

studied and the shift is roughly parallel to the degree of hydrogen-bonding. The fact that no other bands in the region 8–12  $\mu$  were shifted by more than 0.005  $\mu$  in chloroform solution indicates that bonding is not appreciable at any other site.

The marked effect of ring size on the hydrogen bonding of lactones seems explicable on the basis of the carbonyl group being the favored site. The resonance between forms I, II and III will be most favored by a bond angle of 120° between the carbonyl carbon and adjacent atoms, so that the carbon atom can use  $sp^2$  orbitals. When the carbalkoxy group is present in a 4- or 5-membered ring, a smaller angle is required, which results in an unsymmetrical arrangement of bond angles in contributing resonance forms of type II and III. Dampening of resonance between the two oxygens is consequently expected, reducing the gain in electron density of the carbonyl oxygen. The effect, of course, is greater for  $\beta$ -propiolactone than for  $\gamma$ -butyrolactone. Experimental evidence for the difference in the degree of resonance in the lactones is to be had in the carbonyl frequencies and in the dipole moments. As given in Table III, the carbonyl frequency increases in the order  $\delta$ -lactone <  $\gamma$ -lactone <  $\beta$ -lactone, indicating an increase in the rigidity of the carbonyl group. This effect of ring size on the carbonyl frequency has been of value in empirical data of ring size of lactones.<sup>9</sup> There also seems to be a greater resonance increment in the dipole moment of  $\gamma$ -butyrolactone than in that of  $\beta$ -propiolactone. With the assumption of no resonance interaction of the type occurring in ester, the molecular dipoles of the lactones have been calculated by vector addition of the carbonyl dipole of 2.8  $D$ <sup>10</sup> to the dipoles of 2.01  $D$

(9) L. Bauer, Ph.D. Thesis, Northwestern University, June, 1952.

(10) G. C. Hampson and R. J. B. Marsden, *Trans. Faraday Soc.*, **30**, Appendix p. 39 (1934).

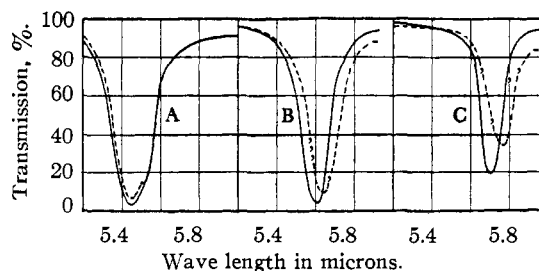


Fig. 1.—Effect of hydrogen bonding on carbonyl bands of lactones: A,  $\beta$ -propiolactone; B,  $\gamma$ -butyrolactone; C,  $\delta$ -valerolactone; solid lines, 10% solutions in carbon-tetrachloride; dotted lines, same with equimolecular amount of methanol added.

and 1.68  $D$  for the trimethylene oxide<sup>9</sup> and tetrahydrofuran,<sup>11</sup> respectively. Bond angles of 90 and 108° were used for the  $\beta$ - and  $\gamma$ -lactone rings, respectively. Both the calculated and measured<sup>12</sup> values for the  $\beta$ -lactone are 3.8  $D$ ; but for the  $\gamma$ -lactone the calculated dipole is 3.7  $D$  and that measured<sup>13</sup> is 4.12  $D$ . Much of this difference may be attributed to the added resonance in this compound.

If the above reasoning is correct, the same order with respect to ring size should be found for the basicity and donor ability in hydrogen-bonding of cyclic ketones. Work is under way to check this point.<sup>14</sup> We also hope to report on the ring-size effect in other similar systems, such as cyclic sulfoxides and amine oxides.

(11) H. D. Robles, *Rec. trav. chim.*, **58**, 111 (1939).

(12) T. L. Gresham, J. E. Jansen and E. W. Shaver, *THIS JOURNAL*, **70**, 998 (1948).

(13) R. J. B. Marsden and L. E. Sutton, *J. Chem. Soc.*, 1383 (1936).

(14) Hydrogen bonding measurements with cyclohexanone and cyclopentanone reported by W. Gordy and S. C. Stanford, *J. Chem. Phys.*, **8**, 170 (1940), are in agreement.

EVANSTON AND URBANA, ILLINOIS

[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, THE FLORIDA STATE UNIVERSITY]

### Azulenes. III.<sup>1</sup> An Attempted Synthesis of 1-Isopropyl-4,8-dimethylazulene. Migration of an Isopropyl Group

BY WERNER HERZ

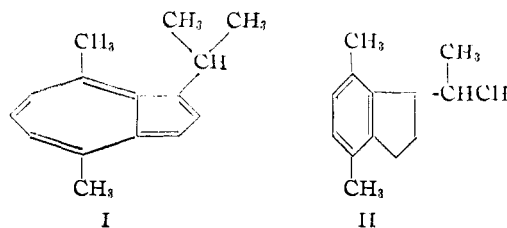
RECEIVED JULY 10, 1952

Various routes leading to 1-isopropyl-4,7-dimethylindan were investigated. The usual diazoacetic ester method for the synthesis of azulenes, when applied to this indan, did not yield the expected 1-isopropyl-4,8-dimethylazulene (I), but vetivazulene. This is ascribed to migration of the isopropyl group from position 1 to position 2 of the azulene nucleus during or after dehydrogenation with palladium-charcoal.

