

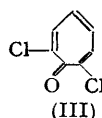
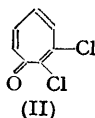
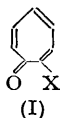
439. *Tropolones. Part V.* Halogenocycloheptatrienones.*

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Tropolone and α -bromotropolone react with thionyl chloride forming respectively 2-chloro- (I; X = Cl) and 2:3(or 7)-dichloro-*cycloheptatrienone* (II or III). In each of these compounds one chloro-substituent is replaced in reactions with anionoid reagents and in reaction with the sodium salt of thio-*p*-cresol the dichloro-compound yields a bis-*p*-tolylthio*cycloheptatrienone*. The bromine atom in α -bromotropolone is similarly reactive.

Several examples of change from the *cycloheptatrienone* to the benzenoid structure are noted incidentally.

THE conception of a vinologous relationship between the acidic function of tropolone and that of a carboxylic acid is acceptable only with reservations, though it provides a useful indication of some aspects of the reactivity of tropolones. For instance, when tropolone is mixed with thionyl chloride in an inert solvent there occurs initially a rapid deposition of tropolone hydrochloride but, on application of heat, this gradually disappears and 2-chloro*cycloheptatrienone* (I; X = Cl)—a compound with some of the properties of an acid chloride—may be recovered from the clear solution. *o*-Chlorobenzaldehyde appears to be a by-product of this reaction. The same chloro-compound is obtained when phosphorus trichloride is used in place of thionyl chloride, and phosphorus tribromide likewise yields the 2-bromo-compound. Thionyl chloride reacts with α -bromotropolone yielding a dichloro*cycloheptatrienone* for which the alternative formulæ (II) and (III) come under consideration but are not differentiated here.



In 2-chloro*cycloheptatrienone* the chloro-substituent is mobile. The compound was hydrolysed to tropolone in aqueous media but, especially in presence of alkali, much benzoic acid was also produced. With anionoid reagents, namely, sodium methoxide, ammonia, and thio-*p*-cresol (as the sodium salt) in methanol, 2-chloro*cycloheptatrienone* yielded products of metathesis—tropolone methyl ether, amino- and *p*-tolylthio-*cycloheptatrienone* (I; X = OMe, NH₂, and SC₆H₄). The dichloro-compound (II) or III behaved similarly. On hydrolysis the only product isolated was *o*-chlorobenzoic acid but by reaction with diethylamine or *p*-toluidine products were obtained which corresponded to the replacement of one chlorine atom by the appropriate amino-group. It is noteworthy that mono-replacement occurred even when an excess of the amine was employed. This result, however, is not necessarily indicative of an unsymmetrical (II) rather than a symmetrical structure (III), since it may be expected (*a*) that at any centre of the *cycloheptatrienone* nucleus a halogen substituent will have some mobility and (*b*) that in successive replacements of two halogen substituents the first will be achieved more readily than the second. The interaction of the sodium salt of thio-*p*-cresol and the dichloro-compound was selected to test mobility of both halogen substituents and it was found that according to the proportions used a chloro-*p*-tolylthio- or a di-*p*-tolylthio-compound was produced.

From the present point of view α -bromotropolone may be regarded as bromohydroxy-*cycloheptatrienone* and it is consistent with the observations described above that by heating its sodium salt with thio-*p*-cresol in pyridine *p*-tolylthiotropolone was produced. By prolonged heating of α -bromotropolone with 50% aqueous alkali there was formed—albeit in very low yield—a substance which is probably α -hydroxytropolone. This substance, or α -bromotropolone itself, afforded salicylic acid when fused with alkali.

* Part IV, *J.*, 1952, 603.

Unsuccessful attempts were made to prepare a ditropolonyl by heating α -bromotropolone with copper powder, but sodium α -bromotropolone reacted with cuprous cyanide in boiling pyridine and, by hydrolysis of the α -cyanotropolone (impure) so produced, tropolone- α -carboxylic acid was obtained. This acid yielded tropolone on decarboxylation and phthalic acid on fusion with alkali. α -Bromotropolone methyl ether reacted with ammonia in methanol, affording a product which appears to be an aminobromocycloheptatrienone which, however, was not obtained analytically pure.

Neither 2-chlorocycloheptatrienone nor the dichloro-compound could be caused to react with aromatic hydrocarbons in presence of aluminium chloride. Indeed the general behaviour of the compounds resembles that of chlorinated *p*-benzoquinones or (*o*:*p*-)nitrated chlorobenzenes rather than that of acid chlorides.

