213. *Experiments on the Synthesis of the Pyrethrins. Part XII.** cyclo*Hexenone Analogues of Cinerone and Pyrethrone.*

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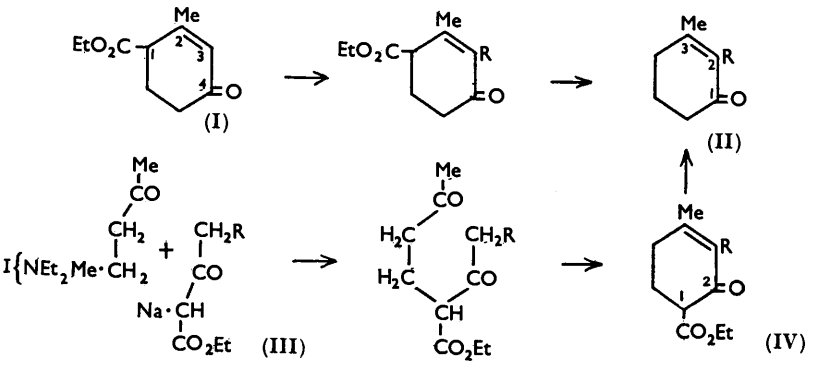
*cyclo*Hexenone analogues of cinerone and pyrethrone are prepared by alkylation of Hagemann's ester, ethyl 2-methyl-4-oxo*cyclo*hex-2-enecarboxylate. 2-Alkyl-4-bromo-3-methyl*cyclo*hex-2-enones could not be obtained by the action of *N*-bromosuccinimide, as aromatisation supervened. However, similar substitution of *iso*phorone (3 : 5 : 5-trimethyl*cyclo*hex-2-enone) gives the crystalline 4-bromo-ketone, converted into the 4-acetoxy- and 4-chrysanthemoyloxy-derivatives without rearrangement; however, alkaline hydrolysis is accompanied by rearrangement to 3 : 4 : 5-trimethylphenol. The chrysanthemic esters synthesised are not insecticidal.

This paper describes the preparation of a series of *cyclo*hexenone analogues of cinerone and pyrethrone and attempts to prepare similar analogues of pyrethrin-I, to discover the effect on insecticidal activity of replacing the *cyclo*pentenone by a *cyclo*hexenone ring.

Although individual members were prepared by lengthy ring closure procedures in the *cyclo*pentenone series,[1] the wider range of *cyclo*hexenone derivatives available suggested the use of a common cyclic intermediate. A suitable compound appeared to be Hagemann's ester (I), for earlier work indicated that alkylation of the sodio-derivative occurs in the 3-position. Subsequent hydrolysis and decarboxylation would give the 2-alkyl-3-methyl*cyclo*hex-2-enone (II; R = alkyl). However, the evidence that alkylation in ethanolic sodium ethoxide occurs in the 3-position is slender. Dieckmann [2] and



Kötz *et al.*[3] respectively oxidised the *iso*propyl and the methyl derivative (II) and obtained semicarbazones considered to be that of 5-oxohexanoic acid. Other evidence is that of Hogg [4] who alkylated Hagemann's ester with 3-methoxyphenethyl bromide, but in liquid ammonia with subsequent refluxing in toluene, and then by cyclisation and dehydrogenation, obtained 7-methoxy-1-methylphenanthrene.

As a preliminary to our use of Hagemann's ester we sought more direct proof that alkylation of the ester (I) in ethanolic sodium ethoxide occurs in the 3-position. Use of *cis*-crotyl chloride followed by hydrolysis and decarboxylation gave a ketone identical with that prepared by the Robinson–Mannich condensation [5] of 4-diethylaminobutan-2-one

* Part XI, *J.*, 1956, 3963.

