dride 4 or possibly as a lactam. The 393 peak corresponded to the anhydride of the monoethyl ester formulated as 5. Elemental analysis gave values in accord with those for an equimolar mixture of the DNPH of CFA 6 and its monoethyl ester.

Anal. Calcd for $(C_{13}H_{12}N_4O_{11}$–$C_{15}H_{16}N_4O_{11})0.5$; C, 40.5; H, 3.4; N, 13.5. Found: C, 40.2; H, 3.8; N, 13.35.

Slow recrystallization from ethanol containing sulfuric acid gave crystals, mp 150–155°, with analysis corresponding to the diethyl ester 7.

Anal. Calcd for $C_{17}H_{18}N_4O_{10}$: C, 46.57; H, 4.11; N, 12.78. Found: C, 46.12; H, 4.09; N, 12.08.

Citroylformic Acid Lactone.—A solution of 20 g of oxaloacetic acid in 60 ml of water was adjusted to pH 3 with 20% sodium hydroxide and allowed to stand for 19–20 hr at 25–30°. Carbon dioxide was evolved during this period. The solution was decationized by passing through an acidified ion exchange resin bed (22 × 500 mm column of Dowex 50W-X8) and evaporated to dryness under a vacuum evaporator at 35°. The final drying was completed in a vacuum desiccator over anhydrous calcium sulfate to give 12–15 g. The dried residue was partially dissolved in a minimum amount (30 ml) of warm, dry acetone. Nitromethane (dry, about 4 volumes) was added to incipient cloudiness. The mixture was filtered and the solution was allowed to stand at room temperature to deposit crystals. Recrystallization gives the pure lactone of citroylformic acid, mp 160–164° dec, turns brown at 150°. Toluene or xylene can be used in place of the nitromethane. The acetone-insoluble residue is apparently polymeric. The lactone is assigned the butyro-γ-lactone structure arbitrarily. The ir data show absorption (in mineral oil) at 1770, 1740, 1700, and 1660 cm^{-1}.

Anal. Calcd for $C_7H_6O_7$: C, 41.6; H, 2.99; neut equiv, 67.3. Found: C, 41.51; H, 2.98; neut equiv, 67.9.

Oxalocitrolactone Monomethyl Ester Hydrates.—The oxalocitrolactone used in this preparation was prepared from dimethyl oxaloacetate and trimethylamine as previously described[13,14] and was obtained analytically pure (neut equiv calcd, 288; found, 285) on recrystallization from water. The molecular weght (mass spectrometer) was found to be 288.048 (theory 288.050) with reference to the $C_6{}^{35}Cl_3{}^{37}Cl_3$ peak at 287.8043 amu. We confirmed the mp 104–106° reported by Dieckmann.[15]

A mixture of 1.0 g of citrolactone trimethyl ester prepared as above and 20 ml of concentrated hydrochloric acid was heated on a steam bath at 50° for 20 min. The residual oil on cooling deposited crystals in 55% yield. The solution remaining was evaporated at room temperature to 10 ml to deposit additional crystals. The yield is 0.3 g, mp 150–154° dec, R_f 24 (EAW).

Anal. Calcd for $C_9H_8O_9 \cdot H_2O$: C, 38.84; H, 3.59; neut equiv, 92.6. Found: C, 38.93; H, 3.53; neut equiv, 91.37. On prolonged drying under vacuum the material lost water.

Anal. Calcd for $C_9H_8O_9$: neut equiv, 86.6. Found: neut equiv, 85.0. The nmr spectrum of the methyl ester in perdeuteriodimethyl sulfoxide showed maxima at about 3.5 (5 H, two carboxylic, one enolic, two water), 3.8 (3 H, one methyl), and 3.3–3.4 ppm (doublet, two methylene H on asymmetric carbon).

The monomethyl ester hydrate was converted to citric acid in low yield by refluxing with lithium hydroxide, R_f (BFW) 63, but is otherwise stable to alkaline hydrolysis short of further degradation.

