bands at 2.80 μ (hydroxyl), 7.22, and 7.32 μ (*gem*-dimethyl group), and 11.45 and 12.52 μ (1,2,4-trisubstitution). It differed markedly in the fingerprint region from the spectrum of the 7-isomer. The ultraviolet maxima (cyclohexane solvent) were at 286 mμ (ε 2140), 279.5 mμ (ε 2010), 278 mμ (ε 2020), and 272 mμ (ε 1490).

Anal. Calcd. for $C_{12}H_{16}O$: C, 81.77; H, 9.15. Found: C, 81.72; H, 9.22.

The phenylurethan melted at 136–137° (hexane).

Anal. Calcd. for $C_{19}H_{21}NO_2$: C, 77.25; H, 7.17; N, 4.74. Found: C, 76.93; H, 7.16; N, 4.98.

3-Bromopropanol-1-d_2.—The procedure of Nystrom[28] for the unlabeled compound was followed. From 23 g. (0.127 mole) of ethyl 3-bromopropionate, 9.8 g. (0.074 mole) of aluminum chloride, and 3.3 g. (0.078 mole) of lithium aluminum deuteride there was isolated 14.8 g. (78.4%) of the bromo alcohol, b.p. 71.5–74° at 10 mm., $n^{22}D$ 1.4840, with C–D bands at 4.52 and 4.74 μ in the infrared. The n.m.r. spectrum in carbon tetrachloride showed a broadened triplet at 7.96 τ (central methylene), a sharp triplet at 6.49 τ ($-CH_2Br$), and a sharp singlet at 6.27 τ (OH) with the correct relative areas.

1-Bromo-3-chloropropane-3-d_2.—Thionyl chloride (14.4 ml., 0.20 mole) was added at 0° dropwise over 45 min. to 14.6 g. (0.0969 mole) of 3-bromopropanol-1-d_2 containing 5 drops of pyridine. The mixture was stirred at room temperature for 8 hr., then refluxed for 2 hr. Hydrolysis on 30 g. of ice followed by extraction with pentane and drying over sodium sulfate gave 13.6 g. (83.5%) of product, b.p. 51–55° at 32 mm. This was, by gas chromatography (20% silicone, 130°), 85% the desired product, and 15% a lower boiling component (dichloride). The n.m.r. spectrum in carbon tetrachloride showed a broad triplet at 7.74 τ (central CH_2) and a sharp triplet at 6.46 τ ($-CH_2Br$) with equal areas (very different from unlabeled chlorobromide, which is an $A_2B_2X_2$ system).

4-Chlorobutyronitrile-4-d_2.—The procedure was essentially that described for the unlabeled compound.[29] From 12.8 g. (0.076 mole) of 1-bromo-3-chloropropane-3-d_2 there was obtained 4.4 g. (56%) of the nitrile, b.p. 72–75° at 12 mm., $n^{23}D$ 1.4433. The n.m.r. spectrum in carbon tetrachloride showed an A_2B_2 pattern in the 7.4–8.1 τ region.

Ethyl 4-Chlorobutyrate-4-d_2.—The procedure was that of Fehnel[30] for unlabeled material. From 4.3 g. (0.041 mole) of 4-chlorobutyronitrile-4-d_2 there was obtained 5.2 g. (83.5%) of colorless ester, b.p. 69–70° at 9 mm., $n^{22}D$ 1.4320. The two methylenes of interest again gave an A_2B_2 pattern from 7.4–8.1 τ in the n.m.r. spectrum (carbon tetrachloride); in addition, there was a triplet at 8.74 τ and quartet at 5.90 τ for the ethyl group.

2-Methyl-5-chloro-2-pentene-5-d_2 (17).—A solution of 5.0 g. (0.033 mole) of ethyl 4-chlorobutyrate-4-d_2 in 30 ml. of ether was added dropwise (30 min.) at 0° to the Grignard reagent from 2.1 g. of magnesium and 13 g. of methyl iodide in 50 ml. of ether. The mixture was stirred for 30 min. at 0° and 2 hr. at room temperature, then hydrolyzed with 55 ml. of saturated ammonium chloride. Extraction with ether, drying (magnesium sulfate), and removal of the solvent afforded 5.4 g. of crude 2-methyl-5-chloro-2-pentanol-5-d_2 (OH, no C=O in the infrared).

