Selective Favorskii Rearrangment of α,α,α'-Dibromochlorocycloalkanones of Medium Ring Size

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α,α,α'-Dibromochlorocycloalkanones of medium ring size have been prepared by treatment of chloro-cycloalkanones with bromine and were separated by chromatography and then submitted to Favorskii reaction. The stereoisomeric reaction products have in each case been evaluated by gas chromatography and the selectivity of bromide elimination deduced.

As bromide is a better leaving group than chloride there should be some selectivity in the loss of bromide over chloride in the Favorskii rearrangement of α,α,α'-dibromochlorocyclo-alkanones. We have observed a selectivity of 99% with a mixture of 2,2-dibromo-12-chlorocyclododecanone and 2,12-dibromo-2-chlorocyclododecanone.[1]

This report extends these studies on the selectivity of the Favorskii reaction to medium-ring dibromochlorocycloalk-anones, in order to ascertain the reaction selectivity according to the size of the ring. This selectivity is very interesting, because it is the basis of a general method of shortening, by one carbon atom, an asymmetric acyloin in a predictable manner and with high yield.

We have prepared two series of new α,α',α- and α,α,α'-dibromochlorocycloalkanones, namely 2,2-dibromo-7-chlorocycloheptanone (1a), 2,7-dibromo-2-chlorocyclo-heptanone (2a), 2,2-dibromo-8-chlorocyclo-octanone (1b), 2,8-dibromo-2-chlorocyclo-octanone (2b), 2,2-dibromo-10-chlorocyclodecanone (1c), 2,10-dibromo-2-chlorocyclo-decanone (2c), 2,2-dibromo-12-chlorocyclododecanone (1d), and 2,12-dibromo-2-chlorocyclododecanone (2d). Each pair of regioisomers (1) + (2) was obtained from the correspond-ing α-chlorocycloalkanone obtained in turn from the corres-ponding acyloin. Each pair of regioisomers was separated by either column chromatography on silica gel or preparative t.l.c. (p.l.c.). In each series the isomers (1) and (2) were submitted to the Favorskii rearrangement with 2.5 equiv. of sodium methoxide in methanol–benzene.

In each case the major product was the methyl 2-chlorocycloalkenecarboxylate (3), whilst the methyl 2-bromocycloalkenecarboxylate (4) was obtained in low yield. (Z) and (E) stereoisomers of compounds of series (3) were readily separated by column chromatography and were characterised by spectroscopic methods. The following methyl 2-chlorocycloalkenecarboxylates were separated by column chromatography: methyl (Z)-2-chlorocyclohex-1-ene-1-carboxylate (3a), methyl (Z)-2-chlorocyclohept-1-ene-1-carboxylate (3b), methyl (Z)- and (E)-2-chlorocyclonon-1-ene-1-carboxylate (3c), methyl (Z)- and (E)-2-chlorocycloundec-1-ene-1-carboxylate (3d). Compounds of series (4) could be identified in the reaction product by g.l.c. comparison with the specimens previously prepared from α,α,α'-tribromocyclo-alkanones.†

The sum of the percentage yields of methyl (Z)- and (E)-chlorocycloalkenecarboxylate (3), determined by g.l.c., represents the selectivity of the Favorskii rearrangement which was >93% in all cases (Table 1). These results allow us to use this reaction as a useful general method to shorten, by one carbon atom, an asymmetric acyloin.
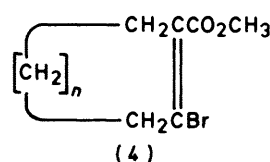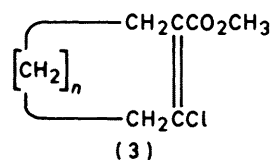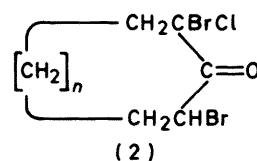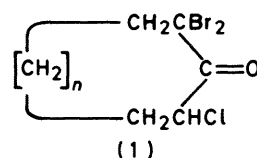
For (1)—(4) a ; n = 2   c ; n = 5
b ; n = 3   d ; n = 7

Table 1.[a] Stereoselectivity in the Favorskii rearrangement of α,α-dibromo-α'-chlorocycloalkanones and α,α'-dibromo-α-chlorocyclo-alkanones

