phase was separated, dried ($MgSO_4$), and evaporated to dryness, and the residual yellow foam was chromatographed on silica gel (60–200 mesh, 20 g). Methylene chloride removed the remaining starting material; the column was then eluted sequentially with methylene chloride/methanol (98:2 and 97:3). Finally, the desired product (**50**) was eluted with methylene chloride/methanol (9:1). This material was homogeneous on TLC, and its NMR spectrum was compatible with the assigned structure: yield 0.6 g (44%); IR (Nujol) 3320, 3200, 1640 cm^{-1}; NMR ($CDCl_3$) δ 1.8–2.9 (m, 5 H), 3.7 (s, 2 H), 3.8 (s, 3 H), 3.85–3.95 (m, 4 H), 4.8 (d, 1 H, J = 4 Hz), 5.3–5.7 (br, 6 H), 6.85 and 7.2 (AB q, 4 H, J = 9 Hz).

2,4-Diamino-6-[[(*p*-methoxybenzyl)thio]methyl]-5,6-dihydro-5-deazapteridine (51) and 2,4-Diamino-6-[[(*p*-methoxybenzyl)thio]methyl]-5-deazapteridine (52). A mixture of 1.7 g of **50** and 25 mL of 1 N HCl was refluxed for 15 min, and the mixture was cooled and neutralized with ammonium hydroxide. The resulting white precipitate was collected by filtration; yield 0.7 g (49%). The NMR spectrum [(TFA-*d*) δ 2.2–4.0 (m), 4.0 (s), 7.0 and 7.25 (AB q, J = 9 Hz), 9.1 (m)] was indicative of a mixture of **51** and **52**. An unsuccessful attempt was made to dehydrogenate **51** to give homogeneous **52** by heating a sample of this material in TFA with 2 equiv of triphenylcarbinol. No way could be found to recrystallize the resulting white deazapteridine to homogeneity, although its mass spectrum indicated that dehydrogenation had indeed been accomplished: calcd for $C_{16}H_{17}N_5OS$ m/e^+ 327, found m/e^+ 327.

Registry No. **6**, 80360-09-4; **12**, 85597-17-7; **13**, 80360-03-8; **14**, 87373-56-6; **15**, 87373-57-7; **16**, 87373-58-8; **17**, 87373-59-9; **18**, 87373-60-2; **19** (n = 1), 87373-61-3; **20**, 87373-62-4; **21**, 87373-63-5; **22**, 87373-64-6; **23**, 87373-65-7; **24**, 87373-66-8; **25**, 87373-67-9; **26**, 80360-04-9; **27**, 87373-68-0; **29**, 65995-93-9; **30**, 87373-69-1; **31**, 38076-78-7; **32**, 85147-10-0; **33**, 87373-70-4; **34**, 87373-71-5; **35**, 87373-72-6; **36**, 87373-73-7; **37**, 87373-74-8; **40**, 76282-55-8; **41**, 87373-75-9; **42**, 87373-76-0; **43**, 87373-77-1; **44**, 87373-78-2; **45**, 87373-79-3; **46**, 87373-80-6; **47**, 87373-81-7; **48**, 87373-82-8; **49**, 87373-83-9; **50**, 87373-84-0; **51**, 87373-85-1; **52**, 87373-86-2; 2,4-diamino-6(1*H*)-pyrimidinone, 56-06-4; triformylmethane, 18655-47-5; dimethyl *p*-aminobenzoyl-L-glutamate, 52407-60-0; 2-methyl-3-ethoxyacrolein, 42588-57-8; cyanothioacetamide, 110-86-1; *p*-nitrofluorobenzene, 350-46-9; pyridine, 7357-70-2; *p*-nitroso-*N*,*N*-dimethylaniline, 138-89-6; quanidine, 113-00-8; ethylene glycol, 107-21-1; methacrolein, 78-85-3; malononitrile, 4341-85-9; dihydrofolate reductase, 9002-03-3; 4-methoxybenzyl bromide, 2746-25-0; *N*-[*p*-(dimethylamino)phenyl]-*C*-[3-cyano-2-[(*p*-nitrophenyl)thio]-5-pyridinyl]nitrone, 87373-87-3.

Competitive Reactions of Alkylidenetriphenylphosphoranes and Methylsulfinyl Carbanion with 3-Methylenespiro[5.5]undeca-1,4-diene

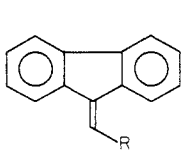
Diane F. Murray*

Department of Chemistry, Princeton University, Princeton, New Jersey 08544

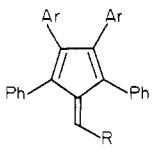
Received December 7, 1982

Treatment of 3-methylenespiro[5.5]undeca-1,4-diene (**3**) with methylenetriphenylphosphorane in Me_2SO provides 3-ethylidenespiro[5.5]undeca-1,4-diene (**4**) as the major product in 33% yield. The expected cyclopropane product dispiro[2.2.5.2]trideca-4,12-diene is obtained in only 1–2% yield. Control experiments show that **4** arises from the reaction of **3** with the methylsulfinyl carbanion. Indeed, when **3** is treated with a Me_2SO solution of the methylsulfinyl carbanion, multiple additions of the methylsulfinyl carbanion occur. The competition between the Wittig reagent and the methylsulfinyl carbanion in reaction with **3** can be shifted to favor the formation of cyclopropane products by increasing the nucleophilicity of the Wittig reagent by alkyl substitution at the carbanionic center. Thus, treatment of **3** with ethylidenetriphenylphosphorane in Me_2SO gives **4** and 1-methyldispiro[2.2.5.2]trideca-4,12-diene in yields of 28% and 17%, respectively, and reaction of **3** with isopropylidenetriphenylphosphorane in Me_2SO gives 1,1-dimethyldispiro[2.2.5.2]trideca-4,12-diene in 64% yield and less than a 1% yield of **4**.

