) at -110° for 30 minutes and then -78° for an additional 30 minutes), copper(I) iodide (1.05 g, 5.51 mmoles) and pyrylium tetrafluoroborate (1.11 g, 6.61 mmoles) to give 4-(2*Z*-phenylethenyl)-4*H*-pyran (861 mg, 85%) **5d** as an unstable yellow oil; R_f 0.55 (light petroleum:ether, 10:1); ir: ν 3081, 3060, 1682, 1620, 1493, 1452, 1098; ^1H nmr (270 MHz, deuteriochloroform): δ 3.93-4.07 (m, 1H, H-4), 4.66-4.75 (m,

2H, H-3 and H-5), 5.62 (dd, 1H, $J = 9.9, 11.4$ Hz, H-1'), 6.32-6.41 (m, 2H, H-2 and H-6), 6.44 (d, 1H, $J = 11.4$ Hz, H-2'), 7.10-7.38 (m, 5H, 5 x PhH); hrms: Calcd. for $C_{13}H_{12}O$: 184.0888. Found (EI): M^+ , 184.0886.

The pyrylium salt was prepared as described above for step 2, using tritylium tetrafluoroborate (1.16 g, 3.52 mmoles) and 4-(2'-Z-phenylethenyl)-4H-pyran **5d** (0.59 g, 3.21 mmoles) to give 4-(2'E-phenylethenyl)pyrylium tetrafluoroborate **6d** (0.44 g, 51%) as a bright yellow solid, mp >200° dec; ir (Nujol): ν 3129, 1635, 1606, 1591, 1571, 1508, 942, 895, 874; 1H nmr (270 MHz, acetonitrile- d_3): δ 7.57 (d, 1H, $J = 16.2$ Hz, H-2'), 7.58-7.67 and 7.89-7.93 (m, 3H and 2H, 5 x PhH), 8.20-8.22 (dd, 2H, $J = 1.5, 4.1$ Hz, H-3 and H-5), 8.39 (d, 1H, $J = 16.2$ Hz, H-1'), 9.13-9.15 (dd, 2H, $J = 1.5, 4.1$ Hz, H-2 and H-6); ^{13}C nmr (67.8 MHz, acetonitrile- d_3): δ 97.0 (C-2'), 99.8 (C-1'), 121.6 (C-3 and C-5), 123.1 (Ph), 130.9 (Ph), 134.2 (Ph), 135.0 (*q*-Ph), 165.2 (C-2 and C-6) and 169.5 (C-4); hrms: Calcd. for $C_{13}H_{11}BF_4O$: 183.0810. Found (FAB): M^+ (cation), 183.0809.

Anal. Calcd. for $C_{13}H_{11}BF_4O$: C, 57.8; H, 4.1. Found: C, 57.4; H, 4.1.

4-*sec*-Butylpyrylium Hexachloroantimonate **6e** (X = SbCl₆).

This procedure was carried out as described above for step 1 above, using *sec*-butylmagnesium chloride, 2.0M in ether (6.99 ml, 13.98 mmoles) and pyrylium tetrafluoroborate (1.56 g, 9.32 mmoles) to give 4-*sec*-butyl-4H-pyran **5e** (478 mg, 37%) as a pale yellow oil.

The pyrylium salt was prepared as described above for step 2, using tritylium hexachloroantimonate (0.93 g, 1.62 mmoles) and 4-*sec*-butyl-4H-pyran **5e** (249 mg, 1.80 mmoles) to give 4-*sec*-butylpyrylium hexachloroantimonate **6e** (263 mg, 31%) as a purple solid, mp 102-103°; 1H nmr (270 MHz, acetonitrile- d_3): δ 1.03-1.08 (t, 3H, $J = 7.0$ Hz, $CH_3CH_2CHCH_3$); 1.51 (d, 3H, $J = 6.6$ Hz, $CH_3CH_2CHCH_3$); 1.93-1.98 (m, 2H, $CH_3CH_2CHCH_3$), 3.28-3.36 (m, 1H, $CH_3CH_2CHCH_3$), 8.34 (d, 2H, $J = 4.9$ Hz, H-3 and H-5) and 9.51 (d, 2H, $J = 4.9$ Hz, H-2 and H-6); ^{13}C nmr (67.8 MHz, acetonitrile- d_3): δ 11.2 ($CH_3CH_2CHCH_3$), 18.8 ($CH_3CH_2CHCH_3$), 29.6 ($CH_3CH_2CHCH_3$), 43.4 ($CH_3CH_2CHCH_3$), 125.5 (C-3 and C-5), 166.7 (C-2 and C-6) and 186.4 (C-4).

