off progressively as the pyrolysis temperature was raised. For example, the catalyst prepared at 200° had a specific surface area of 9.3 sq.m./g. and catalyzed the formation of the alicyclic diamine in 80% yield; the catalyst prepared at 750° also gave alicyclic diamine in 80% yield, although the specific surface area fell to 1.5 sq.m./g. X-Ray examination of the samples prepared at temperatures up to 750° indicated all to be Co_3O_4. However, a diffraction pattern characteristic of CoO was observed with oxide which had been prepared by pyrolysis at 1000°. The specific surface area of this catalyst, which yielded only 26% diamine, had dropped to 0.1 sq.m./g. These observations are confirmed by the work of Natta and Strada,[15] who have identified the three oxides of cobalt, *viz.*, Co_2O_3, Co_3O_4 and CoO, by X-ray diffraction, and found that Co_2O_3 could not be prepared by pyrolysis of cobaltous nitrate hexahydrate.

The presence of calcium oxide is essential for catalytic activity. However, other factors being equal, the promoter activity of calcium oxide, as well as its specific surface area, varies widely and depends to a considerable degree on the temperature used for calcination of calcium hydroxide or calcium carbonate to calcium oxide. For example, calcium oxide prepared by calcination of calcium hydroxide at 500° for 24 hours had a surface area of 22.8 sq.m./g. This sample of calcium oxide when used in conjunction with cobaltic oxide, but without sodium carbonate, promoted the formation of II in 55% yield, while the remainder of the product was accounted for by deamination products. Calcium oxide with a surface area of 6.1 sq.m./g., which was prepared by calcination of calcium hydroxide at 750° for 24 hr. under similar conditions, promoted the formation of II in only 41% yield, together with 46% of 4-(*p*-aminobenzyl)-cyclohexylamine and 13% of deamination products. The presence of sodium carbonate in the catalyst appeared to repress side reactions such as deamination, and thus led to higher yields of II. For example, the use of sodium carbonate with cobaltic oxide and calcium oxide having a surface area of 22.8 sq.m./g. resulted in the formation of II in 74% yield, in contrast to a yield of 55% without added sodium carbonate.

So-called "dead-burnt" lime,[16] obtained at temperatures of the order of 1000° and higher, is characterized by a lack of reactivity toward water. We have found that this type of lime is also characterized by a relatively low surface area and by little or no promoter activity.

Cobalt-on-alumina catalyzed the formation of II in 52% yield by operation at a pressure of 950 atmospheres and 250° in the presence of an 8-fold mole excess of anhydrous ammonia (Expt. 3), although hydrogenation was completely repressed by ammonia at lower temperatures and pressures (Expt. 1). Raney nickel was completely ineffective in the absence of ammonia at 200° and 200 atmospheres (Expt. 5), although 47% yield of II was obtained by hydrogenation at 250° and 915 atmospheres in the presence of anhydrous ammonia (Expt. 4).

Acknowledgments.—The authors wish to acknowledge their indebtedness to Drs. B. W. Howk and R. S. Schreiber for their advice and encouragement during the course of this work, and to Mr. C. G. Wortz for the surface area measurements.

[15] G. Natta and M. Strada, *Gazz. chim. ital.*, **58**, 419 (1928).

[16] N. V. S. Knibbs, "Lime and Magnesia," Ernest Benn, Ltd., London, 1924, p. 99.

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A New Synthetic Approach to the Morphine Structure

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The spiroketone, 2,2-tetramethylene-1-tetralone, was converted to 1,2,3,4,9,10-hexahydrophenanthrene by Wagner rearrangement of the intermediate alcohol. Rearrangement of the methylmagnesium iodide addition product of the spiroketone gave only the product of normal dehydration. On the other hand, condensation of the starting ketone with methyl bromoacetate afforded a substance which smoothly underwent Wagner rearrangement to yield a hydrophenanthroid lactone which, after lithium aluminum hydride reduction followed by dehydration, catalytic hydrogenation, reaction with phosphorus tribromide and subsequent reaction with dimethylamine, was successfully converted to the dihydrodesbase of N-methylisomorphinane. Possible reaction mechanisms involved in the formation of the various intermediates are briefly presented.

