VIIIa was also obtained when khellol (Ib) or 2-norvisnagin (Ic) was oxidized under the same conditions.

Methyl (4,6-Dimethoxybenzofuran)-5-carboxylate (VIIb).—One gram of VIIa was methylated by refluxing it with 25 cc. of acetone, 3 g. of anhydrous potassium carbonate and 5 cc. of methyl iodide for 24 hours. The acetone solution was then filtered off and on its evaporation VIIb was obtained which separated from acetone in colorless crystals, m.p. 83–84°. VIIb was insoluble in alkali and gave a negative ferric chloride reaction.

Anal. Calcd. for $C_{12}H_{12}O_5$: C, 61.0; H, 5.1. Found: C, 61.3; H, 5.2.

6-Hydroxy-4,7-dimethoxybenzofuran-5-carboxylic Acid (VIIc).—When khellin (II) was oxidized with hydrogen peroxide under the same conditions as visnagin, colorless crystals of VIIc were obtained, which, when crystallized from alcohol, had m.p. 149°. VIIc gave a blue color with ferric chloride, and was soluble in sodium bicarbonate solution.

Anal. Calcd. for $C_{11}H_{10}O_6$: C, 55.4; H, 4.2. Found: C, 55.4; H, 4.3.

Condensation of Visnaginone (VIIIa) with Benzaldehyde.—To a mixture of 1 g. of (VIIIa) and 4 cc. of 30% sodium hydroxide solution was added a solution of 1 cc. of benzaldehyde in 5 cc. of alcohol. The red solution was allowed to stand for 24 hours and was then diluted with water to 100 cc. and acidified. The red crystalline precipitate of **5-benzalaceto-4-methoxy-6-hydroxybenzofuran (IXa)** crystallized from ethanol in orange needles, m.p. 106°, m.p. 106° (red melt), and gave a green ferric chloride reaction and a red color with concentrated sulfuric acid, yield 1 g.

Anal. Calcd. for $C_{18}H_{14}O_4$: C, 73.5; H, 4.8. Found: C, 73.3; H, 4.8.

Condensation of Khellinone (VIIIb) with Benzaldehyde.—Khellinone treated as above gave **5-benzalaceto-4,7-dimethoxy-6-hydroxybenzofuran (IXb)** which crystallized from ethanol in orange prisms, m.p. 128° (red melt), giving a brown ferric chloride reaction and a brown-red color with concentrated sulfuric acid.

Anal. Calcd. for $C_{19}H_{16}O_5$: C, 70.4; H, 4.9. Found: C, 69.9; H, 4.8.

4-Methoxy-4',5',5,6-furano-2-benzal-3-coumaranone (XIIa).—To 1.5 g. of IXa dissolved in a mixture of 8 cc. of 16% sodium hydroxide solution and 20 cc. of methanol was added 3 cc. of 15% hydrogen solution. After standing 24 hours in the cold, the precipitate of XIIa was filtered off and crystallized from chloroform–acetone mixture. Yellow prisms, m.p. 189°, were obtained having a negative ferric chloride reaction and giving a blood-red color with concentrated sulfuric acid.

Anal. Calcd. for $C_{18}H_{12}O_4$: C, 74.0; H, 4.1. Found: C, 73.9; H, 4.2.

4,7-Dimethoxy-4',5',5,6-furano-2-benzal-3-coumaranone (XIIb).—It was prepared from IXb by a similar procedure. XIIb crystallized from acetone in orange prisms, m.p. 186° (red melt). It gave no reaction with ferric chloride and an intense violet color with concentrated sulfuric acid.

Anal. Calcd. for $C_{19}H_{14}O_5$: C, 70.8; H, 4.4. Found: C, 70.5; H, 4.4.

CAIRO, EGYPT

[CONTRIBUTION FROM THE LABORATORY OF ORGANIC CHEMISTRY OF THE UNIVERSITY OF WISCONSIN]

Studies Relating to the Formation and Reactions of Glycidic Esters

BY WILLIAM S. JOHNSON, JOHN S. BELEW, LELAND J. CHINN AND RICHARD H. HUNT

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A procedure for effecting the glycidic ester condensation with potassium *t*-butoxide has been developed. This method appears to offer some advantage over previous procedures. The decarboxylation of some glycidic acids has been studied. The most satisfactory method involves conversion to the β-halo-α-hydroxy acid followed by treatment with base which effects spontaneous decarboxylation of the anion. The free glycidic acids corresponding to Ia and Ic were found to be very unstable and easily isomerized into the cyclohexenylglycolic acids IXa and IXb, which do not undergo decarboxylation readily. The latter compounds add bromine, and the resulting dibromo acids are decarboxylated and dehydrobrominated readily with base to form tetrahydrobenzaldehyde and acetylcyclohexene, respectively. Prolonged heating of cyclohexenylglycolic acid with water effects an oxotropic rearrangement to 2-hydroxycyclohexylideneacetic acid (X).

The experiments described in this report were carried out for the purpose of examining some modified techniques of effecting the glycidic ester condensation and of promoting the decarboxylative decomposition to aldehydes and ketones. In the course of this study some interesting rearrangements of glycidic acids were observed and these results are also described.

We have found that potassium *t*-butoxide, which has not hitherto been given serious study as a condensing agent for the glycidic ester condensation,[1] is particularly useful for this purpose. For example, when a solution of this alkoxide in *t*-butyl alcohol was added slowly to a solution of cyclohexanone and ethyl chloroacetate in *t*-butyl alcohol at 10–15°, the glycidic ester Ia was obtained in 83% yield when the reactants were employed on an equimolar basis and in 90% yield from the ketone when the other reactants were used in 10 mole per cent. excess. The best previously reported[2] yield is 65% obtained by the classical sodium ethoxide method. Using equimolar amounts of reactants the new procedure gave an 82% yield of glycidic ester from acetophenone, a 68% yield from benzaldehyde, and a 66% yield from acetone, all of these representing some improvement over the older methods.[1] Other (mostly new) condensations carried out by the modified procedure were: cyclohexanone and *t*-butyl chloroacetate to Ib (82% yield), cyclohexanone and ethyl α-chloropropionate to Ic (86% yield), cyclohexanone and *t*-butyl α-chloropropionate to Id (64% yield), 2-propionyl-6-methoxynaphthalene and ethyl α-chloropropionate to V ($R = C_2H_5$) (71% yield), 3-phenylcyclohexanone and ethyl α-chloropropionate to VII ($R = C_2H_5$) (70% yield), and 3-phenylcyclohexanone and *t*-butyl α-chloropropionate to VII ($R = t\text{-}C_4H_9$) (61% yield).

No generally satisfactory procedure has yet been developed for the hydrolysis and decarboxylation of glycidic esters to aldehydes or ketones.[3] For example, while certain glycidic acids give good yields of the decarboxylation products simply on pyrolysis,[3] the acid obtained by hydrolysis of Ic

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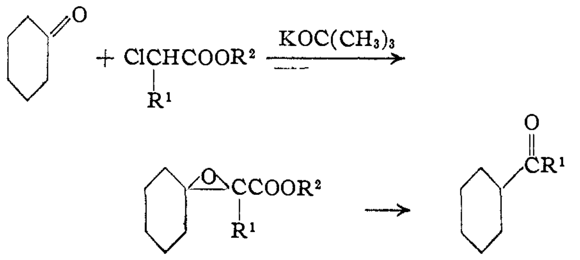
[1] M. S. Newman and B. J. Magerlein, in Adams, "Organic Reactions," Vol. V, John Wiley and Sons, Inc., New York, N. Y., 1949, p. 413.

