667. *Intramolecular Acylation. Part I. The Ring Closure of Some β-Substituted Glutaric Acids.*

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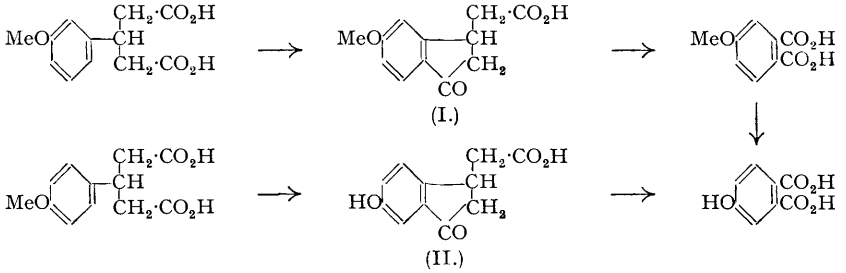
A number of β-arylglutaric acids and acid chlorides are prepared and subjected to the action of anhydrous hydrogen fluoride and aluminium chloride respectively in attempts to obtain ketonic acids. The two methods frequently give markedly contrasting results.

Intramolecular acylation, as exemplified in the cyclisation of aryl-substituted aliphatic acids or acid chlorides with elimination of water or hydrogen chloride, respectively, has frequently provided a useful route for the synthesis of polycyclic systems. By the use of suitably substituted dicarboxylic acids cyclisation can sometimes take place in two stages to yield first a ketonic acid and then a neutral diketone. In a review of this subject (Johnson, "Organic Reactions," Vol. II, Chapter IV, John Wiley and Sons, Inc., New York, 1944) it is shown that the ability of such acids to undergo ring closure and the course followed in such ring closures depend on (*a*) the size of the ring formed, (*b*) the nature of the aromatic nucleus, and (*c*) steric conditions other than those dependent on ring size. In the past the application of this method as a general process for the synthesis of polycyclic systems has been limited by the inaccessibility of many of the aryl-substituted acids required as starting materials. Developments in the past decade have provided not only improved methods for the preparation of such acids, but also new methods for cyclisation, with the result that it is now possible to extend this route to polycyclic systems in several directions. The present communication concerns the preparation and ring closure of a number of β-substituted glutaric acids by means of the action either of anhydrous aluminium chloride on the acid chloride or of anhydrous hydrogen fluoride on the free acid. The latter process, introduced by Fieser and Hershberg (*J. Amer. Chem. Soc.*, 1939, **61**, 1272), was first used with a dicarboxylic acid by Newman and Joshel (*J. Amer. Chem. Soc.*, 1940, **62**, 972).

Several general methods for the preparation of β-arylglutaric acids were investigated, and the best results were achieved by the alkaline hydrolysis of ethyl benzylidenebisacetoacetate and its derivatives, following the general procedure of Knoevenagel (*Annalen*, 1894, **281**, 76; 1898, **303**, 223; *Ber.*, 1896, **29**, 172; 1902, **35**, 392). By this method β-phenylglutaric acid, β-m-*tolylglutaric acid*, and β-*m*-nitro-, β-*p*-methoxy-, β-m-*methoxy*-, β-*p*-nitro-, and β-3 : 5-*dimethyl-phenylglutaric acid*, and β-1-*naphthylglutaric acid* were prepared. The aromatic aldehydes required for the above syntheses were purchased or prepared by published methods, but *m*-toluic aldehyde was prepared in good yield from *m*-toluic acid by conversion into the toluene-*p*-sulphonhydrazide and subsequent treatment with sodium carbonate, a method not hitherto used for this aldehyde (cf. McFadyen and Stevens, *J.*, 1936, 584). β-Phenylglutaric acid was also prepared by the method used by Manske (*J. Amer. Chem. Soc.*, 1931, **53**, 1104) from ethyl sodiomalonate and ethyl α-cyano-β-phenylacrylate, and a similar method was used for the preparation of β-*m*-nitrophenylglutaric acid. In the latter case, the final hydrolysis of the intermediate tricarboxylic ester was effected

with concentrated hydrochloric acid in 15 minutes, whereas with the unsubstituted acid prolonged boiling with concentrated hydrobromic acid was necessary. β-Phenylglutaric acid was used in a new method for the preparation of γ-phenylpimelic acid involving bis-homologation by the double Arndt–Eistert procedure first reported by Walker (*J.*, 1940, 1304). The product thus obtained was identical with the acid prepared from ethyl β-phenylglutarate by the more tedious route, *via* 3-phenylpentane-1 : 5-diol, 1 : 5-dibromo-3-phenylpentane and 1 : 5-dicyano-3-phenylpentane due to Manske (*loc. cit.*) and von Braun and Weissbach (*Ber.*, 1931, **64**, 1785).