Dibromo-chlorocyclo-alkanone	Preferred loss of Br over Cl (%) in		% (Z)-(3) and (E)-(3) formed in MeOH	
	MeOH	C_6H_6	(Z)-(3)	(E)-(3)
(1a)	97.7	96.5	100	—
(2a)	97.6	96.5	100	—
(1b)	97.4	95.5	100	—
(2b)	97.2	93.3	100	—
(1c)	98.3	96.4	96.2	3.8
(2c)	95.8	93.1	51.0	49.0
(1d)	99.0	97.0	90.7	9.3
(2d)	99.0	96.0	76.7	23.3

[a] All values are the average of at least three individual sample measurements. In all cases the agreement between values was better than 1%.

† By direct bromination of cycloalkanones we obtained α,α,α'-tribromocycloalkanones which afforded compounds of series (4) by Favorskii rearrangement.

Table 2. M.p.s and i.r. ($v_{max.}$), ^1H n.m.r. (δ), and low- and high-resolution mass spectra of dibromochlorocycloalkanones

Compound (molecular formula)	M.p.[a] (°C)	$v_{max.}$ (cm^{-1})	^1H N.m.r. spectrum [f] δ values	L.r.m.s. m/z (%)	H.r.m.s. M^+ Found (Required for M)
(1a) (C$_7$H$_9$Br$_2$ClO)	67—68 [b]	1 740 (CO), 653 (CBr$_2$), 620 (CCl)	5.09 (dd, Σ_J 13.4, CHCl), 3.5—2.5 (m, CH$_2$CBr$_2$)	302 (M^+, 2.66), 304 (6.20), 306 (4.43), 308 (0.79), 223 (M^+ − Br, 29.33), 225 (37.67), 227 (9.24), 79 (100)	301.8704 (301.8709)
(1b) (C$_8$H$_{11}$Br$_2$ClO)	99—100 [b]	1 730 (CO), 644 (CBr$_2$), 617 (CCl)	5.01 (two dd partly overlapped, Σ_J 16.4 and Σ_J' 16, CHCl), 3.2—2.6 (m, CH$_2$CBr$_2$)	316 (M^+, 0.60), 318 (1.64), 320 (1.03), 322 (0.23), 237 (M^+ − Br, 2.85), 239 (3.45), 241 (0.90), 39 (100)	315.8865 (315.8865)
(1c) (C$_{10}$H$_{15}$Br$_2$ClO)	73.5—74.5 [b]	1 730 (CO) [d]	5.20 (dd, Σ_J 15.4, CHCl), 3.1—2.6 (m, CH$_2$CBr$_2$)	Only isotopic M^+ at 346 (0.11), 348 (0.07), 265 (M^+ − Br, 1.54), 267 (1.95), 269 (0.47), 98 (100)	265.0002 (264.9995) [g]
(1d) (C$_{12}$H$_{19}$Br$_2$ClO)	104—105 [b]	1 730 (CO) [d]	4.96 (dd, Σ_J 15.4, CHCl), 3.0—2.5 (m, CH$_2$CBr$_2$)	No molecular ions. 293 (M^+ − Br, 1.24), 295 (1.60), 297 (0.32), 98 (100)	293.0302 (293.0308) [g]
(2a) (C$_7$H$_9$Br$_2$ClO)	oil	1 750, 1 715 (CO), [e] 580 (CBr)	4.92 (dd, Σ_J 12.9, CHBr), 3.5—2.6 (m, CH$_2$CBrCl)	302 (M^+, 6.32), 304 (14.38), 306 (9.78), 308 (1.99), 223 (M^+ − Br, 71.86), 225 (90.41), 227 (22.67), 79 (100)	301.8704 (301.8709)
(2b) (C$_8$H$_{11}$Br$_2$ClO)	81—82 [c]	1 735 (CO), 580 (CBr)	5.02 (two dd partly overlapped, Σ_J 16 and Σ_J' 16, CHBr)	316 (M^+, 0.63), 318 (1.48), 320 (0.93), 322 (0.13), 237 (M^+ − Br, 3.58), 239 (4.63), 241 (1.11), 41 (100)	315.8877 (315.8865)
(2c) (C$_{10}$H$_{15}$Br$_2$ClO)	oil	1 737, 1 718 (CO) [e]	5.44 (dd, Σ_J 15.3, CHBr), 3.2—2.5 (m, CH$_2$CBrCl)	No molecular ions. 265 (M^+ − Br, 1.32), 267 (1.81), 269 (0.40), 98 (100)	264.9992 (264.9995) [g]
(2d) (C$_{12}$H$_{19}$Br$_2$ClO)	94—95 [b]	1 727 (CO)	5.11 (dd, Σ_J 14.2, CHBr), 2.8—2.4 (m, CH$_2$CBrCl)	No molecular ions. 293 (M^+ − Br, 1.01), 295 (1.41), 297 (0.26), 98 (100)	293.0314 (293.0308) [g]

