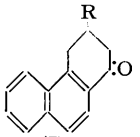
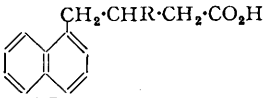
72. *Synthesis of Polycyclic Compounds. Part II.* The Ring Closure of β-Carboxy-γ-1-naphthylbutyric Acid.*

By J. C. Bardhan, D. Nasipuri, and R. N. Adhya.

β-Carboxy-γ-1-naphthylbutyric acid, on ring closure with 85% sulphuric acid at 100°, affords 1 : 2 : 3 : 4-tetrahydro-1-oxophenanthrene-3-carboxylic acid as the sole product. The same substance is produced when the corresponding anhydride reacts with anhydrous aluminium chloride in nitrobenzene. The structure of the keto-acid has been confirmed by unambiguous synthesis.

In another investigation an appreciable quantity of 1 : 2 : 3 : 4-tetrahydro-1-oxophenanthrene-3-carboxylic acid (I; R = CO_2H) was required. Attwood, Stevenson, and Thorpe [1] showed that β-carboxy-γ-phenylbutyric acid in presence of concentrated sulphuric acid readily undergoes ring closure with the formation of 1 : 2 : 3 : 4-tetrahydro-4-oxonaphthalene-2-carboxylic acid. It seemed probable, therefore, that β-carboxy-γ-1-naphthylbutyric acid (II; R = CO_2H) should under similar conditions furnish the desired phenanthrene derivative (I; R = CO_2H).


(I)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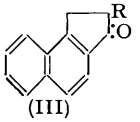
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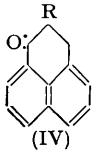
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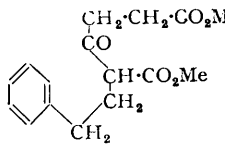
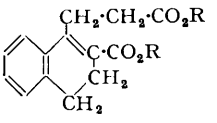
Ethyl 1-naphthylmethylmalonate [2,3] was allowed to react with ethyl bromoacetate, and the resulting product on hydrolysis and decarboxylation afforded β-carboxy-γ-1-naphthylbutyric acid, which in 85% sulphuric acid at 100° readily cyclised to a ketonic acid.[4] This, by the above analogy,[5] should be represented as (I; R = CO_2H), although structures (III and IV; R = $CH_2{\cdot}CO_2H$) are also possible. However, it has been shown by Fieser and Gates [2] and by Ansell [6] that ring closure of a β-1-naphthylpropionic acid gives both a perinaphthan-1-one (IV; R = H) and a 4 : 5-benzindan-1-one (III; R = H). On the other hand, Ansell and Hey [7] demonstrated that an analogous cyclisation of α-1-naphthylmethylglutaric acid gives preferentially the 4 : 5-benzindanone (III; R = $CH_2{\cdot}CH_2{\cdot}CO_2H$).

To throw further light on this matter, we attempted to synthesise the isomeric keto-acids (I; R = CO_2H), (III; R = $CH_2{\cdot}CO_2H$), and (IV; R = $CH_2{\cdot}CO_2H$) by unequivocal methods.

Methyl 2-oxo-1-phenethylbutane-1 : 4-dicarboxylate (V) (Bardhan, *J.*, 1936, 1851) was

(V) 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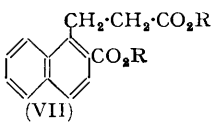
treated with cold concentrated sulphuric acid and the product on hydrolysis gave β-(2-carboxy-3 : 4-dihydro-1-naphthyl)propionic acid (VI; R = H). The corresponding ester (VI; R = Et) was dehydrogenated with sulphur and then hydrolysed, giving β-(2-carboxy-1-naphthyl)propionic acid (VII; R = H). The derived diethyl ester (VII; R = Et), on

* Part I, preceding paper.

