**249.** *Fused Carbon Rings. Part VI. Optical Activity connected with the Presence of Multiplanar Rings.*

By J. W. BARRETT and R. P. LINSTEAD.

WHEN two polymethylene rings are fused in the ortho-position, the bridge carbon atoms (C_1, C_2) acquire a special stereochemical interest. If the rings are fused by *cis*-valencies, the compound is of the *meso*-type. If the locking is *trans*- (I) and the valency angles are approximately tetrahedral, then the two component rings will be multiplanar; *e.g.*, C_4 must lie out of the plane of C_1, C_2, C_3. If the two rings differ in any respect, then C_1 and C_2 become asymmetric and the substance will exist in enantiomorphous forms; for instance,

(I.)   (II.)   (III.)   (IV.)   (V.)   (VI.)
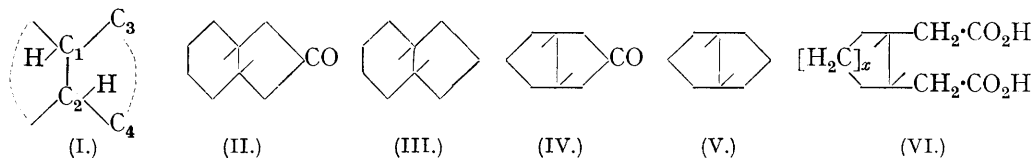
trans-β-hydrindanone (II) should exist in optically active forms, and the same is true of *trans*-hydrindane (III). *trans*-β-*bicyclo*Octanone (IV), on the other hand, although itself capable of existence in two optically isomeric forms, should yield an inactive hydrocarbon (V), in which the bridge carbon atoms are no longer asymmetric.

*trans-cyclo*Hexane-1 : 2-diacetic acid (VI; $x = 4$) was resolved by means of its *cinchonidine* salt.* Both the d- and the l-*acid* were cyclised in the presence of a trace of baryta to d- and l-trans-β-*hydrindanones*. The *l*-ketone was reduced by the Clemmensen method to l-trans-*hydrindane*. *trans-cyclo*Pentane-1 : 2-diacetic acid (VI; $x = 3$) was resolved by means of its *brucine* salt, but only the l-*acid* could be obtained in any quantity. This was converted into d-trans-β-bicyclo*octanone*, which on reduction yielded *trans-bicyclo*-octane, optically inactive and identical with that prepared by the reduction of *dl*-ketone (this vol., p. 436). The specific rotations (λ 5461) of these substances are shown below :

	Acid.	Ketone.	Semicarbazone.	Hydrocarbon.
*cyclo*Hexane series	$\begin{cases} +54\cdot9° \\ -47\cdot9 \end{cases}$	$-337\cdot2°$	$\begin{cases} -109\cdot4° \\ +\ 96\cdot3 \end{cases}$	$-10\cdot8°$
*cyclo*Pentane series	$\begin{cases} +62\cdot3 \\ -63\cdot6 \end{cases}$	$+437$	$+139\cdot6$	nil

The main features of these figures are the great increase in rotatory power and inversion of sign on the conversion of active acid into active ketone, and the fall in rotatory power accompanying the reduction of *l-trans*-β-hydrindanone. These are all paralleled in the terpene group.

* Hückel and Friedrich (*Annalen*, 1927, **451**, 132) have already given evidence that this acid can be resolved. They report its separation into two forms of m. p. 148—150° but give no measurements of rotation.

The active acids differed radically from the corresponding racemates in physical properties; curiously enough, the racemic acid was higher-melting than the active acid in the *cyclo*hexane series (*dl*, 167°, against 152°), but the reverse was true for the *cyclo*pentane compounds (*dl*, 132°, against 151°). Even at the high temperatures required for the conversion into ketone, there was no appreciable racemisation, and the small amounts of active acids which escaped cyclisation were practically pure. *d-trans-β-bicyclo*Octanone is the first solid ketone of the series, its m. p. (41°) being high for a C_8 ketone.

The present work conclusively proves the correctness of the configurations given by Hückel to the *cis*- and *trans*-decalins and hydrindanes, and also those advanced by Cook and Linstead (J., 1934, 949) for the corresponding *bicyclo*octanes.

