yield pure material (90 mg). A second crystallization gave an analytical sample: mp 240–260°; $[\alpha]_D$ +31° (chloroform).

Anal. Calcd for $C_{21}H_{28}O_3$: C, 76.78; H, 8.59. Found: C, 76.61; H, 8.34.

B. **From 17α-Hydroxy-4-pregnene-3,20-dione.**—17α-Hydroxy-4-pregnene-3,20-dione (1 g) and 2,3-dichloro-5,6-dicyanobenzoquinone (0.81 g) in dioxane (50 ml) were heated at reflux for 18 hr. A further 0.2 g of the quinone was added and heating was continued for 20 hr. The reaction mixture was diluted with dichloromethane and washed twice with 1 *N* sodium hydroxide and successively with saturated sodium bisulfite, 1 *N* sodium hydroxide, and water. The solution was dried over magnesium sulfate, and the solvent was evaporated. The residue on crystallization from dichloromethane–acetone gave **12** (472 mg), mp 220–256°. Two further crystallizations gave an analytical sample: mp 245–262°; λ_{max} 244 mμ (ε 15,000) with a slight shoulder at 295 mμ (presumably due to the presence of a trace of the $\Delta^{1,4,6}$-3-ketone); $[\alpha]_D$ +29° (chloroform).

Anal. Calcd for $C_{21}H_{28}O_3$: C, 76.78; H, 8.59. Found: C, 77.04; H, 8.30.

3β-Acetoxy-17α-hydroxy-16α-methyl-5α-pregnan-20-one (18).—Compound **17** (5 g) was hydroxylated as for compound **3**. The crude product was acetylated with excess pyridine–acetic anhydride at ambient temperature and chromatographed on Florisil (175 g) in hexane, eluting with gradually increasing proportions of ether. Hexane–ether (3:2) eluted material (58 mg) which, on crystallization from acetone–hexane, gave **18** (33 mg), mp 169–173° (lit.[19] mp 180–181°).

3β-Acetoxy-17α-hydroxy-16β-methyl-5α-pregnan-20-one (19).—Sodium hydride (0.2 g) was dissolved in dimethylformamide (4 ml) and *t*-butyl alcohol (3 ml) at ambient temperature. Dimethylformamide (4 ml) was added, the mixture was cooled on ice, and oxygen was passed through it. Solutions of sodium methylsulfinate (1 g) in dimethyl sulfoxide (5 ml) and **3** (1 g) in tetrahydrofuran (5 ml) were added simultaneously over 5 min, a slight precipitate forming in the reaction mixture. Passage of oxygen was continued for a further 30 min; the mixture was neutralized with acetic acid and poured into water. The product was extracted with ethyl acetate and crystallized from acetone–hexane to yield **19** (0.5 g), mp 152–155° (lit.[20] mp 161–163°).

Registry No.—**2**, 5618-40-6; **4**, 2543-24-0; **6**, 13900-61-3; **8**, 570-54-7; **10**, 16980-65-7; **12**, 2477-61-4; **18**, 16980-67-9; **19**, 2543-25-1.

---

(19) K. Heusler, J. Kebrle, C. Meystre, H. Uberwasser, P. Wieland, G. Anner, and A. Wettstein, *Helv. Chim. Acta*, **42**, 2043 (1959).

(20) R. Mickova and K. Syhora, *Collect. Czech. Chem. Commun.*, **30**, 2771 (1965).

Fluoroalkylquinonemethides

William A. Sheppard[1]

Contribution No. 1308 from the Central Research Department, Experimental Station, E. I. du Pont de Nemours and Co., Wilmington, Delaware 19898

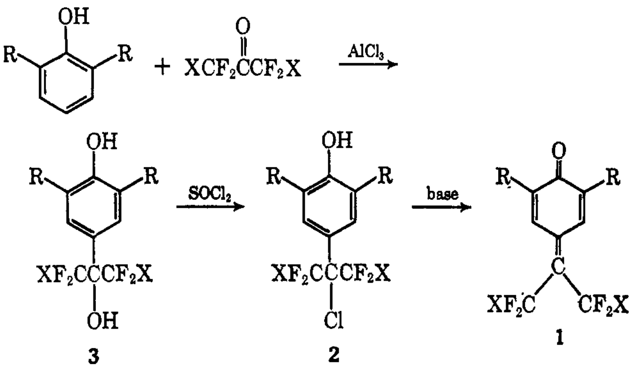
Received February 6, 1968

2,6-Dialkyl-7,7-bis(fluoroalkyl)quinonemethides were prepared in several steps from fluorinated ketones and 2,6-dialkylphenols. The quinonemethides, stabilized by the fluoroalkyl substituents at C-7, can be isolated and characterized, but they are reactive to nucleophilic attack, 1,6 polymerization, and addition of dienes and electron-rich olefins. *o*-Quinonemethides with 7,7-bis(fluoroalkyl) substituents were also prepared but could not be isolated pure; they were characterized by spectral properties and as the Diels–Alder adducts with styrene.

Quinonemethides, or 6-methylene-2,4-cyclohexadien-1-ones and 4-methylene-2,5-cyclohexadien-1-one, have long been of interest. Unfortunately, *p*-benzoquinonemethides are too unstable to isolate and characterize unless highly substituted both in the 2,6 and C-7 positions.[2] Recently, 2,6-di-*t*-butyl-7,7-dimethylquinonemethide,[3a] 2,6-di-*t*-butyl-7,7-dialkylquinonemethides,[3b] and 2,6-dimethyl-7,7-dicyanoquinonemethide[3c] were prepared and shown to be stable (but highly reactive) because of the sterically large or electronegative substituents. However, 2,6-di-*t*-butylquinonemethide with no C-7 substituents could be prepared only in dilute solution[2,4] and dimerized on attempted isolation. *o*-Benzoquinonemethides are less stable than the *para* isomers;[5] they have not been isolated[2b] but are proposed as intermediates in some reactions of substituted *o*-hydroxybenzyl alcohols.

Results and Discussion

A. *p*-Benzoquinonemethides. Synthesis.—Stable 2,6-dialkyl-7,7-bis(fluoroalkyl)quinonemethides, **1a**, **1b**, and **1c**, have been prepared in high yield (60–90%) by hydrogen chloride elimination from the *p*-hydroxybenzyl chlorides **2a** and **2c** with aqueous base or by treatment of *p*-hydroxybenzyl alcohol **3b** with thionyl chloride in pyridine. Benzyl chlorides **2a** and **2c** are readily prepared by condensation of fluorinated ketones with 2,6-disubstituted phenols to give the hydroxybenzyl alcohols **3a** and **3c**[6] which are then treated with thionyl chloride.



a, R = CH_3; X = F
b, R = $C(CH_3)_3$; X = F
c, R = CH_3; X = Cl
d, R = Br; X = F

---

[1] This work was presented at the Fourth International Fluorine Symposium, Estes Park, Colo., July 1967.

[2] (a) L. J. Filar and S. Winstein, *Tetrahedron Lett.*, **No. 25**, 9 (1960); (b) for a review of quinonemethide chemistry, see A. B. Turner, *Quart. Rev.* (London), **18**, 347 (1964).