1-Isopropyl-4,8-dimethylazulene (I) is of interest as an azulene which may be represented as having been formed by the combination of three isoprene units. This union is not of the "regular" or "head to tail" fashion usually found among terpenes of natural origin. However, it has been suggested<sup>2</sup> that "irregular" structures may well occur among azulenes derived from natural sources, inasmuch

(1) Paper II of this series, W. Herz, *THIS JOURNAL*, **74**, 1350 (1952).

(2) A. J. Haagen-Smit, "Azulenes, Fortschritte der Chemie Organischer Naturstoffe," Vol. 5, Springer Verlag, Vienna, 1948, p. 40.



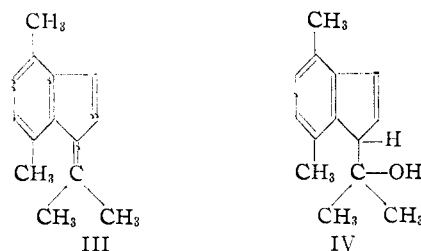
as the number of apparently different azulenes isolated hitherto exceeds the number of "regularly"

constituted formulas which may be written.<sup>3</sup>

The synthesis and characterization of all regularly and irregularly constituted C<sub>15</sub>-azulenes is therefore desirable in order to permit comparison with azulenes of natural origin. In a previous article,<sup>1</sup> the synthesis of one such azulene, 1,8-dimethyl-4-isopropylazulene, was reported. The present paper describes the experiments which were undertaken in an effort to prepare I. Unexpectedly, however, vetivazulene rather than I was the end-product.

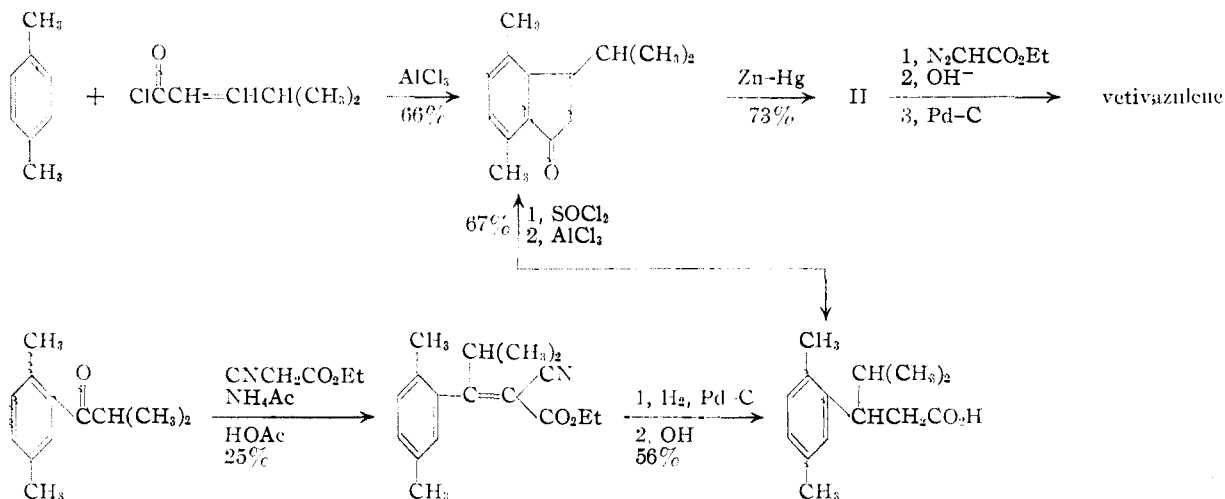
In order to adapt the diazoacetic ester method<sup>4</sup> of Pfau and Plattner<sup>5</sup> to the preparation of the desired azulene, a convenient synthesis of 1-isopropyl-4,7-dimethylindanone (II) was required. The most obvious method, *i.e.*, treatment of the easily available 4,7-dimethylindanone<sup>6</sup> with isopropylmagnesium bromide or isopropylolithium followed by dehydration of the resulting carbinol and catalytic reduction, proved unsuitable, because the initial step resulted in partial recovery of indanone accompanied by a considerable quantity of material of higher molecular weight. The failure of 4,7-dimethylindanone to undergo condensation with isopropylmagnesium bromide or isopropylolithium is apparently due to enolization under the influence of the Grignard reagent rather than steric hindrance, inasmuch as Wagner-Jauregg and co-workers<sup>7</sup> have reported similar experiences with

aluminum hydride. Dehydration led to 4,7-dimethylindene whose condensation with acetone was expected to give the benzofulvene III.<sup>9</sup> Instead, only a small yield of the undehydrated



intermediate IV was realized. It may be demonstrated with the aid of molecular models that the presence of a methyl group in position 7 of the benzene ring interposes an almost insuperable obstacle to the coplanarity of the isopropylidene group and benzene ring which is required by the exocyclic double bond of formula III. This *rationale* for our failure to observe dehydration is supported by the finding that 4,7-dimethylindene furnishes excellent yields of those benzofulvenes where little interference with coplanarity might be expected, *e.g.*, in the product formed by condensation of the indene with benzaldehyde.