The elaboration of the ring system characteristic of the morphine alkaloids has presented numerous difficulties. The extensive literature in this field has been reviewed by Stern[2] and several publications have appeared subsequently.[3] Because of the brilliant culmination of Gates' approach in the total synthesis of morphine,[4] it seemed desirable to report our work on a completely new approach to the morphine structure. We have succeeded in synthesizing the dihydrodesbase obtained by Gates and collaborators[5] from N-methylisomorphinane.

The spiroketone, 2,2-tetramethylene-1-tetralone (I), is theoretically a suitable precursor for an angularly substituted hydrophenanthrene related to naturally occurring products. This ketone was

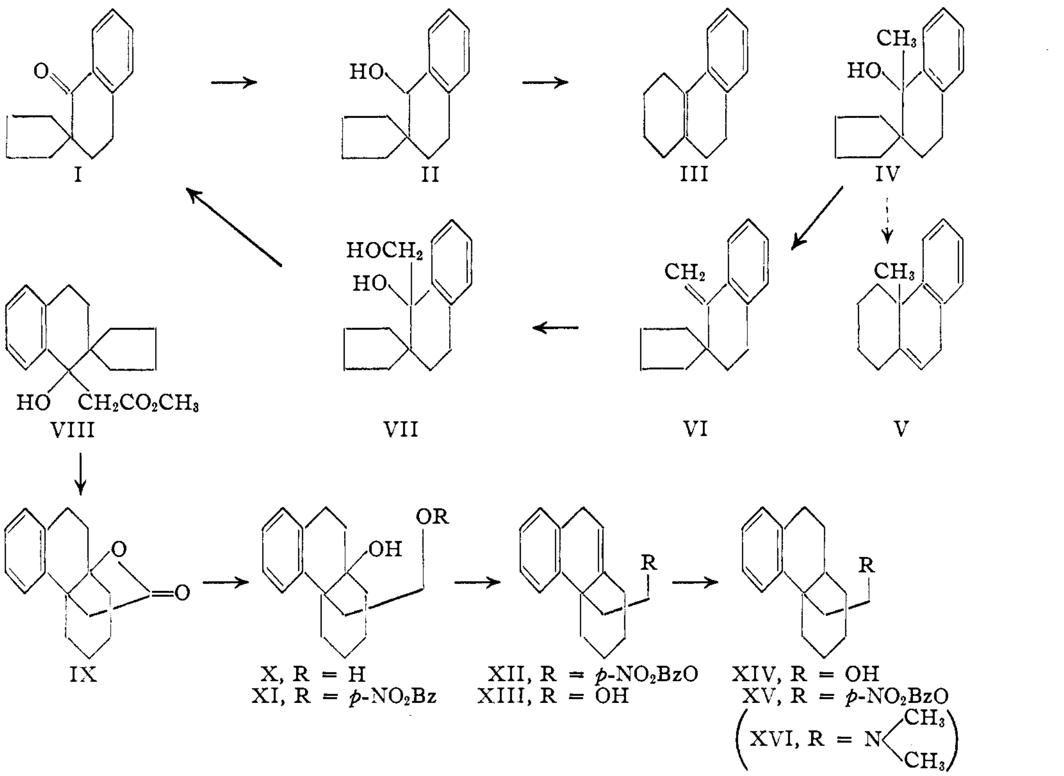
[1] Present address: Department of Chemistry and Chemical Engineering, Case Institute of Technology, Cleveland 6, Ohio.

[2] E. S. Stern, *Quart. Reviews*, **5**, 405 (1951).

[3] G. Stork and H. Conroy, This Journal, **73**, 4748 (1951); M. S. Newman and W. L. Mosby, *ibid.*, **73**, 3738 (1951); J. A. Barltrop and J. S. Nicholson, *J. Chem. Soc.*, 2524 (1951); J. A. Barltrop and J. E. Saxton, *ibid.*, 1038 (1952); D. Ginsburg and R. Pappo, Abstracts of Papers, 121st Meeting of the American Chemical Society at Milwaukee, Wis., March–April 1952, p. 87K.

[4] M. Gates and G. Tschudi, This Journal, **74**, 1109 (1952).

[5] M. Gates, R. B. Woodward, W. F. Newhall and R. Künzli, *ibid.*, **72**, 1141 (1950).


Flow Sheet

prepared by Friedel–Crafts acylation of benzene with α,α-tetramethylenesuccinic anhydride followed by Clemmensen reduction and ring closure. While this work was in progress, Marvel and Geiszler[6] reported the synthesis of this ketone by essentially the same procedure except that their cyclization was carried out with sulfuric acid. In our hands, aluminum chloride cyclization led to a reproducible yield of 75–80% as compared to 20% by the sulfuric acid method.

