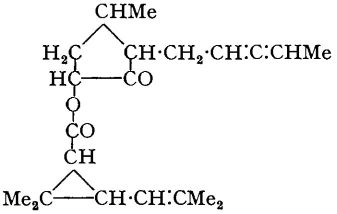
139. *Absorption Spectra and the Structures of Pyrethrins I and II.*

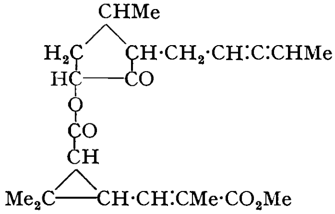
By A. E. Gillam and T. F. West.

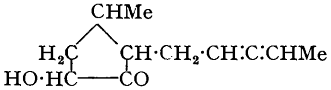
Absorption-spectra data on pyrethrins I and II and related compounds are recorded and discussed in relation to the molecular structures of the compounds. Utilising stepwise hydrogenation with absorption-spectra control, we have obtained results which lead to the following conclusions: (*a*) In the pyrethrolone fragment of the pyrethrin molecules two *separate* chromophoric systems are present each containing more than one double linkage; it follows, therefore, that the trienone chromophoric system which has been postulated (V) cannot be present. (*b*) An αβ-unsaturated ketone grouping is present in a five-atom ring. (*c*) The unsaturation in the side chain is present as a conjugated diene, the presence of a cumulated diene system being precluded by the absorption-spectra evidence.

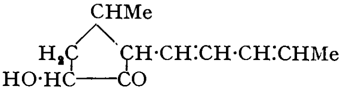
These conclusions necessitate reconsideration of the structure of the pyrethrolone fragment and either a change in the location of the unsaturation in the side chain or a revision of the position of the unsaturated ketone chromophore in the five-atom ring. The effects of these conclusions on the structures of these compounds have been tentatively discussed.

The structural formulæ (I) and (II) assigned to pyrethrin I and pyrethrin II by Staudinger and Ruzicka (*Helv. Chim. Acta*, 1924, **7**, 177) involved for pyrethrolone a *cyclo*pentanolone structure (III) having as one substituent the allene group $\cdot CH_2 \cdot CH{:}C{:}CHMe$ not previously suspected in naturally occurring compounds. The chemical evidence advanced for the allene side chain depended mainly on the production of acetaldehyde on ozonolysis, formaldehyde being produced only in negligible quantity, whereas oxidation of the ozonolysis products with hydrogen peroxide gave malonic acid among other products. With potassium permanganate, acetic acid was produced.


(I.)

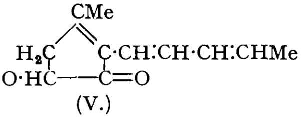

(II.)

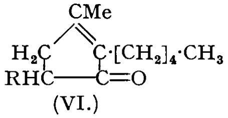

(III.)

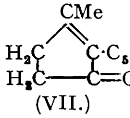

(IV.)

Subsequently, Ruzicka and Pfeiffer (*ibid.*, 1933, **16**, 1208) reconsidered the data and proposed the more frequently encountered conjugated system for the side chain (IV), with the observation " dass über der Lage der Doppelbindungen beim Pyrethrolone noch eine gewisse Unklarheit herrscht."

On the basis of analyses of pyrethrolone, tetrahydropyrethrolone, and their derivatives, LaForge and Haller (*J. Amer. Chem. Soc.*, 1936, **58**, 1061, 1777) replaced the *cyclo*pentanolone by a *cyclo*pentenolone nucleus so that, Ruzicka and Pfeiffer's conjugated side chain being adopted, a trienone system was involved for pyrethrolone (V) and tetrahydropyrethrolone was formulated as (VI, R = OH).


(V.)


(VI.)


(VII.)

Proof of the formula of the latter was confirmed by its conversion into tetrahydropyrethrone (LaForge and Haller, *J. Amer. Chem. Soc.*, 1936, **58**, 1777), which was shown to be identical with dihydrojasmone (VI, R = H) of established constitution (Ruzicka and Pfeiffer, *loc. cit.*; Treff and Werner, *Ber.*, 1933, **66**, 1521). It was pointed out by LaForge and Haller (*loc. cit.*) that the formation of malonic acid as a degradation product of the side chain, which was considered to prove the presence of the grouping $^-CH{\cdot}CH_2{\cdot}CH^-$ in the pyrethrolone side chain (III), may possibly have arisen through oxidation of the nucleus (V).