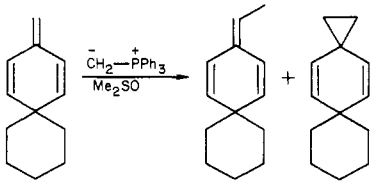
Previous reports of the reactions of alkylidenetriphenylphosphoranes with carbon–carbon double bonds unactivated by heteroatoms have been limited to the 9-alkylidenefluorenes[1] (**1**) and aryl-substituted 1-alkylidene-2,4-cyclopentadienes[2] (**2**). In each of these cases, the observed product is the corresponding spirocyclopropane. In striking contrast to these results, I have observed that treatment of 3-methylenespiro[5.5]undeca-1,4-diene (**3**) with 1.3 equiv of methylenetriphenylphosphorane in dimethyl sulfoxide (Me_2SO) proceeds with 80% conversion to give 3-ethylidenespiro[5.5]undeca-1,4-diene (**4**, eq 1) as the major product and only trace amounts of the cyclopropane product, dispiro[2.2.5.2]trideca-4,12-diene (**5**). A justification of this unexpected behavior forms the basis for this report.



1



2



(1)

3 4 5

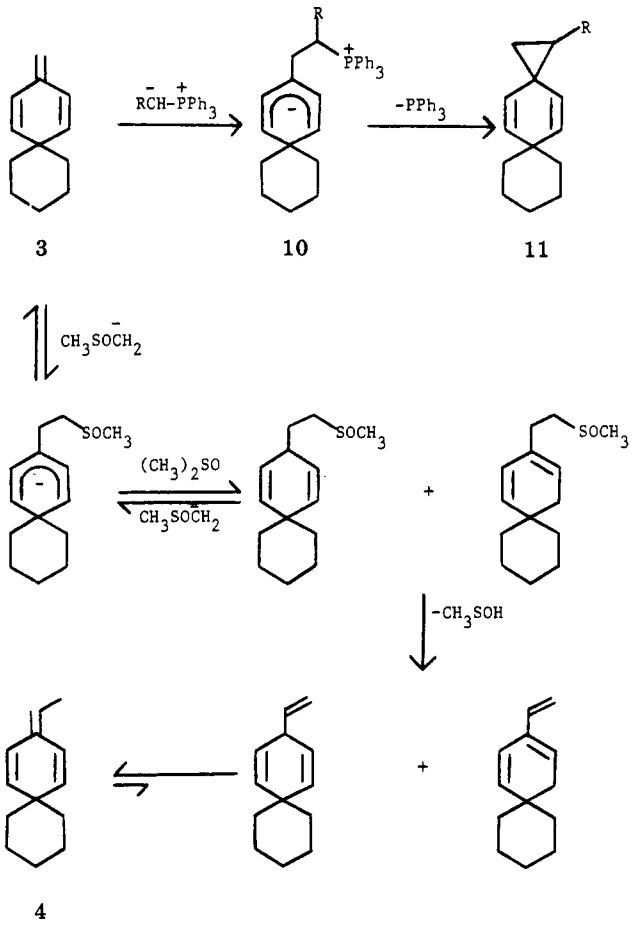
* Present address: Research Center, Hercules Inc., Wilmington, DE 19894.

(1) (a) Mechoulam, R.; Sondheimer, F. *J. Am. Chem. Soc.* **1958**, *80*, 4386–4388. (b) Greenwald, R.; Chaykovsky, M.; Corey, E. J. *J. Org. Chem.* **1963**, *28*, 1128–1129. (c) Bestmann, H. J.; Denzel, T.; Kunstmann, R.; Lengyel, J. *Tetrahedron Lett.* **1968**, 2895–2898.

(2) (a) Ried, W.; Herrmann, H. J. *Justus Liebigs Ann. Chem.* **1974**, 1239–1247. (b) Ried, W.; Knorr, H.; Gürcan, H. *Ibid.* **1976**, 1415–1420.

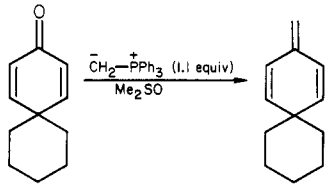
0022-3263/83/1948-4860$01.50/0

Scheme I



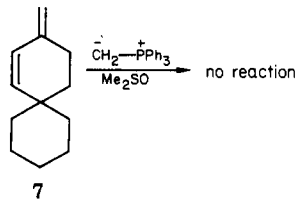
Results and Discussion

Triene **3** was prepared from the known ketone spiro[5.5]undeca-1,4-dien-3-one[3] (**6**) via a standard Wittig reaction (eq 2). Subsequent treatment of **3** with methylenetriphenylphosphorane in Me_2SO provided **4** and **5** in yields of 33% and ca. 1%, respectively. The structure of **4** was confirmed by its independent synthesis from dienone **6** and ethylidenetriphenylphosphorane.