The cyclisation experiments with the above acids or their chlorides and either anhydrous hydrogen fluoride or aluminium chloride respectively show that the two methods frequently give markedly different results in the yields of the cyclic ketones obtained. The cyclisation of β-phenylglutaric acid or the acid chloride to give indan-1-one-3-acetic acid, using sulphuric acid or aluminium chloride, respectively, has been previously reported (Speight, Stevenson, and Thorpe, *J.*, 1924, **125**, 2185; Jackson and Kenner, *J.*, 1928, 573; von Braun and Weissbach, *loc. cit.*; Manske, *loc. cit.*). The use of aluminium chloride on the acid chloride in carbon disulphide solution has been confirmed, but with anhydrous hydrogen fluoride and the free acid the starting material was recovered largely unchanged, and the yield of indan-1-one-3-acetic acid was reduced to the order of 10%. In agreement with earlier workers there was no evidence of double ring closure to give a diketone containing a strained tricyclic structure. Both β-*m*- and β-*p*-nitrophenylglutaric acids were completely resistant to ring closure even with the use of aluminium chloride on the acid chlorides in nitrobenzene at 150° or of anhydrous hydrogen fluoride on the free acids. This result is not unexpected (cf. Ingold and Piggott, *J.*, 1923, **123**, 1505), although Hoyer (*J. pr. Chem.*, 1934, **139**, 94) reported the successful ring closure of β-*o*-nitrophenylpropionyl chloride with aluminium chloride to give 4-nitroindan-1-one in 73% yield. The action of aluminium chloride on β-*m*-methoxyphenylglutaryl chloride at 150° in nitrobenzene gave the expected *5-methoxyindan-1-one-3-acetic acid* (I) in 47% yield, the constitution of which was confirmed by oxidation with potassium permanganate to 4-methoxyphthalic acid. The action of anhydrous hydrogen fluoride on β-*m*-methoxyphenylglutaric acid gave 5-methoxyindan-1-one-3-acetic acid in 83% yield. The ring closure of β-*p*-methoxyphenylglutaryl chloride was achieved with aluminium chloride in nitrobenzene at 150°, which also brought about demethylation to give *6-hydroxyindan-1-one-3-acetic acid* (II) in 35% yield, which was oxidised to 4-hydroxyphthalic acid. On the other hand, with anhydrous hydrogen fluoride β-*p*-methoxyphenylglutaric acid was recovered unchanged.



In both these cases no ring closure was effected with aluminium chloride in carbon disulphide solution. Previous workers have reported that ring closure at a position *meta* with respect to a methoxyl group is achieved only with reluctance with hydrogen fluoride, whereas the Friedel–Crafts method frequently gives much better yields (see Johnson, *loc. cit.*; Johnson and Shelberg, *J. Amer. Chem. Soc.*, 1945, **67**, 1853). Since it is known (Thomas, "Anhydrous Aluminium Chloride in Organic Chemistry," Reinhold Publishing Corp., New York, 1941; Frank and Tarbell, *J. Amer. Chem. Soc.*, 1948, **70**, 1276) that aluminium chloride preferentially effects demethylation in groups attached to the *ortho*- or *para*-positions with reference to a carbonyl group, it is probable the demethylation precedes cyclisation in the action of aluminium chloride on β-*p*-methoxyphenylglutaryl chloride. The ring closure of β-3 : 5-dimethylphenylglutaric acid with anhydrous hydrogen fluoride acid gave 5 : 7-*dimethylindan-1-one-3-acetic acid*, and β-1-naphthylglutaric acid under similar conditions gave a 93% yield of 4 : 5-*benzindan-1-one-3-acetic acid*, the constitution of which was confirmed by oxidation to naphthalene-1 : 2-dicarboxylic anhydride, m. p. 162—164°. The alternative configuration involving cyclisation at position 8 would have given, under similar conditions, naphthalic anhydride, m. p. 274°.