[a] M.p.s are uncorrected. [b] From methanol. [c] From hexane. [d] For these compounds it is difficult to assign the C−X frequencies. [e] These spectra were recorded for liquid films. [f] Σ_J is the sum of coupling constants J of CHX with the vicinal protons (in Hz). The signal for the other CH$_2$ groups of the ring is a multiplet at δ ca. 2.4—1.0. [g] Value for (M − Br).

In addition a series of analytical Favorskii reactions was carried out on each isomer (1) or (2), in methanol or benzene, in order to allow us to investigate the reaction selectivity as a function of the relative position of the halogens and the polarity of the solvent. From the results obtained we may infer that neither the ring size nor the relative positions of the two bromine atoms in the ring exert a significant influence on the selectivity, defined as preferred bromide over chloride elimination; compounds (4) are always formed in yields <7%. The influence of ring size does not alter the yield by more than ±3%. The solvent polarity facilitates this selectivity by ca. 2%. The yields of compounds formed by preferred loss of bromide over chloride are ca. 2% higher in methanol than in benzene. However, ring size and, even more, the relative position of the bromine atoms do exert a remarkable influence on the formation of (Z)- and (E)-(3). The yields of (Z)-(3) are remarkably higher with α,α-dibromo-α'-chlorocycloalkanones. No significant differences were observed in the Z : E ratio on changing the polarity of the solvent.

Spectroscopic Data and Structure Assignment.—Compounds (1) and (2) are regioisomers. α,α-Dibromo-α'-chlorocycloalkanones (1), as pure racemic compounds, have high and sharp melting points. α,α'-Dibromo-α-chlorocycloalkanones are more complicated, due to the presence of two asymmetric carbons with the possibility of cis- and trans-stereoisomers, and they are oils or low-melting solids. The regioisomers do not interconvert when subjected to the action of either BF$_3$–

AcOH–CH$_2$Cl$_2$, HCl–AcOH–CH$_2$Cl$_2$, or H$_2$SO$_4$–AcOH–CH$_2$Cl$_2$ for one week. However, they do interchange, reaching an equilibrium mixture, when treated with HBr–AcOH–CH$_2$Cl$_2$ for one week.[2] The structures of the trihalogenocycloketones have been assigned on the basis of spectroscopic evidence. Thus (1a) and (1b) show strong i.r. bands at 653 or 644 (CBr$_2$) and 620 or 617 (CCl) cm^{-1},* while their regioisomers (2a) and (2b) show a strong band at 580 (CBr) cm^{-1} (Table 2). Isomers (2c) and (2d) show the same ^1H n.m.r. signal for CHBr as the corresponding tribromocycloalkanones, whilst the signal for CHCl for (1c) and (1d) occurs at higher field. The signal for CHX (X = Br, Cl) is the expected double doublet in seven-, ten-, and twelve-membered rings; however, this signal in the cyclotrihalogeno-octanones (1b) and (2b) is a six-peak multiplet, probably due to the presence of two conformations (since when measured at −40 °C in CDCl$_3$ the signal is a double doublet, $J + J'$ 16 Hz).

The (Z)- and (E)-assignments for the stereoisomers (3) and (4) are based on the allylic methylene (CH$_2$CX=) signal, which comes out at higher field (by ca. 0.25 p.p.m.) for the (Z)- than for the (E)-stereoisomer (Table 3);[3] there is a significant deshielding influence of the CO$_2$Me group over the CH_2C=C group of the (E)-stereoisomer, i.e. when these two groups are on the same side of double bond. Besides, the carbonyl and double bond i.r. bands occur at higher frequency for the (Z)- than for the (E)-isomer.