(2)

In order to help define the structural requirements for this reaction, 3-methylenespiro[5.5]undec-1-ene[4] (**7**) was submitted to the same reaction conditions (eq 3).



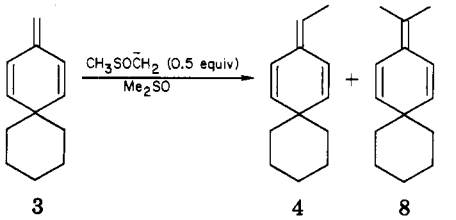
(3)

Treatment of **7** with 1.3 equiv of methylenetriphenylphosphorane in Me_2SO led only to recovery of starting material. Thus, both endocyclic double bonds in triene **3** are required for reaction to occur.

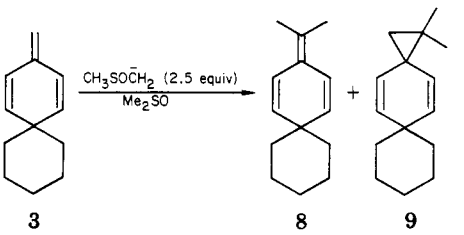
One possible explanation for the unexpected formation of **4** from **3** is that spirocyclopropane **5** is formed initially and then isomerizes to **4** under the reaction conditions. In order to test this possibility, **5** was independently synthesized by cyclopropanation of the terminal double bond in **3** by using diazomethane/palladium(II) acetate.[5] However, no reaction occurred when **5** was heated with methylenetriphenylphosphorane in Me_2SO. Thus, **5** is not an intermediate in the formation of **4** from **3**.

In all but one[1b] of the previous reports of cyclopropanation of olefinic hydrocarbons with Wittig reagents, ethereal solvents were employed. Consistent with these observations, treatment of **3** with methylenetriphenylphosphorane in diethyl ether or tetrahydrofuran (THF) led to no reaction. Thus, the presence of Me_2SO is essential for **3** → **4** + **5** to occur.

It is known that the conjugate base of Me_2SO, the methylsulfinyl carbanion, adds to olefinic hydrocarbons if the resulting carbanionic intermediate is resonance stabilized.[6,7] Both methyl-substituted and cyclopropanated products have been observed.[8,9] These observations suggest that the methylated triene **4**, as well as the spirocyclopropane **5**, could both be products of the reaction of **3** with the methylsulfinyl carbanion. However, when **3** is treated with 0.5 equiv of the methylsulfinyl carbanion in Me_2SO and heated (as under the Wittig reaction conditions), the only products isolated are **4** and 3-isopropylidenespiro[5.5]undeca-1,4-diene (**8**) in yields of 7% and 2%, respectively (eq 4). No **5** was detected. The low yield of volatile products in this reaction seems to be a consequence of their extensive polymerization under the basic conditions. The structure assignment of **8** was confirmed by its independent synthesis from **6** and isopropylidenetriphenylphosphorane. If **3** is allowed to react with 1.3 or 2.5 equiv of methylsulfinyl carbanion, the products obtained are **8** and 1,1-dimethyldispiro[2.2.5.2]trideca-4,12-diene (**9**) in yields of 25% and 31%, respectively (eq 5). Thus, it can be concluded that triene **3**, proceeding through the intermediate products **4** and **8**, is ultimately converted to **9** via sequential additions of the methylsulfinyl carbanion, i.e., **3** → **4** → **8** → **9**.



(4)

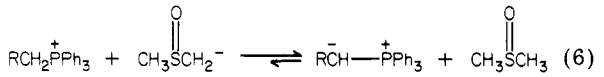


(5)

(3) Kane, V. V. *Synth. Commun.* **1976**, *6*, 237–242.
(4) Diene **7** was prepared from spiro[5.5]undec-1-en-3-one[3] by a Wittig reaction.
(5) Suda, M. *Synthesis* **1981**, 714.
(6) For a review see: Durst, T. *Adv. Org. Chem.* **1969**, *6*, 285–385.
(7) James, B. G.; Pattenden, G. *J. Chem. Soc., Perkin Trans. 1* **1974**, 1195–1204. James, B. G.; Pattenden, G. *Ibid.* **1974**, 1204–1208.
(8) Chaykovsky, M.; Corey, E. J. *J. Org. Chem.* **1963**, *28*, 254–255.
(9) Feldman, M.; Danishefsky, S.; Levine, R. *J. Org. Chem.* **1966**, *31*, 4322–4325.