In order to study the feasibility of Wagner rearrangement in this series, the ketone (I) was reduced to the corresponding alcohol in nearly quantitative yield. On heating with potassium acid sulfate, dehydration occurred and a colorless hydrocarbon resulted in good yield. The formulation of the latter as 1,2,3,4,9,10-hexahydrophenanthrene (III) was deduced from the ease with which it suffered catalytic dehydrogenation to phenanthrene (a few minutes of heating at 300° being sufficient) and from the peak of absorption at 268 mμ (log e 3.86), characteristic of a double bond in conjugation with a benzene ring.[7] Catalytic dehydrogenation of spiranes is considerably more sluggish (*vide infra*). Undesirable rearrangements such as ring contraction of the preformed six-membered ring does not appear to take place.

Dehydration of compound (IV) resulting from the addition of methylmagnesium iodide to the ketone (I) was next studied because of the interesting relationship that one of the expected rearrangement products (V) bears to the terpenes and steroids. Treatment of (IV) with potassium acid sulfate under the same conditions that caused rearrangement of (II),[8] afforded in good yield a colorless liquid hydrocarbon whose structure is thought to be represented by (VI) on the basis of the following evidence: it exhibited a peak of absorption at 257 mμ (log e 3.80) with an inflection at 278–285 mμ in the ultraviolet region. Compared with (III), a shift of 11 mμ to shorter wave lengths has occurred and an inflexion 21 mμ away from the peak of absorption has appeared. Such a spectrum is characteristic of a double bond in conjugation with a benzene ring but *exocyclic to a ring*. From data reported by Bachmann and Controulis[9] it can be inferred that a shift of about 12 mμ and an inflection about 24 mμ away from the new peak should occur. On this basis, the exocyclic position of the double bond in the above hydrocarbon appears well established and structure (VI) is considered more likely than other structures resulting from involved rearrangements. Dehydrogenation of the hydrocarbon affords some phenanthrene but the reaction is sluggish as compared to the aromatization of (III) and variable amounts of oil were recovered along with the phenanthrene. Since it has been well established that spiranes can often lead to completely rearranged aromatization products,[10] dehydrogenation experiments do not invalidate the spiro structure (VI). Unequivocal proof of formulation (VI) was adduced by converting, with osmium tetroxide, the liquid hydrocarbon to a crystalline glycol (VII) which underwent cleavage to the starting ketone (I) when

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[6] E. N. Marvel and A. O. Geiszler, This Journal, 74, 1259 (1952).

[7] B. Belleau, *ibid.*, 73, 5149 (1951).

[8] Other methods of acid-catalyzed dehydration were not tested.

[9] W. E. Bachmann and J. Controulis, This Journal, 73, 2636 (1951).

[10] P. A. Plattner, "Newer Methods of Preparative Organic Chemistry," 2nd ed., Interscience Publishers, Inc., New York, N. Y., 1948, pp. 86, 43.

treated with periodic acid. Ozonolysis experiments with (VI) were not successful due apparently to oxidation at other points of the molecule. That Wagner rearrangement does not occur with (IV) under the conditions of our experiments is not unexpected. It may be that the nature of the end-product of such a reaction is dependent upon the ability of the first possible ionic intermediate to give rise to a conjugated system. However, no precise evaluation of the other various factors involved is possible at this time.

