Intramolecular Acylation. Part V. Preparation and Ring Closure of Some Methoxy-1-naphthyl-acetic, -propionic, -butyric, and -α-ethylglutaric Acids.*

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Thirteen 1-naphthyl-substituted aliphatic acids, containing a methoxyl group in the 4-, 5-, 6-, or 7-position in the naphthalene nucleus, have been subjected to the influence of a number of cyclising agents, either by cyclodehydration of the free acids or by cyclodehydrohalogenation of the acid chlorides. The constitutions of the cyclic ketones thus obtained have been established by the use of chemical methods and ultra-violet spectroscopy. In the series of acids under investigation the presence of a methoxyl group at the 5- or 7-position in the naphthalene nucleus assists cyclisation at the 8-position but with the methoxyl group at the 6-position there appears to be no activation at the 8-position and reaction takes place at the 2-position. With all the α-2-(methoxy-1-naphthyl)ethylglutaric acids, ring closure at the 8-position is inhibited. The ultra-violet spectra of the cyclic ketones have been compared with those of compounds of known structure, and the effects on the spectra of the positions of the substituents and their steric interactions are discussed.

In Part II (Ansell and Hey, *J.*, 1950, 2874) the cyclisation of a number of α-substituted glutaric acids $R{\cdot}CH(CO_2H){\cdot}CH_2{\cdot}CH_2{\cdot}CO_2H$, $R{\cdot}CH_2{\cdot}CH(CO_2H){\cdot}CH_2{\cdot}CH_2{\cdot}CO_2H$, and $R{\cdot}CH_2{\cdot}CH_2{\cdot}CH(CO_2H){\cdot}CH_2{\cdot}CH_2{\cdot}CO_2H$, in which R is phenyl or α- or β-naphthyl, was described. Later (Part III, *J.*, 1953, 1894) similar methods were applied to the three α-methoxyphenylglutaric acids. The present communication extends this work to include the preparation and ring closure of four α-2-(methoxy-1-naphthyl)ethylglutaric acids and for purposes of comparison similar reactions were carried out on a number of methoxy-1-naphthyl-acetic, -propionic, and -butyric acids. Thirteen 1-naphthyl-substituted aliphatic acids, containing a methoxyl group in the 4-, 5-, 6-, or 7-position in the naphthalene nucleus, have been prepared. Of these, five are new, while of the remainder a number have been prepared by new methods or by old methods in improved yield.

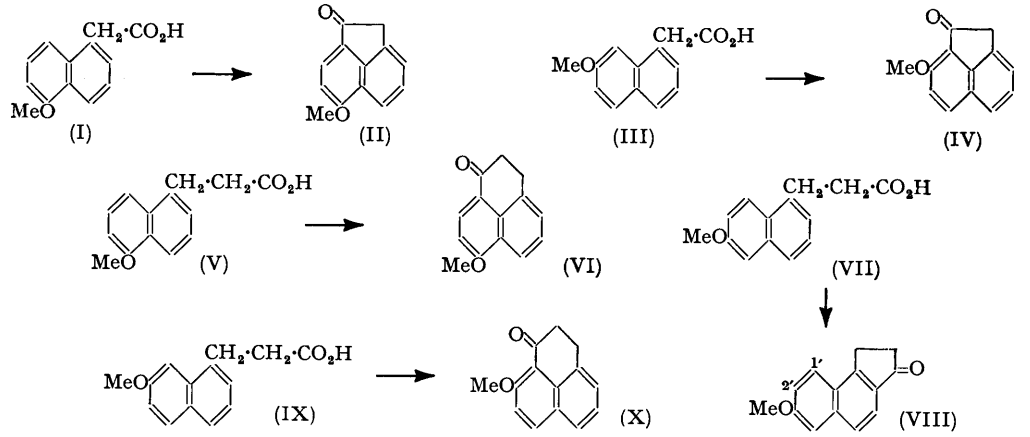
4-Methoxy-1-naphthylacetic acid has been prepared in a new way, by means of the Kindler modification of the Willgerodt reaction. 5-, 6-, and 7-Methoxy-1-naphthylacetic acid have been prepared from the appropriate methoxytetralones by the Reformatsky reaction with methyl bromoacetate and subsequent dehydration and dehydrogenation. This preparation of 5-methoxy-1-naphthylacetic acid (I) is novel, but a preparation of the acid by another method has recently been reported by Ogata, Okano, and Kitamura (*J. Org. Chem.*, 1951, **16**, 1588). Their method does not lead to an unambiguous constitution but both methods give a product having substantially the same melting point. The procedure adopted for the preparation of β-(5-methoxy-1-naphthyl)propionic acid (V) and the

* Part IV, *J.*, 1954, 1204.

corresponding 6-methoxy-compound (VII) involved the conversion of the appropriate methoxynaphthyl bromide (or iodide) into the 2-(methoxynaphthyl)ethanol, which was then converted successively into the bromide and the carboxylic acid by a Grignard reaction with carbon dioxide. In the Grignard reaction with ethylene oxide to obtain the 2-(methoxynaphthyl)ethanol marked improvements in yield were obtained by the addition of a molecular proportion of ethyl bromide in the preparation of the Grignard reagent (cf. Grignard, *Compt. rend.*, 1934, **198**, 625, 2217; Cohen, Cook, and Hewett, *J.*, 1935, 445). The isomeric β-(7-methoxy-1-naphthyl)propionic acid (IX) was prepared from the accessible 7-methoxytetral-1-one by means of Haberland and Heinrich's modification of the Reformatsky reaction with ethyl β-bromopropionate (*Ber.*, 1939, **72**, 1225). γ-(4- and 5-Methoxy-1-naphthyl)butyric acids (XI) and (XIII) were prepared by published methods.

Four α-2-(methoxy-1-naphthyl)ethylglutaric acids (XV, XVII, XIX, and XXI) were prepared by application of the general method previously reported (Ansell and Hey, *J.*, 1950, 1683). The appropriate methoxynaphthylethyl halide was converted into the corresponding 2-methoxynaphthylethylmalonic ester, which was condensed with acrylonitrile. The resulting cyanoethyl derivative was then subjected to hydrolysis and decarboxylation.

The preparation of two γ-methoxynaphthoylbutyric acids, required for comparative purposes, is also described. The action of glutaric anhydride on 2-methoxynaphthalene in the presence of aluminium chloride in nitrobenzene or tetrachloroethane gave a mixture of γ-(6-methoxy-2-naphthoyl)- and γ-(2-methoxy-1-naphthoyl)-butyric acid, the relative proportions depending on the solvent used. The identity of the products was established by oxidation to the known methoxynaphthoic acids.



The main methods used to effect the ring closure of the above acids were the application of polyphosphoric acid or 85% sulphuric acid to the free acid, or of stannic chloride to the acid chloride. In a few cases ring closure was effected by the action of stannic chloride on the free acid, or of aluminium chloride on the acid chloride. The sulphuric acid method was satisfactory for the cyclisation of acids having a suitably activated position but, in the absence of such activation, the competing sulphonation became predominant. The polyphosphoric acid method was carried out according to the general procedure of Snyder and Werber (*J. Amer. Chem. Soc.*, 1950, **72**, 2965) but under slightly milder conditions. Much higher temperatures (150—171°) have been recommended by Evans and Smith (*J.*, 1954, 798), whereas Koo (*J. Amer. Chem. Soc.*, 1953, **75**, 1891) favours lower temperatures. The action of stannic chloride on the acid chloride by the simplified procedure used by Wilds (*ibid.*, 1942, **64**, 1421) was found to be satisfactory with activated acids.

