

a 1.1 × 9 cm. column packed with  $\frac{5}{32}$  in. single turn glass helices gave seven fractions boiling at 168–169° at 735 mm., m.p. 57–59°. The infrared spectrum established the presence of a carbonyl group (5.87  $\mu$ ) as the only functional group. The 2,4-dinitrophenylhydrazone melted at 181–182° and the semicarbazone at 198–199°.

*Anal.* Calcd. for  $C_{10}H_{11}N_3O$ : C, 60.30; H, 10.55. Found: C, 60.40; H, 10.37.

This ketone was identified by the above constants as 3,3,4,4-tetramethyl-2-pentanone (pennone). The identification was confirmed by oxidation of 2 g. of the ketone with 52% nitric acid (following the procedure of Locquin and Sung<sup>19</sup>) to give  $\alpha,\alpha,\beta,\beta$ -tetramethylbutyric acid which melted sharply at 194–195° (uncor.).

Trimethylacetic acid was obtained from the alkaline wash solution from experiment 6 by acidification with sulfuric acid and extraction with ether. Fractional distillation gave 4.5 g., b.p. 161° at 735 mm., m.p. 33°; *p*-bromophenacyl ester, m.p. 75–76°.

Isolation and purification of the *N*-*t*-butyl amide was less successful than direct hydrolysis to *t*-butylamine. The aqueous layers in experiments 2 and 3 were neutralized with barium hydroxide and sodium hydroxide, respectively. After filtration of insoluble barium sulfate and sulfonate, the aqueous solutions were evaporated almost to dryness under vacuum and extracted with hot ethyl acetate. Water was removed by azeotropic distillation, after which the residue was filtered and concentrated. The crystallized amides were mixtures of  $RCONH_2$  and  $RCONHC(CH_3)_3$  as shown by hydrolysis with 20% potassium hydroxide solution. Acetic and propionic acids were identified as their *p*-bromophenacyl esters melting at 84–85° and 63–64°, respectively. *t*-Butylamine and ammonia were identified as described below.

The amides were hydrolyzed directly in experiments 1, 4, 5 and 6. The sulfuric acid layers were neutralized with 50% sodium hydroxide and excess base added to make the final solution 20% by weight in sodium hydroxide. Hydrolysis was effected over a period of 3–5 days by stirring and heating just below the reflux temperature to prevent excessive frothing. Ether, ammonia and amines were swept by a very slow stream of air into traps containing concentrated hydrochloric acid. The hygroscopic hydrochlorides

(19) R. Locquin and W. Sung, *Bull. soc. chim. France*, [4] **35**, 753 (1924); *Compt. rend.*, **178**, 1179 (1924).

obtained by evaporation of the excess hydrochloric acid were dried over calcium chloride in a desiccator. *t*-Butylamine hydrochloride was separated by extraction with anhydrous butanol and crystallized from that solvent. The picrate prepared from the free amine melted at 199–201° (reported 198°).<sup>20</sup> Methylamine hydrochloride was extracted into and crystallized from hot absolute ethanol. The amine was identified as *N*-methylphthalimide, m.p. 131–132° (reported 134°).<sup>21</sup> The residues of ammonium chloride gave a positive test with Nessler reagent and sublimed from 332 to 348°.

The alkaline solution from the hydrolysis was acidified with sulfuric acid in experiment 6. Steam distillation gave 16.1 g. of trimethylacetic acid, m.p. 31–33°; *p*-bromophenacyl ester, m.p. 75–76°.

