EXPERIMENTAL.

The technique of kinetic measurements was that previously described (Parts I and V, *loc. cit.*); x% by volume of organic solvent stands for a medium obtained *by mixing* x ml. of organic solvent and $(100 - x)$ ml.of water containing the appropriate amount of hydrochloric acid to give a 0·1M- or 1M-solution. In practice, aqueous solutions were prepared by mixing x ml. of organic solvent, $(90 - x)$ ml. of water, and 10 ml. of 1M- or 10M-hydrochloric acid, and making up to 100 ml. with a mixture of x ml. of organic solvent and $(100 - x)$ ml. of water. The molar concentration of organic solvent is then given by $1800xd/[18xd + (100 - x)M]$, where d and M are its density and molecular weight, respectively. Anhydrous solutions were prepared immediately before use (Braude, this vol., p. 1975). In view of the considerable ultra-violet light absorption of acetone, the choices of the carbinol concentration and of the dilution ratio for the spectrometric assay were rather more critical than with the other solvents. Four typical runs are given below.

Rearrangements of phenylpropenylcarbinol in 0·1M-*hydrochloric acid at* 30·0°. [Carbinol concentration, 0·2% w/v. Acetone concentration, (*a*) 80%, (*b*) 100%.]

(*a*)	Time, mins.	0	1	2	3	4	∞	
	$E^{1\%}_{1\,\text{cm.}}$ (2510 A.)	30	220	410	520	600	1260	
	10^4k (min.$^{-1}$)	—	1650	1660	1690	1710	—	(Mean) 1680
(*b*)	Time, mins.	0	0·25	0·40	0·55	∞		
	$E^{1\%}_{1\,\text{cm.}}$ (2510 A.)	30	850	1020	1120	1260		
	10^4k (min.$^{-1}$)	—	44,000	41,000	40,000	—	(Mean) 42,000	

Rearrangements of ethynylpropenylcarbinol in 1M-*hydrochloric acid at* 30·0°. [Carbinol concentration, 0·5%. Acetone concentration, (*a*) 80%, (*b*) 100%.]

(*a*)	Time, mins.	0	650	820	1000	1160	∞	
	$E^{1\%}_{1\,\text{cm.}}$ (2230 A.)	—	830	940	1000	1080	1300	
	10^4k (min.$^{-1}$)	—	15·6	15·8	14·8	15·0	—	(Mean) 15·3
(*b*)	Time, mins.	0	0·20	0·40	0·60	∞		
	$E^{1\%}_{1\,\text{cm.}}$ (2230 A.)	—	340	590	760	1300		
	10^4k (min.$^{-1}$)	—	15,300	15,000	14,500	—	(Mean) 14,900	

The authors of this and the two preceding papers thank Professor Sir Ian Heilbron, D.S.O., F.R.S., and Professor E. R. H. Jones for their interest, Mrs. Joy P. Stern for some assistance with the experimental work, and the Rockefeller Foundation for financial assistance.

IMPERIAL COLLEGE OF SCIENCE AND TECHNOLOGY,
LONDON, S.W.7.

[*Received, January 6th*, 1948.]

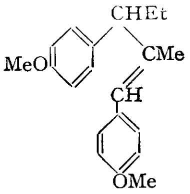
---

404. *Dimerides of Anethole.*

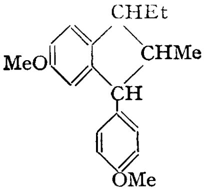
By WILSON BAKER and G. F. FLEMONS.

*iso*Anethole (I), previously known only as an oil, is shown to be a mixture consisting mainly of crystalline (m. p. 40—40·5°) *trans*(?)-*iso*anethole and a smaller amount of liquid *cis*(?)-*iso*anethole. The claim that metanethole (II) exists in two forms, sublimable and non-sublimable, is incorrect.

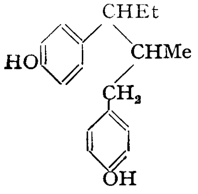
ANETHOLE undergoes dimerisation under the influence of hydrogen chloride to give *iso*anethole, which has been shown by Goodall and Haworth (*J.*, 1930, 2482) to possess the structure (I). These authors oxidised the liquid *iso*anethole to anisic acid and methyl 1-*p*-methoxyphenyl-*n*-propyl ketone, but this experiment leaves in doubt the question, not previously raised, as to whether *iso*anethole is the *cis*- or *trans*- isomeride or a mixture of the two. Formula (I) represents what may be termed the *trans*-form, attention being focussed on the main $Ar-C=C-C-Ar$ chain of the molecule. Optically active forms of *iso*anethole are possible.