[3] (a) C. D. Cook and B. E. Norcross, *J. Amer. Chem. Soc.*, **78**, 3797 (1956), *ibid.*, **81**, 1176 (1959); (b) A. Hubele, H. Suhr, and U. Heilmann, *Chem. Ber.*, **95**, 639 (1962); (c) H. H. Takimoto, G. C. Denault, and L. O. Krbechek, *J. Org. Chem.*, **29**, 1899 (1964).

[4] J. C. McClure, *ibid.*, **27**, 2365 (1962).

[5] (a) P. D. Gardner, H. Sarrafizadeh R., and R. L. Brandon, *J. Amer. Chem. Soc.*, **81**, 5515 (1959); (b) A. Merijan, B. A. Shoulders, and P. D. Gardner, *J. Org. Chem.*, **28**, 2148 (1963).

[6] (a) W. A. Sheppard, *J. Amer. Chem. Soc.*, **87**, 2410 (1965); (b) B. S. Farah, E. E. Gilbert, M. Litt, J. A. Otto, and J. P. Sibilia, *J. Org. Chem.*, **30**, 1003 (1965).

Condensation of hexafluoroacetone with 2,6-di-*t*-butylphenol requires hydrogen fluoride as catalyst; other catalysts such as aluminum chloride and boron trifluoride etherate or treatment of the hydroxybenzyl alcohol **3b** with excess thionyl chloride under acidic conditions caused partial loss or rearrangement of the *t*-butyl groups.

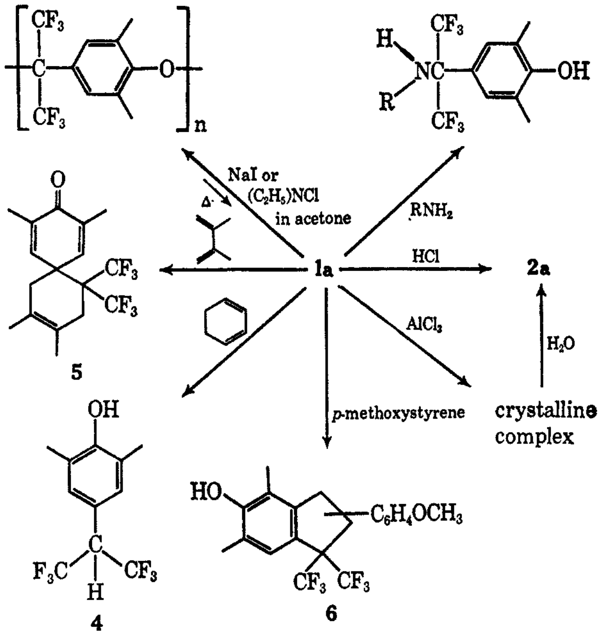
The stabilization by the CF_3 or CF_2Cl group in the C-7 position probably is derived from a combination of steric and electronic factors. Stabilization by the alkyl substituents in the 2,6 positions is needed since the hydroxybenzyl chloride with bromine substituents (**2d**) gave only polymer on treatment with base.

Physical and Spectral Properties.—The quinonemethides **1a**, **1b**, and **1c** are crystalline, orange solids with pungent spicy odors. The quinonemethide **1a** crystallizes in large needles and melts at 36° to an orange liquid which can be refluxed at 200° at atmospheric pressure without decomposition. The quinonemethide structure is clearly verified by spectral properties, as well as the chemical reactions discussed below. In the infrared spectra the strong, characteristic conjugated carbonyl absorption is at 1640 cm^{-1} as for other quinonemethides.[2,3] The intense bands in the ultraviolet spectra of compound **1a** in ethanol at λ_{max} 292 mμ (ε 28,600), of **1b** at λ_{max} 294 mμ (ε 26,700), and of **1c** at λ_{max} 307 mμ (ε 31,800) are similar to those observed for the other alkyl-substituted quinonemethides[2] but of higher energy and lower intensity than for the 7-cyano-substituted derivatives.[3c] The only direct spectral comparison is for compound **1b** [$\lambda_{max}^{isooctane}$ 295 mμ (ε 25,400) and $\lambda_{max}^{methanol}$ 295 mμ (ε 26,600)] with 2,6-di-*t*-butyl-7,7-dimethylquinonemethide [$\lambda_{max}^{isooctane}$ 314 mμ (ε 26,000), $\lambda_{max}^{methanol}$ 322 mμ)]. The energy increase in the ultraviolet absorption for compound **1b** reflects the destabilizing inductive influence of the fluoroalkyl groups on polar contributions in the electronically excited molecule. The proton nmr spectra are almost the same as for the starting phenols **2** but lacking the phenolic hydrogen resonance. As expected, the F^{19} resonance in compound **1a** shifts 15.6 ppm downfield from that of the starting phenol **2a** and shifts an additional 10.9 ppm downfield for the CF_2Cl group in compound **1c**.

The reduction potential of quinonemethide **1a** in acetonitrile is −0.35 eV. The reduction appears to be a two-electron process as is found in tetracyanoquinodimethane complexes. The reduction potential of this quinonemethide is 0.5 eV lower than that of tetracyanoquinodimethane (+0.15 eV)[7] under the same conditions. This lower potential is expected because of the poorer electron-withdrawing power of a trifluoromethyl group relative to a cyano group and the quinonemethide rather than quinodimethane structure. Formation of a stable ion radical appears unlikely because of the two-electron reduction and lower reduction potential. No evidence for ion radical was found, but complexing does occur with some reagents as indicated by the color on mixing; a stable adduct with aluminum chloride was isolated (see below).

Chemical Reactions.—Most of the chemistry of the fluoroalkylquinonemethides was studied on compound **1a** as representative of the series. The reactions are outlined in Chart I. 1,6 addition of nucleophiles occurs readily as reported for other quinonemethides.[2,3c] Anhydrous hydrogen chloride in ether adds to give hydroxybenzyl chloride **2a**, but aqueous hydrochloric acid gives a mixture of phenols **2a** and **3a**. Ammonia, hydrazine, and primary aliphatic amines add easily, but alcohols are sluggish and phenols do not add in contrast to other quinonemethides.[2,3c] The steric repulsion of the trifluoromethyl groups appears greater than that of cyano or alkyl groups, and only relatively unhindered basic nucleophiles attack at C-7. Anions, however, can initiate polymerization (see below). 1,6 reduction to phenol **4** occurs when **1a** is heated with cyclohexadiene. Free-radical initiated polymerization of quinonemethide **1a** gives only very low molecular weight polymers, but anionic polymerization with sodium iodide or tetraethylammonium chloride in acetone gives a crystalline white polymer, mp 220°, that can be pressed into a brittle film at 200°. This polymer, of moderate molecular weight (almost 12,000), decomposes slowly to monomer above 200°. Spectral evidence strongly suggests a 1,6 polymerization. The quinonemethides **1** behave like other 7-substituted quinonemethides and do not show any tendency to dimerize.