On theoretical grounds, a compound such as (VIII) could lead through a Wagner type of rearrangement to an hydrophenanthrene carrying an angular acetic acid ultimately convertible to the ethanamine side chain characteristic of the morphine alkaloids. Condensation of the spiroketone (I) with methyl bromoacetate afforded an oily mixture from which separation of (VIII) was not effected. By heating the crude reaction mixture with formic acid, a readily crystallizable substance of formula $C_{16}H_{18}O_2$ melting at 167° was easily isolated in 58% over-all yield. This material exhibited only benzenoid absorption in the ultraviolet region (max. at 264 mμ, log *e* 2.60) by which normal dehydration can be excluded. The over-all elimination of methanol can logically be dissected into a stepwise hydrolysis of the ester group in (VIII) (by ester interchange with formic acid) coupled with dehydration and concomitant rearrangement. The substance must thus be an acid with an isolated double bond or a lactone. That the latter implication is correct was indicated by the insolubility of the compound in cold but solubility in hot aqueous alkali. The further observation that catalytic dehydrogenation of this lactone proceeded smoothly to yield phenanthrene coupled with theoretical considerations (*vide infra*) pointed to (IX) as the most logical structure for the rearrangement product of (VIII). The correctness of formulation (IX) follows from the ultimate conversion of the lactone to the known end-product (XVI) through a sequence of unambiguous reactions. Reduction of the lactone with lithium aluminum hydride afforded in high yield a crystalline diol (X) which gave a mono *p*-nitrobenzoate (XI) exclusively, thereby establishing the tertiary nature of the alcoholic function in the lactone. Attempted dehydration of the *p*-nitrobenzoate (XI) with phosphorus oxychloride in pyridine failed. However, by substituting phosphorus trichloride for the oxychloride, smooth dehydration occurred and a crystalline mixture of isomers presumably differing only in the position of the double bond was obtained [only (XII) is represented; obviously, the other one has its double bond in the 1,10a-position]. By analogy with known examples, it is unlikely that dehydration of (XI) by such a procedure could be accompanied by rearrangement of the carbon skeleton or side chain migration.[11] Saponification of (XII) and its isomer afforded a crystalline mixture of unsaturated alcohols (XIII plus its $\Delta^{1,10a}$-isomer) which absorbed one molar equivalent of hydrogen over Adams catalyst. The oily hydrogenation product (XIV) yielded a crystalline *p*-nitrobenzoate (XV) melting over a range and which could not be resolved into pure components by chromatography of fractional crystallization. The saturated alcohol (XIV) probably consists therefore of a mixture of two alcohols epimeric at position 10a. However, no conclusion can be drawn as to the stereospecificity of the reduction of each component in the mixture of isomeric unsaturated alcohols. Treatment of the saturated alcohol (XIV) with phosphorus tribromide followed by reaction with dimethylamine afforded a base (XVI) whose picrate melted at 191.5–193° after repeated recrystallization. This picrate caused no depression of the melting point of an authentic sample[12] of the dihydrodesbase picrate already obtained by Gates from N-methylisomorphinane.[5]

The rearrangement of the Reformatsky condensation product (VIII) to the lactone (IX) requires brief comment at this point. It is worthy of note that whereas Wagner rearrangement does not take place with (IV) (*vide supra*), it occurs readily in the case of (VIII) although the two compounds are structurally closely related. This interesting difference in behavior toward dehydration may perhaps be ascribed to the presence in (VIII) of a vicinal nucleophilic center (the carboxyl group) capable of trapping the intermediate carbonium ion formed during the course of ring expansion, thus removing the latter irreversibly from the mixture. Further investigations on the possible conversion of the lactone (IX) to morphinane or isomorphinane are in progress.

Experimental[13]

2,2-Tetramethylene-1-tetralone (I).—Starting from cyclopentanone and cyanoacetic ester, this ketone was prepared essentially as described in ref. 6 except at the final stage of the ring closure which was carried out as follows: to 7.0 g. of phosphorus pentachloride under 10 ml. of benzene was added 7.33 g. of α,α-tetramethylene-γ-phenylbutyric acid in 20 ml. of benzene. The mixture was swirled at room temperature for 30 min., then heated to 100° for 10 min. After evaporation to dryness *in vacuo*, the residue was dissolved in 40 ml. of benzene and 4.50 g. of lumpy anhydrous aluminum chloride added in one portion. The mixture was stirred at 40–50° for 90 min. and finally heated to 100° for 10–15 min. on the steam-bath. The solution was cooled, poured into dilute hydrochloric acid and extracted with ether and the extract was washed with water, aqueous sodium hydroxide and finally water. The ether was dried and evaporated to yield a liquid which was distilled *in vacuo*; at 127–130° (1.5 mm.), 5.0 g. (75% yield) of colorless ketone was obtained.

The oxime was obtained by heating to 100° for 6 hours a mixture of equal weights of ketone and hydroxylamine hydrochloride in ten times by weight of pyridine. It crystal-

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(11) M. Davis and V. Petrow, *J. Chem. Soc.*, 2211 (1951). However, it should be pointed out that the use of thionyl chloride or phosphorus halides in conjunction with pyridine as dehydrating agents does not exclude rearrangement of a carbon skeleton if dehydration must operate through a *cis* elimination reaction. This is clearly exemplified by the phosphorus oxychloride–pyridine dehydration of 18(α)-oleanane-2"β",19(α)-diol-2-acetate to lupenyl acetate (*cis* dehydration) as compared to the dehydration of the corresponding 19(β)-diol-2-acetate to germanicyl acetate (*trans* dehydration) as shown by T. R. Ames, G. S. Davy, T. G. Halsall and E. R. H. Jones, *ibid.*, 2868 (1952). Since regular *trans* dehydration can operate in the case of (XI) no form of rearrangement is likely to occur.