(I.)



(II.)



(III.)

Baker and Enderby (*J.*, 1940, 1094) showed that anethole could be dimerised by refluxing in 43% sulphuric acid, giving a mixture of the saturated, crystalline dimeride metanethole (II) (see below) and *iso*anethole, the latter having the same boiling point and almost the same refractive index as *iso*anethole prepared by the method of Goodall and Haworth. The *iso*anethole was further identified by the oxidative degradation mentioned above, and by catalytic reduction followed by demethylation to give 1 : 3-di-*p*-hydroxyphenyl-2-methylpentane (III), which, after purification, had m. p. 126—127° (see Campbell, Dodds, and Lawson, *Proc. Roy. Soc.*, 1940, *B*, **128**, 253).

trans(?)-iso*Anethole*.—A specimen of *iso*anethole prepared by the sulphuric acid method (Baker and Enderby, *loc. cit.*, p. 1096; the actual specimen is referred to in lines 9 and 10 from bottom) was observed after several months to have begun to crystallise, and, after several years, it had become mainly solid. This solid *iso*anethole was isolated and could be crystallised from methyl alcohol under exactly controlled conditions, the yield being about 60%. *iso*Anethole prepared by the method of Goodall and Haworth was also readily obtained in the solid state, and gave the recrystallised material in 80% yield. This solid iso*anethole*, m. p. 40—40·5°, may be provisionally allotted the *trans*-structure (I), as it apparently possesses a higher melting-point than the other stereoisomeride which has as yet been obtained only as an oil (see below). It may be noted that, for steric reasons, the *trans*-*iso*anethole (I) might be expected to undergo easier cyclisation to metanethole (II) than the *cis*-isomeride, and metanethole is, in fact, formed more smoothly and in somewhat greater yield from solid *iso*anethole than from the liquid isomer by the action of stannic chloride in chloroform (Baker and Enderby). There is the possibility that *cis*- and *trans*-*iso*anetholes might yield different stereoisomers of metanethole, but no evidence was obtained that this was the case. Catalytic reduction followed by demethylation readily gave almost pure 1 : 3-di-*p*-hydroxyphenyl-2-methylpentane (III) in 95% yield without crystallisation.

cis(?)-iso*Anethole*.—*iso*Anethole prepared from anethole by the action of hydrogen chloride or sulphuric acid, after isolation of the crystalline *iso*anethole, yields an oil which gives analyses agreeing with those required by a dimeric anethole. Oxidation with potassium permanganate yielded only anisic acid and methyl 1-*p*-methoxyphenyl-*n*-propyl ketone, so that this liquid product must possess the same structure as solid *iso*anethole, and is doubtless a mixture of *cis*-*iso*anethole and an unknown amount of the solid *trans*-*iso*anethole. Catalytic reduction resulted in the uptake of one molecule of hydrogen, and subsequent demethylation gave as the only isolable solid the same stereoisomeride of 1 : 3-di-*p*-hydroxyphenyl-2-methylpentane (III) as was given by the solid *iso*anethole, but the yield was not above 45%. A liquid stereoisomeride of (III), of which two racemic forms are possible, is doubtless present in the reaction product.

