Journal of Fluorine Chemistry, *25* (1984) 309–327

Received: August 23, 1983; accepted: November 19, 1983

POLYFLUORO-COMPOUNDS BASED ON THE CYCLOHEPTANE RING SYSTEM. PART 8. PENTAFLUOROTROPOLONE AND OTHER HYDROXY- AND METHOXY-POLYFLUOROTROPONES

Malcolm E. ALLEN, Robert STEPHENS and John Colin TATLOW

Chemistry Department, The University of Birmingham, P.O. Box 363, Birmingham B15 2TT (U.K.)

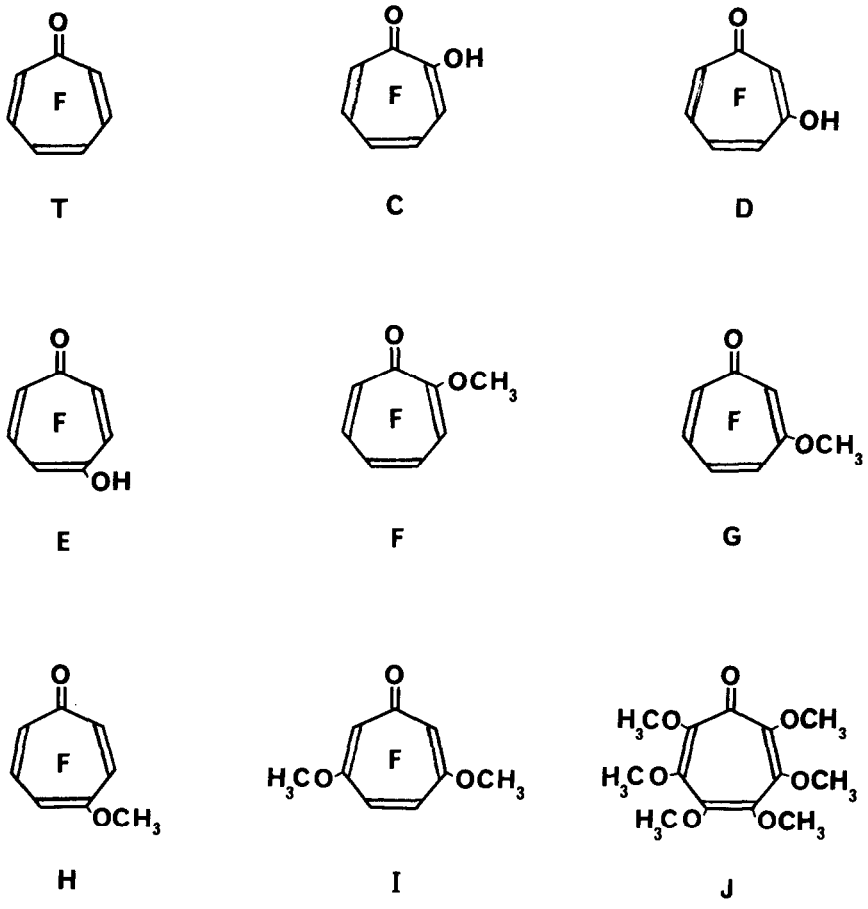
SUMMARY

Hexafluorotropone with aqueous sodium hydroxide afforded 2-, 3-, and 4-hydroxypentafluorotropone in the respective proportions, 15:65:20. The tropolone was isolated pure by chelation, and the 3-hydroxide by salt formation, but the 4-isomer was only obtained in admixture with the 3-hydroxide. Each product gave the corresponding methyl tropyl ether on treatment with diazomethane. Treatment of hexafluorotropone with sodium methoxide under mild conditions gave a mixture, but with predominant formation of the 3-methoxide or the 3,6-dimethoxide: exhaustive methoxylation gave hexamethoxytropone. Reactions with other nucleophiles did not give tractable products.

INTRODUCTION

Following our synthesis of perfluorocyclohept-ene- and -diene- -ones [1], and of hexafluorotropone [2], this paper records attempts at nucleophilic substitution reactions on the latter. Tropone itself shows, to a limited extent only, reactivity related to that of hydrocarbon-based aromatic compounds, whilst its carbonyl reactivity is limited [3]. Tropones and tropolones have often been rearranged to benzenoid compounds by alkaline reagents [3,4], hexachlorotropone and methanol giving methyl pentachlorobenzoate [5]. However, 2-fluorotropone and aqueous alkali afforded tropolone [6].

0022-1139/84/$3.00



Scheme

Various reactions were possible therefore between hexafluorotropone (T; See Scheme) and nucleophiles. If rearrangements to fluorobenzoic acids did not occur, classical addition-elimination at the carbonyl group was possible, or normal addition-elimination at the double bond system, with loss of fluorine. If the latter reaction occurred, substitution could be random, or subject to directive effects, as with the polyfluoro-aromatic compounds [7].