[2] G. Darzens and P. Lefebure, *Compt. rend.*, **142**, 714 (1906). The 68% yield recorded on p. 431 ref. 1 refers to the higher homolog Ic and not Ia.

[3] Reference 1, p. 422.

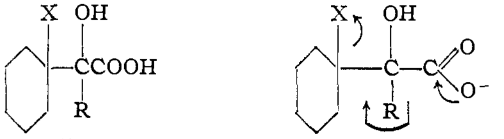


Ia, $R^1 = H, R^2 = C_2H_5$
Ib, $R^1 = H, R^2 = t\text{-}C_4H_9$
Ic, $R^1 = CH_3, R^2 = C_2H_5$
Id, $R^1 = CH_3, R^2 = t\text{-}C_4H_9$
IIa, $R^1 = H$
IIb. $R^1 = CH_3$

gives the ketone IIb in only 27–45% yield.[4] Another case in point is IIa which was obtained in the present work at best in 42% yield by heating the glycidic acid with copper powder. Part of the difficulty appears to lie in the hydrolysis stage which may give glycidic acid of doubtful purity (see below). The procedure of Claisen[5] which consists of treating the glycidic ester with one molar equivalent of sodium ethoxide in absolute alcohol followed by addition of exactly one molar equivalent of water, gives a sodium salt apparently of good quality and in excellent yield. We have found evidence (see below) that even on mild treatment with dilute mineral acid this sodium salt may give rise to a mixture composed of glycidic acid and rearranged products, the latter being unsuitable for decarboxylation. We were, therefore, prompted to study methods which would obviate this step.

A *t*-butyl glycidic ester such as Ib or Id offers an attractive possibility since it would be expected to undergo facile thermal decomposition in the presence of an (anhydrous) acid catalyst to give isobutylene and the free carboxylic acid, which in turn should undergo decarboxylation. Preliminary experiments on direct pyrolysis of Ib, however, did not give promise due to extensive polymerization. When a solution of Ib was heated in a mixture of acetic acid and acetic anhydride with a trace of chloroacetic acid, gas was evolved, and a viscous liquid corresponding in analysis to the diacetate of cyclohexanealdehyde was obtained in less than 24% yield. Treatment of this product with 2,4-dinitrophenylhydrazine gave the 2,4-dinitrophenylhydrazone of cyclohexanealdehyde in 87% yield. When the ester Id was heated at 180° with chloroacetic acid 67% of the calculated volume of gas was evolved, and hexahydroacetophenone (IIb) was isolated as the semicarbazone in 37% yield. After the ester Id had stood for two hours at 0° in a solution of anhydrous hydrogen chloride in acetic acid, 42% of Id was recovered, and hexahydroacetophenone was isolated in 18% yield along with a small amount of crystalline acid, m.p. 92–93°. The nature of this last product is considered below. Other attempts to decompose the *t*-butyl glycidic esters gave even less promising results so the study was abandoned.

Our attention was next turned to the interesting method of Yarnall and Wallis,[4] which consists of treating the glycidic acid with hydrogen chloride followed by decomposition of the resulting β-chloro-α-hydroxy acid (IIIc) in pyridine in the presence of semicarbazide. In this way the acid corresponding to Ic was converted to the semicarbazone of hexahydroacetophenone in 52% yield.[6] This experiment was checked in the present work, the product being obtained in 47% over-all yield from the glycidic acid. In view of the questionable homogeneity of the glycidic acid we modified the procedure of Yarnall and Wallis by treating a suspension of the sodium salt of the glycidic acid (prepared by the Claisen procedure) with anhydrous hydrogen chloride. This gave directly in 98% yield the chlorohydroxy acid IIIc as a crystalline product,



IIIa, X = Cl, R = H
IIIb, X = Br, R = H
IIIc. X = Cl, R = CH_3
IIId. X = Br, R = CH_3

IV

and on treatment with semicarbazide hydrochloride in pyridine, hexahydroacetophenone semicarbazone was produced in 73% yield from crude IIIc, and in 87% yield from recrystallized IIIc. It was discovered that the chloro acid IIIc underwent facile decomposition simply by dissolution in cold dilute sodium bicarbonate solution. From crude IIIc there was thus obtained a 79% yield of hexahydroacetophenone isolated as the semicarbazone. Even on dissolution of IIIc in dilute alcohol solution gas was evolved, and on treatment with sodium acetate and semicarbazide hydrochloride, the derivative was isolated directly in 72% yield. For preparative purposes the chlorohydroxy acid need not be isolated, but is treated directly with dilute sodium hydroxide. Hexahydroacetophenone was thus produced in 68% yield.

The chlorohydroxy acid probably undergoes decarboxylation in the form of the anion.[7] This decomposition may be depicted as shown in formula IV, which postulates that the primary product is the enol form of the ketone. This mechanism is consistent with the findings of Zaugg[7a] that such a process is more rapid as the halide group is changed from Cl to Br to I. Accordingly we examined the bromo acid IIId, and it was observed qualitatively that the decomposition was indeed significantly more rapid, although the yield of semicarbazone (89% from pure IIId) was not appreciably altered. Hence in this instance, the bromo acid offered no preparative advantage. With the lower homologs IIIa and IIIb, however, the yields of cyclohexanealdehyde (as semicarbazone) were 37 and 76%, respectively. The iodo compounds have not been studied.

The modified Yarnall–Wallis method also was applied to the sodium salt V (R = Na) to give in 72% yield the ketone VI (as the semicarbazone), which was desired as an intermediate in a proposed

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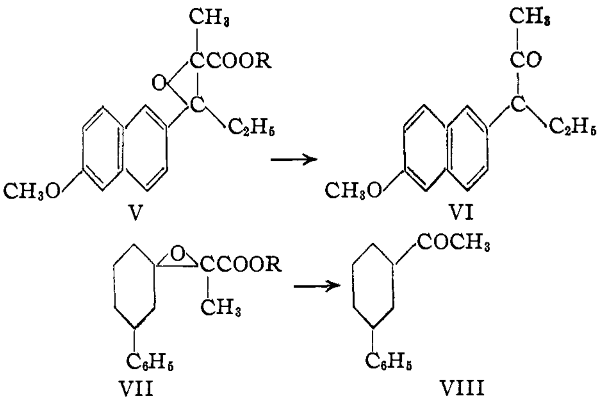
[4] W. A. Yarnall and E. S. Wallis, *J. Org. Chem.*, **4**, 270 (1939).

[5] L. Claisen, *Ber.*, **38**, 693 (1905).

[6] This is the yield of crude material calculated from the weights of materials recorded in ref. 4. The yield of "75%" mentioned in this ref. and reproduced in ref. 1 is probably due to an error in calculation.

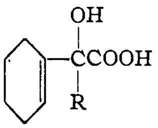
[7] *Cf.* (a) H. E. Zaugg, This Journal, **72**, 2998 (1950); (b) S. J. Cristol and W. P. Norris, *ibid.*, **75**, 632 (1953), and references cited therein.



