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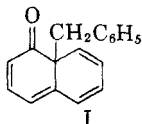
## Nuclear Alkylation of Salts of Naphthols and Anthranol<sup>1</sup>

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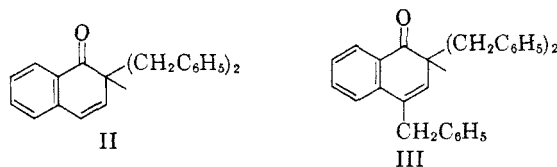
The alkylation with benzyl chloride of the lithium salt of  $\alpha$ -naphthol suspended in toluene has been found to give in addition to the phenolic products 2,2-dibenzyl-1(2)-naphthalenone (II) and a tribenzyl ketone, presumably 2,2,4-tribenzyl-1(2)-naphthalenone (III), but none of the angular benzylation product I was found. Similarly, benzylation of the sodium salt of  $\beta$ -naphthol suspended in dioxane according to the procedure of Zagorevsky<sup>5</sup> has led to the dibenzylated ketone IV, in addition to the products previously reported. Procedures are described for the dibenylation and dimethylation of the lithium salt of anthrone in the 10-position to give the dialkylated anthrones. Again, no evidence of any product formed by alkylation in an angular position is found.

In a continuation of a study of the formation of dienones by the direct alkylation of phenol salts<sup>3</sup> the alkylation of certain naphthol salts was undertaken. The pronounced tendency for *ortho* alkylation<sup>3</sup> made the alkylation of  $\alpha$ -naphthols of particular interest because of the possibility of the formation of polyenones such as I, alkylated in an angular position.



The sodium salt of  $\alpha$ -naphthol had been reported by Claisen, Kremers, Roth, and Tietze<sup>4</sup> to give 2-benzyl-1-naphthol in good yield, but the neutral products, if any, had apparently not been examined. When the lithium salt of  $\alpha$ -naphthol suspended in toluene was treated with benzyl chloride in excess under reflux, there was obtained in addition to some 50% phenolic products approximately 30% carbonyl-containing neutral products. Chromatography of the carbonyl-containing material led to the isolation of a dibenzyl ketone shown to be

2,2-dibenzyl-1(2)-naphthalenone (II) and a tribenzylketone, presumably 2,2,4-tribenzyl-1(2)-naphthalenone (III). None of product I formed by angular benzylation could be detected. A pre-



liminary attempt to improve the preparation of the di- and tribenzylated products II and III by carrying out the benzylation of 2-benzyl-1-naphthol prepared by the method previously reported<sup>4</sup> led to an inseparable mixture of neutral products estimated by the infrared spectrum to contain only about 15% carbonyl compounds.

A rather extensive study of the alkylation of salts of  $\beta$ -naphthol has been reported by Zagorevsky.<sup>5,6,7</sup> For example, benzyl  $\beta$ -naphthyl ether and 1-benzyl-2-naphthol were obtained in yields of 23 and 26% respectively when sodium  $\beta$ -naphthoxide was alkylated in dioxane.<sup>5</sup> In view of the tendency toward polyalkylation shown by lithium

(1) Supported in part by the Office of Ordnance Research, U. S. Army. Taken from the Ph.D. Thesis submitted by Richard Clarence Tuites to the University of Illinois, 1959.

(2) Allied Chemical and Dye Fellow, 1957-58.

(3) See D. Y. Curtin and R. R. Fraser, *J. Am. Chem. Soc.*, **80**, 6016 (1958); **81**, 662 (1959), and references therein cited.

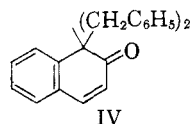
(4) L. Claisen, F. Kremers, F. Roth, and E. Tietze, *Ann.*, **444**, 213 (1925).

(5) V. A. Zagorevsky, *J. Gen. Chem. (U.S.S.R.)*, **27**, 3055 (1957).

(6) V. A. Zagorevsky, *J. Gen. Chem. (U.S.S.R.)*, **28**, 488 (1958).

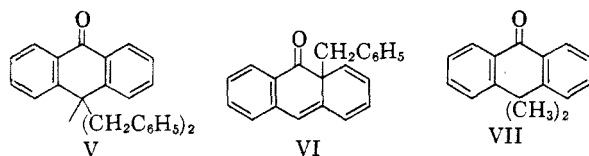
(7) See also E. Wenkert and R. D. Youssefyeh, *J. Am. Chem. Soc.*, in press. We are indebted to Dr. Wenkert for a copy of this paper prior to publication.