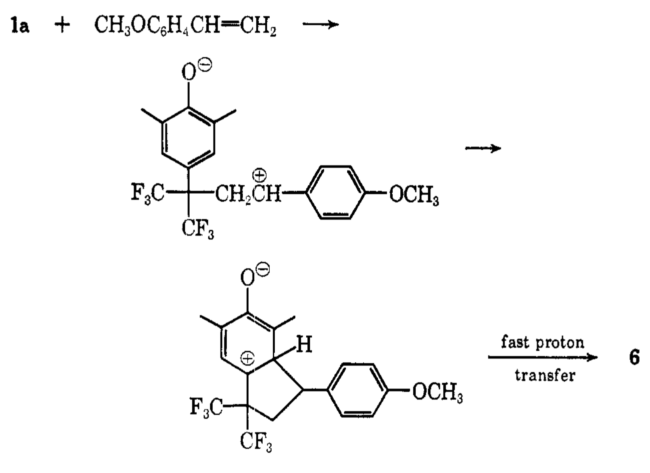
CHART I



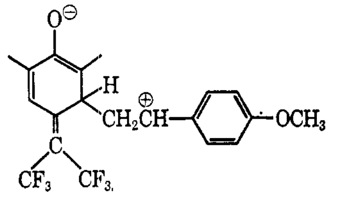
2,3-Dimethylbutadiene adds chiefly across the exocyclic double bond to give the spirane **5**, analogous to addition reactions of other quinonemethides.[4] However, butadiene gives as product an impure oil that is not easily purified; the main reaction appears to be the Diels–Alder addition to the exocyclic double bond. Electron-rich olefins such as *p*-methoxystyrene also react with the quinonemethide **1a**, to give an indanol such as **6**. The structure of the product was determined by spectral analysis; the position of the *p*-methoxyphenyl group was not proved but is suggested to be in the 1 position on the basis of spectra and possible mechanism of formation *via* attack of styrene on the terminal carbon of the exocyclic double bond (analogous to addition of nucleophiles). Alternatively, the

---

(7) D. S. Acker and W. R. Hertler, *J. Amer. Chem. Soc.*, **84**, 3370 (1962).

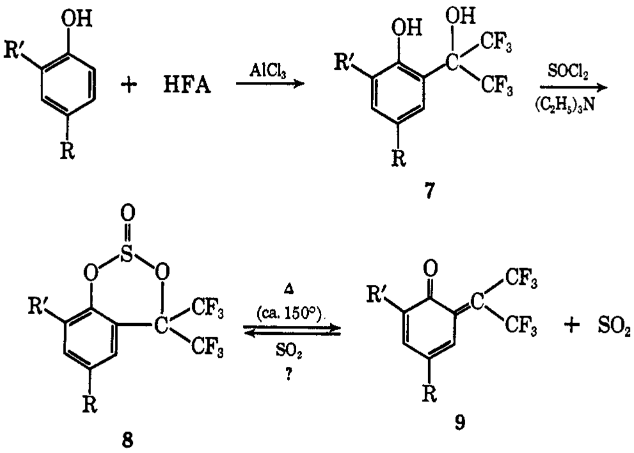


styrene could attack at the 3 position to give an intermediate



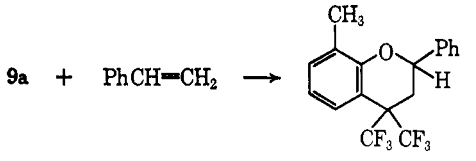
The indanol product would then have a *p*-methoxyphenyl group in the 2 position of the indan ring. Attack in this position would not be hindered by the steric repulsion of the trifluoromethyl groups, but this intermediate would not gain the favorable energy from aromatization. Some oily by-products from this reaction show a carbonyl absorption and may be cycloadducts. *t*-Butyl vinyl sulfide also gives an indanol product, but the spectral properties suggest that the *t*-butylmercapto group is not in the same position as the *p*-methoxyphenyl (the bulky *t*-butyl group may favor attack at the 3 position).

The quinonemethides **1** are not effective π acids, but **1a** forms a stable complex with aluminum chloride in methylene chloride. This complex has limited solubility in methylene chloride (dark green solution) and precipitates as a white solid when the solution is concentrated. The carbonyl absorption at 1640 cm^{-1} is weak and broad in the complex, and the proton nmr spectra are shifted approximately 0.5 ppm to lower field. Hydrolysis of the complex gives phenol **2a**.



a, R' = CH$_3$; R = H
b, R' = R = CH$_3$
c, R' = R = Cl

B. ***o*-Benzoquinonemethides.**—When a phenol with an unsubstituted *ortho* position is treated with hexafluoroacetone with aluminum chloride catalyst, the *o*-hydroxybenzyl alcohol **7** is the main product.[8] Thionyl chloride treatment of **7** gives only the cyclic sulfite ester **8** in high yield.[9] The sulfite ester readily loses sulfur dioxide when heated to 150–200°, and the bright orange color of the *o*-quinonemethide quickly develops. Spectral measurements provide strong evidence for the presence of *o*-quinonemethide **9** [F^{19} nmr—pair of quadruplets at lower field, 57.2 and 58.8 ppm (relative to CCl$_3$F) with J = 9 cps, compared to starting sulfite ester, at 73.7 and 77.3 ppm with J = 9.4 cps, and strong conjugated carbonyl at 1650–1660 cm^{-1} in infrared spectra]. However the *o*-quinononemethides **9** turn to resin when heated excessively; when isolated by distillation, they are mixed with the corresponding sulfite esters **8**. Compound **9a** was isolated in CCl$_3$F solvent by hydrolysis of the sulfite ester with aqueous base. Apparently these *o*-quinonemethides are much less stable than the *para* isomers and decompose almost as fast as they form. Possibly the quinonemethide complexes with the sulfite ester precursor as is observed for some *p*-quinonemethides.[3] Solutions of the *o*-quinonemethides decolorize readily when olefin is added, and the reaction of **9** with styrene gives the adduct **10**. The assignment of phenyl group position is based on nmr spectral analysis and is predicted mechanistically. The adduct **10** was more conveniently prepared by refluxing the sulfite ester in *o*-dichlorobenzene solution containing styrene.



10

Experimental Section

Materials.—All standard chemicals and reagents were obtained from Eastman Kodak or other chemical supply houses. The hexafluoroacetone and 1,3-dichlorotetrafluoroacetone were obtained from Organic Chemicals Department, E. I. du Pont de Nemours and Co.

Quinonemethides.—All new compounds prepared in this work are listed in Table I with physical and spectral properties and analytical data. Representative procedures are given below. The methods of preparation and yields for each compound with reference to the Experimental Section are summarized in Table I with footnotes to describe any significant modifications of reaction conditions.