α-Naphthylacetic acid was converted into acenaphthenone in approximately 40% yield by the polyphosphoric acid method. The sulphuric acid method gave only water-soluble products, while the use of aluminium chloride on the acid chloride by the "inverse" technique of Johnson and Glenn (*ibid.*, 1949, **71**, 1092) gave only a very small yield of acenaphthenone The cyclisation of several substituted naphthylacetic acids has already been reported. Using aluminium chloride on the acid chloride in benzene solution, Koelsch

and Richter (*ibid.*, 1937, **59**, 2165) obtained 2-phenylacenaphthenone from 1-naphthylphenylacetyl chloride and Bachmann and Sheehan (*ibid.*, 1941, **63**, 2598) obtained 3-ethylacenaphthenone from 2-ethyl-1-naphthylacetyl chloride. Using the same method but nitrobenzene as solvent, Mayer and Sieglitz (*Ber.*, 1922, **55**, 1835) obtained 5-bromoacenaphthenone from 4-bromo-1-naphthylacetyl chloride. It is now shown that 6- and 8-methoxyacenaphthenone (II and IV) can be obtained from 5- and 7-methoxy-1-naphthylacetic acid (I and III) respectively in yields of about 50% and 30% by the polyphosphoric acid method. On the other hand, all the methods attempted failed with both 4- and 6-methoxy-1-naphthylacetic acid. It is of interest to record that the successful reactions with polyphosphoric acid in this series gave a deep green translucent complex, whereas in the unsuccessful reactions the mixtures assumed an opaque blue-grey colour. The failure to obtain an acenaphthenone from 6-methoxy-1-naphthylacetic acid is not unexpected, because the *peri*-position will not be significantly activated (cf. de la Mare and Vernon, *J.*, 1951, 1764; Hey and Nagdy, *J.*, 1953, 1894). The failure with the 4-methoxy-acid is less easily understood, although Mayer and Sieglitz (*loc. cit.*) reported an abnormal reaction with β-(4-methoxy-1-naphthyl)propionic acid.

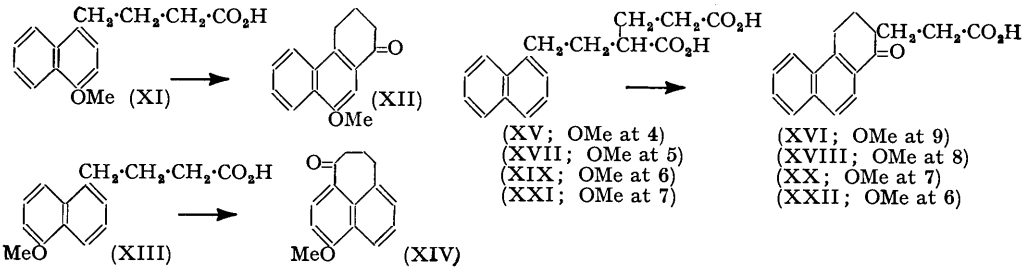
Many examples have been recorded of the conversion of β-1-naphthylpropionic acids into perinaphthanones (Mayer and Sieglitz, *loc. cit.*; Fieser and Gates, *J. Amer. Chem. Soc.*, 1940, **62**, 2335; Fieser and Novello, *ibid.*, p. 1855; Klyne and Robinson, *J.*, 1938, 1991; Badger, Carruthers, and Cook, *J.*, 1949, 1768; Ansell and Hey, *J.*, 1950, 2874; Ansell, *J.*, 1954, 575; Ansell and Berman, *J.*, 1954, 1792). In some cases a perinaphthenone is formed by dehydrogenation and also the isomeric 4 : 5-benzindan-1-one. The cyclisation of β-(5-methoxy-1-naphthyl)- and β-(7-methoxy-1-naphthyl)-propionic acid (V and IX) gives rise to 7- and 9-methoxyperinaphthanone (VI and X) respectively. Cyclisation of the 5-methoxy-acid takes place in 85% yield with sulphuric acid, and in 65—70% yield with polyphosphoric acid or stannic chloride. With the 7-methoxy-acid the yields were lower and the product was contaminated with gummy by-products. The constitution of 7-methoxyperinaphthanone was established by its oxidation to 4-methoxynaphthalic anhydride and confirmed by its ultra-violet spectrum (see below). The constitution of the isomeric 9-methoxyperinaphthanone is similarly based upon its ultra-violet spectrum (see below). In the cyclisation of neither β-(5-methoxy-1-naphthyl)- nor β-(7-methoxy-1-naphthyl)-propionic acid with polyphosphoric acid was any evidence of dehydrogenation to the perinaphthenone encountered; on the other hand, in the cyclisation of β-(2-methoxy-1-naphthyl)propionic acid with phosphoric oxide in benzene, Badger, Carruthers, and Cook (*loc. cit.*) obtained the dehydrogenated ketone as the main product.

The cyclisation of β-(6-methoxy-1-naphthyl)propionic acid (VII) with polyphosphoric acid to give 3′-methoxy-4 : 5-benzindan-1-one (VIII) has been reported by Billeter and Miescher (*Helv. Chim. Acta*, 1946, **29**, 859). This result has been confirmed and no evidence has been obtained of the formation of the isomeric 8-methoxyperinaphthanone by this or by the stannic chloride or the aluminium chloride method. The structure of the benzindanone was established by Billeter and Miescher by an alternative synthesis: its identity is now further confirmed by a comparison of its ultra-violet spectrum with those of related compounds (see below). The non-formation of the perinaphthanone is ascribed to the influence of the 6-methoxyl group which will have little influence on the 8-position but will slightly activate the 2-position.

Formation of 1 : 2 : 3 : 4-tetrahydro-9-methoxy-1-oxophenanthrene (XII) in good yield from γ-(4-methoxy-1-naphthyl)butyric acid (XI) by the Friedel–Crafts method has been demonstrated both by Kon and Ruzicka (*J.*, 1936, 187) and by Bachmann and Holmes (*J. Amer. Chem. Soc.*, 1940, **62**, 2753). This cyclisation has now been effected in about 50% yield by the sulphuric acid method, although this method has failed with the closely related γ-*p*-methoxyphenylbutyric acid (Krollpfeiffer and Schäfer, *Ber.*, 1923, **56**, 620). The cyclisation of the isomeric γ-(5-methoxy-1-naphthyl)butyric acid (XIII) was studied by Kon and Ruzicka (*loc. cit.*) and Kon and Soper (*J.*, 1939, 790), who obtained 8-methoxyhomoperinaphthanone (XIV) by the aluminium chloride method, but when the free acid was boiled with stannic chloride they obtained the isomeric 1 : 2 : 3 : 4-tetrahydro-8-methoxy-1-oxophenanthrene. Lockett and Short (*J.*, 1939, 787), however, reported that only the homoperinaphthanone was isolated in both reactions. In the present investigation

Lockett and Short's results are confirmed in that only 8-methoxyhomoperinaphthanone (XIV) could be obtained by the stannic chloride method or by the sulphuric or polyphosphoric acid method. In this reaction it appears that the activation of the peri-position produced by the 5-methoxy-group is just sufficient to overcome the greater difficulty of forming a 7-membered ring.

Cyclisation of α-2-(4-methoxy-1-naphthyl)ethylglutaric acid (XV) by means of the sulphuric acid method gave a product regarded from its ultra-violet spectrum as β-(1 : 2 : 3 : 4-tetrahydro-9-methoxy-1-oxo-2-phenanthryl)propionic acid (XVI). The same product was obtained from the acid chloride and stannic chloride. This reaction therefore follows closely the behaviour of γ-(4-methoxy-1-naphthyl)butyric acid (XI) reported above. Cyclisation of the isomeric 5-methoxy-acid (XVII), as with γ-(5-methoxy-1-naphthyl)butyric acid (XIII), may give either a homoperinaphthanone or a tetrahydro-oxophenanthrene. The product obtained by three different methods of cyclisation was a mixture, but only one pure keto-acid, m. p. 157—158°, could be isolated although there was some evidence of the formation of a second, of m. p. 186°. The ultra-violet spectrum of the acid of m. p. 157—158° indicates that it is β-(1 : 2 : 3 : 4-tetrahydro-8-methoxy-1-oxo-2-phenanthryl)propionic acid (XVIII). This result is in contrast to thecyclisation of γ-(5-methoxy-1-naphthyl)butyric acid (XIII) (above), which gave only the homoperinaphthanone, but is in agreement with the cyclisation of α-1-naphthylmethylglutaric acid, which gave β-(1-oxo-4 : 5-benzindan-2-yl)propionic acid and not the expected perinaphthanone (Ansell and Hey, *J.*, 1950, 2874).