X-ray crystallographic studies [8] on hexafluorotropone showed that the ring was planar but that the bond lengths were only slightly different from alternating single and double bonds, as with tropone itself. Reactivity completely paralleling that of aromatic fluorocarbons would thus not be expected, though some special behaviour associated with the highly conjugated ring system should be found.

When hexafluorotropone (T) was first made, a reaction with methanolic sodium methoxide was carried out upon it [2]. A dimethoxide (I) was isolated, and though the conversion was low, it was the major product; preliminary evidence indicated it to have methoxy-groups in the 3- and 6- positions [2]. Though this orientation was confirmed as a result of the present work, it turned out that the above reaction was based on a fortuitous choice of reagent and conditions. Other nucleophilic processes either gave mixtures, or, in several cases, no tractable products at all.

RESULTS AND DISCUSSION

Hexafluorotropone (T) was found to react smoothly and readily with dilute (0.1M) aqueous sodium hydroxide and, though only sparingly soluble in water, it could be titrated. There was a slight inflexion in the pH curve at 1 molar equivalent, and a much more pronounced one at two molar equivalents of base. A preparative experiment yielded a product analysing as a monohydroxypentafluorotropone, but which was clearly a mixture (A.2). However, no benzoic acids could be detected. Presumably the first and less well-defined titration inflexion corresponded to nucleophilic attack by one molar equivalent of hydroxyl ion, which was followed by alkoxide formation by the hydroxy-products so formed, to give the second, clear-cut, pH change. Tropolone itself is fairly acidic [9]. Further addition of up to four molar equivalents of 0.1M sodium hydroxide in the cold did not appear to cause more nucleophilic attack. However, boiling the solution after four molar equivalents of alkali had been added did effect further reaction of some sort, though this aspect was not examined further.

Hydroxytropones are readily methylated by diazomethane [9,10] and when the mixture (A.2) was treated with ethereal diazomethane there was formed a product analysing as methoxypentafluorotropone (B). Though it was obviously a mixture, the chromatographic techniques tried did not offer any prospect of an easy separation of the limited quantity of product B that was available.

For the separation of the hydroxypentafluorotropone mixture (A.2), there was utilized firstly the well-known ability [9,3] of tropolones to form stable copper chelates. A neutralized solution of A.2 was treated with buffered cupric acetate, and a green chelate (C.1) was formed. This was extracted into diethyl ether, and no more chelate (C.1) could be isolated from the aqueous phase. Treatment of C.1 in acetone solution with hydrogen sulphide then liberated pentafluorotropolone (C) as colourless crystals. It readily formed an S-benzylthiouronium salt (hydrated) (C.3), apparently more stable than that formed from tropolone [9]. Regeneration of the copper chelate (C.1) from the tropolone (C), and its reconversion back to pure C showed that no untoward effects had resulted from its isolation in this way. Pentafluorotropolone (C) showed infrared and mass spectral peaks (the latter including those due to loss of CO and C_2O_2H) consistent with its structure, and both C and its salt (C.3) had nmr spectra as expected. The ^{19}F peak positions from the anion of the salt C.3 were considerably upfield from those of pentafluorotropolone (C) itself, particularly in the 3,5 and 7 positions.

X-ray crystallographic studies on pentafluorotropolone (C) were carried out by our colleagues [11], the structure being confirmed. Again, the ring was planar, but only small deviations from normal bond lengths were found. It seems that the π-electron delocalisation is not greatly affected, in comparison with that of tropolone, by the substitution of fluorine for hydrogen.

The cupric pentafluorotropolonate (C.1) isolated from mixture A.2 corresponded to less than 20% of the mixed hydroxypentafluorotropones formed. The aqueous mother liquors were acidified and extracted with ether, and a white solid isolated which was different from A.2; this was still a mixture however. 3-Hydroxytropone is even more acidic than tropolone [10]. A fairly acidic product was anticipated therefore, so an aqueous solution of this second mixture was treated with S-benzylthiouronium chloride. There was obtained a second hydrated S-benzylthiouronium salt of a monohydroxypentafluorotropone (D.1). Decomposition of this by dilute sulphuric acid gave the parent hydroxypentafluorotropone (D). Again, the mass spectral and infrared peaks were as expected. The nmr spectra of D and that of its salt D.1 were best explained as arising from the 3-hydroxy-isomer, though this orientation was not absolutely certain at this stage. Again, in the anion, the ^{19}F nmr peaks showed significant upfield shifts, though only those in the 2,5 and 6 positions, and to a lesser extent than in the 2-hydroxy-series.

