

416. *Synthesis and Reactions of Some Cyclohexadienones.*

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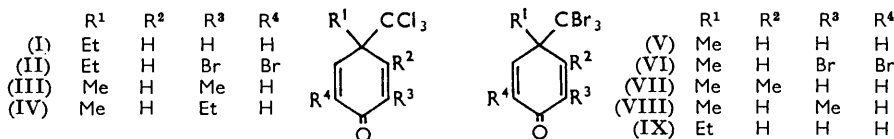
p-Cresols and 4-ethylphenols react with carbon tetrachloride and tetrabromide, to yield cyclohexadienones. The action of phosphorus pentachloride, phosphorus pentabromide, and polyphosphoric acid on the dienones has been studied.

THE recent work of Newman *et al.*¹ on the Zincke-Suhl reaction² of 2,4,5-trimethylphenol with carbon tetrachloride to yield a 4-methyl-4-trichloromethylcyclohexa-2,5-dienone prompts us to report some of our earlier work.³ It has been found that 4-ethylphenols behave similarly, and that both carbon tetrachloride and tetrabromide can be used.

The general method of preparation of the cyclohexadienones, from phenols and carbon tetrachloride or tetrabromide, consists in heating the components together in equimolecular proportions in carbon disulphide, in the presence of the corresponding anhydrous aluminium halide. With 4-ethylphenols, the dienones were usually oils which gave crystalline 2,4-dinitrophenylhydrazones. On treatment with concentrated sulphuric acid, the dienones decomposed, giving hydrogen chloride⁴ or bromide and a mixture of carboxylic acids.

It is interesting that when 2,6-di-*t*-butyl-*p*-cresol was treated with carbon tetrachloride or tetrabromide under the above conditions, the *t*-butyl groups were eliminated and 4-methyl-4-trihalogenomethylcyclohexa-2,5-dienones were obtained.

When the cyclohexadienone (I) was treated with phosphorus pentachloride, an acid was obtained which, on oxidation with permanganate, yielded 4-chlorophthalic acid. The acid could therefore be either 4- or 5-chloro-2-ethylbenzoic acid.



The dienone (III), with phosphorus pentachloride, gave a benzoic acid, m. p. 134—135°. Of the possible compounds for this, it cannot be 4-chloro-2,3-dimethyl- (m. p. 182°), 4-chloro-2,5-dimethyl- (m. p. 153°), 3-chloro-4,6-dimethyl- (lit.,¹ m. p. 165°), or 4-chloro-3,5-dimethyl-benzoic acid (lit.,⁵ m. p. 220°). A sample of the acid depressed the melting point of 2-chloro-3,5-dimethylbenzoic acid (128°) by 22°, and it is therefore assumed to be 3-chloro-2,6-dimethylbenzoic acid. The three of the above acids not previously known were synthesised by standard procedures from the known corresponding amines.⁶⁻⁸

The dienone (V) did not yield a definite product with phosphorus pentachloride. However, with phosphorus pentabromide, it afforded an acid which was oxidised to 4-bromophthalic acid,⁹ and which was shown to be 4-bromo-2-methylbenzoic acid by synthesis from *o*-toluidine as described by Nourrisson.¹⁰ Reaction of the dienone (V) with

¹ Newman, Pawellek, and Ramachandran, *J. Amer. Chem. Soc.*, 1962, **84**, 995, and references therein.

² Zincke and Suhl, *Ber.*, 1906, **39**, 4148.

³ Desai and Merchant, *Current Sci.*, 1960, **29**, 476.

⁴ Miller, *J. Org. Chem.*, 1962, **27**, 1549.

⁵ Fittig and Hoogewerff, *Annalen*, 1869, **150**, 325.

⁶ Hinckel, Collins, and Ayling, *J.*, 1923, **123**, 2972.

⁷ Wheeler and Morse, *J. Amer. Chem. Soc.*, 1924, **46**, 2573.

⁸ Klages, *Ber.*, 1896, **29**, 311; Adams, Weisel, and Mosher, *J. Amer. Chem. Soc.*, 1946, **68**, 883.

⁹ Stephens, *J. Amer. Chem. Soc.*, 1921, **43**, 1952.

