Synthesis of Unsymmetrical $\Delta^{4,4'}$-2,6-Diphenyl-4-(thiopyranyl)-4*H*-pyrans[1]

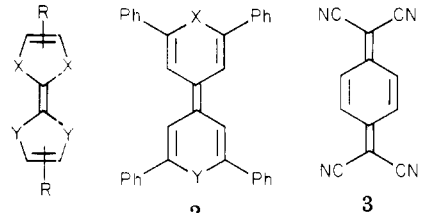
Chin H. Chen* and George A. Reynolds

Research Laboratories, Eastman Kodak Company, Rochester, New York 14650

Received November 27, 1979

Unsymmetrical $\Delta^{4,4'}$-tetraphenyl-4-(thiopyranyl)-4*H*-pyran **17** and related compounds have been synthesized. The reversal in the polarity (umpolung) of 2,6-diphenylpyrylium salt **13** is achieved by the synthesis of the Wittig-Horner reagent (**11**) of diethyl (2,6-diphenyl-4*H*-pyran-4-yl)phosphonate (**15**). This reagent condenses with a variety of ketones, including 2,6-diphenyl-4*H*-5,6-dihydrothiopyran-4-one (**9b**), leading to the $\Delta^{4,4'}$-tetraphenyl-4-(dihydrothiopyranyl)-4*H*-pyran **12b**. Further oxidation of **12b** with NCS and pyridine affords the trans C-5 succinimidyl-substituted compound **16**. A mechanism which accounts for the observed stereospecific formation of trans **16** is proposed. Thermal syn elimination of succinimide from **16** produces **17** in 60% yield.

In analogy to certain derivatives of tetrathiafulvalene (TTF, **1**, X = Y = S), tetraphenyl-substituted $\Delta^{4,4'}$-bi-4*H*-pyran **2** (X = Y = O) and $\Delta^{4,4'}$-bi-4*H*-thiopyran **2** (X = Y = S) represent an interesting new class of donors which

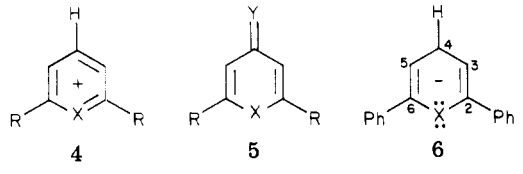


1 **2** **3**

form highly conducting "organic metals" with a suitable acceptor such as tetracyanoquinodimethane (TCNQ, **3**).[2,3]

Most of the work published about **1** has been physical in nature,[4] and the preparation of *unsymmetrical* tetraheterofulvalene **1** ($R \neq R'$, $X \neq Y$) is recent.[5]

In the case of $\Delta^{4,4'}$-bi-4*H*-heteropyrans, however, only a few simple derivatives of *symmetrical* dimers **2** (X = Y) are known, which were prepared by the reductive coupling of a heteropyrylium salt **4**[2] or its precursors, such as **5** (Y



4 **5** **6**

= O or S).[7] Thus, the current methodology is limited to the synthesis of symmetrical dimers and is unsuitable for the production of many potentially interesting unsymmetrical compounds.[8]

The difficulties encountered in the synthesis of unsymmetrical $\Delta^{4,4'}$-bi-4*H*-heteropyrans **2** ($X \neq Y$) can be attributed in part to the relative inaccessibility of a heteropyranyl anion[9] such as **6**. This nucleophilic species would be expected to couple with a suitable electrophile to give an unsymmetrical bipyran derivative. Conceptually, this

Scheme I

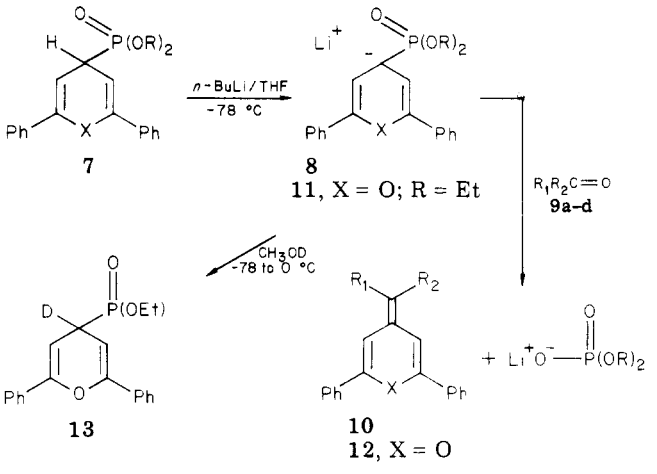
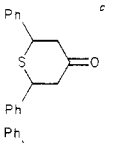
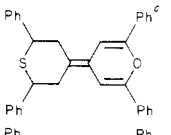
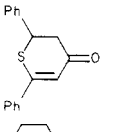
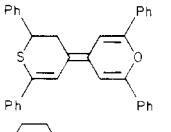
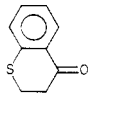
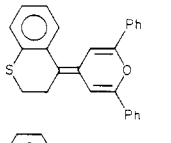
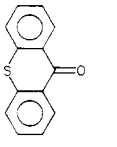
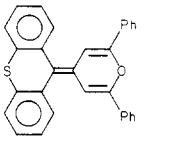


Table I. Δ^4-2,6-Diphenyl-4*H*-pyrans 12a-d Prepared According to Scheme I

	starting ketone (9)	product (12)	yield, %[a]	mp, °C
a			65	250.5[b]
b			12	224.9
c			59	177.6
d			61	273-274

[a] Yields (not optimized) were based on the crude phosphonate **16**. [b] The stereochemistry of **12a** was confirmed by the NMR spectrum which suggests a cis diequatorial diphenyl configuration. [c] The cis isomer.