**Rearrangement of Ethyl *t*-Butyl Ketone by Sulfuric Acid.**—Concentrated sulfuric acid, 33 g., was added dropwise with stirring to 25 g. of the ketone cooled in an ice-bath. The yellow solution was stirred for two days at room temperature and then warmed to 55° for three hours. After cooling overnight to room temperature, the mixture was poured into 100 g. of ice and washed well with four 20-ml. portions of water. Fractionation through a 1.1 × 34 cm. column packed with  $\frac{1}{8}$  in. single turn glass helices gave eight fractions, 18.2 g. (73%) of material boiling at 123–123.5°,  $n_D^{25}$  1.4022–1.4027. The remainder of the liquid in the column was then distilled to dryness at a pressure of 50 mm. Two fractions, 6 g., of distillate were obtained,  $n_D^{25}$  1.4030 and  $n_D^{25}$  1.4035. Infrared absorption spectra were determined from 2 to 13  $\mu$  for authentic samples of ethyl *t*-butyl ketone, b.p. 123–124° at 735 mm.,  $n_D^{25}$  1.4022; methyl *t*-amyl ketone, b.p. 128° at 740 mm.,  $n_D^{25}$  1.4080; methyl neopentyl ketone, b.p. 124° at 740 mm.,  $n_D^{25}$  1.4012; and the various fractions from the above reaction. Methyl *t*-amyl ketone was easily identified by absorption peaks at 7.37, 8.79 and 12.87  $\mu$ . By the conventional methods of quantitative analysis, fractions 1–8 were found to contain 5% of methyl *t*-amyl ketone; fraction 9, 15% and fraction 10, 26%. From these data calculations indicate a total of 9% rearrangement of ethyl *t*-butyl ketone to methyl *t*-amyl ketone. No evidence of methyl neopentyl ketone could be detected.

(20) R. Brown and W. E. Jones, *J. Chem. Soc.*, 782 (1946).

(21) E. J. Sakellarios, *Helv. Chim. Acta*, **29**, 1675 (1946).

UNIVERSITY PARK, PENNSYLVANIA

[CONTRIBUTION FROM THE NOYES CHEMICAL LABORATORY, UNIVERSITY OF ILLINOIS]

## The Condensation of *t*-Butylmagnesium Chloride with Duryl *o*-Isopropenylphenyl Ketone<sup>1</sup>

BY REYNOLD C. FUSON, WILLIAM D. EMMONS<sup>2</sup> AND SHALER G. SMITH, JR.

RECEIVED DECEMBER 6, 1954

It has been shown that duryl *o*-isopropenylphenyl ketone (I in text) reacts with *t*-butylmagnesium chloride in the 1,6-manner. The point of attachment of the *t*-butyl group is, significantly, the *para* position of the benzene ring rather than in the vinyl side chain. Catalytic hydrogenation converted the product, 4-*t*-butyl-2-isopropenylphenyl duryl ketone, to 4-*t*-butyl-2-isopropylphenyl duryl ketone, which has been synthesized by an independent method.

Alkylation of duryl phenyl ketone at the *para* position of the phenyl ring by the action of certain Grignard reagents corresponds to a 1,6-addition followed by oxidation of the adduct.<sup>3</sup> Attempts to achieve 1,6-addition in analogously constituted linear ketones failed, however.<sup>4</sup> We therefore turned to hindered diaryl ketones having a vinyl group in a conjugate position. The present paper reports a study of the behavior of one of these, duryl *o*-isopropenylphenyl ketone (I), toward the *t*-butyl Grignard reagent.

(1) This investigation was supported in part by a grant from the Office of Ordnance Research under Contract No. DA-11-022-ORD-874.

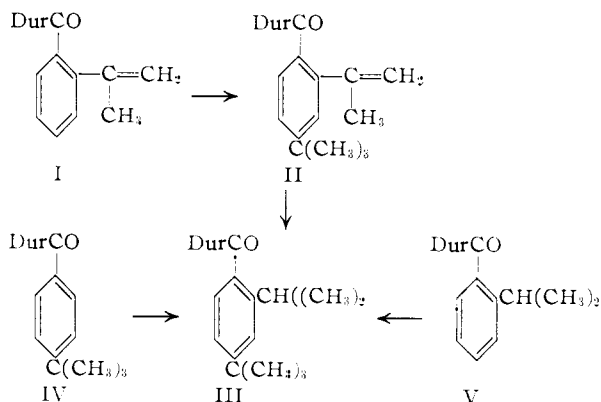
(2) Rohm and Haas Fellow, 1949–1950; Socony-Vacuum Oil Co. Fellow, 1950–1951.