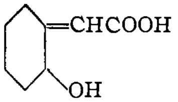
V VI

VII VIII

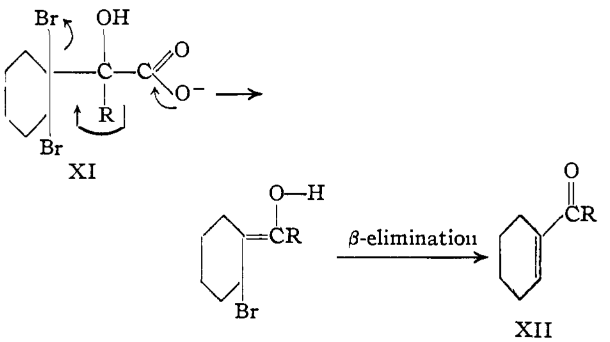
synthesis of bisdehydrodoisynolic acid. 3-Phenylhexahydroacetophenone (VIII) semicarbazone was similarly prepared from VII (R = Na) in 77% yield. The ketone VIII was desired as a reference compound, since it was believed to be a possible constituent of the mixture of isomers produced by the interaction of cyclohexene, acetyl chloride and benzene in the presence of aluminum chloride previously studied in these laboratories.[8] The 3-phenylcyclohexanone required for the preparation of the glycidic ester VII (R = C_2H_5) was prepared by a particularly effective modification of the Robinson–Mannich base synthesis which was developed by Dr. N. F. Albertson.[9] This modification consists in adding dimethyl sulfate to an alcoholic solution of a mixture of sodium ethoxide, ethyl acetoacetate and the Mannich base from acetophenone at 0°. The cyclization and decarboxylation are completed by refluxing with sodium carbonate solution, and thus pure 3-phenyl-2-cyclohexenone was produced in 75% yield.[10] Hydrogenation over palladium-on-carbon readily yielded 3-phenylcyclohexanone.[11]



IXa, R = H
IXb, R = CH_3



X



XI

XII

Rearrangements of Glycidic Acids.—In an attempt to effect decarboxylation under mild acidic conditions, the sodium salt corresponding to Ia was treated with dilute hydrochloric acid for two hours at room temperature. Cyclohexanealdehyde was isolated as the semicarbazone in only 10% yield. The remainder of the material was a crystalline acid which as shown below proved to be 1-cyclohexenylglycolic acid (IXa) isolated in 78% yield. This same material was produced in poor yield by treatment of the glycidic ester Ia with a mixture of sulfuric and acetic acid, followed by saponification of the ethyl cyclohexenylacetoxyacetate. The structure of IXa is established by the following considerations. The m.p. of the pure acid (126–127°) was in agreement with that (126.5°) reported by Chanley[12] for cyclohexenylglycolic acid synthesized from acetylcyclohexene. Catalytic hydrogenation of IXa gave a product melting at that point (135°) reported[13] for hexahydromandelic acid. IXa added bromine readily in a stereospecific manner to give a single diastereoisomer (m.p. 164°) in 81% yield. This on treatment with semicarbazide hydrochloride in pyridine underwent decarboxylation and dehydrohalogenation to produce in 52% yield the semicarbazone of Δ^1-tetrahydrobenzaldehyde (XII, R = H). This transformation can be rationalized by the sequence depicted in formulas XI → XII, and represents the model for a new approach to compounds of the type XII. The sequence has also been carried through in a preliminary study with the homolog (R = CH_3); α-1-cyclohexenyllactic acid (IXb) was isolated in 49% yield from an attempt to effect decarboxylation of the sodium salt corresponding to Ic. Pure IXb melted at 92–93° and there was no depression of the m.p. on admixture with the acid obtained as a by-product from the *t*-butyl ester Id (see above). Addition of bromine to IXb followed by treatment with semicarbazide hydrochloride in pyridine yielded the semicarbazone of 1-acetylcyclohexene, which was compared (mixed m.p.) with authentic material prepared by acetylation of cyclohexene.[14]

On prolonged heating of cyclohexenylglycolic acid (IXa) with water, it was largely isomerized to a new acid, m.p. 156–157°, which did not absorb bromine readily and showed strong end absorption in the ultraviolet, suggesting that it was the α,β-unsaturated tautomer X of an acid-catalyzed three-carbon oxotropic rearrangement.[15] Conclusive proof of the structure of the 157° acid was provided by comparison (mixed m.p.) with authentic material prepared by the action of selenium dioxide on cyclohexylideneacetic acid according to a modification of the method of Kuehl, Linstead and Orkin.[16] For preparative purposes Xa can be obtained directly from the glycidic acid by prolonged treatment with dilute hydrochloric acid.

Experimental[17]

Ethyl 1,α-Epoxycyclohexaneacetate (Ia).—A flask fitted with a thermometer, pressure-equalized dropping funnel

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[8] W. S. Johnson and R. D. Offenhauer, This Journal, **67**, 1045 (1945); C. D. Gutsche and W. S. Johnson, *ibid.*, **68**, 2239 (1946).

[9] We are grateful to Dr. Albertson for making this unpublished information available to us.

[10] *Cf.* the procedure of S. M. Abdullah, *J. Indian Chem. Soc.*, **12**, 62 (1935), which in our hands also gave very low yields.

[11] *Cf.* the method of S. M. Mukherjee and B. K. Bhattacharyya, *ibid.*, **23**, 451 (1946).

[12] J. D. Chanley, This Journal, **70**, 244 (1948).

[13] K. Freudenberg, F. Brauns and H. Siegel, *Ber.*, **56**, 193 (1923).

[14] E. E. Royals and C. M. Hendry, *J. Org. Chem.*, **15**, 1147 (1950).

[15] E. A. Braude, *Quart. Rev.*, **4**, 404 (1950).

[16] F. A. Kuehl, Jr., R. P. Linstead and B. A. Orkin, *J. Chem. Soc.*, 2213 (1950).

[17] Melting points are corrected for stem exposure.

and rubber slip sleeve-sealed wire stirrer was charged with 14.50 g. of freshly distilled cyclohexanone and 18.15 g. of freshly distilled ethyl chloroacetate. A solution of 5.80 g. of potassium in 125 ml. of dry *t*-butyl alcohol[18] was introduced into the dropping funnel and the system was evacuated and filled with nitrogen.[19] The *t*-butoxide was dropped in over a 1.5-hour period with stirring, while the temperature was maintained at 10–15° by cooling the flask with an ice-bath. After the addition was complete, the mixture was stirred for an additional 1–1.5 hours at about 10°. Most of the *t*-butyl alcohol was removed on the steam-bath at reduced pressure, and the residue taken up in ether. The ether solution was washed with water, followed by saturated sodium chloride solution, and finally dried over anhydrous sodium sulfate. The oily liquid remaining on evaporation of the ether was distilled through a 6-inch Vigreux column to give 22.5 g. (82% yield) of colorless glycidic ester, b.p. 139–144° (27 mm.), $n^{25}\text{D}$ 1.4568–1.4577. This material is of good purity as reflected in its behavior in reactions described below.