(1) Presented in part at the Wurster Centennial Symposium at the 178th National Meeting of the American Chemical Society, Washington, DC, Sept 10-14, 1979.

(2) Fabre, C.; Fugnitto, R.; Strzelecka, H.; Normant, H. *C. R. Hebd. Seances Acad. Sci., Ser. C* **1976**, *19*, 175.

(3) Perlstein, J. H. *Angew. Chem., Int. Ed. Engl.* **1977**, *16*, 519.

(4) Grito, A. F.; Herger, A. J. *Acc. Chem. Res.* **1974**, *7*, 232. Engler, E. M. *CHEMTECH* **1976**, 274.

(5) Narita, M.; Pittman, C. U. *Synthesis* **1978**, 489. Spencer, H. K.; Cava, M. P.; Garito, A. F. *J. Chem. Soc., Chem. Commun.* **1976**, 966.

(6) Reynolds, G. A.; Van Allan, J. A.; Regan, T. H. *J. Org. Chem.* **1967**, *32*, 3772.

(7) Hünig, S.; Barner, B. J.; Ruider, G.; Schenk, W. *Justus Liebigs Ann. Chem.* **1973**, 1036.

(8) During the preparation of the manuscript, a paper was published which describes the synthesis of an unsymmetrical 2,2',6,6'-tetracarbethoxythiabipyran from acetonedioxalic ester in 6.4% yield: Sandman, D. J.; Holmes, T. J.; Warner, D. E. *J. Org. Chem.* **1979**, *44*, 880.

(9) Schmidt, R. R.; Burkert, U.; Prewo, R. *Tetrahedron Lett.* **1975**, 3477; Schmidt, R. R.; Burkert, U. *Tetrahedron Lett.* **1973**, 4355.

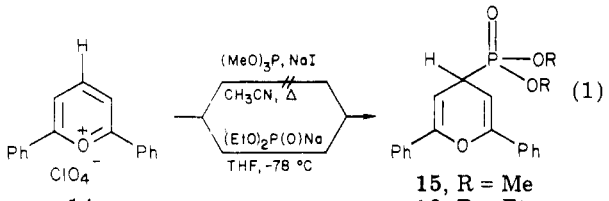
0022-3263/80/1945-2449$01.00/0

is known as the "symmetrization of reactivity"[10] or *umpolung*[11] of the cationic heteropyrylium salt **4**. As part of an 8π system, the anion **6** is antiaromatic. For some stabilization of **6** and enhancement of the regiospecificity at C-4,[12] an electron-withdrawing substituent at C-4 is desirable.

We sought to prepare the 2,6-diphenyl-4*H*-heteropyranyl Wittig–Horner reagent **8** by deprotonation of the corresponding (2,6-diphenyl-4*H*-heteropyran-4-yl)phosphonate **7** at low temperature. Subsequent reaction of **8** with an appropriate carbonyl compound would then provide a general synthetic methodology suitable for the construction of a variety of unsymmetrical Δ^4-2,6-diphenyl-4*H*-pyran derivatives (**10**) as shown in Scheme I. (See also Table I for a definition of structural variations.)

This report describes the synthesis of diethyl (2,6-diphenyl-4*H*-pyran-4-yl)phosphonate (**7**; X = O, R = Et) and its Wittig–Horner reagent (**11**) which leads upon further elaboration to the successful synthesis of the *unsymmetrical* $\Delta^{4,4'}$-2,2′,6,6′-tetraphenyl-4-(thiopyranyl)-4*H*-pyran (**2**; X = O, Y = S).

Recently, phosphonates were synthesized by ambient-temperature reaction of heteroaromatic cations such as 1,3-benzodithiolium, acridinium, xanthylium, thioxanthylium, and thiochromenylium ions with trimethyl phosphite in the presence of sodium iodide.[13] This procedure, when tried on the 2,6-diphenylpyrylium salt **14**,[14] failed to give the desired phosphonate **15** even under forcing conditions. Diethyl (2,6-diphenyl-4*H*-pyran-4-yl)phosphonate (**16**) was successfully prepared, however, by adding an equimolar amount of a benzene solution of sodium diethyl phosphonate[15] to **14** suspended in dry THF at −78 °C (eq 1). The crude phosphonate **16** obtained



14 **15**, R = Me; **16**, R = Et (1)

upon aqueous workup as a reddish, viscous oil (about 88% yield) was used without further purification. The purity of the freshly prepared crude **16** was adequate as judged by comparison of its NMR spectrum and TLC assay with those of an analytical sample obtained in 77% yield by rapid column chromatography[16] over silica gel. This material is fairly stable and can be stored in a freezer without noticeable decomposition (TLC assay).

