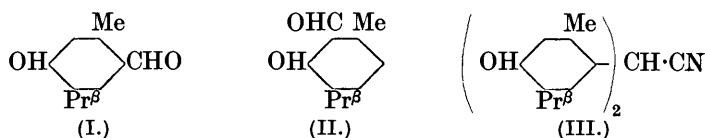


CCLXXXVIII.—*By-products of the Gattermann Aldehyde Reaction.*

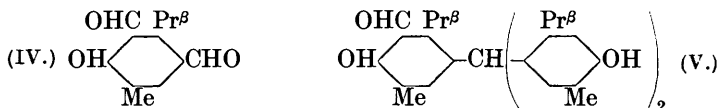
By FRANK BELL and THOMAS ANDERSON HENRY.

THE Gattermann synthesis of *p*-hydroxybenzaldehydes, depending on the primary production of an aldimine by the action of hydrocyanic acid on a phenol, has been the subject of a considerable number of modifications, mainly designed to avoid the use of anhydrous hydrocyanic acid. That due to Adams and Montgomery (*J. Amer. Chem. Soc.*, 1923, **45**, 2373; 1924, **46**, 1518) has been used in these laboratories (Henry and Sharp, *J.*, 1926, 2432), and the present paper gives an account of certain by-products isolated during the preparation of *p*-hydroxybenzaldehydes by this method.

Thymol is stated to give a quantitative yield of the corresponding *p*-aldehyde (I), but a trace of the *o*-aldehyde (II) is invariably formed, together with a small amount of *dithymylacetonitrile* (III).

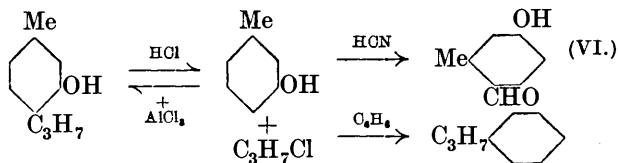


Carvacrol gives analogous products. Kobek (*Ber.*, 1883, **16**, 2104) isolated a small amount of carvacroldialdehyde (IV) when preparing



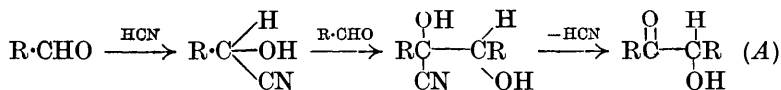
carvacrolaldehyde by the Reimer-Tiemann process, and the formation of this dialdehyde in the Gattermann reaction is now

shown by the isolation of its condensation product (V) with carvacrol. In some experiments with thymol, *isopropylbenzene* and *m*-cresol-aldehyde (VI) (*o*-cresolaldehyde in the case of carvacrol) were isolated, the amounts of these compounds being greatest when the yield of aldehyde was least. This result was traced to the fact that under the conditions of aldehyde formation it is possible to convert thymol almost completely into *m*-cresol and *isopropylbenzene*



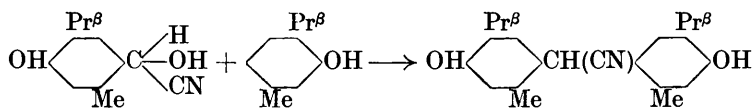
when no hydrocyanic acid is present, thus providing a further example of the reversibility of the Friedel-Crafts synthesis (compare Jacobsen, *Ber.*, 1885, **18**, 339). The possibility of utilising this reaction to introduce the *isopropyl* group into compounds dissolved in non-reactive solvents, *e.g.*, ether, xylene, or *p*-cymene, still awaits examination. A recent paper (Berry and Reid, *J. Amer. Chem. Soc.*, 1927, **49**, 3142) describes the transfer of an *isopropyl* group from *diisopropylbenzene* into naphthalene.

The conditions of the formation of substituted acetonitriles, such as dithymylacetonitrile (III), have been examined. It is well known that aromatic aldehydes show very varying behaviour on treatment with potassium cyanide in aqueous-alcoholic solution. One group, which includes benzaldehyde, *p*-chlorobenzaldehyde (Hantzsch and Glover, *Ber.*, 1907, **40**, 1519), and *o*-methoxybenzaldehyde (Irvine, *J.*, 1901, **79**, 670), readily yields the corresponding benzoin, whereas *o*- and *p*-hydroxybenzaldehydes undergo resinification, and in still other cases, *e.g.*, *o*-nitrobenzaldehyde (Ekecrantz and Ahlqvist, *Ber.*, 1908, **41**, 878; 1910, **43**, 2606), a variety of products other than the benzoin is obtained. There is little doubt of the correctness of Lapworth's theory of the benzoin change (*J.*, 1903, **83**, 995; compare Greene and Robinson, *J.*, 1922, **121**, 2182), according to which the aldehyde, R·CHO, first adds on hydrogen cyanide, then combines with a further molecule of aldehyde, and finally eliminates hydrogen cyanide as in (A). It seemed possible that the cyanohydrin phase in the condensation might be detected in the case of