Oxalocitrolactone Monoethyl Ester Hydrates.—This compound was prepared following the above procedure for the methyl ester, mp 72–75°, R_f (BFW) 65.

Anal. Calcd for $C_{10}H_{10}O_9 \cdot H_2O$: C, 41.1; H, 4.14; neut equiv, 97.3. Found: C, 41.1; H, 4.13; neut equiv, 94.19.

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Registry No.—**1**, 39118-31-5; **3** (R = R′ = H), 41118-38-1; **3a** (R = R′ = CH_3), 41118-39-2; **3b** (R = CH_3; R′ = H), 41118-40-5; **3b** (R = C_2H_5; R′ = H), 41118-41-6; **4**, 41118-42-7; **5**, 41118-43-8; **6**, 41118-44-9; **6** monoethyl ester, 41118-45-0; **7**, 41118-46-1; diethyl oxaloacetate, 108-56-5; oxaloacetic acid, 328-42-7; citric acid, 77-92-9; DNPH, 119-26-6; citroylformic acid γ-lactone, 41118-47-2.

The Beckmann Fragmentation Reaction of Some α-Hydroxy Ketoximes

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The Beckmann fragmentation reaction of 3β,17β-dihydroxy-16-oximino-5-androstene (**2**) and 2-*exo*-hydroxy-3-oximinobornane (**8**) was readily achieved with *p*-toluenesulfonyl chloride in pyridine at 0° or by short boiling with 20% (v/v) H_2SO_4. The structures of the primary fragmentation products **3** and **9** were deduced on the basis of spectral and analytical properties of the corresponding 2,4-dinitrophenylhydrazones **4** and **10**; in addition, **3** was converted into the known lactone **6**. Anti configurations were assumed for the hydroxy oximes **2** and **8** obtained by $NaBH_4$ reduction of **1** and **7**, based on studies of the $NaBH_4$ reduction of *syn*- and *anti*-benzil monoximes.

The fragmentation reaction of some α-oxo and α-hydroxy oximes, under the conditions of Beckmann rearrangement was discovered by Werner and Piguet in 1904.[1] The mechanism and synthetic utility of the reaction has recently been discussed[2] and the geometry (syn or anti) of the oximes has been shown to influence the nature of the fission products.[1,3] Thus, the *anti*-benzoin oxime (anti to the α-hydroxyl group), on treatment with benzenesulfonyl chloride and pyridine, gives equimolar amounts of benzaldehyde and benzonitrile, whereas the syn isomer, under the same experimental conditions, forms benzaldehyde and phenyl isocyanide.[1] Generally, the anti isomers of α-hydroxy oximes, when treated with variety of reagents which induce Beckmann rearrangement, yield aldehydes or ketones, and nitriles, whereas the syn isomers occasionally yield isocyanides[1,3] The Beckmann fission of α-hydroxy oximes has not been widely studies but a recent report described the fragmentation reaction of 5-hydroxy-5α-cholestan-4- and -6-one oximes with thionyl chloride at −20°. A nearly quantitative yield of 5-oxo-4,5-*seco*-cholestano-4-nitrile and 5-oxo-5,6-*seco*-cholestano-6-nitrile was obtained. It should be noted that no direct evidence was given for the geometries of the starting oximes; owing to exclusive formation of oxo nitriles the authors assumed them to have anti configurations.[4]

We wish to report the results of our studies which were undertaken in order to explore the possibility of