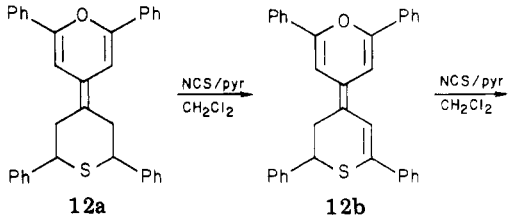
The phosphonate **16** was deprotonated with *n*-BuLi in THF at −78 °C under argon to give, instantaneously, the Wittig–Horner reagent **11** as a dark blue solution, which in turn was allowed to react with a carbonyl compound as depicted in Scheme I.

The structure and stability of the carbanion **11** generated at −78 °C are supported by a deuterium quenching experiment (using excess CH_3OD) from which only 4-deuterated derivative **13** is obtained. Mass spectral analysis of **13** shows that the incorporated deuterium is about 90 ± 5% (M^+ for $C_{21}H_{22}DO_4P$ at m/e 371). The characteristic doublet at δ 5.42 (J_{PCCH} = 4.5 Hz) for the two equivalent vinylic protons found in the ^1H NMR spectrum of **13** confirms the regiospecific C-4 deuterium incorporation. This same phosphorus–hydrogen coupling constant is also observed from a decoupling experiment of the ^1H NMR spectrum of the parent 4*H* compound **16** upon irradiation at the C-4 proton (at about δ 3.69). The 4*H*-pyranyl anion **11**, in THF, is remarkably stable even at 0–5 °C under argon (ice cooling, 40 min) as shown by its ^1H NMR spectrum on quenching with a proton source. Decomposition occurs (observed by TLC, NMR, and a color change from blue to brown) only on warming to ambient temperature.

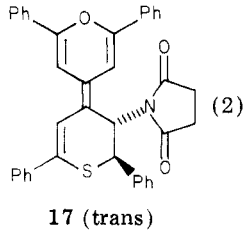
The structures of the Δ^4-2,6-diphenyl-4*H*-pyran products **12**, which were obtained by the method shown in Scheme I, were confirmed by elemental analyses and by ^1H NMR and mass spectra. The results are shown in Table I.

The carbanion **11** does not react with ketones or thiones that are deactivated by cross conjugation with a heteroatom such as is found in 2,6-diphenyl-4*H*-thiopyran-4-thione (**5**, X = Y = S; R = Ph). However, **11** does react with an α,β-unsaturated ketone that is only partially deactivated, such as in 2,6-diphenyl-4*H*-5,6-dihydrothiopyran-4-one (**9b**). This latter reaction is fortunate, because it readily provides $\Delta^{4,4'}$-tetraphenyl-4-(5,6-dihydrothiopyranyl)-4*H*-pyran **12b**, which is only a two-electron oxidation away from the target molecule **2** (X = O, Y = S). The carbonyls of thioxanthen-9-one (**9d**) and thiochromone (**9c**) react satisfactorily with **11** to give **12d** and **12c**, respectively.

The dihydro compound **12b** can also be prepared in ca. 40% yield by allowing **12a** to react with *N*-chlorosuccinimide in the presence of pyridine under oxidative elimination conditions.[17] Further oxidation of **12b** under the same conditions (eq 2) produces a succinimidyl-substituted



12a **12b**



17 (trans) (2)

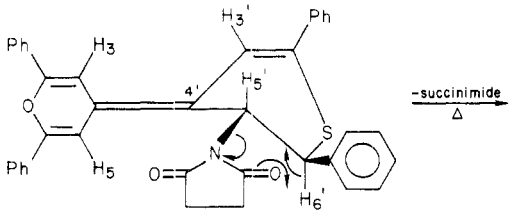
compound (60% yield) which has been assigned the structure of *trans*-**17** on the basis of its elemental analyses and spectroscopic data. The mass spectrum of this compound has the expected M^+ for $C_{38}H_{29}NO_3S$ at m/e 579 (relative intensity 10%). The major fragmentation of M^+ is the loss of succinimide with the formation of the stable radical cation $C_{34}H_{24}OS$ at m/e 480 (relative intensity 100%) and the doubly charged species at m/e 240 (relative intensity 20%). This suggests that the succinimidyl group

(10) Corey, E. J. *Pure Appl. Chem.* **1967**, *14*, 19. Lever, O. W., Jr. *Tetrahedron* **1976**, *32*, 1943.
(11) Adoption of the word umpolung into English has been encouraged: Callear, A. B.; Fleming, I.; Ottewill, R. H.; Wainwright, K.; Warren, S. G.; Prince, R. H. *Chem. Ind. (London)* **1974**, 910.
(12) The parent 4*H*-thiopyran anion is thermodynamically more stable than the 2*H*-thiopyran anion: Grafing, R.; Verkruijsse, H. D.; Brandsma, L. *J. Chem. Soc., Chem. Commun.* **1978**, 596.
(13) Akiba, K.-Y.; Ishikawa, K.; Inamoto, N. *Synthesis* **1977**, 862.
(14) Mezheritskii, V.; Dorofeemko, G. *Zh. Org. Khim.* **1967**, *3*, 1533.
(15) Commercially available from Organometallics, Inc., East Hampstead, NH.
(16) Still, W. C.; Kahn, M.; Mitra, A. *J. Org. Chem.* **1978**, *43*, 2923.
(17) Chen, C. H.; Reynolds, G. A.; Van Allan, J. A. *J. Org. Chem.* **1977**, *42*, 2777.