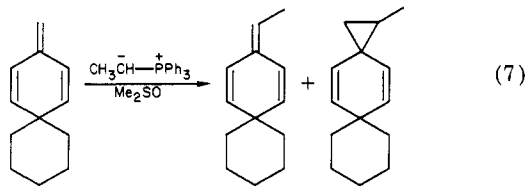
A mechanism for the conversion of 3 to 4 is outlined in Scheme I. The projected sequence of reactions involving initial addition of the methylsulfinyl carbanion to 3, followed by protonation, 1,2-elimination of methanesulfenic acid, and isomerization of the resulting olefins to the thermodynamically most stable triene 4, is generally accepted.[6] Methylation of 4 to give 8 could take place by a similar route. However, formation of 9 from 8 requires that the addition of the methylsulfinyl carbanion to 8 must be followed by the 1,3-elimination of CH_3SOH from the resulting intermediate sulfoxide, since 1,2-elimination is blocked by the methyl substituents. Details of the formation of cyclopropanes in 1,3-elimination reactions from sulfoxides have been studied.[10]

One rationale to account for the behavior of 3 with methylenetriphenylphosphorane in Me_2SO is summarized in Scheme I. Deprotonation of an alkylphosphonium salt by methylsulfinyl carbanion is highly favored[1b] (eq 6).



(6)

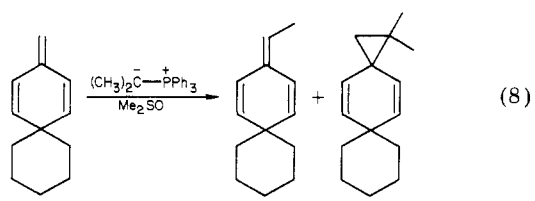
Consequently, the equilibrium concentration of methylsulfinyl carbanion under the reaction conditions should be low. Addition of the Wittig reagent to triene 3 would form the zwitterionic intermediate 10 which should undergo rapid irreversible ring closure to give spirocyclopropane 11. Since only 1–2% of the cyclopropane product is obtained with methylenetriphenylphosphorane (R = H), the addition of this Wittig reagent to 3 must be slow. Thus, 3 reacts predominantly with the much less abundant methylsulfinyl carbanion to give 4. If this interpretation is correct, then increasing the reactivity of the Wittig reagent would be expected to increase the yield of the cyclopropane product 11. Indeed, when 3 was treated with 1.3 equivalents of ethylidenetriphenylphosphorane in Me_2SO, the reaction proceeded with 97% conversion to give the methylsulfinyl carbanion addition product 4 (eq 7) and the Wittig product, 1-methyldispiro[2.2.5.2]tri-



(7)

3 4 12

deca-4,12-diene (12) in yields of 28% and 17%, respectively. Continuing this argument further, reaction of isopropylidenetriphenylphosphorane with 3 in Me_2SO proceeds with complete conversion to afford the spirocyclopropane 9 as the major product in 64% yield (eq 8). The



(8)

3 4 9

monomethylated triene 4 is obtained in less than 1% yield. Moreover, isopropylidenetriphenylphosphorane is so reactive that treatment of 3 with this Wittig reagent even in tetrahydrofuran gives 9 in 75% yield.

(10) Baker, R.; Spillett, M. J. *J. Chem. Soc., Chem. Commun.* **1966**, 757–758. Baker, R.; Spillett, M. J. *J. Chem. Soc. B* **1969**, 581–588. Baker, R.; Spillett, M. J. *Ibid.* **1969**, 880–883.

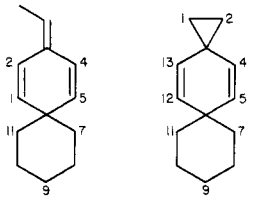
In conclusion, any Wittig reagent formed in Me_2SO must compete with the methylsulfinyl carbanion in reaction with triene 3. As the nucleophilicity of the Wittig reagent is increased by alkyl substitution at the carbanionic center, the reaction of 3 with the methylsulfinyl carbanion becomes less competitive, and the yield of the Wittig product increases.

Experimental Section

Proton magnetic resonance spectra were recorded with a JEOL FX90Q Fourier transform spectrometer at 90 MHz or a Varian XL-100 Fourier transform spectrometer at 100 MHz. Carbon magnetic resonance spectra were obtained with a Varian XL-100 spectrometer at 25.2 MHz or a Bruker Spectrospin Model WM 250 spectrometer at 62.9 MHz. Infrared spectra were recorded on a Perkin-Elmer 283 spectrophotometer. Electron-impact mass spectra were obtained with a Du Pont 21-492B mass spectrometer at an ionization potential of 70 eV. Unless noted otherwise, yields were obtained by integration of appropriate signals in the ^1H NMR spectrum of the product(s) vs. the signal of a predetermined amount of an added standard (1,2-dichloroethylene) and are regarded as being accurate to ca. ±10%. Elemental analyses were performed by Atlantic Microlab, Inc., Atlanta, GA.

Dimethyl sulfoxide was distilled from calcium hydride under reduced pressure immediately before use. The alkyltriphenylphosphonium halides were dried at 100 °C (1 mm) for 10–20 h immediately before use. Reactions involving the methylsulfinyl carbanion and/or a Wittig reagent were carried out under dry argon in oven-dried glassware.

The following numbering schemes are used for the assignment of ^{13}C NMR signals.