The third monohydroxide (E) was not isolated pure in this work. The mother liquor remaining after precipitation of salt D.1 afforded a mixture of the (presumed) 4-hydroxypentafluorotropone (E) and the 3-isomer (D) in the ratio 6:4, respectively. Better separations might be possible, based on further selective precipitations of the S-benzylthiouronium salts, but with the limited amount available to us this was not achieved. Again, the postulated structure seemed the likeliest from the ^{19}F nmr spectrum of the compound, but slight uncertainty still remained. 4-Hydroxytropone [12] is nearly as acidic as the 3-hydroxy-isomer, but it seemed that the S-benzylthiouronium salt of 4-hydroxypentafluorotropone (E) was less well-defined than that (D.1) of the 3-hydroxy-isomer (D), though there could have been simply a solubility effect.

Comparison of its ^{19}F nmr spectrum with those of its components, C, D, and E, showed that the original hydroxypentafluorotropone mixture (A.2) contained the 2-, 3-, and 4-hydroxides in the ratio, C:D:E = 15:65:20. Since hexafluoro-

tropone (T) was very susceptible to attack by alkali, it seemed possible that an attacking species of lower nucleophilicity might give higher selectivity. It was found that water alone was sufficiently nucleophilic to effect substitution. After being kept with water in a sealed tube for six hours at 100°C, all compound T had reacted, though the same three hydroxy-pentafluorotropone products were all present. The 3-isomer (D) was in slightly greater proportion (ca 80%) than when alkali was employed, with approximately 15% of the 4-isomer (E), and only ca 5% of the tropolone (C). When sulphuric acid (4M) was used instead of water under the above conditions, only an intractable dark brown resinous solid was obtained.

Methoxylation of hexafluorotropone (T) had been accomplished successfully previously [2]. A slight excess of sodium methoxide (1.1:1) had been used in dilute solution in methanol (0.06M), in a reaction for 12 hours at 15°C. Much unreacted tropone (T) was recovered and the only product isolated (conversion 12% of total T) was a disubstituted one, thought to be 3,6-dimethoxytetrafluorotropone (I).

In the present work, the first stage in the study of methoxides was the preparation of reference compounds by treatment with diazomethane of samples of pure 2-(C), and of 3-(D), and of mixed 4- (E) + 3- (D) -hydroxypentafluoro-tropones. The three methoxypentafluorotropones were respectively obtained, the 2- (F), and 3-(G) isomers pure, and the 4-isomer (H) in admixture (7:3 ratio) with isomer G. Since even the mild methoxylation conditions of the original reaction had given a dimethoxide, direct substitution on hexafluorotropone (T) was then carried out with a deficiency of sodium methoxide (1:2) in methanol (0.024M) for 1½ hours at 15°C. Partial separation of the product mixture was achieved by chromatography. The principal constituents were identified by ^{19}F nmr spectroscopy as recovered T, 3-methoxy-pentafluorotropone (G) (the major product), and small amounts of its 4-methoxy-isomer (H), and of the 3,6-dimethoxide (I) previously obtained [2]. Refluxing of T in dry methanol alone for 6 hours produced no detectable reaction, but if a little

concentrated sulphuric acid was added to the methanol an intractable dark brown resin was formed. Clearly, hexafluorotropone (T) is decomposed very readily by sulphuric acid. When 3-methoxypentafluorotropone (G) was treated with methoxide, under similar conditions to those used for T, the product consisted of unreacted G (30%) and the 3,6-dimethoxide (I) (70%). Methanol alone also gave from G a little (ca 10%) of dimethoxide (I).

It seemed that replacement of fluorine by methoxy in this series caused progressively easier replacement of further fluorines, unlike the situation in the methoxylation of hexafluorobenzene [13] where progressive substitution becomes more difficult (however, both further methoxylation and methylation of pentafluoroanisole gave all three possible di-substituted products [13], a much less specific orientation than with most nucleophilic aromatic substitutions). This effect of easier progressive substitution was confirmed when hexafluorotropone (T) was treated with an excess of sodium methoxide for 24 hours at 15°C. One major product only was formed, hexamethoxytropone (J); this is one of the few examples of complete replacement of fluorine by nucleophilic substitution to give a specific fluorine-free product.

To remove any doubts about the orientations of the 3- and 4- substituted tropone series (D,E,G,H and I), an X-ray crystallographic examination of the 3-methoxide (G) was undertaken by our colleagues [14]. The structure was confirmed, and again the alternating bond lengths found before were present, with only very limited electronic delocalization. Unequivocally therefore, in both hydroxylation and methoxylation reactions, the major attack is at position 3. Both of the successful nucleophilic reactions on hexafluorotropone (T), give a preponderance of the 3- substituted products. This may be because the negative charge in the particular intermediate for this position of attack can be transferred very easily to the carbonyl oxygen.