[1] Crombie, Edgar, Harper, Lowe, and Thompson, *J.*, 1950, 3552.
[2] Dieckmann, *Ber.*, 1912, **45**, 2697.
[3] Kötz, Blendermann, Mähnert, and Rosenbusch, *Annalen*, 1913, **400**, 72.
[4] Hogg, *J. Amer. Chem. Soc.*, 1948, **70**, 161.
[5] du Feu, McQuillin, and Robinson, *J.*, 1937, 53.

methiodide with ethyl sodio-3-oxo-oct-6-enoate [6] (III; R = CH_2·CH:CHMe-*cis*), followed by cyclisation and decarboxylation. Substitution of the ester (I) had, therefore, occurred in the 3-position and the ketone had structure (II; R = CH_2·CH:CHMe-*cis*), being the analogue of *cis*-cinerone. Further, the structure and geometrical configuration of the allylic halide is retained in this alkylation, consistently with an S_N2 mechanism. Similarly, alkylation of Hagemann's ester with *trans*-crotyl chloride gave the isomeric *trans*-ketone. Alkylation in liquid ammoniacal sodamide occurs in the same position as in ethanolic sodium ethoxide, for the ketones obtained from Hagemann's ester and pentyl bromide in these two media were identical.

2-Allyl-3-methyl*cyclo*hex-2-enone, prepared by alkylation of Hagemann's ester with allyl chloride, was partially hydrogenated over palladised barium sulphate, giving 3-methyl-2-propyl*cyclo*hex-2-enone, which was also obtained from Hagemann's ester and propyl bromide. Alkylation of Hagemann's ester with pent-*trans*-2-enyl bromide gave 3-methyl-2-pent-*trans*-2′-enyl*cyclo*hex-2-enone, the analogue of *trans*-jasmone,[7] which however possessed a mimosa odour.

Synthesis of the *cyclo*hexenone analogues of *cis*- and *trans*-pyrethrone was effected with the same side-chain intermediates as had been employed for *cis*- and *trans*-pyrethrolone.[8,9] Alkylation of Hagemann's ester with pent-4-en-2-ynyl chloride gave 3-methyl-2-(pent-4-en-2-ynyl)*cyclo*hex-2-enone, which was hydrogenated over Lindlar's palladised calcium carbonate: the low intensity of ultraviolet absorption of the resulting diene-ketone ($\varepsilon_{max.}$ 17,200) indicates that, although the product was mainly 3-methyl-2-(penta-*cis*-2 : 4-dienyl)*cyclo*hex-2-enone, reduction was not fully selective as had been observed also with *cis*-pyrethrolone.[10] The ketone showed, *inter alia*, infrared bands at 10·05, 11·1, and 12·75(w) μ, characteristic of the alka-*cis*-2 : 4-dienyl group, previously observed in *cis*-pyrethrolone,[10] which precludes the *trans*-configuration for our ketone.

Alkylation of Hagemann's ester with pent-*trans*-2-en-4-ynyl chloride gave 3-methyl-2-(pent-*trans*-2-en-4-ynyl)*cyclo*hex-2-enone, but hydrogenation of this over palladised calcium carbonate (not Lindlar's catalyst) gave a diene-ketone whose ultraviolet absorption ($\varepsilon_{max.}$ 15,850) showed it to have low conjugated-diene content. A similar heterogeneous product was obtained by alkylation of Hagemann's ester with the chloride of penta-*trans*-2 : 4-dienol (prepared from pent-*trans*-2-en-4-ynol by hydrogenation). This lack of selectivity in the hydrogenation of the penta-*trans*-2-en-4-ynyl system was also observed in our earlier work on *trans*-pyrethrolone.[9] The use, however, of penta-*trans*-2 : 4-dienol, prepared by reduction of penta-*trans*-2 : 4-dienal with lithium aluminium hydride,[9] gave 3-methyl-2-(penta-*trans*-2 : 4-dienyl)*cyclo*hex-2-enone, whose ultraviolet light absorption (Figure) and that of its semicarbazone (Figure) showed it to be pure *trans*-diene-ketone. Consistently with this, the ketone formed an adduct with maleic anhydride which, however, tended to dissociate on recrystallisation.