¹⁰ Nourrisson, *Ber.*, 1887, **20**, 1016.

polyphosphoric acid gave 4-bromo-2-methylbenzoic acid and *p*-bromotoluene, the latter being identified by oxidation to *p*-bromobenzoic acid.¹¹ The reaction of (V) with phenylmagnesium bromide yielded small amounts of a solid of melting point 176—177°, which gave variable results on analysis. However, the reduction of (V) with lithium aluminium hydride gave the expected alcohol.

Treatment of the dienone (VII) with phosphorus pentabromide afforded 4-bromo-2-(2,2,2-tribromoethyl)toluene the structure of which was established as follows.¹² Oxidation of the bromoethyltoluene with permanganate yielded 4-bromophthalic acid,⁹ whilst sodium dichromate and sulphuric acid gave another acid which, from analytical data, appeared to be 4-bromo-2-(2,2,2-tribromoethyl)benzoic acid. Dehydrobromination of the bromoethyltoluene with sodium ethoxide afforded 2ββ-tribromo-4-methylstyrene which was oxidised to 5-bromo-2-methylbenzoic acid.¹³

With hexachloroethane, *p*-cresol did not react, and the reactants were recovered unchanged.

EXPERIMENTAL

Preparation of 4-Alkyl-4-trihalogenomethylcyclohexa-2,5-dienones.—Method A. The 4-alkylphenol (0.05 mole), in carbon disulphide (5 c.c.), was added to a stirred mixture of anhydrous aluminium halide (0.063 mole) in carbon disulphide (25 c.c.) during 10—15 min. The carbon tetrahalide (0.05 mole) (in the case of carbon tetrabromide, its solution in carbon disulphide) was added and the mixture heated in an oil-bath at 45° for 2 hr. The solvent was removed under reduced pressure and the mixture decomposed by addition of ice and concentrated hydrochloric acid. It was extracted with ether and the extract was washed with 10% sodium hydroxide and sodium chloride solution, dried (Na₂SO₄), and evaporated. The brown oily residue was steam-distilled to give the cyclohexadienone.

Method B. The reaction was carried out at 5—20° for 2 hr., and the product was isolated as in method A.

4-Ethyl-4-trichloromethylcyclohexa-2,5-dienone (I).—This was prepared by method A from *p*-ethylphenol¹⁴ and carbon tetrachloride, and was obtained as a yellow oil in 9.1% yield. Its *2,4-dinitrophenylhydrazone*, after several crystallisations from alcohol, had m. p. 170—171° (Found: C, 42.7; H, 2.9; N, 13.1. C₁₅H₁₃Cl₃N₄O₄ requires C, 42.8; H, 3.1; N, 13.3%).

Reaction of the Dienone (I) with Phosphorus Pentachloride.—A mixture of the dienone (I) (3 g.) and phosphorus pentachloride (2.7 g.) was gently warmed until a vigorous exothermic reaction commenced. After 30 min., the mixture was heated for 1 hr. under a vacuum on a steam-bath to remove the phosphorus oxychloride, and boiled with 10% sodium hydroxide until almost all the oil had gone into solution. Acidification with hydrochloric acid gave a compound which is either 4- or 5-chloro-2-ethylbenzoic acid, m. p. 157—158° (from water) (Found: C, 58.1; H, 5.1. C₉H₉ClO₂ requires C, 58.3; H, 4.8%).

A mixture of the acid (1 g.), potassium permanganate (3 g.), magnesium sulphate (2 g.), and water (53 c.c.) was refluxed for 7 hr. After cooling, sulphur dioxide was passed into the mixture and the whole extracted with ethyl acetate and washed well with sodium chloride solution. Removal of the solvent left 4-chlorophthalic acid, m. p. 150—151° (from water). Sublimation of this acid under a vacuum at 150° (oil-bath temperature) yielded 4-chlorophthalic anhydride,¹⁵ m. p. 96°.

2,6-Dibromo-4-ethyl-4-trichloromethylcyclohexa-2,5-dienone (II).—This was prepared by method A from 2,6-dibromo-4-ethylphenol¹⁶ and carbon tetrachloride in 6.5% yield; it was a yellow oil, b. p. 200—217°/10 mm. (Found: C, 26.9; H, 1.9. C₉H₇Br₂Cl₃O requires C, 27.1; H, 1.7%). It did not react with 2,4-dinitrophenylhydrazine.