In further work, however, LaForge and Haller (*J. Org. Chem.*, 1938, **2**, 546) were unable to obtain proof of the presence of either the cumulated or the conjugated system, but regarded the only uncertainty in the formula of pyrethrone to be in the position of one of the two ethylene linkages—since the formation of acetaldehyde on ozonolysis appeared to fix one linkage. In fact, therefore, LaForge and Haller considered that the only difficulty involved was the decision between position 2, 3 (III) or 1, 2 (IV) for the second double bond, with the reservation, however, that " The possibility of the presence of a second ring system that is easily cleaved by hydrogenation, with the formation of a saturated five-membered straight chain, cannot be excluded from consideration."

Subsequent work by Acree and LaForge (*J. Org. Chem.*, 1939, **4**, 569; 1940, **5**, 48, 430), involving the synthesis of allenes for a study of their behaviour towards certain reagents in comparison with that displayed by pyrethrolone and its deoxy-derivative, pyrethrone (VII), provided some indirect evidence for the presence of the cumulated double bonds in the side chain but the issue remained in doubt.

Applying the principles of LaForge and Haller (*J. Amer. Chem. Soc.*, 1935, **57**, 1893), we have readily prepared concentrates containing 80% of pyrethrin II similar to those obtained by those authors, but by introducing suitable modifications we prepared concentrates of pyrethrin I containing 70% of the active principle whereas they reported their concentrates to contain not more than 55% of this compound (*J. Org. Chem.*, 1937, **2**, 49).

It was found that, whereas pyrethrin II can be regenerated from its semicarbazone to provide the pure ester, yet some decomposition occurred during regeneration from pyrethrin I semicarbazone although the absorption data for the original pyrethrin I and II concentrates before conversion into the semicarbazones and after regeneration indicated that the chromophoric system was unaltered.

TABLE I.

Absorption Spectra of Pyrethrins I and II and related compounds.

(*Alcoholic solutions.*)

	Purified samples.		Preliminary samples.		
	$\lambda_{max.}$.	ε.	$\lambda_{max.}$.	ε.	M.W. used.
Pyrethrin I	2270	29,000	2280	24,000	328
Pyrethrin II	2310	35,400	2310	33,000	372
Tetrahydropyrethrin II	2365	24,600	—	—	376
Pyrethrolone (from pyrethrin I)	2280 3085	27,000 96	— —	— —	178 —
Pyrethrolone (from pyrethrin II)	2280	25,800 *	2280	23,700 *	178
Pyrethrolone (from mixed pyrethrins)	2270 (3080) †	26,700 96	2285 (3000)	19,500 178	178 —
Tetrahydropyrethrolone (from pyrethrin I)	2320 3120	11,600 64	— —	— —	182 —
Tetrahydropyrethrolone (from pyrethrin II)	2320	12,800 *	—	—	182
Dihydrojasmone	2370 3040	12,200 55	— —	— —	— —
Pyrethrin I semicarbazone	2290 2670	21,400 21,100	2300 2665	20,000 20,500	385 —
Pyrethrin II semicarbazone	2360 (2660)	31,200 24,000	2355 2640	33,400 26,200	397 —
Pyrethrolone semicarbazone (from pyrethrin I)	2320 2655	20,100 19,500	2290 2655	21,760 19,800	235 —
			Purified samples.		
Pyrethrolone semicarbazone (from pyrethrin II)	—	—	2310 2650	22,300 20,200	235 —
Tetrahydropyrethrolone semicarbazone (from pyrethrin I)	—	—	2650	22,500	239
Tetrahydropyrethrolone semicarbazone (from pyrethrin II)	—	—	2650	21,770	239
Dihydrojasmone semicarbazone	—	—	2665	20,400	—
Tetrahydropyrethrin II semicarbazone	—	—	2620 (2385)	26,200 20,600	401 —

* Ketone band not examined.

† Inflexions on the absorption curves are indicated by parentheses round the values of $\lambda_{max.}$.

The main object of the present paper is to record absorption-spectra data on pyrethrins I and II and their derivatives * and to consider their bearing upon the molecular structures of these compounds.† The numerical data are collected in Table I, a few items only being presented as absorption curves (Figs. 1 and 2).

It is notable that pyrethrin I, pyrethrin II, and the pyrethrolone obtained from either have very similar absorption spectra. Hence, it can be inferred that all three compounds contain similar chromophoric systems,

---

* After nearly completing this work we discovered that Dr. LaForge and his collaborators at the United States Bureau of Insecticides contemplated using absorption-spectra methods in work on the pyrethrins. We communicated with Dr. LaForge and offered to withhold our results for the present, but he informed us that he was not extending the absorption-spectra side of his work and very kindly invited us to publish our results when ready.

† The highly intense absorption bands of the pyrethrins and the five-atom-ring ketone, pyrethrolone, should offer the basis of a useful additional method of determination and control for biological purposes, and this aspect of the work will be dealt with elsewhere.

and that, in transforming the pyrethrins into pyrethrolone, no major change of structure involving the chromophoric groups can have occurred.