A. Synthesis.—The literature procedure[6] was used for the condensation of fluorinated ketones with phenols. The reactions with 1,3-dichlorotetrafluoroacetone were usually run at atmospheric pressure. In reactions with 2,6-di-*t*-butylphenol, the aluminum chloride caused isomerization involving the *t*-butyl group, but hydrogen fluoride was effective as a catalyst. The

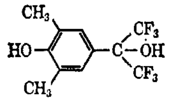
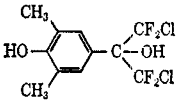
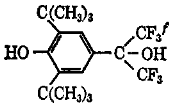
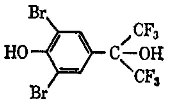
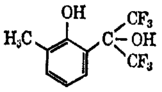
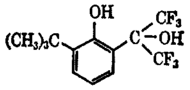
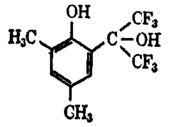
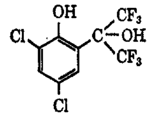
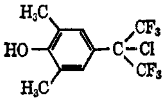
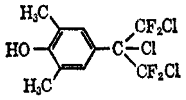
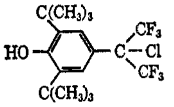
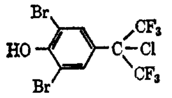
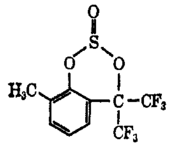
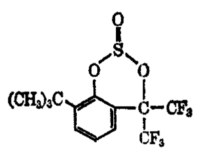
---

[8] Aluminum chloride and *p*-toluenesulfonic acid are reported to give predominantly *ortho* orientation in hexafluoroacetone substitutions of phenols [see ref 6b and D. C. England, French Patent 1,325,204 (1963)], but hydrogen fluoride and boron trifluoride are reported to give almost exclusive *para* substitution (ref 6b and I. L. Knunyants, T.-Y. Chen, M. P. Gambaryan, and E. M. Rokhlin, *Zh. Vses. Khim. Obshchest.*, **5**, 114 (1960); *Chem. Abstr.*, **54**, 20962 (1960)).

[9] Formation of cyclic sulfite ester appears to be a diagnostic test for *ortho* substitution in phenols.

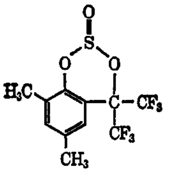
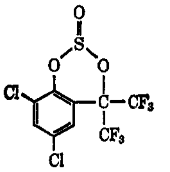
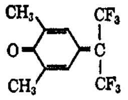
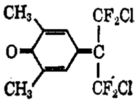
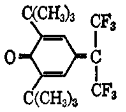
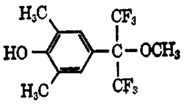
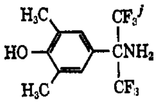
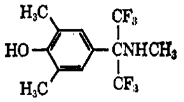
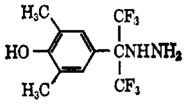
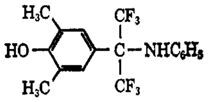
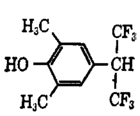
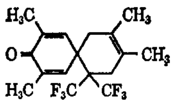
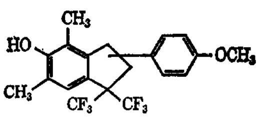
TABLE I

QUINONEMETHIDES, PRECURSORS, AND DERIVATIVES: PREPARATION AND PROPERTIES

Compd	Mp, °C, or n^{25}_{D}	Bp, °C (mm)	Uv[a]		Nmr, δ, ppm (rel intensity)[b]	
			λ, mμ	(ε)	F^{19} (relative to CCl_3F)	Proton (relative to tetramethylsilane)
			A. Precursors			
	90.5–91.8[d]	...	278 (E) 270 226	(900) (940) (7,120)	76.4	7.37 (2) 4.90 (1) 3.55 (1) 2.27 (6)
	95.6–96.8[e]	...	279 (E) 270 230	(800) (895) (7,800)	60.4	7.38 (2) 4.92 (1) 3.78 (1) 2.26 (6)
 [f]	95.5–96.5	...	276 (E) 269 227	(980) (1,000) (7,800)	76.4	7.58 (2) 5.48 (1) 3.33 (1) 1.50 (18)
	85.5–87.1	...	285 (I) 278	(2,200) (1,900)	76.7	7.87 (2) 6.17 (1) 3.57 (1)
	84.0–85.4	...	278 (E) 215	(2,770) (6,440)	76.2, doublet, $J = 1.1$ cps	6.7–7.3 (3) 7.1–7.3 (OH-2) 2.23 (3)
	125–127	...	280 (E) 221 216	(2,400) (7,340) (7,500)	76.2, doublet, $J = 1.0$ cps	7.3 (1), 6.43 (1) } OH 7.47 (1) 7.09 (2) AB pattern with additional splitting 1.27 (9)
	91.8–92.0	95 (3.0)	285 (E) 220	(2,910) (6,710)	76.2, doublet, $J = 1.1$ cps	7.41 (1, OH) 7.21 (2) 6.68 (1, OH) 2.30, 2.25 } (6)
	101.8–103.4	...	293 (E) 232 222	(3,130) (5,630) (7,140)	75.9	7.48 (2) 6.81 (*ca.* 2) (broad)
	96.2–97.2	...	277 (A) 268 232	(900) (1,280) (6,680)	70.8, triplet, $J = 0.8$ cps	7.42 (2) splitting not defined; 3.5 cps width at half-peak height 4.97 (1) 2.23 (6) triplet, $J = 0.5$ cps
	105 (0.4)				54.9, 54.2 } doublets, $J = 8$ cps with additional fine splitting	7.46 (2) 4.92 (1) 2.25 (6)
	126–127	...	295 (I) 276 268 231	(120) (930) (1,160) (6,340)	70.8, triplet $J = 0.8$ cps	7.67 (2) 5.43 (1) 1.47 (18)
	72–73	...	284 (E) 276	(2,030) (2,030)	71.0, triplet $J = 0.7$ cps	7.98 (2) 6.23 (1)
	44–45 1.4485	57 (0.6)	275 270	(1,170) (1,210)	73.7 (1), 77.3 (1) } quadruplets, $J = 9.4$ cps secondary splitting of ~1 cps	6.9–7.5 (3) 2.13 (3)
	1.4479	70 (0.2)	382 (I) 279 271	(122)[h] (1,110) (1,200)	73.0 (1), 76.5 (1) } quadruplets, $J = 9.5$ cps	7.64–7.0 (1) AB but complex on one side with additional peak ~7.6 1.33 (3)