[1] Attwood, Stevenson, and Thorpe, *J.*, 1923, **123**, 1758.
[2] Fieser and Gates, *J. Amer. Chem. Soc.*, 1940, **62**, 2335.
[3] Darzens and Levy, *Compt. rend.*, 1935, **201**, 902; Mayer and Sieglitz, *Ber.*, 1922, **55**, 1835.
[4] Cf. Haworth, *J.*, 1932, 1129.
[5] Cf. Johnson, "Organic Reactions," Wiley, New York, 1944, Vol. II, Chap. 4, p. 116.
[6] Ansell, *J.*, 1954, 575.
[7] Ansell and Hey, *J.*, 1950, 2876.

Dieckmann cyclisation followed by treatment with ethyl bromoacetate, yielded ethyl (2-ethoxycarbonyl-1-oxo-4 : 5-benzindan-2-yl)acetate (VIII; R = $CH_2 \cdot CO_2Et$); hydrolysis with a mixture of concentrated hydrochloric acid and acetic acid then furnished 1-oxo-3 : 4-benzindan-2-ylacetic acid (III; R = $CH_2 \cdot CO_2H$), which did not give a semicarbazone under the usual conditions. On the other hand, alkaline hydrolysis of the ester (VIII; R = $CH_2 \cdot CO_2Et$) furnished β-carboxy-γ-(2-carboxy-1-naphthyl)butyric acid (IX;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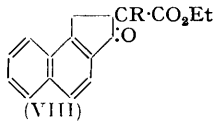
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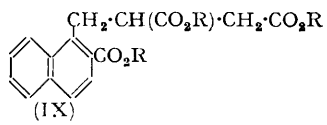
(IX)

R = H), the triester of which, by the Dieckmann procedure, gave 1 : 2 : 3 : 4-tetrahydro-1-oxo-phenanthrene-3-carboxylic acid (I; R = CO_2H), identical with the previous product the structure of which is therefore established.

The keto-acid (IV; R = $CH_2 \cdot CO_2H$) could not be obtained from 8-formyl-1-naphthoic acid,[8] nor as yet by other methods.

Several new 4 : 5-benzindan-1-ones have also been prepared.

Experimental

β-Carboxy-γ-1-naphthylbutyric Acid (II; R = CO_2H).—To a solution of sodium ethoxide prepared from anhydrous ethanol (60 ml.) and sodium (3·5 g.) was added, with cooling, ethyl 1-naphthylmethylmalonate (cf. Fieser and Gates[2]) (45 g.), followed by ethyl bromoacetate (16·8 ml.). The mixture was kept overnight at the room temperature and then heated under reflux for 7 hr. After cooling, potassium hydroxide (42 g.) in water (20 ml.) and ethanol (65 ml.) were added and the whole again boiled for 1 hr. The excess of ethanol was removed on the steam-bath, and the solution cooled in ice and acidified with 2N-hydrochloric acid. The oily precipitate solidified and was decarboxylated at 180—190° for 2 hr. The resulting acid was dissolved in aqueous sodium carbonate, the solution was filtered and acidified, and the solid precipitate collected. On purification from acetic acid (charcoal) *β-carboxy-γ-1-naphthylbutyric acid* formed prisms, m. p. 183° (Found : C, 69·9; H, 5·5. $C_{15}H_{14}O_4$ requires C, 69·7; H, 5·4%). The *anhydride* (5 g.), prepared by heating the acid (8 g.) with acetic anhydride (24 ml.) for 4 hr., had b. p. 220°/4 mm.; it solidified and recrystallised from light petroleum (b. p. 60—80°), in which it is sparingly soluble, as plates, m. p. 135—136° (Found : C, 74·9; H, 5·1. $C_{15}H_{12}O_3$ requires C, 75·0; H, 5·0%). The *anilic acid*, obtained on mixing the anhydride with aniline in dry benzene, crystallised from ethanol as prisms, m. p. 197° (Found : C, 75·5; H, 5·7. $C_{21}H_{19}O_3N$ requires C, 75·7; H, 5·7%), and when heated at 207° for 0·5 hr. gave the *anil*, needles (from ethanol), m. p. 138° (Found : C, 79·6; H, 5·5. $C_{21}H_{17}O_2N$ requires C, 80·0; H, 5·4%).