Cyclisation of α-2-(6-methoxy-1-naphthyl)ethylglutaric acid (XIX) by means of sulphuric or polyphosphoric acid gave β-(1 : 2 : 3 : 4-tetrahydro-7-methoxy-1-oxo-2-phenanthryl)propionic acid (XX) in good yield and a similar result was obtained from the acid chloride on treatment with stannic chloride. This result is to be expected from the well-established cyclisation of γ-(6-methoxy-1-naphthyl)butyric acid to 1 : 2 : 3 : 4-tetrahydro-7-methoxy-1-oxophenanthrene. The structure of the cyclisation product was confirmed by its ultra-violet spectrum (see below). In similar manner the cyclisation of α-2-(7-methoxy-1 naphthyl)ethylglutaric acid (XXI) by means of the sulphuric acid method gave β-(1 : 2 : 3 : 4-tetrahydro-6-methoxy-1-oxo-2-phenanthryl)propionic acid (XXII), m. p. 144°, in good yield. In one experiment only some evidence of the formation of a second compound, m. p. 192°, was obtained. The closely related cyclisation of γ-(7-methoxy-1-naphthyl)butyric acid had given mainly 1 : 2 : 3 : 4-tetrahydro-6-methoxy-1-oxophenanthrene together with a little 10-methoxyhomoperinaphthanone (Bachmann and Horton, *J. Amer. Chem. Soc.*, 1947, **69**, 58). The constitution of the keto-acid, m. p. 144°, is based on its ultra-violet spectrum (see below).

Ultra-violet Absorption Spectra.—The establishment of the identity of many of the cyclic ketones obtained in the above reactions was greatly assisted by the use of ultra-violet absorption spectra. Although no general guide was available by which the constitution of such compounds could be deduced directly from such measurements, it was possible to discern a clear differentiation between the spectra of isomeric compounds and points of similarity with those of known structures in model compounds.

It has been shown by Ramart-Lucas and Hoch (*Bull. Soc. chim.*, 1952, 422) that the ultra-violet spectra of 1 : 2 : 3 : 4-tetrahydro-1- and -4-oxophenanthrene are almost identical with those of 2- and 1-naphthaldehyde respectively. This seems to show that the methylene

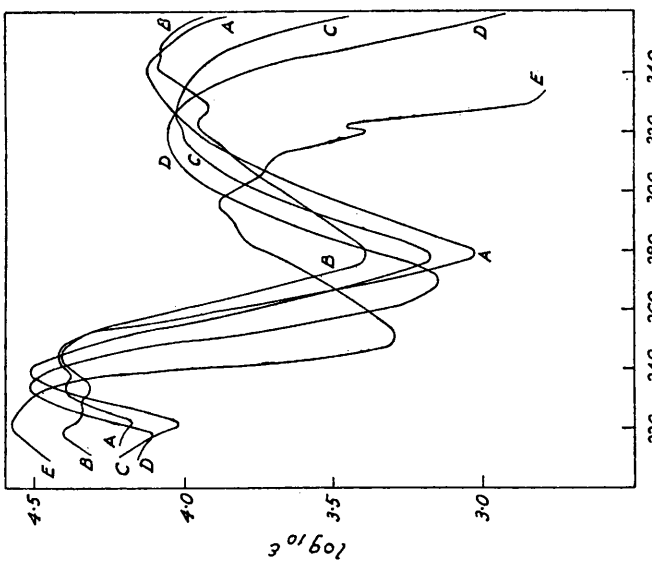
groups in the reduced ring have no appreciable effect on the spectrum and that any naphthalene derivative containing keto- and methoxy-groups in known positions should serve as suitable reference compounds. In order to make the similarity closer, compounds with a carboxyl group in the side-chain were desirable and the compounds chosen for this purpose were methoxynaphthoyl-propionic and -butyric acids.

7-*Methoxyperinaphthanone* (VI). The ultra-violet absorption spectrum of this compound is similar to those of 6-methoxyacenaphthenone (II), 8-methoxyhomoperinaphthanone (XIV), and β-(4-methoxy-1-naphthoyl)propionic acid, which shows that no dehydrogenation has taken place (see Fig. 1). Comparison of these spectra brings to light some interesting points of fine structural detail which may be confirmed by the use of models. The precise positions and intensities of the absorption bands will be mainly dependent on (*a*) the extent of the conjugation between the keto-group and the naphthalene nucleus, which in turn will depend upon their coplanarity, and (*b*) the distortion of the naphthalene system by the strain produced by the formation of the alicyclic ring, which affects the hybridisation of the nuclear carbon atoms. These effects are best illustrated by consideration of the band of longest wave-length. 7-Methoxyperinaphthanone (VI), in which there is no ring strain and in which the keto-group is almost coplanar with the naphthalene ring, has the strongest absorption. The absorption maximum for 6-methoxyacenaphthenone (II) is at the same wave-length but is slightly weaker, the band showing some splitting. In this molecule the keto-group and the naphthalene nucleus are coplanar but the naphthalene ring system itself is distorted by the 5-membered ring. 8-Methoxyhomoperinaphthanone (XIV) absorbs less strongly and at shorter wave-length. The most stable configuration of the 7-membered ring is that with the keto-group at an angle of about 45° to the ring, but since the extent of conjugation depends on the cosine of the angle, considerable conjugation is still found. Coplanarity of the keto-group in β-(4-methoxy-1-naphthoyl)propionic acid is prevented by the steric hindrance of the *peri*-hydrogen atom, as a result of which the most stable configuration of the side chain will be that with the keto-group at a similar angle to the ring to that found in the homoperinaphthanone, and accordingly the spectra of these two compounds will be similar. If the keto-group were perpendicular to the nucleus the spectrum would be similar to that of γ-(5-methoxy-1-naphthyl)butyric acid (XIII) and α-naphthol itself (Daglish, *J. Amer. Chem. Soc.*, 1950, **72**, 4859).

9-*Methoxyperinaphthanone* (X). The ultra-violet spectrum shows a close similarity to that of 8-methoxyacenaphthenone (IV) (see Fig. 2). The spectrum of γ-(2-methoxy-1-naphthoyl)butyric acid was also measured but it shows marked differences from those of the perinaphthanone and acenaphthenone. As in the case of β-(4-methoxy-1-naphthoyl)-propionic acid the keto-group is forced out of the plane of the naphthalene ring by the steric effect of the *peri*-hydrogen atom. With γ-(2-methoxy-1-naphthoyl)butyric acid this effect is enhanced by the 2-methoxyl group, which interferes with the adjacent methylene group of the side chain so that the most stable configuration will be that in which the keto-group is about perpendicular to the ring. This spectrum resembles that of β-naphthol (Daglish, *loc. cit.*).

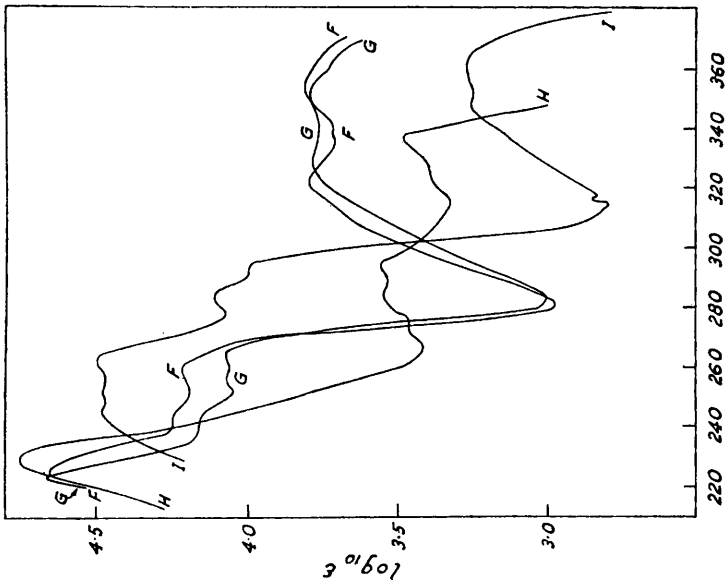
The β-(*tetrahydromethoxyoxophenanthryl*)*propionic acids* (XVI, XVIII, XX, and XXII). The ultra-violet spectrum of β-(1 : 2 : 3 : 4-tetrahydro-9-methoxy-1-oxo-2-phenanthryl)-propionic acid (XVI) shows a close similarity to that of 1 : 2 : 3 : 4-tetrahydro-9-methoxy-1-oxophenanthrene (see Fig. 3). The spectrum of the isomeric β-(1 : 2 : 3 : 4-tetrahydro-8-methoxy-1-oxo-2-phenanthryl)propionic acid (XVIII) shows marked differences from that of 8-methoxyhomoperinaphthanone (XIV) but closely resembles that of the 9-methoxy-acid above, both being derivatives of β-acylnaphthalene containing an α-methoxyl group not actively conjugated with the ketone (see Figs. 1 and 3). The ultra-violet spectrum of β-(1 : 2 : 3 : 4-tetrahydro-7-methoxy-1-oxo-2-phenanthryl)propionic acid (XX) resembles those of γ-(6-methoxy-2-naphthoyl)butyric acid, 3′-methoxy-4 : 5-benzindan-1-one (VIII) (see Fig. 4) and 1 : 2 : 3 : 4-tetrahydro-7-methoxy-2-methyl-1-oxophenanthrene (cf. Wilds *et al.*, *J. Amer. Chem. Soc.*, 1947, **69**, 1982). The absorption of longest wave-length is weaker in the two tetrahydrophenanthrenes, but models show that the keto-group in these molecules is at a small angle to the naphthalene ring, and not coplanar as in the other two compounds. The existence of keto–lactol tautomerism in δ-keto-acids has been suggested

FIG. 1.



