

143. *Observations on the Absorption Spectra of Terpenoid Compounds. Part I. "isoThujone."*

By A. E. GILLAM and T. F. WEST.

The chemical evidence adduced by Wallach indicates that the mixture of ketones produced by the action of sulphuric acid on thujone consists mainly of "isothujone" (*dl*-2 : 3-dimethyl-4-isopropyl- Δ^2 -cyclopentenone), the optically active form of which has since been prepared by Short and Read (J., 1939, 1040). Although the absorption spectrum of the *dl*-ketone clearly indicates the presence of the $C=C-C=O$ chromophoric group, yet the location of the absorption maximum is inconsistent with the presence of an $\alpha\beta$ -trisubstituted chromophoric system, and the observed data can apparently only be explained by the presence of a disubstituted group unless it be assumed that "isothujone" is exceptional among $\alpha\beta$ -unsaturated ketones. The absorption of a specimen of *l*-2 : 3-dimethyl-4-isopropyl- Δ^2 -cyclopentenone derived from *d*-sabinol (Short and Read, *loc. cit.*) shows even greater divergence from the value of λ_{max} expected on the basis of the accepted structure.

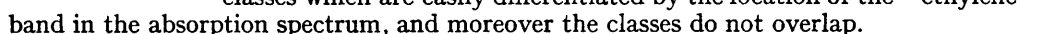
THE action of sulphuric acid on thujone (II) has been investigated by Wallach (*Annalen*, 1895, **286**, 101) and by Haller (*Compt. rend.*, 1905, **140**, 162) and the former showed that the principal product was the *dl*-form of an unsaturated ketone (III) to which he gave the name "isothujone," although Short and Read (J., 1938, 2016) have since pointed out that this should be named systematically as a cyclopentenone derivative. According to Wallach (*Ber.*, 1895, **28**, 1958; *Annalen*, 1902, **323**, 324), when thujone was treated with sulphuric acid, the mixture of ketones thereby produced gave a crude semicarbazone, m. p. 184—192°, which could be separated into an α -semicarbazone, m. p. 208—209°, and a β -semicarbazone, m. p. 184—185°, both of which regenerated *dl*-2 : 3-dimethyl-4-isopropyl- Δ^2 -cyclopentenone. Although identical melting points were given for each of these semicarbazones in both references, no details of the method of separation appear to have been recorded.

The crude semicarbazone obtained by us, from a ketone mixture having appropriate constants, has a melting range similar to that recorded by Wallach, but despite an exhaustive examination (see Experimental), we could only isolate, in addition to the semicarbazone of *d*-carvotanacetone, one semicarbazone having m. p. 207—208°. It may be significant that Wallach later (*Annalen*, 1915, **408**, 163) recorded the difficulty of obtaining uniform "isothujone" free from carvotanacetone, and that Haller (*loc. cit.*) did not describe the preparation of derivatives for identification.

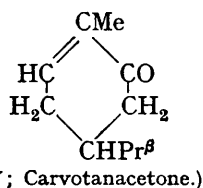
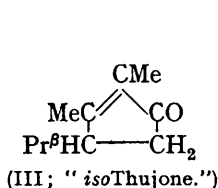
It has been suggested (Simonsen, "The Terpenes," I, p. 297) that the carvotanacetone found in thuja oil (Wallach, *Annalen*, 1893, **275**, 182) may have been formed from thujone during its isolation, but it was evident from the absorption spectrum that the *d*-thujone forming the basis of the present experiments was free from this ketone before treatment with sulphuric acid. The identity of the *dl*-2 : 3-dimethyl-4-isopropyl- Δ^2 -cyclopentenone with the "isothujone" described by Wallach was confirmed by the preparation of the oxime, m. p. 119—120° (*Ber.*, 1895; *Annalen*, 1915, *loc. cit.*).

$$\begin{array}{c} \beta \\ \beta \end{array} > C = C \begin{array}{c} \alpha \\ \diagup \\ R \end{array} - C = O$$

 (I.)


$$\begin{array}{c}
 \text{CHMe} \\
 \diagup \quad \diagdown \\
 \text{HC} \quad \text{CO} \\
 | \quad \quad | \\
 \text{H}_2\text{C} \quad \text{CH}_2 \\
 \diagdown \quad \diagup \\
 \text{CPr}^\beta
 \end{array}$$

(II; Thujone.)