EXPERIMENTAL.

Specific rotations were determined in a 2-dcm. tube for λ 5461. Acids were measured in absolute-alcoholic solution, semicarbazones in glacial acetic acid, ketones and hydrocarbons in purified light petroleum, b. p. 40—50°.

*cyclo*Hexane and Hydrindane Series.—*dl-trans-cyclo*Hexane-1 : 2-diacetic acid, prepared by Thakur's modification (J., 1933, 2151) of Hückel and Friedrich's method, formed large transparent needles and prisms, m. p. 167°. A solution of 15·7 g. of the acid and 47·2 g. of cinchonidine in 160 c.c. of boiling ethyl alcohol was rapidly diluted with 2400 c.c. of boiling water. White crystalline balls rapidly appeared and, after standing over-night, were filtered off and washed thoroughly with cold water (A). The mother-liquor yielded further crops, (B) and (C), by successive evaporations to half bulk, and a residue (D). Fraction (A) (30 g.) after two crystallisations from boiling water yielded an acid of m. p. 149—150°, fern-like tufts of opaque needles, $[\alpha]^{18 \cdot 5°} + 41 \cdot 9°$ ($c = 2 \cdot 564$), probably similar to that of Hückel and Friedrich. 3·5 G. of this acid were resolved as before with 10·4 g. of cinchonidine. The first crop of salt was crystallised twice from water, decomposed with ammonia, and filtered. The acid was isolated on acidification, partly as a precipitate and partly by extraction with ether, processes which gave identical material. d-trans-cyclo*Hexane-1 : 2-diacetic acid* formed opaque needles from water, m. p. 152°, $[\alpha]^{18°} + 54 \cdot 9°$ ($c = 2 \cdot 535$) (Found : C, 60·2; H, 8·0. $C_{10}H_{16}O_4$ requires C, 60·0; H, 8·0%). The process of resolution was repeated, but the cinchonidine salt after three crystallisations yielded an acid with unchanged m. p. and specific rotation.

Fraction (B) (6 g.) gave mainly *dl*-acid (m. p. 163—165°) and fraction (C) (20 g.) gave an impure *l*-acid. Fraction (D) (5 g.) after three crystallisations from water gave small needles of the neutral *cinchonidine* salt of the *l*-acid (Found : C, 69·4; H, 7·8. $C_{48}H_{60}O_6N_4,2H_2O$ requires C, 69·8; H, 7·8%). This yielded a *l-acid*, not quite optically pure, m. p. 148—149°, $[\alpha]^{19°} - 47 \cdot 9°$ ($c = 1 \cdot 832$) (Found : C, 60·1; H, 7·9. $C_{10}H_{16}O_4$ requires C, 60·0; H, 8·0%). A mixture obtained by grinding the *d*- and the *l*-acid together melted at 164—166°; crystallisation of an equal mixture from water yielded an acid of m. p. 166—167°.

A mixture of 4·7 g. of the *d*-acid (m. p. 152°, $[\alpha]^{18°} + 54 \cdot 9°$) with a few crystals of baryta was heated at 290—300°. The product was separated in the usual manner (Barrett and Linstead, this vol., p. 441) into ketone, isolated as semicarbazone (3·5 g.; 82%), and acid (0·1 g. from distillate; 0·08 g. from residue).