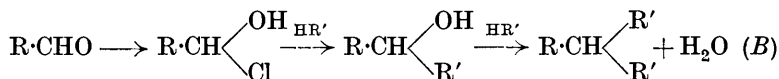


even the hydroxybenzaldehydes, if some substance were present in the solution with which the cyanohydrin might react to form a

stable product. Accordingly mixtures of hydroxybenzaldehydes with the corresponding phenols were warmed with potassium cyanide. In one case only was crystalline material isolated, thymolaldehyde and thymol giving a 12% yield of dithymylacetonitrile.



It might be anticipated that the yield of the nitrile would be considerably increased if the potassium cyanide were replaced by hydrogen cyanide. With this end in view hydrogen chloride was passed into a dry benzene solution of, *e.g.*, thymolaldehyde and thymol containing zinc cyanide in suspension. Only derivatives of triphenylmethane were obtained, and this result is interpreted as indicating that cyanohydrins are not formed under these experimental conditions. The readiness of condensation suggests that the hydrogen chloride forms an intermediate addition product with the aldehyde as shown in (B). If, however, an alcoholic



solution of equimolecular quantities of the aldehyde and phenol is treated with hydrogen cyanide and the mixture is heated to the boiling point after the addition of zinc chloride, three types of behaviour are shown.

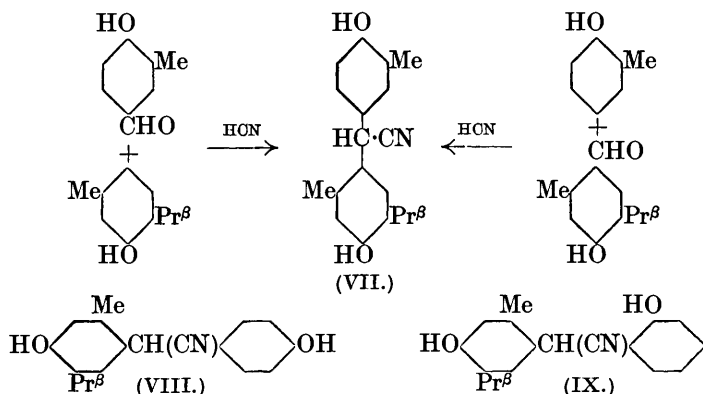
TABLE I.

(Behaviour of substituted benzaldehydes; CHO in position 1.)

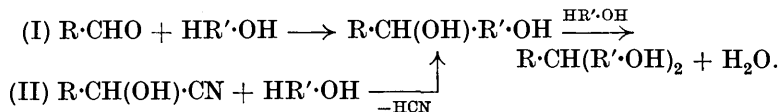
A	B	C
(produce nitriles).	(produce triphenylmethane derivatives).	(unreactive).
Me : Pr <sup>β</sup> : OH = 2 : 5 : 4	Benzaldehyde.	NO <sub>2</sub> = 2
Me : Pr <sup>β</sup> : OH = 5 : 2 : 4	Cl = 2 or 4	
Me : OH = 3 : 4	NO <sub>2</sub> = 3 or 4	
OH = 2 or 4	HO = 3	
OH : OH = 3 : 4		
OMe = 4		

(1) The aldehydes in column A (Table I) give the corresponding diarylacetonitriles, in some cases in quantitative yields. That it is the nuclear hydrogen atom para to the hydroxyl group in the phenol, which is involved in this condensation is clear from the fact that *o*-cresolaldehyde and thymol give the same product (VII) as thymolaldehyde and *o*-cresol. Even when the *o*- and *p*-positions are both equally accessible, as in phenol, condensation takes place

almost exclusively in the *p*-position, the product then formed being (VIII), and the isomeride (IX) could not be detected.

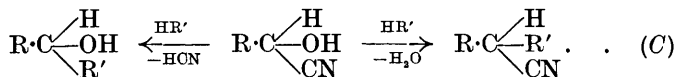


(2) On the other hand, benzaldehyde itself and its derivatives shown in column B (Table I) give triphenylmethane derivatives, and since the yield of these substances greatly exceeds that obtained when hydrogen cyanide is absent, it seems likely that reaction (II) is in operation in place of, or in addition to, reaction (I) :—



*o*-Nitrobenzaldehyde is unique in so far as it is isolated from the reaction mixture in the form of its cyanohydrin, which is apparently very unreactive.