Metanethole.—Metanethole, m. p. 134°, has been prepared, usually in very small yield, by the action of a variety of acidic reagents on anethole (for references see Baker and Enderby, *loc. cit.*), the most convenient being boiling 43% sulphuric acid, which gives a 25% yield. Yamashita (*J. Chem. Soc. Japan*, 1941, **62**, 1216) has since reported the production of metanethole in unstated yield by the action of iodine upon a toluene solution of anethole, and Bruckner (*Ber.*, 1942, **75**, 2034) records the production of a trace of metanethole while investigating the reaction of anethole with maleic anhydride. Van der Zanden, de Vries, and Dijkstra (*Rec. Trav. chim.*, 1942, **61**, 280) obtained metanethole in under 1% yield by the action of the boron fluoride–diethyl ether complex on methylchavicol (*p*-methoxyallylbenzene, source unstated), and Polak and Hixon (*J. Amer. Pharm. Assoc.*, 1945, **34**, 240) claim the formation of metanethole in 2·2% yield by boiling methylchavicol with " 34% sulphuric acid " according to the directions of Baker and Enderby (this is doubtless an error for " 43% sulphuric acid "). In the latter case, at least, it seems very likely that the metanethole may have been derived from a few per cent. of anethole in the methylchavicol, which was isolated from the steam-volatile oil of " anise hyssop " (*Lophanthus anisatus* Benth). Polak and Hixon also report the spontaneous polymerisation of methylchavicol from " anise hyssop " during 8 months' storage, 11—25% passing into a mixture of *iso*anethole and metanethole. They claim, however, that this metanethole, m. p. 134°, sublimes at 110—120°, and differs therein from the " non-sublimable " metanethole of the same m. p. prepared from anethole by the method of Baker and Enderby or by the action of sulphuric acid upon methylchavicol. It was also recalled that Perrenoud (*Annalen*, 1877, **187**, 68), who prepared metanethole by the action of zinc chloride and superheated steam upon anethole, reported that the product was sublimable at 115—120°, and that Glichitch (*Bull. Soc. chim.*, 1924, **35**, 1160), who prepared metanethole by the action of 90% formic acid on anethole, also described it as sublimable. Polak and Hixon, in an attempt to establish a difference between " sublimable " and " non-sublimable " metanethole, found that a mixture of the two " gave one degree depression after the mixture had been melted, cooled, and pulverised three times ".

We have been unable to detect any difference between metanethole prepared by the methods of Baker and Enderby, Perrenoud, and Glichitch. All the specimens sublime exceedingly slowly at *ca.* 115—130° in needles at atmospheric pressure, and even under favourable conditions in a vacuum the rate of sublimation remains minute. In the ordinary use of the term, the specimens would scarcely be described as sublimable. When heated more strongly in a small tube, the melt shows a marked tendency to creep rapidly and solidify on the cooler parts of the tube, a phenomenon which might be mistaken for rapid sublimation. That there is no difference between " sublimable " and " non-sublimable " metanethole is completely confirmed by *X*-ray powder photographs, kindly taken by Dr. T. Malkin and Mr. F. I. G. Small in this laboratory; they report as follows.

" *X*-Ray powder photographs of all three specimens were taken, using a Phillips Metalex tube (CuK_α) running at 10 m.A. With a specimen-to-camera distance of 6 cm., excellent photographs were obtained in half-an-hour. Sixteen lines appeared on the three photographs, identical in intensity and position. The strongest eight lines correspond to spacings of 3·28, 3·57, 3·84, 4·31, 5·12, 5·44, 5·80, and 7·89 A. There can, therefore, be little doubt as to identity of all three specimens."

We are therefore unable to find any difference between " sublimable " and " non-sublimable " metanethole, but we have not been able to examine the material prepared by Polak and Hixon from " anise hyssop ".

The structure (II) of metanethole established by Baker and Enderby has received confirmation in the work of Müller and Richl (*Ber.*, 1943, **76**, 1119), and it is of interest that di*iso*eugenol has now been allotted a precisely similar structure (Cartwright and Haworth, *J.*, 1947, 948) in place of its original formulation as a 9 : 10-dihydroanthracene. Four racemic stereoisomeric forms of metanethole (II) should be capable of existence.

EXPERIMENTAL.