Both samples of acid melted at 151° alone or admixed with pure *d*-acid. United, they had $[\alpha]^{19°} + 53 \cdot 8$. The *l-semicarbazone* was crystallised twice from 500 c.c. of boiling methanol, and formed glistening leaflets, m. p. 242—243° (decomp.). It resembled the *dl*-semicarbazone (m. p. 243°) closely in solubility and did not depress its m. p. It had $[\alpha]^{18°} - 109 \cdot 4°$ ($c = 2 \cdot 396$) (Found : C, 61·4; H, 8·7; N, 20·8. $C_{10}H_{17}ON_3$ requires C, 61·5; H, 8·8; N, 21·6%). The pure semicarbazone was converted into *l-trans-β-hydrindanone* by means of oxalic acid; the ketone, isolated by means of purified light petroleum (b. p. 40—50°), was twice distilled at 83°/10 mm. The second distillate was arbitrarily divided into two fractions, the specific rotations of which were identical, $[\alpha]^{17 \cdot 5°} - 337 \cdot 2°$ ($c = 2 \cdot 540$) (Found : C, 78·1; H, 10·2. $C_9H_{14}O$ requires C, 78·2; H, 10·2%). By similar treatment, the *l*-acid (m. p. 149°, $[\alpha]^{19°} - 47 \cdot 9°$) yielded *d-trans-β*-hydrindanone, isolated as the semicarbazone, glistening leaflets from methanol m. p. 241—242°, $[\alpha]^{18°} + 96 \cdot 3°$ ($c = 2 \cdot 014$). The recovered acid had m. p. 149°, $[\alpha]^{18°} - 46 \cdot 5°$.

1·8 G. of the pure *l*-ketone were reduced by means of 26 g. of amalgamated zinc, 20 c.c. of glacial acetic acid, and 10 c.c. of hydrochloric acid in the apparatus of Linstead and Meade (J., 1934, 945), hydrogen chloride being passed into the mixture during 8 hrs. The hydrocarbon, isolated by distillation in steam and extraction with a little pure ether, was washed with sodium carbonate, water, semicarbazide hydrochloride solution (twice), water, concentrated sulphuric

acid (twice), sodium bicarbonate, and water. (This treatment was necessary to ensure removal of all trace of the active ketone, which, by virtue of its high rotatory power, might produce an appearance of activity in an inactive hydrocarbon.) The product was dried, refluxed for 3 hours over sodium, and distilled twice from sodium and once alone. l-trans-*Hydrindane* had b. p. 156°/747 mm.; $[\alpha]^{19°}$ — 10·8° ($c = 2\cdot129$); $n_D^{18\cdot2°}$ 1·4655, $d_{4°}^{18\cdot2°}$ 0·865, $[R_L]_D$ 39·71 (calc., 39·36) (Found : C, 86·7; H, 13·3. C_9H_{16} requires C, 87·1; H, 12·9%). Hückel (" Theoretische Grundlagen der Organischen Chemie," 1st edtn., II, 151), quoting Sachs (Diss., Göttingen, 1928), gives for dl-trans-hydrindane, b. p. 158°, $n_D^{20°}$ 1·4643, $d_{4°}^{20°}$ 0·863, $[R_L]_D$ 39·62.*

cyclo*Pentane and* bicyclo*Octane Series.*—dl-trans-cycloPentane-1 : 2-diacetic acid could not be resolved by fractional crystallisation of its neutral or acid salts with cinchonine, cinchonidine, quinine, or strychnine, and the acid brucine salt was too soluble, but the neutral salt yielded the desired separation. A solution of 10 g. of the pure acid (m. p. 132—133°; Barrett and Linstead, *loc. cit.*) in 250 c.c. of hot water was treated with 49·4 g. (2 mols.) of brucine. The solution deposited large, flat, transparent prisms (A), the mother-liquor from which on concentration yielded four further crops (B) and a syrupy residue (C). Fraction (A) (20·2 g. after being dried in a vacuum desiccator) crystallised from water in large prisms, often aggregated in radiating clusters. The once-crystallised salt yielded an acid, isolated by means of ether, with m. p. 149°, $[\alpha]^{18°}$ — 52·4°. After 3 and 5 crystallisations of the salt from water, the liberated acid had m. p. 151°, $[\alpha]^{19°}$ — 63·3° ($c = 2\cdot340$), and m. p. 151°, $[\alpha]^{18°}$ — 63·6° ($c = 2\cdot555$), respectively. The neutral *brucine* salt of the l-acid melted at 105—108° (Found : N, 6·15. $C_{56}H_{66}O_{12}N_4$ requires N, 6·0%). 17·5 G. of the pure thrice-crystallised salt yielded 3·3 g. (calc., 3·4 g.) of l-trans-cyclo*pentane*-1 : 2-*diacetic acid*, massive, flat, hexagonal prisms or small octahedra from water, m. p. 151°, $[\alpha]^{18°}$ — 63·5 ($c = 2\cdot630$) (Found : C, 58·0; H, 7·6; equiv., 93·0. $C_9H_{14}O_4$, dibasic, requires C, 58·0; H, 7·6%; equiv., 93·05). An equal mixture with the dl-acid melted at 138—144°.