* In 2,2,7-tribromocycloheptanone and 2,2,8-tribromocyclo-octanone v_{CBr} and v_{CBr_2} appear at 580 and 644 cm^{-1}, respectively.

Table 3. M.p.s and i.r., ^{1}H n.m.r., and low- and high-resolution mass spectra of methyl 2-halogenocycloalk-1-enecarboxylates

Compound (molecular formula)	M.p.[a] (°C)	ν_{max} (cm^{-1})	^{1}H N.m.r. spectra [c] δ values	L.r.m.s. m/z (%)	H.r.m.s. M^+ Found (Required for M)
(Z)-(3a) ($C_8H_{11}ClO_2$)	oil	1 730 (CO), 1 630 (C=C)	2.6—2.2 (m, 2 × CH$_2$C=)	174 (M^+, 37.28), 176 (11.65), 139 (M^+ – Cl, 14.80), 79 (100) [d]	174.0438 (174.0447)
(Z)-(3b) ($C_9H_{13}ClO_2$)	oil	1 730 (CO), 1 630 (C=C)	2.8—2.5 (m, CH$_2$CCl), 2.5—2.2 (m, CH$_2$C=)	188 (M^+, 23.35), 190 (8.01), 153 (M^+ – Cl, 27.60), 93 (100)	188.0604 (188.0604)
(Z)-(3c) ($C_{11}H_{17}ClO_2$)	oil	1 727 (CO), 1 645 (C=C)	2.75—2.2 (m, 2 × CH$_2$C=)	216 (M^+, 2.34), 218 (0.76), 181 (M^+ – Cl, 13.96), 121 (100)	216.0910 (216.0917)
(E)-(3c) ($C_{11}H_{17}ClO_2$)	oil	1 710 (CO), 1 600 (C=C)	3.0—2.2 (m, 2 × CH$_2$C=)	216 (M^+, 3.00), 218 (1.07), 181 (M^+ – Cl, 20.44), 121 (100)	216.0918 (216.0917)
(Z)-(3d) ($C_{13}H_{21}ClO_2$)	48.5—49 [b]	1 732 (CO), 1 642 (C=C)	2.7—2.3 (m, 2 × CH$_2$C=)	244 (M^+, 31.88), 246 (10.51), 209 (M^+ – Cl, 50.92), 149 (100)	244.1239 (244.1231)
(E)-(3d) ($C_{13}H_{21}ClO_2$)	oil	1 720 (CO), 1 610 (C=C)	3.1—2.2 (m, 2 × CH$_2$C=)	244 (M^+, 8.25), 246 (2.65), 209 (M^+ – Cl, 27.92), 149 (100)	244.1228 (244.1231)
(Z)-(4a) ($C_8H_{11}BrO_2$)	oil	1 730 (CO), 1 630 (C=C)	2.8—2.1 (m, 2 × CH$_2$C=)	218 (M^+, 8.91), 220 (8.29), 139 (M^+ – Br, 10.15), 79 (100)	217.9940 (217.9943)
(Z)-(4b) ($C_9H_{13}BrO_2$)	oil	1 730 (CO), 1 640 (C=C)	2.95—2.6 (m, CH$_2$CBr), 2.5—2.2 (m, CH$_2$C=)	232 (M^+, 9.50), 234 (9.16), 153 (M^+ – Br, 37.70), 93 (100)	232.0103 (232.0099)
(Z)-(4c) ($C_{11}H_{17}BrO_2$)	oil	1 730 (CO), 1 642 (C=C)	2.8—2.55 (m, CH$_2$CBr), 2.55—2.2 (m, CH$_2$C=)	260 (M^+, 1.75), 262 (1.90), 181 (M^+ – Br, 29.18), 121 (100)	260.0417 (260.0412)
(E)-(4c) ($C_{11}H_{17}BrO_2$)	oil	1 710 (CO), 1 593 (C=C)	2.9—2.2 (m, 2 × CH$_2$C=)	260 (M^+, 0.28), 262 (0.36), 181 (M^+ – Br, 21.79), 121 (100)	260.0418 (260.0412)
(Z)-(4d) ($C_{13}H_{21}BrO_2$)	46.5—47 [b]	1 732 (CO), 1 642 (C=C)	2.7—2.3 (m, 2 × CH$_2$C=)	288 (M^+, 3.65), 290 (3.44), 209 (M^+ – Br, 56.03), 149 (100)	288.0730 (288.0725)
(E)-(4d) ($C_{13}H_{21}BrO_2$)	oil	1 720 (CO), 1 610 (C=C)	3.1—2.2 (m, 2 × CH$_2$C=)	288 (M^+, 2.49), 290 (2.39), 209 (M^+ – Br, 66.78), 149 (100)	288.0716 (288.0725)