Experimental.

Preparation of Acids.—*β-Phenylglutaric acid.* Method (*a*): α-Cyano-β-phenylacrylic acid was prepared as described by Lapworth and Baker (*Org. Synth.*, Coll. Vol. I, p. 175) and subsequently esterified with ethyl alcohol (*idem, ibid.*, p. 440). β-Phenylglutaric acid (m. p. 140°) was prepared from ethyl α-cyano-β-phenylacrylate and ethyl malonate as described by Manske (*loc. cit.*). Method (*b*): Ethyl benzylidenebisacetoacetate was prepared in almost quantitative yield by Knoevenagel's method (*Annalen*, 1894, **281**, 76), but it was found necessary to use 2—3 times more piperidine than stated. Subsequent hydrolysis with hot concentrated potassium hydroxide gave β-phenylglutaric acid, m. p. 140°, in 66% yield.

γ-Phenylpimelic acid. Method (*a*): Ethyl β-phenylglutarate was converted into successively 3-phenylpentane-1 : 5-diol, 1 : 5-dibromo-3-phenylpentane, 1 : 5-dicyano-3-phenylpentane, and γ-phenylpimelic acid as described by Manske (*loc. cit.*). Method (*b*): β-Phenylglutaric acid was converted into the acid chloride with phosphorus pentachloride. Treatment of the acid chloride in dry ether with an ethereal solution of diazomethane gave the crude diazo-ketone (3·8 g., m. p. 62—65°), which was dissolved in warm dioxan (25 c.c.) to which aqueous ammonia (20%; 12 c.c.) and aqueous silver nitrate (10%; 3 c.c.) were added. When the effervescence had subsided the mixture was boiled on the water-bath and filtered hot. The crude amide (2·6 g.; m. p. 75—78°) which separated was boiled under reflux with aqueous potassium hydroxide (3N.; 20 c.c.). Subsequent acidification gave γ-phenylpimelic acid (2·2 g.), m. p. 84°, after crystallisation from ether, identical with the acid prepared by method (*a*).

β-m-Nitrophenylglutaric acid. Method (*a*): Ethyl α-cyano-β-*m*-nitrophenylacrylate (12·3 g.), prepared from ethyl cyanoacetate and *m*-nitrobenzaldehyde as described by Riedel (*J. pr. Chem.*, 1896, **54**, 544; cf. Bertini, *Gazzetta*, 1901, **31**, 273), was added to a mixture of absolute ethyl alcohol (30 c.c.) to which sodium (1·2 g.) and ethyl malonate (8·5 g.) had been added. The mixture was warmed gently and then boiled under reflux for 15 minutes. When this was cold, water was added and the whole was acidified with hydrochloric acid and extracted three times with ether. Evaporation of the solvent left an oil (20 g.), which was hydrolysed by boiling under reflux with concentrated hydrochloric acid (100 c.c.) for 15 minutes. β-*m*-Nitrophenylglutaric acid separated on cooling (9·3 g.; m. p. 205—206°). Method (*b*): Ethyl *m*-nitrobenzylidenebisacetoacetate (40 g.) was maintained for 2 hours at 70° with aqueous sodium hydroxide (5%; 500 c.c.). When cold, the solution was extracted with ether, and subsequent acidification with dilute sulphuric acid gave β-*m*-nitrophenylglutaric acid (20 g.; m. p. 201°) (cf. Knoevenagel and Schürenberg, *Annalen*, 1898, **303**, 232). Recrystallisation from aqueous alcohol raised the m. p. to 204—205°.

β-p-*Nitrophenylglutaric acid.* Ethyl *p*-nitrobenzylidenebisacetoacetate (23·5 g.), prepared as described by Knoevenagel and Hoffmann (*Annalen*, 1898, **303**, 236), was added to a 5% solution of potassium hydroxide (240 c.c.) and kept at 50—55° for one hour. The cold solution was extracted with ether and then acidified with concentrated hydrochloric acid. The precipitated acid was recrystallised from aqueous alcohol (with charcoal) (7·6 g.; m. p. 234—235°).