This variety of results is all the more remarkable since mandelic acid and mandelonitrile condense normally with a whole series of phenols (Bistrzycki and Flatau, *Ber.*, 1895, **28**, 989; 1897, **30**, 124; Bistrzycki and Simonis, *Ber.*, 1898, **31**, 2812; Cramer, *ibid.*, p. 2813; Simonis, *ibid.*, p. 2821). Considerable further investigation is required to determine the influence of (*a*) substituents and (*b*) physical conditions, *e.g.*, acidity of the solution, on the relative reactivity of the hydroxyl and cyano-groups of cyanohydrins. We have little doubt that the triphenylmethane formation indicates cyano-group reactivity, the intermediate diphenylmethane derivative undergoing further condensation under the experimental conditions, whereas nitrile formation indicates hydroxyl group reactivity (*C*).



The fact that the substituted nitriles do not undergo further con-

densation to triphenylmethane derivatives is only in line with the diminished reactivity of the cyano-group which is shown by its resistance to hydrolytic agents. It appears that the hydroxyl group by virtue of its lone pairs of electrons is a more ready electron source than the cyano-group and that when the nucleus of a cyanohydrin has a positive character the hydroxyl group will tend to become, relative to the cyano-group, less negative, and at the same time less reactive.

#### EXPERIMENTAL.

*Thymolaldehydes and By-products.*—Into an ice-cold, well-stirred mixture of thymol (50 g.), zinc cyanide (100 g.), and benzene (200 c.c.; distilled from phosphoric oxide), was passed a rapid stream of dry hydrogen chloride until it ceased to be absorbed. Aluminium chloride (75 g.) was then added and the stirring continued for 4 hours in a slow current of hydrogen chloride. Towards the end, the reaction bottle was kept immersed in water at about 50°. The semi-solid product was transferred into 10% hydrochloric acid and distilled in steam until thymolaldehyde appeared in the condenser. The residue left on the removal of the solvent from the benzene layer of the steam distillate was distilled in three fractions; the residue in the flask then set solid and proved to be *p*-thymolaldehyde (I). The first fraction, b. p. 60—80°/15 mm., consists mainly of *isopropylbenzene* and is occasionally negligible in amount (see below). The second (b. p. 100—110°/15 mm.) and third (b. p. 110—120°/15 mm.) fractions were dissolved in alcohol and treated with aqueous-alcoholic semicarbazide solution. The precipitate immediately given with fraction 2, after repeated extraction with boiling alcohol, formed a white powder, m. p. 262° (decomp.), which was identified as *m*-cresolaldehyde semicarbazone (Found: C, 55.1; H, 5.6; N, 21.3. Calc.: C, 56.0; H, 5.7; N, 21.8%) by hydrolysis in the following manner: A mixture of the substance (3 g.), sulphuric acid (10 c.c.), and water (50 c.c.) was heated to boiling and the resultant *m*-cresolaldehyde (VI) removed in a current of steam. It crystallised from petroleum in long needles, m. p. 63° (Found: C, 70.4, 70.3; H, 5.8, 6.0. Calc.: C, 70.6; H, 5.9%).

In the case of fraction 3 acicular crystals gradually separated and after repeated crystallisation from alcohol had m. p. 198° (Found: C, 61.5; H, 7.2; Sem., 31.4%). The semicarbazide group (Sem. = N·NH·CO·NH<sub>2</sub>) was estimated by the method of Veibel (*Bull. Soc. chim.*, 1927, **41**, 1410). This compound can only be the *semicarbazone* of 2-aldehydo-3-methyl-6-*isopropylphenol* (*o*-thymolaldehyde) (II) (C<sub>12</sub>H<sub>17</sub>O<sub>2</sub>N<sub>3</sub>) requires C, 61.3; H, 7.2; Sem., 31.1%).

The residue left after steam distillation was extracted with ether, and the extract evaporated. Two methods of purifying the crude

*p*-aldehyde (about 50 g.; identical with the yield obtained by Gattermann's original method, *Ber.*, 1898, **31**, 1765) were adopted : (1) extraction with 25% alcohol, a small crystalline residue, m. p. 205°, being finally obtained; (2) crystallisation from alcohol, the final low-melting crops being dissolved in chloroform and filtered from a small amount of the same substance, m. p. 205°, subsequently shown to be dithymylacetonitrile (see p. 2224). 4-Aldehydo-3-methyl-6-isopropylphenol (I) forms colourless needles, m. p. 135°; when aqueous-alcoholic semicarbazide solution is added to its alcoholic solution the slightly impure *semicarbazone* separates in deep yellow needles, m. p. 222° (Found : C, 60.6, 60.7; H, 7.3, 7.3%), which rapidly become colourless on recrystallisation from acetic acid or alcohol and melt at 226° (Found : C, 61.2; H, 7.3; Sem., 30.5.  $C_{12}H_{17}O_2N_3$  requires C, 61.3; H, 7.2; Sem., 31.1%).