The Swiss and the American workers having approximately determined the structures of these compounds by chemical work, we now attempt to draw inferences from absorption-spectra data as to the distribution of the unsaturated linkages in the several molecules, since the exact location of some of these linkages remains in doubt.

Let us consider the postulated structures from the point of view of the presence of light-absorbing groups. The first of the chromophores is attached to the three-atom ring in each of the pyrethrins. In pyrethrin I it is a single ethylene linkage (I), which should give rise to an absorption band situated below 2000 A. and can therefore be neglected in work with a quartz spectrograph which is limited to the range *ca.* 2150—7700 A. The corresponding chromophore in pyrethrin II [$\cdot CH{:}CMe{\cdot}CO_2Me$; cf. (II)], although a conjugated one, would be expected to give rise to a band situated on the extreme edge of the quartz ultra-violet region by analogy with crotonic acid which, with a similar chromophoric group, exhibits $\lambda_{max.}$ at 2080 A. ($\varepsilon = 12{,}200$). This grouping also can therefore be ignored in the present work.

This leaves us with three main possibilities for the other chromophoric groups : (*a*) a cumulated system of two ethylene linkages, $\cdot CH{:}C{:}CHMe$, with an isolated $C{:}C{\cdot}C{:}O$ chromophore in addition; (*b*) a $C{:}C{\cdot}C{:}C$ system in crossed conjugation with a $C{:}C{\cdot}C{:}O$ group; and (*c*) a $C{:}C{\cdot}C{:}C$ system unconjugated with a $\cdot C{:}C{\cdot}C{:}O$ group (this suggestion has not been advanced previously but must be considered).

In considering the absorption spectra of a compound containing several chromophoric groups it is helpful if the chromophores can be eliminated one by one, and the absorption spectra of the simpler absorbing entities examined separately. With the pyrethrins, the first stage in this process is to convert them into pyrethrolone, thus eliminating the chain containing the $C{:}C$ link (pyrethrin I) or the $C{:}C{\cdot}CO_2Me$ group (pyrethrin II). The fact that the absorption spectra of the two pyrethrins are closely similar to that of the pyrethrolone derived from them (Table I) further justifies the above assumption that the two chromophoric groups just mentioned can be ignored.

The next stage in the process is to remove some of the unsaturation and examine the absorption spectra due to the thus simplified chromophoric groups. It happens that when pyrethrolone is hydrogenated with a platinum catalyst a good yield of the tetrahydro-derivative is obtained, two ethylene linkages being saturated. The absorption spectrum of the product (cf. Table I and Fig. 1, where only the *K*-band is shown) is typical of that of an αβ-unsaturated ketone and consistent with formula (VI, R = OH). The intense band is situated at shorter wave-lengths than is to be expected for a trisubstituted αβ-unsaturated ketone (Woodward, *J. Amer. Chem. Soc.*, 1941, **63**, 1123) but it has been shown (Gillam and West, this vol., p. 487) that the five-atom ring environment displaces the maximum of the *K*-band to shorter wave-lengths and to approximately the same extent in other five-atom ring compounds (dihydrojasmone and *iso*thujone).

We now have the observed facts that when two ethylene linkages in pyrethrolone are removed by hydrogenation the resulting tetrahydro-compound exhibits an absorption spectrum typical of that of an αβ-unsaturated ketone in a five-atom ring environment, and further, that the absorption maximum of the tetrahydro-compound is located at a wave-length not far removed from that of the original pyrethrolone. Although we have not yet found a model substance having the crossed conjugated system as postulated in (V), its absorption spectrum might be expected to be closer to that of a conjugated triene than a conjugated diene, in which case it should absorb at distinctly longer wave-lengths than the observed 2300 A. (seven trienes which have been examined, including hexatriene, calciferol, and tachysterol, absorb maximally between 2550 and 2800 A.; cf. Koch, *Chem. and Ind.*, 1942, **61**, 273).

