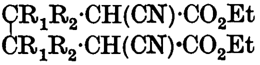
CCXLII.—*Syntheses of Cyclic Compounds. Part IX. The Reduction of Ethyl 3-Methyl*cyclo*pentylidene-1-cyanoacetate with Moist Aluminium Amalgam and its Bearing upon the Configuration of the 3-Methyl*cyclo*pentane Ring.*

By ARTHUR ISRAEL VOGEL.

PURE 3-methyl*cyclo*pentanone being now readily available (Vogel, this vol., p. 907), the present research was carried out along the lines described in Part III (J., 1928, 2010) in order to compare the 3-methyl*cyclo*pentane ring with the other ring systems already studied and thereby to obtain evidence as to the influence of the methyl group upon the properties of the 5-carbon ring. The method consists in the reduction of the cyano-esters (I) with aluminium amalgam in moist ether under standard conditions (J., 1927, 594),

(I.) $\mathrm{CR_1R_2{:}C(CN)\cdot CO_2Et}$

(II.) $\mathrm{CHR_1R_2\cdot CH(CN)\cdot CO_2Et}$

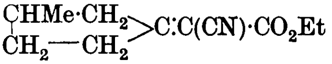


$$\begin{array}{l}\mathrm{CR_1R_2\cdot CH(CN)\cdot CO_2Et}\\ |\\ \mathrm{CR_1R_2\cdot CH(CN)\cdot CO_2Et}\end{array}$$

(III.)

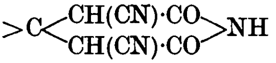
whereby a mixture, readily separable by distillation, of the unimolecular compound (II) and the bimolecular compound (III) is produced. Owing to the practical non-volatility of (III) in ether vapour and its almost complete insolubility in water, the yield of the bimolecular ester is employed for comparative purposes. It must be emphasised that the method is regarded merely as one to be compared ultimately with the results obtained by physical methods, such as the determination of the dissociation constants of appropriately substituted dibasic acids, which forms the basis of a concurrent series of investigations.

3-Methyl*cyclo*pentanone condenses readily with ethyl cyanoacetate in the presence of piperidine to yield the *cyano-ester* (IV), which exists in a solid (α) and a liquid (β) form, both of which are produced in approximately equal quantities in the condensation. The liquid form has all the properties of an αβ-compound : it exhibits an exaltation of molecular refraction, condenses readily with alco-



$$\mathrm{\begin{array}{l}CHMe\cdot CH_2\\ CH_2{-}CH_2\end{array}\!\!>C{:}C(CN)\cdot CO_2Et}$$

(IV.)



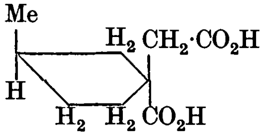
$$\mathrm{>C<\begin{array}{l}CH(CN)\cdot CO\\ CH(CN)\cdot CO\end{array}\!\!>NH}$$

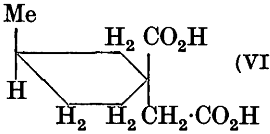
(V.)

$\mathrm{>CH(CO_2H)_2}$

(VI.)

(VII.)





(VIII.)

holic potassium cyanide (compare Lapworth and McRae, J., 1922, **121**, 2741) to give an excellent yield of a *succinic acid* which has the configuration (VII) or (VIII), and is completely reduced by moist aluminium amalgam in ether in 6—7 hours. The solid ester likewise condenses with alcoholic potassium cyanide to give a good yield of the same succinic acid, which is accompanied by another acid, the quantity of which, however, was too small for isolation in a state of purity. Both forms yield 3-methyl*cyclo*pentanone on oxidation with aqueous potassium permanganate at 0°, and give the dicyano-imide of 3-methyl*cyclo*pentane-1 : 1-diacetic acid (V) on condensation with ethyl cyanoacetate and ammonia in alcoholic solution. They differ, however, in their solubility in alcohol (the α-form is the less soluble) and in the rate of reduction by moist aluminium amalgam. The solid ester (IV) is incompletely reduced after 6—7 hours but completely after 20 hours. The yield of the bimolecular compound (III) is 13% for the liquid and 16% for the solid form. The same unimolecular compound (II) is produced from the two forms, since hydrolysis with alcoholic potassium hydroxide yields the same *malonic acid* (VI) in nearly quantitative yield.