Attempts to convert *p*-thymolaldehyde into the corresponding dialdehyde by (a) the Adams and Montgomery method, (b) the Gattermann method were unsuccessful. This failure is not surprising in view of the highly substituted character of the ring, and also of the disinclination of hydrogen cyanide to attack the position ortho to a hydroxyl group. It may be mentioned that even *p*-cresol gives a very small yield of the aldehyde when submitted to the same treatment as produces a satisfactory yield from *o*-cresol (see below).

*Action of Aluminium Chloride on Thymol.*—As it was surmised that the formation of isopropylbenzene in the reaction just described was due to interaction of thymol and benzene in presence of aluminium chloride, a well-stirred mixture of thymol (25 g.), dry benzene (200 c.c.), and aluminium chloride (35 g.) was warmed at about 50° for 4 hours while a current of dry hydrogen chloride was passed in. The clear solution was poured into 10% hydrochloric acid and distilled in steam. The benzene layer of the steam distillate was separated and evaporated and the residue obtained was distilled in a vacuum, giving fractions b. p. 60°, 95—100°, 100—118°, and ca. 170°/15 mm. The low-boiling fraction (about 10 g.) was redistilled under ordinary pressure, and the fraction, b. p. 150—155°, redistilled from sodium. It then boiled constantly at 153° and agreed in properties with isopropylbenzene (Found : C, 90.3; H, 9.9. Calc. : C, 90.0; H, 10.0%). The fraction, b. p. 95—100°/15 mm., gave pure *m*-cresol, b. p. 200—202° (6 g.), which was identified as its *p*-nitrobenzoyl derivative. The higher-boiling fraction consisted of neutral substances, being apparently a mixture of *m*-tolyl ether and thymyl ether. When the above reaction was carried out in the presence of toluene a fraction, b. p. 65—75°/15 mm., was obtained which on redistillation had b. p. 175—180°, being slightly impure *p*-cymene.

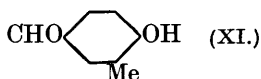
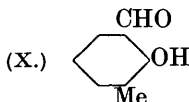
*Carvacrolaldehydes and By-products.*—The preparation was effected as described for thymolaldehyde (see above). The steam distillate gave fractions, b. p. 60°, 100—110°, 110—120°, and 120—130°/15 mm., and a residue of the *p*-aldehyde, which could be sublimed at 150°/1 mm. The first fraction consisted of *isopropylbenzene* (see below). The remaining fractions were dissolved separately in alcohol and treated with aqueous-alcoholic semicarbazide solution. The fraction, b. p. 100—110°/15 mm., gave crude *o*-cresolaldehyde semicarbazone (compare thymol above), and from the fraction, b. p. 110—120°/15 mm., was isolated a trace of material which crystallised from pyridine or acetic acid in thick, pale yellow prisms, m. p. 275° (Found: C, 73·2; H, 7·9; N, 7·8%). It is suggested that this compound is the *semicarbazone* of 4-hydroxy-3-aldehydo-5-methyl-2-*isopropylphenyldicarvacrylmethane* (V) (C<sub>33</sub>H<sub>43</sub>O<sub>4</sub>N<sub>3</sub> requires C, 72·7; H, 7·9; N, 7·7%) formed by the interaction of carvacrol and carvacroldialdehyde during the distillation. The fourth fraction, b. p. 120—130°/15 mm., gave more soluble material, which crystallised from aqueous alcohol in long glistening needles, m. p. 180° (Found: C, 61·3; H, 7·3; Sem., 31·5%), and must be the *semicarbazone* of 2-aldehydo-6-methyl-3-*isopropylphenol* (*o*-carvacrolaldehyde semicarbazone) (C<sub>12</sub>H<sub>17</sub>O<sub>2</sub>N<sub>3</sub> requires C, 61·3; H, 7·2; Sem., 31·1%).