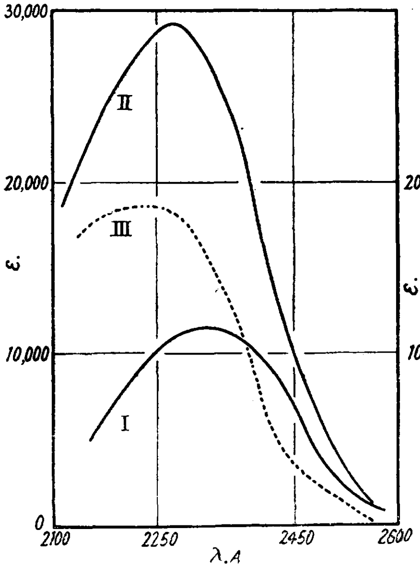
It can thus be inferred that the chromophoric group containing the two ethylene linkages in the side chain of pyrethrolone is not conjugated with the $C{:}C{\cdot}C{:}O$ group, and that the absorption spectrum of pyrethrolone is in fact a summation of the absorption due to $C{:}C{\cdot}C{:}O$ and that due to the two ethylene linkages (whether cumulated or conjugated). This inference is strongly supported by the observation that in the semicarbazone of pyrethrolone part of the absorption is displaced to 2650 A., which is usual with the semicarbazones of $C{:}C{\cdot}C{:}O$ compounds in general. In pyrethrins I and II also there is residual absorption near 2300 A. which is not affected by semicarbazone formation, and this should therefore be due to the isolated non-ketonic chromophore (cf. Fig. 2).

Having thus isolated the $C{:}C{\cdot}C{:}O$ chromophore by hydrogenation of pyrethrolone, we now have to isolate and examine the absorption due to the two ethylene linkages in the side chain, and we do this indirectly as follows. Accepting as proven that the two chromophores are in fact isolated and that their absorption will therefore be a summation, we have a record of the absorption due to the two chromophores together and to the $C{:}C{\cdot}C{:}O$ separately. Then the absorption due to the two ethylene linkages should be given by the arithmetical difference between these two curves, since unconjugated chromophores produce additive effects only. The observed curves and the subtraction curve for the pair of compounds pyrethrolone and tetrahydropyrethrolone are shown in Fig. 1.

The point now at issue is whether these double bonds are cumulated or conjugated. Now we know that acyclic dienes, either open-chain or with one cyclic substituent, absorb between 2170 and 2365 A. (Booker, Evans, and Gillam, J., 1940, 1453) with ε ranging from 5,000 to 25,000. The subtraction curve shows $\lambda_{max.}$ near 2275 A., with $\varepsilon = 18{,}600$, data which are thus absolutely typical of a conjugated diene. On the other hand, cumulated dienes are only weakly absorbing substances; *e.g.*, ethylallene exhibits an inflection only near 2270 A., with ε = only 900 approx. (Carr and Stücklen, quoted by Burr and Miller, *Chem. Rev.*, **1941**, **29**, 419), whilst keten and diethylketen containing the analogous cumulated C:C:O system have values of ε at 2270 A. of order only 28 and 280 respectively (I.C.T., Vol. V).

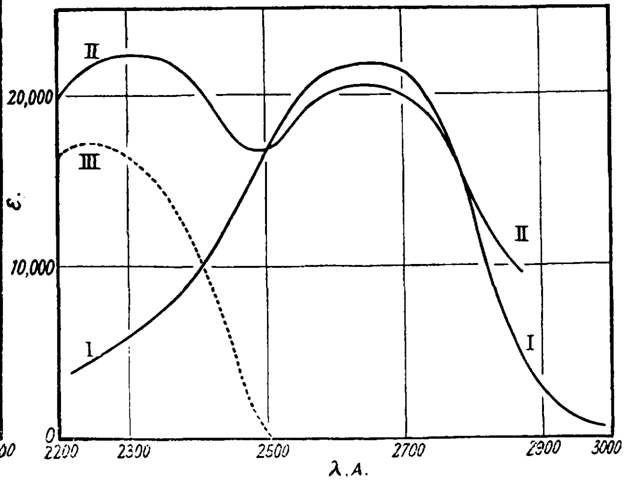
The absorption due to the diene can be obtained independently from other data presented here by a subtraction method using the observed absorption of the semicarbazones of pyrethrolone and tetrahydropyrethrolone. This is shown in Fig. 2. The subtraction curve of the ketones gives $\lambda_{\text{max.}}$ 2275 A. ($\varepsilon = 18{,}600$) for the absorption of the diene component, whilst the corresponding value from the semicarbazones is $\lambda_{\text{max.}}$ 2245 A. ($\varepsilon = 17{,}200$). The two independent results are in good agreement with each other, and after comparison of the light-absorption of *cumulated* dienes with that of *conjugated* dienes there can be no doubt that the two ethylene linkages in the C_5 side chain of pyrethrolone and its semicarbazone are conjugated and not cumulated. This is also consistent with experience that cumulated systems of ethylene linkings have not so far been observed in natural products. The possible criticism that there may have been a change from a cumulated to a conjugated system in passing from pyrethrin to pyrethrolone is not valid, since (as already pointed out) the absorptions of both the pyrethrins and pyrethrolone are so alike as to preclude changes of structure involving the chromophoric groups.

FIG. 1.



