Chemical Structure of Kitol (I)
Double Bonds and Hydroxyl Groups

By
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In 1943 Embree and Shantz[1] postulated the molecular formula $C_{40}H_{58}(OH)_2$ for kitol isolated from whale liver oil, and in 1947 Baxter and co-workers[2] succeeded to obtain kitol in crystalline form, but since that time no research about the chemical structure of kitol has been reported. The author[3] studied on thermal decomposition of kitol with absorption spectra, yet definite conclusion has not been obtained. The decomposition of kitol has smoothly occurred only in case of molecular distillation, different from the pyrolyses of common substances. This interest reaction must be connected with the chemical structure of kitol, so that the author planned to confirm its structure and the study is now going on. This paper is concerned with results from preparatory experiments on double bonds, especially conjugated double bonds, and hydroxyl groups in kitol molecule.

Hydrogenation of Kitol Concentrate.—Through the hydrogenation of kitol concentrate having E (286 mμ) of 580, Embree and Shantz determined eight double bonds in a molecule. The author tried to purify kitol with the method similar to that of their report, obtaining the concentrate having E (290 mμ) of 482, which was used in the study to trace the hydrogeneration curve, while the number of double bonds was not confirmed. As shown in Fig. 1, it was remarkable that hydrogen absorption proceeded rapidly during the former two third period, but very slowly during the remaining one third period.

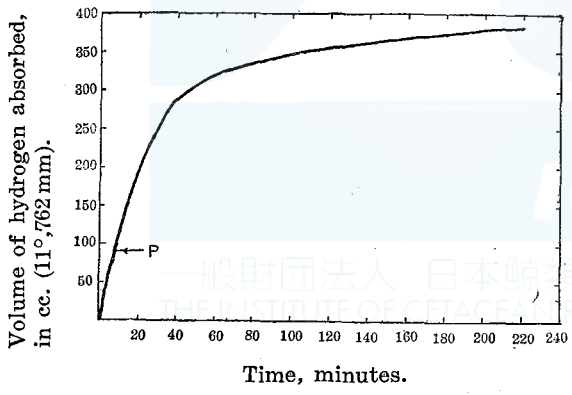

Fig. 1. Hydrogenation curve of kitol.
P: end point of the reduction of platinum oxide catalyst.

Conjugated Double Bonds.—The absorption maximum of kitol was reported 290 mμ (no solvent being mentioned) by Baxter etc.[2], 286 mμ

(in ethanol) by Embree etc.[1], while the author obtained 290 mμ (in isopropanol) in previous paper[3], and 284 mμ (in isopropanol) in this report. These differences seem to be due to steric isomerization of kitol, besides to its change during purification.

From the absorption spectrum, Barua and Morton[5] proposed four conjugated double bonds in kitol, considering five ones in vitamin A. The author has independently had the same opinion as theirs for the last two years. The data of absorption spectra about hydrocarbons[6] and alcohols[7] with a conjugated system shows that the addition of each new —CH=CH— group causes the absorption bands to shift toward the longer wave length region by some 40 mμ in the region of 250 mμ to 350 mμ.

Therefore, kitol having an absorption maximum at 285—290 mμ must have one less conjugated double bonds, which furthermore situated in the chain bond, not in the ring one, than vitamin A having a maximum at 325—8 mμ.

It was, moreover, proved through absorption spectra that conjugated double bond in kitol reacted with maleic anhydride to decrease its extinction as shown in Fig. 2. As clarified in the figure about 30% of kitol reacted with maleic anhydride in toluene at 100° for thirty minutes.

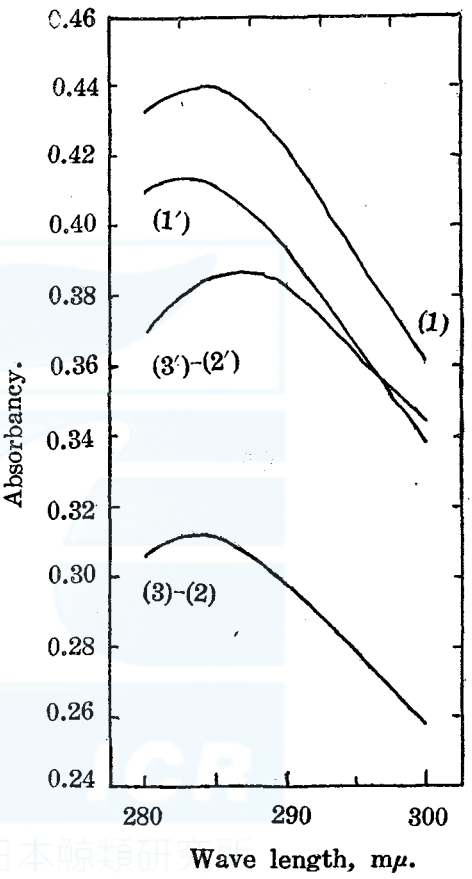

Fig. 2. Reaction of kitol with maleic anhydride, spectrophotometric curve of: (1) kitol, (1′) kitol after heating, (3)–(2) kitol immediately after mixing with maleic anhydride, and (3′)–(2′) kitol after heating with maleic anhydride solution.