Anal. Calcd. for $C_9H_{13}SbCl_6O$: C, 22.9; H, 2.8. Found: C, 22.8; H, 2.7.

4-*sec*-Butylpyrylium Hexafluorophosphate **6e** (X = PF₆).

This procedure was carried out as described above for step 1, using *sec*-butylmagnesium chloride, 2.0M in ether (4.46 ml, 8.92 mmoles), copper(I) iodide (0.71 g, 3.73 mmoles) and pyrylium hexafluorophosphate (0.84 g, 3.72 mmoles) to give 4-*sec*-butyl-4H-pyran **5e** (369 mg, 72%) as a pale yellow oil.

The pyrylium salt was prepared as described above for step 2, using tritylium hexafluorophosphate (1.00 g, 2.58 mmoles) and 4-*sec*-butyl-4H-pyran **5e** (369 mg, 2.67 mmoles) to give 4-*sec*-butylpyrylium hexafluorophosphate **6e** (413 mg, 57%) as a dark brown solid, mp 92-94°; 1H nmr (270 MHz, trifluoroacetic acid-*d*): δ 1.15-1.20 (t, 3H, $J = 7.0$ Hz, $CH_3CH_2CHCH_3$), 1.64 (d, 3H, $J = 6.5$ Hz, $CH_3CH_2CHCH_3$), 1.97-2.07 (m, 2H, $CH_3CH_2CHCH_3$), 3.31-3.39 (m, 1H, $CH_3CH_2CHCH_3$), 8.38 (br d, 2H, H-3 and H-5) and 9.50 (br d, 2H, H-2 and H-6); ^{13}C nmr (67.8 MHz, trifluoroacetic acid-*d*): δ 12.4 ($CH_3CH_2CHCH_3$), 20.1 ($CH_3CH_2CHCH_3$), 31.9 ($CH_3CH_2CHCH_3$), 46.5 ($CH_3CH_2CHCH_3$), 127.5 (C-3 and C-5), 168.2 (C-2 and C-6) and 189.4 (C-4).

Anal. Calcd. for $C_9H_{13}PF_6O$: C, 38.3; H, 4.6. Found: C, 38.6; H, 4.8.

4-Cyclohexylpyrylium Tetrafluoroborate **6f** (X = BF₄).

This procedure was carried out as described above for step 1, using cyclohexylmagnesium chloride, 2.0M in ether (27.0 ml, 54.0 mmoles) and pyrylium tetrafluoroborate (6.00 g, 35.7 mmoles) to give 4-cyclohexyl-4H-pyran **5f** (3.76 g, 64%) as a pale yellow oil.

The pyrylium salt was prepared as described above for step 2, using tritylium tetrafluoroborate (5.65 g, 17.1 mmoles) and 4-cyclohexyl-4H-pyran **5f** (2.81 g, 17.1 mmoles) to give 4-cyclohexylpyrylium tetrafluoroborate **6f** (2.18 g, 51%) as a pale tan solid; mp 112-114°; ir (Nujol): ν 3142, 3073, 1631, 1526, 961, 845; 1H nmr (270 MHz, trifluoroacetic acid-*d*): δ 1.12-1.78 (m, 10H, 5 x CH_2 -cyclohexyl), 2.80 (m, 1H, CH-cyclohexyl), 7.94 (br d, 2H, H-3 and H-5) and 9.05 (br d, 2H, H-2 and H-6); ^{13}C nmr (67.8 MHz, trifluoroacetic acid-*d*): δ 26.7 (CH_2 -cyclohexyl), 27.4 (CH_2 -cyclohexyl), 34.4 (CH_2 -cyclohexyl), 49.4 (CH-cyclohexyl), 127.1 (C-3 and C-5), 167.9 (C-2 and C-6) and 188.7 (C-4).

Anal. Calcd. for $C_{11}H_{15}BF_4O$: C, 52.8; H, 6.1. Found: C, 52.8; H, 6.0.

4-Cyclohexylpyrylium Hexachloroantimonate **6f** (X = SbCl₆).