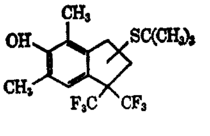
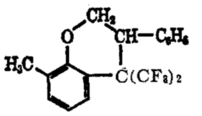
Method of preparation[c] (% yield), recrystallization solvent	Formula	Registry no.	Analysis, %							
			Carbon		Hydrogen		Fluorine		Others	
			Calcd	Found	Calcd	Found	Calcd	Found	Calcd	Found
			A. Precursors							
A1 (71), CCl_4 or hexane	$C_{11}H_{10}F_6O_2$	2950-32-5					39.6	39.4		
A1 (43), CCl_4 or hexane	$C_{11}H_{10}Cl_2F_4O_2$	2093-02-9	41.2	41.2	3.14	3.26	23.7	22.7 23.6	Cl, 22.1	21.4 22.0
A1[f] (59), pentane	$C_{17}H_{22}O_2F_6$	16867-83-7	54.8	54.9	5.96	5.95	30.6	30.1		
A1 (63), CCl_4	$C_9H_4Br_2F_6O_2$	16867-84-8	25.9	26.0	0.96	0.86	27.3	26.9	Br, 38.2	39.2
A1 (70), CCl_4, prec. with pentane	$C_{10}H_8F_6O_2$	3015-33-6	43.8	43.8	2.94	3.19	41.6	42.7		
A1[g] (48), hexane	$C_{13}H_{14}F_6O_2$	16878-08-3	49.4		4.47		36.1	36.2		
A1 (20), hexane	$C_{11}H_{10}F_6O_2$	16867-86-0	45.8	45.7	3.50	3.50	39.6	39.5		
A1 (45), CCl_4 or hexane	$C_9H_4Cl_2F_6O_2$	16867-87-1	32.9	33.0	1.22	1.38	34.7	35.2	Cl, 21.6	21.5
A2 (91), CCl_4 or hexane	$C_{11}H_9ClF_6O$ 306.6	16867-80-4	43.1	43.1	2.96	3.27	37.2	36.8	Cl, 11.6	11.6
A2 (75)	$C_{11}H_9F_4Cl_3O$	16878-09-4					22.4	22.4		
B1a (84), sublimed	$C_{17}H_{12}F_6ClO$	16867-88-2					30.0	30.0		
A2 (99), pentane	$C_9H_3Br_2ClF_6O$	16867-89-3					26.1	26.5	Br, 36.6 Cl, 8.12	35.3 8.52
A2 (89)	$C_{10}H_6F_6O_3S$	16878-06-1	37.5	37.8	1.89	2.01	35.6	35.8	S, 10.0	10.1
A2 (97)	$C_{13}H_{12}F_6O_3S$	16867-67-7	43.1		3.34		31.5	31.5		

TABLE I (*Continued*)

Compd	Mp, °C, or $n^{25}D$	Bp, °C (mm)	Uv[a] λ, mμ	Uv[a] (ε)	Nmr, δ, ppm (rel intensity)[b] F^{19} (relative to CCl_3F)	Nmr, δ, ppm (rel intensity)[b] Proton (relative to tetramethylsilane)
	1.4544	82 (4.0)	282 (E) 275	(1,590) (1,620)	76.6 (1) 73.1 (1) } quadruplets J = 9.4 cps	7.37 (2) 2.35 } (6) 2.27
	65–66	...	292 (A) 284 235 sh 204	(1,510) (1,530) (7,120) (42,400)	72.5 (1) 76.6 (1) } quadruplets J = 9.6 cps	7.68 (1), doublet J = 2.1 cps 7.54 (1), complex
B. Quinonemethides						
	35–36 1.4787	107 (50)	292 (E)	(28,600)	54.2 10-line symmetrical pattern, J = 0.6 cps	7.45 (1) 2.08 (3) } poorly defined splitting, 3 to 4.5 cps width at half-peak height
	62.2–63.0	90–90.5 (1.6)	307 (E)	(31,800)	43.3 half-peak width of 3 cps	7.49 (1) 2.08 (3)
	50–51	...	455 (E) 294	(19) (26,700)	54.3, triplet J = 1.1 cps	7.37 (1) 1.28 (9)
C. Reaction Products						
	98.5–98.7	...	277 (I) 268 266	(730) (790) (7,400)	76.4, quadruplet J = 0.9 cps	7.13 (2) 4.67 (1) 3.43 (3), quadruplet 2.26 (6)
	74–75	...				
	95.5–95.9	...	277 (I) 268 220	(760) (780) (7,500)	70.0 quadruplets J = 0.8 cps	7.32 (2) 4.8 broad (1) 2.4 broad 2.27 sharp } (10) 2.1 v. broad
	162–162.5	...	279 (E) 270 228	(870) (980) (7,580)	68.9 (C)[b]	7.32 (2) 3 to 5 (4) 2.32 (6)
	83.5–84.2	...	288 (I) 278 273 231	(1,200) (2,300) (2,000) (17,100)	68.4	7.33 (2) 7.2 to 6.3 (6) 4.78 (1) 4.38 (1) 2.23 (6)
	62–63.8	...	277 (I) 272 269 217	(1,080) (990) (1,000) (8,200)	66.4, doublets J = 8.4 cps split into triplets J = 0.6 cps	7.11 (2) 4.78 (1, OH) 3.89 (1, heptuplet, J = 8 cps) 2.28 (6)
	85.5–87.0	...	338 (E) 238	(30) (13,800)	64.6	6.67 (2) 2.60 (2) 2.13 (2) 1.81 (6) 1.72 (3) 1.60 (3)
	128.5–129.1	...	283 (E) 278 275 227 sh	(2,890) (3,400) (3,270) (21,500)	72.6 (1) 70.6 (1) } quadruplets J = 9.8 cps	See Experimental Section

Method of preparation[c] (% yield), recrystallization solvent	Formula	Registry no.	Analysis, %							
			Carbon		Hydrogen		Fluorine		Others	
			Calcd	Found	Calcd	Found	Calcd	Found	Calcd	Found
A2 (31)	$C_{11}H_8F_6O_3S$	16867-68-8	39.5	39.8	2.43	2.57	34.1	33.7	S, 9.60	8.43
A2 (79), hexane	$C_9H_2Cl_2F_6O_3S$	16867-69-9					30.4	30.6	S, 8.55	8.06
			B. Quinonemethides							
A3a (91)	$C_{11}H_8F_6O$	16915-87-0	48.9	49.0 49.0	2.99	3.13 3.09	42.2	42.5		
A3a (62)	$C_{11}H_8Cl_2F_4O$	16867-70-2	43.6	43.9	2.66	2.60	25.1	25.0	Cl, 23.4	23.4
A3a[i] (68), sublimed	$C_{17}H_{20}F_6O$	16867-71-3	57.6	56.8	5.69	5.76	32.2	32.3		
			C. Reaction Products							
B1c (93), hexane	$C_{12}H_{12}F_6O_2$	16867-72-4	47.7	47.6	4.01	4.01	37.7	37.6		
B1b (93), petroleum ether	$C_{11}H_{11}F_6NO$	14355-85-2	46.0	46.2	3.86	3.95	39.7	39.3	N, 4.88	4.72
B1b (87), hexane	$C_{12}H_{13}F_6NO$	16867-74-6	47.8	47.7	4.35	4.41	37.8	37.6	N, 4.65	4.73
B1b (90), hexane–benzene	$C_{11}H_{12}F_6N_2O$	16867-75-7	43.7	44.2	4.01	4.02	37.7	37.9	N, 9.27	9.27
B1b (94), hexane	$C_{17}H_{15}F_6NO$	16867-76-8	56.2	56.0	4.16	4.09	31.4	30.9	N, 3.86	3.87
B3 (39), hexane	$C_{11}H_{10}F_6O$	16867-77-9	48.7	48.9	3.35	3.81	42.1	41.9		
B4a (76), hexane	$C_{17}H_{18}F_6O$	16867-78-0	58.0	57.9 58.3	5.15	4.92 5.33	32.4	32.2		
B5a (42), cyclohexane	$C_{20}H_{18}F_6O_2$		59.4	59.6	4.49	4.72	28.2	27.8	Mol wt 363	404 369 (bp benzene)

TABLE I (*Continued*)