The crude alcohol (4.0 g.) was distilled (50–140°) from 0.5 g. of freshly fused potassium bisulfate to give 2.7 g. of a pale yellow liquid which contained (gas chromatography) 2,2-dimethyltetrahydrofuran, 2-methyl-5-chloro-1-pentene-5-d_2, and mainly the desired 2-methyl-5-chloro-2-pentene-5-d_2. The latter was isolated (0.8 g.) by preparative gas chromatography (20% silicone, 115°, retention time 25 min.). Analysis of its infrared and n.m.r. spectra, as explained in the Discussion, showed that the sample consisted of 79% the desired material, 13% of the 1-olefin, and 8% of 2-methyl-5-chloro-2-pentene-4-d_2.

Alkylation of Phenol with 2-Methyl-5-chloro-2-pentene-5-d_2 (17).—A mixture of 4.0 g. of phenol and 0.50 g. of chloride (79% the desired isomer, as described immediately above) was heated for 8.5 hr. at 150°, then taken up in 15 ml. of methylene chloride and extracted successively with 10 ml. of 20% potassium hydroxide, two 4-ml. portions of Claisen solution, and water, then dried over sodium sulfate. The residue after removal of the solvent was purified by gas chromatography (175°, 20% silicone) to give 110 mg. (15%) of 5,5-dimethylhomochroman as colorless plates, m.p. 47–48°. The n.m.r. spectrum showed a sharp singlet at 8.66 τ (6 methyl protons), a multiplet at 8.1–8.5 τ (3 methylene protons), a singlet at 6.15 τ (1 proton on carbon adjacent to oxygen), and a complex aromatic spectrum, 2.7–3.2 τ (4 protons).

The alkaline extracts were acidified (hydrochloric acid), extracted with methylene chloride, dried, and distilled to remove most of the unreacted phenol. The residue was purified by gas chromatography (20% silicone, 181°) to give 50 mg. of a mixture of deuterated 1,1-dimethyl-5- and 7-tetralols, the former predominating. This, and the low yield, was a reflection not of the product ratio, but of insufficient heat on the exit line, which resulted in some loss of the 7-isomer. The n.m.r. spectrum in carbon tetrachloride showed a complex multiplet at 3.3–3.7 τ (3 aromatic protons), a sharp singlet at 5.28 τ (OH), a structured peak at 7.35–7.45 τ (1 benzylic proton), a complex multiplet at 8.2–8.6 τ (3 methylene protons), and two unequal peaks, singlets, at 8.77 and 8.84 τ (total 6 methyl protons), consistent with equilibration of carbon 3 and 4 of the tetralols.

In an interrupted alkylation, 2 ml. of unlabeled chloride (1) and 6 g. of phenol, heated in a sealed tube at 125° for 1 hr., gave, on gas chromatography, 0.7 g. of recovered chloride and 0.15 g. of crystalline 5,5-dimethylhomochroman. Under identical conditions and reactant ratios, using 0.7 g. of labeled chloride 17, the recovered chloride was completely equilibrated at C-4 and C-5, as was clear from analysis of its n.m.r. spectrum. Finally, a sample of 0.7 g. of 17 was heated with 2 g. of phenol at 125° for 10 min. Under these conditions the amount of alkylation was negligible (gas chromatography). Yet the recovered (90%) chloride was completely equilibrated between 17 and 19 (n.m.r. analysis).

(28) R. F. Nystrom, *J. Am. Chem. Soc.*, **81**, 610 (1959).

(29) C. F. H. Allen in "Organic Syntheses," Coll. Vol. I, John Wiley and Sons, Inc., New York, N. Y., 1932, p. 156.

(30) E. A. Fehnel, *J. Am. Chem. Soc.*, **74**, 1569 (1952).

[CONTRIBUTION FROM THE CHEMISTRY DEPARTMENT, DUKE UNIVERSITY, DURHAM, N. C.]

Alkylations at the γ-Position of Acetoacetaldehyde and α-Benzylacetoacetaldehyde through their Dicarbanions[1]

BY THOMAS M. HARRIS, SANDRA BOATMAN, AND CHARLES R. HAUSER

RECEIVED JUNE 17, 1963

The dicarbanion of acetoacetaldehyde, prepared from sodioacetoacetaldehyde and a molecular equivalent of potassium amide in liquid ammonia, was alkylated at the γ-position with benzyl, methyl, *n*-butyl, and *n*-octyl halides. The resulting monocarbanions were isolated as their copper chelates. Several were also isolated by cyclization with cyanoacetamide to form the cyanopyridones and by self-condensation to form the triacylbenzenes. Similarly, the dicarbanion of α-benzylacetoacetaldehyde underwent benzylation and butylation at the γ-position. This novel mode of alkylation through dicarbanions furnishes a useful method for the synthesis of a number of β-ketoaldehydes and their derivatives.