3-Methylenespiro[5.5]undeca-1,4-diene (3). Typical Procedure.[1b] Sodium hydride (355 mg, 14.8 mmol, as a 50% dispersion in mineral oil) was washed three times with *n*-pentane and dried under vacuum. Dry Me_2SO (15 mL) was added via syringe to the sodium hydride and the mixture heated with stirring at 75–80 °C for 45 min to yield a cloudy, gray-green solution of the sodium methylsulfinyl carbanion. This solution was cooled in an ice–water bath, and a solution of methyltriphenylphosphonium bromide (4.84 g, 13.5 mmol) in Me_2SO (30 mL) was added in one portion. The resulting red-brown solution of the Wittig reagent was stirred at room temperature for 15 min. A solution of 6[3] (2.00 g, 12.3 mmol) in warm Me_2SO (8 mL) was then added all at once, and the reaction mixture was heated at 60–65 °C for 3–4 h. The mixture was then cooled, poured into water (15 mL), and extracted with *n*-pentane (5 × 25 mL). The combined pentane extracts were washed with a 1:1 water–Me_2SO solution (1 × 30 mL) and saturated aqueous sodium chloride (1 × 60 mL) and then dried over anhydrous magnesium sulfate. Evaporation of the solvent at reduced pressure gave a yellow oil. Kugelrohr distillation [65–70 °C (0.2 mm)] provided 3 (1.63 g, 83% yield) as a light yellow liquid. Column chromatography of this liquid on silica gel with *n*-pentane removed traces of unreacted ketone and provided 3 as a colorless liquid. An analytically pure sample of 3 was obtained by GLC (6 ft × 0.25 in. 20% SE-30 column, 140 °C): ^1H NMR ($CDCl_3$) δ 6.16 (d, J = 10.3 Hz, 2 H, 2 vinyl CH), 5.89 (d, J = 10.3 Hz, 2 H, 2 vinyl CH), 4.78 (s, 2 H, CH_2=C), 1.78–1.18 (m, 10 H); ^{13}C NMR ($CDCl_3$) δ 138.5 (C-3), 137.5 (2 endocyclic vinyl C), 125.3 (2 endocyclic vinyl C), 110.9 (exocyclic methylene C), 38.6 (C-6), 38.3 (C-7 and C-11), 26.0 (C-9), 21.4 (C-8 and C-10); IR (CCl_4) 3095, 3035, 2935, 2850, 1755, 1665, 1585, 1450, 920, 910, 870 cm^{-1}; exact mass calcd for $C_{12}H_{16}$ 160.125, found 160.122. Anal. Calcd for $C_{12}H_{16}$: C, 89.94; H, 10.06. Found: C, 89.86; H, 10.06.

Reaction of 3 with Methylenetriphenylphosphorane in Me_2SO. Treatment of 3 (220 mg, 1.38 mmol) with methylene-

triphenylphosphorane (1.79 mmol) in Me_2SO (8 mL) according to the typical procedure described above gave a viscous oil which by ^1H NMR analysis contained ca. 43 mg (20% yield) of unreacted **3**, 64 mg (33% yield based on the amount of **3** consumed) of **4**, and 2–4 mg (1–2% yield) of **5**. The crude product mixture was Kugelrohr distilled [65–70 °C (0.2 mm)] and purified further by GLC (5 ft × 0.25 in. 10% FFAP column, 110 °C). The ^1H NMR spectra of the GLC-isolated products were identical with those of **4** and **5** prepared by alternative procedures (see below).

3-Ethylidenespiro[5.5]undeca-1,4-diene (4). A solution of ethylidenetriphenylphosphorane (3.39 mmol) in Me_2SO (12 mL) was prepared from a solution of sodium methylsulfinyl carbanion (3.39 mmol) in Me_2SO and ethyltriphenylphosphonium bromide (1.26 g, 3.39 mmol) according to the same procedure employed for generation of methylenetriphenylphosphorane in Me_2SO. Reaction of the ylide solution with **6** (500 mg, 3.08 mmol), elution of the crude product with *n*-pentane through a silica gel column, and Kugelrohr distillation [65–70 °C (0.2 mm)] of the resulting material provided **4** (236 mg, 44% yield) as a colorless oil. An analytically pure sample of **4** was obtained by GLC (5 ft × 0.25 in. 10% FFAP column, 100 °C): ^1H NMR ($CDCl_3$) δ 6.40 (d, J = 10.2 Hz, 1 H, vinyl CH), 6.12–5.56 (complex m, 3 H, 3 vinyl CH), 5.26 (q, J = 7.5 Hz, 1 H, CH_3CH=C), 1.75 (d, J = 7.5 Hz, 3 H, CH_3CH=C), 1.70–1.22 (m, 10 H); ^{13}C NMR ($CDCl_3$) δ 136.9 and 133.9 (2 endocyclic vinyl C), 131.5 (C-3), 127.0 (CH_3CH=C), 121.7 and 119.9 (2 endocyclic vinyl C), 39.3 (C-6), 38.7 (C-7 and C-11), 26.0 (C-9), 21.4 (C-8 and C-10), 12.8 (CH_3); IR (CCl_4) 3035, 3020, 2925, 2850, 1450, 1375, 920, 910, 830 cm^{-1}; exact mass calcd for $C_{13}H_{18}$ 174.141, found 174.140. Anal. Calcd for $C_{13}H_{18}$: C, 89.59; H, 10.41. Found: C, 89.34; H, 10.51.