2,4-Dimethyl-4-trichloromethylcyclohexa-2,5-dienone (III).—The dienone, prepared by method B from 2,4-dimethylphenol and carbon tetrachloride, was obtained (4%) as a yellow oil. It gave a *2,4-dinitrophenylhydrazone*, m. p. 167—168° (from acetic acid) (Found: C, 42.5; H, 3.3; N, 13.6. C₁₅H₁₃Cl₃N₄O₄ requires C, 42.8; H, 3.1; N, 13.3%).

¹¹ Hale and Thorp, *J. Amer. Chem. Soc.*, 1913, **35**, 269.

¹² Newman and Wood, *J. Amer. Chem. Soc.*, 1959, **81**, 6453.

¹³ Keuning and Evenhuis, *Rec. Trav. chim.*, 1935, **54**, 73.

¹⁴ Clemmensen, *Ber.*, 1914, **47**, 53.

¹⁵ Blicke and Smith, *J. Amer. Chem. Soc.*, 1929, **51**, 1866.

¹⁶ Baddeley and Plant, *J.*, 1943, 525.

Reaction of the Dienone (III) with Phosphorus Pentachloride.—A mixture of the dienone (3 g.) and phosphorus pentachloride (2.7 g.) was heated gently and the mixture was worked up as in the preparation of the 4- or 5-chloro-2-ethylbenzoic acid, to yield an acid, m. p. 134—135° (from water) (Found: C, 58.0; H, 4.9. $C_9H_9ClO_2$ requires C, 58.3; H, 4.8%), shown to be 3-chloro-2,6-dimethylbenzoic acid.

4-Chloro-2,3-dimethylbenzoic Acid.—4-Chloro-2,3-dimethylaniline⁶ (2 g.) was added to 50% hydrochloric acid (20 c.c.) and diazotised at 0°. Cuprous cyanide and potassium cyanide solution were added in the usual manner, and the mixture was steam-distilled, to yield the corresponding nitrile, m. p. 62° (from aqueous alcohol) (Found: C, 65.2; H, 5.0; N, 8.5. C_9H_8ClN requires C, 65.0; H, 4.82; N, 8.43%).

A mixture of the nitrile (2 g.), concentrated sulphuric acid (7.5 c.c.), and water (5 c.c.) was boiled for $\frac{1}{2}$ hr.¹⁷ After cooling, the mixture was treated with sodium hydrogen carbonate solution, filtered, and acidified, to give 4-chloro-2,3-dimethylbenzoic acid, m. p. 182—183° (from water) (Found: C, 58.2; H, 4.9. $C_9H_8ClO_2$ requires C, 58.3; H, 4.8%).

4-Chloro-2,5-dimethylbenzoic Acid.—4-Chloro-2,5-dimethylaniline⁷ (2 g.) was converted, as above, into the nitrile, m. p. 86—87° (from aqueous alcohol) (Found: C, 64.9; H, 5.1; N, 8.2%). The nitrile was then hydrolysed as above to yield 4-chloro-2,5-dimethylbenzoic acid, m. p. 153° (from water) (Found: C, 58.3; H, 4.7%).

2-Chloro-3,5-dimethylbenzoic Acid.—2-Chloro-3,5-dimethylaniline was treated as above to give the corresponding nitrile as a dark yellow steam-volatile oil (Found: N, 8.5. C_9H_8ClN requires N, 8.4%). The nitrile was hydrolysed with sulphuric acid as above to give 2-chloro-3,5-dimethylbenzoic acid, m. p. 128° (from aqueous methanol) (Found: C, 58.5; H, 4.5%), mixed m. p. with the acid obtained from reaction of phosphorus pentachloride with the dienone (III), 106°.

2-Ethyl-4-methyl-4-trichloromethylcyclohexa-2,5-dienone (IV).—This was obtained by method B, from 2-ethyl-4-methylphenol¹⁸ and carbon tetrachloride, as a dark yellow oil; 2,4-dinitrophenylhydrazone, m. p. 130—131° (from acetic acid) (Found: C, 43.8; H, 3.0; N, 12.7. $C_{16}H_{16}Cl_3N_4O_4$ requires C, 44.0; H, 3.2; N, 12.9%).