No other success was achieved in attempted reactions of hexafluorotropone (T) with nucleophiles. Under mild conditions, methyl lithium gave a complex mixture in which nothing could be identified, and sodium borohydride gave unreacted T and a brown

viscous liquid highly sensitive to heat. These reagents gave smooth substitution reactions with perfluorocyclohept-enes and -dienes [15,2]. 2,4-Dinitrophenylhydrazine and semicarbazide gave complex mixtures, and no components corresponding to simple attack at the carbonyl group, or simple replacement of fluorine, could be detected, though there was liberation of fluoride ion.

From the viewpoint of reactivity, it is clear that hexafluorotropone (T) behaves as would be expected of a perfluoropoly-ene-one. It shows high reactivity towards nucleophiles, more reminiscent of octafluorocycloheptatriene [2] than of hexafluorobenzene [7]. Even though hydroxylation gives products (C+D+E) more resistant to further attack by alkali than is T itself, this is only relative, and more profound reaction of some sort can be induced under conditions still quite mild by fluorocarbon chemistry standards. It is of interest though that the ^{19}F nmr spectra of the hydroxypentafluorotropones (C,D,E) show that they are all conjugated enols, with no peaks due to tautomeric keto-forms showing up: the 2- and 3-isomers are quite acidic (D is the precise vinylog of a carboxylic acid).

It is noteworthy that no chemical reactions of these polyfluorotropone derivatives have so far yielded any detectable aromatic derivatives, despite ready conversions of classical tropones to such products [3-5]. Most of our compounds show large peaks due to loss of CO in their mass spectra, and they begin to decompose thermally around 200°C. However, as yet, no aromatic products have been isolated from such thermal decompositions either, only from pyrolyses of polyfluorocycloheptadienes [2] where the prior formation of polyfluorotropones is by inference.

Finally, it is worth mentioning that preliminary tests showed that the 3-hydroxide (D) and the 3-methoxide (G) have significant antifungal activity (but not antibacterial), though, if any potentially useful properties of this sort are available within the series, a much easier synthetic approach is required before they can be exploited.

EXPERIMENTAL

Spectra

Equipment used was as follows: A.E.I. MS9 (Mass Spectra): Perkin Elmer 257 (Infrared spectra; values given in cm^{-1}; s = strong, m = medium): Perkin Elmer R10 and R12, 60 MHz, and Varian XL100, 100 MHz (nmr spectra; ^{19}F in ppm to highfield of CCl_3F as internal reference; ^{1}H in ppm downfield from $(CH_3)_4Si$ as internal reference; s = singlet, d = doublet, t = triplet, c = complex, b = broad): Unicam S.P.800 (ultraviolet spectra; measurements in solutions in ethanol; λ_{max} values in nm, ε_{max} values in brackets).

(A) Reaction of hexafluorotropone (T) with aqueous alkali

(1) Hexafluorotropone [2] (0.11 g; 5.14×10^{-4} mole) was stirred with water (20 cm^3; only sparingly soluble) for 10 min at 24°C (pH then 3.65). Small aliquots of aqueous sodium hydroxide (0.1M) were added progressively from a burette, and the solution stirred for 15 min after each addition before the pH of the mixture was recorded. Inflexions in the titration curve occurred at the additions of alkali of 5.0-5.4 cm^3 (pH 5-6) and 10.0-10.5 cm^3 (pH 7-10) corresponding to alkali uptakes of 1.0 and 2.0 molar equivalents respectively.

(2) Aqueous sodium hydroxide (46.6 cm^3; 0.1M) was added dropwise during 10 min to a stirred suspension of hexafluorotropone (0.50 g) in water (5 cm^3) at 0°C. The yellow solution was then stirred for 2 h at 15°C. After acidification with dilute sulphuric acid (4M), the solution was extracted continuously with ether for 48 h. The ether extracts were dried ($MgSO_4$) and evaporated in vacuo to leave a residue, which was sublimed (150°C/20 mm pressure) to give mixed hydroxypentafluorotropones (A.2) (0.32 g), m.p. 210°C (decomp.) (Found: C, 39.8; H, 0.5; F, 45.3. Calc. for $C_7HF_5O_2$: C, 39.6; H, 0.5; F, 44.8%); M/e 212 (M); uv, 240 (13,900), 258 (15,600), 312 (4,470), 322 (5020), 366 (5,470). After individual compounds had been isolated (see later) comparison of their ^{19}F nmr spectra with that of this mixture (see Table) indicated an isomer distribution, C:D:E = 15:65:20.