The intermediate crops (B) yielded mixtures of dl- and active acids even after thorough crystallisation. The syrupy residue (C) was decomposed to the nearly pure d-*acid*, which crystallised in flat prisms from water, 0·6 g., m. p. 150—151°, $[\alpha]^{19°}$ + 62·3° ($c = 2\cdot014$) (Found : equiv., 93·2). An equal mixture of the d- and the l-acid melted at 132—136° when ground together, and after crystallisation from water, at 132—133°. The active acids appear to be less soluble than the racemic acid in water.

l-trans-cyclo*Pentane*-1 : 2-diacetic acid (3·2 g., m. p. 151°, $[\alpha]^{18°}$ — 63·5°) was converted into ketone in the same way as the d-cyclohexane acid (above), except that a temperature of 330—350° was necessary. Yield of semicarbazone, 1·80 g. (58%); acid recovered, 0·20 g. (9%); m. p. 150—151°, $[\alpha]^{17°}$ — 62·0° ($c = 0\cdot762$). The active acid thus forms a ketone in approximately the same yield and at the same temperature as the dl-acid (Barrett and Linstead, *loc. cit.*). The *semicarbazone* of d-trans-β-0 : 3 : 3-bicyclo*octanone* crystallised from 350 c.c. of boiling methanol in stellate clusters of short thick prisms, m. p. 249° (no decomp.), $[\alpha]^{18°}$ + 139·6° ($c = 1\cdot074$) (Found : C, 59·6; H, 7·9. $C_9H_{15}ON_3$ requires C, 59·6; H, 8·3%). The active semicarbazone was practically indistinguishable in crystalline form and solubility from the dl-, and did not depress its m. p. On regeneration with oxalic acid and distillation in steam, the ketone solidified in the distillate. It was isolated by means of light petroleum, and, after distillation, formed a hard crystalline mass, which could not be recrystallised; yield 90%. d-trans-β-0 : 3 : 3-bicyclo*Octanone* has m. p. 41°, $[\alpha]^{18°}$ + 437° ($c = 1\cdot058$) (Found : C, 77·1; H, 9·4. $C_8H_{12}O$ requires C, 77·4; H, 9·8%); it was very volatile, crystallised very readily without supercooling, and melted sharply. An equal mixture with the dl-ketone melted at 24—31°.

The pure d-ketone (0·84 g.) was reduced in a small all-glass apparatus with 10 g. of amalgamated zinc, 4 c.c. of concentrated hydrochloric acid, and 8 c.c. of glacial acetic acid. The product was worked up in the manner described for l-trans-hydrindane (above). 0·24 G. of d·semicarbazone was recovered, m. p. 249°, $[\alpha]^{18°}$ + 138·8° ($c = 0\cdot523$), together with 0·36 g. of trans-0 : 3 : 3-*bicyclo*octane, b. p. 132°/762 mm., which showed no rotation ($c = 2\cdot60$). This hydrocarbon melted at — 30° to — 29° alone or admixed with that prepared from the dl-ketone. [The m. p. (— 36°) given for this hydrocarbon in our former paper (*loc. cit.*, p. 437) is incorrect, owing to an error in the correction for stem exposure. The other m. p.'s in the same table are also 5° too low.] The other physical properties were also in almost exact agreement ($d_{4°}^{14°}$ 0·867; $n_D^{14°}$ 1·4651; $[R_L]_D$ 35·12) (Found : C, 87·2; H, 12·6. Calc. for C_8H_{14} : C, 87·2; H, 12·8%).

IMPERIAL COLLEGE, LONDON, S.W. 7. [*Received, May 4th*, 1935.]

* If a small arithmetical error is corrected, this becomes 39·7.