The pyrylium salt was prepared as described above for step 2, using tritylium hexachloroantimonate (1.59 g, 2.77 mmoles) and 4-cyclohexyl-4H-pyran **5f** (504 mg, 3.07 mmoles) to give 4-cyclohexylpyrylium hexachloroantimonate **6f** (649 mg, 43%) as a purple solid, mp 97-98°; 1H nmr (270 MHz, acetonitrile- d_3): δ 1.60-2.08 (m, 10H, 5 x CH_2 -cyclohexyl), 3.18 (m, 1H, CH-cyclohexyl), 8.30 (br d, 2H, H-3 and H-5) and 9.45 (br d, 2H, H-2 and H-6); ^{13}C nmr (67.8 MHz, acetonitrile- d_3): 825.3 (CH_2 -cyclohexyl), 31.9 (CH_2 -cyclohexyl), 38.3 (CH_2 -cyclohexyl), 46.1 (CH-cyclohexyl), 125.4 (C-3 and C-5), 166.7 (C-2 and C-6) and 184.4 (C-4).

Anal. Calcd. for $C_{11}H_{15}SbCl_6O$: C, 26.6; H, 3.0. Found: C, 26.8; H, 3.0.

4-Cyclopentylpyrylium Hexachloroantimonate **6g** (X = SbCl₆).

This procedure was carried out as described above for step 1, using cyclopentylmagnesium chloride, 2.0M in ether (5.81 ml, 11.62 mmoles) and pyrylium tetrafluoroborate (1.30 g, 7.74 mmoles) to give 4-cyclopentyl-4H-pyran **5g** (641 mg, 55%) as a pale yellow oil.

The pyrylium salt was prepared as described above for step 2, using tritylium hexachloroantimonate (2.22 g, 3.86 mmoles) and 4-cyclopentyl-4H-pyran **5g** (641 mg, 4.27 mmoles) to give 4-cyclopentylpyrylium hexachloroantimonate **6g** (96 mg, 5%) as a purple solid, mp 144-146°; 1H nmr (270 MHz, acetonitrile- d_3): 1.56-2.12 (m, 8H, 4 x CH_2 -cyclopentyl), 3.24 (m, 1H, CH-cyclopentyl), 7.94 (br d, 2H, H-3 and H-5) and 9.02 (br d, 2H, H-2 and H-6); ^{13}C nmr (67.8 MHz, acetonitrile- d_3): δ 28.0 (CH_2 -cyclopentyl), 36.8 (CH_2 -cyclopentyl), 50.7 (CH-cyclopentyl), 127.3 (C-3 and C-5), 167.7 (C-2 and C-6) and 189.5 (C-4).

Anal. Calcd. for $C_{10}H_{13}SbCl_6O$: C, 24.8; H, 2.7. Found: C, 25.0; H, 2.5.

4-Cyclopentylpyrylium Hexafluorophosphate **6g** (X = PF₆).

The pyrylium salt was prepared as described above for step 2, using tritylium hexafluorophosphate (2.57 g, 6.62 mmoles) and 4-cyclopentyl-4H-pyran **5g** (1.00 g, 6.67 mmoles) to give

4-cyclopentylpyrylium hexafluorophosphate **6g** (0.91 g, 47%) as a purple solid, mp 118–119°; ir (Nujol): ν 3120, 3054, 1622, 1524, 961, 837; ^1H nmr (270 MHz, trifluoroacetic acid-d): δ 1.56–2.12 (m, 8H, 4 x CH_2 -cyclopentyl), 3.24 (m, 1H, CH-cyclopentyl), 7.94 (br s, 2H, H-3 and H-5) and 9.02 (br s, 2H, H-2 and H-6); ^{13}C nmr (67.8 MHz, trifluoroacetic acid-d): δ 28.0 (CH_2 -cyclopentyl), 36.8 (CH_2 -cyclopentyl), 50.7 (CH-cyclopentyl), 127.3 (C-3 and C-5), 167.7 (C-2 and C-6) and 189.5 (C-4).

Anal. Calcd. for $\text{C}_{10}\text{H}_{13}\text{PF}_6\text{O}$: C, 40.8; H, 4.5. Found: C, 40.5; H, 4.3.

General Procedure for the Addition of Organolithiums to 4-Substituted Pyrylium Salts.