1 : 2 : 3 : 4-*Tetrahydro-1-oxophenanthrene-3-carboxylic Acid* (I; R = CO_2H).—(*a*) β-Carboxy-γ-1-naphthylbutyric acid (2 g.) was heated on the water-bath with concentrated sulphuric acid (6 ml.) and water (2 ml.) for 1·5 hr. The solution was cooled and poured on ice, and the solid collected. Repeated crystallisation from ethanol (charcoal) gave 1 : 2 : 3 : 4-*tetrahydro-1-oxophenanthrene-3-carboxylic acid* as plates, m. p. 218° (Found : C, 74·9; H, 5·1. $C_{15}H_{12}O_3$ requires C, 75·0; H, 5·0%). The *semicarbazone* crystallised from aqueous acetic acid in scales, m. p. 268° (decomp.) (Found : C, 64·3; H, 5·1. $C_{16}H_{15}O_3N_3$ requires C, 64·6; H, 5·0%).

(*b*) The anhydride of β-carboxy-γ-1-naphthylbutyric acid (5 g.), dissolved in nitrobenzene (35 ml.), was added gradually with stirring to a solution of anhydrous aluminium chloride (6 g.) in nitrobenzene (25 ml.) cooled in ice. After 2 days at room temperature the mixture was decomposed with ice and dilute hydrochloric acid, and the excess of nitrobenzene distilled off in steam. The solid residue on purification from ethanol gave the 3-carboxylic acid, m. p. 218°, identical with that prepared by method (*a*). The *ethyl ester* was prepared by heating the acid (10 g.) with ethanol (40 ml.), and 4 ml. of ethanol previously saturated with hydrogen chloride at 0°, for 10 hr., forming a pale yellow liquid (8·4 g.), b. p. 210—214°/4 mm., colourless needles, m. p. 99—100° (from aqueous ethanol) (Found : C, 76·0; H, 6·0. $C_{17}H_{16}O_3$ requires C, 76·1; H, 5·9%).

[8] Cf. Graebe and Gfeller, *Annalen*, 1893, **276**, 13.

β-(2-*Carboxy*-3 : 4-*dihydro*-1-*naphthyl*)*propionic Acid* (VI; R = H).—Methyl 2-oxo-1-phenethylbutane-1 : 4-dicarboxylate [9] (5 g.) was stirred during 3 hr. with sulphuric acid (*d* 1·84; 30 ml.) at −10°. The product was poured on ice, the organic layer collected in ether, and the solvent removed from the dried extract. The residue was hydrolysed with potassium hydroxide (2·5 g.) in water (2 ml.) and ethanol (25 ml.) in the usual way, yielding β-(2-*carboxy*-3 : 4-*dihydro*-1-*naphthyl*)*propionic acid* (3 g.) which on repeated crystallisation from aqueous acetic acid (charcoal) formed colourless prisms, m. p. 171° (Found: C, 68·4; H, 5·6. $C_{14}H_{14}O_4$ requires C, 68·3; H, 5·7%). The *ethyl ester* had b. p. 194—195°/3 mm. (Found: C, 70·9; H, 7·1. $C_{18}H_{22}O_4$ requires C, 71·5; H, 7·3%).

β-(2-*Carboxy*-1-*naphthyl*)*propionic Acid* (VII; R = H).—The preceding ester (10 g.) was heated with sulphur (1·07 g.) at 240—250° for 2 hr. On distillation, a liquid (8·5 g.), b. p. 195—205°/4 mm., was collected, which on hydrolysis by boiling 20% ethanolic potassium hydroxide (50 ml.) for 1 hr. gave β-(2-*carboxy*-1-*naphthyl*)*propionic acid*, needles (from aqueous ethanol; charcoal), m. p. 203° (Found: C, 68·9; H, 5·0. $C_{14}H_{12}O_4$ requires C, 68·8; H, 4·9%). The *ethyl ester*, prepared by means of ethanol and sulphuric acid, had b. p. 196—198°/3 mm. (Found: C, 71·8; H, 6·7. $C_{18}H_{20}O_4$ requires C, 72·0; H, 6·7%).