TABLE

Nmr spectra of new compounds

Compound Number	Chemical Shift	Relative Intensity	Position in Formula	Type of signal and Coupling
C (F)	138.7	2	3,7	c
$[(CD_3)_2CO]$	140.8	2	4,6	c
	154.7	1	5	tt, J=18.5 and 1.2
(H)	7.2	-	2	s
C.3 (F)	149.6	2	4,6	cd, J_d=25.9
$[(CD_3)_2SO]$	153.3	2	3,7	cd, J_d=10.2
	177.6	1	5	tt, J=25.9 and 10.2
(H)	3.3	2	H_2O of cryst.	b
	4.5	2	$-CH_2-$	b
	7.3	5	aromatic ring	b
	9.5	3	NH_3^+	b

D.1 (F)	136.0	2	4,7	cd, J_d=30.4
$[(CD_3)_2SO]$	142.9	1	2	tt, J=30.4 and 6.2
	155.8	2	5,6	cd, J_d=6.2
(H)	3.4	4	H_2O of cryst.	b
	4.4	2	$-CH_2-$	b
	7.2	5	aromatic ring	b
	9.0	3	NH_3^+	b
D (F)	131.4	1	2	tt, J=27.9 and 6.6
$[(CD_3)_2CO]$	135.7	2	4,7	cd, J_d=27.9
	145.9	2	5,6	cd, J_d=6.6
(H)	8.9	-	3	s
E (F)	131.7	2	2,3	c
In the presence of ca. 40% of D	138.9	1	6	t, J_t=17.6
$[(CD_3)_2CO]$	143.5	2	5,7	cd, J_d=17.6
(H)	6.5	-	4	s

(Continued overleaf)

TABLE (cont.)

Compound Number	Chemical Shift	Relative Intensity	Position in Formula	Type of Signal and Coupling
A.2 (F)	131.7	24	D(2) + E(2,3)	
mixture	136.0	24	D(4,7)	
	139.1	10	C(3,7) + E(6)	
	141.1	6	C(4,6)	
	143.7	8	E(5,7)	
	146.1	28	D(5,6)	
	155.0	3	C(5)	
F (F)	128.5	1	7	dddd
	131.9	1	3	"
$[(CD_3)_2CO]$	140.1	1	6	"
	142.5	1	4	"
	146.9	1	5	"
(H)	4.1	-	2	d, J_d=0.5

G	(F)	121.3	1	2	dddd
		128.6	1	7	"
$[(CD_3)_2CO]$		135.9	1	4	"
		138.8	1	6	"
		144.9	1	5	"
	(H)	4.10	-	3	dd, J=2.0 and 0.5
H	(F)	127.4	2	2,7	c
In the presence of ca. 30% of G		130.1	1	3	ddd, J=11.3, 11.3 and 2.8
		136.5	1	5	ddd, J=15.5, 15.5 and 2.8
$[CDCl_3]$		137.9	1	6	c
	(H)	4.13	-	4	c
J	(H)	3.89	2	3,4,5,6	b
$[CDCl_3]$		3.93	1	2,7	b

(B) Methylation of mixed hydroxypentafluorotropones (A.2)

Diazomethane [prepared by addition of potassium hydroxide (0.4 g) in ethanol (10 cm^3) to N-methyl-N-nitroso-p-toluenesulphonamide (2.14 g) in ether (100 cm^3)] was distilled into a solution of mixed hydroxypentafluorotropones (0.37 g; from expt. A.2) in ether (100 cm^3) at 0°C. The mixture was left for 18 h in an unstoppered flask in a fume hood and then the rest of the ether was evaporated in vacuo to leave a buff-coloured solid (0.36 g). Sublimination at 80°C and 20 mm pressure gave mixed methoxypentafluorotropones (B) (0.26 g), m.p. 80-82°C (Found: C, 42.6; H, 1.5; F, 41.9. Calc. for $C_8H_3F_5O_2$: C, 42.5; H, 1.3; F, 42.0%); M/e 226 (M); ir 1615-1600 (s), 1510 (s).