In a run carried out as described above except that 20.0 g. of ethyl chloroacetate and 6.4 g. of potassium were used, the yield of material boiling at 127–131° (16–18 mm.) was 24.5 g. (90% based on ketone), $n^{25}\text{D}$ 1.4567. The glycidic ester Ia is reported to boil at 128–129° (17 mm.).[2]

Ethyl β-Methyl-β-phenylglycidate.—By the procedure described above for cyclohexanone, the condensation was carried out with 17.85 g. of acetophenone to yield 25.23 g. (82%) of glycidic ester, b.p. 92–99° (0.5–0.6 mm.), $n^{25}\text{D}$ 1.5109. It is reported to boil at 111–114° (3 mm.).[20]

Ethyl β-Phenylglycidate.—By the procedure described above for cyclohexanone, the condensation was carried out with 15.7 g. of benzaldehyde to yield 19.4 g. (68%) of colorless glycidic ester, b.p. 168–172° (28 mm.), $n^{25}\text{D}$ 1.5126. The reported b.p. is 279.5° at atm. pressure.[21]

Ethyl β,β-Dimethylglycidate.—By the procedure described above for cyclohexanone, the condensation was carried out with 8.6 g. of acetone to give 14.17 g. (66% yield), of colorless glycidic ester, b.p. 87–89.5° (30 mm.), $n^{25}\text{D}$ 1.4181. The reported b.p. is 163–168° (760 mm.).[22]

***t*-Butyl 1,α-Epoxycyclohexaneacetate (Ib).**—The glycidic ester condensation with cyclohexanone was carried out just as described above except that 22.3 g. of *t*-butyl chloroacetate (prepared as described below) was used in place of the ethyl ester. The product amounted to 25.82 g. (82% yield), b.p. 97–101° (1–2 mm.). A sample was redistilled, and three arbitrary fractions were taken: (1) b.p. 80–81° (0.4 mm.), $n^{25}\text{D}$ 1.4528; (2) b.p. 81° (0.35 mm.), $n^{25}\text{D}$ 1.4530; (3) b.p. 79° (0.25 mm.), $n^{25}\text{D}$ 1.4529. Fraction 2 was analyzed.

Anal. Calcd. for $C_{12}H_{20}O_3$: C, 67.89; H, 9.50. Found: C, 68.07; H, 9.61.

Ethyl 1,α-Epoxy-α-cyclohexanepropionate (Ic).—By the procedure described above for the preparation of Ia, 29.4 g. of cyclohexanone and 40.8 g. of ethyl α-chloropropionate were treated with 11.9 g. of potassium dissolved in 275 ml. of *t*-butyl alcohol. The product amounted to 51.5 g. (86% yield) of colorless oil, b.p. 117–120° (14 mm.), $n^{25}\text{D}$ 1.4569. The reported b.p. is 127° (19 mm.).[4]

***t*-Butyl 1,α-Epoxy-α-cyclohexanepropionate (Id).**—By the procedure described above for the preparation of Ia, 23.0 g. of cyclohexanone and 38.0 g. of *t*-butyl α-chloropropionate (prepared as described below), were treated with 9.0 g. of potassium dissolved in 230 ml. of *t*-butyl alcohol. The product amounted to 34.03 g. (67% yield) of oil, b.p. 127–128° (13 mm.), $n^{25}\text{D}$ 1.4508.

Anal. Calcd. for $C_{13}H_{22}O_3$: C, 68.99; H, 9.80. Found: C, 68.84; H, 9.82.

Ethyl α-Methyl-β-ethyl-β-(6-methoxy-2-naphthyl)-glycidate (V, R = C_2H_5).—The reaction was carried out according to the procedure for the preparation of Ia except that benzene was added to render the mixture of ketone and chloro ester homogeneous. Thus 10.71 g. of 2-propionyl-6-methoxynaphthalene (m.p. 110.5–111.5°)[23] and 6.8 g. of ethyl α-chloropropionate in 250 ml. of benzene was treated with a solution of 2.0 g. of potassium in 60 ml. of *t*-butyl alcohol. Evaporative distillation of the product at 90° (0.05 mm.) gave 2.04 g. of recovered ketone, and, on raising the temperature to 130°, 11.21 g. (71% yield) of viscous yellow oily glycidic ester. This material was not purified further, but was converted directly to the sodium salt (see below).

Ethyl 1,α-Epoxy-α-(3-phenylcyclohexane)-propionate (VII, R = C_2H_5).—By the procedure described above for the preparation of Ia, 3.22 g. of 3-phenylcyclohexanone (prepared as described below), and 2.80 g. of ethyl α-chloropropionate were treated with 0.8 g. of potassium dissolved in 20 ml. of *t*-butyl alcohol. The product amounted to 3.54 g. (70% yield) of colorless oil, b.p. 134–136° (0.1 mm.).

Anal. Calcd. for $C_{17}H_{22}O_3$: C, 74.42; H, 8.08. Found: C, 74.49; H, 7.98.

***t*-Butyl 1,α-Epoxy-α-(3-phenylcyclohexane)-propionate (VII, R = *t*-C_4H_9).**—By the procedure described above for the preparation of Ia, 2.61 g. of 3-phenylcyclohexanone and 2.47 g. of *t*-butyl α-chloropropionate were treated with 0.60 g. of potassium dissolved in 15 ml. of *t*-butyl alcohol. Evaporation of the ether from the crude product left 2.77 g. (61% yield) of crystalline glycidic ester, m.p. 136–139°. Three recrystallizations from ethanol gave colorless needles, m.p. 140–141°.

Anal. Calcd. for $C_{19}H_{26}O_3$: C, 75.46; H, 8.67. Found: C, 75.36; H, 8.69.

***t*-Butyl Chloroacetate.**—The general method of McCloskey, Fonken and Johnson[24] was used. A mixture of 94.5 g. of monochloroacetic acid, 110 g. of isobutylene, 15 ml. of dioxane and 4 ml. of concentrated sulfuric acid was allowed to stand in a capped heavy-walled Pyrex bottle at room temperature with occasional shaking. After about 15 hours the mixture had become homogeneous. The bottle was chilled in an ice–salt-bath, opened and the mixture poured with stirring into a cold solution of 90 g. of potassium hydroxide in 1 l. of water. The organic layer was separated, washed twice with water, dried over anhydrous potassium carbonate, and distilled through a short Vigreux column. The yield of colorless *t*-butyl ester was 95.3 g. (63%), b.p. 56–57° (16–17 mm.). A sample was redistilled and three arbitrary fractions taken: (1) 58–58.5° (18 mm.), $n^{25}\text{D}$ 1.4209; (2) b.p. 58.5° (18 mm.), $n^{25}\text{D}$ 1.4210; (3) b.p. 58.5–59° (18 mm.), $n^{25}\text{D}$ 1.4204. The product thus appears to be essentially homogeneous. The high carbon values obtained on analysis of fraction (2) suggest, however, that the material is a mixture (azeotrope ?) containing approximately 7% of a polyisobutylene. Irrespective of the contaminant, ester of this quality is entirely suitable for use in the glycidic ester condensation (see above) giving pure products.

Anal. Calcd. for $C_6H_{11}O_2Cl$: C, 47.85; H, 7.36. Found: C, 50.55, 50.29; H, 7.97, 7.87.

***t*-Butyl α-Chloropropionate.**—This ester was prepared essentially as was the lower homolog described above, except that the dioxane was omitted. Thus from 53.0 g. of α-chloropropionic acid, 100 g. of isobutylene and 2 ml. of concentrated sulfuric acid, after 2 days at room temperature, there was obtained 50.1 g. (63% yield) of colorless ester, b.p. 52–53° (12 mm.), $n^{25}\text{D}$ 1.4163. It is especially important in this case that all distillation equipment be rinsed with alkali before use in order to avoid decomposition of the ester.

Anal. Calcd. for $C_7H_{13}O_2Cl$: C, 51.07; H, 7.96. Found: C, 50.80; H, 7.98.