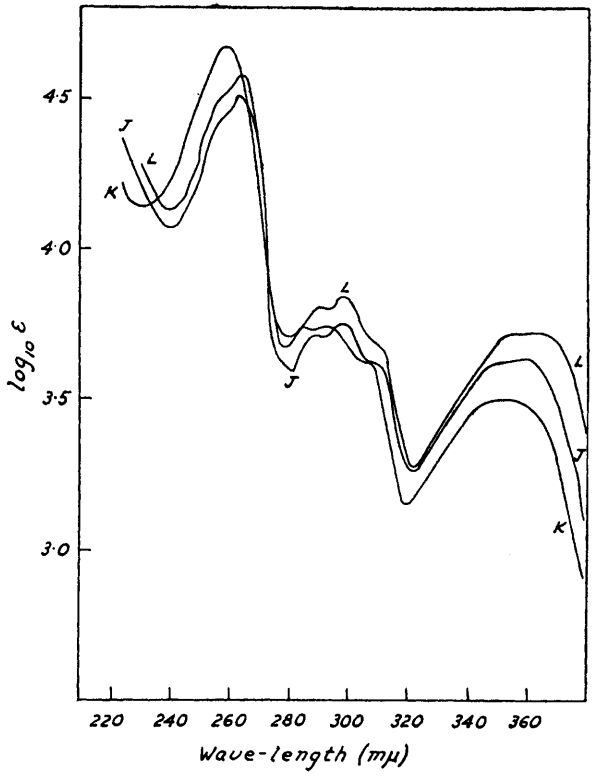
A, 7-Methoxyperinaphthanone.
B, 6-Methoxyacenaphthenone.
C, 8-Methoxyhomoperinaphthanone.
D, β-(4-Methoxy-1-naphthoyl)propionic acid.
E, γ-(5-Methoxy-1-naphthyl)butyric acid.

FIG. 2.



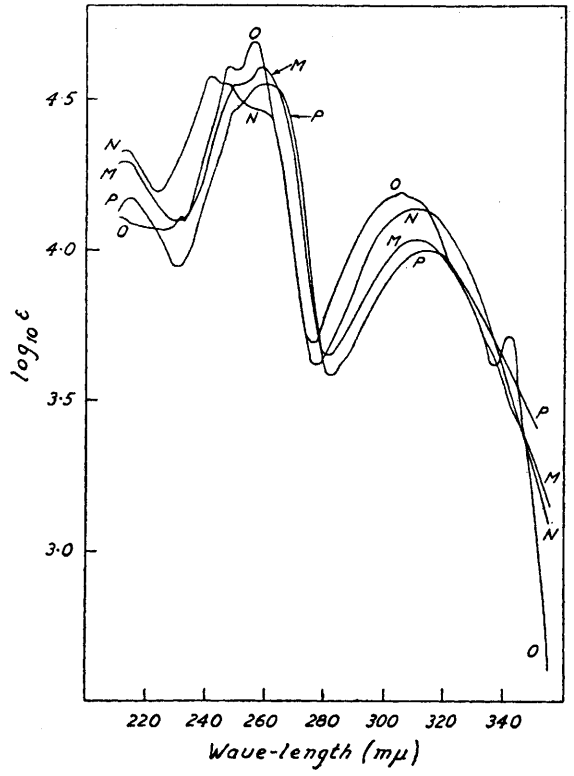
F, 9-Methoxyperinaphthanone.
G, 8-Methoxyacenaphthenone.
H, γ-(2-Methoxy-1-naphthoyl)butyric acid.
I, β-(1 : 2 : 3 : 4-Tetrahydro-6-methoxy-1-oxo-2-phenanthryl)propionic acid.

FIG. 3.



J, β-(1 : 2 : 3 : 4-*Tetrahydro*-9-*methoxy*-1-*oxo*-2-*phenanthryl*)*propionic acid.*
K, β-(1 : 2 : 3 : 4-*Tetrahydro*-8-*methoxy*-1-*oxo*-2-*phenanthryl*)*propionic acid.*
L, 1 : 2 : 3 : 4-*Tetrahydro*-9-*methoxy*-1-*oxophenanthrene.*

FIG. 4.



M, β-(1 : 2 : 3 : 4-*Tetrahydro*-7-*methoxy*-1-*oxo*-2-*phenanthryl*)*propionic acid.*
N, γ-(6-*Methoxy*-2-*naphthoyl*)*butyric acid.*
O, 3′-*Methoxy*-4 : 5-*benzindan*-1-*one.*
P, *Methyl* β-(1 : 2 : 3 : 4-*tetrahydro*-7-*methoxy*-1-*oxo*-2-*phenanthryl*)-*propionate.*

by Kon, Stevenson, and Thorpe (*J.*, 1922, **121**, 651) but its existence in β-(1 : 2 : 3 : 4-tetrahydro-7-methoxy-1-oxo-2-phenanthryl)propionic acid (XX) is extremely doubtful both from considerations of bond energies and from the fact that it is the keto-form which is stabilised by resonance with the naphthalene ring. This is confirmed by the ultra-violet spectrum of its methyl ester, which is almost identical with that of the free acid (see Fig. 4).

The ultra-violet spectrum of β-(1 : 2 : 3 : 4-tetrahydro-6-methoxy-1-oxo-2-phenanthryl)-propionic acid (XXII) shows large differences in the positions and intensities of the absorption maxima from those of 8-methoxyacenaphthenone (IV) and 9-methoxyperinaphthanone (X), although it is similar in shape (see Fig. 2). These differences are not compatible with a homoperinaphthanone structure, but the spectrum is not inconsistent with a tetrahydro-1-oxophenanthrene structure, which would show the three β-acylnaphthalene bands with approximately the same wave-lengths and intensities found, the 6-methoxyl group being in an inactive position {cf. β-[1 : 2 : 3 : 4-tetrahydro-8(and 9)-methoxy-1-oxo-2-phenanthryl]-propionic acid; Fig. 3}.

Experimental

Preparation of the acids.

4-Methoxy-1-naphthylacetic Acid.—1-Acetyl-4-methoxynaphthalene (Buu-Hoï and Cagniant, *Rec. Trav. chim.*, 1945, **64**, 216) was converted into 4-methoxy-1-naphthylthioacetomorpholide, m. p. 166—167° (after repeated extraction with boiling ethanol and treatment with charcoal), by the method used by Carmack and Spielman ("Organic Reactions," Wiley, New York, 1946, Vol. III, p. 97) for the preparation of 1-naphthylthioacetomorpholide. The methoxynaphthylthioacetomorpholide (2 g.) was boiled under reflux for 5 hr. with glacial acetic acid (4 c.c.), water (0·8 c.c.), and sulphuric acid (0·6 c.c.), then cooled and diluted with water. Crystallisation of the precipitate (0·6 g.; m. p. 200—203°) from water gave 4-hydroxy-1-naphthylacetic acid in plates, m. p. 202—204° with slight decomp. (Found: C, 70·8; H, 4·9. Calc. for $C_{12}H_{10}O_3$: C, 71·3; H, 4·9%). Ogata, Okano, and Kitamura (*J. Org. Chem.*, 1951, **16**, 1588) recorded m. p. 192—194° for this acid prepared by another method. A suspension of 4-methoxy-1-naphthylthioacetomorpholide (2 g.) with water (2·5 c.c.), ethanol (2·5 c.c.), and potassium hydroxide (2 g.) was boiled under reflux for 24 hr., during which three portions of water (1 c.c.) and ethanol (1 c.c.) were added to maintain a constant volume. The solution was diluted with water, washed with ether, boiled with charcoal, filtered, cooled, and acidified. Crystallisation of the precipitate from water gave 4-methoxy-1-naphthylacetic acid (0·7 g.) in needles, m. p. 147—148°. Mauthner (*J. pr. Chem.*, 1917, **95**, 60) recorded m. p. 144—145° for this acid prepared by another method.