The synthesis of the indan II was finally achieved by the sequence of reactions



6-methyl- and 4,6-dimethylindanone where hindrance would not be expected to be a factor. Further evidence for this point of view is furnished by a similar lack of success when the conditions recommended by Swain<sup>8</sup> for the Grignard reaction with hindered ketones were observed.

We next attempted to prepare II *via* the following sequence of reactions. 4,7-Dimethylindanone was reduced to the corresponding alcohol with lithium

Proof that the Friedel-Crafts reaction between *p*-xylene and 2-(4-methyl)pentenoyl chloride had taken the desired course was furnished by an independent synthesis of 3-isopropyl-4,7-dimethylindanone, using 2,5-dimethylisobutyrophenone as starting material. The low yields encountered at several stages of the second series of reactions render it distinctly less valuable. Analogously, the Reformatsky reaction between 2,5-dimethylisobutyrophenone and ethyl bromoacetate which was also investigated as a possible source of the substituted phenylpropionic acid V proceeded only in very low yield whereas, as shown earlier,<sup>10</sup> the condensation of 2,5-dimethylacetophenone and ethyl bromoacetate is a satisfactory preparative method.

(3) A recent addition to this group of apparently well-characterized azulenes of unknown constitution is the azulene obtained by dehydrogenation of the bitter principal helenalin, R. Adams and W. Herz, *THIS JOURNAL*, **71**, 2554 (1949).

(4) M. Gordon, *Chem. Revs.*, **50**, 127 (1952).

(5) A. St. Pfau and Pl. A. Plattner, *Helv. Chim. Acta*, **22**, 202 (1939).

(6) F. Mayer and P. Müller, *Ber.*, **60**, 2278 (1927).

(7) Th. Wagner-Jauregg, H. Arnold and F. Hüter, *ibid.*, **75**, 1293 (1942); Th. Wagner-Jauregg and H. Hippchen, *ibid.*, **76**, 694 (1943).

(8) C. G. Swain, *THIS JOURNAL*, **73**, 870 (1951).

(9) J. Thiele and K. Merck, *Ann.*, **415**, 257 (1918).

(10) W. Herz, *THIS JOURNAL*, **74**, 1351 (1952).

An azulene was obtained from the indan by repeated treatment with ethyl diazoacetate, saponification of the resulting ester, simultaneous dehydrogenation and decarboxylation with palladium-charcoal, conversion to the trinitrobenzene complex and liberation by passage through an alumina column. However, the color of this preparation was not *blue* as might be expected by analogy with the 1,4,8-trisubstituted azulenes previously prepared in our laboratory<sup>1</sup> and by applica-

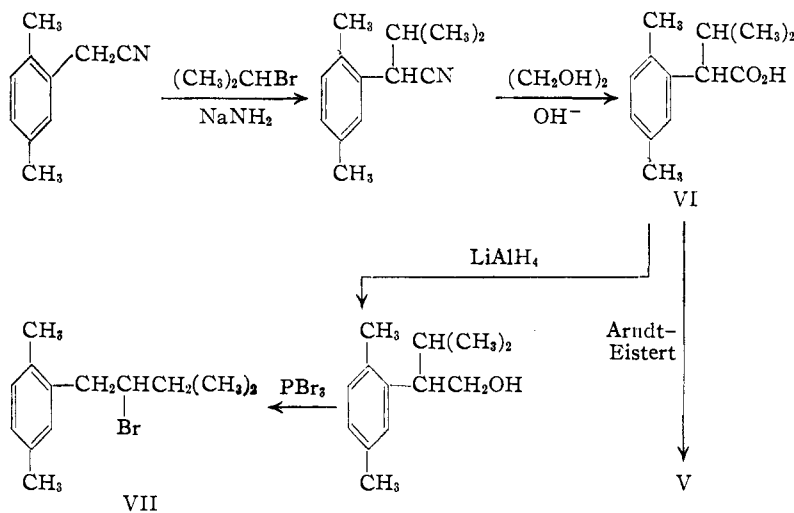
tion of the rules formulated by Plattner<sup>11</sup> for the relationship between color and constitution in the azulene series. Instead, its *violet-blue* color, intermediate between the shades exhibited by 1,4,8-<sup>1</sup> and 2,4,8-trimethylazulene,<sup>12</sup> suggested the presence of a mixture consisting largely of vetivazulene (2-isopropyl-4,8-dimethylazulene) contaminated by a small amount of the desired I. This was corroborated by an examination of the ultraviolet spectrum which exhibited the high intensity absorption and characteristic band structure of vetivazulene,<sup>13</sup> blurred somewhat by the presence of another constituent. Furthermore, the melting points of the complexes formed with trinitrobenzene, trinitrotoluene and picric acid approached the melting points reported for the corresponding derivatives of vetivazulene.<sup>14</sup>