Compd	Mp, °C or $n^{25}D$	Bp, °C (mm)	Uv[a] λ, mμ	Uv[a] (ε)	Nmr δ, ppm (rel intensity)[b] F¹⁹ (relative to CCl_3F)	Nmr δ, ppm (rel intensity)[b] Proton (relative of tetramethylsilane)
	94.4–95.6	...	255	(8,210)	67.3, pentuplet $J = 0.8$ cps (from overlapping quadruplets?)	7.32 (2) 6.43 (2; AB, $J = 16$ cps, $\delta = 0.78$ ppm) 4.94 (1, OH) 2.27 (6) 1.37 (9)
	89–90	...	283 (I) 276	(2,540) (2,520)	69.7 complex overlapping quadruplets? with $J = \sim 9$ cps with additional splitting	See Experimental Section

[a] Solvents used are E, ethanol; I, isooctane; and A, acetonitrile. [b] Proton nmr spectra obtained in CCl_4 or $CDCl_3$ with internal reference of tetramethylsilane, F¹⁹ nmr spectra obtained in CCl_3F as solvent and internal references, or if too low solubility in $CHCl_3$ with internal CCl_3F (designated by letter c). Concentration of 5–10% used for all spectra. [c] Letter and number refer to procedure listed in Experimental Section. [d] Lit.[6b] mp 93–104°. [e] Lit.[6b] mp 95°. [f] We are indebted to Dr. D. M. Gale of this laboratory for first preparing this compound. Anhydrous hydrogen fluoride is required as catalyst in this reaction. Both aluminum chloride and boron trifluoride–etherate cause rearrangement of *t*-butyl group. [g] Only product isolated when 2,6-di-*t*-butylphenol was condensed

products were purified by recrystallization usually followed by sublimation.

The *p*-hydroxybenzyl alcohol was dissolved in excess thionyl chloride and a small amount (few drops to 1 ml) of triethylamine was added. A mild reaction (gas evolution, exothermic) occurred, and the solution was heated at reflux overnight. The product was usually separated by pouring the reaction mixture into a large excess of ice–water to destroy the excess thionyl chloride, and the solid was suction filtered, washed with water, dried, and recrystallized from hexane, pentane, or carbon tetrachloride, or if a liquid, was extracted into methylene chloride, dried, and distilled. The product, in yields generally of 60–90%, from the *p*-hydroxybenzyl alcohol **3** was the benzyl chloride **2**, whereas from the *ortho* isomer **7** it was the sulfite ester **8**. The 2,6-di-*t*-butyl compound **3b** was partly decomposed and rearranged by this treatment. It was treated with thionyl chloride in pyridine and converted directly into quinonemethide.

The *p*-hydroxybenzyl chloride **2**, finely powdered, was stirred with excess 10% sodium carbonate or sodium hydroxide solution in water until all the white crystals had changed to an orange oil. This oil was separated by methylene chloride extraction, dried, and vacuum distilled.

The 2,6-di-*t*-butylquinonemethide **1b** was prepared by heating the *p*-hydroxybenzyl alcohol **3b** with thionyl chloride in pyridine solution at 80° for 15 min and separated by pouring the reaction mixture into ice–water.

The cyclic sulfite ester **8** was heated in a flask at *ca.* 150° until major gas evolution ceased. The product was distilled at reduced pressure. The distillate was found to be a mixture of recovered sulfite ester **8** with quinonemethide **9**; usually a considerable residue of a light-colored resin remained in the pot.

The sulfite ester **8a**, 7.3 g, was heated at 150–180° in a pot connected to a spinning-band distillation column. Sulfur dioxide evolution started at 150°, and the liquid turned orange. A total of 6.3 g of orange liquid [bp 94° (9.5 mm) to 111° (15 mm), $n^{25}D$ 1.4501–1.4481] was collected in six fractions. The F¹⁹ nmr spectra on a middle fraction showed the distillate contained about 90% of starting sulfite ester and 10% of quinonemethide **9a**.

A mixture was dissolved in trichlorofluoromethane and shaken with excess sodium hydroxide solution for several minutes. The trichlorofluoromethane solution was separated, dried, and used for spectral analysis: F¹⁹ nmr quadruplets at 57.2 and 58.8 ppm relative to CCl_3F with $J = 9$ cps (no other fluorine detected); proton nmr, equal intensity areas at δ 7.4 to 6.2 (complex) and 1.98 ppm (single) (10% impurity at 2.3 ppm). The quinonemethide was further characterized by the carbonyl absorption at 1660–1670 cm^{-1}. A 3.8-g sample of a mixture of quinonemethide **9a** and sulfite ester **8a** was added to 1.0 g of styrene in 10 ml of methylene chloride. The orange color of the quinonemethide faded to yellow after approximately 10 min, and the solution was colorless in a few hours. The methylene chloride was evaporated, and the residual oil was triturated with excess sodium hydroxide solution to hydrolyze and dissolve the sulfite ester. The white crystalline solid was filtered off and dried, 0.28 g, mp 89.0–90.0°, and recrystallized from hexane–pentane, mp 88.0–88.6°. The product (also prepared from *o*-quinonemethide **9a** that was purified and isolated for spectral measurements) was characterized as the Diels-Alder adduct **10** by analysis (see Table I), infrared spectra, F¹⁹ nmr (see Table I), and proton nmr spectra (δ in ppm with intensity in parentheses): complex aromatic 7.3–6.5 (8), tertiary hydrogen as doublet at 5.1 (1) with $J = 10$ cps, complex CH_2 2.8–2.2 (*ca.* 2, overlaps with methyl), CH_3 singlet 2.23 (3). The assignment of the phenyl α to the oxygen is based on the proton shift for the CH_2 group which should be approximately 1 ppm to lower field if in the other position, α to oxygen. Mechanistically both from steric and electronic considerations, the orientation for styrene addition is also expected to be as assigned.

The *o*-quinonemethide **9a** was generated and trapped *in situ* by refluxing a solution of 1.8 g of sulfite ester **8a** and 5 g of inhibited styrene in 20 ml of *o*-dichlorobenzene overnight. The solvent was removed under reduced pressure and the oily residue was extracted with pentane. The adduct **10a** crystallized from the pentane extract in a yield of 1.2 g (60%).

B. Reactions of 2,6-Dimethyl-α,α-bis(trifluoromethyl)quinomethides (1a). 1. Hydrogen Chloride Addition.—A solution of 2.0 g (7.4 mmol) of quinonemethide **1a** in 20 ml of ether was saturated with dry hydrogen chloride gas and allowed to stand in a stoppered flask. After about 1 hr, the orange color of the quinonemethide disappeared. The solution was evaporated under nitrogen, and a residue of white crystalline solid, 2.26 g, mp 97.6–98.4° (99.7% yield), was obtained. The product was shown by mixture melting point and spectral comparison to be 2,6-dimethyl-4-(2-chlorohexafluoroisopropyl)phenol (**2a**).

Reaction of the quinonemethide **1a** with concentrated hydrochloric acid gave a product that was shown by spectral analysis to be a mixture of **2a** and the corresponding benzyl alcohol **3a**, showing that water addition has also occurred.