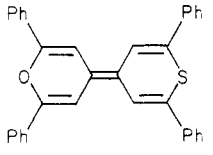
in **17** is in a favorable position for elimination.

The ^{1}H NMR spectrum of **17** displays the usual singlet at δ 2.51 for the four succinimidyl ring protons and the downfield multiplets at δ 7.2–7.8 which account for 21 protons (20 phenyl plus 1 buried vinyl, H_3'). In addition, there are two sets of AB quartets at δ 4.6, 5.62 (J = 7.5 Hz) and δ 6.31, 6.85 ($J \simeq$ 2 Hz), corresponding to H_5' and H_6' and the unsymmetrical vinylic protons H_5 and H_3, respectively (see A). The large chemical shift difference ($\Delta\delta$ = 1.02 ppm) between H_5' and H_6' immediately rules out the isomeric structure in which the succinimidyl group is substituted at C-6′ adjacent to sulfur.

The relatively large coupling constant between H_5' and H_6' on the dihydrothiopyran ring system requires that these two protons be situated in the pseudo-trans-diaxial (dihedral angle ~180°) positions. A conformation that is consistent with all the observed spectral data is depicted as A (eq 3). The bulky succinimidyl and phenyl sub-



A (proposed conformation of **16**)



(3)

18

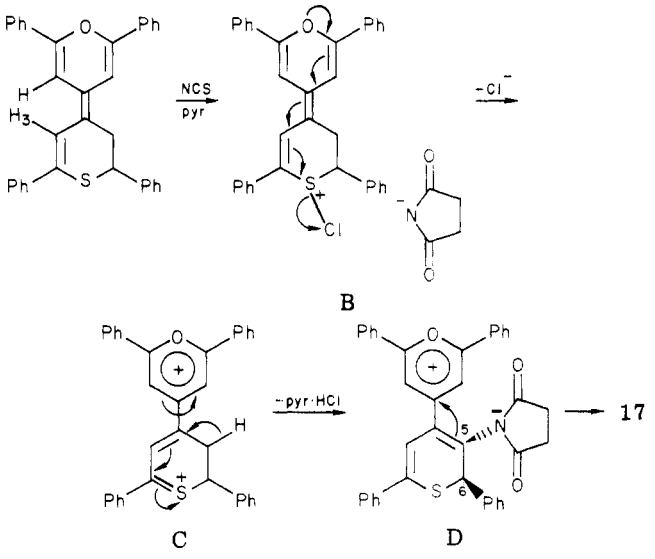
stituents on the dihydrothiopyran ring occupy the most favorable pseudoequatorial positions. Furthermore, to achieve favorable pπ–pπ interaction, the dihydrothiopyran ring must be flattened at C-4′ (sp^2 configuration). This forces the carbonyl of the *equatorial* succinimidyl group within proximity of H_6' and hence is ideal for a six-membered syn elimination. This was substantiated experimentally by refluxing a xylene (bp 138–140 °C) solution of **17**, which produced the unsymmetrical O,S dimer **18** in 60% yield along with 1 equiv of succinimide (eq 3).

The unsymmetrical $\Delta^{4,4'}$-4*H*-thiobipyran **18** was characterized by ^{1}H NMR, IR, and mass spectra [*m/e* 480 (M^+) for $C_{34}H_{24}OS$] and elemental analysis and is identical with a sample prepared by an independent route from the Wittig reagent of (2,6-diphenyl-4*H*-pyran-4-yl)triphenylphosphonium perchlorate. This alternative synthesis of unsymmetrical $\Delta^{4,4'}$-4*H*-thiobipyrans will be the subject of the following paper.[18]

Although the detailed reaction path of the unusual NCS oxidation of **12b** awaits further study, a reasonable mechanism which accounts for the stereospecific formation of the trans C-5 substituted succinimidyl compound **17** is proposed in Scheme II.

In the presence of the positive chlorine source (NCS), the formation of the chlorosulfonium salt B is expected to be favored over the competing electrophilic substitution of chlorine at the vinylic sulfide function.[17] This presumably is due to the steric crowding and the decrease of electron density at C-3 by the delocalization of the elec-

Scheme II



trons of the pyranylidene portion of the molecule. The displacement of chloride ion from B to form the dication C is expected to be a facile process for the following reasons: (1) a pyrylium 6π sextet is restored by shifting the electrons on oxygen to sulfur; (2) the steric compression which is present in the intermediate B is relieved in C, and there is considerable single bond character and some degree of free rotation at the central linkage.