[a] M.p.s are uncorrected. [b] From methanol. [c] Signal for the other CH$_2$s of the ring is a multiplet at δ ca. 2.0—1.0 and the signal for CO$_2$CH$_3$ is a singlet at δ ca. 3.7. [d] In all the cases the base peak corresponds to M$^-$HX$^-$CO$_2$CH$_3$ (X = Cl or Br).

Experimental

General Techniques.—I.r. spectra were recorded as liquid films for oils and in KBr discs for solids in a Perkin-Elmer model 281 spectrophotometer. ^{1}H N.m.r. spectra were determined on a Perkin-Elmer model R-12B spectrometer, using SiMe$_4$ as internal standard and CDCl$_3$ as solvent. Mass spectra were performed at 70 eV on a Varian 166 machine, using the direct inlet system. Gas chromatography was carried out on a Perkin-Elmer model 3920B, using helium as carrier gas and a Minigrator to integrate the areas. The R_t (retention time) values are given for a column of OV-1 5% on Chromosorb W-AW-DMCS, 2 m long and ⅛ in o.d., using helium as carrier gas at a flow rate of 30 ml min^{-1} with θ$_{inj.}$ 200 °C and θ$_{det.}$ 200 °C (column temperatures indicated). Column chromatography was performed over silica gel Merck (0.063—0.200 mm) and t.l.c. on plates (0.25 mm) of silica gel Merck (G.60 and 60 HF$_{254}$).

Preparation of α-Chlorocycloalkanones.—α-Chlorocyclo-alkanones were obtained through acyloin condensation of dimethyl alkanedioates with sodium in boiling xylene,[4] followed by conversion of the resulting 2-hydroxy-cyclo-alkanones into the mesylates and conversion of the mesylates into the 2-chlorocycloalkanones with LiCl in dimethyl-formamide.[1] The spectroscopic and physical data are in agreement with those reported in the literature.[5]

Synthesis and Isolation of α,α-Dibromo-α'-chlorocyclo-alkanones (1) *and α,α'-Dibromo-α-chlorocycloalkanones* (2).— The α,α,α'-dibromochlorocycloalkanones were obtained by treatment of the corresponding chlorocycloalkanones in CH$_2$Cl$_2$ with an excess of bromine in acetic acid at room temperature. As an example a stirred solution of 2-chloro-cycloheptanone (0.484 g, 3.30 mmol) in CH$_2$Cl$_2$ (3 ml) was slowly treated with a solution of bromine (0.44 ml, 8.52 mmol) in acetic acid (2.66 ml) during 30 min while the temperature was kept at ca. 5 °C; the temperature was then allowed to rise to room temperature and the mixture was stirred for a further 20 h before being poured into water and the reaction product extracted with CH$_2$Cl$_2$. The extract was washed in turn with 5% Na$_2$SO$_3$, saturated NaHCO$_3$, and NaCl solutions and was dried over anhydrous sodium sulphate. Evaporation of the solvent under reduced pressure gave an oil (0.956 g, 95%). This oil (0.450 g) was separated by p.l.c. on silica gel with hexane–diethyl ether (12 : 1) as developer into 2,2-*dibromo-7-chloro-cycloheptanone* (1a) (0.354 g) and 2,7-*dibromo-2-chlorocyclo-heptanone* (2a) (0.052 g). Relative yields of (1a) and (2a) were estimated by gas chromatography as 87.2 and 12.8%, respectively.

By the same technique were prepared compounds (1b) and (2b) (90%; relative yields 87 and 13%, respectively), (1c) and (2c) (85%; relative yields 32.8 and 67.2%), and (1d) and (2d) (86%; relative yields 59.5 and 40.5%).