$\alpha$ -naphthoxide in our experiments, Zagorevsky's alkylation of sodium  $\beta$ -naphthoxide was repeated. Infrared examination of the acidic products led to an estimated yield of 1-benzyl-2-naphthol of 22% and examination of the neutral fraction indicated that 22% of benzyl  $\beta$ -naphthyl ether was present. These results are in excellent agreement with those reported by Zagorevsky.<sup>5</sup> However, in addition, the infrared examination of the neutral fraction revealed the presence of a carbonyl-containing compound which was isolated by chromatography on alumina and shown to be the dibenzyl ketone (IV). A comparison of the infrared spectrum of the original neutral fraction with that of IV indicated



that 13% of IV was formed and it was isolated in 9% yield. As IV undoubtedly arose from further alkylation of some of the 1-benzyl-2-naphthol first formed, the ratio of carbon- to oxygen-alkylation products is appreciably larger than was indicated by the work of Zagorevsky. As the amount of dialkylation product previously overlooked is probably greatest in those experiments in which there was considerable carbon-alkylation, the conclusions of Zagorevsky are not affected qualitatively by the presence of such dialkylated products. Alkylation of the lithium salt suspended in toluene of 1-benzyl-2-naphthol with  $\alpha$ -deuterobenzyl chloride was used to prepare the deuterated counterpart of the ketone IV which was needed for an NMR study.<sup>8</sup>

The reactions of the lithium salt of anthrone with benzyl chloride and methyl iodide were also examined. The reaction of the lithium salt suspended in toluene with benzyl chloride resulted in a 65% yield of 10,10-dibenzylanthrone (V) and the single narrow carbonyl absorption maximum in the infrared indicated that no significant amount of the angular benzylation product (VI) had formed.



Although the alkylation of anthrone with methyl iodide in the presence of aqueous potassium hydroxide had been reported to yield 10,10-dimethylanthrone (VII) in unspecified yield,<sup>9</sup> more recent attempts to prepare VII by this method have not been successful.<sup>10</sup> The major product of the reaction is 10-methyl-9-methoxyanthracene with yields of 0 to 3% of the dimethyl ketone VII being reported.

(8) J. C. Martin, R. C. Tuites, D. H. Dybvig, and D. Y. Curtin, Manuscript in preparation.

(9) F. Hallgarten, *Ber.*, **21**, 2508 (1888); **22**, 1069 (1889).

More recently, Richardson<sup>11</sup> found that heating the lithium salt of anthrone suspended in methyl iodide at 130° for twenty four hours followed by removal of the excess methyl iodide, re-formation of the salt, and repetition of the heating to attempt to insure dialkylation led to only a 6.5% yield of isolated VII, and infrared examination of the crude reaction mixture indicated that not more than 23% of the desired ketone could have been present. A reexamination of this reaction has led to convenient synthesis of the dimethyl anthrone VII. A suspension of the lithium salt of anthrone together with an equimolar amount of lithium methoxide in methyl iodide containing a few drops of *t*-butyl alcohol gave, after heating at 150° for twenty-four hours and evaporation of the solvent, a 64% yield of dimethylanthrone VII. Again there was no evidence of the alkylation product analogous to VI.

It is concluded, then, that alkylation of polynuclear phenol salts in non-polar medium gives *para*-substitution in preference to alkylation in an angular position and also that the choice of a non-polar medium may be a valuable aid to directing alkylation to a *para*-carbon atom when the *ortho*-positions are blocked. Recently Kornblum and Lurie have advanced evidence that heterogeneity plays an important part in determining the position of alkylation of phenol salts.<sup>12</sup> As all the results described in the present paper were carried out in heterogeneous medium, they provide no information on this point.