Isolation of Solid trans(?)-iso*Anethole* (I).—(*a*) Part of the analytically pure specimen of *iso*anethole prepared by Baker and Enderby (*loc. cit.*, p. 1096) (50 g.) which was finally of the consistency of well-crystallised honey, was pressed on porous earthenware (see below) and yielded a white, crystalline powder (35·5 g.), melting at 38—40° to a turbid melt which became clear at 45°. (*b*) *iso*Anethole prepared by the method of Goodall and Haworth, b. p. 186—191°/0·5 mm., crystallised at once after distillation without intentional seeding to a hard mass, m. p. 28—35°, which could not be plated. This material (35·5 g.) and that described under (*a*) were separately treated as follows. The solid *iso*anethole was dissolved in warm methyl alcohol (280 c.c.), cooled, a very little more methyl alcohol added so that the solution remained clear at 20° but was slightly cloudy at 19°, seeded at 20°, and allowed to crystallise at room temperature with occasional gentle stirring for several hours. Further separation of crystals occurred on keeping overnight in the ice-chest, and the product was then collected, washed with a little ice-cold methyl alcohol and dried. Material from (*a*) (31·3 g.) had m. p. 39—40°, becoming clear at *ca.* 45°; no further crystalline material was obtained from the mother liquors. Material from (*b*) (23·3 g.) had m. p. 39—40°, the melt being almost clear, and more solid (5·1 g.) was obtained from the mother-liquor by concentration and crystallisation as before. Further similar recrystallisations of the *iso*anethole from (*a*) did not materially alter its properties; the turbidity of the melt is probably due to a persistent trace of metanethole. A specimen of *iso*anethole of satisfactory purity was obtained from (*b*) by dissolving the once crystallised product (23·3 g.) in methyl alcohol (solution clear at 20°, turbid at 19°), collecting the solid which separated at room temperature (14·7 g.), and cooling the mother-liquor to 0°; a product (5·3 g.) had m. p. 40—40·5°, the melt being quite clear. No depression of the melting point was observed when specimens from the two sources were mixed.

trans(?)-iso*Anethole* forms thin, colourless plates, having in the supercooled state $n_D^{20°}$ 1·5830 (Found : C, 81·1; H, 8·2. $C_{20}H_{24}O_2$ requires C, 81·0; H, 8·2%).

Liquid cis(?)-iso*Anethole*.—(*a*) The oily *iso*anethole contained in the porous plate (above) was extracted and distilled twice under diminished pressure, giving a very pale yellow oil (12·5 g.), b. p. 174°/0·05 mm., $n_D^{20°}$ 1·5764 (Found : C, 81·0; H, 8·3. Calc. for $C_{20}H_{24}O_2$: C, 81·0; H, 8·2%). (*b*) The methyl alcoholic mother-liquors from the crystallisation of the solid *iso*anethole prepared by the method of Goodall and Haworth [section (*b*) above] were distilled, giving an oil, b. p. 174—176°/0·05 mm., $n_D^{20°}$ 1·5770. Neither specimen could be induced to crystallise, and both, when oxidised by potassium permanganate in acetone, gave anisic acid, m. p. 184°, and methyl 1-*p*-methoxyphenyl-*n*-propyl ketone (characterised as the semicarbazone, thin, rhombic plates from alcohol, m. p. 190—191°; Goodall and Haworth record m. p. 189°) in similar yields.

Conversion of Solid and Liquid iso*Anetholes into Metanethole* (II).—Each *iso*anethole (5 g.) was treated with anhydrous stannic chloride in chloroform solution, and the metanethole was isolated, as described by Baker and Enderby. The solid *iso*anethole readily gave metanethole (0·5 g.), m. p. 134°. The liquid *iso*anethole gave at first a less pure product yielding finally metanethole (0·4 g.), m. p. 134°. No other crystalline material could be isolated from either.

Conversion of Solid and Liquid iso*Anetholes into* 1 : 3-*Di*-p-*hydroxyphenyl*-2-*methylpentane* (III).—(*a*) Solid *iso*anethole (6·0 g.) was reduced (10 minutes) in alcohol (25 c.c.) with hydrogen in presence of a 2% palladium–strontium carbonate catalyst. The product was isolated and refluxed for 5 hours with glacial acetic acid (25 c.c.) and hydrobromic acid (25 c.c.; *d*, 1·47). Addition of water then precipitated (III) as an oil which rapidly solidified to a colourless solid (5·2 g.), m. p. 124—127°, recrystallisation of which from chloroform gave stout prisms, m. p. 129° (Campbell, Dodds, and Lawson, *loc. cit.*, give m. p

128° from *cyclo*hexane). (*b*) Similar treatment of liquid *iso*anethole (6·0 g.) gave a brown oil of low melting point (5·0 g.) which after one crystallisation from chloroform gave material, m. p. 122—128° (2·6 g.). Further crystallisation gave the pure compound, m. p. 129°. No other solid material could be isolated from the mother-liquors.

The authors' thanks are due to the Colston Research Society and Imperial Chemical Industries Limited for grants which have defrayed part of the cost of this research, and to Mr. L. J. Breddy for the preparation of specimens of metanethole by the methods of Perrenoud and Glichitch.

THE UNIVERSITY, BRISTOL.

[*Received, January* 16*th*, 1948.]