Repeated purification of the azulene mixture through the various complexes finally yielded a pure *violet* azulene identical in all respects with vetivazulene, as shown by its ultraviolet spectrum and the melting points of its derivatives. It is therefore concluded that palladium-charcoal dehydrogenation of the addition product of 1-isopropyl-4,7-dimethylindan and diazoacetic ester, after saponification, is accompanied or followed by partial migration of the isopropyl group from position 1 to position 2 of the azulene nucleus. The analogous migration of a phenyl group in the course of an attempted synthesis of 1-phenylazulene from 1-phenylindan has been reported<sup>15</sup> and evidence has been adduced<sup>16</sup> to show that migration takes place on the aromatic nucleus after dehydrogenation. It is interesting, however, that when the isopropyl group is replaced by a methyl radical, no migration occurs and the expected 1,4,8-substituted azulenes may be isolated.<sup>1</sup>

Observance of milder dehydrogenating conditions, such as the use of sulfur at 200°, might con-

ceivably minimize migration of the isopropyl group. Unfortunately, this method does not give good results when applied to the products of the diazoacetic ester synthesis.<sup>15</sup> It was therefore not investigated.

A number of attempts were made to improve the preparation of V in the course of a series of model experiments for future work. Alkylation of 2,5-dimethylphenylacetonitrile with isopropyl bromide in the presence of sodamide furnished a nitrile



which was hydrolyzed with difficulty to VI. The crystalline diazoketone of this acid gave a poor yield of V by the usual Arndt-Eistert procedure. Better yields were realized when the Wolff rearrangement was carried out in ammoniacal solution. Reduction of VI with lithium aluminum hydride furnished the corresponding alcohol which was converted to a bromide by treatment with phosphorus tribromide. The reactions of this compound, however, indicated that it did not possess the expected structure. Treatment with aqueous potassium cyanide resulted in recovery of starting material. Reaction with magnesium was very sluggish and did not appear to yield the desired Grignard reagent. It is concluded that the structure of the bromide is best represented by VII and that treatment of the alcohol with phosphorus tribromide has resulted in rearrangement accompanied by phenyl migration. It is intended to elucidate this point more fully in subsequent work.

**Acknowledgment.**—This work was supported in part by a grant from the Research Council of the Florida State University.

### Experimental<sup>17</sup>

**3-Isopropyl-4,7-dimethylindanone.**—In adapting the preparation of 3,4,7-trimethylindanone<sup>18</sup> to the synthesis of the 3-isopropyl analog, 64 g. of 4-methyl-2-pentenoyl chloride<sup>19</sup> was added slowly to a mixture of 48 g. of *p*-xylene, 96 g. of aluminum chloride and 720 ml. of carbon disulfide with stirring and chilling. After 12 hours an additional 96 g. of aluminum chloride and 400 ml. of carbon disulfide was added to promote cyclization; the mixture was heated on

(17) Melting points are uncorrected. Analyses were performed by Clark Microanalytical Laboratory, Urbana, Illinois.

(18) K. V. Auwers and E. Risse, *Ann.*, **502**, 282 (1933); Pl. A. Plattner, A. Fürst and H. Schmid, *Helv. Chim. Acta*, **28**, 1647 (1945).

(19) A. A. Goldberg and R. P. Linstead, *J. Chem. Soc.*, 2353 (1928).

(11) Pl. A. Plattner, *Helv. Chim. Acta*, **24**, 283E (1941).

(12) W. Herz, *This Journal*, **73**, 4923 (1951).

(13) A survey of the ultraviolet absorption spectra of azulenes recorded hitherto<sup>4</sup> reveals that vetivazulene absorbs somewhat more strongly than other alkyl azulenes. For example,  $\log \epsilon_{290 \text{ m}\mu}$  of vetivazulene is 5.1, whereas  $\log \epsilon_{290 \text{ m}\mu}$  of comparable azulenes rarely exceeds 4.75.<sup>14</sup>

(14) (a) N. A. Sörensen and F. Hougen, *Acta Chem. Scand.*, **2**, 447 (1948); (b) B. Susz, A. St. Pfau and P. A. Plattner, *Helv. Chim. Acta*, **20**, 471 (1937).

(15) Pl. A. Plattner, R. Sandrin and J. Wyss, *ibid.*, **29**, 1604 (1946).