#### EXPERIMENTAL<sup>13</sup>

*Alkylation of lithium  $\alpha$ -naphthoxide with benzyl chloride. 2,2-Dibenzyl-1(2)-naphthalenone (II).* The lithium salt of  $\alpha$ -naphthol was prepared by refluxing a solution of 6.0 g. (0.042 mol., 5% excess) of freshly sublimed  $\alpha$ -naphthol in 80 ml. of toluene with a suspension of lithium methoxide in absolute methanol obtained from 0.28 g. (0.04 g. atom) of lithium metal and absolute methanol (24 ml.). The methanol was distilled until the refractive index of the distillate ( $n_D^{25}$ : 1.4930) was that of pure toluene. Benzyl chloride

(10) (a) K. H. Meyer and H. Schlossen, *Ann.*, **420**, 130 (1920). (b) H. Heymann and L. Trowbridge, *J. Am. Chem. Soc.*, **72**, 84 (1950). (c) N. J. Leonard and P. Mader, Unpublished Results. See P. Mader, Ph.D. Thesis, University of Illinois, 1950.

(11) W. Richardson, Ph.D. Thesis, University of Illinois, 1958.

(12) N. Kornblum and A. P. Lurie, *J. Am. Chem. Soc.*, **81**, 2705 (1959).

(13) Microanalyses were determined by Mr. J. Nemeth, Miss C. Higham, Mrs. M. Stingl and Mrs. F. Ju. Infrared spectra were measured by Mr. P. McMahon, Mr. J. Brader, Mr. B. Cloonan, Mr. S. Portnow, and Miss M. DeMott using 0.1-mm. cells with a Model 21 Perkin-Elmer spectrophotometer. Ultraviolet spectra were measured by Mr. M. Chao and Mr. J. Chiu in 1-cm. cells with a Cary model 14 M spectrophotometer. Photographs of the original spectra are in the thesis of R. C. T. available on microfilm from University Microfilms, Ann Arbor, Michigan. The NMR spectra of the products described here are to be reported elsewhere.<sup>8</sup> All melting points are corrected.

(15 g., 0.12 mol.) was added and the reaction was refluxed for 2.5 hr. and filtered, yielding 3.5 g. of residue.

The neutral fraction remaining in the dried toluene layer (50 ml.) after separation of acidic products by extraction with Claisen's alkali<sup>14</sup> showed infrared absorption at 1675 and 1660  $\text{cm}^{-1}$ . Comparison of the spectrum with that of the naphthalenone II measured in chloroform (absorption at 1670  $\text{cm}^{-1}$ ) suggested that the yield of ketonic products was roughly 30% and with that of benzyl  $\alpha$ -naphthyl ether (absorption at 1098–1100  $\text{cm}^{-1}$ ) indicated that about 4% of this ether was present. From the acidified alkaline extracts 3.7 g. of material was recovered. Removal of the toluene from the solution containing the neutral products gave 15 g. which was chromatographed on 100 g. of alumina not specially activated and eluted with hexane and hexane-benzene mixtures. After the first fractions containing benzyl chloride and a portion of the benzyl  $\alpha$ -naphthyl ether there was obtained 5.6 g. of yellow liquid consisting mainly of carbonyl-containing products. Crystallization occurred on standing to give 1.13 g. of a light pink solid, m.p. 60–64°. Attempted recrystallization from methanol-water, acetic acid-water and *n*-hexane was unsuccessful, apparently because of instability of the product. (It discolored and its m.p. range broadened on standing.) Chromatography of the remaining carbonyl-containing fractions together with material from a previous run (total 4.5 g.) on 90 g. of activated alumina gave 50 fractions (100-ml. amounts of eluting solvent) from fraction 29, of which was obtained II as a pale yellow solid, m.p. 60–65°. The infrared spectrum of a 10% chloroform solution contained bands at 1670 and 1645  $\text{cm}^{-1}$  (relative intensities 9/3). The ultraviolet spectrum of a 95% ethanol solution showed  $\lambda_{\text{max}}$  237  $\text{m}\mu$ ,  $\epsilon$  29,000. The assigned structure is strongly supported by the NMR spectrum which showed in addition to the characteristic absorption attributable to the benzylic<sup>8</sup> and aromatic hydrogens a quartette at -66, -57, -51 and -42 c.p.s. (40 Mc., 20% carbon tetrachloride solution). This is the absorption to be expected of two non-equivalent olefinic hydrogens *cis* to one another (J 9 c.p.s.).<sup>15</sup>

Anal. Calcd. for  $\text{C}_{24}\text{H}_{20}\text{O}$ : C, 88.9; H, 6.2. Found: C, 88.8; H, 6.6.