(12) Generously supplied by Dr. M. Gates.

(13) All melting points and boiling points are uncorrected and ultraviolet spectra were determined with a Beckman quartz spectrophotometer, model DU. All microanalyses were kindly performed by Dr. Yvon Perron, Department of Chemistry, University of Montreal.

lized from methanol in the form of small colorless prisms, m.p. 133–135°.[14]

Anal. Calcd. for $C_{14}H_{17}ON$: N, 6.51. Found: N, 6.47.

2,2-Tetramethylene-1-tetralol (II).—To a solution of 0.50 g. of lithium aluminum hydride in 200 ml. of anhydrous ether was added 1.0 g. of the above ketone in a little ether. After heating under reflux for one hour, the excess hydride was decomposed with ethyl acetate and the mixture hydrolyzed with dilute hydrochloric acid. The ether, after one water-wash, was dried and evaporated to yield 1.0 g. of colorless oil. It gave a crystalline *phenylurethan* which separated from methanol–acetone in the shape of colorless needles, m.p. 155–156°.

Anal. Calcd. for $C_{21}H_{23}O_2N$: C, 78.47; H, 7.21; N, 4.35. Found: C, 78.46; H, 7.20; N, 4.39.

1,2,3,4,9,10-Hexahydrophenanthrene (III).—Eight hundred and seventeen milligrams of the preceding tetralol (II) was intimately mixed with 2.30 g. of fused potassium acid sulfate and the mixture heated under nitrogen to 160–170° for 90 min. Water was added followed by extraction with ether. The ether was dried and evaporated to yield an oil which was distilled *in vacuo;* at 110–111° (1.3 mm.), 575 mg. of a light colorless oil, $n^{23}\text{D}$ 1.5921 and $\lambda^{\text{CH}_3\text{OH}}_{\text{max}}$ 268 mμ (log *e* 3.86) was collected.

Anal. Calcd. for $C_{14}H_{16}$: C, 91.24; H, 8.75. Found: C, 90.90; H, 8.63.

Dehydrogenation was accomplished by heating under nitrogen 175 mg. of the hydrocarbon with 175 mg. of 10% palladium-on-charcoal to 300–310° for 30 min. The dehydrogenation product formed colorless leaflets from methanol, m.p. 99–100° by itself or admixed with an authentic sample of phenanthrene.

2,2-Tetramethylene-1-methylene-1,2,3,4-tetrahydronaphthalene (VI).—An ethereal solution of methylmagnesium iodide was prepared from 1.20 g. of magnesium and 3.20 ml. of methyl iodide in 50 ml. of anhydrous ether. To this was added 2.0 g. of 2,2-tetramethylene-1-tetralone in a little ether and the mixture heated under reflux for one hour. It was decomposed and worked up in the usual way to give a colorless oil which failed to react with phenyl isocyanate.

All of the oil was heated with 6.0 g. of potassium acid sulfate in the same manner as described above in the case of 2,2-tetramethylene-1-tetralol. An oil was obtained which was distilled *in vacuo* to yield 1.0 g. of a colorless oil, b.p. 113–115° (1.5 mm.), $n^{24}\text{D}$ 1.5774 and $\lambda^{\text{CH}_3\text{OH}}_{\text{max}}$ 257 mμ (log *e* 3.80) (inflection at 278–285 mμ). It is unstable and undergoes air oxidation within a few days, but is stable when kept in a sealed container.

Anal. Calcd. for $C_{15}H_{18}$: C, 90.85; H, 9.14. Found: C, 90.46; H, 8.99.

Dehydrogenation was carried out by heating to 300–310° for 90 min. under nitrogen a mixture of 200 mg. of the hydrocarbon and 200 mg. of 10% palladium-on-charcoal. Upon working up, oily crystals of low m.p. were obtained and no adequate purification could be performed by simple recrystallization. Purification was readily accomplished by treatment with picric acid in methanol. Recrystallization of the picrate from methanol afforded orange-colored needles m.p. 146–148° which caused no depression of the m.p. of an authentic sample of phenanthrene picrate.