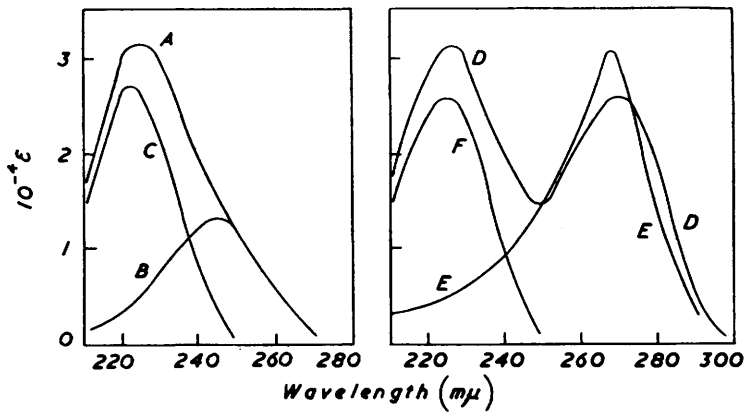
The 3-methyl*cyclo*hex-2-enones with a non-chromophoric 2-substituent absorb maximally, with one exception, within the wavelength limits (247 ± 5 mμ) predicted by Woodward [11] for trisubstituted αβ-unsaturated ketones (Table). However, the ketones containing a conjugated diene or enyne chromophore in the side chain absorb maximally at shorter wavelengths (225—234 mμ). In the case of 3-methyl-2-(penta-*trans*-2 : 4-dienyl)*cyclo*hex-2-enone this is due to superposition of the more strongly absorbing diene chromophore ($\lambda_{max.}$ *ca.* 223 mμ) on that of the enone chromophore ($\lambda_{max.}$ 245 mμ), as is shown in the Figure. Support for this is provided by the semicarbazone, for the absorption maxima of the C=C–C=C (*ca.* 225 mμ) and C=C–C=N (*ca.* 266 mμ) chromophores are sufficiently displaced for the absorption curve to be resolved into distinct maxima.

[6] Crombie, Harper, Stedman, and Thompson, *J.*, 1951, 2445.
[7] Crombie and Harper, *J.*, 1952, 869.
[8] Crombie, Harper, Newman, Thompson, and Smith, *J.*, 1956, 126.
[9] Crombie, Harper, and Thompson, *J.*, 1951, 2906.
[10] Crombie, Harper, and Newman, *J.*, 1956, 3963.
[11] Woodward, *J. Amer. Chem. Soc.*, 1941, **63**, 1123; 1942, **64**, 72, 76.

Crombie, Elliott, and Harper [12] used *N*-bromosuccinimide to convert 2-alkyl-3-methyl*cyclo*pent-2-enones into the 4-bromo-ketones and thence by replacement into alkylrethrolones and their chrysanthemic esters. A similar series of reactions with 2-alkyl-3-methyl*cyclo*hex-2-enones could not be realised. In initial small-scale experiments 3-methyl- and 3-methyl-2-pentyl-*cyclo*hex-2-enone reacted smoothly with *N*-bromosuccinimide in the presence of benzoyl peroxide, but in all subsequent experiments either with or without benzoyl peroxide a brown colour developed which was followed by a rapid evolution of hydrogen bromide and a phenolic smell. Such a course of events would follow from elimination of hydrogen bromide from the 4-bromo-ketone, the resultant *cyclo*hexadienone passing into a phenol by enolisation.

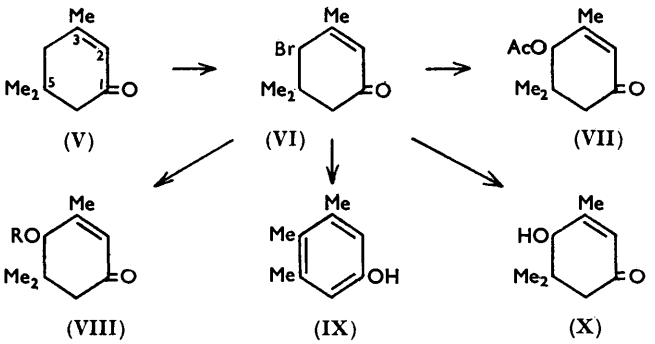
Attention was turned to the 5 : 5-disubstituted *cyclo*hex-2-enone, *iso*phorone (V), whose 4-bromo-derivative (VI) cannot lose hydrogen bromide directly. Reaction with *N*-bromosuccinimide yielded smoothly a stable crystalline monobromo-ketone, presumed

Light absorption of 3-*methyl*-2-(*penta*-trans-2 : 4-*dienyl*)cyclo*hex*-2-*enone*.