I. *Tetrahydropyrethrolone.*
II. *Pyrethrolone.*
III. *Subtraction curve* (II—I) *equals the absorption of the diene component in pyrethrolone.*

FIG. 2.



I. *Tetrahydropyrethrolone semicarbazone.*
II. *Pyrethrolone semicarbazone.*
III. *Subtraction curve* (II—I) *equals absorption of diene component in pyrethrolone.*

Absorption spectra in alcohol.

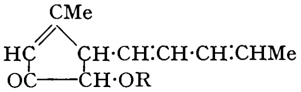
Since the absorption data so clearly indicate the presence of two separate conjugates in pyrethrolone, the possibility of a second ring cleaved by hydrogenation as postulated by LaForge (*loc. cit.*) appears to be ruled out of consideration.

We have just seen that two independent but indirect determinations of the light absorption due to the diene chromophore in pyrethrolone give values of $\lambda_{\text{max.}}$ of 2245 and 2275 A. respectively. This gives an average value of 2260 ± 15 A. (average $\varepsilon = 17{,}900$). If we apply Woodward's empirical method of predicting the absorption spectrum of a conjugated diene (*loc. cit.*), we can calculate that for an unsymmetrical disubstituted diene of the type CHR:CH·CH:CHMe the absorption band should lie at 2270 A., which compares well with the 2260 ± 15A. observed. It should be noted, however, that the estimated value for $CH_2R{\cdot}CH{:}CH{\cdot}CH{:}CH_2$ comes to 2220 A., which is not very significantly different.

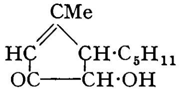
The general conclusions reached above are supported by an examination of the Ponndorf–Meerwein *reduction product* of pyrethrolone methyl ether, which shows maximum absorption situated at nearly the same wavelength as that of the methyl ether itself but at a reduced intensity. This observation precludes the presence of a conjugated triene system in the reduced product, and therefore presumably in the original pyrethrolone.

If the jasmone ring structure is accepted, then the only possible formulæ for the pyrethrins must contain the $\cdot CH_2{\cdot}CH{:}CH{\cdot}CH{:}CH_2$ side chain; but this involves the assumption that during ozonolysis the terminal double linkage migrates, leaving the grouping :CHMe which is necessary to explain the production of acetaldehyde. On the other hand, if the terminal group :CHMe be accepted, revision of the *cyclo*pentenolone ring becomes necessary, and this in turn involves the assumption that during the production of dihydrojasmone (VI, R = H) by hydrogenation an isomerisation occurs. This is only possible if a tentative structure (VIII), which is in accordance with the absorption data, be assigned to the pyrethrolone fragment of the pyrethrin molecules.

(VIII.)



(IX.)



A similar change must then be assumed to take place during the preparation of dihydrojasmone from tetrahydropyrethrolone *via* the chloro-compound which LaForge and Haller (*J. Amer. Chem. Soc.*, 1936, **58**, 1777) formulated as (VI; R = Cl). In this connection it may be significant that tetrahydropyrethrolone shows maximum absorption at 2320 A., whereas dihydrojasmone and *iso*thujone absorb at 2370 A. and 2375 A. respectively. Hence, tetrahydropyrethrolone would be more suitably formulated as the disubstituted αβ-unsaturated ketone (IX), which should absorb at a shorter wave-length than the corresponding trisubstituted systems of dihydrojasmone and *iso*thujone (cf. Woodward, *loc. cit.*; Gillam and West, this vol., p. 487). Although no chemical evidence appears to exist in support of this change, the fact that both pyrethrolone and tetrahydropyrethrolone are readily obtained in enolic forms (cf. Haller and LaForge, *J. Org. Chem.*, 1938, **3**, 543) clearly indicates the labile nature of the ring system. Furthermore, we have definite absorption-spectra evidence that tetrahydro*iso*pyrethrolone enol is tautomeric, since at a concentration (alcohol) of 0·0055% the absorption maximum is situated at 2540 A., whereas in 0·025% solution the maximum is displaced to 2460 A. We hope to investigate the absorption spectra of these enolic compounds more fully later

EXPERIMENTAL.

Carbon and hydrogen determinations are by Drs. Weiler and Strauss, Oxford. Absorption data are only given here if they do not appear in the main table.

