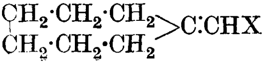
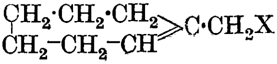
CLXXXIII.—*The Chemistry of the Three-carbon System. Part XXI. Some* cyclo*Heptane Compounds.*

By Wilfred Eynon Hugh, George Armand Robert Kon, and Thomas Mitchell.

In extending previous work on the mobility and the point of equilibrium of tautomeric compounds in relation to structure (J., 1928, 1630; this vol., p. 572), we were led to examine the effect of the *cyclo*heptane group, both in acids and in ketones, of the types (I) and (II).

(I.) 

$$\begin{array}{l} CH_2\cdot CH_2\cdot CH_2 \\ CH_2\cdot CH_2\cdot CH_2 \end{array}\!\!>C{:}CHX$$

 (II.)

$$\begin{array}{l} CH_2\cdot CH_2\cdot CH_2 \\ CH_2-CH_2-CH \end{array}\!\!\gg C\cdot CH_2X$$

(X = CO_2H or COMe.)

*cyclo*Heptylideneacetic acid on treatment with alkali passed into an equilibrium mixture from which about 25% of unchanged acid could be recovered by Bougault's method (Kon and May, J., 1927, 1549). The equilibrium ratio for this acid and its βγ-isomeride (not obtained in a pure state) was therefore approximately 25 : 75. No estimate of mobility was, however, possible.

We have now repeated the equilibration of the acid and determined its mobility and point of equilibrium, using Linstead and May's extrapolation method (J., 1927, 2565), since pure Δ^1-*cyclo*heptenylacetic acid (II, $X = CO_2H$) (now obtainable from the equilibrium mixture : see Experimental) was not available. Our results confirm Kon and May's estimate of the point of equilibrium (26% αβ), but subsequent experiments with the pure βγ-acid suggest that this value may be 2 or 3% low. The mobility, $(k_1 + k_2) \times 10$, calculated in the usual way is 0·66.

The αβ-acid is readily converted through the acid chloride into the ketone (I, X = COMe), which was shown to have the αβ-structure by its physical properties and by oxidation to suberone. Its semicarbazone (m. p. 172—173°) is identical with the semicarbazone prepared by Kon from calcium *cyclo*heptanediacetate (J., 1921, **119**, 810) and thought to be that of the βγ-ketone : this discrepancy is due to the sparing solubility of the semicarbazone, which is readily obtained even from mixtures containing considerable quantities of the βγ-isomeride.

The ketone regenerated without appreciable change from the semicarbazone was employed throughout this work.

The difficulty of preparing the βγ-ketone (II, X = COMe) is so great that it is doubtful whether the pure material has yet been obtained. The process employed by Dickins, Hugh, and Kon (this vol., p. 572) for the synthesis of *cyclo*pentenylacetone gives a product which closely resembles Kon's ketone (*loc. cit.*) in physical properties and, as it has a high reactivity towards iodine chloride, consists to a great extent of the βγ-ketone. The semicarbazone prepared from it, however, does not appear to be homogeneous, crystallises badly, and gives only a very small amount of material of constant melting point. On the other hand, the ketone gives on treatment with sodium ethoxide an equilibrium mixture of practically the same iodine addition as that from the pure αβ-ketone, so it cannot contain much saturated impurity.

The equilibration of the two ketones under Kon and Linstead's standard conditions (this vol., p. 1270) shows that the system is extremely mobile. Exact calculations have not been made because the ketone is practically at equilibrium after 5 minutes' treatment with sodium ethoxide; a rough extrapolation gives the half-change period as less than 2 minutes, and the mobility, $(k_1 + k_2) \times 10^4$, must therefore be greater than 3500.

The values for the final equilibrium and for the intermediate points fluctuate somewhat more than they do for the *cyclo*hexane compounds (Kon and Linstead, *loc. cit.*), so the accuracy attained is not of such a high order; the equilibrium point lies between 63·5 and 66·2% of αβ-ketone; the average figure obtained is 65%.

The point of equilibrium of the ketones is therefore definitely on the αβ-side, although not as much as in the *cyclo*pentane compounds, in general agreement with the views previously expressed. The high mobility, comparable with that of the *cyclo*pentane compounds (an exact comparison is not yet possible) is not readily accounted for and is in contrast with the low mobility of the acids. It appears, therefore, that the mobility and the point of equilibrium of ketones cannot be simply correlated with those of the corresponding acids.