The results of the reduction, together with all the results thus far obtained (J., 1928, 2010; 1930, 768), are in Table I.

TABLE I.

$CR_1R_2{:}C(CN){\cdot}CO_2Et$.	$CHR_1R_2{\cdot}CH(CN){\cdot}CO_2Et$.	$CR_1R_2{\cdot}CH(CN){\cdot}CO_2Et$. $CR_1R_2{\cdot}CH(CN){\cdot}CO_2Et$
R_1R_2 = *gem*-dimethyl ...	63	21
CR_1R_2 = *cyclo*pentane	79	13
= 3-methyl*cyclo*-pentane (liquid)	75	13
= *cyclo*heptane	72	12
= *trans*-hexahydro-β-hydrindene*	75	15
= *cyclo*hexane	84	6
= 3-methyl*cyclo*-hexane	83	6
= 4-methyl*cyclo*-hexane	87	4
= *trans*-decahydro-β-naphthalene	78	7

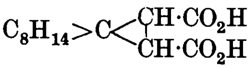
* The values for *trans*-hexahydro-β-hydrindene are due to Kandiah (this vol., p. 930), and have been computed from his actual experimental results; his figures for relative yields of 82% and 18% are erroneous.

The yield of bimolecular compound in the 3-methyl*cyclo*pentane series is almost identical with that of *cyclo*pentane and *cyclo*heptane, both of which are strainless rings. It is reasonable, therefore, to conclude that the 3-methyl*cyclo*pentane ring is likewise strainless and its influence upon the tetrahedral angle is similar to that of *cyclo*pentane and other strainless rings. Support for this view is given by parachor measurements on 3-methyl*cyclo*pentanone (see Experimental). By substituting Sugden's values of 2H for :O, the parachor of the methyl*cyclo*pentane ring can be evaluated and by further replacing the value for CH_3 by that of H, the contribution per CH_2 group, $[P'_1/n]$, which is an important criterion of the configuration of the ring (Vogel, J., 1928, 2018; 1930, 770), can be calculated. This leads to a value of $[P'_1/n]$ of 40·9, which agrees well with the figure (41·0) previously obtained for the simple *cyclo*pentane ring.

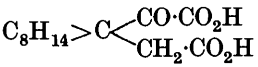
Table I has some features of interest. The *cyclo*hexane ring, either alone or substituted by one methyl group or fused to another like ring, gives a yield of 6—7% of bimolecular compound, whereas the *cyclo*-pentane and -heptane rings (now accepted as strainless) give approximately twice this yield. It appears that the behaviour of ring systems in this reaction falls into two classes : (1) *cyclo*hexane, 3- and 4-methyl*cyclo*hexane, and *trans*-decahydro-β-naphthalene, (2) the accepted strainless rings, *viz.*, *cyclo*heptane and *cyclo*pentane, and also 3-methyl*cyclo*pentane and *trans*-hexahydro-β-hydrindene.

The inference for *trans*-hexahydro-β-hydrindene is in accord with the experiments of Kandiah (this vol., p. 952) upon the stability of the *trans*-*spiro*-acid (IX) towards hydrochloric acid and upon the equilibrium (X) $\rightleftharpoons$ (XI) in concentrated alkali solution. The result for *trans*-decahydro-β-naphthalene is, however, diametrically opposed to the conclusions of Rao (J., 1930, 1162), who, by methods analogous to those just mentioned, deduced that it simulated the *cyclo*pentane ring in behaviour and was therefore strainless and consisted of two multiplanar 6-carbon rings. No explanation is at present offered of this serious anomaly.

(IX.)

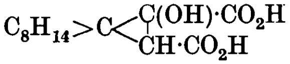


$$\mathrm{C_8H_{14}{>}C{<}}\begin{array}{l}\mathrm{CH\cdot CO_2H}\\ \mathrm{CH\cdot CO_2H}\end{array}$$



$$\mathrm{C_8H_{14}{>}C{<}}\begin{array}{l}\mathrm{CO\cdot CO_2H}\\ \mathrm{CH_2\cdot CO_2H}\end{array}$$

(X.)



$$\mathrm{C_8H_{14}{>}C{<}}\begin{array}{l}\mathrm{C(OH)\cdot CO_2H}\\ \mathrm{CH\cdot CO_2H}\end{array}$$

(XI.)