Purification of Pyrethrum Extract.—An extract (1360 g.) (containing pyrethrin I, 14·6%; pyrethrin II, 18·4% by the Wilcoxon–Holaday method), obtained by extracting Kenya pyrethrum flowers with light petroleum, was dissolved in acetone (cf. B.P. 493,074), the insoluble portion rejected, and the extract then purified according to LaForge and Haller (*J. Amer. Chem. Soc.*, 1935, **57**, 1893). In this manner two concentrates were obtained containing (*a*) pyrethrin II 79·6, pyrethrin I 17·1%, and (*b*) pyrethrin I 57·7, pyrethrin II 5·0%. The latter (120 g.) was dissolved in methyl alcohol (1275 ml.), and water (225 ml.) added in small quantities with efficient shaking. After standing overnight at 0°, the insoluble material was filtered off, the methyl alcohol removed from the filtrate by distillation under reduced pressure, and the oil which separated extracted with light petroleum; this solution was dried over sodium sulphate, and the solvent removed to give a product (65 g.) containing pyrethrin I 69·4, pyrethrin II 8·1% (Wilcoxon–Holaday). Further details of the method of purification and separation will be recorded elsewhere with notes on the Wilcoxon–Holaday and Seil methods of analysis as compared with the biological activity of various extracts.

Pyrethrin I and Derivatives.—The pyrethrin I concentrate (60 g.), dissolved in alcohol (220 ml.) and pyridine (135 ml.), and a solution of semicarbazide hydrochloride (36 g.) in hot water (45 ml.) were mixed and treated as described by Haller and LaForge (*J. Org. Chem.*, 1936, **1**, 47). The first crop of crystals, after being washed successively with 60% aqueous alcohol, dilute acid, water, and 85% alcohol and dried in a vacuum desiccator over calcium chloride, had m. p. 109° (sinter 96°) (54 g.). A second crop (7 g.), m. p. 107° (sinter 91°), was obtained by adding to the filtrate the alcoholic washings from the first crop and water (75 ml.). The first crop was recrystallised twice from alcohol, and crystals (31 g.) having m. p. 113° (sinter 104°), and a portion of this was used for the preparation of pyrethrolone. This product (7 g.) was again recrystallised twice from alcohol, and the pyrethrin I semicarbazone (3·9 g.) had m. p. 113° (sinter 108°) (Found: C, 67·5; H, 8·2. Calc. for $C_{22}H_{31}O_3N_3$: C, 68·6; H, 8·05%).

The semicarbazone (3 g.) was heated with oxalic acid (6 g.) in water (40 ml.) on the water-bath for 5 hours, agitation being achieved by a stream of carbon dioxide. The regenerated pyrethrin I (1·26 g.) obtained by extraction with light petroleum (Staudinger and Ruzicka, *Helv. Chim. Acta*, 1924, **7**, 177; Haller and LaForge, *J. Org. Chem.*, 1936, **1**, 48) had $n_D^{18°}$ 1·5192, $[\alpha]_D$ − 32·3° (*c*, 5·66 in ether) (Found: C, 76·4; H, 8·9. Calc. for $C_{21}H_{28}O_3$: C, 76·8; H, 8·5%). It contained some pyrethrin II, and some decomposition appeared to have occurred during regeneration because it had a pyrethrin I content of only 65·4% and contained 6·3% of pyrethrin II (Wilcoxon–Holaday; the corresponding Seil figures were 70·5 and 8·0%).

The above semicarbazone, m. p. 113° (sinter 104°) (24 g.), was treated with 600 ml. of methyl alcohol and 45 ml. of 0·5N-sodium methoxide (Haller and LaForge, *J. Org. Chem.*, 1936, **1**, 50). After standing at room temperature for eight days and at 0° for 1 day crystals (8·2 g.) separated, and by concentration under reduced pressure and addition of water a second crop (4·1 g.) was obtained. The two crops were bulked, and recrystallised twice from methyl alcohol, 1 g. of insoluble material being rejected. The pyrethrolone semicarbazone (8 g.) had m. p. 210—211° (decomp.) (rapid heating) (Found: C, 61·0; H, 6·9. Calc. for $C_{12}H_{17}O_2N_3$: C, 61·3; H, 7·2%).

The pyrethrolone (1·05 g.) regenerated from this semicarbazone (3 g.) in the presence of cold potassium hydrogen sulphate solution and ether in an atmosphere of carbon dioxide (Haller and LaForge, *J. Amer. Chem. Soc.*, 1937, **59**, 1678) had b. p. 144°/1 mm., $n_D^{18°}$ 1·5390, $d_{19°}^{19°}$ 1·05, $[\alpha]_D$ + 14·1° (*c*, 6·23 in ether) (Found: C, 73·7; H, 8·3. Calc. for $C_{11}H_{14}O_2$: C, 74·15; H, 7·9%).