Elimination of a proton by pyridine (as pyridinium hydrochloride) gives the key intermediate pyrylium D which, by virtue of its electron-deficient character at C-5, is a good Michael-type acceptor. The succinimidyl anion, which is a better nucleophile than chloride, attacks the C-5 from the least hindered side of D (away from the bulky phenyl group at C-6) to give *only* the trans C-5 substituted succinimidyl product **17**. An alternative process involving the abstraction of the proton by the succinimidyl anion at C-6 to form directly the O,S dimer **18** is apparently hindered by the bulky phenyl substituent.

An alternative approach to the synthesis of **18** involving the addition of **4** (perchlorate, X = S) to **11** followed by either thermal or base-promoted elimination (Et_3N) was not successful.

The oxidation potentials of the unsymmetrical $\Delta^{4,4'}$-4-(thiopyranyl)-4*H*-pyran **18** and related compounds measured by cyclic voltammetry are compared with $\Delta^{4,4'}$-2,2′,6,6′-tetraphenyl-bi-4*H*-pyran (**19**)[3] and bi-4*H*-thiopyran **20**[3] in Table II.

Although there is no reversible oxidation observed for the $\Delta^{4,4'}$-(tetrahydrothiopyranyl)-4*H*-pyran **12a**, the dihydro compound **12b** has a reversible oxidation potential at ~+0.43 V. As expected, the unsymmetrical 4*H*-thiobipyran **17** has a first reversible (one-electron) oxidation potential ($E^{\circ\prime}$ = +0.22 V) lying between those of the bi-4*H*-pyran **2** (X = Y = O; $E^{\circ\prime}$ = +0.16 V) and bi-4*H*-thiopyran **2** (X = Y = S; $E^{\circ\prime}$ = +0.28 V).[8] Interestingly, $\Delta^{4,9'}$-2,6-diphenyl-4-(thioxanthenyl)-4*H*-pyran (**12d**), in contrast to the other dimers, displays a single *two-electron*-per-molecule *reversible* oxidation at +0.50 V having a peak separation of only 40 mV. This is further confirmed by coulometric analysis of **12d**, indicating that two electrons per molecule of sample were indeed involved in the electronic process. This suggests that the central double bond in **12d** must possess considerable single bond, diradical character in the ground state. Presumably, this is induced by twisting the central double bond away from

(18) Reynolds, G. A.; Chen, C. H. *J. Org. Chem.*, following paper in this issue.

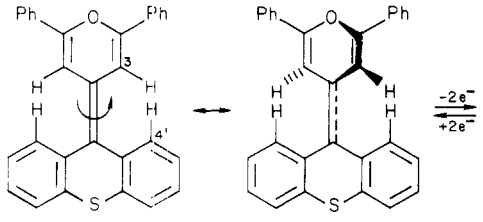
(19) Chen, C. H.; Reynolds, G. A.; Zumbulyadis, N.; Van Allan, J. A. *J. Heterocycl. Chem.* **1978**, *15*, 289. Henrichs, P. M.; Chen, C. H. *J. Org. Chem.* **1979**, *44*, 3591.

Table II. Cyclic Voltammetry Oxidation Potentials[a,b] (Volts)

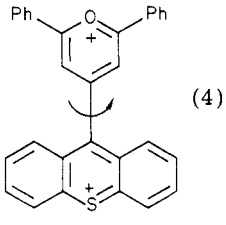
	I			II		
	$E^{\circ\prime}$			$E^{\circ\prime}$		
compd	forward	reverse	E_p	forward	reverse	E_p
12a			+0.68			
12b	+0.46[c]	+0.39[c]				+0.71
17	+0.27	+0.17		+0.59	+0.32[d]	
2 (X = Y = O)[e]	+0.17	+0.13		+0.50	+0.45	
2 (X = Y = S)[e]	+0.33	+0.24		+0.55	+0.45	
12c			+0.68			+1.59
12d	+0.52	+0.48				

[a] Solvent, CH_3CN; supporting electrolyte, 0.1 M tetrabutylammonium tetrafluoroborate; indicating electrode, glassy carbon; reference electrode, SCE (saturated aqueous NaCl); bridge solution for SCE, CH_3CN/0.1 M $TBABF_4$, scan rate, 0.1 V/s. [b] Potential values are reported as E_p, the peak potential of the cyclic voltammogram for irreversible systems, and as $E^{\circ\prime}$, the potential for reversible systems. [c] Indicating electrode: Pt. [d] Adsorption (5×10^{-4} M CH_2Cl_2 solution). [e] Hünig, S.; Garner, B. J.; Ruider, G.; Schenk, W. *Justus Liebigs Ann. Chem.* 1973, 1036.

coplanarity so that the steric interaction between the C-3 and the C-4′ hydrogens in **12d** can be minimized (eq 4).[20]



12d



(4)

Experimental Section

Melting points, obtained on a Mettler FPI instrument, are uncorrected. NMR spectra were recorded in $CDCl_3$ on a Varian EM-390 spectrometer using Me_4Si as internal standard. Mass spectra were obtained on an AEI MS-30 mass spectrometer. UV spectra were recorded on a Cary-17 spectrophotometer. Elemental analyses were done by the Analytical Sciences Division, Kodak Research Laboratories. Cyclic voltammograms were obtained on a Heath polarography system, Model EUW-401.