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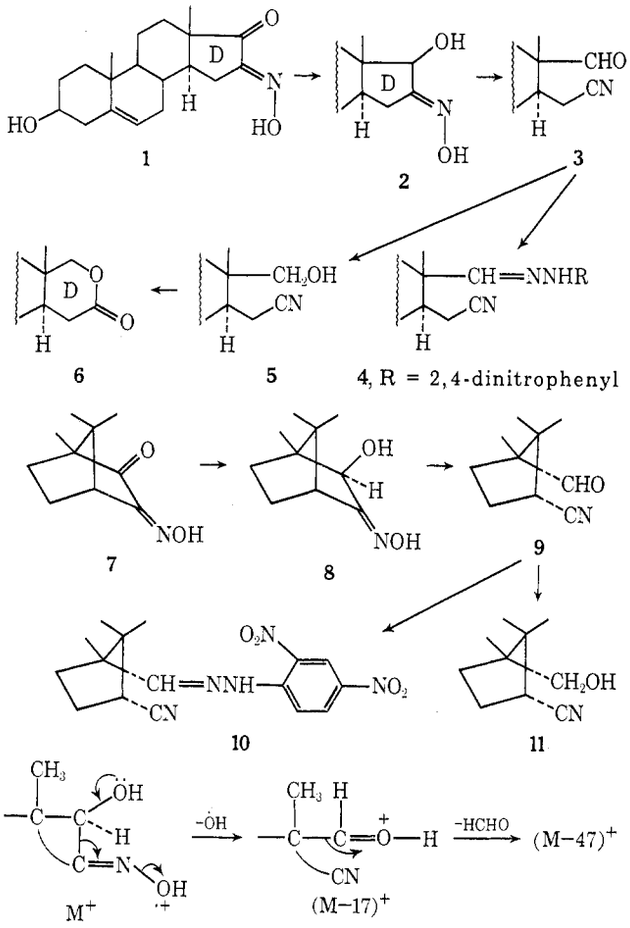
using the Beckmann fission reaction for the synthesis of ring-D seco steroids (certain ring- D seco steroids in the estrone series are known to be very active hypocholesterolemic agents[5]). For our studies we selected the readily available 3β-hydroxy-5-androsten-17-one which was converted into the corresponding 16-oximino derivative (**1**) according to the procedure of Stodola, Kendall, and McKenzie.[6] The anti configuration of 3β-hydroxy-16-oximino-5-androsten-17-one (with respect to the 17-carbonyl group) was proved by a shift in λ_{max} from 240 to 288 nm upon addition of base to the oximino ketone.[7] We intended to reduce the oximino ketone (**1**) with $NaBH_4$ to the corresponding oximino alcohol (**2**) and then to study the Beckmann cleavage reaction using **2** as a substrate. Except for one example,[8] the selectivity of $NaBH_4$ reductions of the keto function in α-oximino ketones has not been studied. Besides, there exists a possibility for syn–anti isomerization during such a reduction. Therefore, we examined the $NaBH_4$ reduction of the syn and anti isomers of benzil monoximes since all the geometrical isomers of benzil monoximes and benzoin oximes are well known.[9] The $NaBH_4$ reduction was carried out in dilute aqueous NaOH or in methanol at room temperature. It was observed that the reduction of the syn isomer proceeded at a considerably slower rate than that of the anti isomer, but, in both cases, the reduced products were obtained in high yield without any syn–anti isomerization detectable.

Thus, the $NaBH_4$ reduction of *anti*-3β-hydroxy-16-oximino-5-androsten-17-one (**1**) should afford only *anti*-3β,17β-dihydroxy-16-oximino-5-androstene (**2**). The 17β orientation was assumed on the basis of the well-known stereochemical course of the $NaBH_4$ reduction of 17-keto group in steroids.[10] The Beckmann cleavage of **2** using *p*-toluenesulfonyl chloride in pyridine at 0° afforded in almost quantitative yield the unstable cyanoaldehyde (**3**), isolated as the 2,4-dinitrophenylhydrazone (**4**). In addition to analytical and spectroscopic data for the 2,4-dinitrophenylhydrazone (**4**), the structure of the primary fragmentation product **3** was proved by its unambiguous transformation to the known lactone (**6**).[11]

An analogous sequence of reactions was carried out in the camphor series. The *anti*-oximinocamphor (**7**) was prepared according to the procedure of Claisen and Manasse[12] (the geometry of **7** was verified by the method used in the case of **1**[7]). The $NaBH_4$ reduction of **7** according to Chittenden and Cooper[8] yielded **8** (60%) where the exo configuration of the 2-hydroxyl group was assigned on the basis of nmr measurements.[8] Although the authors did not discuss the geometrical isomerism of **8**, it seems that the anti configuration can be assumed on the basis of the $NaBH_4$ reduction of the benzil monoximes.