EXPERIMENTAL.

Equilibration of cyclo*Heptylideneacetic Acid.*—The acid (Kon and May, *loc. cit.*) was purified by reprecipitation from its solution in sodium hydrogen carbonate and crystallised from light petroleum. The *anilide*, prepared by way of the acid chloride, b. p. 120—121°/13 mm., formed long silky needles, m. p. 90—91°, from ethyl acetate–petroleum (Found: C, 78·3; H, 8·4. $C_{15}H_{19}ON$ requires C, 78·5; H, 8·4%).

The pure acid was heated with potassium hydroxide solution under the standard conditions used by Linstead (J., 1927, 2579; Goldberg and Linstead, J., 1928, 2343), and the change estimated by Linstead and May's second method (*loc. cit.*):

Time of heating (hours).	% Iodine addition in						
	30	60	90	120	150	180	210 mins.
0	Nil	—	—	—	—	—	—
3	13·3	13·6	14·0	14·0	14·2	—	—
9	32·9	35·0	35·2	35·9	36·5	—	—
15	43·0	46·4	46·5	47·1	47·3	—	—
24	54·2	57·4	60·0	61·3	62·1	62·2	62·2
40	60·6	67·2	69·7	70·7	71·0	71·6	71·8
72	61·9	69·0	72·5	74·6	76·6	76·8	77·4

The figures obtained by extrapolation are:

Time (hours) ...	0	3	9	15	24	40	72
% $\alpha\beta$-Acid	100	87	66	54	40	31	26
$(k_1 + k_2)$	—	0·0643	0·0682	0·0647	0·0693	0·0673	—

Preliminary experiments had shown that there was no further change after 72 hours. The mobility calculated from these figures is 0·66.

Δ^1-cyclo*Heptenylacetic Acid* (II, X = CO_2H).—The crude acid obtained by Wallach's method (*Annalen*, 1902, **314**, 157) contains up to 25% of the αβ-acid and all the methods of preparation used gave similar mixtures. The pure acid was obtained from it by the method successfully used to isolate hydrosorbic (Δ^{β}-hexenoic) acid (Linstead and Eccott, unpublished work). The crude acid (36 g.) was kept at room temperature with 216 c.c. of absolute alcohol and 72 c.c. of 1% alcoholic hydrogen chloride for 5 hours; an excess of sodium carbonate solution was then added and the ester isolated by means of ether. The unesterified acid recovered from the alkaline solution was practically pure αβ-acid. The ester, b. p. 104—107°/12 mm., $d_4^{18\cdot4°}$ 0·97172, $n_D^{18\cdot4°}$ 1·44689, $[R_L]_D$ 52·00 (calc., 51·99), showed a high reactivity towards iodine chloride (54·1% addition in 10 minutes, 73·6% in 60 minutes). It was hydrolysed with cold 10% aqueous-alcoholic potassium hydroxide: the *acid*, isolated in the usual manner, had b. p. 153°/17 mm., 107°/2·5 mm., $d_4^{15\cdot0°}$ 1·01155, $n_D^{15\cdot0°}$ 1·48820, $[R_L]_D$ 42·78 (calc., 42·75); its iodine addition was 76·5% in 10 minutes and 86·6 in 30 minutes, so it was evidently the pure Δ^1-isomeride (Found: C, 69·8; H, 9·1. $C_9H_{14}O_2$ requires C, 70·1; H, 9·2%). The acid chloride had b. p. 100—104°/13 mm. and gave the *anilide*, which formed plates, m. p. 79—80°, from benzene–petroleum (Found: C, 78·5; H, 8·2. $C_{15}H_{19}ON$ requires C, 78·5; H, 8·4%). The pure Δ^1-acid was obtained after the equilibration experiments had been completed; graphic interpolation between the iodine addition in 30 minutes of the αβ- and the βγ-acid gave a value of 28% of αβ-acid for the final equilibrium value (72 hours), in good agreement with that calculated above.

cyclo*Heptylideneacetone* (I, X = COMe).—The ketone was obtained in good yield from the αβ-acid by the Blaise–Maire reaction and boiled at 94—95°/9 mm. The semicarbazone was readily formed and crystallised from methyl alcohol in small plates, m. p. 172—173°, which did not depress the m. p. of Kon's original specimen (compare above). The *ketone* regenerated from it had b. p. 96°/10 mm., $d_4^{17\cdot8°}$ 0·94852, $n_D^{17\cdot8°}$ 1·49518, $[R_L]_D$ 46·79 (calc., 45·84) (Found: C, 79·1; H, 10·7. $C_{10}H_{16}O$ requires C, 78·9; H, 10·6%).