Diethyl (2,6-Diphenyl-4*H*-pyran-4-yl)phosphonate (16). To a suspension of 2,6-diphenylpyrylium perchlorate (**14**; 60 g, 0.18 mol) in 700 mL of dry THF at −78 °C under nitrogen was added dropwise an equimolar (110 mL) solution of sodium diethyl phosphonate[15] (1.7 M) in benzene. The reddish suspension was allowed to equilibrate slowly to ambient temperature overnight. The product was extracted with ether and washed twice with brine. The combined ether extracts were dried ($MgSO_4$), and the solvent was removed on a rotary evaporator to give 59 g (88%) of crude **16** as a viscous dark reddish oil. This material, which showed only a small amount of reddish, nonpolar impurity on TLC, was suitable for use for the subsequent reactions.

An analytical sample was obtained by rapid column chromatography[16] over silica gel (9:1 EtOAc/petroleum ether) of 2 g of this crude product from which 1.73 g (77% based on **14**) of pure **16** was isolated as a colorless oil: mass spectrum, (relative intensity) m/e 370.1344 (M^+, 2.59) (calcd for $C_{21}H_{23}O_4P$ = 370.1332 amu), 233.0954 (100); NMR δ 1.31 (t, J = 7.5 Hz, 6), 3.69 (2 t, J_{PCH} = 27 Hz and J_{HCCH} = 4.5 Hz, 1, methine), 4.15 (quintet, J = 7.5 Hz), 5.46 (t, J_{PCCH} = 4.5 Hz and $J_{HH} \simeq$ 1.5 Hz, 2, olefinic), 7.2–7.8 (m, Ar H, 10).

Anal. Calcd for $C_{21}H_{23}O_4P$: C, 68.1; H, 6.3; P, 8.4. Found: C, 68.1; H, 6.3; P, 8.0.

$\Delta^{4,9'}$-2,6-Diphenyl-4-(9′-thioxanthenyl)-4*H*-pyran (12d). To a solution of 1 g (2.7 mmol) of the crude **16** in 40 mL of dry THF cooled to −78 °C under argon was added dropwise by syringe 1.3 mL of 2.4 M *n*-BuLi in hexane (1.1 equiv). A dark blue solution immediately resulted, and a solution of 0.57 g (1 equiv) of thioxanthen-9-one in 25 mL of dry THF was added quickly. The mixture was slowly equilibrated to room temperature (2 h) and stirred overnight under argon. The brown solution was poured into aqueous NH_4Cl (500 mL), and the precipitated orange solid was filtered, washed with water, and air-dried to give 0.95 g of crude **12d**. Recrystallization from 200 mL of heptane afforded 700 mg (61%) of **12d**. An analytical sample was obtained by further recrystallization from ethyl acetate (450 mL): mp 273–274 °C; mass spectrum, (relative intensity) m/e 428 (M^+, 100), 214 (M^{2+}, 48); NMR δ 6.93 (s), 7.15 (s), 7.0–7.8 (m).

Anal. Calcd for $C_{30}H_{20}OS$: C, 84.1; H, 4.7; S, 7.5. Found: C, 83.5; H, 5.0; S, 7.8.

$\Delta^{4,4'}$-2,6-Diphenyl-4-(4′-thiochromanyl)-4*H*-pyran (12c). To the Wittig–Horner reagent prepared from 8 g (0.0216 mol) of crude **16** and 10 mL of *n*-BuLi (2.4 M in hexane) in 100 mL of dry THF at −78 °C was added dropwise a solution of 3.55 g of thiochroman-4-one (**9c**) in 25 mL of dry THF. The reaction was slowly equilibrated to room temperature and stirred overnight under nitrogen. The dark precipitate was filtered and recrystallized from 175 mL of acetonitrile to give 2.5 g of pure **12c** as dark purple prisms: mp 177.6 °C; mass spectrum, m/e 380 (M^+); NMR δ 2.93 (A_2B_2 q, 4, methylenes), 6.46 (d, $J \simeq$ 2 Hz, 1, olefinic), 6.85 (d, $J \simeq$ 2 Hz, 1, olefinic), 6.8–8.0 (m, Ar H, 14).

Anal. Calcd for $C_{26}H_{20}OS$: C, 82.1; H, 5.3; S, 8.4. Found: C, 82.0; H, 5.3; S, 8.8.

The combined filtrate and mother liquors from the first crop was added to aqueous NH_4Cl and extracted with ether, and the ether extracts were stripped to give 6 g of a dark reddish oil. This was dissolved in ca. 50 mL of acetonitrile; the solution, on seeding, produced 2 g of a second crop of the product. The total yield was 59% based on the crude **16**.