β-Diketones such as acetyl- and benzoylacetones have previously been alkylated at their terminal methyl group instead of at their more acidic methylene group by employing, as intermediates, their dicarbanions instead of their monocarbanions.[2] The dicarbanions were prepared by means of two molecular equivalents of an alkali amide in liquid ammonia (eq. 1).

$$RCOCH_2COCH_3 \xrightarrow[\text{liq. } NH_3]{2KNH_2} RCO\bar{C}HCO\bar{C}H_2 \xrightarrow[2,\ NH_4Cl]{1,\ R'X} RCOCH_2COCH_2R' \quad (1)$$

In the present investigation the dicarbanions of certain β-ketoaldehydes were prepared and alkylated

(1) (a) Supported by grants from the National Science Foundation and the National Institutes of Health; (b) presented at the 142nd National Meeting of the American Chemical Society, Atlantic City, N. J., September, 1962.

(2) (a) C. R. Hauser and T. M. Harris, *J. Am. Chem. Soc.*, **80**, 6360 (1958); (b) R. B. Meyer and C. R. Hauser, *J. Org. Chem.*, **25**, 158 (1960); (c) K. G. Hampton, T. M. Harris, and C. R. Hauser, *ibid.*, **28**, 1946 (1963).

at the α-position,[3] which corresponds to the terminal methyl position of acetyl- and benzoylacetones (see eq. 1). First, the dicarbanion of acetoacetaldehyde (II) was prepared from monosodioacetoacetaldehyde (I) and a molecular equivalent of potassium amide in liquid ammonia and alkylated with benzyl, methyl, *n*-butyl, and *n*-octyl halides to form monocarbanions IIIa–d. These were isolated as their copper chelates IVa–d in yields of 55–80% (Scheme A and Table I).

SCHEME A

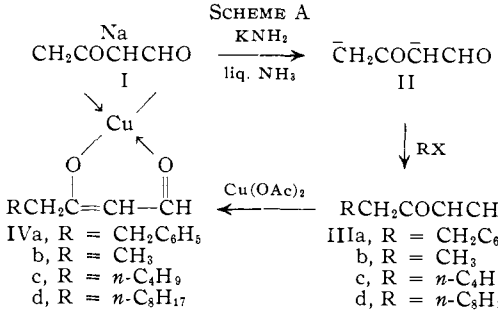


TABLE I

COPPER CHELATES IVa–d ACCORDING TO SCHEME A

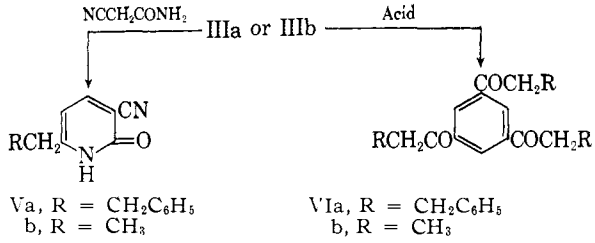
Alkyl halide	Copper chelate	Yield, %[a]	M.p., °C.	Lit. m.p., °C.
$C_6H_5CH_2Cl$	IVa	80	176–178[b]	176[c]
CH_3Br	IVb	66	123–124[d]	...[e]
n-C_4H_9Br	IVc	72	125.5–127.5[f]	...[g]
n-$C_8H_{17}Br$	IVd	55	124–124.5[h]	122[i]

[a] Over-all yield from I; yield reported of material of slightly lower purity than that for which the melting point is recorded. [b] Recrystallized from ethanol–chloroform. [c] Ref. 7. [d] Recrystallized from hexane; see Experimental. [e] *Anal.* Calcd. for $C_{10}H_{14}O_4Cu$: C, 45.88; H, 5.39; Cu, 24.28. Found: C, 45.69; H, 5.20; Cu, 24.14. [f] Recrystallized from carbon tetrachloride. [g] *Anal.* Calcd. for $C_{16}H_{26}O_4Cu$: C, 55.55; H, 7.58; Cu, 18.37. Found: C, 55.26; H, 7.61; Cu, 18.29. [h] Recrystallized from benzene–hexane. [i] Ref. 8.