Pyrethrin II and Derivatives.—The pyrethrin II concentrate (35 g.) was dissolved in alcohol (117 ml.) and pyridine (51 ml.) and treated with a solution of semicarbazide hydrochloride (14·5 g.) in water (17·5 ml.); on standing at room temperature for 2 days the solution deposited a considerable bulk of crystals. Water (10 ml.) was now added with stirring, and the solution cooled to 0° for 36 hours. The crystals were washed successively with 60% alcohol, dilute acid, water, and 85% alcohol before being dried in a vacuum desiccator; the product (27·8 g.) had m. p. 162—163°. By adding the aqueous-alcoholic washings and water (47 ml.) to the filtrate and cooling to 0° overnight, a second crop (4·4 g.) was obtained, m. p. 150° (sinter 125°). The first crop was recrystallised twice from ether as described by Haller and LaForge (*J. Org. Chem.*, 1936, **1**, 44) and had m. p. 165° (Found: C, 64·6; H, 7·2. Calc. for $C_{23}H_{31}O_5N_3$: C, 64·3; H, 7·2%).

The pyrethrin II was regenerated by heating the semicarbazone (3 g.) with a solution of oxalic acid (6·2 g.) in water (42 ml.) at 100° for 5½ hours, agitation being ensured by a stream of carbon dioxide. The oil (1·15 g.) recovered by extraction with light petroleum had $n_D^{21·5°}$ 1·5290 (Found: C, 71·2; H, 7·55; OMe, 8·4. Calc. for $C_{22}H_{28}O_5$: C, 71·0; H, 7·5; OMe, 8·3%). This showed a pyrethrin II content of 99·0% by the Wilcoxon–Holaday, and 100·4% by the Seil method.

Pyrethrin II semicarbazone (15 g.), dissolved in methyl alcohol (60 ml.), was mixed with 0·5N-sodium methoxide (72 ml.) and water (3·6 ml.) (Haller and LaForge, *J. Org. Chem.*, 1936, **1**, 48). After standing at 0° for 6 days, a crop of crystals (6·9 g.) was obtained, and by treating the filtrate as described by Haller and LaForge, a further 1·15 g. The first crop was recrystallised twice from methyl alcohol (0·85 g. of insoluble material rejected), and the product (4·4 g.) had m. p. 212—213° (decomp.) (rapid heating) (Found : C, 61·5; H, 7·0%).

The pyrethrolone (0·8 g.) regenerated from this semicarbazone (3 g.) in the presence of a cold potassium hydrogen sulphate solution and ether had b. p. 156—158°/2 mm., $n_D^{19\cdot5^\circ}$ 1·5422, $d_{16^\circ}^{16^\circ}$ 1·06, $[\alpha]_D + 14\cdot2^\circ$ (*c*, 3·87 in ether) (Found : C, 73·0; H, 8·15%).

Before purifying the larger quantity of extract referred to above, preliminary experiments were carried out with 450 g. of a similar pyrethrum extract (containing pyrethrin I, 14·4; pyrethrin II, 13·2%) and the derivatives and relevant details of preparation are recorded below, absorption data being in the foregoing table.

Preliminary Preparation of Pyrethrins and Derivatives.—A purified pyrethrin concentrate (pyrethrin I, 33·8; pyrethrin II, 47·2%) (50 g.) was dissolved in alcohol (200 ml.) and treated with a solution of semicarbazide hydrochloride (23 g.) and crystalline sodium acetate (37 g.) in water (36 ml.) (see Staudinger and Ruzicka, *Helv. Chim. Acta*, 1924, **7**, 177). After standing for 2 days, the first crop (13·8 g.) when washed with 80% alcohol had m. p. 110° (sinter 96°). After recrystallising once from acetone and three times from alcohol the product had m. p. 116—118° (Found : N, 10·35. Calc. for $C_{22}H_{31}O_3N_3$: N, 10·9%). The pyrethrin I regenerated in the presence of oxalic acid solution had $n_D^{19\cdot5^\circ}$ 1·5232 and contained pyrethrin I, 57·5; pyrethrin II, 15·8% (Wilcoxon–Holaday method). The second crop (5 g.), which separated on standing, had m. p. 104° (sinter 92°). This was converted into pyrethrolone semicarbazone by treatment with methyl alcohol (20 ml.), 0·5N-sodium methoxide (24 ml.), and water (1·2 ml.). The recrystallised pyrethrolone semicarbazone (1·5 g.) obtained had m. p. 208° (Found : N, 17·6. Calc. for $C_{12}H_{17}O_2N_3$: N, 17·9%). The regenerated pyrethrolone had $n_D^{20^\circ}$ 1·5350. After removal of the second crop, the solution was concentrated under reduced pressure and extracted with ether to give a syrupy liquid (40 g.). This semicarbazone mixture was converted into pyrethrolone semicarbazone as described by Staudinger and Ruzicka (*loc. cit.*), and this after recrystallisation from acetone had m. p. 208° (decomp.). The constants and absorption of the regenerated ketone indicated that it was the purest sample obtained in our experiments [the difficulty of obtaining satisfactory analytical data for pyrethrolone and its tetrahydro-derivative has been stressed by LaForge and Haller (*J. Amer. Chem. Soc.*, 1936, **58**, 1777)]. It had b. p. 150°/1·5 mm., $n_D^{21^\circ}$ 1·5410, $d_{20^\circ}^{20^\circ}$ 1·042, $[\alpha]_D + 19\cdot9^\circ$ (*c*, 3·912 in ether) (Found : C, 74·2; H, 8·0%).