EXPERIMENTAL

Ammonium Salts of Tropolone and α -Bromotropolone.—Addition of concentrated aqueous ammonia (1 c.c.) to a solution of tropolone (0.02 g.) in water (0.5 c.c.) precipitated the *ammonium* salt of tropolone as a yellow crystalline powder which was dried at 100° and had m. p. 145—150° (Found: C, 60.8; H, 6.35. $C_7H_9O_2N$ requires C, 60.4; H, 6.5%). The m. p. was progressively lowered to about 125—130° by crystallisation from a solution of ammonia in ethanol. The *ammonium* salt of α -bromotropolone, similarly prepared, had m. p. 185—190° (Found: C, 38.9; H, 3.25. $C_7H_8O_2NBr$ requires C, 38.5; H, 3.7%).

2-Chlorocycloheptatrienone.—(a) Tropolone (1 g.), benzene (10 c.c.), and thionyl chloride (10 c.c.) were heated under reflux for 3 hours. The white precipitate of tropolone hydrochloride, m. p. 119—125° (Found: C, 53.4; H, 5.0. Calc. for $C_7H_7O_2Cl$: C, 53.0; H, 4.4%), which was initially formed, gradually re-dissolved. After concentration *in vacuo*, addition of benzene and renewed concentration, the residual gum was distilled at 90°(bath)/2 mm. A solution of the distillate in benzene was shaken with saturated aqueous sodium hydrogen sulphite, and the resulting solid (*A*) was collected. The washed, dried, and concentrated benzene solution afforded 2-chlorocycloheptatrienone as colourless needles, m. p. 63—64°, from light petroleum (b. p. 60—80°) (Found: C, 59.8; H, 3.7. C_7H_5OCl requires C, 59.8; H, 3.6%). The bisulphite compound (*A*) was treated with aqueous sodium carbonate, and the mixture was extracted with benzene. The recovered oil was oxidised by potassium permanganate to *o*-chlorobenzoic acid, m. p. and mixed m. p. 143—144°, and also afforded a 2:4-dinitrophenylhydrazone, m. p. 205° (Found: C, 48.6; H, 3.2. Calc. for $C_{13}H_9O_4N_4Cl$: C, 48.7; H, 2.8%), and a semicarbazone, m. p. 239—240°, which were identified by mixed m. p. with authentic specimens prepared from *o*-chlorobenzaldehyde.

(b) 2-Chlorocycloheptatrienone, m. p. and mixed m. p. 64°, was also obtained by heating under reflux a mixture of tropolone (0.5 g.), benzene (15 c.c.), and phosphorus trichloride (4 c.c.) for 1 hour, and was isolated by fractional distillation. It neither reacted with a solution of 2:4-dinitrophenylhydrazine in hydrochloric acid nor gave a colour with aqueous ferric chloride but when heated with aqueous silver nitrate it gave a precipitate of silver chloride.

2-Bromocycloheptatrienone, colourless leaflets of m. p. 117—119°, was prepared as in (b) (above) from tropolone (0.2 g.) and phosphorus tribromide (0.5 c.c.) in benzene (5 c.c.) (Found: C, 45.9; H, 2.5. C_7H_5OBr requires C, 45.4; H, 2.7%).

(2:3 or 2:7)-*Dichlorocycloheptatrienone.*— α -Bromotropolone (1 g.) and thionyl chloride (10 c.c.) in benzene (10 c.c.) were heated under reflux for 5 hours. After volatile liquids had been removed *in vacuo* the residual solid was sublimed at 80°/2 mm. and afforded the *dichloro*-compound as colourless needles, m. p. 129—130°, from light petroleum (b. p. 60—80°) (Found: C, 47.8; H, 2.2. $C_7H_4OCl_2$ requires C, 48.0; H, 2.3%).

Reactions of 2-Chlorocycloheptatrienone.—(i) 2-Chlorocycloheptatrienone and 3% aqueous sodium hydroxide were heated at 50—60° for 30 minutes. After acidification and extraction with ether, benzoic acid, m. p. and mixed m. p. 119—120°, was recovered. Benzoic acid was also obtained when the 2-chloro-compound was (a) boiled with water or (b) heated under reflux with methanol and the solution, which had the smell of methyl benzoate, was subsequently heated with aqueous acid.

(ii) 2-Chlorocycloheptatrienone was heated with concentrated aqueous ammonium chloride. After acidification, extraction with ether afforded material from which a small quantity of copper tropolone was isolated.

(iii) 2-Chlorocycloheptatrienone and a saturated solution of sodium methoxide in methanol

were heated in a sealed tube at 80° for 4 hours. Neutral material was recovered in ether and afforded tropolone methyl ether hemihydrate, m. p. and mixed m. p. 35—36°.