Position of Hydroxyl Groups in Perhydrokitol.—Hydrogenated kitol, which will be called "perhydrokitol" was obtained as white solid through hydrogenation of kitol. The carbon hydrogen analyses of perhydrokitol concentrate about agreed with the formula $C_{40}H_{76}O_2$, this

sample being used in the following experiments. Though kitol itself is unstable, perhydrokitol, being a saturated compound, seemed to be stable. As the position of hydroxyl groups in perhydrokitol is same as that of groups in kitol, one can clarify the position of hydroxyl groups in kitol based on the experiments with perhydrokitol.

From this standpoint perhydrokitol was examined by Murahashi's method[8] and was proved to be primary alcohol: 44—69% of the hydroxyl group in perhydrokitol were esterified after heating at 155° for one hour with phenylacetic acid, under the same conditions 39—59% in case of cetyl alcohol (primary), and in case of cholesterol (ring and secondary) 16—34%.

In order to ascertain the fact the esterification rate with phthalic anhydride was measured. The percentage of esterified hydroxyl group after heating for one hour to that after heating for thirty hours was observed with perhydrokitol, cetyl alcohol and cholesterol, 25.4%, 29.5% and 0.0% being respectively obtained, so that perhydrokitol was proved to be primary alcohol. Thus, the hydroxyl groups in perhydrokitol, accordingly in kitol, was found to be primary, just same as that of vitamin A, from which the author may presume that two moles of vitamin A polymerize into kitol without any change in the position of hydroxyl groups.

Experimental Part

1. Kitol Concentrate.—The unsaponifiable matter from Antarctic whale liver oil was distilled in a molecular still to distil out vitamin A, the remaining portion[4] was chromatographed four times on alumina in petroleum ether to produce kitol concentrate, which was yellowish white solid having an absorption maximum at 284 mμ, E(284 mμ) of 489 and E(290 mμ) of 482. Compared with a crystalline kitol having E(290 mμ) of 707, the concentrate contained only 68% of pure kitol, yet appeared to be chromatographically pure. It melted at 87—90°, giving bloodish red color with antimony triohloride reagent, deep red with trichloracetic acid, and red then yellow with concentrated sulfuric acid and acetic anhydride reagent.

2. Hydrogenation of Kitol.—1.0387 g. of above concentrate was dissolved in 20 cc. glacial acetic acid, being hydrogenated with 0.500 g. of platinum oxide catalyst to produce the hydrogenation curves shown in Fig. 1. The total volume of absorbed hydrogen was 277 cc., so the 271 cc. (at normal state) of hydrogen for one gram of the sample. Assuming the molecular formula $C_{40}H_{60}O_2$ and eight double bonds one gram of kitol must consume 313 cc. of hydrogen, then the fouud volume absorbed corresponds 87% of the calculated volume.

3. Reaction of Kitol with Maleic Anhydride.—Three samples were prepared: (A) kitol solution (80 mg. kitol per 100 cc. toluene), (B) maleic anhydride solution (5 g. maleic anhydride per 100 cc. toluene), and (C) an equivolume mixture of (A) and (B). (A), (B) and (C) were heated for thirty minutes at 100°. Before and after heating,

exactly 1 cc. of the sample solutiou was pipetted, diluted with isopropanol into 50 cc., with which the absorption spectrum was measured. Correcting the absorption by toluene, and adjusting the dilution same, the absorbancy of each sample was calculated and summarized in Table I.

Table I.
Reaction of Kitol with Maleic Anhydride

mμ	(1)	(2)	(3)	(1)′	(2)′	(3)′
280	0.4325	0.2715	0.640	0.410	0.270	0.576
284	0.440	0.231	0.615	0.412	0.237	0.549
290	0.423	0.1733	0.5565	0.394	0.191	0.4895
300	0.361	0.1113	0.4555	0.339	0.138	0.3965

Absorbancy with same dilution, of (1) kitol solution (A), (2) maleic anhydride solution (B), and (3) equivolume mixture (C): and of (1)′, (2)′ and (3)′, corresponding to (1), (2) and (3) after heating for thirty minutes at 100°.

From Table I, (3)−(2) represents the absorption only by kitol immediately after mixing with maleic anhydride in the solvent, while (3)′−(2)′ means that of kitol after heating in maleic anhydride solution. These values are plotted in Fig. 2, (above shown).