SCHEME I



The Beckmann fragmentation of **8** proceeded extremely easily. Boiling of **8** with dilute H_2SO_4 for 2 min, in the presence of a slight excess of 2,4-dinitrophenylhydrazine, afforded in quantitative yield the corresponding 2,4-dinitrophenylhydrazone (**10**). The unstable cyanoaldehyde **9** was reduced with $NaBH_4$ to the cyano alcohol **11**[13] which, however, could not be hydrolyzed to the known lactone.

The facile formation of the cyano aldehydes **3** and **9** as the only products indicates that the Beckmann fission of α-hydroxy oximes is a concerted process. It can be seen that the axis of the lone pair on the oxygen, the carbon–carbon bond to be broken and the bond between the nitrogen and the leaving group are all parallel, which is the required condition for concerted fragmentation as was first pointed out by Grob.[14]

Finally, it is interesting to note that the α-hydroxy oximes **2** and **8** undergo the Beckmann fission in the vapor phase under the conditions of mass spectrometry. In **8** the most abundant peak is M − 47, whereas in **2**, owing to the presence of the 3β-hydroxyl group and the 5,6 double bond, the mass spectrum is more complex; the M − 47 peak is still of considerable intensity. In both cases, however, the unusual M − 17 peaks are formed as a consequence of the fragmentation process.

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Experimental Section

The melting points are uncorrected. Optical rotations were determined with a Cary 60 spectropolarimeter in a 1.0-cm cell. The ir spectra were recorded in KBr pellets with a Perkin-Elmer infrared spectrophotometer, Model 257, and nmr spectra with a Varian T-60 spectrometer with tetramethylsilane as the internal standard. Chemical shifts (σ) are expressed in parts per million. Mass spectra were recorded with a Varian CH-5 spectrometer.

Sodium Borohydride Reduction of *anti*-Benzil Monoxime.—To an aqueous NaOH solution (20 ml of H_2O; 0.5 g of NaOH, 12.5 mmol) of *anti*-benzil monoxime[9] (0.5 g, 2.2 mmol) sodium borohydride (0.1 g, 2.6 mmol) was added, and the reaction mixture was kept 12 hr at room temperature. After the solution was acidified with 2 *N* sulfuric acid to pH 5, white crystals of the *anti*-benzoin oxime were collected, washed with water, and dried *in vacuo*. Recrystallization from benzene gave a pure sample (0.43 g; 85% yield; mp 152°) which was identical (ir, nmr and mixture melting point) with independently synthesized *anti*-benzoin oxime.[9]

Sodium Borohydride Reduction of *syn*-Benzil Monoxime.—An aqueous solution (20 ml of H_2O) containing NaOH (0.5 g, 12.5 mmol), $NaBH_4$ (0.1 g, 2.6 mmol), and *syn*-benzil monoxime[9] (0.5 g, 2.2 mmol) was kept for 72 hr at room temperature (the reduction was followed by tlc using 4:1 benzene–ethyl acetate as eluent). The reaction mixture was then acidified to pH 5 with 2 *N* H_2SO_4 and extracted with ether. In order to obtain the *syn*-benzoin oxime in a crystalline form, the method described by Werner[1] was used. The ether solution of noncrystalline *syn*-benzoin oxime was kept in a loosely covered beaker for several days at room temperature. The separated crystals were collected, washed with 1:1 ether–hexane, and dried at 50° *in vacuo* (0.42 g; 83% yield; mp 99°). An authentic sample of *syn*-benzoin oxime, synthesized by Werner's method,[1] was identical (ir, nmr and mixture melting point) with the sample prepared by $NaBH_4$ reduction of *syn*-benzil monoxime.