A, 3-*Methyl*-2-(*penta*-trans-2 : 4-*dienyl*)cyclo*hex*-2-*enone*. *B*, 3-*Methyl*-2-*pentyl*cyclo*hex*-2-*enone*. *C*, *Subtraction curve* (*A* — *B*) *equals the absorption of the diene chromophore in* 3-*methyl*-2-(*penta*-trans-2 : 4-*dienyl*)cyclo*hex*-2-*enone*. *D*, 3-*Methyl*-2-(*penta*-trans-2 : 4-*dienyl*)cyclo*hex*-2-*enone semicarbazone*. *E*, 3-*Methyl*-2-*pentyl*cyclo*hex*-2-*enone semicarbazone*. *F*, *Subtraction curve* (*D* — *E*) *equals the absorption of the diene chromophore in* 3-*methyl*-2-(*penta*-trans-2 : 4-*dienyl*)cyclo*hex*-2-*enone*.

to be 4-bromo*iso*phorone (VI) rather than the 6-bromo- or 3-bromomethyl isomer by analogy with the similar bromination of 2-alkyl-3-methyl*cyclo*pent-2-enones [12] and evidence below. An unstable liquid bromo-ketone was also formed but was not examined.



Replacement of bromine by acetoxyl was accomplished by use of silver acetate, without rearrangement, for the product (VII) formed a 2 : 4-dinitrophenylhydrazone and showed the light absorption of an αβ-unsaturated ketone. Similarly, treatment with silver

[12] Crombie, Elliott, and Harper, *J.*, 1950, 971.

chrysanthemate gave the *iso*phorone ester (VIII; R = chrysanthemoyl). Alkaline hydrolysis, however, of 4-acetoxy*iso*phorone (VII) was accompanied by rearrangement, for the product was 3 : 4 : 5-trimethylphenol (IX), formed presumably by alkyl–oxygen fission of the ester, followed by Wagner–Meerwein rearrangement of the carbonium ion and aromatisation by enolisation. The formation of 3 : 4 : 5-trimethylphenol as the sole phenolic product confirms the conclusion that the crystalline monobromo-ketone is the 4-isomer. Hydrolysis of 4-bromo*iso*phorone with aqueous sodium carbonate gave a mixture of the phenol (IX) and a neutral product, assumed to be 4-hydroxy*iso*phorone (X), since its ultraviolet-light absorption (max. at 225 mμ; ε 9050) is that of an αβ-unsaturated ketone.

Treibs and Bast [13] showed that *cyclo*hexenes are acetoxylated at the α-methylene group when heated with mercuric acetate, with concomitant separation of metallic mercury. Attempts to acetoxylate *cyclo*hex-2-enones in the 4-position failed, although nearly quantitative separation of mercury occurred. 3-Methyl*cyclo*hex-2-enone and *iso*phorone gave traces of phenols, presumably *m*-cresol and 3 : 4 : 5-trimethylphenol respectively.

An attempt to prepare a 6-chloro- and a 6-hydroxy-ketone by a procedure similar to that used by LaForge and Soloway [14] for 2-butyl-5-hydroxy-3-methyl*cyclo*pent-2-enone was unsuccessful. 2-Allyl-3-methyl*cyclo*hex-2-enone (II; R = CH_2·CH:CH_2) gave the ester (IV; R = CH_2·CH:CH_2) in good yield on use of ethyl carbonate and sodium hydride, and the derived sodio-derivative was converted by toluene-*p*-sulphonyl chloride into the 1-chloro-ester, but acid hydrolysis failed to give the desired α-chloro-ketone.

The (±)-*trans*-chrysanthemic esters of 4-hydroxy*iso*phorone and 3 : 4 : 5-trimethylphenol were non-toxic to houseflies and mustard beetles.

Experimental

Hagemann's ester was prepared by Smith and Rouault's procedure [15] in 40% yield, but cooling the reactants to −5° (cf. Horning *et al.*[16]) increased the yield to 45%. Like Smith and Rouault, we could not reach the 71% yield reported by Bergmann and Weizmann.[17] The ester had b. p. 96—98°/0·3 mm., n_D^{20} 1·4850—1·4854.