2,2-Tetramethylene-1-hydroxymethylene-1-hydroxy-1,2,-3,4-tetrahydronaphthalene (VII).—To 780 mg. of the above hydrocarbon (VI) in 25 ml. of anhydrous ether was added 1.0 g. of osmium tetroxide and the mixture allowed to stand at room temperature for 62 hours. The ether was evaporated *in vacuo* and the black osmate shaken with 5.0 g. of sodium sulfite in methanol–water. After standing for 24 hours the mixture was extracted with ether and the extract dried and evaporated to yield 867 mg. of crystalline material. Recrystallization from petroleum ether (b.p. 30–60°) afforded fine elongated colorless needles, m.p. 95–95.5°.

Anal. Calcd. for $C_{15}H_{20}O_2$: C, 77.55; H, 8.67. Found: C, 77.68; H, 8.55.

Periodic Acid Cleavage of the Glycol (VII).—Four hundred milligrams of glycol was dissolved in a mixture of 10 ml. of ethanol and 10 ml. of ethyl acetate. To this was added 3 ml. of an aqueous solution containing 175 mg. of periodic acid per ml. Titration (by the arsenite method) of an aliquot indicated that the reaction was complete within 10 min. The solution was poured into aqueous sodium hydroxide and extracted with ether. The extract was washed with water, dried and evaporated to yield 276 mg. of a slightly yellowish liquid. This was treated with hydroxylamine hydrochloride in the same manner as described above in the case of the spiroketone (I). The oxime thus obtained was crystallized from methanol to give small colorless prisms, m.p. 131–133°, which gave no depression of the m.p. when admixed with the oxime of 2,2-tetramethylene-1-tetralone.

4a-Carboxymethyl-10a-hydroxy-1,2,3,4,4a,9,10,10a-octahydrophenanthrene Lactone (IX).—Three and five-tenths grams of 2,2-tetramethylene-1-tetralone was dissolved in a mixture of 50 ml. of dry benzene and 50 ml. of anhydrous ether followed by the addition of 4.0 g. of freshly cleaned granulated zinc, 3 ml. of redistilled methyl bromoacetate and one crystal of iodine. The mixture was heated under reflux and after 5–10 min. a vigorous reaction ensued. At every 45-min. interval, additions of 2.0 g. of zinc were made and after one hour 1.2 ml. of methyl bromoacetate was introduced. After a total of 3.5 hours of heating, the mixture was cooled and shaken vigorously with dilute hydrochloric acid. The organic phase was then washed twice with 5% aqueous sodium hydroxide and once with water and finally dried and evaporated. The liquid residue was dissolved in 50 ml. of anhydrous formic acid containing 2 drops of concentrated hydrochloric acid and heated to 100° on the steam-bath for 45 min. The resulting dark solution was evaporated to dryness *in vacuo* whereupon oily crystalline material deposited. Recrystallization of the residue from methanol afforded 1.40 g. (33% yield) of white crystals, m.p. 165–167°. Evaporation of the mother liquors yielded a colored liquid which upon distillation *in vacuo* afforded 1.50 g. of pure starting ketone, b.p. 125–129° (1.4 mm.), thus bringing up the yield of crystalline material to 58% based on unrecovered ketone. Recrystallization of the first crop from methanol produced large, irregular colorless plates, m.p. 167–167.5°.

Anal. Calcd. for $C_{16}H_{18}O_2$: C, 79.22; H, 7.48. Found: C, 79.20; H, 7.38.

Other solvent mixtures for the Reformatsky reaction proved to be less satisfactory and much lower yields were obtained.

The crystalline material is insoluble in cold aqueous sodium hydroxide but dissolves slowly on prolonged heating. It has $\lambda^{\text{CH}_3\text{OH}}_{\text{max}}$ 265 mμ (log *e* 2.60) and was recovered unchanged after prolonged heating with thionyl chloride or phosphorus pentachloride in benzene solution, or upon standing for one week in concentrated methanolic ammonia.

Dehydrogenation of the compound was accomplished by heating to 305–310° in a carbon dioxide atmosphere a mixture of 75 mg. of lactone and 75 mg. of 10% palladium-on-charcoal for one hour. Crystallization of the reaction product from methanol gave leaflets, m.p. 97–99°, which did not depress the m.p. of an authentic sample of phenanthrene upon admixture.