Preparative Favorskii Rearrangement of Dibromochloro-cycloalkanones.—Sodium (0.054 g, 2.3 mmol) was dissolved in anhydrous methanol (2.6 ml) and to this stirred solution was added dropwise a solution of dibromochlorocycloheptanone [(1a) and (2a)] (0.320 g, 1.05 mmol) in dry benzene (1.4 ml) and anhydrous methanol (1.6 ml) during 15—30 min while the temperature was kept at 10—20 °C. After the addition was complete the mixture was stirred at 20 °C for a further 15 min.

The mixture was then poured into ice–water and the reaction product was extracted with hexane, the extract was washed in turn with dilute hydrochloric acid, saturated aqueous NaHCO₃, and aqueous NaCl and was dried over anhydrous sodium sulphate. Evaporation of the solvent under reduced pressure gave an oil (0.180 g, 98%). G.l.c. analysis of the reaction product (145 °C) showed a major peak due to *methyl* (*Z*)-2-*chlorocyclohex*-1-*ene*-1-*carboxylate*, (*Z*)-(3a) (*R*ₜ 254 s; 96.6%), and a minor peak due to *methyl* (*Z*)-2-*bromocyclohex*-1-*ene*-1-*carboxylate* (*Z*)-(4a) (*R*ₜ 363 s; 2.3%).

Favorskii rearrangement of the dibromochlorocyclo-octanones (1b) and (2b) (0.591 g) gave an oil (0.347 g, 99%) which showed (g.l.c.; 150 °C) a peak due to (*Z*)-(3b) (*R*ₜ 224 s; 96.6%) and a minor peak due to (*Z*)-(4b) (*R*ₜ 330 s; 3.4%).

Favorskii rearrangement of the dibromochlorocyclodec-anones (1c) and (2c) (0.909 g) afforded a reaction product (0.562 g, 99%), g.l.c. analysis of which (150 °C) showed two major peaks due to (*E*)-(3c) (*R*ₜ 469 s; 29.7%) and (*Z*)-(3c) (*R*ₜ 511 s; 61.3%), as well as two minor peaks due to the (*E*)- and (*Z*)-isomer of *methyl* 2-*bromocyclonon*-1-*ene*-1-*carboxylate* {(*E*)-(4c) + (*Z*)-(4c) 4.0%}. Isomers (*E*)-(3c) and (*Z*)-(3c) were isolated by silica-gel chromatography with hexane–diethyl ether (8 : 2) as developer.

Favorskii rearrangement of dibromochlorocyclo-dodecanones (1d) and (2d) (1.000 g) gave a reaction product (0.634 g, 97%), g.l.c. analysis of which (170 °C) showed two major peaks due to (*E*)-(3d) (*R*ₜ 433 s, 17.9%) and (*Z*)-(3d) (*R*ₜ 519 s; 79.8%) together with another peak due to (*Z*)-(4d) (*R*ₜ 700 s; 0.5%). Each isomer was isolated by silica-gel chromatography [hexane–diethyl ether (8 : 2)].

Analytical Favorskii Rearrangement of each Isomeric Dibromochlorocycloalkanone.—We developed an analytical procedure to estimate the selectivity of the Favorskii rearrangement of dibromochlorocycloalkanones in methanol and in benzene: (*a*) *in methanol* each isomeric dibromochlorocyclo-alkanone was treated as in the preparative procedure; (*b*) *in benzene* each dibromochlorocycloalkanone (1 mmol) was added to a magnetically stirred suspension of NaOMe (4 mmol) in dry benzene (22 ml) at 20—30 °C, during 15—30 min. Reaction products, extracted with hexane, were separated by gas chromatography into (*Z*)- and (*E*)-chlorocycloalkene-carboxylates and bromocycloalkenecarboxylates.