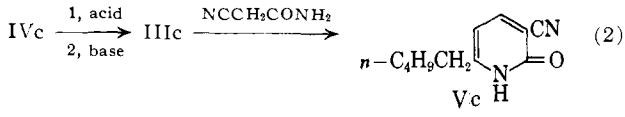
Sodio salt I was prepared by formylation of acetone with ethyl formate effected by sodium methoxide.[4] Free acetoacetaldehyde was not isolated in the preparation of dicarbanion II because this β-ketoaldehyde is known to undergo facile self-condensation to form triacetylbenzene.[5] For the same reason the monocarbanions IIIa–d, formed in the γ-alkylation of dicarbanion II (see Scheme A) were isolated as the copper chelates instead of as the free β-ketoaldehydes.

Furthermore, the monocarbanions IIIa and IIIb were converted to cyanopyridones Va–b and to triacylbenzenes VIa–b, which were obtained by cyclization with cyanoacetamide and by self-condensation of the free β-ketoaldehydes, respectively (Scheme B). The yields of Va–b from I were 61–73%, and those of VIa–b were 27–29%.

SCHEME B



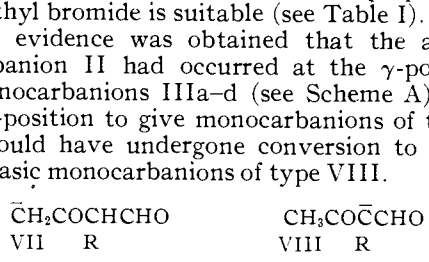
Also copper chelate IVc was converted through monocarbanion IIIc to cyanopyridone Vc (eq. 2, see Experimental).



(2)

It should be pointed out that the solution of monocarbanion IIIb produced by methylation of dicarbanion II with methyl iodide is satisfactory for the preparation of cyanopyridone Vb or triacylbenzene VIb but not for that of copper chelate IVb.[6] For the preparation of IVb, methyl bromide is suitable (see Table I).

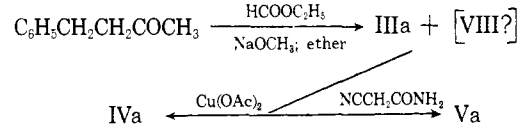
Ample evidence was obtained that the alkylation of dicarbanion II had occurred at the γ-position to form monocarbanions IIIa–d (see Scheme A) and not at the α-position to give monocarbanions of type VII, which would have undergone conversion to the more weakly basic monocarbanions of type VIII.



Copper chelates IVa and IVd, cyanopyridones Va and Vc, and triacylbenzenes VIa and VIb have previously been prepared by other methods, and the melting points and other physical properties of our products were essentially in agreement with those reported (see Table I and Experimental). Moreover, monocarbanions IIIa–b, but not those of type VIII, can undergo self-condensation to form an aromatic system such as VIa–b.[4,5]

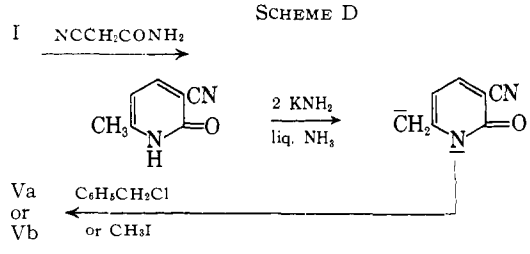
The structures of copper chelate IVa and cyanopyridone Va were confirmed by preparing these compounds from a sample of monocarbanion IIIa that had been independently synthesized by formylation of 4-phenyl-2-butanone under conditions previously shown[7,8] to afford mainly IIIa (Scheme C).

SCHEME C



Still further substantiation for the structures of cyanopyridones Va and Vb was obtained by an independent route involving alkylation of the dianion of 6-methyl-3-cyano-2(1)-pyridone[9] (Scheme D).

SCHEME D



That the alkylation product of dicarbanion II consisted exclusively of the γ-alkyl derivative (see Scheme A) was supported by the fact that it afforded directly the blue copper chelate uncontaminated with the green copper chelate of the α-alkyl derivative.

(3) For a preliminary communication, see T. M. Harris and C. R. Hauser, *J. Am. Chem. Soc.*, **84**, 1750 (1962).

(4) See C. R. Hauser, F. W. Swamer, and J. T. Adams, *Org. Reactions*, **8**, 87 (1954).

(5) Although this self-condensation occurs readily (see R. L. Frank and R. H. Varland, "Organic Syntheses," Coll. Vol. III, John Wiley and Sons, Inc., New York, N. Y., 1955, p. 829), free acetoacetaldehyde has recently been isolated and characterized: D. Dahm, R. Johnson, and F. H. Rathmann, *Proc. N. Dakota Acad. Sci.*, **12**, 19 (1958); *Chem. Abstr.*, **53**, 2084 (1959).