The ether-soluble portion of the residue left after steam distillation was repeatedly extracted by decantation with petroleum (b. p. 90—120°), which slowly removed the *p*-carvacrolaldehyde (30—40 g.) as colourless plates, m. p. 102°. With aqueous-alcoholic semicarbazide solution this yielded a slightly impure, deep yellow *semicarbazone*, m. p. 222° (Found: C, 60·8; H, 7·3%), which on crystallisation from acetic acid gave colourless needles, m. p. 224° (Found: Sem., 31·1. C<sub>12</sub>H<sub>17</sub>O<sub>2</sub>N<sub>3</sub> requires C, 61·3; H, 7·2; Sem., 31·1%). The tar which remained after the complete removal of this aldehyde was moistened with alcohol and kept for several weeks. Crystals slowly formed, which after recrystallisation from aqueous alcohol had m. p. 240° and were subsequently shown to consist of dicarvacrylacetonitrile (see p. 2223).

*Action of Aluminium Chloride on Carvacrol* (compare corresponding experiment with thymol, p. 2220).—Fractions, b. p. 60° (11 g.), 100° (11 g.), and 102—115°/15 mm. (5 g.) were obtained. The residue, after being heated to 150°/1 mm., crystallised from petroleum in long thick needles, m. p. 148—150° (0·3 g.) (Found: C, 83·3, 83·7; H, 8·5, 8·8%). This substance was not obtained in sufficient quantity for identification. The low-boiling fraction was almost pure *isopropylbenzene*, and the intermediate fraction gave *o*-cresol, b. p. 188—190° (7 g.), identified as the *p*-nitrobenzoate.

*Reimer-Tiemann Reaction with Carvacrol.*—Carvacrol (20 g.), sodium hydroxide (40 g.), water (300 c.c.), and chloroform (25 g.) were used. The reaction mixture was acidified and distilled in steam. The distillate consisted of unchanged carvacrol and the *o*-aldehyde, isolated only as its semicarbazone (see above). The residue was purified as described above and gave a very small yield of the *p*-aldehyde, identical with that described above.

*o-Cresolaldehydes.*—Preparation as above, *o*-cresol (50 g.) being used in place of thymol. The steam distillate, freed from solvent, boiled at 85—90°/15 mm. (15 g.), leaving only a small residue of the *p*-aldehyde. To a solution of the fraction, b. p. 85—90°/15 mm., in alcohol (15 c.c.) was added aqueous-alcoholic semicarbazide solution. The resultant precipitate (3 g.) was repeatedly extracted with boiling alcohol; the residue then remained unchanged in m. p. (248°, decomp.) by crystallisation from pyridine, from which it separated in glistening needles. It was identified as the *semicarbazone* of 6-aldehydo-2-methylphenol (X) (Found: C, 55·5;



H, 5·8; N, 21·6; Sem., 38·5.  $C_9H_{11}O_2N_3$  requires C, 56·0; H, 5·7; N, 21·8; Sem., 37·8%), by hydrolysis to the corresponding aldehyde, which was then converted into the known phenylhydrazone.

The ether-soluble portion of the residue left after steam distillation was extracted with boiling water until all the *p*-aldehyde (XI) (about 20 g.) had been removed, leaving an uncrystallisable tar. The *p*-aldehyde gave a *semicarbazone* crystallising from acetic acid in needles, m. p. 216° (Found: N, 21·8; Sem., 37·2.  $C_9H_{11}O_2N_3$  requires N, 21·8; Sem., 37·8%).

*Action of Potassium Cyanide on Hydroxybenzaldehydes.*—(1) No crystalline material could be isolated from the gums obtained by the action of potassium cyanide on alcoholic solutions of salicylaldehyde, *p*-hydroxybenzaldehyde, or carvacrolaldehyde, either alone or when mixed with phenol or carvacrol respectively.

(2) Nine mixtures of thymolaldehyde, alone and with thymol, potassium cyanide and aqueous alcohol were heated under reflux for varying periods. In only one experiment (*a*) in which thymol was omitted was any yield of substance, m. p. 205°, obtained, and experiment (*b*) furnished the highest yield of the series.

(*a*) Thymolaldehyde (3·6 g.), alcohol (6 c.c.), potassium cyanide (1 g.), and water (2 c.c.) were mixed and heated at 100° for 1 hour. After 2 days the mixture was made acid and left for 10 days. The resultant tar was filtered off, and the residual solid crystallised from



alcohol. Yield, 0.25 g.; m. p. 205°. As this experiment could not be repeated, it is assumed that the thymolaldehyde used in the first instance must have contained thymol.