Ethyl 3-*Alkyl*-2-*methyl*-4-*oxo*cyclo*hex*-2-*enecarboxylates*.—A typical preparation was as follows: Hagemann's ester (182 g., 1 mol.) was added during 30 min. to a stirred solution of sodium (23 g.) in absolute ethanol (800 ml.) cooled to room temperature. After a further 45 min. (to complete formation of the sodio-derivative) allyl chloride (76·5 g., 1 mol.) was added during 1 hr., and the mixture was stirred during another 2 hr. and refluxed for 3 hr. Most of the ethanol was removed in a vacuum, water added, and the oil extracted with ether. The dried extract ($MgSO_4$) was evaporated and distilled, to give *ethyl* 3-*allyl*-2-*methyl*-4-*oxo*cyclo*hex*-2-*enecarboxylate* (170 g., 80%), b. p. 108—109°/0·1 mm., 120—122°/0·6 mm., n_D^{20} 1·4950—1·4958, max. at 241 mμ (ε 11,000) (Found: C, 69·9; 70·1; H, 8·0, 8·4. $C_{13}H_{18}O_3$ requires C, 70·2; H, 8·15%). The 2 : 4-*dinitrophenylhydrazone* separated as deep red plates (from ethanol), m. p. 106° (Found: C, 57·2; H, 5·3. $C_{19}H_{22}O_6N_4$ requires C, 56·7; H, 5·5%).

The majority of the 3-alkyl-esters prepared were used for the next stage without isolation, but the following were characterised:

Ethyl 3-*butyl*-2-*methyl*-4-*oxo*cyclo*hex*-2-*enecarboxylate* (from butyl bromide) (66%), b. p. 110—117°/0·1 mm., n_D^{20} 1·486 (Found: C, 70·3; H, 9·8. $C_{14}H_{22}O_3$ requires C, 70·6; H, 9·9%). The *semicarbazone* formed needles, m. p. 121°, from ethanol (Found: C, 60·7; H, 8·4. $C_{15}H_{25}O_3N_3$ requires C, 61·0; H, 8·5%).

Ethyl 3-*but*-cis-2′-*enyl*-2-*methyl*-4-*oxo*cyclo*hexenecarboxylate* (from *cis*-crotyl chloride [6]) (70%), b. p. 120—122°/0·5 mm., n_D^{20} 1·4982, max. at 241 mμ (ε 10,350) (Found: C, 71·9; H, 8·8. $C_{14}H_{20}O_3$ requires C, 71·1; H, 8·5%), and the trans-*analogue* (from *trans*-crotyl bromide [1])

[13] Treibs and Bast, *Annalen*, 1949, **561**, 165.
[14] LaForge and Soloway, *J. Amer. Chem. Soc.*, 1947, **69**, 2932.
[15] Smith and Rouault, *J. Amer. Chem. Soc.*, 1943, **65**, 631.
[16] Horning, Denekas, and Field, *J. Org. Chem.*, 1944, **9**, 547.
[17] Bergmann and Weizmann, *J. Org. Chem.*, 1939, **4**, 267.

(89%), b. p. 116—117°/0·1 mm., n_D^{20} 1·4982 (Found: C, 70·9; H, 8·8%) [2 : 4-*dinitrophenylhydrazone*, orange-red needles (from ethanol), m. p. 119—120° (Found: C, 58·5; H, 5·9. $C_{20}H_{24}O_6N_4$ requires C, 57·7; H, 5·8%)].

Ethyl 3-but-2′-ynyl-2-methyl-4-oxo*cyclo*hex-2-enecarboxylate (from but-2-ynyl chloride [6]), b. p. 118—121°/0·1 mm., n_D^{20} 1·507 [prepared with Mr. R. E. STEDMAN].