β-p-*Methoxyphenylglutaric acid.* Ethyl *p*-methoxybenzylidenebisacetoacetate (50 g.), prepared in 90% yield as described by Knoevenagel and Goecke (*Annalen*, 1898, **303**, 247), was dissolved in a hot solution of potassium hydroxide (225 g.) in water (170 c.c.) and maintained at 90—100° for 30 minutes. After the addition of twice its volume of water, the cold solution was extracted with ether and then acidified with hydrochloric acid. The precipitated acid (25 g.) separated from a mixture of ethyl acetate and benzene in needles, m. p. 163° (Found: C, 60·5; H, 6·0. Calc. for $C_{12}H_{14}O_5$: C, 60·5; H, 5·9%). Jackson and Kenner (*J.*, 1928, 1657) record m. p. 165° for this acid prepared from ethyl malonate and ethyl *p*-methoxycinnamate.

β-m-*Methoxyphenylglutaric acid.* To a mixture of *m*-methoxybenzaldehyde (64 g.) and ethyl acetoacetate (122 g.) cooled at 0°, piperidine (5 g.) was added dropwise. After 2 hours at 0° the mixture was kept for 3 days at room temperature. The resulting solid was drained on the pump and washed with ether. The crude ester (160 g.) on crystallisation from alcohol gave *ethyl* m-*methoxybenzylidenebisacetoacetate* in fine needles, m. p. 135—135·5° (Found: C, 63·9; H, 6·7. $C_{20}H_{26}O_7$ requires C, 63·5; H, 6·9%). The *monoxime* was prepared by heating the ester with hydroxylamine hydrochloride in aqueous alcohol at 50°. Addition of a cold concentrated solution of sodium carbonate precipitated the oxime, which crystallised from ethyl alcohol in fine needles, m. p. 181° (Found: C, 60·9; H, 6·7; N, 3·4. $C_{20}H_{27}O_7N$ requires C, 61·05; H, 6·9; N, 3·6%). The ethyl *m*-methoxybenzylidenebisacetoacetate (160 g.) was dissolved in a hot solution of potassium hydroxide (160 g.) in water (108 c.c.) and maintained at 90—100° for 30 minutes. Water was added and the cold solution was extracted with ether. Subsequent acidification precipitated the crude acid as an oil which rapidly solidified. Crystallisation from a mixture of ethyl acetate and benzene gave β-m-*methoxyphenylglutaric acid* (65 g.) in fine needles, m. p. 126—126·5° (Found: C, 60·4; H, 6·1. $C_{12}H_{14}O_5$ requires C, 60·5; H, 5·9%).

β-m-*Tolylglutaric acid.* Ethyl *m*-toluate (37 g.) was converted into the hydrazide (30 g.; m. p. 97°), as described by Stollé and Stevens (*J. pr. Chem.*, 1904, **69**, 369), which was dissolved in dry pyridine (100 g.) and shaken with the addition of toluene-*p*-sulphonyl chloride (40 g.) added in small portions. When the reaction was complete, the pyridine was removed under reduced pressure and the residual oil, which solidified, was crystallised from aqueous alcohol. *Toluene*-p-*sulphonyl*-m-*toluoylhydrazide* (60 g.) was obtained in needles, m. p. 140° (Found: N, 9·3. $C_{15}H_{16}O_3N_2S$ requires N, 9·2%). This substance (29·5 g.) was dissolved in ethylene glycol (100 c.c.) at 100° and anhydrous sodium carbonate (29·5 g.) was added. After being heated for 3 minutes at 160°, the mixture was cooled, water was added, and the whole extracted with ether. Evaporation of the solvent from the dried extract left *m*-tolualdehyde (8·5 g.), which was collected at 196—199°. Piperidine (2 g.) was added to a mixture of the aldehyde (17 g.) and ethyl acetoacetate (36·8 g.) at 0°. After 4 days, the solid was collected (33·5 g.) and washed with ether. *Ethyl* m-*methylbenzylidenebisacetoacetate* separated from alcohol in needles, m. p. 123° (Found: C, 65·8; H, 7·3. $C_{20}H_{26}O_6$ requires C, 66·3; H, 7·2%). This ester (33·0 g.) was added to a solution of potassium hydroxide (33 g.) in water (40 c.c.) at 100°. After 10 minutes the mixture was diluted with twice its volume of water, cooled, and extracted with ether. Acidification of the aqueous

layer liberated the acid, which was extracted with ether. Evaporation of the ether from the dried extract left an oil, which was purified by treatment with aqueous sodium carbonate, boiling with charcoal, filtration, and extraction with ether. Acidification of the carbonate solution gave *β-m-tolylglutaric acid* (17 g.), which separated from ether–light petroleum (b. p. 40—60°) in fine needles, m. p. 106—107° (Found: C, 65·1; H, 6·2. $C_{12}H_{14}O_4$ requires C, 64·8; H, 6·35%).