(b) Thymolaldehyde (18 g.), alcohol (60 c.c.), thymol (12 g.), potassium cyanide (6 g.), and water (12 c.c.) were mixed and heated at 100° for 20 hours. After 2 days concentrated hydrochloric acid (10 c.c.) was added, and after 2 days more the mixture was poured into water and extracted with ether. The ethereal extract was evaporated, and the dried residue extracted with hot chloroform. The insoluble matter (4.0 g.) had m. p. 205° (see below).

Thymolaldehyde and benzonitrile underwent no interaction when a concentrated alcoholic solution was boiled under reflux or allowed to stand for some days. In the hope of obtaining the compounds in better yields, the following experiments were tried. (1) Thymolaldehyde (10 g.), thymol (20 g.), zinc cyanide (20 g.), and dry benzene (200 c.c.) were well stirred while a slow stream of dry hydrogen chloride was passed in. The mixture was maintained at 40–60° for the last 2 hours. The highly coloured, viscous mass was transferred into 10% hydrochloric acid by the aid of a small bulk of boiling alcohol, and then distilled in steam. The tarry residue was extracted with ether, the extract evaporated, and the dried mass boiled with chloroform. The colourless residue (15 g., m. p. 276°) after crystallisation from aqueous alcohol formed prisms, m. p. 280° (Found: C, 80.2; H, 8.6%). This substance must be *trithymylmethane* (C<sub>31</sub>H<sub>40</sub>O<sub>3</sub> requires C, 80.8; H, 8.7%), a conclusion which was confirmed by the preparation of the acetyl derivative. The compound (2.5 g.) and acetic anhydride (15 c.c.) were heated under reflux for 2 hours. On cooling, the liquid filled with crystals of *triacetylthymylmethane*, which after recrystallisation from benzene-petroleum formed glistening leaflets, m. p. 186° (Found: Ac, 22.0. C<sub>37</sub>H<sub>46</sub>O<sub>6</sub> requires Ac, 22.0%).

(2) Carvacrolaldehyde (10 g.) and carvacrol (25 c.c.), treated as in (1), gave *tricarvacrylmethane*, m. p. 275° (Found: C, 80.8; H, 8.8%). The compound was acetylated as described above and yielded *triacetylcarvacrylmethane*, which after crystallisation from petroleum formed leaflets, m. p. 185° (Found: C, 76.1; H, 8.1. C<sub>37</sub>H<sub>46</sub>O<sub>6</sub> requires C, 75.8; H, 7.9%). Both compounds gave the customary large depression in melting point when mixed with the corresponding derivatives of thymol.

Little condensation occurs if the zinc cyanide is omitted in these experiments. Moreover the yield of triphenylmethane derivatives is considerably greater than when the experiment is conducted in alcoholic solution with hydrogen chloride or zinc chloride as condensing agent.

*Action of Hydrogen Cyanide on Substituted Benzaldehydes.*—*General method.* Dry hydrogen cyanide from potassium ferrocyanide (70 g.; method of Johnson and Lane, *J. Amer. Chem. Soc.*, 1921, **43**, 357) was passed into a solution of equimolecular proportions of the aldehyde (10 g.) and the phenol in absolute alcohol (50—100 c.c.). Zinc chloride (20—25 g.) was then added, the mixture boiled for 2 hours, and the solution poured into 10% hydrochloric acid. Excess of the reagents was removed in a current of steam, and the residual solid or plastic mass filtered off.

(1) Thymolaldehyde and thymol combined to give a quantitative yield of *dithymylacetonitrile*, which after recrystallisation from alcohol formed prismatic needles, m. p. 205° (Found: C, 78·4; H, 8·2, 8·1; N, 4·3, 4·2.  $C_{22}H_{27}O_2N$  requires C, 78·3; H, 8·0; N, 4·1%). No combination occurred when the zinc chloride was omitted.

Dithymylacetonitrile was not attacked by boiling hydrochloric acid or by sulphuric acid (50—65%), and higher concentrations produced resinous masses (compare Michael and Jeanprêtre, *Ber.*, 1892, **25**, 1615). Hydrolytic experiments with 3% hydrogen peroxide (Radziszewski, *Ber.*, 1885, **18**, 355) or 100% phosphoric acid (Berger and Olivier, *Rec. trav. chim.*, 1927, **46**, 600) were also unsuccessful. The substance (5 g.) was heated at 100° with potassium hydroxide (20 g.) in 90% alcohol (100 c.c.) for 10 hours. After standing 2 days, the solution was poured into 10% hydrochloric acid and the precipitated *dithymylacetamide* crystallised from alcohol. It formed a colourless, heavy crystalline powder, m. p. 243° (decomp.) (Found: C, 73·8; H, 8·2.  $C_{22}H_{29}O_3N$  requires C, 74·4; H, 8·2%). *Diacetylthymylacetonitrile*, formed by heating dithymylacetonitrile (3 g.) with acetic anhydride (15 c.c.) and recrystallising the product from chloroform—petroleum, formed needles, m. p. 174° (Found: C, 74·3, 74·1; H, 7·5, 7·5; Ac, 20·4.  $C_{26}H_{31}O_4N$  requires C, 74·1; H, 7·4; Ac, 20·4%). On hydrolysis with dilute alcoholic potassium hydroxide it regenerated dithymylacetonitrile, m. p. 205°.