An attempt to convert the lactone to the corresponding hydroxymethyl ester by saponification followed by immediate esterification with diazomethane was unsuccessful, most of the lactone being recovered unchanged.

4a-(β-Hydroxyethyl)-10a-hydroxy-1,2,3,4a,9,10,10a-octahydrophenanthrene (X).—To a solution of 2.50 g. of lithium aluminum hydride in 400 ml. of anhydrous ether was added a solution of 2.83 g. of the preceding lactone in a little benzene and the mixture heated under reflux for 3 hours. The excess hydride was decomposed with ethyl acetate and the mixture hydrolyzed with dilute hydrochloric acid. The ethereal phase after washing with water, was dried and evaporated to yield a crystalline mass which after recrystallization from ethyl acetate melted at 167–169° and weighed 2.57 g. (89% yield). Recrystallization from ethyl acetate afforded colorless rectangular plates, m.p. 168–169°. When admixed with the starting lactone, a 35° depression of the m.p. was observed.

Anal. Calcd. for $C_{16}H_{22}O_2$: C, 78.00; H, 9.00. Found: C, 78.00; H, 8.97.

The compound gave an oily acetate and an oily benzoate but produced a crystalline *p*-nitrobenzoate (XI) in 93%

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[14] The reported m.p. in ref. 6 is 101–102°. However, Dr. E. N. Marvel has informed us in a personal communication that this is in error because of the presence of impurities in his sample and that a redetermination of the m.p. gave 101–130° and not 101–102°.

yield which when recrystallized from ethanol afforded cream-colored prisms, m.p. 147–147.5°.

Anal. Calcd. for $C_{23}H_{25}O_5N$: C, 69.85; H, 6.37; N, 3.54. Found: C, 69.90; H, 6.34; N, 3.52.

4a-(β-Hydroxyethyl)-1,2,3,4,4a,9(and 2,3,4,4a,9,10)-hexahydrophenanthrene (XIII and Isomer).—A solution of 4.18 g. of the preceding diol *p*-nitrobenzoate (XI) in 30 ml. of pyridine was treated dropwise while cooling with 5 ml. of phosphorus trichloride and the solution warmed to 50° for 2 hours. The mixture was poured on crushed ice and extracted with chloroform and the extract washed with dilute hydrochloric acid and water and finally dried and evaporated to yield a crystalline mass. Recrystallization from acetone–methanol gave cream-colored blades, m.p. 124–130°. Further purification failed to raise or sharpen the m.p.

Anal. Calcd. for $C_{23}H_{23}O_4N$: C, 73.19; H, 6.14; N, 3.71. Found: C, 73.15; H, 6.11; N, 3.73.

Saponification was accomplished by heating under reflux for 2 hours a solution of 2.50 g. of the product in 150 ml. of methanol containing 5 g. of potassium hydroxide. Most of the methanol was evaporated, water was added and the product extracted with ether and the extract washed with water, then dried and evaporated. Crystallization of the residue from ether–petroleum ether (b.p. 30–60°) gave 1.033 g. (68% yield) of crystals (XIII), m.p. 84–90°. Three additional recrystallizations from ether–petroleum ether afforded fine colorless needles, m.p. 93–100°. Further recrystallizations did not alter this m.p.

Anal. Calcd. for $C_{16}H_{20}O$: C, 84.16; H, 8.82. Found: C, 84.29; H, 8.81.

4a-(β-Hydroxyethyl)-1,2,3,4,4a,9,10,10a-octahydrophenanthrene (XIV).—Of the above unsaturated alcohol mixture, 933 mg. was dissolved in 50 ml. of glacial acetic acid and hydrogenated over 200 mg. of platinum oxide under a pressure of 15 lb. p.s.i. of hydrogen. After 20 min. 105% of the theoretical amount of hydrogen was absorbed. The catalyst was removed by filtration and the filtrate evaporated to dryness *in vacuo*. The residue was dissolved in 50 ml. of methanol containing 5 g. of potassium hydroxide and after standing for one hour the solution was diluted with water and extracted with ether. The ether, after one water-wash, was dried and evaporated to yield an oil which resisted all attempts at crystallization. It was distilled *in vacuo* to give 808 mg. of a viscous and colorless oily distillate, b.p. 185–190° (1.5 mm.).

Anal. Calcd. for $C_{16}H_{22}O$: C, 83.42; H, 9.62. Found: C, 83.15; H, 9.76.