(3) R. C. Fuson and R. Tull, *THIS JOURNAL*, **71**, 2543 (1949).

(4) R. C. Fuson and W. Y. Libby, *J. Org. Chem.*, **16**, 626 (1951).

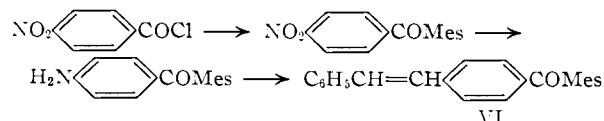
This ketone might conceivably undergo attack not only at the *para* position but also at the terminal position of the vinyl side chain. Experiment showed that *para* alkylation occurs, the product being 4-*t*-butyl-2-isopropenylphenyl duryl ketone (II). The yield was low, however, and, since no other products have been identified, 1,6-addition involving the side chain cannot be excluded as a possibility.

The structure of the butylated ketone was established by reference to 4-*t*-butyl-2-isopropylphenyl duryl ketone (III) to which it could be converted by hydrogenation. The saturated ketone was made, in turn, by treating *p*-*t*-butylphenyl duryl ketone (IV) with the isopropyl Grignard reagent and by the action of *t*-butylmagnesium chlo-



ride on duryl *o*-isopropylphenyl ketone (V). The butylation of the isopropyl compound, also of the 1,6-type, is of special interest in that it gave the alkylation product in 77.8% yield, the highest yet observed in this type of reaction.

*p*-Mesitylstilbene (VI) was treated with the benzyl reagent in the hope of realizing 1,8-addition. A product of the composition that corresponds to the addition of two moles of the reagent was isolated, in fact, but the amount was not sufficient to permit identification. The stilbene was made by the following sequence of reactions, the third step of which was carried out by the method of Meerwein, Büchner and van Emster.<sup>5</sup>



In a second synthesis of the stilbene VI, diazotized *p*-aminobenzoic acid was coupled with cinnamic acid and the chloride of the resulting *p*-carboxystilbene was treated with the mesityl Grignard reagent.

#### Experimental<sup>6</sup>

**Methyl *o*-Duroylbenzoate.**—A mixture of 100 g. of *o*-duroylbenzoic acid<sup>7</sup> and 100 ml. of thionyl chloride was heated under reflux for one hour, and the excess thionyl chloride removed by the aid of a water-pump. The acid chloride was heated under reflux with 2.5 l. of methanol. The ester crystallized when the solution was cooled; m.p. 155.0–156.5°, yield 85 g. (81%).

**Duryl *o*-Isopropenylphenyl Ketone. A. From Methyl *o*-Duroylbenzoate.**—A solution of 10 g. of the ester in 100 ml. of warm, dry benzene was added to a Grignard reagent prepared from 28.8 g. of methyl iodide, 4.93 g. of magnesium and 80 ml. of dry ether. The mixture was stirred under reflux for 4 hours. Decomposition was accomplished with cold, dilute hydrochloric acid. The organic layer was washed thoroughly with water, and the solvent removed. Crystallization of the residue from aqueous ethanol yielded 6.85 g. of a yellow crystalline material. Fractional crystallization of this mixture from ethanol produced 3.3 g. (35%) of duryl *o*-isopropenylphenyl ketone (m.p. 148.5°<sup>8</sup>) and 3.5 g. (35%) of a more alcohol-soluble product.

The infrared spectrum<sup>8</sup> of the isopropenyl compound contained bands attributable to a carbonyl group (1674 cm.<sup>-1</sup>) and probably to a carbon-carbon double bond (1636 cm.<sup>-1</sup>).

(5) H. Meerwein, E. Büchner and K. van Emster, *J. prakt. Chem.*, **162**, 237 (1939).

(6) All melting points are corrected unless otherwise stated.

(7) H. W. Underwood, Jr., and W. L. Walsh, *THIS JOURNAL*, **57**, 940 (1935).