Absorption spectra of ethyl-alcoholic solutions.

By hydrogenation in the presence of colloidal palladium, this alcohol gives *d*-2:3-dimethyl-4-isopropyl- Δ^2 -cyclopentenol, which is oxidised by Beckmann's chromic acid mixture to the *l*-ketone (Short and Read, J., 1939, 1043). The absorption spectrum of this compound showed the usual two maxima, at 2310 Å. ($\epsilon = 6180$) and 3100 Å. ($\epsilon = 35$), to be expected from an $\alpha\beta$ -unsaturated ketone.

Comparison of these data with the spectrum given by *isothujone* at once raises two points. First, these two compounds are sufficiently different in the locations of the main absorption maxima as to raise considerable doubts as to their identity, since stereoisomerides (or *l*- and *dl*-compounds) usually have identical absorption spectra. Secondly, this *l*-pentenone is even more anomalous than the *dl*-*isothujone* in that its absorption band is displaced to shorter wave-lengths (λ_{\max} , 2310 Å.), *i.e.*, even further away from the value (2540 ± 50 Å.) to be expected of the trisubstituted $\alpha\beta$ -unsaturated ketone represented by the five-membered ring formula (III).

TABLE I.

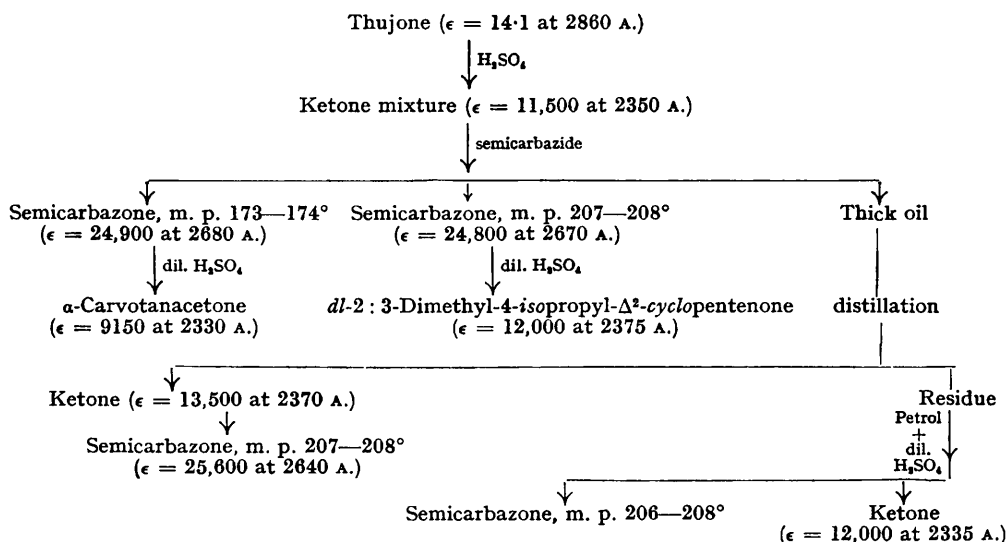


TABLE II.

Absorption-spectra data for solutions in alcohol.

| | K-Band. | | R-Band. | |
|--|--------------------|---------------------|--------------------|---------------------|
| | λ_{\max} . | ϵ_{\max} . | λ_{\max} . | ϵ_{\max} . |
| Carvone ¹ | 2353 | 19,050 | 3175 | 42 |
| <i>d</i> -Carvotanacetone (IV) | 2330 | 9,150 | not measured | |
| <i>iso</i> Thujone (III) | 2375 | 12,000 | (3100) | 80 |
| <i>l</i> -2 : 3-Dimethyl-4-isopropyl- Δ^2 -cyclopentenone | 2310 | 6,180 | 3100 | 35 |
| 1-Methylcyclohexen-3-one ² | 2350 | 12,930 | 3120 | 46 |
| Thujone (II) | — | — | 2860 | 14.1 |
| <i>iso</i> Thujone semicarbazone | 2670 | 24,800 | — | — |
| Carvotanacetone semicarbazone | 2680 | 24,900 | — | — |

¹ Data by Cooke and Macbeth (J., 1938, 1408).