3β,17β-Dihydroxy-16-oximino-5-androstene (2).—An aqueous methanolic solution (15 ml of H_2O and 45 ml of MeOH) containing 3β-hydroxy-16-oximino-5-androsten-17-one (**1**)[6,7] (1.0 g, 3.15 mmol), KOH (0.5 g, 8.9 mmol), and $NaBH_4$ (1.0 g, 26 mmol) was kept for 12 hr at room temperature (at the end of this time a portion of the reduction product separated out). Sulfuric acid (2 *N*) was added to pH 5 and the reaction mixture was kept for several hours at room temperature in order to complete crystallization. The crude **2** was collected and washed thoroughly with 50% aqueous methanol. Recrystallization from methanol (120 ml) afforded analytically pure **2**: 0.75 g; 75% yield; mp 255–257° dec; $[\alpha]^{27}D$ −80° (*c* 1.0 in Py); ir 3600–3050, 1635, 1080, 1050, and 950 cm^{-1}; nmr (Py-d_5): 0.97 (18 methyl), 1.02 (19 methyl), 3.80 (3 α proton, m), 4.43 (17 α proton, s), and 5.40 (C-6 olefinic proton, m); mass spectrum 319 (19, M^+), 301 (38), 286 (34), 283 (28), 272 (52), 268 (43), 231 (33), and 105 (100).

Anal. Calcd for $C_{19}H_{29}NO_3$: C, 71.44; H, 9.15; N, 4.39. Found: C, 71.56; H, 8.88; N, 4.29.

3β-Hydroxy-16,17-*seco*-17-oxo-5-androsteno-16-nitrile 2′,4′-Dinitrophenylhydrazone (4).—To a cold (0°) pyridine solution (20 ml) of 3β,17β-dihydroxy-16-oximino-5-androstene (**2**) (1.0 g, 3.1 mmol) a pyridine solution (5 ml) of *p*-toluenesulfonyl chloride (0.665 g, 3.5 mmol) was added dropwise over a period of 5–10 min. The reaction mixture was kept at 0° for 12 hr and then poured into an excess of cold 2 *N* HCl. The crude 16,17-*seco*-cyanoaldehyde **3** was extracted with $CHCl_3$. After drying and evaporating the chloroform extract, **3** remained in a form of foam: 0.89 g; *ca.* 95%; ir 3600, 3430, 2250, 1720, 1075, 1050, and 1025 cm^{-1}. The crude **3** was dissolved in ethanol (50 ml) and mixed at once with a solution of 2,4-dinitrophenylhydrazine (0.60 g, 3.5 mmol) in 20% H_2SO_4 (25 ml). The fine yellow precipitate of the 2,4-dinitrophenylhydrazone (**4**) separated almost immediately upon mixing; this was filtered off, washed with water until neutral, and dried at 110° *in vacuo* (1.35 g; *ca.* 90% yield, calcd on basis of **2**; mp 218–220°). The crude **4** was recrystallized twice from benzene, giving an analytically pure sample: 1.20 g; 80% yield, mp 228–230°; $[\alpha]^{27}D$ +26° (*c* 1.0 in $CHCl_3$); ir 3600–3150, 3300, 3100, 2245, 1620, 1580, 1340, 1310, 1135, 1055, 840, 830, and 740 cm^{-1}; nmr (in Py-d_5) 1.00 (19 methyl), 1.33 (18 methyl), 3.80 (3α proton, m), 5.40 (C-6 olefinic proton, m), 7.83 (C-17 aldehydic proton, s), 8.07 (C-6′ proton, d, $J_{5',6'}$ = 10 Hz), 8.42 (C-5′ proton, d, $J_{5',6'}$ = 10 Hz), and 9.01 (C-3′ proton, s); mass spectrum 481 (5, M^+).