3-Methylenespiro[5.5]undec-1-ene (7). Treatment of spiro[5.5]undec-1-en-3-one[3] (1.00 g, 6.09 mmol) with methylenetriphenylphosphorane (6.70 mmol) in Me_2SO (20 mL) according to the procedure employed for the preparation of **3** from **6**, followed by Kugelrohr distillation [65–70 °C (0.2 mm)], provided **7** (440 mg, 45% yield) as a colorless oil. An analytically pure sample of **7** was obtained by GLC (6 ft × 0.25 in. 20% SE-30 column, 140 °C): ^1H NMR ($CDCl_3$) δ 6.04 (d, J = 10.3 Hz, 1 H, vinyl CH), 5.72 (d, J = 10.3 Hz, 1 H, vinyl CH), 4.84–4.67 (m, 2 H, CH_2=C), 2.35 (t, J = 6.3 Hz, 2 H, CH_2=C—CH_2), 1.69-1.22 (m, 12 H, containing CH_2=C—CH_2CH_2 triplet at δ 1.56, J = 6.3 Hz); ^{13}C NMR ($CDCl_3$) δ 143.7 (C-3), 139.4 and 127.3 (C-1 and C-2), 110.2 (exocyclic methylene C), 37.4 (C-7 and C-11), 34.5 (C-6), 34.1 (C-4), 26.6 (C-5 or C-9), 26.4 (C-5 or C-9), 21.8 (C-8 and C-10); IR (CCl_4) 3085, 3030, 2930, 2855, 1635, 1450, 900, 880 cm^{-1}; exact mass calcd for $C_{12}H_{18}$ 162.141, found 162.138. Anal. Calcd for $C_{12}H_{18}$: C, 88.82; H, 11.18. Found: C, 88.73; H, 11.22.

Dispiro[2.2.5.2]trideca-4,12-diene (5). An ethereal solution of diazomethane was prepared from *N*-methyl-*N*-nitroso-*p*-toluenesulfonamide (3.48 g, 16.2 mmol) and potassium hydroxide (1.12 g) by the method of de Boer and Backer.[11] By use of the procedure of Suda,[5] **3** (372 mg, 2.32 mmol) was added all at once to the magnetically stirred diazomethane solution at 0 °C. Palladium(II) acetate (8.5 mg) was then added, and the reaction mixture was stirred for 10 min at 0 °C. Upon addition of the palladium(II) acetate, vigorous gas evolution occurred, and the bright yellow color of diazomethane gradually faded. The reaction mixture was warmed to room temperature and gravity filtered to remove the palladium catalyst. Evaporation of the ether under vacuum provided a yellow oil which by ^1H NMR analysis consisted of a ca. 1:1 mixture of **5** and unreacted **3**. In order to affect complete conversion of **3**, the crude product mixture was resubmitted to the reaction conditions two more times, each time using twice as much diazomethane and palladium(II) acetate as noted above. Kugelrohr distillation [70 °C (0.2 mm)] of the residue afforded 148 mg (37% yield) of **5**. Final purification by GLC (5 ft × 0.25 in. 10% FFAP column, 100 °C) provided **5** as a colorless liquid: ^1H NMR ($CDCl_3$) δ 5.69 (d, J = 9.0 Hz, 2 H, vinyl CH β to the cyclopropane), 4.98 (d, J = 9.0 Hz, 2 H, vinyl CH α to the cyclopropane), 1.48 (br s, 10 H), 0.73 (s, 4 H, cyclopropyl H); ^{13}C NMR ($CDCl_3$) δ 132.5 (C-5 and C-12), 129.8 (C-4 and C-13), 39.5 (C-7 and C-11), 36.4 (C-6), 26.1 (C-9), 21.4 (C-8 and C-10), 21.0 (C-3), 16.4 (C-1 and C-2); IR (CCl_4) 3080, 3015, 2925, 2860, 1700, 1630, 1450, 1050, 975, 950, 915, 910, 855 cm^{-1}; exact mass calcd for $C_{13}H_{18}$ 174.141, found 174.141. Anal. Calcd for $C_{13}H_{18}$: C, 89.59; H, 10.41. Found: C, 89.42; H, 10.46.

Reaction of 3 with Methylsulfinyl Carbanion. (A) With 0.5 Equiv. A stirred solution of sodium methylsulfinyl carbanion, prepared from sodium hydride (22.4 mg, 0.935 mmol) and dry Me_2SO (1.4 mL), was cooled to room temperature, and a solution of **3** (300 mg, 1.87 mmol) in Me_2SO (0.5 mL) was added via syringe. The reaction mixture was heated at 60–65 °C for 3 h and then quenched by the addition of water (10 mL). The aqueous layer was extracted with *n*-pentane (5 × 15 mL). The combined pentane extracts were washed with a 1:1 water–Me_2SO solution (1 × 20 mL) and saturated aqueous sodium chloride (1 × 40 mL) and then dried over anhydrous magnesium sulfate. Evaporation of the solvent at reduced pressure gave a viscous oil which by ^1H NMR analysis contained ca. 21 mg (7% yield) of **4** and 6.6 mg (2% yield) of **8**.