² Evans and Gillam (following paper).

EXPERIMENTAL.

(Analyses by Drs. Weiler and Strauss, Oxford.)

Preparation of Thujone.—After a number of experiments the thujone was satisfactorily extracted from tansy oil as follows. The oil (150 g.), showing 72% w/w of a ketone $\text{C}_{10}\text{H}_{16}\text{O}$ by the hydroxylamine hydrochloride method, was added to a saturated sodium bisulphite-sulphite solution (150 ml.) and 50 ml. of industrial alcohol, and this mixture shaken during 9 hours. The bisulphite cake was sucked dry, and washed twice with a mixture of alcohol (2 parts) and ether (3 parts). This cake (148 g.) was added to a 20% solution of sodium hydroxide (1 l.) and ether (100 ml.), and the mixture stirred mechanically for 20 mins. The ethereal solution was separated, the alkaline solution again extracted with ether, and the bulked extracts dried with sodium sulphate. After removal of solvent, the thujone (54 g.) distilled at 76—80°/3 mm., and had n_D^{18} 1.4550, d_4^{18} 0.9186, $\alpha_D + 70.8^\circ$. The ketone showed maximum absorption at 2860 Å. ($\epsilon = 14.1$) typical of a saturated ketone. There was therefore no evidence for the formation of carvotanacetone during its isolation.

Action of Sulphuric Acid on Thujone.—In a typical experiment sulphuric acid (60 g.) was cooled to 0°, and thujone (20 g.) added slowly with stirring below 5° (cf. Haller, *Compt. rend.*, 1905, 140, 1630). The mixture was at once poured into ice water (1 l.), and the oil extracted with ether. The ethereal solution was washed with water until neutral, dried with sodium sulphate, the solvent removed, and the oil distilled. The main fraction (15 g.) had b. p. 87–90°/3 mm., 228–230°/751 mm., n_D^{20} 1.4807, d_4^{15} 0.9263, $\alpha_D + 17.6^\circ$. The absorption spectrum consisted of a band of high intensity at 2375 Å. ($\epsilon = 12,000$) and a subsidiary inflexion near 3100 Å. ($\epsilon = 80$), the two together being characteristic of $\alpha\beta$ -unsaturated ketones.

Examination of the Mixed Semicarbazone.—Semicarbazide hydrochloride (16.5 g.) and crystalline sodium acetate (22.5 g.) were dissolved in water (22 ml.), and 37 ml. of alcohol added. The warm solution was added to the ketone mixture, prepared from *d*-thujone as described above (22.5 g.), dissolved in 75% alcohol (75 ml.). After standing overnight at room temperature, the solution was cooled until no further solid material separated. These crystals (8 g.) had m. p. 186–191°, raised by two recrystallisations from methyl alcohol to 207–208° (decomp.) (Found : N, 19.8. Calc. for $C_{11}H_{19}ON_3$: N, 20.1%). The *dl*-2 : 3-dimethyl-4-isopropyl- Δ^2 -cyclopentenone regenerated from this semicarbazone by steam-distillation in the presence of dilute sulphuric acid had b. p. 87–88°/3 mm., n_D^{20} 1.4839, d_4^{15} 0.9285, $\alpha_D \pm 0^\circ$ (*c*, 6.5 in alcohol) (Found : C, 78.2; H, 10.6. Calc. for $C_{10}H_{16}O$: C, 78.9; H, 10.5%). The semicarbazone showed maximum absorption at 2670 Å. ($\epsilon = 24,800$) and the regenerated ketone showed $\epsilon = 12,000$ at 2375 Å. (see figure). The oxime had m. p. 119° (Wallach, *Ber.*, 1895, 28, 1958).