Anal. Calcd for $C_{25}H_{31}N_5O_5$: C, 62.35; H, 6.49; N, 14.55. Found: C, 62.44; H, 6.60; N, 14.46.

3β,17β-Dihydroxy-16,17-*seco*-5-androsteno-16-nitrile (5).—The crude 3β-hydroxy-16,17-*seco*-16-oxo-5-androsteno-16-nitrile (**3**) (0.9 g) obtained as described in the preceding preparation was dissolved in methanol (30 ml). $NaBH_4$ (1.0 g) was added portionwise to this solution at room temperature, and after 30 min, the reaction mixture was poured into cold 2 *N* HCl. The precipitate was filtered off, washed with water, and dried *in vacuo* at 100° (0.83 g; 87% yield based on **2**; mp 160°). Recrystallization from benzene or methylene chloride–hexane afforded pure **5**: mp 188°; $[\alpha]^{27}D$ −70° (*c* 1.0 in $CHCl_3$); ir 3600–3300, 2250, and 1050 cm^{-1}; nmr (Py-d_5) 1.02 (18 methyl), 1.05 (19 methyl), 3.5 and 3.7 (C-17 protons, AB system, J_{AB} = 10 Hz), 3.6 (3α proton, m), 5.4 (C-6 olefinic proton, m); mass spectrum 303 (13, M^+), 285 (19), 270 (21), 245 (27), 159 (19), 145 (26), 105 (45), 91 (60) and 31 (100).

Anal. Calcd for $C_{19}H_{29}NO_2$: C, 75.20; H, 9.63; N, 4.62. Found: C, 75.09; H, 9.52; N, 4.57.

Lactone of 3β,17β-Dihydroxy-16,17-*seco*-androsten-16-oic Acid (6).—A methanolic solution (10 ml) containing 3β,17β-dihydroxy-16,17-*seco*-5-androsteno-16-nitrile (**5**) (100 mg, 0.33 mmol) and KOH (200 mg, 3.5 mmol) was refluxed for 2 hr, and, after cooling, the solution was acidified with 2 *N* HCl. The crude lactone (**6**) was filtered, washed with water, and dried at 50° *in vacuo* (92 mg; 92% yield; mp 203°). Recrystallization from benzene or methylene chloride–hexane afforded pure **6** (mp 207°, $[\alpha]^{27}D$ +92.6°; this is in an excellent agreement with the reported data[11]).

2-Oxo-3-cyano-2,3-*seco*-bornane 2′,4′-Dinitrophenylhydrazone (10).—*anti*-3-Oximinocamphor (**7**)[12,15] (1.0 g, 6 mmol) and $NaBH_4$ (1.0 g, 26 mmol) were dissolved in water (100 ml) and the solution was kept for 6 hr at room temperature. During this time formation and crystallization of 2-*exo*-hydroxy-3-oximinobornane (**8**)[8,16] was completed. The crude **8** was recrystallized from petroleum ether (bp 70–100°, 70 ml) affording a pure sample (0.605 g; 60% yield; mp 156° in accordance with reported data[8]).