It gave a crystalline **p-nitrobenzoate (XV)** which after numerous recrystallizations from acetone melted at 120–128°. This m.p. was not significantly altered by additional recrystallization from acetone or other solvent mixtures. Chromatography on alumina was not more successful, all the fractions having similar diffuse m.p.

Anal. Calcd. for $C_{23}H_{25}O_4N$: C, 72.77; H, 6.64; N, 3.69. Found: C, 72.75; H, 6.63; N, 3.72.

***trans*-4a-(β-Dimethylaminoethyl)-1,2,3,4,4a,9,10,10a-octahydrophenanthrene (XVI).**—Seven hundred and fifteen milligrams of the preceding alcohol (XIV) was dissolved in 10 ml. of dry benzene and one ml. of redistilled phosphorus tribromide added. After standing for 3 hours the solution was warmed to 60° for 30 min. and poured into ether which was washed with dilute aqueous sodium hydroxide and water and finally dried and evaporated to yield 517 mg. of an oil which gave a strongly positive Beilstein test for halogen. This was dissolved in 50 ml. of pure anhydrous dioxane and the solution saturated with anhydrous dimethylamine. The mixture was heated to 100° in a sealed tube for 44 hours after which time it was concentrated to a small volume *in vacuo* and poured into ether. The ether extract was washed with dilute aqueous sodium hydroxide and water and then extracted with dilute hydrochloric acid. The acid extract was made alkaline with aqueous sodium hydroxide and extracted with ether. The ether extract was washed with water and finally dried and evaporated to yield 245 mg. of a yellowish oil. This was treated in a little methanol with 200 mg. of picric acid whereupon 344 mg. of yellow crystals, m.p. 160–180°, deposited. Five additional recrystallizations from large volumes of ethanol afforded 96 mg. of large yellow blades with a constant m.p. of 191.5–193°. [Reported[5] for N-methylisomorphinane dihydrodesbase picrate: 191–192.5° (cor.)]. It caused no depression of the m.p. of an authentic sample[12] of N-methylisomorphinane dihydrodesbase picrate upon admixture.

Anal. Calcd. for $C_{24}H_{30}O_7N_4$: N, 11.51. Found: N, 11.56.

Because of the small amount of material obtained, attempts at the isolation of an isomeric picrate from the mother liquors have not been successful thus far.

QUEBEC, QUEBEC

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

The Decarboxylation of α,β-Unsaturated Malonic Acid Derivatives *via* β,γ-Unsaturated Intermediates. II. The Effect of α-Substituents upon Product Composition and Rate

BY ELIAS J. COREY

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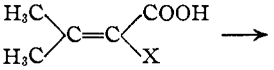
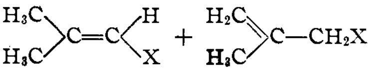
The variation in the relative amounts of α,β- and β,γ-unsaturated products formed by the decarboxylation of each of ten malonic acid derivatives (IA-E, IVA-E) in pyridine has been determined. The malonic acids afford the highest proportion of β,γ-unsaturated decarboxylation product (over 90%) and appear to be the most satisfactory precursors for the synthesis of β,γ-unsaturated acid derivatives by decarboxylation. Evidence has been obtained from rate data for participation of the carboxyl function in isomerization of α,β- to β,γ-unsaturated malonic acid derivatives. Both steric inhibition and copper(II) ion catalysis of decarboxylation *via* β,γ-unsaturated intermediates have been observed and are discussed.

It has been shown recently[1] that the decarboxylation of ethyl hydrogen isopropylidenemalonate (IC) in pyridine occurs *via* the β,γ-unsaturated isomer and affords a mixture of α,β- and β,γ-unsaturated products (25% IIC and 75% IIIC) both of which are stable under the reaction conditions. Since a knowledge of the relationship between the substituent X in compounds of type I (X = CN, $CONH_2$, COOH, $CON(CH_3)_2$) and product composition is necessary for the evaluation of decarboxylation as a synthetic route to β,γ-unsaturated acids and acid derivatives, we have investigated the change in the ratio of α,β- to β,γ-unsaturated decarboxylation product for the series IA-IE. In addition, a parallel series of β,γ-


I

A, X = CN
B, X = $CONH_2$
C, X = $COOC_2H_5$
D, X = COOH
E, X = $CON(CH_3)_2$


II III

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[1] E. J. Corey, THIS JOURNAL, 74, 5897 (1952).