After removal of the crude semicarbazone, the filtrate was poured into water and extracted with ether. The oil thus recovered was diluted with light petroleum (300 ml.), and the solution cooled for some days until no further crystals separated. These crystals (3.2 g.) had m. p. 164–166°, raised by repeated crystallisation from methyl alcohol to 173–174° (decomp.) (Simonsen and Rau, *J.*, 1922, 121, 876) (Found : N, 19.6. Calc. for $C_{11}H_{19}ON_3$: N, 20.1%). The *d*-carvotanacetone regenerated from this semicarbazone had b. p. 86–87°/3 mm., n_D^{20} 1.4797, d_4^{15} 0.943, $\alpha_D + 36^\circ$ (*c*, 2.45 in alcohol) (Found : C, 78.8; H, 10.6. Calc. for $C_{10}H_{16}O$: C, 78.9; H, 10.5%). The semicarbazone showed maximum absorption at 2680 Å. ($\epsilon = 24,900$) and the regenerated ketone at 2330 Å. ($\epsilon = 9000$).

Removal of the light petroleum from the filtrate produced a viscous yellow oil which gave by vacuum distillation 10 g. of oil (b. p. 85–97°/3 mm.). This was shaken with 10% sulphuric acid and redistilled to give an oil having b. p. 86–88°/2 mm., n_D^{20} 1.4840, d_4^{15} 0.920, $\alpha_D + 8.6^\circ$ (Found : C, 79.4; H, 10.8. Calc. for $C_{10}H_{16}O$: C, 78.9; H, 10.5%). The semicarbazone had m. p. 207–208°, and the oxime m. p. 119–120° (Found : N, 8.2. Calc. for $C_{10}H_{17}ON$: N, 8.4%). The ketone displayed maximum absorption at 2370 Å. ($\epsilon = 13,500$) and an inflexion ($\epsilon = 383$) at 3020 Å., probably largely due to an impurity. The semicarbazone had ϵ_{max} 25,600 at 2640 Å.

The residue left after distillation of the above fraction was dissolved in benzene–light petroleum, and after long standing at 0° the crystals (0.6 g.) had m. p. 168–172°, raised to 206–208° by repeated recrystallisation from methyl alcohol, not depressed by admixture with *dl*-2 : 3-dimethyl-4-isopropyl- Δ^2 -cyclopentenone semicarbazone.

After removal of solvent from the filtrate, 10% sulphuric acid (60 ml.) was added to the residue, the mixture steam-distilled, and the oil from the distillate worked up. The product (4 g.) had b. p. 87–90°/3 mm., n_D^{20} 1.4802, d_4^{15} 0.925, $\alpha_D + 7^\circ$ (Found : C, 78.7; H, 10.6. Calc. for $C_{10}H_{16}O$: C, 78.9; H, 10.5%). It showed maximum absorption at 2335 Å. ($\epsilon = 12,000$) and an inflection near 3080 Å. ($\epsilon = 86$). It was not possible to obtain a crystalline oxime, and the semicarbazone, in spite of repeated crystallisation, was obviously a mixture, since the crystals sintered at 130°, began to darken at 145°, and finally melted at 160–161°.

1-2 : 3-Dimethyl-4-isopropyl- Δ^2 -cyclopentenone (cf. Read and Short, *J.*, 1939, *loc. cit.*).—Prof. Read's specimen of this compound had b. p. 89°/13 mm., α_D^{18} -12.72° . The solution in alcohol showed λ_{max} 2310 ($\epsilon = 6180$) and 3100 Å. ($\epsilon = 35$).

Determinations of absorption spectra were made on a Hilger E₃ quartz spectrograph in conjunction with a Spekker photometer, standard methods being used.

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THE UNIVERSITY, MANCHESTER.

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