(C) Isolation of pentafluorotropolone

(1) Cupric pentafluorotropolonate (C.1) Aqueous sodium hydroxide (56.6 cm^3; 0.12M) was added dropwise during 10 min to a stirred suspension of hexafluorotropone (T) (0.70 g) in water (5 cm^3) at 15°C. After being stirred for 1 h further at 15°C, the solution was neutralized (dil. H_2SO_4; 1M) to pH 7. A solution of cupric acetate (1.50 g) and potassium acetate (0.40 g) in water (25 cm^3) was then added (colour change, pale yellow → bright green). After being kept for 30 min with occasional shaking, the solution was extracted with ether (5 x 50 cm^3). The combined ether extracts were dried ($MgSO_4$) and evaporated in vacuo to leave a green solid which was recrystallised from ethanol to give cupric pentafluorotropolonate (C.1) nc (0.13 g), m.p. 270°C (decomp.) (Found: C, 34.9; H, 0.0. $C_{14}CuF_{10}O_4$ requires C, 34.6; H, 0.0%); ir 1505 (s).

(2) Pentafluorotropolone (C) A saturated solution of hydrogen sulphide in acetone was added dropwise to a solution of cupric pentafluorotropolonate (C.1) (0.31 g) in acetone (20 cm^3), until no green colour remained. The dark brown solution was evaporated in vacuo and the residue sublimed at 100°C/20 mm pressure to give a white solid (0.24 g). Recrystallisation from carbon tetrachloride afforded pentafluorotropolone (C) nc (0.20 g), m.p. 145°C (Found: C, 39.9; H, 0.7; F, 44.8%); M/e 212 (M), 184 (M-CO), 155 (C_5F_5); ir 3150 (s), 1620 (s), 1585 (s); uv 240 (28,300), 328 (10,550), 398 (7,550).

(3) The S-benzylthiouronium salt (C.3) A solution of S-benzylthiouronium chloride (0.10 g) in water (1 cm^3) was added to a solution of pentafluorotropolone (C) (0.05 g) in ethanol (1 cm^3). After being kept for 1 h at 2°C with occasional shaking, the precipitate was filtered off (0.092 g), and recrystallised from aqueous ethanol to give the monohydrate of S-benzylthiouronium pentafluorotropolonate (C.3) nc (0.70 g), m.p. 130°C (decomp.) (Found: C, 45.6; H, 3.3; F, 24.3; N, 7.1. $C_{15}H_{11}F_5N_2O_2S.H_2O$ requires C, 45.5; H, 3.3; F, 24.0; N, 7.1%).

(4) Chelation of pentafluorotropolone (C) by copper acetate A solution of C (0.0283 g) in ether (2 cm^3) was shaken with a solution of cupric acetate (0.0312 g) and potassium acetate (0.0105 g) in water (5 cm^3) for 5 min. The green ether layer was separated off, dried ($MgSO_4$), and evaporated to give cupric pentafluorotropolonate (C.4) (0.0306 g), identical (ir) with a specimen from expt. C.1.

Sample C.4 was redissolved in ether (5 cm^3) and hydrogen sulphide in acetone added till no green colour remained. The solution was dried ($MgSO_4$) and evaporated to give a residue which on sublimation (100°C/20 mm) yielded pentafluorotropolone (C) (0.014 g) (correct ir).

(D) Isolation of 3-hydroxypentafluorotropone

(1) The S-benzylthiouronium salt (D.1) The aqueous layer remaining after extraction of cupric pentafluorotropolonate by ether (expt. C.1) was acidified with dilute sulphuric acid (4M) and extracted with ether (3 x 50 cm^3). The combined ether extracts were dried ($MgSO_4$) and evaporated *in vacuo* to leave a white solid (0.57 g). This was dissolved in water (40 cm^3) and added to a solution of S-benzylthiouronium chloride (3.40 g) in water (40 cm^3). After 2 h at 2°C, the precipitate was filtered off and recrystallised from water to give the hydrate of S-benzylthiouronium 3-hydroxypentafluorotropone (D.1) nc (0.50 g), m.p. 190°C (decomp.) (Found: C, 43.7; H, 3.6; F, 22.9; N, 6.7. $C_{15}H_{11}F_5N_2O_2S.2H_2O$ requires C, 43.5; H, 3.6; F, 22.9; N, 6.8%).

(2) 3-Hydroxypentafluorotropone (D) This salt (D.1) (0.50 g) was shaken with dilute sulphuric acid (4M; 40 cm^3) at 15°C, until dissolution was complete (ca. 10 min). After being kept at 15°C for 24 h, the solution was extracted with ether (3 x 50 cm^3), the combined extracts then being dried ($MgSO_4$) and evaporated in vacuo to leave a white solid (0.22 g). Sublimation (150°C/20 mm pressure) afforded 3-hydroxypentafluorotropone (D) nc (0.13 g), m.p. 215-220°C (decomp.) (Found: C, 39.8; H, 0.3; F, 44.4%); M/e 212 (M), 184 (M-CO), 155 (C_5F_5); ir 1570 (s), 1515 (s); uv 259 (31,500), 310 (8750), 319 (7,830).