EXPERIMENTAL.

Condensation of 3-*Methyl*cyclo*pentanone with Ethyl Cyanoacetate : Ethyl* 3-*Methyl*cyclo*pentylidene*-1-*cyanoacetate* (IV).—A mixture of 49 g. of the ketone, b. p. 143—145°, prepared from pure β-methyladipic acid, m. p. 96—97° (Vogel, this vol., p. 912), 57 g. of ethyl cyanoacetate, and 1 g. of piperidine was kept at room temperature for 54 hours, then heated on the steam-bath for 3 hours, cooled, and poured into water. The heavy oil produced was isolated by means of ether (two extractions), washed with dilute hydrochloric acid and then with water, dried with anhydrous sodium sulphate, and distilled; 3-methyl*cyclo*pentanone and ethyl cyanoacetate passed over first (39—40 g.), followed by a small fraction at 145—156°/13 mm. (4 g.), partially solidifying on cooling, and the pure cyano-ester (IV) at 155—157°/12 mm. (41·5—43 g.), the last-named solidifying to a somewhat sticky solid on cooling. The sticky solid was spread on a large porous plate during 4 days; the resultant crystalline solid (20—21 g.), after two crystallisations from 80% alcohol, from which it separated in lustrous plates, had m. p. 70° (light petroleum, b. p. 40—60°, may also be employed). This was the α-form of (IV) (Found: C, 68·1; H, 7·6. $C_{11}H_{15}O_2N$ requires C, 68·3; H, 7·8%). The porous plate was extracted with a large volume of boiling ether during 3 hours, the ether evaporated and the residue distilled. The β-form of 3-*methyl*cyclo*pentylidene*-1-*cyanoacetate* (16—17 g.) passed over at 155—156°/12 mm. as a colourless viscid liquid, which had $d_{4^\circ}^{19^\circ}$ 1·039, $n_D^{19^\circ}$ 1·484 (Abbé refractometer), whence $[R_L]_D$ 53·18 (calc., 51·59) (Found: C 68·2; H, 7·6%). It solidified in ice. Treatment of the low b. p. fraction with piperidine and keeping at the room temperature for 2 days results in the separation of a considerable quantity of solid, which on dissolution in ether and working up as described above, gives further quantities of the solid and liquid unsaturated cyano-esters.

Oxidation with potassium permanganate. 3 G. of the ester (IV) were treated with the required amount of ice-cold 3% aqueous potassium permanganate and the solution was kept for one hour at 0°. 3-Methyl*cyclo*pentanone, isolated by the addition of excess of semicarbazide acetate to the first 25 c.c. of the steam distillate, was identified in the form of the semicarbazone (m. p. and mixed m. p. 184—185°). The yield of semicarbazone from the liquid form was greater than that from the solid form.

Reduction of (IV) *with Moist Aluminium Amalgam. Preparation of Ethyl* r-3-*Methyl*cyclo*pentyl*-1-*cyanoacetate.—Liquid form.* 9·41 G. were reduced with 20 g. of aluminium amalgam in moist ether under the usual conditions (J., 1927, 594). The product was worked up in the usual manner after 7 hours and distilled; *ethyl* r-3-*methyl*cyclo*pentyl*-1-*cyanoacetate* (7·08 g.) passed over at 135—137°/12 mm. The residue solidified when left in a vacuum over calcium chloride after previous trituration with dry light petroleum, b. p. 40—60°; yield, 1·23 g. It had m. p. 69—76° and was probably a mixture of isomeric bimolecular cyano-esters (Found: *M*, in camphor, 392. $C_{22}H_{32}O_4N_2$ requires *M*, 388). The liquid reduction product on redistillation boiled at 140°/14 mm., and had $d_{4^\circ}^{17^\circ}$ 1·0067, $n_D^{17^\circ}$ 1·448, whence $[R_L]_D$ 51·93 (calc., 52·21) (Found: C, 68·0; H, 8·5. $C_{11}H_{17}O_2N$ requires C, 67·6; H, 8·8%).