4-Methyl-4-tribromomethylcyclohexa-2,5-dienone (V).—*p*-Cresol and carbon tetrabromide reacted according to method A to give the dienone (V), m. p. 146—147°⁸ (from benzene—light petroleum; 2,4-dinitrophenylhydrazone, m. p. 187—188° (from acetic acid) (Found: N, 10.7. $C_{14}H_{11}Br_3N_4O_4$ requires N, 10.4%; oxime, m. p. 172—173° (from alcohol) (Found: N, 3.4. $C_8H_8Br_3NO$ requires N, 3.7%).

Reaction of the Dienone (V) with Phosphorus Pentabromide.—A mixture of the dienone (V) (9 g.) and phosphorus pentabromide (10.5 g.) was gently warmed and the reaction mixture worked up as before, to yield 4-bromo-2-methylbenzoic acid,¹⁰ m. p. (from water) and mixed m. p. 186°. A mixture of this acid (0.5 g.), potassium permanganate (4.0 g.), water (5 c.c.), and pyridine (7 c.c.) was heated on a steam-bath for 8 hr. After cooling and filtering, the reaction mixture was acidified, to give 4-bromophthalic acid,⁹ m. p. 168—169° (from water) (Found: C, 39.3; H, 2.3. Calc. for $C_8H_5BrO_4$: C, 39.2; H, 2.0%).

Reaction of the Dienone (V) with Polyphosphoric Acid.—A mixture of the dienone (V) (3.5 g.) and polyphosphoric acid (7.7 g.) was stirred for 5 hr. at 90—100° under dry nitrogen. The reaction mixture was decomposed with ice-cold water (50 c.c.), extracted with ether, and the ethereal solution washed with alkali and sodium chloride solution. Acidification of the alkaline extract gave 4-bromo-2-methylbenzoic acid,¹⁰ m. p. and mixed m. p. 186—187° (from water). Removal of the solvent from the dried (Na_2SO_4) extract left a small amount of *p*-bromotoluene, identified by oxidation with potassium permanganate to *p*-bromobenzoic acid,¹¹ m. p. 251—253° (from water) (Found: C, 41.8; H, 2.3. Calc. for $C_7H_5BrO_2$: C, 42.0; H, 2.5%).

4-Methyl-4-tribromomethylcyclohexa-2,5-dienol.—To a stirred suspension of lithium aluminium hydride (0.8 g.) in dry ether (100 c.c.) was added a solution of the dienone (V) (1 g.) in dry ether—benzene and the suspension was refluxed for 5 hr., decomposed with ice-cold 2% sulphuric acid, and worked up, to give the dienol, m. p. 187—188° (from benzene) (Found: C, 26.8; H, 2.7. $C_8H_9Br_3O$ requires C, 26.6; H, 2.5%).

2,6-Dibromo-4-methyl-4-tribromomethylcyclohexa-2,5-dienone (VI).—A mixture of 2,6-dibromo-*p*-cresol,¹⁹ anhydrous aluminium bromide, and carbon tetrabromide reacted according to

¹⁷ Fisher and Grant, *J. Amer. Chem. Soc.*, 1935, **57**, 718.

¹⁸ Auwers and Müller, *Annalen*, 1909, **364**, 165.

¹⁹ Thiele and Eichwede, *Annalen*, 1900, **311**, 374.

method A, and the brown gummy product was washed several times with ether, to yield the *dienone* (VI) (1.2 g.) m. p. 99—100° [from benzene-light petroleum (b. p. 40—60°)] (Found: C, 18.7; H, 1.1; Br, 77.2. $C_8H_5Br_3O$ requires C, 18.5; H, 0.9; Br, 77.5%). It did not react with 2,4-dinitrophenylhydrazine.

3,4-Dimethyl-4-tribromomethylcyclohexa-2,5-dienone (VII).—3,4-Dimethylphenol (6.18 g.), carbon tetrabromide (16.6 g.), and anhydrous aluminium bromide (16.8 g.) reacted together, in carbon disulphide (35 ml.), according to method B, to yield the *dienone* (VII), m. p. 125—126° [from benzene-light petroleum (b. p. 40—60°)] (Found: C, 29.0; H, 2.4; Br, 64.2. $C_9H_9Br_3O$ requires C, 28.9; H, 2.4; Br, 64.3%). The 2,4-dinitrophenylhydrazone had m. p. 182—183° (from dioxan-water) (Found: N, 9.7. $C_{15}H_{13}Br_3N_4O_4$ requires N, 10.0%).