(iv) 2-Chlorocycloheptatrienone (0.2 g.) and a 10% solution (5 c.c.) of ammonia in methanol were heated at 100° for 4 hours. The solid, recovered from the solution, was sublimed at 80°/1 mm., affording 2-aminocycloheptatrienone as yellowish needles, m. p. 100—101°, from benzene-methanol (Found : C, 69.9; H, 5.8. Calc. for C_7H_7ON : C, 69.4; H, 5.8%).

(v) Ethanol solutions (2 c.c. each) of 2-chlorocycloheptatrienone (0.1 g.) and of thio-*p*-cresol (0.09 g.) with sodium hydroxide (0.03 g.) were mixed and heated to the b. p. The bright yellow precipitate, which was produced on cooling and dilution with water, afforded 2-*p*-tolylthiocycloheptatrienone as yellow needles, (micro-)m. p. 148°, from benzene-light petroleum (b. p. 60—80°) (Found : C, 73.7; H, 5.3. $C_{14}H_{12}OS$ requires C, 73.6; H, 5.3%).

(vi) A solution of the 2-chloro-compound (0.11 g.) in benzene (2 c.c.) was added to a suspension of aluminium chloride (0.2 g.) in benzene (2 c.c.). In separate experiments the mixture was kept below 10° for 16 hours or was heated under reflux for 1 hour. In each case 2-chlorocycloheptatrienone, m. p. and mixed m. p. 62—63°, was recovered from the washed and dried benzene solution.

Reactions of the Dichlorocycloheptatrienone (II) or (III).—(i) The dichloro-compound was heated with 3% aqueous alkali at 60° for 1 hour. *o*-Chlorobenzoic acid, m. p. and mixed m. p. 143—145°, was recovered from the acidified solution.

(ii) The dichloro-compound (0.3 g.), diethylamine (1 c.c.), and benzene (3 c.c.) were heated under reflux for 2 hours. The benzene solution, after being washed with dilute acid and then with water, was dried and concentrated, affording an orange-yellow residue. This, when heated in a sublimation tube at 80°/2 mm., gave a sublimate which afforded (?)-chloro-(?)-diethylaminocycloheptatrienone as orange prisms, (micro-)m. p. 56°, from benzene-light petroleum (b. p. 60—80°) (Found : C, 62.3; H, 6.7. $C_{11}H_{14}ONCl$ requires C, 62.4; H, 6.7%).

(iii) The dichloro-compound (0.1 g.), *p*-toluidine (0.5 g.), and xylene (10 c.c.) were heated under reflux for 30 minutes. The cooled solution, after being washed with dilute acid, was dried and evaporated and gave (?)-chloro-(?)-*p*-toluidinocycloheptatrienone as yellow needles, (micro-)m. p. 121°, from benzene (Found : C, 68.3; H, 4.8; N, 5.8. $C_{14}H_{12}ONCl$ requires C, 68.4; H, 4.9; N, 5.6%).

(iv) Ethanol solutions (2 c.c. each) of the dichloro-compound (0.1 g.) and thio-*p*-cresol (0.08 g.) with sodium hydroxide (0.02 g.) were mixed and heated to the b. p. The orange precipitate, which was produced on cooling and dilution with water, afforded (?)-chloro-(?)-*p*-tolylthiocycloheptatrienone as yellow needles, (micro-)m. p. 165°, from benzene-light petroleum (b. p. 60—80°) (Found : C, 64.1; H, 4.2. $C_{14}H_{11}OCIS$ requires C, 64.0; H, 4.2%).

(v) Experiment (iv) was repeated with twice the quantities of thio-*p*-cresol and sodium hydroxide. 2 : (3 or 7)-*Di-p*-tolylthiocycloheptatrienone was thereby obtained as dark-yellow crystals of m. p. 266°, from benzene (Found : C, 71.7; H, 5.4. $C_{21}H_{18}OS_2$ requires C, 72.0; H, 5.2%).

(vi) Attempted condensation of the dichloro-compound with benzene in presence of aluminium chloride (as described for the 2-chloro-compound) led to recovery of the dichloro-compound. Likewise, under reflux conditions, with *m*-xylene as hydrocarbon there resulted 70% recovery of the dichlorocycloheptatrienone but in this case chromatography on alumina afforded also a small quantity of unidentified orange-coloured prisms, m. p. 279—281°, from light petroleum (b. p. 40—60°).