(6) When the solution of IIIb obtained with methyl iodide was treated with cupric acetate, the chelate IVb was not obtained. Apparently reaction had occurred between cupric and iodide ions liberating iodine, which reacted with IIIb.

(7) S. N. Joshi, R. Kaushal, and S. S. Deshapande, *J. Indian Chem. Soc.*, **18**, 479 (1941).

(8) L. M. Roch, *Ann. chim.* (Paris), **6**, 105 (1961).

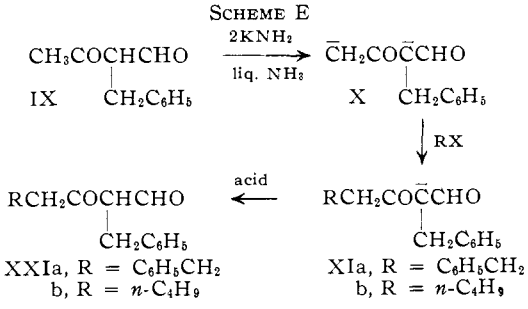
(9) For a communication on this method, see T. M. Harris and C. R. Hauser, *J. Org. Chem.*, **27**, 2967 (1962). Fuller details will be published soon.

The present method appears to be quite general, at least with primary halides. It seems superior in many cases to the common Claisen-type formylation of methyl–methylene ketones, with which condensation may occur at either the methyl group or the methylene group. Actually formylation of 2-butanone,[10,11] 2-pentanone,[11,12] and 2-octanone[13] has been shown to afford appreciable amounts of the methyl formyl derivative even when these reactions were effected in an aprotic solvent, such as benzene or ether, which is known[8] to favor the formation of the latter derivative. Although formylation of 4-phenyl-2-butanone, as well as certain other methyl–methylene ketones, has been reported[8] to give the methyl formyl derivative in an aprotic solvent, we obtained the methyl formyl derivative IIIa evidently contaminated with the methylene derivative VIII in such a solvent (see Scheme C). Thus the copper chelate prepared from the product was blue-green even after several recrystallizations (see Experimental).

It should be mentioned that certain β-ketoaldehydes corresponding to type III carbanions have been prepared satisfactorily by the Friedel–Crafts type of acylation of acetylene[14] or vinyl chloride[15] with acid chlorides.

Next, α-benzylacetoacetaldehyde (IX) was converted by two molecular equivalents of potassium amide in liquid ammonia to dicarbanion X, which was alkylated with benzyl and butyl halides to form γ-derivatives XIIa and XIIb in yields of 51 and 27%, respectively (Scheme E).

SCHEME E



The starting β-ketoaldehyde IX was prepared by formylation of 4-phenyl-2-butanone with ethyl formate effected by means of sodium ethoxide in ethanol.[3] This β-ketoaldehyde and also the γ-alkylation products XIIa-b were sufficiently stable to allow isolation of the free compounds.

That the alkylation products of dicarbanion X were the γ-derivatives XIIa–b was supported by positive enol tests with ferric chloride and by infrared spectra which indicated the presence of enolic structures. Structure XIIa was confirmed by deformylation with alkali to form ketone XIII (50%), and structure XIIb by cyclization with cyanoacetamide to give amide XIV. The conversion of the cyanide group to the amide group may have occurred either before or after the cyclization.

Although some of the α- and/or O-alkylation derivatives might have been formed in the reaction, these would have been separated from XIIa–b by the purification procedure (see Experimental).

The present method of alkylation of an α-substituted acetoacetaldehyde such as IX appears to be useful for the synthesis of certain α-substituted β-ketoaldehydes such as XIIa–b. Although Mariella[16] has observed exclusive formylation at the 2-position of 3-heptanone to form such a compound, a mixture of isomers might be expected in the formylation of many other unsymmetrical methylene–methylene ketones.

Experimental[17]

Sodioacetoacetaldehyde (I).—To a stirred, nitrogen-purged suspension of 43 g. (0.8 mole) of sodium methoxide in 1000 ml. of anhydrous ether cooled in an ice bath was added over 15 min. a mixture of 49.3 g. (0.85 mole) of acetone and 74 g. (1.0 mole) of ethyl formate.[4] The reaction mixture was allowed to warm to room temperature and then to stand for 10 hr. The thick suspension was filtered and the filter cake washed with ether. After drying, there was obtained 75 g. (87%) of sodio salt I, which was protected from atmospheric moisture. This solid salt I was stored without apparent decomposition in a tightly capped bottle until used in subsequent reactions.