The organolithium solution was added dropwise to a suspension of the appropriate 4-substituted pyrylium salt **6** in dry ether or tetrahydrofuran at -78° under a nitrogen atmosphere. The reaction mixture was stirred at the same temperature for 18 hours, then quenched at that temperature with saturated aqueous ammonium chloride (10 ml), and warmed to room temperature. Water (10 ml) was added and the aqueous phase was extracted with ethyl acetate (5 x 10 ml), the combined organic layers were washed with brine (10 ml), dried (sodium sulfate) and the solvent removed under reduced pressure to give an orange oil. The crude product was purified by flash silica column chromatography to give the dienal **8** as a yellow oil.

3-(2'E-Phenylethenyl)-2Z-heptenal **8a**.

The dienal was prepared according to the general procedure described above, using phenyllithium, 1.8M in cyclohexane/ether (0.13 ml, 0.23 mmole) and 4-*n*-butylpyrylium hexafluorophosphate **6a** (57 mg, 0.20 mmole) in tetrahydrofuran (5 ml). Flash silica chromatography eluting with light petroleum:ethyl acetate:triethylamine (95:5:0.1) gave 3-(2'E-phenylethenyl)-2Z-heptenal **8a** (17 mg, 40%) as a pale yellow oil; R_f 0.26 (light petroleum:ethyl acetate, 97:3); ir: ν 2871 (CH stretching, aldehyde), 1660 (C=O, aldehyde), 1616, 1583, 1465; ^1H nmr (270 MHz, deuteriochloroform): δ 0.85–0.92 (m, 3H, $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2$), 1.27–1.37 (m, 4H, $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2$), 2.40–2.46 (m, 2H, $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2$), 5.88 (d, 1H, $J = 7.5$ Hz, H-2), 6.90 (d, 1H, $J = 15.8$ Hz, H-5), 7.18–7.45 (m, 5H, 5 x PhH), 7.58 (d, 1H, $J = 15.8$ Hz, H-4) and 10.18 (d, 1H, $J = 7.5$ Hz, H-1); ^{13}C nmr (67.8 MHz, deuteriochloroform): δ 13.8, 22.5, 31.1, 34.3, 122.7, 127.2, 127.3, 128.8, 129.9, 135.9, 136.4, 159.0 and 190.4; ms: m/z (EI) 214 (M^+ , 100%), 157 (M^+ -Bu, 100), 129 (-CO, 49) and 77 (17); hrms: Calcd. for $\text{C}_{15}\text{H}_{18}\text{O}$: 214.1358. Found (EI): M^+ , 214.1363.

3-Benzyl-2Z,4E-nonadienal **8b**.

The dienal was prepared according to the general procedure described above, using *n*-butyllithium, 2.5M in hexanes (0.42 ml, 1.05 mmoles) and 4-benzylpyrylium hexafluorophosphate **6b** (300 mg, 0.95 mmole) in tetrahydrofuran (10 ml). Purification by flash silica chromatography eluting with light petroleum:ethyl acetate:triethylamine (400:20:1) gave 3-benzyl-2Z,4E-nonadienal **8b** (74 mg, 34%) as a yellow/orange oil; R_f 0.25 (light petroleum:ethyl acetate, 16:1); ir: ν 2936, 1675, 1601, 1465, 1293, 1263, 963, 876; ^1H nmr (270 MHz, deuteriochloroform): δ 0.99 (m, 3H, $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2$), 1.35 (m, 4H, $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2$), 2.29 (m, 2H, $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2$), 3.80 (s, 2H, CH_2 (benzyl)), 5.83 (d, 1H, $J = 7.9$ Hz, H-2), 6.32 (dt, 1H, $J = 15.6, 6.9$ Hz, H-5), 7.02 (d, 1H, $J = 15.6$ Hz, H-4), 7.25–7.43

(m, 5H, 5 x PhH), 10.25 (d, 1H, $J = 7.9$ Hz, H-1); irradiation of H-2 in a DIFNOE experiment caused enhancement of the signal for the benzyl CH_2 group but no enhancement at H-4; ^{13}C nmr (67.8 MHz, deuteriochloroform): δ 12.9, 21.2, 29.9, 32.2, 39.9, 123.6, 125.7, 127.0, 127.6, 127.9, 136.7, 140.5, 156.9 and 189.8; ms: m/z (EI) 228 (M^+ , 5%), 200 (5), 183 (3), 171 (100), 128 (10), 115 (8), 91 (25); hrms: Calcd. for $\text{C}_{16}\text{H}_{20}\text{O}$: 228.1514. Found (EI): M^+ , 228.1511.