(16) Pl. A. Plattner, A. Fürst, M. Gordon and K. Zimmerman, *ibid.*, **33**, 1910 (1950).

the steam-bath for three hours, cooled and decomposed by pouring over ice-hydrochloric acid. The organic layer was separated and the carbon disulfide removed in an air stream. The residual oil was distilled with steam, the distillate was extracted with ether and the dried ether extract was fractionated. The light yellow fraction boiling at 130–140° (4 mm.) was collected. It weighed 61 g. (66%).

*Anal.* Calcd. for  $C_{14}H_{18}O$ : C, 83.11; H, 8.97. Found: C, 82.83; H, 8.81.

The dinitrophenylhydrazone melted at 224° after several recrystallizations from ethyl acetate.

*Anal.* Calcd. for  $C_{20}H_{22}N_4O_4$ : N, 14.65. Found: N, 14.44.

This ketone was also prepared by the cyclization of 4-methyl-3-(2,5-dimethylphenyl)-pentanoyl chloride. A mixture of 77 g. of the corresponding acid, whose preparation is described below, and 100 g. of thionyl chloride was heated on the steam-bath for two hours and allowed to stand overnight. The distilled acid chloride, b.p. 125–135° (3 mm.), wt. 72.5 g., was added cautiously to 55 g. of aluminum chloride in 200 ml. of dry benzene. After 12 hours the mixture was decomposed with ice-hydrochloric acid and extracted with ether. Distillation of the washed and dried extracts gave 47.5 g. of the indanone (67%), b.p. 125–139° (3 mm.). Admixture of the dinitrophenylhydrazone prepared from this fraction, m.p. 223.5–224°, to the derivative previously prepared caused no depression of the m.p.

**1-Isopropyl-4,7-dimethylindan.**—Reduction of 46.5 g. of the indanone with amalgamated zinc in the manner previously described yielded 32.5 g. (73%) of indan, b.p. 97–105° (3 mm.), and 7.5 g. of higher boiling material consisting largely of unreduced indanone. The analytical sample boiled at 86–88° (1.8 mm.),  $n_D^{25}$  1.5197.

*Anal.* Calcd. for  $C_{14}H_{20}$ : C, 89.29; H, 10.71. Found: C, 89.12; H, 10.64.

**Reaction of 1-Isopropyl-4,7-dimethylindan with Diazoacetic Ester. Isolation of Vetivazulene.**—Two runs were carried out. One of these, by a fortuitous combination of circumstances, resulted directly in the isolation of vetivazulene and is described below. Reaction of 32 g. of the indan with six 8-g. portions of diazoacetic ester resulted in recovery of 19 g. of indan (b.p. up to 120° at 1.5 mm.) and 24 g. of highly-colored ester, b.p. 120–180° (1 mm.). This was saponified by refluxing for eight hours with 12 g. of potassium hydroxide, 25 ml. of water and 120 ml. of ethanol. The yield of viscous dark-green acid, b.p. 165–185° (2 mm.) was 8.5 g. Two decarboxylations and dehydrogenations in the manner previously described, using 2 g. of 10% palladium-charcoal for each run, gave 2.2 ml. of crude trialkylazulene, b.p. 90–160° (2 mm.). A solution of the azulene in 25 ml. of ethanol was mixed with 2 g. of trinitrobenzene in 75 ml. of warm ethanol. The complex which precipitated on cooling weighed 0.42 g. The azulene was regenerated by chromatography over alumina, a mixture of cyclohexane and benzene (3:1) serving as eluent. The eluate was violet-blue. It was converted to the trinitrobenzene complex. After two recrystallizations from ethanol, the violet needles melted at 151.5–152.5° (lit. 154–155°, <sup>14a</sup> 151.5–152°<sup>14b</sup>).

*Anal.* Calcd. for  $C_{21}H_{21}N_3O_6$ : C, 61.34; H, 5.14; N, 10.21. Found: C, 61.19; H, 5.09; N, 10.13.

Decomposition of 7.5 mg. of this derivative by passage through an alumina column, using spectral grade isoctane as eluent, gave a violet solution which was used to determine the ultraviolet spectrum. Maxima and extinction coefficients were identical with those reported for vetivazulene<sup>14</sup> ( $\lambda_{max}$  247, 282, 290, 308, 334, 349; log  $\epsilon_{max}$  4.82, 5.06, 5.11, 4.00, 3.93, 4.03).

The trinitrotoluene complex was recrystallized twice from ethanol and melted at 77.5–78° (lit. 78.5–79°, <sup>14a</sup> 80.5–81°<sup>14b</sup>).

*Anal.* Calcd. for  $C_{22}H_{23}N_3O_6$ : C, 62.11; H, 5.45. Found: C, 61.97; H, 5.32.

The picrate, black needles, was recrystallized twice from ethanol and melted at 121–122° (lit. 122.5°, <sup>14a</sup> 121.5–122°<sup>14b</sup>).