Conversion of Monosodio Salt I to Dicarbanion II.—In a typical experiment, 10.8 g. (0.10 mole) of solid monosodioacetoacetaldehyde (I) was added to a stirred solution of 0.11 mole of potassium amide, which had been prepared from 4.3 g. (0.11 g.-atom) of potassium in 250 ml. of commercial, anhydrous liquid ammonia.[2a] After stirring for 15 min., the resulting solution was considered to contain 0.10 mole of dicarbanion II. The solution was employed immediately in the alkylations described below.

Alkylations of Dicarbanion II to form Monocarbanions IIIa–d and Copper Chelates IVa–d (Table I).—To a stirred solution of 0.10 mole of dicarbanion II in 250 ml. of liquid ammonia was added 0.11 mole of benzyl chloride. After 30 min. the ammonia was evaporated as 250 ml. of ether was added. The resulting ethereal suspension was shaken with 200 ml. of cold water. After most of the suspended material had dissolved, the two layers were separated. The aqueous layer, which contained monocarbanion IIIa, was added to 200 ml. of saturated cupric acetate solution, containing 6.6 g. (0.11 mole) of glacial acetic acid. The resulting heavy, gray-blue precipitate, which formed immediately, was separated by extraction into chloroform. The chloroform solution was dried over magnesium sulfate and the solvent evaporated to leave blue copper chelate IVa, which was recrystallized (see Table I).

The alkylations of dicarbanion II with methyl, *n*-butyl, and *n*-octyl bromides to form monocarbanions IIIb–d and copper chelates IVb–d were conducted in a similar fashion. The copper chelate IVb was contaminated with a small amount of gummy material which was removed by passage of a hot hexane solution through a short column of alumina. The chelate was then recrystallized.

Preparation of 6-Alkyl-3-cyano-2(1)-pyridones Va–b from Monocarbanions IIIa–b.—To an aqueous solution of monocarbanion IIIa, prepared from 0.056 mole of dicarbanion II and 0.056 mole of benzyl chloride, was added 6.0 g. (0.072 mole) of cyanoacetamide and 0.5 g. of piperidine acetate. After refluxing for 2 hr., the mixture was cooled and acidified with acetic acid to give 9.6 g. (73% based on I) of 6-phenethyl-3-cyano-2(1)-pyridone (Va), m.p. 186–190°. The m.p. was raised to 204–205° by recrystallization from acetone–ethanol, reported m.p. 198.[7]

In a similar fashion, monocarbanion IIIb, prepared from 0.1 mole of dicarbanion II and 0.13 mole of methyl iodide, was treated with cyanoacetamide. Acidification of the reaction mixture gave 9.0 g. (61% based on I) of 6-ethyl-3-cyano-2(1)-pyridone (Vb), m.p. 231–235°. Three recrystallizations from ethanol–water gave m.p. 244–246°.

Anal. Calcd. for $C_8H_8N_2O$: C, 64.85; H, 5.44; N, 18.91. Found: C, 65.01; H, 5.38; N, 19.03.

Preparation of Cyanopyridone Vc from Copper Chelate IVc.—A small sample of copper chelate IVc was treated with ether and cold, dilute hydrochloric acid. The ether layer was separated and extracted with cold aqueous sodium hydroxide. The basic solution was neutralized with acetic acid, then treated with excess cyanoacetamide and made basic with piperidine. After refluxing 1 hr. the reaction mixture was cooled and acidified with

(10) R. P. Mariella and E. Godar, *J. Org. Chem.* **22**, 566 (1957).

(11) E. E. Royals and K. C. Brannock, *J. Am. Chem. Soc.*, **75**, 2050 (1953); **76**, 1180 (1954).

(12) R. P. Mariella and R. Stansfield, *ibid.*, **73**, 1268 (1951).

(13) E. E. Royals and E. R. Covington, *ibid.*, **77**, 3155 (1955).

(14) N. K. Kochetkov, *Doklady Akad. Nauk S.S.S.R.*, **84**, 289 (1952); *Chem. Abstr.*, **47**, 3309 (1953).

(15) P. R. Hills and F. J. McQuillin, *J. Chem. Soc.*, 4060 (1953).

(16) R. P. Mariella and V. Kvinge, *J. Am. Chem. Soc.*, **70**, 3126 (1948).