Solid form. 6·65 G., m. p. 69—70°, were similarly reduced with 15 g. of moist aluminium amalgam. There was very little action during the first 7 hours although the ether was saturated with water. It was worked up after 20 hours (when most of the amalgam had reacted) and yielded 4·82 g. of ethyl *r*-3-methyl*cyclo*pentyl-1-cyanoacetate, b. p. 135—136°/11 mm., $d_4^{20°}$ 1·0006, $n_D^{20°}$ 1·448, whence $[R_L]_D$ 52·17 (Found : C, 67·7 ; H, 8·6%), and 1·10 g. of the solid bimolecular compound, m. p. 69—77° (Found : *M*, in camphor, 390).

If the reduction product is worked up after 7 hours, it solidifies to a sticky mass when left in a vacuum and yields the unchanged cyano-ester, m. p. 69—70°, when spread on porcelain.

r-3-*Methyl*cyclo*pentyl*-1-*malonic Acid* (VI).—Solutions of ethyl *r*-3-methyl*cyclo*pentyl-1-cyanoacetate (7·5 g.), from the liquid form of (IV), in rectified spirit (15 g.), and of potassium hydroxide (12 g.) in water (24 g.) were mixed, refluxed for 36 hours (the evolution of ammonia had then ceased), and evaporated to dryness on the steam-bath. The residue was triturated with ether to remove any unchanged ester, and cautiously acidified with dilute sulphuric acid; 3-*methyl*cyclo*pentyl*-1-*malonic acid* (5·1 g.), m. p. 151—153° (decomp.), was precipitated and after one crystallisation from benzene, from which it separated in rectangular plates, had m. p. 153—154° (decomp.) (Found : C, 58·3 ; H, 7·4. $C_9H_{14}O_4$ requires C, 58·0 ; H, 7·6%. Found for the *silver* salt : Ag, 54·0. $C_9H_{12}O_4Ag_2$ requires Ag, 53·8%). Ether extracted an additional 0·45 g. of the acid after saturation of the filtrate with ammonium sulphate. The presence of an isomeric acid could not be detected.

Similar hydrolysis of ethyl *r*-3-methyl*cyclo*pentyl-1-cyanoacetate (4·5 g.) derived from the solid ester (IV) yielded *r*-3-methyl*cyclo*pentyl-1-malonic acid (3·0 g.), m. p. and mixed m. p. with the above acid, 153—154° (decomp.).

Condensation of the Ester (IV) *with Ethyl Cyanoacetate.*—3·0 G. of the ester (IV) (liquid form) were treated with ethyl cyanoacetate (1·8 g.) and absolute ethyl alcohol saturated with ammonia at − 5° (25 c.c.) and kept in the ice-chest for 4 days. No solid separated, but when the product was worked up in the manner previously described (Vogel, this vol., p. 913), the ω-imide of 3-methyl*cyclo*pentane-1 : 1-dicyanoacetic acid was obtained in satisfactory yield. The m. p. previously given (*loc. cit.*) was raised to 193—194° by crystallisation from dilute alcohol.

The solid cyano-ester (3·0 g.) condensed similarly with 1·8 g. of ethyl cyanoacetate and 75 c.c. of ethyl-alcoholic ammonia (this volume was necessary owing to the smaller solubility in ethyl alcohol) to the ω-imide (V), but the yield was less than that obtained from the liquid ester.

Condensation of Ethyl 3-*Methyl*cyclo*pentylidene*-1-*cyanoacetate with Alcoholic Potassium Cyanide. Preparation of* 1-*Carboxy*-3-*methyl*cyclo*pentane*-1-*acetic Acid.—Liquid form of* (IV). The pure liquid ester (3·0 g.) in 15 g. of rectified spirit was treated with a solution of 2·1 g. of potassium cyanide in 4·6 g. of water. The mixture, which became warm, was kept for 60 hours, the alcohol was then distilled off, very large excess of concentrated hydrochloric acid added, and the liquid heated under reflux for 4 hours, cooled, diluted with water, and extracted three times with ether after addition of ammonium sulphate. The residue, after evaporation of the ether, was a viscid oil which on dissolution in a mixture of ether–benzene–light petroleum (b. p. 40—60°)—all sodium dried —and keeping for 12 hours, deposited 2·85 g. of the crude acid, m. p. 111—113°. 1-*Carboxy*-3-*methyl*cyclo*pentane*-1-*acetic acid* separated from concentrated hydrochloric acid in prisms, m. p. 117° (Found: C, 58·1; H, 7·7. $C_9H_{14}O_4$ requires C, 58·0; H, 7·6%. Found for the *silver* salt: Ag, 54·0. $C_9H_{12}O_4Ag_2$ requires Ag, 53·8%).