5-Methoxy-1-naphthylacetic Acid.—2-*o*-Methoxyphenylethanol, b. p. 98—100°/0·05 mm., prepared as described by Hardegger, Redlich, and Gal (*Helv. Chim. Acta*, 1945, **28**, 628), was converted into 2-*o*-methoxyphenylethyl bromide and thence into 2-*o*-methoxyphenylethylmalonic acid, m. p. 137—139°, by the general method of Bachmann, Cole, and Wilds (*J. Amer. Chem. Soc.*, 1940, **62**, 824). Decarboxylation at 175° followed by distillation under reduced pressure gave γ-*o*-methoxyphenylbutyric acid, b. p. 130—140°/0·03 mm., m. p. 39°, in almost quantitative yield. Hardegger, Redlich, and Gal (*loc. cit.*) recorded m. p. 39°. Cyclodehydration of γ-*o*-methoxyphenylbutyric acid to 5-methoxytetral-1-one, yellow needles, m. p. 88—89° [from light petroleum (b. p. 60—80°)], was carried out as described by Lockett and Short (*J.*, 1939, 787). To pure dry zinc foil (2 g.), activated by washing successively with dilute hydrochloric acid, water, and acetone, were added 5-methoxytetralone (4·2 g.), ether (28 c.c.), benzene (28 c.c.), methyl bromoacetate (2 c.c.), and a trace of iodine, and the mixture was boiled under reflux for 5 hr. At four intervals of 45 min. further portions of activated zinc (2 g.) were added, and after 1½ hr. more methyl bromoacetate (2 c.c.). The mixture was then cooled, poured into water, and acidified with acetic acid. The product was extracted with benzene, and the extract was washed with dilute aqueous ammonia and then water. The residue obtained on evaporation of the solvent was boiled with 90% formic acid (10 c.c.) for 20 min. After removal of formic acid in a current of air, the unsaturated ester was boiled for 4 hr. with water (15 c.c.) and methanol (15 c.c.) containing potassium hydroxide (3 g.). The solution was cooled, diluted, washed with ether, boiled with charcoal, filtered, cooled in ice, and acidified. Crystallisation from methanol of the solid which separated gave the unsaturated acid (3·5 g.) in needles, m. p. 166—168°. Dehydrogenation by sulphur for 30 min. at 200—230° gave 5-methoxy-1-naphthylacetic acid (60%) in needles, m. p. 195—196° (from aqueous methanol) (Found: C, 72·0; H, 5·5. Calc. for $C_{13}H_{12}O_3$: C, 72·2; H, 5·6%). Ogata, Okano, and Kitamura (*loc. cit.*) recorded m. p. 194—195° for this acid prepared by another method.

6-*Methoxy*-1-*naphthylacetic Acid*.—γ-*p*-Methoxyphenylbutyric acid (Martin, *op. cit.*, 1942, Vol. I, p. 167) was converted into 7-methoxytetral-1-one, m. p. 60—61°, in 85% yield and thence into 6-methoxytetralin, b. p. 125—135°/15 mm., in 71% yield by Thomas and Nathan's method (*J. Amer. Chem. Soc.*, 1948, **70**, 331). Subsequent oxidation, as described by Burnop, Elliott, and Linstead (*J.*, 1940, 727), gave 6-methoxytetral-1-one, m. p. 77·5—78·5°. Application of the Reformatsky reaction to this ketone (2·7 g.), as described above for the 5-methoxy-isomeride, gave the unsaturated acid (0·4 g.) which, as in the preceding example, was dehydrogenated with sulphur at 220—240°. 6-Methoxy-1-naphthylacetic acid was obtained in needles, m. p. 155—157°, from aqueous methanol. Haberland (*Ber.*, 1936, **69**, 1380) gave m. p. 155°.

7-*Methoxy*-1-*naphthylacetic Acid*.—This acid, m. p. 153—154°, was prepared from 7-methoxytetral-1-one as described by Campbell and Todd (*J. Amer. Chem. Soc.*, 1942, **64**, 928), but in the final dehydrogenation sulphur, as described by Haberland (*loc. cit.*), was found to be superior to chloranil.

β-(5-*Methoxy*-1-*naphthyl*)*propionic Acid*.—1-Bromo-5-nitronaphthalene (Shoesmith and Rubli, *J.*, 1927, 3104) was converted into 5-bromo-1-naphthylamine by Fries and Kohler's method (*Ber.*, 1924, **57**, 504) and thence into 1-bromo-5-methoxynaphthalene as described by Hill, Short, and Stromberg (*J.*, 1937, 1619). In addition, 1-iodo-5-methoxynaphthalene was prepared from 5-amino-1-naphthol by Lockett and Short's method (*J.*, 1939, 789). A solution of 1-bromo-5-methoxynaphthalene (23·5 g.) and ethyl bromide (7·6 c.c.) in dry ether (150 c.c.) was added during 1 hr. with stirring to magnesium turnings (4·9 g.). The mixture was boiled under reflux for 1 hr. and then cooled in ice and salt. With vigorous stirring, a solution of ethylene oxide (14 c.c.) in ether (25 c.c.) was added dropwise during 30 min. The mixture was stirred at 0° for a further 30 min. and then left at room temperature overnight. After removal of the ether the residue was decomposed with ice and dilute hydrochloric acid. The product was extracted with ether, washed with water, and dried ($CaCl_2$). Evaporation followed by distillation under reduced pressure gave (i) methyl α-naphthyl ether (1 g.), b. p. 80—130°/0·3 mm., and (ii) 2-(5-methoxy-1-naphthyl)ethyl alcohol, b. p. 154—156°/0·3 mm., which crystallised from light petroleum (b. p. 60—80°) in needles (16·5 g.), m. p. 55°. An identical product was obtained in similar yield from 1-iodo-5-methoxynaphthalene. Kon and Ruzicka (*J.*, 1936, 187) recorded m. p. 53—54°. The alcohol was converted into 2-(5-methoxy-1-naphthyl)ethyl bromide, b. p. 130°/0·17 mm., m. p. 34°, by Kon and Ruzicka's method (*loc. cit.*). A solution of 2-(5-methoxy-1-naphthyl)ethyl bromide (3·9 g.) and ethyl bromide (1·1 c.c.) in dry ether (30 c.c.) was added to magnesium (0·72 g.) and a trace of iodine. The mixture was boiled under reflux for 5 hr. and then cooled. The ether layer was poured rapidly on solid carbon dioxide (*ca.* 10 g.), and the mixture was allowed to attain room temperature during 2 hr. After decomposition with ice and dilute hydrochloric acid the product was extracted with ether, and the ethereal extract was washed with aqueous sodium hydroxide. Acidification of the alkaline solution precipitated β-(5-*methoxy*-1-*naphthyl*)*propionic acid* (2 g.), which crystallised from glacial acetic acid in plates, m. p. 183—184° (Found: C, 72·1; H, 6·3. $C_{14}H_{14}O_3$ requires C, 73·0; H, 6·1%). This acid appeared to retain a small trace of solvent in spite of prolonged standing *in vacuo* and heating in an air oven. Lin, Resuggan, Robinson, and Walker (*J.*, 1937, 70) reported a similar observation on the isomeric 6-methoxy-acid.