A second run, using 71 g. of indan, gave a somewhat larger yield of the azulene. A total of 0.95 g. of violet-blue liquid, b.p. 110–123° (1 mm.), was obtained; m.p. of trinitrobenzolate, 147°; m.p. of trotylate, 77–78°. The ultraviolet spectrum of this material was somewhat less sharp than that of the product obtained above. When the

azulene mixture was chromatographed it was noticed that the first few drops of eluate (cyclohexane) were blue. However, it was not possible to obtain sufficient material in this manner to permit characterization of the blue azulene, presumably I, although the separation of 1- and 2-phenylazulene by chromatographic adsorption has been reported.<sup>15</sup>

**Ethyl 2-Cyano-3-(2,5-dimethylphenyl)-4,4-dimethylcrotonate.**—A mixture of 132 g. (0.75 mole) of 2,5-dimethylisobutyrophenone,<sup>20</sup> 74.9 g. of ethyl cyanoacetate, 11.55 g. of ammonium acetate, 36 g. of acetic acid and 150 ml. of benzene<sup>21</sup> was refluxed for 36 hours until the volume of water in the trap had become constant. Fractionation of the product yielded 148 g. of a mixture of starting materials and 51 g. (25%) of condensation product, b.p. 130–135° (1 mm.),  $n_D^{25}$  1.5218. The ester crystallized after prolonged standing, and was recrystallized from methanol, m.p. 51°.

*Anal.* Calcd. for  $C_{17}H_{21}O_2N$ : C, 75.23; H, 7.80; N, 5.16. Found: C, 75.50; H, 7.59; N, 5.55.

Repeated fractionation of the forerun resulted in recovery of 75–80 g. of dimethylisobutyrophenone.

**Ethyl 2-Cyano-3-(2,5-dimethylphenyl)-isocaproate.**—A solution of 10 g. of the above in 20 ml. of ethanol was reduced at room temperature with 5% palladium-on-charcoal catalyst until hydrogen uptake ceased (10 hours). Distillation gave 6.5 g. of viscous oil, b.p. 130–138° (2 mm.). The analytical sample boiled at 122–124° (1.2 mm.),  $n_D^{25}$  1.5038.

*Anal.* Calcd. for  $C_{17}H_{23}O_2N$ : C, 74.68; H, 8.48. Found: C, 74.40; H, 8.18.

**4-Methyl-3-(2,5-dimethylphenyl)-pentanoic Acid (V).**—Ammonia was evolved when a solution of 5.5 g. of the reduced ester was refluxed with 55 g. of 10% potassium hydroxide solution. After 18 hours the viscous acid fraction was isolated in the usual way. A small amount of the malonic acid was recrystallized several times from benzene-ligroin and melted at 147°.

*Anal.* Calcd. for  $C_{13}H_{20}O_4$ : C, 68.16; H, 7.63. Found: C, 68.33; H, 7.93.

The remaining malonic acid was decarboxylated by heating at 200°. The viscous residue crystallized very slowly on standing; yield 2.1 g. Recrystallization from ligroin gave crystals of m.p. 91.5°.

*Anal.* Calcd. for  $C_{14}H_{20}O_2$ : C, 76.33; H, 9.15. Found: C, 76.40; H, 9.33.

When later preparations of this acid were carried out on a larger scale, hydrogenation of the initial condensation product proceeded very slowly. The theoretical amount of hydrogen was only taken up after repeated addition of catalyst. The solvent was removed at reduced pressure and the crude product was hydrolyzed as described above. Hydrolysis also proceeded very slowly. The malonic acid was decarboxylated by distillation at reduced pressure. From 136 g. of condensation product there was obtained 46 g. (42%) of the pentanoic acid, b.p. 150–170° (3 mm.), and 23 g. of acidic material boiling in the range 170–190° (3 mm.). The higher boiling fraction apparently consisted primarily of unsaturated acid and was reduced with platinum oxide in ethanol. In this manner there was obtained an additional 15.5 g. of the desired acid.

The amide was prepared in the usual way<sup>22</sup> and melted at 119–120° after three recrystallizations from ligroin.

*Anal.* Calcd. for  $C_{14}H_{21}NO$ : N, 6.39. Found: N, 6.35.

#### Reformatsky Reaction of 2,5-Dimethylisobutyrophenone.

—Treatment of 137 g. of the ketone with several portions of ethyl bromoacetate and zinc, as previously described for 2,5-dimethylacetophenone,<sup>19</sup> resulted in recovery of 89 g. of starting material and 15.5 g. of a fraction boiling unsharply in the range 90–130° (1.8 mm.). To complete the dehydration this was refluxed with 8 ml. of phosphorus oxychloride in 125 ml. of dry benzene and worked up as usual. 10.5 g. of a fraction boiling unsharply at 110–150° (3.5 mm.) was collected and hydrolyzed with 25 g. of 50% potassium hydroxide solution in 100 ml. of ethanol. The acid frac-

(20) A. Claus, *J. prakt. Chem.*, [2] **46**, 474 (1892).