3-Phenyl-2E,4E-nonadienal **8c**.

The dienal was prepared according to the general procedure described above, using *n*-butyllithium, 2.5M in hexanes (0.24 ml, 0.60 mmole) and 4-phenylpyrylium hexafluorophosphate **6c** (166 mg, 0.55 mmole) in tetrahydrofuran (5 ml). Purification by flash silica chromatography eluting with light petroleum:ethyl acetate:triethylamine (500:20:1) gave 3-phenyl-2E,4E-nonadienal **8c** (81 mg, 69%) as a yellow-orange oil; R_f 0.33 (light petroleum:ethyl acetate, 16:1); ir: ν 2848, 1661, 1615, 1118, 924, 750, 691; ^1H nmr (270 MHz, deuteriochloroform): δ 0.86–0.96 (t, 3H, $J = 7.1$ Hz, $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2$), 1.29–1.52 (m, 4H, $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2$), 2.30 (m, 2H, $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2$), 6.04 (dt, 1H, $J = 15.5, 6.9$ Hz, H-5), 6.12 (d, 1H, $J = 7.9$ Hz, H-2), 6.89 (d, 1H, $J = 15.5$ Hz, H-4), 7.41 (s, 5H, 5 x PhH), 10.12 (d, 1H, $J = 7.9$ Hz, H-1); irradiation of H-2 in a DIFNOE experiment caused enhancement of the signal for the phenyl ring protons but no enhancement at H-4; ^{13}C nmr (67.8 MHz, deuteriochloroform): δ 13.9, 22.3, 30.9, 33.2, 125.0, 126.9, 128.2, 128.6, 139.2, 145.7, 159.1 and 191.1; ms: m/z (EI) 214 (3%), 157 (100), 128 (10); hrms: Calcd. for $\text{C}_{15}\text{H}_{18}\text{O}+\text{H}^+$: 215.1436. Found (CI): $\text{M}+\text{H}^+$, 215.1441.

3-(2'E-Phenylethenyl)-2E,4E-pentadienal **8d**.

The dienal was prepared according to the general procedure described above, using *n*-butyllithium, 2.1M in hexanes (0.28 ml, 0.57 mmole) and 4-(2'E-phenylethenyl)-pyrylium tetrafluoroborate **6d** (130 mg, 0.48 mmole) in tetrahydrofuran (15 ml). Flash silica chromatography eluting with light petroleum:ether:triethylamine (10:1:0.1) gave 3-(2'E-phenylethenyl)-2E,4E-pentadienal **8d** (61 mg, 53%) as a yellow-brown oil; R_f 0.73 (light petroleum:ether, 1:1); ir: ν 3155, 3019, 2931 (CH stretching, aldehyde), 1656 (C=O, aldehyde), 1613, 1467, 1382, 1218, 1096; ^1H nmr (270 MHz, deuteriochloroform): δ 0.96 (t, 3H, $J = 7.3$ Hz, $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2$), 1.26–1.61 (m, 4H, $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2$), 2.33 (m, 2H, $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2$), 6.05–6.16 (m, 2H, H-2 and H-5), 6.49 (d, 1H, $J = 15.5$ Hz, H-4), 6.90 (d, 1H, $J = 16.2$ Hz, H-1), 7.06 (d, 1H, $J = 16.2$ Hz, H-2), 7.35–7.54 (m, 5H, 5 x PhH), 10.00 (d, 1H, $J = 8.3$ Hz, H-1); ^{13}C nmr (67.8 MHz, deuteriochloroform): δ 13.9, 22.3, 31.0, 33.1, 122.7, 127.1, 127.3, 128.3, 128.9, 129.2, 135.9, 137.0, 143.1, 156.0 and 192.5; ms: m/z (EI) 240 (M^+ , 4%), 183 (M^+ -Bu, 100); hrms: Calcd. for $\text{C}_{17}\text{H}_{20}\text{O}$: 240.1514. Found (EI): M^+ , 240.1509.

3-sec-Butyl-5-phenyl-2Z,4E-pentadienal **8e**.