2. Ammonia,[10] Amines, and Hydrazine Addition.—Anhydrous methylamine was bubbled into a solution of 2.4 g (0.010 mol) of quinonemethide **1a** in 25 ml of anhydrous ether at room temperature. The orange color of **1a** gradually faded to a pale yellow while passing in the amine. The solution was stoppered. After standing at room temperature for several hours, it became colorless and was evaporated to dryness. The crystalline residue was recrystallized from hexane to give 2.6 g (87%) of white crystalline solid, mp 95.5–95.9°, characterized by analysis and spectra as 3,5,N-trimethyl-4-hydroxy-α,α-bis(trifluoromethyl)benzylamine.

Ammonia was added in a similar manner. Hydrazine dissolved in ether was added to an ether solution of compound **1a**. The reaction was extremely exothermic, and part of the product

---

[10] We are indebted to Dr. C. G. Krespan of this laboratory for the experiment with ammonia.

Method of preparation[i] (% yield), recrystallization solvent	Formula	Registry no.	Analysis, % Carbon Calcd	Found	Hydrogen Calcd	Found	Fluorine Calcd	Found	Others Calcd	Found
B5b (24), hexane	$C_{17}H_{20}F_6OS$		52.8	53.1 52.7	5.22	5.44 4.53	29.50	29.2	S, 8.3	8.3
See A3b	$C_{18}H_{14}F_6O$	16867-79-1	60.0	60.0	3.92	3.94	31.6	31.5		

with hexafluoroacetone in presence of boron trifluoride–etherate as catalysts at 100°. Product appeared to decompose during recrystallization. An isomer tetatively assigned *para* orientation of hexafluoroacetone to phenolic group has been reported,[6b] mp 63–71. [h] Product light orange color; absorption at 382 mμ may be due to impurity of quinonemethide formed during distillation. [i] By reaction of the hydroxybenzyl alcohols with thionyl chloride in pyridine. [j] See ref 10. This compound was first prepared by condensation of hexafluoroisopropylidenimine with 2,6-dimethylphenol: D. M. Gale and C. G. Krespan, *J. Org. Chem.*, **33**, 1002 (1968).

precipitated as white crystals during reaction. Aniline formed a wine red solution on mixing with the quinonemethide in ether; the adduct was isolated after standing overnight.

3. **Methanol Addition.**—The quinonemethide **1a** was dissolved in methanol, and a drop of concentrated sulfuric acid added. The orange color of the quinonemethide gradually faded, and the solution became colorless overnight. The methanol was evaporated, and the crystalline solid was washed with water and recrystallized.

4. **Polymerization.**—Quinonemethide **1a** and styrene reacted only when heated in the presence of benzoyl peroxide. The product appeared to be a low molecular weight polymer.

Attempts to prepare the anion radical of quinonemethide **1a** using a solution of sodium iodide in acetone gave only a white crystalline polymer. Thus, when 5 g of sodium iodide in 20 ml of acetone was mixed with a solution of 2.70 g (0.010 mol) of quinonemethide in 5 ml of acetone, the brown color of iodine developed immediately, and a white solid precipitated gradually. This white solid (1.92 g), mp 219–222°, was recrystallized from chloroform and was shown from spectral properties and analysis to be a polymer.

Anal. Calcd for $(C_{11}H_8F_6O)_x$: C, 48.9; H, 2.99; F, 42.2. Found: C, 49.4; H, 3.09; F, 41.4; ash content, 0.61%; mol wt (bp in benzene) 12,500, 11,840.

This material was pressed at about 200° into a brittle film, but some decomposition occurred (color and odor of monomer noted).

A series of polymerization experiments was carried out in an effort to prepare a higher molecular weight polymer. If the amount of sodium iodide was reduced below *ca.* 5–10%, the polymer did not form satisfactorily. The polymer of slightly lower melting point was also obtained with tetraethylammonium chloride in acetone. However, no polymers were obtained with sodium iodine or tetramethylammonium chloride in chloroform. Boiling the polymer in acetic anhydride increased the melting point slightly but did not improve the stability or the character of the pressed film. Heating in dimethyl sulfate also did not change the properties of the polymer.

A sticky gum was obtained in attempted polymerization experiments with sodium methoxide in alcohol or glyme. Oily products also obtained in these reactions may be the result of a nucleophilic attack by methoxide or alcohol on the quinonemethide but were not examined further.

5. **Reduction.**—A solution of 5.4 g (0.020 mol) of quinonemethide **1a** in 10 ml of 1,3-cyclohexadiene (80% purity) was refluxed overnight. The orange color of the quinonemethide faded to a pale yellow. The hydrocarbon was evaporated and residual solid sublimed at 100° (10–20 mm). A total of 2.06 g of white crystalline solid, mp 46–53°, was obtained. This product was recrystallized from hexane and resublimed, mp 62–63.8°. On the basis of analysis (see Table I) and spectral properties (OH in ir, tertiary hydrogen resonance split into a septuplet in nmr), the product was characterized as 2,6-dimethyl-4-(2H-hexafluoroisopropyl)phenol resulting from reduction of quinonemethide with the cyclohexadiene.

6. **With Dienes.**—A solution of 2.70 g (0.010 mol) of quinonemethide **1a** and 5 ml of 2,3-dimethylbutadiene was refluxed overnight. The orange color of the quinonemethide faded to a very pale yellow in a few hours. The excess diene was evaporated under nitrogen, and a residual white crystalline solid (3.42 g), mp 65–78°, was sublimed and recrystallized twice from hexane and resublimed, mp 85.5–87.0°. The analytical and spectral data are given in Table I. On the basis of the single F^{19} fluorine resonance, the simplicity of the proton nmr spectra, and the carbonyl frequency and carbon–carbon double bond at 1640 and 1680 cm^{-1} in the infrared spectrum, the spirane structure **5** (resulting from addition of the diene to the exocyclic double bond) was assigned.

A sealed Carius tube containing quinonemethide **1a** (9.1 g, 0.030 mol) and *ca.* 5 ml of butadiene was heated on a steam bath overnight. The orange color of the quinonemethide faded to pale yellow. The excess hydrocarbon was evaporated under nitrogen and the resulting oil was distilled, bp 108–115° (3.0 mm). The product, a colorless syrup, on the basis of analytical and spectral data (see Table I), was believed to contain approximately 75% of the spirane isolated from the 2,3-dimethylbutadiene reaction. The remainder is believed to be an isomeric adduct possibly contaminated with a 2:1 adduct.

Cyclopentadiene or hexachlorocyclopentadiene reacted with **1a** to give a black tar after extensive heating. 2,5-Diphenylisobenzofuran and **1a** in ethylene chloride formed a black complex, but no reaction could be detected.

7. **With Electron-Rich Olefins.**—A solution of 10.8 g (0.040 mol) of quinonemethide **3a** and 5.36 g (0.040 mol) of *p*-methoxystyrene (containing 0.1% hydroquinone) was heated at 100° under nitrogen overnight. The product was a viscous brown oil, and the orange color of the quinonemethide was no longer apparent. After cooling, the product was a glass which partly crystallized on standing. The oily material was extracted by trituration; the residue (10.5 g) was recrystallized once from methanol with hot filtration, mp 116–126°, and three times from cyclohexane. A total of 6.4 g of white crystalline solid, mp 128.5–129.1°, was obtained. On the basis of analysis (see Table I) and infrared (OH), ultraviolet, and nmr spectral properties, the indanol structure was assigned.