The *anhydride*, readily prepared by refluxing the acid for 4 hours with 4 mols. of pure acetyl chloride (Vogel, J., 1928, 2010), was a liquid, b. p. 156—158°/11 mm. (Found: C, 58·0; H, 7·7. $C_9H_{12}O_3$ requires C, 58·0; H, 7·6%). It yielded the original acid, m. p. 117—118°, on boiling with aqueous potassium hydroxide for 30 minutes, followed by acidification.

Solid form of (IV). The condensation of the solid ester (3·0 g.) was carried out as above, except that 30 g. of rectified spirit were employed. The resultant viscid oil was kept for 48 hours until most of the mixed solvents had evaporated spontaneously. The crude solid acid (2·3 g.), after trituration with benzene, melted at 115—116°, and at 117—118° after one crystallisation from concentrated hydrochloric acid. It was identical (mixed m. p.) with the acid obtained from the liquid ester. The benzene extract yielded *ca.* 0·1 g. of a somewhat sticky acid on evaporation, but the quantity was too small for investigation.

Surface-tension and Density Measurements on 3-*Methyl*cyclo*pentanone.*—The apparatus and procedure employed in these determinations were those already described (Vogel, J., 1928, 2027). The correction for the meniscus was 0·24 mm. and the mean constant K, 1·8638. The symbols in the table have already been defined (Vogel, *loc. cit.*). The 3-methyl*cyclo*pentanone was prepared from β-methyladipic acid, m. p. 96—97°, and was regenerated from the bisulphite compound; it then boiled at 143·5—144°/759 mm. $M = 98{\cdot}08$.

Densities determined : $d_{4^\circ}^{17\cdot5^\circ}$ 0·9155, $d_{4^\circ}^{61\cdot6^\circ}$ 0·8775, $d_{4^\circ}^{86\cdot6^\circ}$ 0·8550.

t.	h.	H.	$d_{4^\circ}^{t^\circ}$.	γ.	Parachor.
20·0°	18·00	17·76	0·9132	30·23	251·8
60·6	16·37	16·13	0·8784	26·41	253·1
81·8	15·33	15·09	0·8593	24·17	253·1
				Mean	252·7

Correction. In Part VIII (this vol., p. 910), the first paragraph should be deleted, since the distillation of the calcium salts of *cyclo*hexane- and *cyclo*heptane-1 : 1-diacetic acids (Kon, J., 1921, **119**, 810) has, the author regrets, been confused with the action of potassium on the corresponding esters (Kon, J., 1922, **121**, 513, and unpublished observations). This in no way affects either the theory developed in the paper or the conclusions deduced from the experimental results.

The author's thanks are due to the Chemical Society for a grant towards the cost of materials, to the Dixon Fund Committee of the University of London for a grant for the purchase of the microscope, and to Imperial Chemical Industries for a grant to the Chemical Department.

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Addendum. Since the above was written, a paper has appeared by Desai (this vol., p. 1216) describing the preparation of ethyl 3-methyl*cyclo*pentylidene-1-cyanoacetate and its reduction by moist aluminium amalgam. The existence of the liquid cyano-ester, which forms about 50% of the condensation product between ethyl cyanoacetate and pure 3-methyl*cyclo*pentanone (from β-methyladipic acid, m. p. 96—97°; Desai's acid had m. p. 90—91°) in the presence of piperidine, has been overlooked. For the solid cyano-ester, no weights of the amounts of the uni- and bi-molecular reduction products isolated are recorded; it is stated (pp. 1217, 1222) that the yield of the latter, no evidence of its bimolecular character being adduced, is 12% (the true yield is 16%).

Pure 1-carboxy-3-methyl*cyclo*pentane-1-acetic acid, prepared from the liquid unsaturated cyano-ester and purified through the anhydride, has m. p. 117—118°. Desai records a m. p. of 125°, which would suggest that the separation of the isomeric acid was incomplete.

[*Added, June* 14*th*, 1931.]