(21) A. C. Cope, C. M. Hoffmann, C. Wyckoff and E. Hardenbergh, *This Journal*, **63**, 3453 (1941).

(22) R. L. Shriner and R. C. Fuson, "Systematic Identification of Organic Compounds," 3rd ed., John Wiley and Sons, Inc., New York, N. Y., 1948, p. 157.

tion distilled at 130–145° (2.5 mm.), wt. 6.3 g. A middle cut boiling at 150–152° (4.5 mm.) was used for analysis.

*Anal.* Calcd. for  $C_{14}H_{18}O_2$ : C, 77.02; H, 8.31. Found: C, 76.74; H, 8.22.

Catalytic reduction of 5 g. of the unsaturated acid in ethanol, using platinum oxide catalyst, resulted in the uptake of one molecular equivalent of hydrogen. The solution was filtered and refluxed with 16 g. of 40% potassium hydroxide solution to saponify any ester formed during the reaction. Distillation yielded 4.1 g. of a product boiling sharply at 140–142° (3 mm.),  $n_D^{25}$  1.5214, which was shown to be V by analysis and preparation of the amide.

**1-Hydroxy-4,7-dimethylindan.**—Lithium aluminum hydride reduction of 10 g. of 4,7-dimethylindanone in ether solution yielded 8.5 g. of an oil which gradually crystallized on standing and stirring with cold petroleum ether. Several recrystallizations from low-boiling petroleum ether yielded colorless needles, m.p. 68°.

*Anal.* Calcd. for  $C_{11}H_{14}O$ : C, 81.44; H, 8.70. Found: C, 81.76; H, 8.72.

An attempt to prepare this compound by catalytic hydrogenation of the indanone with platinum oxide in ethanol solution was unsuccessful.

**4,7-Dimethylindene.**—In an experiment utilizing 80 g. of 4,7-dimethylindanone and 7.5 g. of lithium aluminum hydride, the crude 1-hydroxy-4,7-dimethylindane obtained by removal of ether on the steam-bath was distilled *in vacuo*. The fraction boiling at 72–78° (3 mm.) weighed 58 g. (81%) and turned yellow on standing. The analytical sample boiled at 63–65° (1.7 mm.),  $n_D^{25}$  1.5583.

*Anal.* Calcd. for  $C_{11}H_{12}$ : C, 91.61; H, 8.39. Found: C, 91.30; H, 8.28.

**1-(1-Hydroxyisopropyl)-4,7-dimethylindan.**—A mixture of 25 g. of 4,7-dimethylindene, 100 ml. of acetone and 10 g. of 30% methanolic potassium hydroxide was refluxed for three hours and poured into water. The dried ether extract was fractionated, yielding mesityl oxide, 19.5 g. of dimethylindene and 3.6 g. of a fraction boiling at 135–140° (2 mm.). Redistillation of the latter gave a light-yellow oil, b.p. 125–128° (1.6 mm.),  $n_D^{25}$  1.5473.

*Anal.* Calcd. for  $C_{14}H_{18}O$ : C, 83.11; H, 8.96. Found: C, 83.48; H, 8.74.

**3-Phenyl-4,7-dimethylbenzofulvene.**—On adding a mixture of 6 g. of dimethylindene and 6.6 g. of freshly distilled benzaldehyde to methanolic potassium hydroxide and warming, an almost quantitative yield of the expected benzofulvene was obtained after cooling and working up the mother liquors. The yellow needles were recrystallized repeatedly from methanol, m.p. 65°.

*Anal.* Calcd. for  $C_{15}H_{16}$ : C, 93.06; H, 6.94. Found: C, 93.01; H, 6.89.

**2-(2,5-Dimethylphenyl)-isovaleronitrile.**—2,5-Dimethylphenylacetone nitrile, b.p. 88–90° (1.7 mm.), was prepared in 92% yield from chloromethyl-*p*-xylene<sup>23</sup> by refluxing with potassium cyanide in aqueous ethanol.<sup>24</sup> A mixture of 72.5 g. (0.5 mole) of the nitrile in 250 ml. of dry toluene was treated with 19.5 g. of sodamide. After the initial reaction had moderated, heating and stirring was continued for 12 hours until the evolution of ammonia had ceased completely. This was followed by dropwise addition of 61.5 g. of isopropyl bromide while the reaction mixture was kept at reflux temperature and then by another six-hour period at reflux. The solution was decomposed with water and worked up in the usual manner. Fractional distillation yielded 67 g. (71%) of product, b.p. 97–102° (1.7 mm.),  $n_D^{25}$  1.5088.

*Anal.* Calcd. for  $C_{12}H_{17}N$ : C, 83.36; H, 9.15. Found: C, 83.42; H, 9.02.