4. Perhydrokitol.—The colorless transparent solution of hydrogenated kitol was filtered to separate from catalyst, added with excess volume of water, and extracted with ether. Ether solution was evaporated, the residue being saponified with methanolic potash. The nonsaponifiable matter was extracted with ether. After evaporating ether in vacuo the remaining portion became white solid which could not easily be crystallized. The elementary analyses of the compound were as follows:

	Found		Required for
	(1)	(2)	$C_{40}H_{76}O_2$
C	81.11	80.78	81.54
H	12.50	12.75	13.02
O (diff.)	6.40	6.47	5.44

Molecular weight was determined by cryoscopic (camphor) method:

Sample, mg.	Camphor, mg.	Temperature difference	Molecular weight
10.02	121.17	9.3	355
5.48	104.32	4.5	469
		Required for $C_{40}H_{76}O_2$	589

5. Determination of Hydroxyl Group in Perhydrokitol.—Customary methods [9) 10)] to determine OH groups were semimicronized as follows.

Reagent: 2 g. of phthalic anhydride (sublimed) to 12 cc. pyridine. Standard aqueous potassium hydroxide solution, 0.01026n (to benzoic acid).

Method: A weighed sample in a small thin glass test-tube is added with exact volume (0.210 cc.) of the reagent. Sealing the test-tube, it is kept at 100° for seventy-five minutes. After the reaction the sealed tube was broken in the flask, 1 cc. water

added, then a few drops of phenolphthalein indicator dropped into, and the flask contents are titrated with standard alkali solution. A blank is run in the same manner as the sample, and the difference of alkali cc. used for the sample and that for a blank shows the alkali cc. corresponding to the hydroxyl group.

The data with perhydrokitol, cetyl alcohol and cholesterol are summarized in the following. In the table, corr. OH% means found OH% minus quantity of free acid in the sample, expressed in OH%. Free acids in perhydaokitol, cetyl alcohol and cholesterol were respectively found to be 0.13, 0.09 and 0.42 OH%.

	Sample, mg.	Alkali, cc.	OH%	corr. OH%	theor. OH%
Perhydro-kitol	22.48	11.60	8.99	8.86	5.76
	13.30	7.82	10.25	10.12	5.76
Cetyl alcohol	19.98	12.30	10.72	10.6	6.95
	12.91	9.80	13.23	13.1	6.95
Chole-sterol	29.90	7.70	4.49	4.07	4.40
	23.51	8.30	6.15	5.73	4.40

$OH\% = (0.01026 \times 17.0 \times cc./mg.) \times 100\%$

6. Rate of Esterification of Perhydrokitol with Phenylacetic Acid. — Murahashi's method[8] was used, except that 10 cc. methanol plus 1 cc. chloroform were added before titration in order to dissolve the solid which was insoluble in aqueous alkali solution. A blank, of course, was carried witk the solvent. Data with cetyl alcohol and cholesterol are also quoted for a comparison. A standard was 0.01025n. KOH aq. solution. A.G. means % of acid esterified after one hour at 155°.

	Sample, mg.	Phenylacetic acid, mg.	Alkali, cc.	A.G.
Perhydro-kitol	9.04	6.38	3.27	43.7
	10.73	6.07	1.91	68.9
Cetyl alcohol	14.82	6.89	2.62	39.0
	12.41	7.00	2.10	58.8
Chole-sterol	12.09	6.94	4.50	15.8
	12.36	7.09	4.04	33.6

7. Rate of Esterification of Perhydrokitol with Phthalic Anhydride.—After so many preparatory experiments on cetyl alcohol and cholesterol, the author found the following method to discriminate primary alcohol from secondary one: almost same method as the determination of hydroxyl group in experiment 5, except the reaction temperature kept at 100° for one and thirty hours.

		Sample, mg.	Alkali, cc.	OH (corr.) %
After 1 hr.	Perhydrokitol	10.60	1.00	1.45
	Cetyl alcohol	13.00	2.10	2.61
	Cholesterol	15.30	0.07	0.0
After 30 hrs.	Perhydrokitol	12.00	4.00	5.72
	Cetyl alcohol	15.50	7.90	8.85
	Cholesterol	16.70	3.67	3.44

From above data the percentage of OH% after 1 hr. to OH% after 30 hrs. was calculated as follows: perhydrokitol 25.4, cetyl alcohol 25.5, cholesterol 0.0.

Summary

From the expriments on the hydrogenation curve and the addition with maleic anhydride of chromatographically pure kitol, the author presumed four conjugated double bonds containing one in the ring and proved that they reacted with maleic anhydride.

Esterification of perhydrokitol prepared from kitol through hydrogenation, when treated with phenylacetic acid at 155° for one hour, showed that perhydrokitol is a primary alcohol. The fact was also confirmed by the method to measure the esterification rate of an alcohol with phthalic anhydride in pyridine at 100°.

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