(17) Melting points were taken on a Mel-Temp capillary melting point apparatus and are uncorrected. Infrared spectra were determined with a Perkin–Elmer Infracord by the potassium bromide pellet method. Elemental analyses were by Dr. Ing. A. Schoeller, Mikro-Labor, Kronach, West Germany, and by Galbraith Laboratories, Knoxville, Tenn.

acetic acid. The resulting oil was separated by decantation, and gradually crystallized on standing. Recrystallization from hexane gave 6-amyl-3-cyano-2(1)-pyridone (Vc), m.p. 99–100.5° (reported[14] m.p. 95–96°).

Preparation of Triacylbenzenes VIa–b from Monocarbanions IIIa–b.—An aqueous solution of monocarbanion IIIa, obtained from 0.052 mole of dicarbanion II and 0.052 mole of benzyl chloride, was acidified with hydrochloric acid. The liberated β-ketoaldehyde was taken up in ether and 10 ml. of glacial acetic acid was added. The acidified ethereal solution was warmed and then allowed to stand to room temperature for 24 hr. The solvent was evaporated and the residue was recrystallized from methanol to give 2.4 g. (29% based on I) of 1,3,5-tris-(3-phenylpropionyl)-benzene, m.p. 114–117°. Another recrystallization from methanol raised the m.p. to 121.5–122.5°, reported[18] m.p. 122°.

A solution of monocarbanion IIb, obtained from 0.12 mole of dicarbanion II and 0.13 mole of methyl iodide, was acidified with acetic acid, heated 12 hr. at 60°, and then allowed to stand at room temperature for 3 days. A precipitate formed which was removed by filtration and recrystallized from hexane to give 2.7 g. (27% based on I) of 1,3,5-tripropionylbenzene (VIb), m.p. 66–69°. Chromatography of a pentane solution of VIb on alumina raised the m.p. to 71–73°, reported[15] m.p. 74–75°.

Independent Synthesis of Monocarbanion IIIa, Copper Chelate IVa, and Cyanopyridone Va.—To a stirred suspension of 2.70 g. (0.05 mole) of sodium methoxide in 200 ml. of anhydrous ether was added a mixture of 7.40 g. (0.05 mole) of 4-phenyl-2-butanone and 3.70 g. (0.05 mole) of ethyl formate.[7,8] The reaction mixture was allowed to stand at room temperature with occasional shaking for 6 hr., during which a thick suspension of IIIa appeared. Copper chelate IVa was isolated in the same manner as above. The crude chelate was blue-green, m.p. 164–170°, indicating the presence of some of the chelate of VIII. One recrystallization from chloroform–ethanol gave 4.35 g. (42%) of chelate IVa, m.p. 173–175° and 173–176° after two more recrystallizations. Although the recrystallized chelate was blue-green, while that prepared *via* the dicarbanion was blue, a mixture melting point of the two samples was undepressed and their infrared spectra were essentially identical.

A portion of the purified chelate IVa, m.p. 173–176°, was decomposed with dilute hydrochloric acid, and the liberated β-ketoaldehyde was taken up in ether. The ethereal solution was extracted with cold dilute sodium hydroxide solution, and the alkaline extract was neutralized to pH 8. This solution was treated with cyanoacetamide to give cyanopyridone Va, m.p. 193–198° after one recrystallization from water. Further recrystallization from ethanol gave m.p. 204–205°, reported[7] m.p. 198°. A mixture m.p. with Va (m.p. 204–205°) prepared above was undepressed.

2-Benzyl-1,3-butanedione (IX).—4-Phenyl-2-butanone was acylated with ethyl formate in ethanol solution by the method of Roch[8] to give β-ketoaldehyde IX, m.p. 99–101°, reported m.p. 100–101°.

Preparation of Dicarbanion X.—To a stirred solution of 0.24 mole of potassium amide, prepared from 9.4 g. of potassium, in 250 ml. of liquid ammonia was added 15.8 g. (0.09 mole) of 2-benzyl-1,3-butanedione in 100 ml. of tetrahydrofuran. After stirring for 90 min., formation of dicarbanion X was assumed to be complete.

Benzylation of Dicarbanion X.—To a suspension of 0.09 mole of dicarbanion X in a mixture of liquid ammonia and tetrahydrofuran was added 35 g. (0.278 mole) of benzyl chloride and the mixture stirred for 2 hr. The ammonia was evaporated and the tetrahydrofuran removed under reduced pressure. The residue was taken up in ice water and excess benzyl chloride and any neutral products were removed by extraction with ether. The aqueous solution was acidified with acetic acid and extracted three times with ether. The ethereal extracts were combined and dried. Distillation at reduced pressure gave initially several grams of starting β-ketoaldehyde IX, which crystallized in the column, followed by 12.1 g. (51%) of 2-benzyl-5-phenyl-1,3-butanedione (XIIa), b.p. 170–173° at 0.6 mm.