β-(6-*Methoxy*-1-*naphthyl*)*propionic Acid*.—5-Acetamido-2-naphthol (Campbell, Laforge, and Campbell, *J. Org. Chem.*, 1949, **14**, 351) was converted successively into 1-acetamido- and 1-iodo-6-methoxynaphthalene as described by Wilds and Close (*J. Amer. Chem. Soc.*, 1947, **69**, 3079). The iodo-compound (46 g.) and ethyl bromide (12·3 c.c.) in ether (300 c.c.) were added to magnesium turnings (7·9 g.), and subsequent reaction with ethylene oxide (25 c.c.) in ether (50 c.c.), as described in the preceding preparation, gave (i) ethylene iodohydrin (*ca.* 10 g.), b. p. 40°/0·1 mm., (ii) methyl β-naphthyl ether (3 g.), b. p. 70—130°/0·1 mm., and (iii) 2-(6-methoxy-1-naphthyl)ethyl alcohol (23 g.), b. p. 160°/0·1 mm. The last was converted into 2-(6-methoxy-1-naphthyl)ethyl bromide (needles, m. p. 56—57°, from alcohol) as described by Cohen, Cook, and Hewett (*J.*, 1935, 452). The bromide (3·47 g.) was converted by the method described in the previous example into β-(6-methoxy-1-naphthyl)propionic acid (1·8 g.), which separated from glacial acetic acid in plates, m. p. 159—160°. Lin, Resuggan, Robinson, and Walker (*loc. cit.*) recorded m. p. 159°, and Billeter and Miescher (*Helv. Chim. Acta*, 1946, **29**, 865), m. p. 162° for this acid prepared by different methods.

β-(7-*Methoxy*-1-*naphthyl*)*propionic Acid*.—A solution of 7-methoxytetral-1-one (10 g.) and ethyl β-bromopropionate (10·3 g.) in sodium-dried toluene (100 c.c.) was boiled under reflux for 3 hr. with magnesium turnings (1·4 g.) activated with iodine (cf. Haberland and Heinrich, *Ber.*, 1939, **72**, 1225). The solution was cooled and decomposed with ice and dilute hydrochloric

acid. The toluene layer was separated and the aqueous layer was washed with ether. The combined extracts were washed with water, and the solvents were evaporated. The residual ester was hydrolysed by boiling it for 2 hr. with water (25 c.c.) and methanol (25 c.c.) containing potassium hydroxide (10 g.). The cooled solution was diluted and washed with ether, which removed unchanged 7-methoxytetral-1-one (1·5 g.). Acidification of the alkaline layer, previously boiled with charcoal, gave an oil which on distillation at 180—190°/0·2 mm. gave the unsaturated acid (1·4 g.), m. p. 138—140° (plates from methanol–benzene). Dehydrogenation of the acid (0·11 g.) with sulphur (0·018 g.) at 220—240° for 30 min. gave β-(7-methoxy-1-naphthyl)propionic acid (0·06 g.) in plates, m. p. 158—160° (from aqueous methanol). Campbell and Todd (*loc. cit.*) recorded m. p. 162·5—164° for this acid, prepared by another method and after repeated crystallisation from ether–hexane.

γ-(4-Methoxy-1-naphthyl)butyric Acid.—This acid, m. p. 127°, was prepared from methyl α-naphthyl ether and succinic anhydride as described by Bachmann and Holmes (*J. Amer. Chem. Soc.*, 1940, **62**, 2750).

γ-(5-Methoxy-1-naphthyl)butyric Acid.—This acid, m. p. 141—142°, was prepared in improved yield from 2-(5-methoxy-1-naphthyl)ethyl bromide and ethyl malonate by Kon and Ruzicka's method (*loc. cit.*), with the modified procedure used by Bachmann, Cole, and Wilds (*J. Amer. Chem. Soc.*, 1940, **62**, 825) for the 6-methoxy-acid.

α-2-(4-Methoxy-1-naphthyl)ethylglutaric Acid.—1-Bromo-4-methoxynaphthalene (Buu-Hoï, *Annalen*, 1944, **556**, 1) (23·5 g.) was converted into 2-(4-methoxy-1-naphthyl)ethyl alcohol (13 g.) by means of a Grignard reaction with ethylene oxide (12 c.c.) and ethyl bromide (7·6 c.c.) as described above for the corresponding reaction with 1-bromo-5-methoxynaphthalene. Repeated crystallisation to constant m. p. from benzene–light petroleum gave the alcohol in needles, m. p. 74° (Found: C, 77·1; H, 7·0. Calc. for $C_{13}H_{14}O_2$: C, 77·2; H, 6·9%). Kon and Ruzicka (*loc. cit.*) have reported m. p. 87° for this compound after repeated crystallisation. In a second preparation a melting point of 83° (after one recrystallisation) was obtained. The alcohol, m. p. 74°, was converted into 2-(4-methoxy-1-naphthyl)ethyl bromide and thence into ethyl 2-(4-methoxy-1-naphthyl)ethylmalonate as described by Kon and Ruzicka (*loc. cit.*). Acrylonitrile (0·86 c.c.) was added dropwise to a stirred solution of ethyl 2-(4-methoxy-1-naphthyl)ethylmalonate (4·5 g.) and 30% methanolic potassium hydroxide (0·3 g.) in *tert.*-butyl alcohol (7 c.c.) at 30—35°. After the addition the solution was stirred at this temperature for 3 hr., after which it was diluted with water (10 c.c.), neutralised with 2N-hydrochloric acid, and extracted with ether. Evaporation of the dried ($MgSO_4$) extract left ethyl α-(2-cyanoethyl)-α-2-(4-methoxy-1-naphthyl)ethylmalonate as a viscous oil which was boiled under reflux for 2 hr. with potassium hydroxide (4·5 g.) in alcohol (5 c.c.) and water (4 c.c.). At the end of this time more water (4 c.c.) was added and boiling continued for 3 hr. The alcohol was removed by distillation and the solution was diluted and washed with ether. Acidification of the aqueous layer gave the free tricarboxylic acid, which was extracted with ether and dried ($MgSO_4$). Evaporation of the ether left an oil, which was decarboxylated by heating it for 1 hr. in an oil-bath at 180—190°. The cooled product was boiled with water and extracted with ether. Evaporation left *α-2-(4-methoxy-1-naphthyl)ethylglutaric acid* (2·0 g.), which crystallised from ethylene chloride in needles, m. p. 137° (Found: C, 67·9; H, 6·4. $C_{18}H_{20}O_5$ requires C, 68·3; H, 6·3%).

α-2-(5-Methoxy-1-naphthyl)ethylglutaric Acid.—2-(5-Methoxy-1-naphthyl)ethyl bromide (4·5 g.) and ethyl malonate (5 c.c.), by Kon and Ruzicka's method (*loc. cit.*), gave ethyl 2-(5-methoxy-1-naphthyl)ethylmalonate (3·5 g.). Subsequent reaction of this ester (2·0 g.) with acrylonitrile, as described for the corresponding 4-methoxy-isomeride above, followed by hydrolysis and decarboxylation, gave *α-2-(5-methoxy-1-naphthyl)ethylglutaric acid* (0·7 g.), which separated from ethylene chloride in plates, m. p. 137° (Found: C, 68·4; H, 6·4%).

α-2-(6-Methoxy-1-naphthyl)ethylglutaric Acid.—In similar manner 2-(6-methoxy-1-naphthyl)-ethyl bromide (14 g.) and ethyl malonate (15 c.c.) gave ethyl 2-(6-methoxy-1-naphthyl)ethylmalonate (12 g.; b. p. 190—220°/0·05 mm.) (cf. Bachmann, Cole, and Wilds, *loc. cit.*; Wilds and Close, *J. Amer. Chem. Soc.*, 1947, **69**, 3079), which in turn was converted into *α-2-(6-methoxy-1-naphthyl)ethylglutaric acid* (8 g.), which separated from ethylene chloride as a microcrystalline powder, m. p. 148—149° (Found: C, 67·8; H, 6·5%).

α-2-(7-Methoxy-1-naphthyl)ethylglutaric Acid.—1-Iodo-7-methoxynaphthalene (40 g.), prepared from 8-amino-2-naphthol by Bachmann and Horton's method (*J. Amer. Chem. Soc.*, 1947, **69**, 58), was converted by a Grignard reaction with ethylene oxide (26 c.c.) in presence of ethyl bromide (10·8 c.c.), as described above, into 2-(7-methoxy-1-naphthyl)ethyl alcohol (20·5 g.; m. p. 83°, from benzene–light petroleum). Conversion into the bromide (11 g.) and subsequent reactions with ethyl malonate and then with acrylonitrile, as in the preceding examples, gave α-2-(7-

methoxy-1-naphthyl)ethylglutaric acid (4·5 g.) in needles, m. p. 162°, from ethylene chloride (Found: C, 67·9; H, 6·4%).