(B) With 1.3 Equiv. Treatment of **3** (200 mg, 1.25 mmol) with methylsulfinyl carbanion (1.63 mmol) in Me_2SO by the procedure described above produced a viscous oil. Analysis of the crude product by ^1H NMR indicated that ca. 46 mg (19% yield) of **8** and 15 mg (6% yield) of **9** were obtained. See below for the spectral and analytical characterization of **8** and **9**.

(C) With 2.5 Equiv. Treatment of **3** (199 mg, 1.24 mmol) with methylsulfinyl carbanion (3.10 mmol) in Me_2SO by the procedure described above afforded a viscous oil which by ^1H NMR analysis contained ca. 59 mg (25% yield) of **8** and 78 mg (31% yield) of **9**.

3-Isopropylidenespiro[5.5]undeca-1,4-diene (8). A solution of isopropylidenetriphenylphosphorane (3.53 mmol) in Me_2SO (11 mL) was prepared from a solution of sodium methylsulfinyl carbanion (3.53 mmol) in Me_2SO and isopropyltriphenylphosphonium iodide (1.53 g, 3.53 mmol) according to the same procedure employed for generation of methylenetriphenylphosphorane in Me_2SO. Reaction of the ylide solution with **6** (520 mg, 3.21 mmol), elution of the crude product with *n*-pentane through a silica gel column, and Kugelrohr distillation [65–75 °C (0.2 mm)] of the resulting material provided 314 mg (52% yield) of **8**. Final purification by GLC (6 ft × 0.25 in. 20% SE-30 column, 150 °C) gave **8** as a colorless oil: ^1H NMR ($CDCl_3$) δ 6.47 (d, J = 10.5 Hz, 2 H, 2 vinyl CH), 5.79 (d, J = 10.5 Hz, 2 H, 2 vinyl CH), 1.85 (s, 6 H, CH_3), 1.68–1.29 (m, 10 H); ^{13}C NMR ($CDCl_3$) δ 134.5 (2 endocyclic vinyl C), 128.2 (C-3 or $(CH_3)_2C$=C), 125.3 (C-3 or $(CH_3)_2C$=C), 121.8 (2 endocyclic vinyl C), 38.9 (C-7 and C-11), 37.9 (C-6), 26.0 (C-9), 21.3 (C-8 and C-10), 20.1 (CH_3); IR (CCl_4) 3045, 2935, 2860, 1450, 1375, 920, 910 cm^{-1}; exact mass calcd for $C_{14}H_{20}$ 188.156, found 188.155.

Reaction of 3 with Ethylidenetriphenylphosphorane in Me_2SO. A solution of ethylidenetriphenylphosphorane (3.48 mmol) in Me_2SO (14 mL) was prepared from a solution of sodium methylsulfinyl carbanion (3.48 mmol) in Me_2SO and ethyltriphenylphosphonium bromide (1.29 g, 3.45 mmol). Reaction of the ylide solution with **3** (429 mg, 2.68 mmol) according to the general procedure provided a yellow, viscous residue. Analysis of the crude product mixture by ^1H NMR showed that **3**, **4**, and **1-methyldispiro[2.2.5.2]trideca-4,12-diene (12)** were obtained in ca. yields of 3%, 28%, and 17%, respectively. Purification of this material by Kugelrohr distillation [65–70 °C (0.2 mm)] and GLC (5 ft × 0.25 in. 10% FFAP column, 105 °C) provided **12** as a colorless liquid: ^1H NMR ($CDCl_3$) δ 5.78 (d of d, J = 10.1, 2.1 Hz, 1 H, vinyl CH β to the cyclopropane and syn to the CH_3 group), 5.64 (d of d, J = 9.9, 2.1 Hz, 1 H, vinyl CH β to the cyclopropane and anti to the CH_3 group), 5.21 (d of d, J = 10.1, 2.1 Hz, 1 H, vinyl CH α to the cyclopropane and syn to the CH_3 group), 4.92 (d of d, J = 9.9, 2.1 Hz, 1 H, vinyl CH α to the cyclopropane and anti to the CH_3 group), 1.47 (br s, 10 H), 1.21–0.77 (m, 5 H, CH_3 and 2 cyclopropyl H), 0.54–0.42 (m, 1 H, cyclopropyl H); ^{13}C NMR ($CDCl_3$) tentative assignments δ 134.2 (C-5), 131.5 (C-4 or C-12), 131.4 (C-4 or C-12), 126.0 (C-13), 39.7 (C-7 or C-11), 39.4 (C-7 or C-11), 36.7 (C-6), 26.2 (C-9), 25.2 (C-3), 24.4 (C-2), 22.5 (CH_3), 21.4 (C-8 and C-10), 13.9 (C-1); IR (CCl_4) 3065, 3000, 2930, 2865, 2845, 1450, 1380, 1095, 1055, 980, 915, 905, 890, 865, 845 cm^{-1}; exact mass calcd for $C_{14}H_{20}$ 188.156, found 188.156.