Preparation of α,α,α'-*Tribromocycloalkanones.*—The α,α,α'-tribromocycloalkanones were obtained by treatment of the corresponding cycloalkanone in CH₂Cl₂ with an excess of bromine (3.5 equiv.) in acetic acid at room temperature for 24 h. The following tribromocycloalkanones had the properties given in the literature: 2,2,7-tribromocyclohepta-none,[6a] 2,2,8-tribromocyclo-octanone,[6b] 2,2,10-tribromocyclo-decanone,[6c] and 2,2,12-tribromocyclododecanone.[6c]

Favorskii Rearrangement of α,α,α'-*Tribromocycloalkanones.*
—The same procedure as employed for the α,α,α'-dibromo-

chlorocycloalkanones was used. Favorskii rearrangement of 2,2,7-tribromocycloheptanone (0.214 g) afforded only methyl (*Z*)-2-bromocyclohex-1-ene-1-carboxylate, (*Z*)-(4a) (0.131 g, 98%). G.l.c. analysis of the reaction products (145 °C) showed one peak due to (*Z*)-(4a) (*R*ₜ 363 s; 100%).

2,2,8-Tribromocyclo-octanone (0.545 g) yielded methyl (*Z*)-2-bromocyclohept-1-ene-1-carboxylate, (*Z*)-(4b) (0.343 g, 98%). G.l.c. analysis of the reaction product (150 °C) showed one major peak due to (*Z*)-(4b) (*R*ₜ 330 s; 98.1%).

2,2,10-Tribromocyclodecanone (1.075 g) afforded an oil (0.674 g, 94%) which was chromatographed on silica gel [hexane–diethyl ether (95 : 5)]; eluted first was methyl (*E*)-2-bromocyclonon-1-ene-1-carboxylate (*E*)-(4c) (0.071 g), second a mixture of (*Z*)-(4c) and (*E*)-(4c) (0.493 g), and third methyl (*Z*)-2-bromocyclonon-1-ene-1-carboxylate (*Z*)-(4c) (0.061 g). G.l.c. analysis of the reaction product (150 °C) showed two major peaks due to (*E*)-(4c) (*R*ₜ 708 s; 11.8%) and (*Z*)-(4c) (*R*ₜ 739 s; 82.0%).

2,2,12-Tribromocyclododecanone (0.990 g) gave a solid reaction product (0.657 g, 96%), g.l.c. analysis of which (170 °C) showed two major peaks due to methyl (*E*)-2-bromocycloundec-1-ene-1-carboxylate (*E*)-(4d) (*R*ₜ 598 s; 24%) and methyl (*Z*)-2-bromocycloundec-1-ene-1-carboxylate (*Z*)-(4d) (*R*ₜ 700 s; 75%). Each isomer was isolated by p.l.c. [silica gel; hexane–diethyl ether (8 : 2)] of the reaction product (0.380 g); (*E*)-(4d) (0.081 g) and (*Z*)-(4d) (0.276 g).

References

1 A. Abad, M. Arnó, J. R. Pedro, and E. Soane, *Tetrahedron Lett.*, 1981, 22, 1733.
2 M. D. Mehta, D. Miller, and D. J. Tidy, *J. Chem. Soc.*, 1963, 4614.
3 H. B. Kagan, 'Stereochemistry,' Georg Thieme, Stuttgart, 1977, vol. 1, p. 50.
4 P. D. Gardner, G. R. Haynes, and R. L. Brandon, *J. Org. Chem.*, 1957, 22, 1206; C. D. Hurd and W. H. Saunders, Jr., *J. Am. Chem. Soc.*, 1952, 74, 5324; N. L. Allinger, *Org. Synth.*, 1967, Coll. Vol. IV, 2nd edn, p. 840; M. Stoll and A. Rouvé, *Helv. Chim. Acta*, 1947, 30, 1822.
5 M. C. Castinel, G. Chiurdoglu, M. M. L. Josien, J. Lascombe, and E. Vanlanduyt, *Bull. Soc. Chim. Fr.*, 1958, 807; Beilstein, vol. 7, 1st supplement, p. 10; A. Kohda, K. Veda, and T. Sato, *J. Org. Chem.*, 1981, 46, 509.
6 (*a*) W. von E. Doering and A. Abdul-Rida, *J. Am. Chem. Soc.*, 1954, 76, 39; (*b*) G. Hesse and F. Urbanek, *Chem. Ber.*, 1958, 91, 2733; (*c*) Rhone-Poulenc S.A., Neth. Appl. 6-605 908/1966; (*Chem. Abstr.*, 1967, 66, 85538s).