Action of Glutaric Anhydride on 2-Methoxynaphthalene (cf. Johnson, Jones, and Schneider, *J. Amer. Chem. Soc.*, 1950, **72**, 2395).—A solution of glutaric anhydride (12 g.; prepared by Fieser and Martin's method, *Org. Synth.*, Coll. Vol. II, p. 560, for succinic anhydride) in nitrobenzene (25 c.c.) was added dropwise during 1 hr. with vigorous stirring to 2-methoxynaphthalene (15·6 g.) and aluminium chloride (28 g.) in nitrobenzene (100 c.c.), the whole being cooled in ice–salt. The resulting sludge was stirred for a further 10 min. and the flask was then fitted with a soda-lime guard-tube and kept in the refrigerator for 6 days. The complex was added to ice and dilute hydrochloric acid, and the nitrobenzene removed with steam. The solid residue was collected and extracted with aqueous sodium carbonate. The alkaline solution was shaken with charcoal, filtered, and cooled in ice. Acidification with hydrochloric acid gave a mixture of acids (23 g.). Crystallisation from acetone gave γ-(6-*methoxy*-2-*naphthoyl*)*butyric acid* (6·1 g.), m. p. 176° (Found: C, 70·2; H, 5·8. $C_{16}H_{16}O_4$ requires C, 70·5; H, 5·8%). A further crop (1 g.) of the same acid was obtained on concentration of the mother-liquor. The residual acetone solution (100 c.c.) was boiled under reflux for 5 hr. with methanol (100 c.c.) and a little sulphuric acid. The product was poured into water and extracted with ether, and the ether was evaporated from the dried ($CaCl_2$) extract. The residual oil crystallised from alcohol, and the product (3 g.; m. p. 47—49°) was hydrolysed with boiling 2N-sodium hydroxide. Acidification of the cooled solution gave γ-(2-*methoxy*-1-*naphthoyl*)*butyric acid* (2 g.), which crystallised from ethyl acetate–light petroleum (b. p. 80—100°) in needles, m. p. 108° (Found: C, 69·9; H, 5·8. $C_{16}H_{16}O_4$ requires C, 70·5; H, 5·8%). In a similar reaction carried out with 2-methoxynaphthalene (7·85 g.) and aluminium chloride (14 g.) in tetrachloroethane (50 c.c.) to which glutaric anhydride (6 g.) in nitrobenzene (20 c.c.) was added, the products were γ-(6-methoxy-2-naphthoyl)butyric acid (2 g.), m. p. 174—175°, and γ-(2-methoxy-1-naphthoyl)butyric acid (5·5 g.), m. p. 108°.

Oxidation of γ-(2-Methoxy-1-naphthoyl)butyric Acid.—γ-(2-Methoxy-1-naphthoyl)butyric acid (1 g.) was added to a cold solution of sodium hydroxide (3 g.) in water (50 c.c.) to which bromine (1 c.c.) had been added. After 12 hr. the solid was collected and boiled with water, and the aqueous solution acidified. Crystallisation of the precipitate from ethyl acetate–light petroleum (b. p. 80—100°) gave 2-methoxy-1-naphthoic acid in pale yellow plates, m. p. 175°. Short, Stromberg, and Wiles (*J.*, 1936, 319) recorded m. p. 174—175°.

Oxidation of γ-(6-Methoxy-2-naphthoyl)butyric Acid.—In a similar manner γ-(6-methoxy-2-naphthoyl)butyric acid gave 6-methoxy-2-naphthoic acid, which separated from ethyl acetate in needles, m. p. 195—196° (Found: C, 71·2; H, 5·0. Calc. for $C_{12}H_{10}O_3$: C, 71·3; H, 5·0%). The same product was also obtained by oxidation of β-(6-methoxy-2-naphthoyl)propionic acid, prepared by the method of Bachmann and Morin (*J. Amer. Chem. Soc.*, 1944, **66**, 553). Short, Stromberg, and Wiles (*loc. cit.*) have recorded m. p. 205° for 6-methoxy-2-naphthoic acid, and Fries and Schimmelschmidt (*Ber.*, 1925, **58**, 2840) m. p. 209°, but our m. p. is in agreement with that reported by Price and Kaplan (*J. Amer. Chem. Soc.*, 1944, **66**, 477). The identity of the acid, m. p. 195—196°, is confirmed by the ultra-violet spectrum of the methoxynaphthoylbutyric acid from which it was derived.

Ring closure experiments.

Five methods of ring closure were used, namely (A) the action of polyphosphoric acid on the acid, (B) the action of 85% sulphuric acid on the acid, (C) the action of stannic chloride on the acid, (D) the action of aluminium chloride on the acid chloride, and (E) the action of stannic

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NOTES TO TABLE ON OPPOSITE PAGE.

* Pet = light petroleum (b. p. 60—80°). † In benzene in place of tetrachloroethane (see Johnson and Glenn, *J. Amer. Chem. Soc.*, 1949, **71**, 1092). ‡ Temp. not above 70°. § Temp. not above 60°. ¶ Temp. not above 80°.

[a] Graebe and Jequier (*loc. cit.*). [b] For $C_{13}H_{10}O_2$. [c] For $C_{14}H_{12}O_2$. [d] For $C_{18}H_{18}O_4$. [e] Billeter and Miescher (*loc. cit.*) recorded m. p. 133°. [f] Kon and Ruzicka (*loc. cit.*) recorded m. p. 98°. [g] *Idem* (*ibid.*) recorded m. p. 88—89°. [h] Oxidation with sodium dichromate in acetic acid, as described by Kon and Soper (*loc. cit.*) for 8-methoxyhomoperinaphthanone, gave 4-methoxynaphthalic anhydride, m. p. 257°. [i] The *methyl ester*, prepared with methanol–sulphuric acid, separated from methanol in plates, m. p. 103—104° (Found: C, 72·3; H, 6·7. $C_{19}H_{20}O_4$ requires C, 73·1; H, 6·4%). [j] Some evidence was obtained of the formation of a compound, m. p. 186°. [k] In one experiment evidence was obtained of the formation of a second compound, m. p. 192°. The main bulk of the product (0·6 g.) had m. p. 56—59°. [m] Wt. of crude product.

Ring closure experiments.