After several months, fractions 37–40 (0.67 g.) crystallized to give a yellowish solid which when recrystallized from *n*-hexane had m.p. 97–98° and is presumed to be 2,2,4-tribenzyl-1(2)-naphthalenone (III). The infrared spectrum showed a maximum at 1665  $\text{cm}^{-1}$  with a shoulder at 1650  $\text{cm}^{-1}$  (10% chloroform solution). The ultraviolet spectrum of a solution in 95% ethanol showed  $\lambda_{\text{max}}$  242  $\text{m}\mu$ ,  $\epsilon$  16,000.

Anal. Calcd. for  $\text{C}_{31}\text{H}_{26}\text{O}$ : C, 89.8; H, 6.3. Found: C, 89.9; H, 6.2.

**Reduction of 2,2-dibenzyl-1(2)-naphthalenone (II).** When 102.4 mg. of ketone II in 15 ml. of ethyl acetate was reduced over 5.3 mg. of Adams' platinum catalyst at room temperature and atmospheric pressure with hydrogen gas for 19 hr. 8.4 ml. had been absorbed (the theoretical amount for the reaction of 1 mol. is 8.0 ml.). The reaction mixture was filtered and distillation of the solvent yielded 100 mg. of colorless gummy product which did not crystallize, and reddened on exposure to air. The ultraviolet spectrum of the reduced product in 95% ethanol showed  $\lambda_{\text{max}}$  243–247  $\text{m}\mu$ ,  $\epsilon$  9,250 and  $\lambda_{\text{max}}$  290  $\text{m}\mu$ ,  $\epsilon$  1,540 in good agreement with those previously reported for 2,2-dimethyl-1(2)-naphthalenone.<sup>16</sup> The NMR spectra of the reduced product showed no absorption in the region -66 to -42 c.p.s.

**Alkylation of sodium  $\beta$ -naphthoxide with benzyl bromide. 1,1-Dibenzyl-2(1)-naphthalenone (IV).** The reaction conditions employed were those of Zagorevsky.<sup>5</sup> To the sodium

salt, prepared from the reaction for 16 hr. of 2.88 g. (0.02 mol.) of  $\beta$ -naphthol in 35 ml. of refluxing dioxane containing 0.46 g. (0.02 g. atom) of sodium metal was added 3.76 g. (0.022 mol.) of freshly distilled benzyl bromide in 5 ml. of dioxane over a period of 2.5 hr. and the reaction was heated for an additional 2 hr. at 104–106°. Separation of the acidic fraction with Claisen's alkali<sup>14</sup> left 3.1 g. of neutral residue the infrared spectrum of which (in chloroform) showed strong absorption at 1645 and a shoulder at 1630  $\text{cm}^{-1}$ . Comparisons with the spectra of 1,1-dibenzyl-2(1)-naphthalenone (IV) (using the absorption intensity at 1645  $\text{cm}^{-1}$  and of benzyl  $\beta$ -naphthyl ether (absorption at 1175  $\text{cm}^{-1}$ ) indicated that the yields of these products were 13 and 22% respectively. Removal of the diethyl ether from the acidic fraction gave 1.98 g. of residue. Comparison of the infrared spectrum with that of 1-benzyl-2-naphthol (absorption at 987  $\text{cm}^{-1}$ ) indicated that the yield was 22%.

Chromatography on 60 g. of activated alumina of the neutral fraction described above gave 0.78 g. of yellow liquid which crystallized on standing. Rechromatography and recrystallization from *n*-hexane gave white crystalline IV (0.56, 8.7%), m.p. 96–97°. The infrared spectrum in chloroform showed a strong maximum at 1645  $\text{cm}^{-1}$  and a shoulder at 1630  $\text{cm}^{-1}$ . The ultraviolet spectrum in 95% ethanol showed  $\lambda_{\text{max}}$  314  $\text{m}\mu$ ,  $\epsilon$  7,620 and  $\lambda_{\text{max}}$  243  $\text{m}\mu$ ,  $\epsilon$  10,500.

Anal. Calcd. for  $\text{C}_{24}\text{H}_{20}\text{O}$ : C, 88.9; H, 6.2. Found: C, 88.9; H, 6.4.