(3) 4-Hydroxypentafluorotropone (E) (in admixture with D) The mother-liquor from expt. D.1 (remaining after precipitation of salt D.1) was acidified with dilute sulphuric acid (4M) and extracted with ether (3 x 50 cm^3). The combined ether extracts were dried ($MgSO_4$) and evaporated in vacuo to leave a white solid (0.23 g) which was sublimed (150°C/20 mm pressure) to give a mixture (0.14 g) of 4-hydroxypentafluorotropone (E) (ca. 60%) and 3-hydroxypentafluorotropone (D) (ca. 40%).

(4) Reaction of hexafluorotropone (T) with water and with sulphuric acid Compound T (0.20 g) and water (20 cm^3) were shaken together for 6 h at 100°C in a sealed Pyrex tube. The solution was extracted continuously with ether for 48 h. The ether extract was shaken with cupric acetate (0.80 g) and potassium acetate (0.20 g) in water (50 cm^3). The ether layer and further extracts were dried ($MgSO_4$) and evaporated to give cupric pentafluorotropolonate (C.1) (0.01 g). The residual aqueous layer was acidified (dilute H_2SO_4; 4M) and extracted continuously with ether for 60 h. After drying ($MgSO_4$) evaporation gave a white solid mixture (D + E) (0.18 g) shown by ^{19}F nmr to be mainly D (>80%).

A repeat of this reaction using sulphuric acid (4M) gave a dark brown resinous solid which could not be purified by crystallisation or sublimation.

With dry methanol, no reaction was detected and hexafluorotropone (87%) was recovered, When dry methanol containing concentrated sulphuric acid (2 drops) was used, a dark brown intractable resin was obtained.

2-Methoxypentafluorotropone (F) Methylation of pentafluorotropolone (C) (0.093 g) as in expt. B gave, as an oil, 2-methoxypentafluorotropone (F) nc (0.060 g), b.p. 233°C (decomp.) (Found: M, 226.0045. $C_8H_3F_5O_2$ requires M, 226.0053); M/e 226 (M), 196 (M-CH_2O), 195 (M-CH_3O), 183 (C_6F_5O); ir 2940, shoulder 2850 (m), 1620-1600 (s), 1510 (s); uv 233, 318.

3-Methoxypentafluorotropone (G) Treated as in expt. B, 3-hydroxypentafluorotropone (D) (0.19 g) gave a yellow solid (0.17 g), sublimation of which (80°C/20 mm pressure) gave 3-methoxypentafluorotropone (G) nc (0.14 g), m.p. 91-92°C (Found: C, 42.8; H, 1.4; F, 41.7%); M/e 226 (M), 198 (M-CO), 184 (C_6F_5OH), 183 (C_6F_5O), 168 (C_6HF_5); ir 1600 (s), 1505 (m); uv 242 (25,900), 317 (7,540).

4-Methoxypentafluorotropone (H) (in admixture with G) The mixture E + D from expt. D.3 (0.14 g) treated as in expt. B gave a yellow solid (0.13 g). Sublimation (80°C/20 mm pressure) afforded a mixture (0.07 g) of H + G, m.p. 80-83°C (Found: C, 42.8; H, 1.5; F, 41.6%); ir 1610 (s), 1510 (s); uv 231 (24,900), 324 (9000). The ratio H:G was approx. 70:30.

(I) Reaction of hexafluorotropone (T) with sodium methoxide

Sodium methoxide in methanol (0.095M; 17.2 cm^3) was added dropwise during 20 min to a stirred solution of T (0.70 g) in dry methanol (50 cm^3) at 15°C. The mixture was stirred for 90 min further at 15°C, after which most of the methanol was evaporated in vacuo and the residue (10 cm^3) was poured into water (80 cm^3). After extraction with ether (8 x 25 cm^3), the combined extracts were dried ($MgSO_4$), and evaporated in vacuo, to leave a pale yellow solid (0.64 g). Tlc (uv active silica gel/chloroform) showed starting material + three products. Separation by column chromatography (silica gel column 36 x 2 cm; chloroform as eluant) gave: (i) hexafluorotropone (T) (0.01 g) (ir): (ii) a mixture (0.09 g) of T (ca. 65%) and 3-methoxypentafluorotropone (G) (ca. 35%) (ir and nmr): (iii) a mixture (0.16 g) of T (ca. 30%) and G (ca. 70%) (ir and nmr): (iv) a mixture (0.08 g) of G (ca. 70%), 4-methoxypentafluorotropone (H) (ca. 15%) and 3,6-dimethoxytetrafluorotropone (I) (ca. 15%) (ir and nmr): (v) a residue (0.08 g) not examined further.