anti-2-*exo*-Hydroxy-3-oximinobornane (**8**) (1.83 g, 10 mmol) was heated for 2 min at 80–100° with dilute sulfuric acid (20 ml; 4:1 v/v H_2O–H_2SO_4); an oily fragmentation product (**9**) separated from the hot solution. Upon cooling in an ice bath a semicrystalline solid (1.60 g; *ca.* 95% yield; ir 2800, 2700, 2220, and 1715 cm^{-1}) was recovered. The crude **9** was dissolved in methanol (50 ml) and mixed with a solution of 2,4-dinitrophenylhydrazine (2.18 g; 11 mmol) in 20% H_2SO_4 (25 ml). The yellow precipitate was filtered, washed with water, and dried at 50° *in vacuo* (3.40 g; 98% yield; mp 182–185°).[17] Recrystallization from methylene chloride–hexane afforded the analytical sample: mp 194–196°; 88% yield; $[\alpha]^{27}D$ +35° (*c* 1.0, $CHCl_3$); ir 3280, 3260, 3110, 2240, 1615, 1585, 1510, 1330, 1140, 1070, 835, 830, and 740 cm^{-1}; nmr ($CDCl_3$) 1.13 (2 methyl groups), 1.16 (1 methyl group), *ca.* 3.0 (CHCN, m), 11.10 (NH, broad), 9.01 (C-3′ proton, d, $J_{3',5'}$ = 2.4 Hz), 8.36, C-5′ proton, two doublets, $J_{3',5'}$ = 2.4 Hz, $J_{5',6'}$ = 10 Hz), 7.95 (C-6′ proton, d, $J_{5',6'}$ = 10 Hz), and 7.6 (C-2 aldehydic proton, s).

Anal. Calcd for $C_{16}H_{19}N_5O_4$: C, 55.64; H, 5.55; N, 20.28. Found: C, 55.66; H, 5.55; N, 20.29.

2-Hydroxy-3-cyano-2,3-*seco*-bornane (11).—The crude **9** (1.60 g), obtained as described above, and $NaBH_4$ (1.0 g) were dissolved in methanol (50 ml). After standing for 2 hr at room temperature, the reaction mixture was acidified with 2 *N* HCl, diluted with water (200 ml), and extracted with ether. After drying and evaporating the ether extract, the residue was recrystallized several times from hexane: mp 140°; 1.25 g; 80% yield; $[\alpha]^{20}D$ +84° (*c* 1.0, $CHCl_3$); ir 3600–3300, 2240, 1460, 1380, 1050, and 1030 cm^{-1}; nmr ($CDCl_3$) 0.97 (1 methyl group),

(15) The mixture of *syn*- and *anti*-3-oximinocamphor prepared according to Claisen and Manasse[12] was converted almost completely into only anti isomer by boiling the mixture for several hours with water.

(16) This presents a considerable simplification over the procedure of Chittinden, *et al.*[8] Mass spectrum of **8**: 183 (4.4, M^+), 166 (29), 136 (100), 122 (40), 109 (94), and 95 (98).

(17) 2,4-Dinitrophenylhydrazone **10** can be prepared in a simpler way: boiling of **8** with dilute H_2SO_4 in the presence of a slight molar excess of 2,4-dinitrophenylhydrazine. An almost quantitative yield of compound **10** was obtained.

1.07 (2 methyl groups), *ca.* 3.0 (CHCN, m), 3.60 (CH_2OH, broad s).

Anal. Calcd. for $C_{10}H_{17}NO$: C, 71.81; H, 10.25; N, 8.38. Found: C, 71.70; H, 10.15; N, 8.44.

Registry No.—**1**, 40962-87-6; **2**, 40962-88-7; **3**, 40962-89-8; **4**, 40962-90-1; **5**, 40962-91-2; **6**, 40962-92-3; **7**, 13854-87-0; **8**, 32231-98-4; **9**, 40962-95-6; **10**, 40962-96-7; **11**, 40962-97-8.

Synthetic Reactions of Propynyllithium and Propynylsodium

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An investigation of the reactions in aprotic solvents of propynyllithium and propynylsodium is reported. Optimum conditions for the formation of 1-(1-propynyl)cyclohexanol, 91% yield, and 2-butynoic acid, 87% yield, are given. A number of other reagents reacted with these two propynyl alkali metal compounds in good to high yield. The coupling of these compounds with alkyl halides was studied in a number of solvents.