β-3 : 5-Dimethylphenylglutaric acid. Piperidine (5 c.c.) was added to a mixture of ethyl acetoacetate (72 g.) and 3 : 5-dimethylbenzaldehyde (37 g.), prepared as described by Marvel, Saunders, and Overberger (*J. Amer. Chem. Soc.*, 1946, **68**, 1085). After 2 days at room temperature more piperidine (2 c.c.) was added, and after a further 2 days the solid reaction product was collected and washed with ether. The crude ester (79 g.) was purified by crystallisation from alcohol. *Ethyl 3 : 5-dimethylbenzylidenebisacetoacetate* was obtained in prisms, m. p. 151—152° (Found: C, 66·8; H, 7·4. $C_{21}H_{28}O_6$ requires C, 67·0; H, 7·5%). The ester (74 g.) was added in small portions to a solution of potassium hydroxide (75 g.) in water (75 c.c.) at 100°. After the ester had dissolved the solution was kept at 100° for 10 minutes and then diluted with three times its volume of water. When cold the mixture was extracted with ether, and acidification of the filtered alkaline layer deposited an oil which solidified. The solution was also extracted with ether and on evaporation a further quantity of the oil was obtained. The total product (40 g.), which solidified, was recrystallised from ethyl acetate. *β-3 : 5-Dimethylphenylglutaric acid* (24·7 g.) was obtained in prisms, m. p. 160° (Found: C, 66·1; H, 6·7. $C_{13}H_{16}O_4$ requires C, 66·1; H, 6·8%).

β-1-Naphthylglutaric acid [with M. F. ANSELL]. A mixture of α-naphthaldehyde (6·3 g.), prepared from α-bromomethylnaphthalene as described by Badger (*J.*, 1941, 535), and ethyl acetoacetate (10·5 g.) was treated with piperidine (0·5 g.) and after 6 days at room temperature the solid was collected (3·3 g.) and washed with ether. Recrystallisation from alcohol gave *ethyl 1-naphthylidenebisacetoacetate* in needles, m. p. 161·5° (Found: C, 69·5; H, 6·6. $C_{23}H_{26}O_6$ requires C, 69·3; H, 6·6%). The *monoxime*, prepared as in previous examples, separated from alcohol in colourless needles, m. p. 195—196° (Found: N, 3·3. $C_{23}H_{27}O_6N$ requires N, 3·4%). The ester (1·8 g.) was added to a solution of potassium hydroxide (3·6 g.) in water (2·4 c.c.) at 100° and after ½ hour the mixture was diluted, cooled, and extracted with ether. The acid was precipitated from the aqueous layer with hydrochloric acid and extracted with ether. Evaporation of the dried extract left an oil which solidified (0·9 g.). Crystallisation from ethyl acetate–benzene gave *β-1-naphthylglutaric acid* in needles, m. p. 181·5° (Found: C, 69·65; H, 5·6. $C_{15}H_{14}O_4$ requires C, 69·75; H, 5·5%).