Reaction of 3 with Isopropylidenetriphenylphosphorane in Me_2SO. A solution of isopropylidenetriphenylphosphorane

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(4.05 mmol) in Me_2SO (15 mL) was prepared from a solution of sodium methylsulfinyl carbanion (4.05 mmol) in Me_2SO and isopropyltriphenylphosphonium iodide (1.75 g, 4.05 mmol). Reaction of the ylide solution with **3** (500 mg, 3.12 mmol) according to the general procedure afforded a yellow oil containing a white solid (PPh_3). Analysis of the crude product mixture by ^1H NMR showed that **1,1-dimethyldispiro[2.2.5.2]trideca-4,12-diene (9)** was obtained in ca. 64% yield and that **4** was obtained in less than 1% yield. Purification of the crude product mixture by Kugelrohr distillation [70–75 °C (0.2 mm)] and GLC (6 ft × 0.25 in. 20% SE-30 column, 155 °C) provided **9** as a colorless liquid: ^1H NMR ($CDCl_3$) δ 5.74 (d, J = 9.9 Hz, 2 H, vinyl CH β to the cyclopropane), 5.27 (d, J = 9.9 Hz, 2 H, vinyl CH α to the cyclopropane), 1.44 (br s, 10 H), 1.07 (s, 6 H, CH_3), 0.70 (s, 2 H, cyclopropyl H); ^{13}C NMR ($CDCl_3$) δ 133.7 (C-5 and C-12), 128.0 (C-4 and C-13), 40.1 (C-7 or C-11), 38.8 (C-7 or C-11), 36.2 (C-6), 31.4 (C-2), 29.5 (C-1 or C-3), 26.0 (C-9), 25.4 (C-1 or C-3), 22.6 (CH_3), 21.6 (C-8 or C-10), 21.4 (C-8 or C-10); IR (CCl_4) 3040, 2990, 2930, 2860, 1620, 1450, 1380, 1125, 975, 950, 920, 905, 845 cm^{-1}; exact mass calcd for $C_{15}H_{22}$ 202.172, found 202.169. Anal. Calcd for $C_{15}H_{22}$: C, 89.04; H, 10.96. Found: C, 88.99; H, 10.99.

Reaction of 3 with Isopropylidenetriphenylphosphorane in Tetrahydrofuran. A solution of n-butyllithium in hexane (1.4 mL, 2.8 mmol) was added dropwise to a stirred suspension of isopropyltriphenylphosphonium iodide (1.32 g, 3.05 mmol) in dry tetrahydrofuran (45 mL) under argon at room temperature. The resulting yellow solution was stirred at room temperature for 3 h. A solution of **3** (350 mg, 2.18 mmol) in dry THF (12 mL) was injected, and the reaction mixture was heated at reflux for 20 h. The reaction mixture was then cooled to 0 °C and quenched with water (30 mL). The layers were separated, and the aqueous phase was extracted with pentane (4 × 25 mL). The combined organic extracts were washed with water (2 × 25 mL) and saturated aqueous sodium chloride (1 × 25 mL) and dried over anhydrous magnesium sulfate. Evaporation of the solvent at reduced pressure yielded a yellow oil which by ^1H NMR analysis contained ca. 333 mg (75% yield) of **9**.

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Synthesis of Highly Lipophilic Crown Ether Carboxylic Acids[1]

Richard A. Bartsch,* Yung Liu, Sang Ihn Kang, Byungki Son, Gwi Suk Heo, Paul G. Hipes, and Lyndra J. Bills

Department of Chemistry, Texas Tech University, Lubbock, Texas 79409

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Synthetic routes to eight highly lipophilic crown ether carboxylic acids are described. Structural variations within this series of crown ether carboxylic acids include changes in the crown ether cavity size, the lipophilic group attachment site, and the basicity of the crown ether oxygens.

Lipophilic crown ether carboxylic acids have been utilized for the solvent extraction of alkali and alkaline earth cations from aqueous solutions as well as for the transport of these metals cations across bulk liquid and liquid surfactant (emulsion) membranes.[2-11] Such ionizable crown ethers possess the distinct advantage over neutral crown compounds in that transport of the metal cation from the aqueous phase into the organic medium does not involve concomitant transfer of the aqueous phase anion.[4]

Previously we have described the preparation of lipophilic benzo and dibenzo crown ether carboxylic acids **1–6**.[9,12,13] All of these compounds are sufficiently lipophilic to avoid loss of the complexing agent from an organic phase into a contacting, highly alkaline, aqueous phase during the solvent extraction of metal ions. However, this series of lipophilic crown ether carboxylic acids provides only for a very limited variation of the crown ether cavity size.

We now report the synthesis of eight additional lipophilic crown ether carboxylic acids **7–14** (see Chart I). In combination with **3** and **4**, these new compounds provide for systematic variation of several structural features of lipophilic crown ether carboxylic acids.

Results and Discussion

Compounds **7**, **3**, **8**, and **9** are dibenzo crown ether carboxylic acids in which the lipophilic and carboxylic groups remain constant while the crown ether cavity size is varied from 14-crown-4 to 16-crown-15 to 19-crown-6 to 22-crown-7. A more limited variation of the crown ether cavity size for a somewhat different type of dibenzo crown ether carboxylic acid is provided by **11** and **13**. Compounds **3**, **4**, and **11** are a series of structural isomers in which the

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