**Alkylation of lithium 1-benzyl-2-naphthoxide with  $\alpha$ -deuterobenzyl chloride. 1-Benzyl-1-benzyl- $\alpha$ -d-2(1)-naphthalenone.** The lithium salt of 1-benzyl-2-naphthol was prepared from 4.0 g. (0.017 mol., 5% excess) of the naphthol in 105 ml. of toluene and lithium methoxide made by the reaction of 0.11 g. (0.016 g. atom) of lithium metal with 15 ml. of methanol and distillation of the methanol.  $\alpha$ -Deuterobenzyl chloride<sup>17</sup> (2.1 g., 0.016 mol.) was added and the reaction was heated under reflux for 20 hr. and filtered. After separation of the acidic fraction with Claisen's alkali,<sup>14</sup> removal of the solvent from the neutral fraction yielded 2.0 g. of residue. Comparison of the infrared spectrum at 1645  $\text{cm}^{-1}$  with that of the undeuterated ketone IV indicated that the yield of carbonyl-containing product was about 24%. Chromatographic separation through 40 g. of neutralized alumina yielded about 1.2 g. of product which after recrystallization from *n*-hexane gave 1-benzyl-1-benzyl- $\alpha$ -d-2(1)-naphthalenone, m.p. 95–97°.

Anal. Calcd. for  $\text{C}_{24}\text{H}_{19}\text{DO}$ : C, 88.6; H, 6.1; D, 5.0. Found: C, 88.7; H, 6.4; D, 5.5.

A similar reaction carried out with undeuterated benzyl chloride yielded 2.7 g. of neutral residue indicated by the infrared spectrum to contain about a 40% yield of the dibenzyl-naphthalenone IV.

**Alkylation of the lithium salt of anthrone with benzyl chloride. 10,10-Dibenzylanthrone (V).** The lithium salt of anthrone was prepared by allowing 3.9 g. (0.02 mol.) of anthrone in 80 ml. of toluene to react with a suspension of lithium methoxide in methanol, prepared from 0.56 g. (0.080 g. atom) lithium metal and 14 ml. of absolute methanol, at reflux. After the removal of the methanol, 7.6 g. (0.060 mol.) of benzyl chloride with 0.2 ml. of *t*-butyl alcohol was added and the reaction was allowed to run at reflux for 15 hr. and filtered, giving 2.4 g. residue.

After separation of acidic products with Claisen's alkali, the infrared spectrum of the neutral fraction showed a large single carbonyl peak at 1665  $\text{cm}^{-1}$ . Comparison with that of the purified V, described below, indicates that the yield of V was not more than 67%. The solution was concentrated under 20 mm. pressure to give 2.0 g. of crude V. Further concentration gave 3.5 g. of gummy residue, not identified. An attempt to sublime the product at 100°/0.8 mm for 3 days was unsuccessful. Rechromatography on alumina gave 1.8 g. (23%), m.p. 226–227.5°. This was recrystallized twice

(14) Prepared by dissolving 350 g. of potassium hydroxide in 250 g. of demineralized water and dilution with absolute methanol to make the volume 1 l.

(15) See M. Karplus, *J. Chem. Phys.*, **30**, 11 (1959).

(16) P. Ramart and M. J. Hoch, *Bull. soc. chim. France* [5] **5**, 860 (1938).

(17) We are indebted to Dr. J. C. Martin and Mr. D. Tulcen for this compound.

from pyridine-water and once from benzene-low boiling petroleum ether yielding white V, m.p. 226–227°. The ultraviolet spectrum in 95% ethanol had an  $\epsilon$  of 18,000 at 270 m $\mu$ .

*Anal.* Calcd. for C<sub>28</sub>H<sub>22</sub>O: C, 89.8; H, 5.9. Found: C, 89.8; H, 6.2.

*Alkylation of the lithium salt of anthrone with methyl iodide.* 10,10-Dimethylanthrone (VII). The lithium salt of anthrone was prepared in the manner described for the benzyl chloride reaction using 7.3 g. (0.040 mol.) of anthrone and 0.56 g. (0.080 g. atom) of lithium metal, giving 2 equivalents of lithium methoxide. The toluene and methanol were removed from the salt by gently heating the flask with a steady stream of nitrogen gas passing over the mixture for 3.5 hr. The dry mixture of the lithium salt of anthrone

and lithium methoxide was heated in a sealed tube previously flushed with nitrogen, together with 25 ml. (a 10-fold excess) of methyl iodide and 0.2 ml. of *t*-butyl alcohol at 150° for 24 hr., and cooled.