The dienal was prepared according to the general procedure described above, using phenyllithium, 1.8M in cyclohexane/ether (0.30 ml, 0.54 mmole) and 4-sec-butylpyrylium hexafluorophosphate **6e** (130 mg, 0.46 mmole) in tetrahydrofuran (10 ml). Flash silica chromatography eluting with light petroleum:ethyl acetate:triethylamine (95:5:0.01) gave 3-sec-butyl-5-phenyl-2Z,4E-pentadienal **8e** (53 mg, 54%) as a pale yellow oil; R_f 0.25 (light petroleum:ethyl acetate, 97:3); ir: ν 2871 (CH stretching, aldehyde), 1658 (C=O, aldehyde), 1617,

1457, 1380; ^1H nmr (270 MHz, deuteriochloroform): δ 0.77-0.86 (m, 3H, CH_3CH_2), 1.08-1.39 (m, 3H, CH_3CH), 1.41-1.57 (m, 1H, CH), 2.50-2.58 (m, 2H, CH_3CH_2), 5.90 (d, 1H, $J = 8.0$ Hz, H-2), 6.82 (d, 1H, $J = 16.0$ Hz, H-5), 7.17-7.20 (m, 6H, H-4 and 5 x PhH) and 10.05 (d, 1H, $J = 8.0$ Hz, H-1); ^{13}C nmr (67.8 MHz, deuteriochloroform): δ 12.3, 20.3, 29.4, 40.1, 123.5, 127.2, 127.7, 129.3, 129.5, 136.4, 137.5, 166.0 and 191.9; ms: m/z (CI) 215 ($\text{M}+\text{H}^+$, 100%) and 157 ($\text{M}^+-\text{C}_5\text{H}_9$, 69); hrms: Calcd. for $\text{C}_{15}\text{H}_{18}\text{O}+\text{H}^+$: 215.1436. Found (CI): $\text{M}+\text{H}^+$, 215.1443.

3-Cyclohexyl-5-phenyl-2Z,4E-pentadienal **8f**.

The dienal was prepared according to the general procedure described above, using phenyllithium, 1.8M in cyclohexane/ether (1.20 ml, 2.16 mmoles) and 4-cyclohexylpyrylium tetrafluoroborate **6f** (474 mg, 1.90 mmoles) in ether (10 ml). Purification by flash silica chromatography eluting with light petroleum:ethyl acetate:triethylamine (95:5:0.1) gave 3-cyclohexyl-5-phenyl-2Z,4E-pentadienal **8f** (221 mg, 48%) as a pale yellow oil; R_f 0.30 (light petroleum:ethyl acetate, 97:3); ir: ν 2923, 2852, 1661, 1614, 1449, 1258, 1199, 1117, 962, 750, 691; ^1H nmr (270 MHz, deuteriochloroform): δ 1.22-1.38 (m, 8H, 4 x CH_2 -cyclohexyl), 1.70-1.80 (m, 2H, CH_2 -cyclohexyl), 2.36-2.84 (m, 1H, CH-cyclohexyl), 5.91 (d, 1H, $J = 7.0$ Hz, H-2), 6.80 (d, 1H, $J = 15.0$ Hz, H-5), 7.24-7.44 (m, 6H, H-4 and 5 x PhH) and 10.05 (d, 1H, $J = 7.0$ Hz, H-1); irradiation of H-2 in a DIFNOE experiment caused enhancement of the signal for the cyclohexyl ring CH and CH_2 protons but no enhancement at H-4; ^{13}C nmr (67.8 MHz, deuteriochloroform): δ 25.9, 26.5, 32.5, 42.8, 123.2, 126.2, 127.2, 128.8, 129.0, 135.9, 136.6, 165.4 and 191.7; ms: m/z (CI) 241 ($\text{M}+\text{H}^+$, 100%), 157 (44) and 128 (6); hrms: Calcd. for $\text{C}_{17}\text{H}_{20}\text{O}+\text{H}^+$: 241.1592. Found (CI): $\text{M}+\text{H}^+$, 241.1596.

3-Cyclopentyl-5-phenyl-2Z,4E-pentadienal **8g**.