3-Phenylcyclohex-2-ene-1-one.[9]—Sodium (4.8 g.) was dissolved in 125 ml. of absolute alcohol, 33 ml. of ethyl acetoacetate was added, followed by 25.0 g. of phenyl β-piperidinoethyl ketone hydrochloride.[25] The mixture was cooled with an ice–salt-bath, stirring was begun, and 19 ml. of dimethyl sulfate was added slowly from a dropping funnel over a period of 45 minutes. After the addition was complete the mixture was allowed to stand overnight at

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[18] The alcohol is best dried over sodium as described in reference 19, followed by distillation over calcium hydride (1 g. for 4 liters) obtained from Metal Hydrides, Inc.

[19] W. S. Johnson and W. P. Schneider, *Org. Syntheses*, **30**, 18 (1950).

[20] C. F. H. Allen and J. Van Allan, *ibid.*, **24**, 82 (1944).

[21] C. Glaser, *Ann.*, **147**, 104 (1868).

[22] G. Darzens, *Compt. rend.*, **139**, 1214 (1904).

[23] W. S. Johnson and R. P. Graber, THIS JOURNAL, **72**, 925 (1950).

[24] G. S. Fonken and W. S. Johnson, *ibid.*, **74**, 831 (1952).

[25] F. F. Blicke in Adams' "Organic Reactions," Vol. I, John Wiley and Sons, Inc., New York, N. Y., 1942, p. 303.

room temperature, most of the alcohol was removed by distillation at reduced pressure, and 100 ml. of water was added to the residue which was then extracted with ether. The ether solution was dried over anhydrous sodium sulfate, concentrated (steam-bath), and the excess ethyl acetoacetate removed by distillation at reduced pressure. The oily residue was refluxed with 200 ml. of 10% sodium carbonate solution for 20 hours. and the mixture was then extracted with ether. The ether solution was dried over anhydrous sodium sulfate, and concentrated on the steam-bath. Upon cooling, the residue, which amounted to 16.31 g. (94% yield), crystallized, m.p. 42–50°. Distillation gave 12.78 g. (75% yield) of ketone. b.p. 141–144° (0.5 mm.), m.p. 62–63° (reported[10] 64°).

3-Phenylcyclohexanone.—A solution of 6.23 g. of the unsaturated ketone of the preceding experiment in 70 ml. of ethyl acetate was hydrogenated over 0.65 g. of 5% palladium-on-carbon[26] at room temperature and 1–2 atmospheres. After the calculated amount of hydrogen was absorbed, the mixture was filtered, the filtrate concentrated. and the residue distilled. The product amounted to 5.06 g. (81% yield). b.p. 145–149° (11–12 mm.); reported b.p. 140° (6 mm.).[11] The semicarbazone melted at 167.5–169° (reported[11] 169°).

Decarboxylation Studies

Saponification of the Glycidic Esters.—This step was carried out according to the procedure of Claisen.[5] and is typified by the following experiment. To a cool solution of 1.87 g. of sodium in 36 ml. of absolute alcohol was added 15.00 g. of ethyl 1,α-epoxycyclohexaneacetate (Ia). The solution was cooled with an ice-bath and 1.50 ml. of water was added slowly with shaking. The resulting thick white pasty suspension was allowed to stand overnight. The salt was separated by suction filtration, washed with dry ether and dried at 60–70° to constant weight. The yield was 13.97 g. (96%).

A solution of 0.25 g. of the salt in 1 ml. of water was made just acid to litmus and treated with 0.39 g. of *p*-bromophenacyl bromide in 10 ml. of 95% alcohol. After refluxing for 1.5 hours the solution was concentrated to about one-half the original volume. The crystalline product which separated amounted to 0.38 g. (77% yield) of crude *p*-bromobenzoylmethyl **1,α-epoxycyclohexaneacetate**, m.p. 100–110°. Repeated recrystallization from 95% alcohol gave colorless needles. m.p. 108.6–109.4°.

Anal. Calcd. for $C_{16}H_{17}O_4Br$: C, 54.40; H, 4.85. Found: C, 54.40; H. 5.08.

Preliminary Studies in the Preparation of Cyclohexanealdehyde (IIa). (*a*) *Pyrolysis of Acid.*—The glycidic acid was prepared from 12.05 g. of the sodium salt (described in the preceding experiment) by dissolution in water, and acidification in the cold with dilute hydrochloric acid followed by separation through ether extraction. After drying over anhydrous sodium sulfate. the ether was evaporated and the oily residue was heated in a distilling flask at 190–200°. As the acid decarboxylated with vigorous bubbling, a liquid distilled at about 135–180°. Redistillation gave 1.27 g. (15% yield) of crude colorless cyclohexanealdehyde, b.p. 156–157° (reported[2] 155–157°). The identity of all specimens was confirmed by conversion to the orange **2,4-dinitrophenylhydrazone**, m.p. after repeated recrystallization from alcohol–ethyl acetate, 173–173.8°.

Anal. Calcd. for $C_{13}H_{16}O_4N_4$: C, 53.42; H, 5.52. Found: C. 53.70; H, 5.10.

(*b*) *Pyrolysis of Acid in Presence of Copper.*—The glycidic acid obtained as described above from 40.5 g. of the sodium salt was pyrolyzed at 200° in the presence of 1 g. of copper powder. The pyrolysate (b.p. 95–165°) was redistilled giving 11.45 g. (45% yield) of colorless aldehyde, b.p. 153–157°.

(*c*) *Sodium Bisulfite Method.*—A solution of 29.40 g. of sodium glycidate in 150 ml. of saturated sodium bisulfite solution was refluxed for 1.5 hours. then cooled and treated with excess sodium carbonate solution. The alkaline mixture was steam distilled. the distillate saturated with sodium chloride and extracted with ether. The ether solution was dried over anhydrous sodium sulfate, concentrated, and the residue distilled to give 6.14 g. (33% yield) of aldehyde. b.p. 157–162°.

(*d*) *From the t-Butyl Ester Ib.*—A solution of 5.58 g. of the ester and 50 mg. of chloroacetic acid in 5 ml. each of acetic acid and acetic anhydride was heated under reflux until gas evolution ceased (7.25 hours). A total of 59% of the gas calculated for 2 moles per mole of ester was collected in a eudiometer. The solvents were removed under reduced pressure and the residue distilled at 0.1–0.2 mm. to give 1.36 g. of crude colorless **cyclohexanealdehyde diacetate**, b.p. 85–125° and 1.55 g. of a dark viscous product boiling up to 185°. The former fraction was redistilled and a middle fraction, b.p. 83–84° (0.35 mm.), $n^{25}D$ 1.4533, was analyzed.

Anal. Calcd. for $C_{11}H_{18}O_4$: C, 61.66; H, 8.47. Found: C, 62.75; H, 8.53.

The crude sample formed a 2,4-dinitrophenylhydrazone, m.p. 170–173°, in 87% yield. The m.p. was not depressed on admixture with the derivative prepared from cyclohexanealdehyde.

Preliminary Studies in the Preparation of Hexahydroacetophenone (IIb). (*a*) *From the t-Butyl Ester Id.*—A solution of 2.26 g. of Id and 0.45 g. of chloroacetic acid in 30 ml. of ethylene glycol was heated at 180°. After 45 minutes the evolution of gas (48% of the calculated amount) stopped. The mixture was cooled, diluted with water, extracted with ether, and the ether solution was dried over anhydrous potassium carbonate. Evaporation of the ether left an oil which was converted to 0.31 g. (17% yield) of semicarbazone of hexahydroacetophenone, m.p. 173–175°, undepressed on admixture with authentic material.