After most of the methyl iodide was distilled, the residue was digested with diethyl ether and acidic products extracted with Claisen's alkali.<sup>14</sup> Removal of the ether from the neutral fraction yielded 6.2 g. (70%) of the dimethylanthrone VII, m.p. 95–105°. Chromatography on alumina gave 5.7 g., 96.5–98° (64%). The ultraviolet spectrum of the analytical sample had an  $\epsilon$  of 20,000 at 270 m $\mu$ .

*Anal.* Calcd. for C<sub>16</sub>H<sub>14</sub>O: C, 86.4; H, 6.4. Found: C, 86.4; H, 6.6.

URBANA, ILLINOIS

[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, DUKE UNIVERSITY]

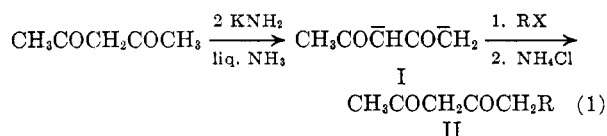
## Alkylations of Acetylacetone and Certain Other $\beta$ -Diketones at the Terminal Methyl Group through Dicarbanions<sup>1</sup>

ROBERT B. MEYER<sup>2</sup> AND CHARLES R. HAUSER

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The generality of the alkylation of the dicarbanion of acetylacetone was investigated. Good yields of terminal alkylation products were obtained when the dicarbanion was treated with primary alkyl halides, but only a fair yield was obtained with isopropyl bromide. Tertiary butyl chloride failed to alkylate the dicarbanion. Benzhydryl chloride and  $\beta$ -phenylethyl chloride gave tetraphenylethylene and styrene respectively when treated with the dicarbanion. Both mono- and symmetrical dialkylation products were obtained with *n*-octyl bromide. Benzylation of dipotassio-*o*-hydroxyacetophenone gave exclusively 2,2-dibenzyl-2'-hydroxyacetophenone. Alkylations of the dicarbanions of other  $\beta$ -diketones were also realized. Mechanisms and synthetic applications are indicated.

It was shown recently in this laboratory<sup>3</sup> that acetylacetone can be benzylated at the terminal methyl group rather than at the methylene carbon where alkylation has generally been observed. This was accomplished by converting the  $\beta$ -diketone to its dicarbanion<sup>4</sup> by means of two molecular equivalents of potassium amide in liquid ammonia, and then adding one molecular equivalent of benzyl chloride. The reaction may be represented by Equation 1, in which R is benzyl:



In the present investigation a study was made of the generality of this mode of alkylation. First it was shown that, at least for the alkylation with benzyl chloride, the intermediate dicarbanion I may be prepared by means of sodium amide as

well as potassium amide.<sup>5</sup> However, dicarbanion I is evidently not produced satisfactorily with two equivalents of lithium amide in liquid ammonia, since the subsequent addition of benzyl chloride failed to yield the alkylation product, the acetylacetone (61%) being recovered.

In Table I are summarized the yields and other data obtained in the alkylations of dicarbanion I with five primary halides and one secondary halide. It can be seen from this table that the primary halides produced good yields (60–77%), but that isopropyl bromide gave only a fair yield (27%). The alkylation failed with *t*-butyl chloride under similar conditions, and the acetylacetone (64%) was recovered.

Since the *n*-butyl, *n*-heptyl, and *n*-octyl halides employed are usually typical of the homologous series of primary alkyl halides, the reaction represented by Equation 1 may be considered quite general when R is primary.

The lower yield with the secondary halide and the failure with the tertiary halide are not surprising since similar observations have been reported in the alkylations of the more common monocarbanions, for example, that of malonic ester.<sup>6</sup>

(5) Whereas dipotassioacetylacetone is formed as a precipitate in liquid ammonia, disodioacetylacetone remains essentially in solution (black).

(6) See A. C. Cope, H. L. Holmes, and H. O. House, *Org. Reactions*, 9, 124 (1957).

(1) Supported in part by the National Science Foundation.

(2) James B. Duke Fellow, 1958–1959.

(3) C. R. Hauser and T. M. Harris, *J. Am. Chem. Soc.*, 80, 6360 (1958).

(4) For the present purpose the dipotassio salt of the  $\beta$ -diketone is considered to consist of the 1,3-dicarbanion I, although other resonance forms may contribute more to the structure of the molecule.