(8) The infrared spectra were recorded and interpreted by Miss Elizabeth Petersen, Miss Helen Miklas and Mr. James Brader.

*Anal.*<sup>9</sup> Calcd. for C<sub>20</sub>H<sub>22</sub>O: C, 86.28; H, 7.97. Found: C, 86.02; H, 8.01.

After repeated recrystallizations from ethanol the more soluble compound melted at 131–134°. Its infrared spectrum indicated the presence of a *t*-alcohol and a hindered carbonyl group. When a mixture of 0.1 g. of the alcohol and 100 ml. of 20% sulfuric acid was heated on the steam-bath for 4 hours, the isopropenyl ketone (m.p. 146–148°) was formed.

In a second experiment a somewhat different procedure was employed. The reaction mixture was decomposed with cold, dilute hydrochloric acid and then was stirred at room temperature for 2.5 hours. During this time the solution assumed a dark red color. The crude product, obtained as before, was crystallized once from ethanol. Fractional sublimation of this material (120° at 0.3 mm.) followed by a final recrystallization produced the pure isopropenyl ketone in a 43% yield.

**B. From *o*-Bromophenyl Duryl Ketone.**<sup>10</sup>—A solution of 6.3 g. of *o*-bromophenyl duryl ketone in 100 ml. of ether was placed in a nitrogen-swept flask immersed in a solid carbon dioxide-acetone-bath, and a solution of 0.024 mole of *n*-butyllithium in 20 ml. of ether was added. The reaction mixture was swirled for 15 minutes; a deep red color developed. A solution of 2 ml. of acetone in 50 ml. of ether was added and the mixture allowed to stand for 15 minutes. The product, isolated in the usual way, was recrystallized repeatedly from methanol and finally sublimed, m.p. 146–147°. A mixture with an authentic sample of duryl *o*-isopropenylphenyl ketone melted at the same point. The infrared spectra of the two samples were identical.

**Reaction of Duryl *o*-Isopropenylphenyl Ketone with *t*-Butylmagnesium Chloride.**—A solution of 3.0 g. of duryl *o*-isopropenylphenyl ketone in 40 ml. of dry benzene was added, with stirring, to a Grignard reagent made in ether from 5.55 g. of *t*-butyl chloride and 1.32 g. of magnesium. The mixture was heated under reflux for 45 minutes and decomposed with dilute hydrochloric acid. The organic layer was washed with water, with dilute sodium bicarbonate solution and again with water. Most of the solvent was evaporated on the steam-bath, ethanol was added and the hot solution was brought to cloudiness by the addition of water. The yellow, granular crystals that formed were recrystallized from low-boiling petroleum ether; yield of buff needles 0.75 g. (20%), m.p. 154–158° (uncor.), m.p. after sublimation 157–157.5°.

When the condensation was carried out under different conditions, three other products were obtained that were not identified.

**Duryl *o*-Isopropylphenyl Ketone.**—A solution of 2.1 g. of duryl *o*-isopropenylphenyl ketone in 100 ml. of purified dioxane was treated with hydrogen for 2.5 hours in the presence of 0.25 g. of platinum oxide catalyst in a low-pressure hydrogenation apparatus. An additional 0.25 g. of catalyst was then added and the treatment continued for 2.5 hours. The catalyst was removed by filtration, and the solution was concentrated by evaporation of solvent. Enough water was introduced to produce incipient cloudiness. The product separated in long, colorless needles which, after sublimation, melted at 152–153°; the yield was nearly quantitative.

*Anal.* Calcd. for C<sub>20</sub>H<sub>24</sub>O: C, 85.66; H, 8.63. Found: C, 85.73; H, 8.73.

**4-*t*-Butyl-2-isopropylphenyl Duryl Ketone. A. From *p*-*t*-Butylphenyl Duryl Ketone.**—A solution of 3 g. of the ketone<sup>11</sup> in 30 ml. of benzene was added, with stirring, to a solution containing a Grignard reagent prepared from 6.27 g. of isopropyl bromide and 1.24 g. of magnesium in 50 ml. of dry ether. The mixture was heated under reflux, with stirring, for 45 minutes. Dry air was then passed for 30 minutes into the flask containing the boiling mixture. The product, isolated by the usual procedure, was recrystallized from ethanol and sublimed; m.p. 142.5–143°, yield 46.6%.