In another experiment 4.90 g. of Id in 1.00 g. of chloroacetic acid was heated at 180°. After 5 hours 67% of the calculated amount of gas was evolved. The product was isolated as described above to give 1.46 g. (37% yield) of semicarbazone, m.p. 172.5–175°.

(*b*) *The Hydrogen Chloride–Acetic Acid Method.*—Concentrated hydrochloric acid (5.00 g.) was added slowly to 20.0 g. of cold (ice–salt-bath) acetic anhydride. The ester Id (2.26 g.) was added to this solution, and the mixture was kept at 0° for 2 hours with occasional swirling. Excess saturated sodium bicarbonate solution was added, and the mixture extracted with ether. The ether solution was dried over anhydrous potassium carbonate, concentrated and the residue was evaporatively distilled at 100° (14 mm.). The oily distillate was converted to 0.33 g. (18% yield) of semicarbazone, m.p. 173–175°. The remaining oil appeared to consist largely of starting material.

The bicarbonate solution was acidified, extracted with ether, and the ether solution was dried over anhydrous sodium sulfate. Evaporation of the ether gave a semi-solid residue. which after drying for 6 hours at 14–16 mm. amounted to 0.34 g., m.p. 87–90°. Repeated recrystallization from benzene gave colorless needles. m.p. 92–93°, undepressed on admixture with α-1-cyclohexenyllactic acid (see below).

Decomposition of the β-Halo-α-hydroxy Acids. (*a*) *Formation of Hexahydroacetophenone.*—Dry hydrogen chloride was passed through a stirred and cooled (ice-bath) suspension of 3.81 g. of sodium 1,α-epoxy-α-cyclohexanepropionate (prepared in 92% yield from Ic as described above for Ia) in 50 ml. of dry ether. After 30 minutes the excess hydrogen chloride was removed by concentrating the solution on the steam-bath. The residue was treated with ether, and filtered to remove the sodium chloride. Evaporation of the ether left 3.98 g. of **α-hydroxy-α-(1-chlorocyclohexane)-propionic acid** (IIIc). m.p. 105–109° dec. Repeated recrystallization from benzene–petroleum ether gave colorless plates. m.p. 113–114° dec.

Anal. Calcd. for $C_9H_{15}O_3Cl$: C, 52.30; H. 7.32. Found: C, 52.37; H, 6.96.

A 0.483-g. sample of the above acid. m.p. 112–114°. was suspended in a solution of 1.50 g. of semicarbazide hydrochloride in 3 ml. of water. On the addition of 5 ml. of pyridine to this suspension evolution of carbon dioxide began immediately and after 1 minute semicarbazone began to precipitate. After 2 hours at room temperature the reaction appeared to be over, and 30 ml. of water was added. The semicarbazone of hexahydroacetophenone amounted to 0.375 g. (87% yield). m.p. 173.5–175°, without recrystallization.

A similar experiment performed with 3.62 g. of crude IIIc, m.p. 105–109°. 1.50 g. of semicarbazide hydrochloride. and 10 ml. of pyridine. yielded after heating on the steam-bath

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[26] R. Mozingo, *Org. Syntheses*, **26**. 77 (1946).

for 30 minutes, 2.34 g. (73% yield) of semicarbazone, m.p. 174–175°.

A 1.90-g. sample of IIIc, m.p. 110–112°, was dissolved in 20 ml. of water and 20 ml. of 95% alcohol. Gas evolution was observed, and on addition of a mixture of 2.0 g. of sodium acetate and 2.71 g. of semicarbazide hydrochloride, semicarbazone began to precipitate. After standing overnight 1.21 g. (72% yield) of material, m.p. 172–174°. was obtained.

A mixture of 1.26 g. of IIIc and 40 ml. of 5% sodium bicarbonate was heated gently on the steam-bath for 10 minutes. The mixture was extracted with ether, and the ether solution dried over anhydrous potassium carbonate. The oily ketone remaining on evaporation of ether was converted to the semicarbazone by the sodium acetate method; yield 0.89 g. (79%), m.p. 173.5–175°.

For preparing the ketone directly, 13.80 g. of the sodium glycidate suspended in 200 ml. of dry ether was treated as described above with dry hydrogen chloride. Stirring was employed in this experiment. While the reaction temperature was maintained at 5–10°, 7% sodium hydroxide solution was added slowly to the stirred solution. After the mixture became basic to litmus, an additional 30 ml. of the sodium hydroxide solution was added, and stirring continued for 15 minutes. The mixture was extracted with ether, and the ether solution dried over anhydrous potassium carbonate. The ether was removed by distillation through a 14-inch Vigreux column. The residue was then distilled to give 6.21 g. (68% yield) of colorless hexahydroacetophenone, b.p. 87–90° (30 mm.), $n^{25}\mathrm{D}$ 1.4462 (reported b.p. 74–76° (18 mm.)[27] and $n^{16}\mathrm{D}$ 1.4497[28]).

By a procedure identical to that described above for the preparation of the chlorohydroxy acid IIIc, except that hydrogen bromide was used in place of hydrogen chloride. 3.47 g. of the sodium glycidate yielded 3.84 g. of crude solid **α-hydroxy-α-(1-bromocyclohexane)-propionic acid** (IIId). Upon exposure to the atmosphere this material gradually became oily. Four recrystallizations of crude IIId from benzene–petroleum ether gave 3.56 g. (78% yield) of colorless plates, m.p. 106.3–108.6° dec.

Anal. Calcd. for $C_9H_{15}O_3Br$: C. 43.04; H, 6.02. Found: C, 43.18; H, 5.91.

A 0.290-g. sample of the above bromohydroxy acid IIId was treated with 1.50 g. of semicarbazide hydrochloride in 3 ml. of water, just as described above for IIIc. On addition of 5 ml. of pyridine, violent evolution of carbon dioxide was noted. The yield of semicarbazone was 0.188 g. (89%), m.p. 175–176°.

(*b*) *Formation of Cyclohexanealdehyde.*—A suspension of 2.47 g. of sodium 1,α-epoxy-α-cyclohexaneacetate prepared from Ic (see above) in 40 ml. of dry ether was treated with hydrogen chloride as described under part (a) above. The semi-solid ether-soluble material (IIIa) could not be successfully purified; so was treated directly with 3.50 g. of semicarbazide hydrochloride in water and 10 ml. of pyridine. Slow gas evolution was observed. After standing overnight, water was added, and 0.88 g. (37% yield) of cyclohexanealdehyde semicarbazone was obtained, m.p. 170–172° (reported[29] 174°).

In an experiment in which hydrogen bromide was used in place of hydrogen chloride, 4.45 g. of sodium glycidate suspended in 50 ml. of dry ether (stirring) was converted into 5.27 g. of crude, solid **α-hydroxy-α-(1-bromocyclohexane)-acetic acid (IIIb)**. Three recrystallizations from benzene gave 3.47 g. (58% yield) of colorless plates. m.p. 114.9–116.8° dec.

Anal. Calcd. for $C_8H_{13}O_3Br$: C, 40.52; H. 5.52. Found: C. 40.65; H, 5.35.

A 0.385-g. sample of the above bromohydroxy acid IIIb was treated with 1.00 g. of semicarbazide hydrochloride in 2 ml. of water, and 3.5 ml. of pyridine, just as described above for IIIc. The yield of cyclohexanealdehyde semicarbazone was 0.208 g. (76%). m.p. 170–172°.