Reaction of the Dienone (VII) with Phosphorus Pentabromide.—A mixture of (VII) (3 g.) and phosphorus pentabromide (3.5 g.) was shaken, set aside for 30 min., heated for 1 hr. under a vacuum on a steam-bath, poured into water, and extracted with ether. Removal of ether from the dried (Na_2SO_4) extract and distillation, gave an oil (80%), b. p. 105—115°/0.1 mm. (Found: Br, 73.1. $C_9H_9Br_4$ requires Br, 73.3%), assumed, by analogy with the results of Newman and Wood,¹² to be 4-bromo-2-(2,2,2-tribromoethyl)toluene.

A mixture of the oil (2 g.), potassium permanganate (8 g.), water (8 c.c.), and pyridine (25 c.c.) was heated on a steam-bath for 6 hr. More potassium permanganate (8 g.) was added and the heating continued for a further 6 hr. The reaction mixture was then worked up as usual, to yield 4-bromophthalic acid,⁹ m. p. 168—169° (from water) (Found: C, 38.4; H, 2.2. Calc. for $C_8H_5BrO_4$: C, 39.2; H, 2.0%). In another oxidation, the oil (0.67 g.) was heated for 12 hr. on a steam-bath with a solution of sodium dichromate (0.8 g.), concentrated sulphuric acid (1 c.c.), water (8 c.c.), and acetic acid (35 c.c.), to give 4-bromo-2-(2,2,2-tribromoethyl)-benzoic acid, m. p. 167—168° (Found: C, 23.4; H, 1.5. $C_9H_5Br_3O_2$ requires C, 23.1; H, 1.2%).

In a dehydrobromination experiment, a solution of sodium ethoxide (0.40 g.) in absolute ethanol (8 c.c.) was added to an alcoholic solution of the oil (6.2 g.), and set aside for 3 hr. Alcohol was then removed and the resultant oil distilled, to give a fraction, b. p. 62—65°/0.1 mm., assumed to be 4-bromo-2-(2-bromoethyl)toluene. Addition of a drop of this to alcoholic silver nitrate gave an immediate precipitate of silver bromide, and oxidation with alkaline permanganate, as above, yielded 4-bromophthalic acid. A second fraction of the oil distilled at 82—85°/0.1 mm. and was presumed to be 2 β -tribromo-4-methylstyrene. To a stirred solution of potassium permanganate (0.32 g.), in pyridine (1.5 c.c.) and water (2.5 c.c.), was added the above tribromostyrene (0.22 g.) in pyridine (2.5 c.c.). An exothermic reaction ensued and, after filtration and acidification, 5-bromo-2-methylbenzoic acid (0.040 g.) was obtained, m. p. and mixed m. p. 168—169° (from aqueous alcohol) (Found: C, 44.3; H, 3.4. Calc. for $C_8H_7BrO_2$: C, 44.6; H, 3.2%).

2,4-Dimethyl-4-tribromomethylcyclohexa-2,5-dienone (VIII).—This *dienone* was prepared by method B and had m. p. 116—117° [from light petroleum (b. p. 40—60°)] (Found: C, 28.6; H, 2.2; Br, 64.0. $C_9H_9Br_3O$ requires C, 28.9; H, 2.4; Br, 64.3%); 2,4-dinitrophenylhydrazone, m. p. 191° (from dilute acetic acid) (Found: N, 9.9. $C_{15}H_{13}Br_3N_4O_4$ requires N, 10.1%).

4-Ethyl-4-tribromomethylcyclohexa-2,5-dienone (IX).—A mixture of *p*-ethylphenol,¹⁴ carbon tetrabromide, and anhydrous aluminium bromide, in carbon disulphide, reacted according to method A, to yield the *dienone* (IX) as a yellow oil; 2,4-dinitrophenylhydrazone, m. p. 176° (from dioxan-water) (Found: C, 32.8; H, 2.0; N, 10.2. $C_{15}H_{13}Br_3N_4O_4$ requires C, 32.5; H, 2.3; N, 10.1%).

*Reaction of 2,6-Di-*t*-butyl-*p*-cresol with Carbon Tetrahalides.*—The reactions of 2,6-di-*t*-butyl-*p*-cresol with carbon tetrahalide, in the presence of the corresponding anhydrous aluminium halide, were carried out by methods A and B. Working up of the reaction mixture afforded the 4-methyl-4-trihalogenomethylcyclohexa-2,5-dienones, identified by mixed m. p.s.

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