*Anal.* Calcd. for C<sub>24</sub>H<sub>32</sub>O: C, 85.66; H, 9.59. Found: C, 85.75; H, 9.43.

(9) Microanalyses by Miss Emily Davis, Miss Fachel Kopel, Mrs. Esther Fett, Mrs. Jean Fortney, Mrs. Lucy Chang and Mr. Joseph Nemeth.

(10) This synthesis was carried out by Dr. G. W. Parshall.

(11) R. C. Fuson and B. C. McKusick, *THIS JOURNAL*, **65**, 60 (1943).

**B. From Duryl *o*-Isopropylphenyl Ketone.**—By a procedure very similar to that just given, 1.5 g. of this ketone was treated with *t*-butylmagnesium chloride (0.0321 mole). The product (m.p. 141.5–143°, yield 77.8%) was shown by the method of mixed melting points to be identical to the 4-*t*-butyl-2-isopropylphenyl duryl ketone made by method A.

**C. From 4-*t*-Butyl-2-isopropenylphenyl Ketone.**—The procedure described for duryl *o*-isopropylphenyl ketone was followed except that the treatment was continued for 24 hours. The product (m.p. 142–143°) did not depress the melting point of an authentic specimen of 4-*t*-butyl-2-isopropylphenyl duryl ketone.

***p*-Mesitoylstilbene A. From *p*-Carboxystilbene.**—A mixture of 23.5 g. of *p*-carboxystilbene and 86.9 g. of thionyl chloride was heated under reflux for 3 hours, and the unchanged thionyl chloride removed under reduced pressure. The acid chloride<sup>12</sup> separated from high-boiling petroleum ether in light, buff needles, m.p. 131–133° (uncor.), yield 18.4 g. (72%). To a mixture of 10.4 g. of the chloride in 50 ml. of dry ether was added a Grignard reagent prepared from 9.0 g. of bromomesitylene, 1.1 g. of magnesium and 15 ml. of ether. The mixture was heated under reflux for 5 minutes and decomposed in the usual way. The ketone separated from methanol as colorless crystals, yield 2.1 g. (16%). After repeated recrystallization from ether and methanol it melted at 132–133°.

*Anal.* Calcd. for C<sub>24</sub>H<sub>22</sub>O: C, 88.30; H, 6.79. Found: C, 88.35; H, 6.81.

**B. From *p*-Nitrobenzoyl Chloride.**—To a chilled solution of 25 g. of *p*-nitrobenzoyl chloride, 16.2 g. of mesitylene and 15 ml. of dry benzene was added, in small portions and with stirring, 19.8 g. of aluminum chloride over a period of 20 minutes. Stirring was continued at 0° for 2 hours and the resulting pasty mass was decomposed with cold, dilute sulfuric acid. Ether was added and the organic layer was washed with water, and a 5% sodium bicarbonate solution and again with water. The solution was concentrated by evaporation of solvent; yellow prisms separated, m.p. 125.5–127°, yield 33 g. (91%). Recrystallization from

methanol gave the pure mesityl *p*-nitrophenyl ketone, m.p. 126.5–127.5°.

*Anal.* Calcd. for C<sub>16</sub>H<sub>13</sub>NO<sub>3</sub>: C, 71.40; H, 5.62; N, 5.20. Found: C, 71.67; H, 5.77; N, 5.12.

**Catalytic reduction** was accomplished by treating a slurry of 110 g. of the nitro ketone in ethanol with hydrogen at an initial pressure of 2000 lb. per sq. in. over 10 g. of Raney nickel. The hydrogenation required 4 hours at a temperature below 60°. The crude orange-buff amine melted at 152–154°, yield 80–85%. The pure *p*-aminophenyl mesityl ketone crystallized from high-boiling petroleum ether in long, white needles, m.p. 154–155°.