Ethyl 2-*Ethoxycarbonyl*-1-*oxo*-4 : 5-*benzindan*-2-*ylacetate* (VIII; R = CH_2CO_2Et).—The foregoing ester (6 g.), dry benzene (25 ml.), and sodium (0·46 g.) were heated under reflux until formation of the biscuit-coloured sodio-derivative was complete (2 hr.), then cooled in ice and treated with ethyl bromoacetate (2·5 ml.), kept at room temperature overnight, and then heated on the steam-bath for 6 hr. Water was added, and the benzene layer was washed with water, dried, and evaporated. The residue yielded a viscous liquid (5 g.), b. p. 210—215°/3 mm., which solidified on rubbing with ethanol. On recrystallisation from aqueous ethanol *ethyl* 2-*ethoxycarbonyl*-1-*oxo*-4 : 5-*benzindan*-2-*ylacetate* formed needles, m. p. 103° (Found: C, 70·5; H, 5·8. $C_{20}H_{20}O_5$ requires C, 70·6; H, 5·8%), not giving a colour with ethanolic ferric chloride.

1-*Oxo*-4 : 5-*benzindan*-2-*ylacetic Acid* (III; R = $CH_2{\cdot}CO_2H$).—The above keto-ester (VIII; R = $CH_2{\cdot}CO_2Et$) (2 g.) was boiled with concentrated hydrochloric acid (5 ml.) and acetic acid (10 ml.) for 10 hr. 1-*Oxo*-4 : 5-*benzindan*-2-*ylacetic acid* separated from ethanol in needles, m. p. 226—227° (Found: C, 74·9; H, 5·1%; equiv., 240·2. $C_{14}H_{11}O{\cdot}CO_2H$ requires C, 75·0; H, 5·0%; equiv., 240·0).

β-*Carboxy*-γ-(2-*carboxy*-1-*naphthyl*)*butyric Acid* (IX; R = H).—The keto-ester (VIII; R = $CH_2{\cdot}CO_2Et$) (5 g.) was boiled with potassium hydroxide (5 g.) in water (3 ml.) and ethanol (10 ml.) for 1 hr. The excess of ethanol was evaporated, and the residual solution extracted once with ether and acidified with hydrochloric acid. The *butyric acid* separated from hot water (charcoal) in nodules, m. p. 214—215° [Found: C, 63·4; H, 4·6%; equiv., 101·0. $C_{13}H_{11}(CO_2H)_3$ requires C, 63·6; H, 4·6%; equiv., 100·7]. The *triethyl ester* was prepared by heating the acid (6 g.) with ethanol (35 ml.) and concentrated sulphuric acid (3·5 ml.) at 115—120° in a current of ethanol vapour for 6 hr. It (5·4 g.) had b. p. 215—217°/3 mm. (Found: C, 68·3; H, 6·7. $C_{22}H_{26}O_6$ requires C, 68·4; H, 6·7%).

Tetrahydro-1-*oxophenanthrene*-3-*carboxylic Acid* (I; R = CO_2H) (cf. above).—(*c*) The above ester (5 g.) was heated on the steam-bath with powdered sodium (0·31 g.) and dry benzene (12 ml.) for 2 hr. On cooling, ice and hydrochloric acid were added and the benzene layer was washed with water, dried, and evaporated. The residue (5 g.) was hydrolysed by hot concentrated hydrochloric acid (10 ml.) and acetic acid (20 ml.) for 12 hr. On repeated crystallisation from ethanol (charcoal) the phenanthrene acid formed plates, m. p. and mixed m. p. 218—219° (Found: C, 74·9; H, 5·0. Calc. for $C_{15}H_{12}O_3$: C, 75·0; H, 5·0%). The semicarbazone separated from acetic acid in prisms, m. p. and mixed m. p. 268° (decomp.) (Found: C, 64·5; H, 5·1. Calc. for $C_{16}H_{15}O_3N_3$: C, 64·6; H, 5·0%).