Ring Closure Experiments.—β-Phenylglutaric acid. (*a*) To β-phenylglutaryl chloride (prepared from 5·2 g. of acid with phosphorus pentachloride) in carbon disulphide (6 c.c.) anhydrous aluminium chloride (3·5 g.) was added. After storage at room temperature for one hour the mixture was boiled under reflux for 2 hours. After removal of the solvent the residue was treated with hydrochloric acid and ice and extracted with ether. The ethereal extract was washed with aqueous sodium carbonate, and the alkaline washings were acidified and extracted with ether. Evaporation of the solvent gave indan-1-one-3-acetic acid (3·0 g.), which after crystallisation from water melted at 153—154° (cf. Manske, *loc. cit.*; von Braun and Weissbach, *loc. cit.*). (*b*) β-Phenylglutaryl chloride (prepared as above from the acid, 5·2 g.) was dissolved in nitrobenzene (50 c.c.) and anhydrous aluminium chloride (3·5 g.) was added. The mixture was maintained at 70—80° for ½ hour and then left overnight at room temperature. After the addition of ice and hydrochloric acid the nitrobenzene was removed with steam. The mixture was then extracted with ether, and the extract washed with aqueous sodium carbonate Alkaline washings were extracted with ether after acidification, and evaporation of the solvent left a residue of indan-1-one-3-acetic acid (2·0 g.), m. p. 152—153° after crystallisation from water. (*c*) Anhydrous hydrogen fluoride (*ca.* 100 g.) was added to β-phenylglutaric acid (5·2 g.) in a polythene beaker. After about 15 hours in the open air under shelter, most of the hydrogen fluoride had evaporated and some solid had separated (3·0 g., m. p. 140—141°), which consisted of β-phenylglutaric acid. This was removed by filtration, and to the filtrate an excess of aqueous sodium carbonate was added and the solution was extracted with ether. The alkaline layer was then acidified and extracted rapidly with ether. Evaporation of the ether gave a mixture of indan-1-one-3-acetic acid and β-phenylglutaric acid (2·0 g.; m. p. 128—132°). After two crystallisations from benzene indan-1-one-3-acetic acid (0·5 g.) was obtained in needles, m. p. 153—154°.

β-m- and β-p-Nitrophenylglutaric acid. The acid chlorides, prepared as above from the corresponding acids, failed to undergo ring closure with (*a*) aluminium chloride in carbon disulphide, or (*b*) aluminium chloride in nitrobenzene at 150°. The free acids also failed to undergo ring closure with anhydrous hydrogen fluoride.

β-p-Methoxyphenylglutaric acid. (*a*) A mixture of *β-p*-methoxyphenylglutaryl chloride, prepared from the acid (5·95 g.) and phosphorus pentachloride, nitrobenzene (50 c.c.), and anhydrous aluminium chloride (3·5 g.) was heated slowly to 150° and maintained at that temperature for 15 minutes. The cooled mixture was treated with hydrochloric acid and ice, and the nitrobenzene was removed with steam. The residue was extracted with ether, and the ethereal extract was washed with aqueous sodium carbonate. The carbonate washings were acidified and extracted with ether. Evaporation of the solvent gave *6-hydroxyindan-1-one-3-acetic acid* (1·8 g.), which separated from alcohol in plates, m. p. 161—161·5° (Found: C, 63·5; H, 5·3. $C_{11}H_{10}O_4$ requires C, 64·0; H, 4·9%). To a solution of this acid (0·45 g.) in aqueous sodium hydroxide (10%; 10 c.c.) was added a cold saturated solution of potassium permanganate until the colour persisted (cf. Atwood, Stevenson, and Thorpe, *J.*, 1923, **123**, 1764). The solution was decolorised with sulphur dioxide, and the manganese dioxide was filtered off. After the addition of dilute sulphuric acid followed by boiling to remove sulphur dioxide, the cooled solution was extracted with ether. Evaporation of the solvent left an oily residue which was dissolved in ethyl acetate. Addition of benzene precipitated 4-hydroxyphthalic acid, m. p. 203—204°, which on sublimation gave the anhydride, m. p. 170°. (*b*) The attempted ring closure of *β-p*-methoxyphenylglutaryl chloride with aluminium chloride in carbon disulphide, or with aluminium chloride in nitrobenzene at 70—80°, was unsuccessful. In both cases *β-p*-methoxyphenylglutaric acid was recovered. (*c*) *β-p*-Methoxyphenylglutaric acid (5·95 g.) was treated with anhydrous hydrogen fluoride (*ca.* 100 g.) as in the previous example. The solid which had separated (4·5 g.) consisted of unchanged acid, m. p. 163—164°. The

ethereal extract from the acidified carbonate solution was evaporated and the residue was dissolved in hot aqueous sodium carbonate as above. Acidification precipitated a further quantity of *β-p*-methoxyphenylglutaric acid (1·0 g.), m. p. 163—164°.