(2) Carvacrolaldehyde and carvacrol, treated in like manner, gave a quantitative yield of *dicarvacrylacetonitrile*, which crystallised from aqueous alcohol in prisms, m. p. 240° (Found: C, 78·3; H, 8·2; N, 3·7.  $C_{22}H_{27}O_2N$  requires C, 78·3; H, 8·0; N, 4·1%). *Di-acetylcarvacrylacetonitrile* crystallised from alcohol in colourless needles, m. p. 196° (Found: C, 74·0; H, 7·6; N, 3·5.  $C_{26}H_{31}O_4N$  requires C, 74·1; H, 7·4; N, 3·3%).

(3) Thymolaldehyde and carvacrol, or carvacrolaldehyde and thymol, gave *thymylcarvacrylacetonitrile*, which formed prisms, m. p. 227°, from alcohol (Found: C, 78·1; H, 8·3.  $C_{22}H_{27}O_2N$  requires C, 78·3; H, 8·0%). It yielded a *diacetyl* derivative, m. p.

145° (Found: C, 73.7; H, 7.4.  $C_{26}H_{31}O_4N$  requires C, 74.1; H, 7.4%).

(4) *o*-Cresolaldehyde and thymol, or thymolaldehyde and *o*-cresol, gave *tolylthymylacetoneitrile* (VII), the first pair giving a quantitative and the second a 70% yield. It crystallised from aqueous alcohol in prisms, m. p. 153° (loss in weight on drying at 100° = 10.4%) (Found for dry substance: C, 77.1; H, 7.3.  $C_{19}H_{21}O_2N$  requires C, 77.3, H, 7.1%). The substance (5 g.) was warmed with potassium hydroxide (20 g.) in 90% alcohol (100 c.c.) at 100° for 24 hours. The solution was poured into 10% hydrochloric acid and extracted with ether. The ethereal extract was shaken with dilute sodium carbonate solution, and the aqueous and ethereal layers were separated and well washed with ether and water respectively. The ethereal layer was evaporated, and the dried residue extracted with hot benzene. The residual *tolylthymylacetamide* crystallised from alcohol in prisms, m. p. 211° (Found: C, 72.6; H, 7.4; N, 4.7.  $C_{19}H_{23}O_3N$  requires C, 72.9; H, 7.3; N, 4.5%). The aqueous layer was poured into 10% hydrochloric acid, and the resulting gum dried in a vacuum desiccator. After boiling with benzene, it formed a pale brown powder, m. p. 188°. It was free from nitrogen and must be crude *tolylthymylacetic acid* (Found: C, 71.2, 71.6, 71.2; H, 7.1, 7.2, 6.9.  $C_{19}H_{22}O_4$  requires C, 72.6; H, 7.0%). *Acetyltolylacetylthymylacetoneitrile* forms prisms, m. p. 131° (Found: Ac, 23.3.  $C_{23}H_{25}O_4N$  requires Ac, 22.7%).

(5) *p*-Hydroxybenzaldehyde and thymol gave a brown resinous mass, which crystallised from chloroform in needles, m. p. 142°. Recrystallised from benzene, *p*-hydroxyphenylthymylacetoneitrile (VIII) formed large prisms, which on drying at 110° lost 12.6% by weight and left a residue, m. p. 144° (Found: C, 76.3; H, 6.8.  $C_{18}H_{19}O_2N$  requires C, 76.8; H, 6.8%). Phenol and thymolaldehyde gave an 80% yield of the same substance.

(6) Anisaldehyde (*p*-methoxybenzaldehyde) and thymol gave a thick oil, which was extracted with ether. The gum remaining after evaporation of the ether was dissolved in chloroform. After some days crystals separated, which were well washed with petroleum and repeatedly recrystallised from benzene, pure *anisylthymylacetoneitrile* being obtained in 10% yield. It formed large prisms, m. p. 106° (Found: C, 77.6; H, 7.2.  $C_{19}H_{21}O_2N$  requires C, 77.3; H, 7.1%).