The dienal was prepared according to the general procedure described above, using phenyllithium, 1.8M in cyclohexane/ether (0.31 ml, 0.56 mmole) and 4-cyclopentylpyrylium hexafluorophosphate **6g** (138 mg, 0.47 mmole) in ether (5 ml). Flash silica chromatography eluting with light petroleum:ethyl acetate:triethylamine (95:5:0.1) gave 3-cyclopentyl-5-phenyl-2Z,4E-pentadienal **8g** (64 mg, 60%) as a pale yellow oil; R_f 0.28 (light petroleum:ethyl acetate, 97:3); ir: ν 2869, 1658, 1619, 1581, 1450; ^1H nmr (270 MHz, deuteriochloroform): δ 1.46-1.95 (m, 8H, 4 x CH_2 -cyclopentyl), 2.85-2.94 (m, 1H, CH-cyclopentyl), 5.94 (d, 1H, $J = 7.5$ Hz, H-2), 6.84 (d, 1H, $J = 16.0$ Hz, H-5), 7.21-7.43 (m, 6H, H-4 and 5 x PhH) and 10.07 (1H, d, $J = 7.5$ Hz, H-1); ^{13}C nmr (67.8 MHz, deuteriochloroform): δ 25.2, 32.4, 44.1, 123.5, 125.6, 127.1, 128.8, 128.9, 135.9, 136.9, 164.1 and 191.4; ms: m/z (CI) 227 ($\text{M}+\text{H}^+$, 100%)

and 157 (29); hrms: Calcd. for $\text{C}_{16}\text{H}_{18}\text{O}+\text{H}^+$: 227.1435. Found (CI): $\text{M}+\text{H}^+$, 227.1440.

Acknowledgements.

We thank the EPSRC for the award of a postdoctoral research assistantship (K.H.), and Zeneca Pharmaceuticals, Alderley Park, U.K. and the EPSRC for the award of a CASE studentship (D.McK.). We would also like to thank Dr. Huw Davies (Zeneca, Alderley Park) for his interest in this research.

REFERENCES AND NOTES

- [1] M. Furber, J. M. Herbert and R. J. K. Taylor, *J. Chem. Soc., Perkin Trans. 1*, 683 (1989).
- [2] See Y. Y. Belosludtsev, B. C. Borer and R. J. K. Taylor, *Synthesis*, 320 (1991) and references therein.
- [3] See, for example, B. C. Borer and R. J. K. Taylor, *J. Chem. Res., (S)*, 162 (1992); E. F. De Medeiros, J. M. Herbert and R. J. K. Taylor, *J. Chem. Soc., Perkin Trans. 1*, 2725 (1991); B. C. Borer and R. J. K. Taylor, *Synlett*, 117 (1992); P. Charoenying, D. H. Davies, D. McKeercher and R. J. K. Taylor, *Tetrahedron Letters*, **37**, 1913 (1996).
- [4] K. Hemming, E. F. de Medeiros and R. J. K. Taylor, *J. Chem. Soc., Perkin Trans. 1*, 2385 (1995) and *J. Chem. Soc., Chem. Commun.*, 2623 (1994).
- [5] A. T. Balaban, A. Dinculescu, G. N. Dorofeenko, G. W. Fischer, A. V. Koblik, V. V. Mezheritskii and W. Schroth, *Adv. Heterocyclic Chem., Supplement 2*, Academic Press, New York, 1982, pp 5-30 and references therein.
- [6] J. Royer and J. Dreux, *Bull. Soc. Chim. France*, 707 (1972).
- [7] A. Safieddine, J. Royer and J. Dreux, *Bull. Soc. Chim. France*, 703 (1972); O. Chalvet, C. Decoret, J. Dreux, A. Safieddine and J. Royer, *ibid*, 716 (1972).
- [8] K. Dimroth, K. Wolf and H. Kroke, *Liebigs Ann. Chem.*, **678**, 183 and 202 (1964).
- [9] Y. Yamamoto, T. Kume and K-ya Akiba, *Heterocycles*, **26**, 1495 (1987).
- [10] D. L. Comins and A. H. Abdullah, *J. Org. Chem.*, **47**, 4315 (1982).
- [11] K-ya Akiba, Y. Iseki and M. Wada, *Tetrahedron Letters*, **23**, 429 (1982).
- [12] K-ya Akiba, Y. Iseki and M. Wada, *Bull. Chem. Soc. Japan*, **57**, 1994 (1984).
- [13] W. G. Kofron and L. M. Baclawski, *J. Org. Chem.*, **41**, 1879 (1976).
- [14] R. J. K. Taylor and G. Casy, *Organocopper Reagents: A Practical Approach*, R. J. K. Taylor, ed, Oxford University Press, 1994, pp 27-72.
- [15] W. C. Still, M. Kahn and A. Mitra, *J. Org. Chem.*, **48**, 2923 (1978).
- [16] H. Neumann and D. Seebach, *Tetrahedron Letters*, **17**, 4869 (1976).