β-m-*Methoxyphenylglutaric acid.* (*a*) A mixture of *β-m*-methoxyphenylglutaryl chloride, prepared as above from the acid (5·95 g.), nitrobenzene (50 c.c.), and aluminium chloride (3·5 g.) was heated slowly to 150° and kept at this temperature for 10 minutes. When it was cold, hydrochloric acid and ice were added and the nitrobenzene was removed with steam. The residual solution was extracted with ether. Evaporation gave 5-*methoxyindan*-1-*one*-3-*acetic acid* (2·6 g.), which separated from alcohol in needles, m. p. 151° (Found: C, 65·55; H, 5·7. $C_{12}H_{12}O_4$ requires C, 65·5; H, 5·5%). This acid was oxidised with alkaline potassium permanganate, in the manner described for 6-hydroxyindan-1-one-3-acetic acid, to give 4-methoxyphthalic acid, m. p. 160—161°, which on sublimation gave the anhydride, m. p. 94°. (*b*) The attempted ring closure with aluminium chloride in carbon disulphide was unsuccessful. (*c*) *β-m*-Methoxyphenylglutaric acid (5·95 g.) was treated with anhydrous hydrogen fluoride (*ca.* 100 g.) as described above for *β*-phenylglutaric acid. The solid which had separated and the residue from the ethereal extraction were united, dissolved in hot aqueous sodium carbonate, boiled with charcoal, filtered, and acidified. The precipitate consisted of crude 5-methoxyindan-1-one-3-acetic acid (4·6 g.), which after crystallisation from alcohol melted at 151—152°.

β-3 : 5-*Dimethylphenylglutaric acid.* (*a*) *β*-3 : 5-Dimethylphenylglutaryl chloride, prepared from the acid (8·0 g.) and phosphorus pentachloride, was dissolved in carbon disulphide (40 c.c.) to which anhydrous aluminium chloride (9·0 g.) was added. After boiling under reflux for 3 hours, the solvent was removed under reduced pressure and the residue was decomposed with ice-cold dilute hydrochloric acid. It was extracted with ether and the ethereal extract was washed with aqueous sodium carbonate. Evaporation of the ether left a dark tarry residue (2·5 g.), which was devoid of ketonic properties. The alkaline solution was boiled with charcoal, filtered, and acidified. From the acidified solution ether extracted only unchanged *β*-3 : 5-dimethylphenylglutaric acid (5·6 g.), m. p. 160° after crystallisation from alcohol. (*b*) *β*-3 : 5-Dimethylphenylglutaric acid (8 g.) was treated with anhydrous hydrogen fluoride (*ca.* 150 g.) as in the previous examples. The reaction product was neutralised with aqueous sodium carbonate and washed with ether. After being boiled with charcoal the filtered solution was acidified and extracted with ether. Evaporation of the ether left 5 : 7-*dimethylindan*-1-*one*-3-*acetic acid* (6·8 g.), m. p. 140—142°. Recrystallisation from alcohol gave the pure acid in prisms, m. p. 146° (Found: C, 71·3; H, 6·4 $C_{13}H_{14}O_3$ requires C, 71·5; H, 6·5%).

β-1-*Naphthylglutaric acid* [with M. F. Ansell]. *β*-1-Naphthylglutaric acid (1·75 g.) was treated with anhydrous hydrogen fluoride (*ca.* 40 g.) as in the previous examples. The reaction product was treated with ice, and the precipitated solid collected, digested with 5% aqueous sodium carbonate, and extracted with ether. Acidification of the aqueous layer yielded a single product (1·63 g.), m. p. 203—206°. Recrystallisation from aqueous acetic acid gave 4 : 5-*benzindan*-1-*one*-3-*acetic acid* in clusters of small needles, m. p. 206—208° (Found: C, 74·6; H, 5·1. $C_{15}H_{12}O_3$ requires C, 75·0; H, 5·0%). To a solution of this acid (0·5 g.) in aqueous sodium hydroxide (10 c.c.; 10%) was added a cold saturated solution of potassium permanganate until the colour persisted. The solution was decolorised with sulphur dioxide, and the manganese dioxide filtered off. After the addition of dilute sulphuric acid followed by boiling to remove the sulphur dioxide, the cooled solution was extracted with ether. Evaporation of the solvent left an oily residue which, when heated at 180—200° under reduced pressure, gave a sublimate of naphthalene-1 : 2-dicarboxylic anhydride, m. p. 162—164° after recrystallisation and resublimation. This m. p. was raised to 166—167° on admixture with an authentic specimen, m. p. 167—168°.

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