A solution of quinonemethide in excess vinyl ether was allowed to stand at room temperature. After *ca.* 2 weeks, the solution became a colorless syrup and could not be induced to crystallize. Nmr analysis indicated the product was complex. Further characterization was not carried out.

Heating at 100–125° overnight, 2.70 g (0.010 mol) of quinonemethide **1a** with 1.16 g (0.010 mol) of *t*-butyl sulfide gave a dark, viscous oil, from which *ca.* 1 g of light-colored crystals, mp 91–94°, was obtained by pentane trituration. This product was characterized as the indanol of structure **6** with a *t*-butylthio group in place of *p*-methoxyphenyl, but possibly in the other position because of much smaller F^{19} chemical shift difference between the trifluoromethyl groups. The steric bulk of the *t*-butyl group could change the orientation in addition.

8. With Aluminum Chloride.—A solution of 2.70 g (0.010 mol) of quinonemethide **1a** in methylene chloride was added to 1.33 g (0.010 mol) of anhydrous aluminum chloride in 15 ml of methylene chloride. After about one-third of the quinonemethide solution was added, a dark green color developed, and a mild exothermic reaction was noted. After addition was complete, the solution was stirred for about 1 hr and filtered under nitrogen to separate a white precipitate, 0.88 g. The greenish black mother liquor was evaporated under nitrogen leaving 2.84 g of a tan solid streaked with green. The ir and nmr spectra of these two solids were almost identical and showed the same proton nmr spectra as the starting quinonemethide but with a chemical shift to lower field. In the ir spectra, the carbonyl absorption at 1640 cm^{-1} was weak and broad. The first precipitate above was hydrolyzed in water and extracted into methylene chloride; it was shown by melting point, mixture melting point, and infrared and nuclear magnetic resonance spectra to be the benzyl chloride **2a**.

Notes

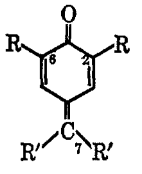
Perhalo Ketones. XIV.[1]
7,7-Bis(trifluoromethyl)quinonemethide

J. J. Murray

Industrial Chemical Division, Allied Chemical Corporation, Morristown, New Jersey 07960

Received December 27, 1967

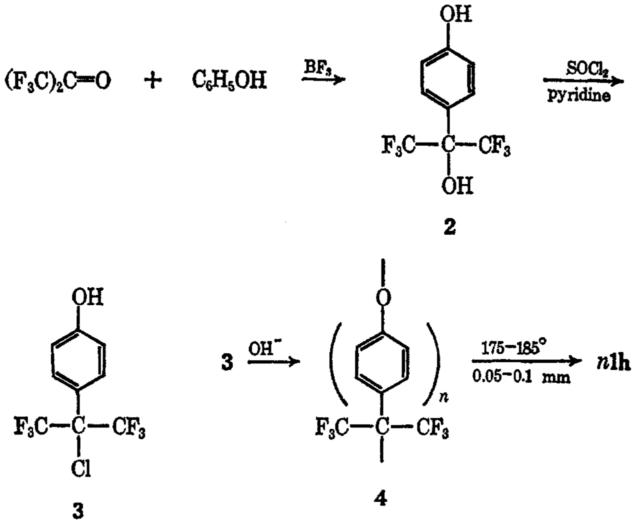
Although *p*-benzoquinonemethides (**1**) containing highly conjugated systems, such as **1i**, are stable,[2] those in which R′ is hydrogen or alkyl have required the presence of alkyl groups in the 2,6 positions to permit isolation in dilute solution. Thus, 2,6-di-*t*-butylquinonemethide with no C-7 substituents (**1a**) could be prepared only in dilute solution, and dimerized on attempted isolation.[3] 2,6-Di-*t*-butyl-7,7-dialkylquinonemethides (**1b**)[4] and 2,6-dimethyl-7,7-dicyanoquinonemethide (**1c**)[5] have been isolated as stable compounds. Sheppard[6] has recently prepared fluoroalkylquinonemethides with R′ = $-CF_3$ or $-CF_2Cl$, and with R = CH_3 or *t*-butyl (**1d**, **e**, and **f**), and has found them to be stable at temperatures even considerably above room temperature. He concluded that the presence of alkyl substituents in the 2,6 positions was essential for stability. We wish to report the preparation and isolation of 7,7-bis(trifluoromethyl)quinonemethide (**1h**), a compound without 2,6 substitution but stable at room temperature in pure form for a short time, and for at least several weeks in solution.



1a, R = *t*-butyl; R′ = H
b, R = *t*-butyl; R′ = alkyl
c, R = CH_3; R′ = CN
d, R = CH_3; R′ = CF_3
e, R = *t*-butyl; R′ = CF_3
f, R = CH_3; R′ = CF_2Cl
g, R = Br; R′ = CF_3
h, R = H; R′ = CF_3
i, R = H; R′ = C_6H_5

Compound **1h** was prepared from phenol and hexafluoroacetone *via* **2**[7] and **3**[8] (Scheme I).

Scheme I



The structure of 7,7-bis(trifluoromethyl)quinonemethide (**1h**) is quite clear from its infrared and nmr spectra. In carbon tetrachloride solution its infrared spectrum exhibited bands at 6.1 and 6.2 μ ascribed to the conjugated carbonyl group,[3,6] and strong C–F absorption in the 8–9-μ region.

Its nmr spectrum in carbon tetrachloride solution consisted of AA′BB′ spin pattern (of an $AA'BB'X_3X_3'$ system) with A calculated δ 7.68 and B at δ 6.59 (J_{AB} = 10.5 Hz). The A portion shows fine structure due to coupling with the CF_3 groups: ($J_{AX} \cong J_{AX'} \cong J_{A'X} \cong$

---

[1] Perhalo Ketones. XIII: R. E. A. Dear, E. E. Gilbert, *J. Org. Chem.* **33**, 819 (1968).

[2] A. Bistrzycki and C. Herbst, *Ber.*, **36**, 2335 (1903).

[3] J. D. McClure, *J. Org. Chem.*, **27**, 2365 (1962); L. J. Filar and S. Winstein, *Tetrahedron Lett.*, **25**, 9 (1960).

[4] A. Hubele, H. Suhr, and U. Heilmann, *Ber.*, **95**, 639 (1962); C. D. Cook and B. E. Norcross, *J. Amer. Chem. Soc.*, **78**, 3797 (1956).

[5] H. H. Takimoto, G. C. Denault, and L. O. Krbechek, *J. Org. Chem.*, **29**, 1899 (1964).

[6] W. A. Sheppard paper presented at the Fourth International Fluorine Symposium, Estes Park, Colo., July 24–28, 1967.

[7] B. S. Farah, E. E. Gilbert, M. Litt, J. A. Otto, and J. P. Sibilia, *J. Org. Chem.*, **30**, 1003 (1965).

[8] I. L. Knunyants, C. Ching-Yun, N. P. Gambaryan, and E. M. Rokhlin, *Zh. Vses. Khim. Obshch.*, **5**, 114 (1960); *Chem. Abstr.*, **54**, 20962 (1960).