Acid	G.	Method	Product	g.	Form, solvent,* m. p.	Found (%)	Calc. (%)	Acid recovered (g.)
1-Naphthylacetic	0·5	A	Acenaphthenone	0·18	Yellow needles, aq. EtOH, 119—120° [a]	—	—	Trace
,,	0·5	B	Water soluble	—	—	—	—	0·1
,,	0·9	D †	Acenaphthenone	0·02 [l]	—	—	—	Trace
4-Methoxy-1-naphthylacetic	0·2	A	—	—	—	—	—	0·1
,, ,,	0·3	B	—	—	—	—	—	Trace
,, ,,	0·65	D †	Gum	—	—	—	—	0·05
5-Methoxy-1-naphthylacetic	0·2	A	6-*Methoxyacenaphthenone*	0·09	Needles, Pet, 143—144°	C, 77·8 H, 4·9	C, 78·8 [b] H, 5·05 [b]	0·02
,, ,,	0·1	B	Water-soluble	—	—	—	—	Trace
,, ,,	0·25	D	6-Methoxyacenaphthenone	0·07	143—144°	—	—	—
6-Methoxy-1-naphthylacetic	0·04	A	Gum	—	—	—	—	Trace
7-Methoxy-1-naphthylacetic	0·2	A	8-*Methoxyacenaphthenone*	0·05	Needles, Pet, 97—98°	C, 78·4 H, 5·25	C, 78·8 [b] H, 5·05 [b]	Trace
,, ,,	0·2	B	Water-soluble	—	—	—	—	0·02
,, ,,	0·2	E	Tar	—	—	—	—	0·12
β-(5-Methoxy-1-naphthyl)propionic	0·1	A	7-*Methoxyperinaphthanone* [h]	0·06	Yellow plates, Pet, 104—105°	C, 79·2 H, 5·8	C, 79·2 [c] H, 5·7 [c]	Trace
,, ,, ,,	0·45	B	,, ,,	0·35	,, ,,	—	—	—
,, ,, ,,	0·2	E	,, ,,	0·13	,, ,,	—	—	—
β-(6-Methoxy-1-naphthyl)propionic	0·3	A	3′-Methoxy-4 : 5-benzindan-1-one	0·12	Needles, aq. MeOH, 133° [e]	—	—	—
,, ,, ,,	0·45	D †	,, ,,	0·1	,, ,,	—	—	—
,, ,, ,,	0·45	E	,, ,,	0·2 [m]	,, ,,	—	—	—
,, ,, ,,	0·2	B	Water-soluble	(Trace)	—	—	—	Trace
β-(7-Methoxy-1-naphthyl)propionic	0·1	B ‡	9-*Methoxyperinaphthanone*	0·02	Pale green needles, Pet, 80—81°	C, 79·3 H, 5·9	C, 79·2 [c] H, 5·7 [c]	0·04
,, ,, ,,	0·06	A	,, ,,	0·01	,, ,,	—	—	—
γ-(4-Methoxy-1-naphthyl)butyric	1·0	B §	1 : 2 : 3 : 4-Tetrahydro-9-methoxy-1-oxophenanthrene	0·46	Needles, aq. EtOH, 95—96 ° [f]	—	—	—
γ-(5-Methoxy-1-naphthyl)butyric	0·5	B ¶	8-Methoxyhomoperinaphthanone	0·15	Prisms, Pet, 87—88° [g]	—	—	0·05
,, ,, ,,	0·5	C	,, ,,	0·15	,, ,,	—	—	0·15
,, ,, ,,	0·15	A	,, ,,	0·07 [m]	,, ,,	—	—	Trace
α-2-(4-Methoxy-1-naphthyl)ethylglutaric	0·1	B ‡	β-(1 : 2 : 3 : 4-*Tetrahydro*-9-*methoxy*-1-*oxo*-2-*phenanthryl*)*propionic acid*	0·08	Needles, aq. dioxan, 212°	C, 72·1 H, 6·3	C, 72·5 [d] H, 5·7 [d]	—
,, ,, ,,	0·1	E	,, ,,	0·07 [m]	,, ,,	—	—	—
α-2-(5-Methoxy-1-naphthyl)ethylglutaric	0·5	B	β-(1 : 2 : 3 : 4-*Tetrahydro*-8-*methoxy*-1-*oxo*-2-*phenanthryl*)*propionic acid*	0·45 [m]	Plates, aq. dioxan, 157—158°	C, 71·8 H, 5·9	C, 72·5 [d] H, 5·7 [d]	—
,, ,, ,,	0·2	A	Gums	—	—	—	—	—
,, ,, ,,	0·63	E	Gums [j]	—	—	—	—	—
α-2-(6-Methoxy-1-naphthyl)ethylglutaric	1·0	B	β-(1 : 2 : 3 : 4-*Tetrahydro*-7-*methoxy*-1-*oxo*-2-*phenanthryl*)*propionic acid* [i]	0·9 [m]	Needles, aq. dioxan, 193°	C, 72·4 H, 5·8	C, 72·5 [d] H, 5·7 [d]	—
,, ,, ,,	0·5	A	,, ,, ,,	0·35	,, ,,	—	—	0·05
,, ,, ,,	0·63	E	,, ,, ,,	0·45	,, ,,	—	—	—
α-2-(7-Methoxy-1-naphthyl)ethylglutaric	0·2	B ‡	β-(1 : 2 : 3 : 4-*Tetrahydro*-6-*methoxy*-1-*oxo*-2-*phenanthryl*)*propionic acid* [k]	0·18 [m]	Needles, aq. dioxan, 144°	C, 72·0 H, 5·9	C, 72·5 [d] H, 5·7 [d]	—

chloride on the acid chloride. These methods are illustrated by the following five typical examples and the complete results of all the ring closures carried out are summarised in the Table.

Method A. (For references see Evans and Smith, *J.*, 1954, 798.) 1-Naphthylacetic acid (0·5 g.) was added to stirred polyphosphoric acid (5—10 c.c.) at 60°. The temperature was slowly raised to 100° and maintained thereat for 30 min. Ice was added to the cooled mixture, which was then extracted with ether. The ethereal extract was washed with aqueous sodium hydroxide, then with water, and dried (Na_2SO_4). Evaporation of the solvent left crude acenaphthenone (0·18 g.), which separated from aqueous alcohol in pale yellow needles, m. p. 119—120°. Graebe and Jequier (*Annalen*, 1896, **290**, 198) recorded m. p. 121°. Acidification of the alkaline washings gave only a trace of the unchanged acid.

Method B. (For references see Johnson, *Org. Reactions*, Vol. II, p. 162 *et seq.*) β-(5-Methoxy-1-naphthyl)propionic acid (0·45 g.) was added slowly to 85% sulphuric acid (10 c.c.) at 0—5° with stirring. After 15 min. the temperature was slowly raised to 100° and maintained thereat until all the acid had dissolved. The cooled solution was poured on ice and extracted with ether, the ethereal extract being washed successively with aqueous sodium hydroxide and water and then dried (Na_2SO_4). Evaporation of the ether left 7-*methoxyperinaphthanone* (0·35 g.), which crystallised from light petroleum (b. p. 60—80°) in yellow plates, m. p. 104—105° (Found: C, 79·2; H, 5·8. $C_{14}H_{12}O_2$ requires C, 79·2; H, 5·7%).

Method C. (Cf. Kon and Soper, *J.*, 1939, 790.) A suspension of γ-(5-methoxy-1-naphthyl)-butyric acid (0·5 g.) in sodium-dried toluene (1 c.c.) and stannic chloride (1 c.c.) was heated on a water-bath for 1 hr. The cooled product was decomposed with ice and hydrochloric acid and extracted with ether. The ethereal layer was washed with aqueous sodium hydroxide and water, and then dried (Na_2SO_4). Evaporation of the ether and toluene gave 8-methoxyhomoperinaphthanone (0·15 g.), m. p. 87—88° after recrystallisation from light petroleum (b. p. 60—80°). Kon and Ruzicka (*loc. cit.*) recorded m. p. 88—89°. Unchanged acid (0·15 g.) was recovered from the alkaline washings.

Method D. (Cf. Haworth and Sheldrick, *J.*, 1934, 1950.) To 5-methoxy-1-naphthylacetic acid (0·25 g.) in benzene (1 c.c.) was added phosphorus pentachloride (0·28 g.) and after 1 hr. the phosphorus oxychloride was removed by distillation with benzene (2 × 5 c.c.) under reduced pressure. The residual acid chloride in tetrachloroethane (3 c.c.) was added to stirred aluminium chloride (0·2 g.) in the same solvent (3 c.c.) cooled in ice. After 3 hr. at 0—5° the mixture was left at room temperature overnight. After addition of ice and dilute hydrochloric acid, the product was extracted with ether. The extract was washed successively with dilute hydrochloric acid aqueous sodium hydrogen carbonate, and aqueous potassium hydroxide, after which the solvents, were removed by steam-distillation. The non-volatile residue was extracted with ether, and the extract dried (Na_2SO_4). Evaporation left crude 6-*methoxyacenaphthenone* (0·07 g.), which crystallised from light petroleum (b. p. 60—80°) in needles, m. p. 143—144° (Found: C, 77·8; H, 4·9. $C_{13}H_{10}O_2$ requires C, 78·8; H, 5·05%). No acid was recovered from the bicarbonate washings, and no phenolic material from the potassium hydroxide washings.

Method E. (Cf. Wilds, *J. Amer. Chem. Soc.*, 1942, **64**, 1421.) To a suspension of β-(5-methoxy-1-naphthyl)propionic acid (0·2 g.) in benzene (2 c.c.) was added phosphorus pentachloride (0·16 g.) and after 30 min. the mixture was warmed to complete the formation of the acid chloride. To this solution, cooled in ice, was added a chilled solution of stannic chloride (0·2 c.c.) in benzene (2 c.c.). After 2 hr. the complex was decomposed with ice and hydrochloric acid, and the whole was extracted with ether. The ethereal extract was washed successively with aqueous sodium hydroxide and water. Evaporation of the solvent from the dried (Na_2SO_4) extract left 7-methoxyperinaphthanone (0·13 g.), which crystallised from light petroleum (b. p. 60—80°) in yellow plates, m. p. 104—105°, identical with the compound prepared by method B above.

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