(*c*) *Formation of 3-(6-Methoxy-2-naphthyl)-pentanone-2* (*VI*).—The crude oily glycidic ester V (R = C_2H_5) was converted to the sodium salt V (R = Na) in 74% yield by the procedure described above for Ia.

A suspension of 6.84 g. of V (R = Na) in 100 ml. of dry ether was treated in the cold with dry hydrogen chloride for 30 minutes as described above under part (a). The crude oily chlorohydroxy acid was treated with 5.0 g. of semicarbazide hydrochloride in water, and 10 ml. of pyridine. The mixture was heated for 30 minutes on the steam-bath, and upon cooling 4.82 g. (72% yield) of semicarbazone of VI crystallized, m.p. 211–214° dec. Repeated recrystallization from methanol–benzene gave colorless needles, m.p. 217–219° dec. with previous softening (introduced at 190°).

Anal. Calcd. for $C_{17}H_{21}O_2N_3$: C, 68.20; H, 7.07. Found: C, 68.60; H, 6.82.

The free ketone was produced by hydrolysis of 1.61 g. of pure semicarbazone with 200 ml. of 5% aqueous oxalic acid. After heating for 10 hours, the mixture was extracted with ether, washed with 5% sodium carbonate solution and dried over anhydrous potassium carbonate. Evaporation of the ether left 1.12 g. (86% yield) of an oil which turned to a colorless crystalline mass, m.p. 54–56°. Three recrystallizations from methanol gave colorless needles, m.p. 60–61°.

Anal. Calcd. for $C_{16}H_{18}O_2$: C. 79.31; H, 7.49. Found: C, 79.32; H, 7.52.

(*d*) *Formation of 3-Phenylhexahydroacetophenone* (*VIII*).—The glycidic ester VII (R = C_2H_5) was converted to the sodium salt VII (R = Na) in 75% yield by the procedure described above for Ia.

A suspension of 0.329 g. of VII (R = Na) in 30 ml. of dry ether was treated in the cold with dry hydrogen chloride for 20 minutes as described above under part (a). The crude chlorohydroxy acid was a colorless crystalline material which, however, turned dark on exposure to the atmosphere and was therefore treated directly with 1.5 g. of semicarbazide hydrochloride in 3 ml. of water. and 5 ml. of pyridine. The crude **semicarbazone of VIII** amounted to 0.245 g. (77% yield). m.p. 196–199° dec. Repeated recrystallization from absolute alcohol gave colorless needles, m.p. 205.2–206.8° dec. (introduced at 160°).

Anal. Calcd. for $C_{15}H_{21}ON_3$: C, 69.46; H, 8.16. Found: C. 69.83; H, 7.93.

The free ketone was prepared by hydrolysis of the semicarbazone, m.p. 203–205°, with 5% oxalic acid. The product was a colorless oil after evaporative distillation at 180° (10 mm.). Attempts to induce crystallization failed.

Anal. Calcd. for $C_{14}H_{18}O$: C. 83.12; H, 8.97. Found: C, 82.58; H, 8.85.

An experiment in which the decomposition of the crude chlorohydroxy acid was effected with dilute sodium bicarbonate gave semicarbazone. m.p. 172.5–175° dec., in 67% yield.

Attempts to isolate semicarbazone of VIII from mixtures of the derivative prepared from fraction no. 8 in the distillation of the Nenitzescu reaction product[8] failed even upon seeding with authentic material prepared as described above.

Rearrangement of Glycidic Acids

1-Cyclohexenylglycolic Acid (IXa).—A solution of 10.00 g. of the sodium glycidate derived from Ia (see above) in 50 ml. of water was treated with 50 ml. of concentrated hydrochloric acid, and the mixture was stirred at room temperature for 2 hours. The mixture was extracted with ether. the ether solution washed thoroughly with sodium bicarbonate solution and dried over anhydrous sodium sulfate. Evaporation of the ether gave 0.94 g. of an oil which was converted to 0.95 g. (10% yield) of semicarbazone of cyclohexanealdehyde. m.p. 171–173°.

Acidification of the bicarbonate wash solutions yielded 6.82 g. (78% yield) of crude 1-cyclohexenylglycolic acid. m.p. 116–120°. Recrystallization from benzene raised the m.p. to 122.6–123.5° which was undepressed on admixture with the analytical specimen described below.

Ethyl 1-Cyclohexenylacetoxyacetate.—To 88.6 g. of ethyl 1,α-epoxycyclohexaneacetate (Ia) was added with cooling (ice-bath) and stirring 400 ml. of 1 *M* sulfuric acid in glacial acetic acid over a period of 1.5 hours. The temperature of the reaction mixture was maintained at 4–10°. After the addition was complete. the yellow solution was allowed to come to room temperature. After 5.5 hours ether and water were added, the ether layer was washed thoroughly with water. then with saturated sodium bicarbonate solution. followed by saturated sodium chloride solution. and finally dried over anhydrous sodium sulfate. The ether was removed by distillation and the residue fractionated

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(27) G. Darzens. *Compt. rend.*, **144**. 1123 (1907).

(28) N. D. Zelinsky and E. M. Tarassowa, *Ann.*, **508**. 115 (1934).

(29) N. Zelinsky and J. Gutt. *Ber.*, **40**. 3051 (1907).

through an 18-in. Vigreux column. The main portion of the product (fractions 3–12) boiled at 102–112° (0.6–1.2 mm.), and decolorized bromine rapidly. Fractions 6–8 (n^{25}D 1.4661–1.4711) were combined and refractionated through a 10-in. Podbielniak type column. The main product boiled at 98–99° (0.4 mm.), n^{25}D 1.4645.

Anal. Calcd. for $C_{12}H_{18}O_4$: C, 63.70; H, 8.02. Found: C, 63.47; H, 8.01.

Acidification of the bicarbonate wash solutions yielded 5.21 g. (7% yield) of crude acidic material. It was recrystallized twice from benzene to give 4.9 g. of 1-cyclohexenylglycolic acid, m.p. 123–124°. Repeated recrystallization raised the m.p. to 126–127° (reported[12] 126–126.5°).

Anal. Calcd. for $C_8H_{12}O_3$: C, 61.52; H, 7.75; neut. equiv., 156.18. Found: C, 61.63; H, 7.84; neut. equiv., 157.

Saponification of a specimen of the pure ethyl 1-cyclohexenylacetoxyacetate gave the free hydroxy acid in 67% yield after one recrystallization, m.p. 122–123°, undepressed on admixture with the specimen of IXa described above.

p-Bromobenzoylmethyl 1-Cyclohexenylglycolate was prepared in the conventional manner from IXa and p-bromophenacyl bromide. After repeated recrystallization from benzene–petroleum ether it was obtained as fine, colorless needles, m.p. 79.5–81.3°. The analytical specimen was evaporatively distilled at 100° (0.05 mm.).

Anal. Calcd. for $C_{16}H_{17}O_4Br$: C, 54.40; H, 4.85. Found: C, 54.50; H, 4.79.

Hexahydromandelic Acid.—A solution of 0.17 g. of IXa, m.p. 124–124.8°, in 6 ml. of glacial acetic acid was hydrogenated over 45 mg. of platinum oxide. After 35 minutes 96% of the calculated amount of hydrogen was absorbed, and no further uptake of gas was observed. The mixture was filtered, the filtrate evaporated to dryness, and the residue crystallized from chloroform to give 0.074 g. of colorless leaflets, m.p. 135–135.5° (reported[13] 134–135°). A second crop amounting to 0.039 g., m.p. 131.8–134°, was isolated.