cyclo*Heptenylacetone* (II, X = COMe).—This ketone was similarly obtained from the βγ-acid; the yield of crude ketone was poor and on treatment with semicarbazide a mixture containing an appreciable amount of the αβ-semicarbazone, m. p. 172—173°, was precipitated. The crude semicarbazone was ground with light petroleum and hydrolysed with oxalic acid. The regenerated ketone, after treatment with aluminium amalgam to remove the αβ-ketone (compare Dickins, Hugh, and Kon, *loc. cit.*), was fractionated, fractions of b. p. 91—93°/13 mm., and 95°/13 mm. being collected; the second of these had the higher iodine addition and was used for plotting the reference curve; it had $d_4^{18\cdot8^\circ}$ 0·93558, $n_D^{18\cdot8^\circ}$ 1·47595, $[R_L]_D$ 45·86 (calc., 45·84). Both fractions gave an indefinite, very soluble *semicarbazone*, from which only a very small amount of long, flattened needles (from ethyl acetate–petroleum), m. p. 128—129°, could be isolated (Found: C, 62·8; H, 9·2. $C_{11}H_{19}ON_3$ requires C, 63·1; H, 9·2%).

Equilibration of the Ketones.—For the analysis of mixtures a reference curve was constructed from the following values for the addition of iodine in chloroform solution (in 10 minutes):

Mixture (% $\alpha\beta$)	0	10	25	50	75	90	100
Addition (%)	94·7	93·4	91·5	80·2	58·8	41·9	29·8

The very high addition of the $\beta\gamma$-ketone will be noted; even the lower fraction (see above) had an addition of 92·8%.

The equilibrations were carried out under Kon and Linstead's standard conditions. In the first experiments the $\alpha\beta$-ketone purified by distillation was used, but the equilibrium mixture obtained had a much lower iodine addition than the equilibrium mixture obtained from the pure ketone, owing to the presence of some less mobile impurity (esters): this conclusion was borne out by the somewhat higher density of the ketone ($d_4^{18\cdot8^\circ}$ 0·95260). Afterwards the pure ketone regenerated from the semicarbazone was used. The $\alpha\beta$-ketone appears to be practically unaffected by the process of regeneration, the best sample obtained having actually a lower iodine addition (25·9%) than the specimen used in plotting the reference curve, and only one had an addition of 35·6%.

The first experiments with the $\beta\gamma$-ketone were carried out on the assumption that the rate of change would be slower than in the *cyclo*hexane compound, and the times chosen were 20, 40 and 60 minutes; the % iodine additions were 71·2 (corresponding to 61·2% of $\alpha\beta$-ketone), 68·3 (64·8%) and 66·9 (66·5%) respectively. The last specimen then had $d_4^{20\cdot0^\circ}$ 0·94212 and $n_D^{20\cdot0^\circ}$ 1·48571. The three specimens were combined and equilibrated for 20 hours; an iodine addition of 67·7% was then obtained.

The following values were obtained with the $\alpha\beta$-ketone:

	% Iodine addition.		
Time (mins.).	(*a*).	(*b*).	(*c*).
5	—	65·4	—
10	66·1	—	68·2
20	67·6	—	—
40	67·1	—	—
60	67·2 *	—	69·6
1020	—	69·4	—

* This specimen had $d_4^{19^\circ}$ 0·94473 and $n_D^{19^\circ}$ 1·48860.

The combined fractions of (*a*) were treated again for 16 hours and then again for 18 hours; the product had an addition of 69·5% in each case. A similar experiment with the fractions of (*c*) gave a final value of 67·7%. Rejecting the values below 67% addition and averaging the remaining eleven, we obtained 68·4% (corresponding to 65% of αβ-ketone approximately) as the equilibrium point with an uncertainty of about 1%.

The estimate of the mobility must necessarily be very rough, but by interpolation between the zero and the 5-minute value for the αβ-ketone a half-change period of less than 2 minutes is obtained.

The authors' thanks are due to the Royal Society and the Chemical Society for grants which have defrayed the cost of the investigation, and to the Salters' Institute for a maintenance grant to one of them (T. M.).

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

[*Received, May* 14*th*, 1929.]