Considerable literature exists describing the optimum conditions for the reaction of alkali metal acetylides ($HC{\equiv}CM$) with organic compounds in aprotic solvents, but there are few such references delineating preferred reaction conditions for propynyl alkali ($CH_3C{\equiv}CM$), and higher alkynyl alkali metal ($RC{\equiv}CM$) compounds in aprotic solvents. The optimum reaction conditions for lithium or sodium acetylide with organic compounds should not necessarily correspond to the higher alkynyl alkali metal compounds because of the greater basicity of the substituted acetylenic anions and potential solubility differences. This paper reports a study of the optimization of reaction conditions for propynyllithium and propynylsodium with cyclohexanone and carbon dioxide in aprotic solvents. A number of other organic compounds also reacted with these two compounds. An optimization study of the reaction of *n*-butyllithium with ketones has recently been published in which the higher reactivity observed of the alkyl anion contrasts with the greatly reduced reactivity of the alkynyl anion in this study.[1]

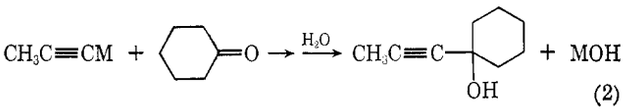
Propynyllithium and propynylsodium may be prepared from the corresponding metal and propyne in liquid ammonia or other solvents, by the reaction of an organometallic and propyne, and by the reaction of lithium or sodium hydride with dimethyl sulfoxide (DMSO) with subsequent addition of propyne.[2] These references also include examples of specific reactions of propynyl alkali compounds. Propynyllithium and propynylsodium are nonpyrophoric, white to off-white powders rapidly decomposed by air and moisture, and are insoluble in hydrocarbon solvents, diethyl ether, 1,2-dimethoxyethane and tetrahydrofuran (THF).[3,4] These two compounds are soluble in DMSO, but the metalation of the DMSO is a competing reaction (eq 1).[2c,5] In fact, this equilibrium appears to be

$$CH_3C{\equiv}CM + CH_3SOCH_3 \longrightarrow CH_3SOCH_2M + CH_3C{\equiv}CH \quad (1)$$

general and favors the dimsyl anion for all alkynes higher than acetylene itself. *N,N*-Dimethylacetamide was slowly attacked by propynyllithium when it was used as the reaction solvent. Therefore, this study focused on the use of the nonreactive solvents, THF, diethyl ether, and hydrocarbons.

Results and Discussion

Optimization of Reaction Conditions for Cyclohexanone.—A commonly used reaction of acetylenic alkali metal compounds is the reaction with ketones to form tertiary alcohols.[6] Cyclohexanone which is sensitive to enolization side reactions was selected as a model ketone to determine the optimum conditions and important factors for the reaction of propynyllithium and propynylsodium with ketones (eq 2).



$$CH_3C{\equiv}CM + \bigcirc{=}O \xrightarrow{H_2O} CH_3C{\equiv}C\text{-}\bigcirc\text{-}OH + MOH \quad (2)$$

M = Li, Na

The results of this study are summarized in Table I. Solvent and temperature were found to be the most critical factors in obtaining a good yield of the tertiary alkynyl alcohol from cyclohexanone. An explanation for the higher yields obtained in THF than in diethyl ether or benzene may be a greater "incipient" solubility of the propynyllithium and/or the lithium salt of the product. The presence of ethylenediamine (EDA) increased the yields greatly in diethyl ether and slightly in THF, probably owing to the increased solubility of the propynyllithium–EDA complex. [The $(CH_3C{\equiv}CLi)_2$–EDA complex has been isolated.][7] The effect of the EDA is almost catalytic considering the first 0.1 mol gives the greatest increase in yield and there is no benefit above 0.5 mol. The dramatic effect of temperature may also be due to a slightly increased "incipient" solubility of the propynyllithium or the salt of the reaction product. Competing side reactions become a problem over 40–45° so that this is the optimum temperature range for cyclohexanone. The addition of lithium bromide to suppress the amount of enolization and increase the solubility of the propynyl-

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