$\Delta^{4,4'}$-2,6-Diphenyl-4-(*cis*-2′,6′-diphenyl-4′*H*-tetrahydrothiopyranyl)-4*H*-pyran (12a). To the dark blue Wittig–Horner reagent prepared from 1 g (2.7 mmol) of the crude **16** and 1.3 mL of *n*-BuLi (2.4 M in hexane) in 30 mL of dry THF at −78 °C under argon was added dropwise a solution of 720 mg of *cis*-2,6-diphenyltetrahydro-4*H*-thiopyran-4-one (**9a**) in 25 mL of dry THF. The reaction mixture was slowly equilibrated to room temperature and then refluxed for 3 h as most of the THF was distilled under argon. The residue was poured into aqueous NH_4Cl, and the precipitated solid was filtered, washed with water, and air-dried to give 1.3 g of an orange solid which was recrystallized from 50 mL of ethyl acetate, giving 500 mg of pure **12a**: mp 250.5 °C; mass spectrum, m/e 484 (M^+); NMR δ 2.55 (t, J_{AB} = 12 Hz, J_{AX} = 12 Hz, 2, axial protons of the methylene), 3.3 (2 d; $J_{BA} \simeq$ 12 Hz, $J_{BX} \simeq$ 2 Hz, 2, equatorial protons of the methylene), 4.0 (2 d; J_{XA} = 12 Hz, $J_{XB} \simeq$ 2 Hz, 2, benzylic), 6.45 (s, 2, olefinic), 7.2–7.9 (m, 20, Ar H). The ABX proton splitting pattern observed for this compound confirms the correct assignment of the symmetrical *cis*-2,6-diphenyl substituents occupying the equatorial positions

(20) Bithioxanthylidene was reported to exhibit a single but *irreversible* two-electron oxidation potential at E_p = +1.34 V: Kissinger, P. T.; Holt, P. T.; Reilley, C. N. *J. Electroanal. Chem.* 1971, *33*, 1.

in a chair conformation.[19]

Anal. Calcd for $C_{34}H_{28}OS$: C, 84.3; H, 5.8; S, 6.6. Found: C, 84.7; H, 6.0; S, 7.1.

A second crop of 350 mg of **12a** was obtained on concentrating the mother liquor (to ca. 20 mL) and seeding. The yield was 65% based on the crude **16**.

$\Delta^{4,4'}$-2,6-Diphenyl-4-(2',6'-diphenyl-4'*H*-dihydrothiopyranyl)-4*H*-pyran (12b). To the dark blue Wittig–Horner reagent prepared from 1 g (2.7 mmol) of the crude **16** and 1.3 mL of *n*-BuLi (2.4 M in hexane) in 30 mL of dry THF at −78 °C under argon was added dropwise a solution of 700 mg of 2,6-diphenyl-4*H*-dihydrothiopyran-4-one (**9b**)[17] in 10 mL of dry THF. The solution was slowly equilibrated to room temperature and kept overnight under argon. The mixture was poured into 300 mL of aqueous NH_4Cl and extracted with ether. The ether extracts were separated, dried ($MgSO_4$), and stripped on a Rotavap to give about 1 g of a dark reddish gum. This was recrystallized from a small amount of ethyl acetate (chilled in a freezer) to give 110 mg of pure **12b** as bright red needles: mp 224.9 °C; mass spectrum, *m/e* 482 (M^+); NMR δ 2.7–3.4 (m, 2, methylene), 4.35 (2 d, J = 12 Hz and J = 3 Hz, 1, sulfide benzylic), 6.53 (d, $J \simeq$ 2 Hz, 1, olefinic), 6.8 (d, $J \simeq$ 2 Hz, 1, olefinic), 7.13 (s, 1, olefinic), 7.15–7.85 (m, 20, Ar H).

Anal. Calcd for $C_{34}H_{26}OS$: C, 84.6; H, 5.4; S, 6.6. Found: C, 84.2; H, 5.3; S, 6.7.

A second crop of 50 mg of pure product was obtained from the mother liquor by rapid column chromatography[16] over silica gel, eluting with CH_2Cl_2/hexanes (1:3 v/v). The total yield was 12% based on the crude **16**.

$\Delta^{4,4'}$-2,6-Diphenyl-4-(2',6'-diphenyl-4'*H*-dihydrothiopyranyl)-4*H*-pyran (12b). To a solution of 360 mg (0.74 mmol) of **12a** and 58.7 mg (1 equiv) of dry pyridine in 10 mL of methylene chloride at room temperature was added 104 mg (1 equiv) of solid NCS. The reaction mixture was stirred overnight, poured into water, and extracted with methylene chloride. The extracts were dried ($MgSO_4$) and concentrated on a Rotavap to give a dark brown solid (350 mg) of which 210 mg was purified by preparative TLC (silica gel, 2 mm thick). The top orange band was removed, giving 170 mg of crude **12b** which contained ca. 38% of starting material **12a** (NMR). This material was purified further by recrystallization from a small amount of ethyl acetate (chilled), giving ca. 85 mg of **12b** as bright red needles. This crop, which contained less than 10% starting material **12a** (NMR), was suitable for use in the next reaction. Total yield of this material based on **12a** was ca. 40%.