(J) Further methoxylation of 3-methoxypentafluorotropone (G)

(1) With sodium methoxide Sodium methoxide in methanol (0.095M; 2.74 cm^3) was added dropwise during 3 min to a stirred solution of 3-methoxypentafluorotropone [(G) made by methylation of 3-hydroxypentafluorotropone (D)] (0.12 g) in methanol (10 cm^3) at 15°C. After being stirred for 90 min further at 15°C, the mixture was poured into water (100 cm^3) and extracted with ether (3 x 50 cm^3). The combined extracts were dried ($MgSO_4$) and evaporated in vacuo to leave a solid (0.09 g) which was sublimed (100°C/20 mm pressure) to give a product (0.04 g), consisting of starting material (G) (ca. 30%) and 3,6-dimethoxy-tetrafluorotropone (I) (ca. 70%) [2] (ir and nmr).

(2) With methanol After being stirred for 2 h at 15°C in dry methanol (15 cm^3), 3-methoxypentafluorotropone (G) (0.13 g) had undergone no detectable reaction. Refluxing for 5 h, followed by evaporation in vacuo, gave a yellow solid, shown by ^{19}F nmr to be mainly G (ca. 90%), containing some 3,6-di-methoxide (I) (ca. 10%).

Hexamethoxytropone (J)

Sodium methoxide in methanol (0.22M; 50 cm^3) was added dropwise during 20 min to a stirred solution of hexafluorotropone (T) (0.20 g) in dry methanol (50 cm^3) at 0°C. The mixture was stirred for 24 h at 15°C. Most of the methanol was evaporated off in vacuo, the residue (10 cm^3) being then poured into water (100 cm^3). Extraction with ether (4 x 50 cm^3) followed by drying ($MgSO_4$) and evaporation in vacuo left a yellow oil (0.22 g) which gradually solidified. Tlc (uv active silica gel/ether) showed only one major product. Separation by column chromatography (as in expt. I, ether eluant) afforded hexamethoxytropone (J) nc (0.15 g), m.p. 55-57°C (Found: C, 54.7; H, 6.4. $C_{13}H_{18}O_7$ requires C, 54.5; H, 6.3%); M/e 286 (M), 271 (M-CH_3), 258 (M-CO), 243 (M-$COCH_3$), 215 ($C_{10}H_{15}O_5$), 213 ($C_{10}H_{13}O_5$), 200 ($C_9H_{12}O_5$); ir 1585, 1560 double peak, shoulder 1530 (s); uv 264 (29,900), 345 (6820).

REFERENCES

1 Part 7 of this Series; C.M. Jenkins, R. Stephens and J.C. Tatlow, J. Fluorine Chem., 25 (1984) 233.

2 Part 5 of this Series; D.J. Dodsworth, C.M. Jenkins, R. Stephens and J.C. Tatlow, J. Fluorine Chem., 24 (1984) 41.

3 T. Nozoe, Non-Benzenoid Aromatic Compounds, Editor D. Ginsburg, Interscience New York, 1959, p.339; D. Lloyd, Carbocyclic Non-Benzenoid Aromatic Compounds, Elsevier Amsterdam, 1966, p.117; P.L. Pauson, Chem. Rev., 55 (1955) 9.

4 E.J. Forbes, D.C. Warrell and W.J. Fry, J. Chem. Soc. (C), (1967) 1693.

5 K. Scherer, J. Amer. Chem. Soc. 90 (1968) 7352; K. Kusada, R. West and V.N.M. Rao, J. Amer. Chem. Soc., 93 (1971) 3627.

6 B.C. Pratt and O.W. Webster, U.S.P., 2894 989; Chem. Abs., 55 (1961) 420.

7 J.C. Tatlow, Endeavour, 22 (1963) 89.

8 J.J. Guy, T.A. Hamor and C.M. Jenkins, J. Fluorine Chem., 5 (1975) 89.

9 J.W. Cook, A.R. Gibb, R.A. Raphael and A.R. Somerville, J. Chem. Soc., (1951) 503.

10 R.B. Johns, A.W. Johnson and M. Tišler, J. Chem. Soc., (1954) 4605.

11 J.J. Guy and T.A. Hamor, J. Fluorine Chem., 5 (1975) 377.

12 R.S. Coffey and A.W. Johnson, J. Chem. Soc., (1958) 1741.

13 J. Burdon, W.B. Hollyhead and J.C. Tatlow, J. Chem. Soc., (1965) 5152.

14 M.J. Hamor and T.A. Hamor, Acta Crystallog., B32 (1976) 2475.

15 A.E.M.M. Khalil, R. Stephens and J.C. Tatlow, J. Fluorine Chem., 22 (1983) 133.