Partial Isomerization of 1,α-Expoxycyclohexaneacetic Acid into IXa.—When the sodium glycidate was treated carefully with mineral acid in the cold, and immediately extracted with ether, an oily product was produced which probably consisted mainly of the glycidic acid. None of IXa could be separated even with the aid of seeds.

When 0.795 g. of the above oily acid was triturated with 5 ml. of 1:1 hydrochloric acid for 20 minutes. the oil became more viscous. The product was separated by ether extraction and on seeding with IXa it partially solidified. Crystallization from benzene–petroleum ether gave 0.105 g. of crude IXa, m.p. 104–115°. Repeated recrystallization from benzene gave 0.065 g. of IXa, m.p. 122°.

1,2-Dibromocyclohexaneglycolic Acid (IX, R = H).—A 5% solution of bromine in carbon tetrachloride was added slowly to a solution of 2.61 g. of IXa. m.p. 121–123°, in 300 ml. of carbon tetrachloride until the bromine color persisted for 1 minute. The solution was concentrated to about one-half its original volume and on cooling the dibromide crystallized; yield 4.32 g. (81%), m.p. 161–165° dec. A sample repeatedly recrystallized from ethyl acetate and from carbon tetrachloride was obtained as colorless clusters of plates, m.p. 163.5–164° dec.

Anal. Calcd. for $C_8H_{12}O_3Br_2$: C, 30.40; H, 3.83. Found: C. 30.67; H. 3.97.

Δ^1-Tetrahydrobenzaldehyde (XII. R = H),—A solution of 1.00 g. of semicarbazide hydrochloride in 2 ml. of water was added to 0.199 g. of the dibromo acid XI (R = H) described above. Upon the addition of 3 ml. of pyridine, carbon dioxide was evolved, and the semicarbazone began to precipitate. After 2 hours at room temperature 10 ml. of water was added. and 0.055 g. (52% yield) of crude **semicarbazone of XII** (R = H) was obtained. m.p. 207–210°. Recrystallization from absolute alcohol gave colorless plates. m.p. 211–212.5° (reported[30] 212–213°).

Anal. Calcd. for $C_8H_{13}ON_3$: C, 57.46; H, 7.84. Found: C. 57.73; H. 7.74.

The 2.4-dinitrophenylhydrazone was prepared directly from the semicarbazone. Recrystallization from ethyl acetate gave reddish-orange needles, m.p. 219.5–220.5° (reported[31] 219–220°).

α-1-Cyclohexenyllactic Acid (IX, R = CH_3).—A solution of 9.60 g. of the sodium glycidate derived from Ic (see above) in 50 ml. of water was treated with 15 ml. of concentrated hydrochloric acid, and the mixture was stirred at room temperature for 6 hours. The products were isolated as described above for the lower homolog. The semicarbazone of hexahydroacetophenone isolated amounted to 1.75 g. (19% yield). The crude acidic fraction amounted to 4.17 g. of crystalline material, m.p. 80–84°. Recrystallization from benzene gave 3.37 g. of IX (R = CH_3), m.p. 88–90°. Further recrystallizations from benzene–petroleum ether gave colorless prisms, m.p. 92.5–93.5°.

Anal. Calcd. for $C_9H_{14}O_3$: C, 63.51; H, 8.29, neut. equiv., 170.2. Found: C, 63.32; H, 8.29; neut. equiv., 166.

From the mother liquors of the above acid fraction, 0.28 g. of a second acid was obtained. Recrystallization from benzene gave colorless prisms, m.p. 125–126°. This material has not been investigated further.

Anal. Calcd. for $C_9H_{16}O_4$: C, 57.43; H, 8.57. Found: C, 57.53; H, 8.53.

Acetylcyclohexene (XII, R = CH_3).—A 5% solution of bromine in carbon tetrachloride was added to a solution of 0.257 g. of IX (R = CH_3), m.p. 88–90°, in 25 ml. of carbon tetrachloride until the bromine color persisted for more than 1 minute. The brown oily dibromo compound XI (R = CH_3) which remained on evaporation of the solvent did not crystallize readily, so it was treated directly with 0.50 g. of semicarbazide hydrochloride dissolved in water, and 3 ml. of pyridine as described above for the lower homolog. The crude semicarbazone amounted to 0.091 g. (33% yield), m.p. 210–213°. Three recrystallizations from absolute alcohol raised the m.p. to 220–221°. The m.p. was not depressed on admixture with an authentic specimen, m.p. 219.5–221°, of the semicarbazone of acetylcyclohexene prepared by the method of Royals and Hendry.[14]

2-Hydroxycyclohexylideneacetic Acid (X). (*a*) *From the Glycidic Acid.*—A mixture of 4.0 g. of the sodium glycidate derived from Ia (see above), 200 ml. of water and 96 ml. of 0.23 N hydrochloric acid was boiled under reflux for 94 hours, and then concentrated to a small volume by distillation. The residue was extracted with ether, and the ether solution was washed with saturated sodium chloride solution and dried over anhydrous sodium sulfate. Evaporation of the ether left 1.01 g. of tan solid melting at 150–154° with previous softening. Repeated recrystallization from benzene and then ethyl acetate gave colorless prisms of the acid X, m.p. 156–156.8° (reported[16] 154°).

Anal. Calcd. for $C_8H_{12}O_3$: C, 61.52; H, 7.75; neut. equiv., 156.18. Found: C, 61.19; H, 7.51; neut. equiv., 158.

The p-bromobenzoylmethyl ester was prepared in the conventional manner from p-bromophenacyl bromide. On repeated recrystallization from benzene–petroleum ether it was obtained as colorless prisms. m.p. 117.2–118.2°.

Anal. Calcd. for $C_{16}H_{17}O_4Br$: C, 54.40; H, 4.85. Found: C, 54.29; H, 4.97.

(*b*) *From 1-Cyclohexenylglycolic Acid.*—A mixture of 0.100 g. of the cyclohexenylglycolic acid (IXa), m.p. 123–123.5°, and 1 ml. of water was boiled under reflux for 69 hours. On evaporation to dryness, the residue. after heating at 100° (10 mm.) for 1 hour, amounted to 0.084 g., m.p. 150–154°. Recrystallization from ethyl acetate gave material. m.p. 155–156.5°, undepressed on admixture with the specimen prepared as described above, part (a).

(*c*) *By Independent Synthesis.*—1-Hydroxycyclohexaneacetic acid was prepared by the Reformatsky reaction on cyclohexanone according to the procedure of Wallach.[32] After recrystallization from petroleum ether it melted at 61–62.5° (reported[32] 62–64°). Dehydration of the hydroxy acid was effected with acetic anhydride according to the procedure of Wallach.[32] The resulting cyclohexylideneacetic acid melted at 89.7–90.3° (reported[32] 91°). Hydroxylation was carried out directly on the unsaturated acid with selenium dioxide in alcohol. Kuehl. Linstead and Orkin[16] described the hydroxylation of the ethyl ester with selenium dioxide in acetic anhydride. After crystallization from ethyl acetate–petroleum ether it melted at 153–154° (reported[16] 154°). There was no m.p. depression on admixture with the analytical specimen described above. part (a).

MADISON. WISCONSIN

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[32] O. Wallach, *Ann.*, **347**, 329 (1906); **365**, 261 (1909).