$\Delta^{4,4'}$-2,6-Diphenyl-4-(2',6'-diphenyl-5'-*trans*-succinimidyl-4'*H*-dihydrothiopyranyl)-4*H*-pyran (17). To a solution of 50 mg (0.1 mmol) of the dihydro derivative **12b** and 8 mg (1 equiv) of dry pyridine in 10 mL of methylene chloride at ambient temperature was added 14 mg (1 equiv) of NCS. The mixture, which turned quickly from orange to dark green, was stirred overnight at room temperature. The reaction mixture, which changed back to a bright orange, homogeneous solution, was concentrated on a Rotavap. The residue was diluted with 200 mL of water, and the precipitated orange solid (35 mg, 60%) was essentially pure **17** (one major spot on TLC; silica gel, CH_2Cl_2). An analytical sample was obtained by recrystallization from 150 mL of chilled benzene and hexanes (1:30 v/v), affording ca. 20 mg of pure **17**: mp 245–247 °C (sintered and turned black at ca. 190 °C); mass spectrum, *m/e* 579 (M^+); NMR δ 2.51 (s, 4 H), 4.6 and 5.62 (AB q, J_{HH} = 7.5 Hz, 2 H), 6.31 and 6.85 (AB q, $J_{HH} \simeq$ 2 Hz, 2 H), 7.2–7.8 (m, 21 H).

Anal. Calcd for $C_{38}H_{29}NO_3S$: C, 78.7; H, 5.0; N, 2.4. Found: C, 78.6; H, 4.7; N, 2.4.

$\Delta^{4,4'}$-2,6-Diphenyl-4-(2',6'-diphenyl-4'*H*-thiopyranyl)-4*H*-pyran (18). A solution of 120 mg (0.21 mmol) of crude **17** in 25 mL of xylene (bp 138–140 °C) was refluxed for 18 h (or until a TLC assay showed the disappearance of **17** from the reaction mixture). The crystallized solid, which contained 1 equiv of succinimide, was collected and washed thoroughly with water (to remove the coprecipitated succinimide), giving ca. 60 mg (60%) of **18**: mp 280–281 °C; mass spectrum, *m/e* 480 (M^+ for $C_{34}H_{24}OS$), 240 (M^{2+}); NMR δ 6.62 (br s, 2, vinylic thiopyran), 6.88 (br s, 2, vinylic pyran), 7.1–7.8 (m, 20, Ar H); IR (KBr) 3080, 3060, 3025, 2920 (=CH), 1650 (s, C=C), 1596 (aromatic), 1575, 1491 (s, aromatic), 1445, 1335, 1275 (br), 1076, 930 (s), 841, 820, 760 (s), 748 (sh), 688 (s), 521 cm^{-1}.

Anal. Calcd for $C_{34}H_{24}OS$: C, 85.0; H, 5.0; S, 6.7. Found: C, 85.1; H, 4.9; S, 6.2.

This material is identical with an authentic sample prepared by an independent route.[18]

Acknowledgment. We thank Lauren B. Smith of the Special Projects Laboratory, Analytical Sciences Division of the Kodak Research Laboratories, for measuring the redox potentials by using cyclic voltammetry.

Registry No. *cis*-**9a**, 18456-44-5; **9b**, 60839-95-4; **9c**, 3528-17-4; **9d**, 492-22-8; *cis*-**12a**, 73454-70-3; **12b**, 73466-68-9; **12c**, 73466-69-0; **12d**, 73454-71-4; **14**, 3558-68-7; **16**, 73454-72-5; *trans*-**17**, 73454-73-6; **18**, 73453-50-6; sodium diethyl phosphonate, 2303-76-6; *N*-chlorosuccinimide, 128-09-6.

Synthesis and Reactions of (4*H*- and 2*H*-2,6-Diphenylthiopyran-4-yl)phosphonates[1a]

Chin H. Chen* and George A. Reynolds

Research Laboratories, Eastman Kodak Company, Rochester, New York 14650

Received November 27, 1979

The umpolung of 2,6-diphenylthiopyrylium salts is achieved by the synthesis of the Wittig–Horner reagent of diethyl (2,6-diphenyl-4*H*-thiopyran-4-yl)phosphonate (**7**). This 4*H*-lithiated species is a kinetically controlled product which equilibrates to the more stable 2*H*-lithiated species at −78 °C. The 4*H* anion does react with thioxanthen-9-one (**9**) and *p*-(dimethylamino)benzaldehyde (**9a**) at low temperature to give the normal Wittig adducts in 43 and 67% yields, respectively. A facile synthesis of (2*H*-2,6-diphenylthiopyran-4-yl)phosphonates **11** and **25** from 2,6-diphenyl-4*H*-tetrahydrothiopyran-4-one (**20**) is described. Lithiation of **11** and **25** with lithium diisopropylamide in THF (−78 °C), however, produces only a small amount of the 4*H* anion from which, on addition of the carbonyl compounds **9** and **9a**, the corresponding Wittig adducts **10** and **10a** are obtained in 14 and 16% yields, respectively.

We have reported the synthesis of diethyl (2,6-diphenyl-4*H*-pyran-4-yl)phosphonate (**1**) and its lithiated anion **2**.[1b] This Wittig–Horner reagent, which is quite stable at low temperature (−78 to 5 °C), condenses with

0022-3263/80/1945-2453$01.00/0