Reactions of α -Bromotropolone.—(i) The sodium salt of α -bromotropolone (1 g.), thio-*p*-cresol (1 g.), and pyridine (10 c.c.) were heated under reflux for 1 hour. Precipitated sodium bromide was filtered off and the solvent was removed *in vacuo*, leaving a residue which afforded α -*p*-tolylthiotropolone as straw-coloured needles, m. p. 175°, from methanol (Found : C, 69.0; H, 5.2. $C_{14}H_{12}O_5S$ requires C, 68.9; H, 4.9%). The product was soluble in alkali, gave a brown colour with aqueous ferric chloride, and when treated as the sodium salt with Raney nickel in ethanol afforded tropolone, m. p. and mixed m. p. 49°, which was recovered by sublimation.

(ii) Fusion of α -bromotropolone (0.25 g.), potassium hydroxide (2 g.), and water (1 c.c.) in a nickel crucible at 300—310° for 25 minutes, followed by dissolution in dilute sulphuric acid and recovery from ether, gave a brown solid. This on sublimation afforded salicylic acid, m. p. and mixed m. p. 160°.

(iii) Sodium bromotropolone (0.5 g.) and 50% aqueous sodium hydroxide (5 c.c.) were heated under reflux for 15 hours. The acidified solution was extracted with ether in a continuous extractor, and the dried ethereal extract afforded a dark brown residue on evaporation. This was sublimed at 150°/1 mm. and the sublimate (0.05 g.) afforded α -hydroxytropolone, m. p. 244°.

(decomp.) as yellow crystals from benzene-methanol (Found: C, 60.6; H, 4.5; $C_7H_6O_3$ requires C, 60.85; H, 4.35%). The compound gave a brown colour with aqueous ferric chloride and when fused with alkali as in (ii) afforded salicylic acid, m. p. and mixed m. p. 160°.

(iv) A mixture of α -bromotropolone and copper powder was heated at 250° for 2 hours. Extraction with ether in presence of mineral acid gave (a) an ether-soluble fraction which was fractionally sublimed and afforded tropolone, subliming at 40°/1 mm., m. p. and mixed m. p. 49°, and (b) unchanged α -bromotropolone, subliming at 85°/1 mm., m. p. and mixed m. p. 103—105°.

(v) Sodium bromotropolone (4 g.), cuprous cyanide (5 g.), and pyridine (5 c.c.) were heated under reflux for 15 hours. A washed and dried ethereal extract of the cooled and acidified solution gave a solid on evaporation. The solid was sublimed at 130—150°(bath)/2 mm., affording α -cyanotropolone as yellow leaflets of m. p. 165° from benzene-methanol. Although the product melted sharply it was not obtained analytically pure. It (1 g.) was heated for 12 hours with 30% aqueous potassium hydroxide (5 c.c.). The acidified solution was extracted by ether in a continuous extractor, and a brownish solid was recovered. This solid, after sublimation at 140—160°(bath)/1—2 mm., formed yellow needles of *tropolone- α -carboxylic acid*, m. p. (decomp.) 212—213°, from benzene-methanol (Found: C, 58.0; H, 3.8. $C_8H_6O_4$ requires C, 57.85; H, 3.6%). When heated at 240—250° the acid gave a semi-solid sublimate from which tropolone, m. p. and mixed m. p. 49° [from light petroleum (b. p. 40—60°)], was isolated. Fusion of the carboxylic acid with potassium hydroxide, as described under (ii) of this section, afforded after sublimation phthalic anhydride, m. p. and mixed m. p. 130—131°, which was hydrolysed by hot water to phthalic acid, m. p. and mixed m. p. 228—231°.

(vi) α -Bromotropolone methyl ether (0.2 g.) (Cook, Gibb, Raphael, and Somerville, *J.*, 1951, 503) was heated with a 15% solution (5 c.c.) of dry ammonia in methanol at 110° for 8 hours. The residue obtained by removing the solvents was crystallised from light petroleum (b. p. 60—80°) and was then sublimed at 110°(bath)/1 mm. It formed a yellow powder and afforded an aminobromocycloheptatrienone as yellow needles, m. p. 140°, from benzene, but could not be prepared analytically pure (Found: C, 41.0; H, 3.0. Calc. for C_7H_6ONBr : C, 42.0; H, 3.0%).

Hydrogenolysis.—The following experiments—typical of others involving catalytic hydrogenation—indicate the occurrence of dehalogenation and desulphurisation although homogeneous products were not obtained.

(i) A solution of the dichloro-compound (0.1 g.) in ethanol (5 c.c.) containing Raney nickel (0.5 g.) in suspension was heated under reflux for 2 hours. The colourless oil, which was obtained on filtration and concentration, distilled at 70—80°/2 mm. (Found: C, 72.6; H, 10.4%).

(ii) Similar treatment of the chloro-*p*-tolylthiocycloheptatrienone (m. p. 165°) gave a colourless oil, b. p. 50—60°/2 mm. (Found: C, 80.7; H, 7.2%).

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