(7) Salicylaldehyde and thymol gave a resin, which crystallised from chloroform in prisms, m. p. 142°, and when dried at 110° lost 18.9% by weight (Found, for dry substance: C, 76.6; H, 6.9.  $C_{18}H_{19}O_2N$  requires C, 76.8; H, 6.8%). The yield of purified *o*-hydroxyphenylthymylacetoneitrile (IX) was less than 50% of the theoretical.

(8) Protocatechualdehyde and thymol gave a gummy mass, which was extracted with benzene, and the product repeatedly crystallised from chloroform. *Catechylthymylacetoneitrile* formed prisms, m. p. 147—149° (Found: N, 4.7.  $C_{18}H_{19}O_3N$  requires N, 4.7%).

(9) Benzaldehyde and thymol gave a quantitative yield of phenyldithymylmethane, which crystallised in prisms, m. p. 167—168°, containing one molecule of alcohol (loss in weight at 110° = 10.5%; calc., 11%). This description agrees with that of Russanow (*Ber.*, 1889, 22, 1947).

(10) *m*-Hydroxybenzaldehyde and thymol gave a poor yield of *m*-hydroxyphenyldithymylmethane, which crystallised from chloroform in prisms, m. p. 165° (Found: C, 80.5; H, 8.1.  $C_{27}H_{32}O_3$  requires C, 80.2, H, 7.9%).

(11) *o*-Nitrobenzaldehyde and thymol gave a product, which crystallised from chloroform in needles, m. p. 95—97°, and proved to be *o*-nitrobenzaldehydecyanohydrin (Found: C, 54.1; H, 3.5. Calc.: C, 53.9%; H, 3.4%). The fact that this cyanohydrin survives the general method of treatment (see above) is remarkable. No different result was obtained when phenol was used in place of thymol.

(12) *m*-Nitrobenzaldehyde and thymol gave an almost quantitative yield of *m*-nitrophenyldithymylmethane, which crystallised readily from aqueous alcohol in prisms, m. p. 171° (Found: C, 74.7; H, 7.2.  $C_{27}H_{31}O_4N$  requires C, 74.8; H, 7.2%).

(13) *p*-Nitrobenzaldehyde and thymol gave a tarry mass; this after several recrystallisations from benzene formed colourless needles, which became pale yellow on drying and then melted at 145° (loss in weight on drying, 20.9.  $C_{27}H_{31}O_4N, 1\frac{1}{2}C_6H_6$  requires loss, 21.2%) (Found for the residual *p*-nitrophenyldithymylmethane: C, 75.0; H, 7.2.  $C_{27}H_{31}O_4N$  requires C, 74.8; H, 7.2%). The mother-liquor contained *p*-nitrobenzaldehydecyanohydrin.

(14) *p*-Chlorobenzaldehyde and thymol gave a quantitative yield of *p*-chlorophenyldithymylmethane, which crystallised from alcohol in prisms; these, dried at 110°, lost 15.0% by weight, and the residue melted at 156° (Found: C, 76.4; H, 7.3.  $C_{27}H_{31}O_2Cl$  requires C, 76.7; H, 7.3%).

(15) *o*-Chlorobenzaldehyde and thymol gave a viscid mass, which, however, readily crystallised from aqueous alcohol to give an almost theoretical yield of *o*-chlorophenyldithymylmethane. Dried at 110°, this lost 16.6% by weight, and the residue melted at 138° (Found: C, 76.4; H, 7.2.  $C_{27}H_{31}O_2Cl$  requires C, 76.7; H, 7.3%).

Since it might be suggested that when triphenylmethane formation occurs, combination takes place between the aldehyde and the

phenol before the hydrogen cyanide is introduced, the experiments with *m*-nitro- and *o*- and *p*-chloro-benzaldehydes were repeated, the thymol not being added until after the passage of the hydrogen cyanide. The experimental results were unaltered, and this is not surprising in face of the results of the following experiments.

(a) The experiment with *p*-chlorobenzaldehyde (14 above) was repeated, this time without the addition of zinc chloride. No combination occurred.

(b) *p*-Chlorobenzaldehyde (5 g.), thymol (10.7 g.), and zinc chloride (20 g.) in absolute alcohol (40 c.c.) were heated under reflux for 4 hours and then poured into 10% hydrochloric acid and the excess of the reagents was removed in steam. The residual crude *p*-chlorophenyldithymylmethane weighed 4 g. (25% yield).

(c) *m*-Nitrobenzaldehyde and thymol treated as in (b) gave crude *m*-nitrodithymylmethane in only 20% yield.

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