A pyrethrin II concentrate (pyrethrin II, 81·6%; pyrethrin I, 5·9%) (2·7 g.) was converted as described by LaForge and Haller (*J. Org. Chem.*, 1936, **1**, 44) into pyrethrin II semicarbazone, m. p. 164—165° (Found : N, 9·7. Calc. for $C_{23}H_{31}O_5N_3$: N, 9·8%). The regenerated pyrethrin II showed $\lambda_{max.}$ 2310 A. ($\varepsilon = 33,000$).

Tetrahydropyrethrin II.—Pyrethrin II semicarbazone, m. p. 164—165° (4·93 g.), was hydrogenated in ethyl acetate with platinum oxide as catalyst (Haller and LaForge, *J. Org. Chem.*, 1936, **1**, 46). The solvent was removed by distillation, the residue dissolved in ether, and the ethereal solution washed successively with potassium carbonate solution (1%) and water and dried over sodium sulphate. After removal of ether, the oily residue (4·46 g.) quickly set to a solid, m. p. 130° (sinter 125°), and was recrystallised readily from *cyclo*hexane, but in order to remove the solvent from the crystals it was necessary to reflux them with light petroleum. The product thus obtained (3·3 g.) had m. p. 134° (sinter 124°) raised by recrystallisation from alcohol to 139—141° (Found : C, 63·3; H, 7·7. Calc. for $C_{23}H_{35}O_5N_3$: C, 63·7; H, 8·1%).

This semicarbazone (1·5 g.) was heated for 5 hours at 100° with oxalic acid (3 g.) in water (20 ml.), and the oil extracted with light petroleum. This solution was washed until neutral, dried, and kept at 0° for some hours to remove a small amount of unchanged semicarbazone. The oil obtained (375 mg.) by removing the solvent had $n_D^{23\cdot5^\circ}$ 1·5115 (Found : C, 71·0; H, 8·7. Calc. for $C_{22}H_{32}O_5$: C, 70·2; H, 8·5%).

Reduction of Pyrethrolone Methyl Ether.—This ether (Staudinger and Ruzicka, *Helv. Chim. Acta*, 1924, **7**, 212) had b. p. 110—113°/2 mm., $n_D^{21^\circ}$ 1·5142, $\lambda_{max.}$ 2260 A. ($\varepsilon = 28,800$) (Found : C, 75·6; H, 8·9. Calc. for $C_{12}H_{16}O_2$: C, 75·0; H, 8·3%). A sample (5·2 g.) was reduced with aluminium *iso*propoxide (1·95 g.) in dry *iso*propyl alcohol (17 ml.), the constant-volume distillation being continued until the distillate no longer gave a test for acetone with 2 : 4-dinitrophenylhydrazine (6½ hours). The solution was subjected to steam distillation and a light petroleum extract of the distillate, washed and dried, yielded on distillation three fractions which appeared to be mixtures of the reduced product and unchanged pyrethrolone methyl ether :

Fraction.	B. p./1 mm.	Wt., g.	$n_D^{22^\circ}$.	$\lambda_{max.}$.	$\varepsilon_{max.}$.	C, %.	H, %.
1	96—98°	0·78	1·5051	2260	17,500	73·6	8·9
2	100—103	1·12	1·5081	2270	20,000	73·3	9·0
3	103—108	1·67	1·5118	2270	23,800	73·9	8·9
Residue	—	0·25	—	—	—	—	—
Calc. for $C_{12}H_{18}O_2$		—	—	—	—	74·2	9·3

Determinations of absorption spectra were made in alcoholic solution on a Hilger E_3 quartz spectrograph in conjunction with a Spekker photometer, standard methods being used.

We thank Mr. R. P. Merritt for his interest in this investigation of the pyrethrins, and one of us (T. F. W.) is indebted to the Directors of Messrs. Stafford Allen and Sons, Ltd., for facilities and to Mr. J. B. S. Wilson for assistance in the tedious purification of the pyrethrum extracts.

THE UNIVERSITY, MANCHESTER.
STAFFORD ALLEN AND SONS, LTD., LONDON, N.1.

[*Received, August 27th,* 1942.]