**2-(2,5-Dimethylphenyl)-isovaleric Acid (VI).**—A mixture of 46 g. of the preceding nitrile, 400 ml. of ethylene glycol, 40 ml. of water and 90 g. of potassium hydroxide was refluxed until the evolution of ammonia ceased. This required 30–60 hours. It was found expedient to distill off most of the water in order to raise the reflux temperature to 175–180° and to shorten the time required for the hydrolysis. Much of the glycol was then removed by distillation at re-

duced pressure. The residue was diluted with water, acidified and filtered with suction while hot. The material remaining on the filter paper was air-dried and extracted with three 250-ml. portions of hot benzene. The benzene was removed at reduced pressure and the residue was recrystallized from 250 ml. of ligroin (b.p. 65–110°). On cooling there precipitated 39.2 g. of colorless crystals. The total yield, including 2.5 g. from the mother liquors, amounted to 82%. Several recrystallizations from petroleum ether gave needles with a constant m.p. of 126.5–127°.

*Anal.* Calcd. for  $C_{13}H_{18}O_2$ : C, 75.68; H, 8.79. Found: C, 75.81; H, 8.67.

When the hydrolysis was carried out in amyl alcohol, the desired acid constituted only 15% of the total product. The remainder, due to incomplete hydrolysis at the lower temperature, consisted of the amide, white needles, m.p. 175.5° from benzene.

*Anal.* Calcd. for  $C_{13}H_{19}NO$ : N, 6.82. Found: N, 6.87.

**Arndt-Eistert Reaction of VI.**—A mixture of 25 g. of VI and 25 g. of thionyl chloride was warmed on the steam-bath for one hour and allowed to stand overnight. Distillation yielded 23.5 g. of slightly-colored liquid, b.p. 95–101° (2 mm.). A solution of 15.6 g. of the acid chloride in 50 ml. of anhydrous ether was added to diazomethane prepared from 45 g. of nitrosomethylurea in 500 ml. of ether. After 12 hours the ether was removed at reduced pressure. The yellow residue (16 g.) crystallized in the course of several days.

The Wolff rearrangement of 7.5 g. of the diazoketone, carried out as described for  $\alpha$ -naphthoic acid,<sup>25</sup> gave only 1.35 g. (18%) of V. Better yields were realized when the rearrangement was carried out in aqueous ammonia. A solution of 2.5 g. of the diazoketone in 12 ml. of dioxane was warmed on the steam-bath and treated gradually with a mixture of 15 ml. of concd. ammonium hydroxide and 3 ml. of 10% silver nitrate solution. After one hour on the steam-bath, the mixture was diluted with water. 2.1 g. (85%) of crude amide separated. Recrystallization raised the m.p. to 116–117°, undepressed on admixture of an authentic sample. Alkaline hydrolysis of the amide gave a 65% yield of V.

**2-(2,5-Dimethylphenyl)-3-methyl-1-butanol.**—A solution of 40.5 g. of VI in 350 ml. of anhydrous ether was added dropwise to 9.5 g. of lithium aluminum hydride in 250 ml. of anhydrous ether. The mixture was stirred for an additional hour, decomposed with water and 200 ml. of 10% sulfuric acid, the ether layer was separated, washed, dried and distilled. The product was represented by 32.5 g. (85%) of a fraction boiling at 105–108° (2 mm.),  $n_D^{25}$  1.5150.

*Anal.* Calcd. for  $C_{13}H_{20}O$ : C, 81.19; H, 10.49. Found: C, 81.11; H, 10.48.

To 19.3 g. of this alcohol was added dropwise 13.6 g. of phosphorus tribromide. The mixture was heated on the steam-bath for two hours, poured into ice-water, stirred and thoroughly extracted with ether. The extracts yielded 21.5 g. (84%) of bromide, b.p. 112–115° (2 mm.),  $n_D^{25}$  1.5310.

*Anal.* Calcd. for  $C_{13}H_{19}Br$ : C, 61.18; H, 7.50. Found: C, 61.45; H, 7.69.

This compound was recovered unchanged after refluxing with potassium cyanide in ethanol-water solution for six hours. Further evidence for the assigned structure was furnished by an attempted conversion to a Grignard reagent followed by carbonation. A solution of 20 g. of the bromide in 100 ml. of anhydrous ether was added dropwise with stirring to 2 g. of magnesium under 25 ml. of ether. Although a vigorous reaction ensued, only a small part of the magnesium dissolved. The mixture was carbonated in the usual way, but no acidic products could be isolated. The neutral fraction yielded 7.9 g. of a mobile compound, b.p. 60–62° (1 mm.),  $n_D^{25}$  1.5013, and 4.8 g. of viscous material, b.p. 150–185° (2 mm.), apparently the result of coupling. The low-boiling fraction readily decolorized a solution of bromine in chloroform, but apparently was not the expected dehydrohalogenation product.

*Anal.* Found: C, 87.79, 87.48; H, 11.35, 11.25.

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