Anal. Calcd. for $C_{18}H_{18}O_2$: C, 81.17; H, 6.81. Found: C, 81.31; H, 6.95.

Ketoaldehyde XIIa gave a violet enol test with ferric chloride and the infrared spectrum showed an enol band at 6.18 μ.

Treatment of XIIa with copper acetate solution gave a green copper chelate, m.p. 163–164° after three recrystallizations from ethanol.

Anal. Calcd. for $C_{36}H_{34}O_4Cu$: C, 72.77; H, 5.77; Cu, 10.69. Found: C, 72.59; H, 5.93; Cu, 10.60.

Alkaline hydrolysis of a sample of undistilled reaction product XIIa gave 1,5-diphenyl-3-pentanone (XIII), b.p. 152–154° at 0.6 mm., in 50% yield. Vapor phase chromatography showed the presence of XIII and 4-phenyl-2-butanone, which presumably arose from starting material. The semicarbazone of XIV melted at 115–117° after three recrystallizations from 80% ethanol, reported[19] m.p. 120–121°.

Butylation of Dicarbanion X.—To a solution of 0.1 mole of dicarbanion X in a mixture of ammonia and tetrahydrofuran was added 40.0 g. (0.29 mole) of *n*-butyl bromide. After 6 hr., the ammonia was evaporated and ether and water were added. The aqueous layer was separated and acidified with cold dilute hydrochloric acid. The acidified mixture was extracted with ether and the combined ether extracts dried. Most of the solvent was removed to precipitate 7.0 g. (40%) of starting β-ketoaldehyde IX, which crystallized out and was removed by filtration. The remainder of the solvent was removed from the filtrate, and the residue distilled to give 2.5 g. (14%) more β-ketoaldehyde IX, b.p. 95–100° at 0.4 mm., and 6.2 g. (27%) of 2-benzyl-1,3-octanedione (XIIb), b.p. 125–140° at 0.4 mm.

Anal. Calcd. for $C_{15}H_{20}O_2$: C, 77.55; H, 8.68. Found: C, 77.74; H, 8.98.

Ketoaldehyde XIIb gave a violet enol test with ferric chloride solution and the infrared spectrum indicated the presence of an enol structure.

Treatment of XXIb with cyanoacetamide in the same manner as above gave pyridoneamide XIV, m.p. 195–197° after recrystallization from acetone. The infrared spectrum showed no nitrile band near 4.5 μ but showed amide absorption at 3.02 and 3.18 μ.

Anal. Calcd. for $C_{18}H_{22}N_2O_2$: C, 72.45; H, 7.43; N, 9.39. Found: C, 72.79; H, 7.32; N, 9.58.

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[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, MASSACHUSETTS INSTITUTE OF TECHNOLOGY, CAMBRIDGE 39, MASS.]

Molecular Asymmetry of Olefins. I. Resolution of *trans*-Cyclooctene[1-3]

BY ARTHUR C. COPE, C. R. GANELLIN, H. W. JOHNSON, JR., T. V. VAN AUKEN,[4] AND HANS J. S. WINKLER

RECEIVED JUNE 12, 1963

Resolution of *trans*-cyclooctene has been accomplished through platinum complexes containing optically active α-methylbenzylamine. Separate fractional crystallizations of *trans*-dichloro-(*trans*-cyclooctene)-[(+ or −)-α-methylbenzylamine]-platinum(II) were carried out to constant rotation. The complexes were destroyed with aqueous potassium cyanide, yielding optically active (−)- and (+)-*trans*-cyclooctene. This novel type of asymmetry demonstrates the inability of the *trans*-olefinic linkage to rotate with respect to the rest of the molecule.

Molecular asymmetry due to restriction of rotation about a pivot bond has been well documented in biphenyl compounds suitably substituted with bulky substituents.[5] In the cyclophane series, molecular asymmetry has been demonstrated more recently.[6]

(1) For preceding communications on this subject see: (a) A. C. Cope, C. F. Howell, and A. Knowles, *J. Am. Chem. Soc.*, **84**, 3190 (1962); (b) A. C. Cope, C. R. Ganellin, and H. W. Johnson, Jr., *ibid.*, **84**, 3191 (1962).

(2) This work has appeared in part in a brief communication, ref. 1b.

(3) Supported in part by the Army Research Office (Durham) under Grant No. DA-ARO-D-31-124-G240.

(4) National Science Foundation Postdoctoral Fellow, 1961–1962.

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