6 : 7 : 8 : 9-*Tetrahydro*-4 : 5-*benzindan*-1-*one*.—β-(2-Carboxy-3 : 4-dihydro-1-naphthyl)propionic acid (5 g.), on reduction with sodium amalgam (200 g.; 3%) in the usual way, gave the *tetrahydro-acid* as a semisolid mass (5 g.) which was boiled with acetic anhydride (15 ml.) for 3 hr. and then slowly distilled. The *ketone* (3 g.) thus obtained had b. p. 140°/3 mm. (Found: C, 83·7; H, 7·6. $C_{13}H_{14}O$ requires C, 83·9; H, 7·5%). The *semicarbazone* had m. p. 235° (Found: 69·1; H, 7·0. $C_{14}H_{17}ON_3$ requires C, 69·1; H, 7·0%). A mixture of the ketone (5 g.) and ethyl formate (10 ml.) was gradually introduced into powdered sodium (5 g.) kept under anhydrous benzene (150 ml.) at 0°. The whole was kept in ice overnight, then diluted with ice-water, and the aqueous solution was separated and acidified. The crystalline *hydroxymethylene derivative* which separated was collected, washed with water, and on recrystallisation from aqueous acetone had m. p. 149—150° (Found: C, 78·4; H, 6·5. $C_{14}H_{14}O_2$ requires C, 78·5; H, 6·5%).

6 : 7-*Dihydro*-4 : 5-*benzindan*-1-*one*.—β-(2-Carboxy-3 : 4-dihydro-1-naphthyl)propionic acid, on treatment with acetic anhydride in the usual way, readily afforded 6 : 7-*dihydro*-4 : 5-*benzindan*-1-*one*, prisms, m. p. 86°, from light petroleum (b. p. 40—60°) (Found : C, 84·7; H, 6·5. $C_{13}H_{12}O$ requires C, 84·8; H, 6·5%).

4 : 5-*Benzindan*-1-*one* (III; R = H).—β-(2-Carboxy-1-naphthyl)propionic acid, on treatment with acetic anhydride, gave an oil, b. p. 160—165°/3 mm., which solidified and on further purification from light petroleum (b. p. 60—80°) afforded needles, m. p. 126—127° (Found : C, 85·7; H, 5·4. Calc. for $C_{13}H_{10}O$: C, 85·7; H, 5·5%). Fieser and Gates (*loc. cit.*) record m. p. 120·6—121·4°; Cook and Hewett (*J.*, 1934, 373) give m. p. 120—121°.

4-*Oxo*-7-*phenylheptanoic Acid*.—Methyl 2-oxo-1-phenethylbutane-1 : 4-dicarboxylate [9] (V) on hydrolysis with concentrated hydrochloric acid and acetic acid yielded the *keto-acid*, which on recrystallisation from light petroleum (b. p. 40—60°) formed needles, m. p. 83° (Found : C, 70·8; H, 7·3. $C_{13}H_{16}O_3$ requires C, 70·9; H, 7·3%). The *semicarbazone* separated from ethanol (charcoal) in prisms, m. p. 168—169° (Found : C, 60·4; H, 6·9. $C_{14}H_{19}O_3N_3$ requires C, 60·6; H, 6·9%).

5-*Methyl*-4-*oxo*-7-*phenylheptanoic acid*, prepared from methyl 1-methyl 2-oxo-1-phenethylbutane-1 : 4-dicarboxylate [9] in an analogous manner, crystallised from light petroleum (b. p. 40—60°) as needles, m. p. 73—74° (Found : C, 71·9; H, 7·7. $C_{14}H_{18}O_3$ requires C, 71·8; H, 7·7%). This did not, however, give a semicarbazone under the usual conditions.

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[9] Bardhan and Nasipuri, preceding paper.