*Anal.* Calcd. for C<sub>16</sub>H<sub>17</sub>NO: C, 80.30; H, 7.16; N, 5.85. Found: C, 80.47; H, 7.24; N, 5.86.

The catalytic reduction was carried out also with Adams catalyst, and chemical reduction was accomplished with hydrochloric acid and mossy tin.

**Diazotization** was effected by dropwise addition, at 0° with stirring, of a saturated, aqueous solution of 8.79 g. of sodium nitrite to a slurry of 30 g. of the amino ketone, 35.1 g. of concentrated hydrochloric acid and 35.1 g. of ice. Saturated solutions of 40.5 g. of sodium acetate in water and 48.4 g. of *trans*-cinnamic acid in acetone were added to the solution of diazotized amine, and then a saturated, aqueous solution of 6.81 g. of cupric chloride was added dropwise. The mixture was stirred several hours at 0° and allowed to stand overnight. The product crystallized from ether in colorless needles, m.p. 132–133°, yield 21.7 g. (53%). A mixture with *p*-mesitoylstilbene made by method A showed no lowering of the melting point.

Treatment of *p*-mesitoylstilbene with benzylmagnesium chloride gave a product (m.p. 120–121°) that had the composition of a dibenzyl derivative.

*Anal.* Calcd. for C<sub>38</sub>H<sub>36</sub>O: C, 89.72; H, 7.13. Found: C, 89.88; H, 7.25.

The infrared spectrum indicates the presence of a normal hindered ketone group and the absence of an olefinic double bond.

URBANA, ILLINOIS

(12) G. A. R. Kon, *J. Chem. Soc.*, 224 (1948).

[CONTRIBUTION FROM THE NOYES CHEMICAL LABORATORY, UNIVERSITY OF ILLINOIS]

## Calculation of Molecular Geometry by Vector Analysis. Application to Six-membered Alicyclic Rings<sup>1</sup>

BY ELIAS J. COREY AND RICHARD A. SNEEN

RECEIVED OCTOBER 11, 1954

A method for the accurate calculation of molecular geometry by vector analysis is outlined and applied to cyclohexane, cyclohexylidene, cyclohexene, *trans*- $\Delta^1$ -octalin and *trans*- $\Delta^2$ -octalin. The effect of the double bond on the stability and reactivity of these systems is discussed. For example, the calculated data are used to explain the extra strain in cyclohexene over 2-butene (1 kcal./mole), the greater stability of 1-methylcyclohexene over methylenecyclohexane and the tendency of 3-ketoallosteroids to enolize to the  $\Delta^2$ -enols rather than the  $\Delta^3$ -enols.

Continued progress in the study of the chemistry of compounds containing isolated, fused or bridged rings requires in many cases an accurate knowledge of the molecular geometry of these systems. The problem of determining the effect of introducing exo- and endocyclic double bonds on the geometry of the cyclohexane ring, for example, is one of salient importance. Because of our interest in the general subject and in this particular example we have devised a method by which molecular geometry can be calculated accurately, and which, in principle, is applicable to all molecules. This paper presents the essentials of this method, which involves vector analysis, and the results of the calculations for some six-membered alicyclic systems. The examples used

herein illustrate the utility of the vector analytical approach in the solution of problems for which even the finest mechanical models available are inadequate.

### Calculations

The general method of vector analysis was used for all calculations in the following way. The molecule in question was located in a three-dimensional coordinate system having X, Y and Z axes in a manner convenient for the calculations and for the subsequent interpretation of results. The bonds between atoms were designated as vectors in terms of (1) *i*, *j* and *k* which represent the unit vectors in the positive X, Y and Z directions, respectively, and (2) the various atomic coordinates (both known and unknown). Standard values for bond lengths and bond angles were employed except, as is indicated below, where these values were not physically possible. The unknown coordinates and bond angles then were calculated by means of standard trigonometric and vector relationships, especially important among these

(1) Presented in part at the Fifth Conference on Organic Reaction Mechanisms, Durham, N. H., September, 1954.