*Ethyl 2-methyl-4-oxo-2-pentyl*cyclo*hex-2-enecarboxylate* (from pentyl bromide) (62%), b. p. 120—123°/0·05 mm., n_D^{20} 1·4842 (Found: C, 70·8; H, 9·4. $C_{15}H_{24}O_3$ requires C, 71·4; H, 9·6%) [2 : 4-*dinitrophenylhydrazone*, orange needles (from ethanol), m. p. 72° (Found: C, 58·4; H, 6·5; N, 13·3. $C_{21}H_{28}O_6N_4$ requires C, 58·3; H, 6·5; N, 13·0%)]. [When prepared in liquid ammonia by Hogg's procedure [4] the keto-ester (31%) had b. p. 120—130°/0·3 mm., n_D^{20} 1·4835, and the 2 : 4-dinitrophenylhydrazone, m. p. and mixed m. p. 72° (Found: C, 58·7; H, 6·6; N, 12·7%).]

Ethyl 2-methyl-4-oxo-2-(pent-trans-2-*en*-4-*ynyl*)cyclo*hex-2-enecarboxylate* (from pent-*trans*-2-en-4-ynyl chloride,[9] b. p. 80—83°/190 mm., n_D^{25} 1·489) (55%), b. p. 125—127°/10^{-3} mm., n_D^{20} 1·5239 (Found: C, 71·1; H, 7·4. $C_{15}H_{18}O_3$ requires C, 73·1; H, 7·4%) [*semicarbazone*, prisms (from ethanol or 2-methoxyethanol), m. p. 141—142° (Found: C, 63·1; H, 7·1. $C_{16}H_{21}O_3N_3$ requires C, 63·3; H, 7·0%)].

2-*Alkyl*-3-*methyl*cyclo*hex-2-enones*.—A typical preparation was as follows: Ethyl 3-allyl-2-methyl-4-oxo*cyclo*hex-2-enecarboxylate (111 g.) was heated under reflux with 15% ethanolic potassium hydroxide (250 ml.) during 8 hr. Next day most of the solvent was distilled off and the residue diluted with ice-water (200 ml.). After acidification with dilute hydrochloric acid the mixture was heated to 50° during 1 hr. (to bring about decarboxylation), then cooled, and the product was isolated with ether. Distillation gave 2-*allyl*-3-*methyl*cyclo*hex-2-enone* (48 g., 64%), having a floral odour, b. p. 65—66°/0·05 mm., n_D^{20} 1·5050, for light absorption see the Table (Found: C, 79·4, 79·6; H, 9·55, 9·5. $C_{10}H_{14}O$ requires C, 79·9; H, 9·4%). The *semicarbazone* separated as needles (from ethanol), m. p. 172—173°, for light absorption see the Table (Found: C, 63·9; H, 8·2. $C_{11}H_{17}ON_3$ requires C, 63·7; H, 8·3%). There was a 12% recovery of unhydrolysed keto-ester, b. p. 112—116°/0·2 mm., n_D^{20} 1·498.

*Ultraviolet light absorption of 2-alkyl-3-methyl*cyclo*hex-2-enones in ethanol.*

	Ketones		Semicarbazones	
Alkyl	$\lambda_{max.}$ (mμ)	ε	$\lambda_{max.}$ (mμ)	ε
2-Propyl	242	12,900	—	—
2-Allyl	242	12,450	269 *	19,000
2-Butyl	245 *	13,750	—	—
2-But-*cis*-2′-enyl	242	13,250	—	—
2-But-*trans*-2′-enyl	242 *	9,700	269 *	18,900
2-But-2′-ynyl	239	11,050	—	—
2-Pentyl	245 *	13,350	267 *	31,250
2-Penta-*cis*-2′ : 4′-dienyl	231	17,200	232, 268	25,350, 27,500
2-Penta-*trans*-2′ : 4′-dienyl	225 *	31,200	226,* 271 *	31,250, 26,000
2-Pent-4′-en-2′-ynyl	226, 234	17,900, 18,600	236, 268	18,300, 23,250

* Absorptions thus marked were determined with a Hilger Uvispek Photoelectric Spectrophotometer H700, and the remainder with a Unicam Photoelectric Spectrophotometer SP.500.

The following ketones were prepared similarly (for light absorptions see the Table):

3-*Methyl*-2-*propyl*cyclo*hex-2-enone* (from propyl bromide) (40% overall), b. p. 100—101°/10 mm., n_D^{20} 1·4871 (Found: C, 77·9; H, 10·25. $C_{10}H_{16}O$ requires C, 78·9; H, 10·6%) [*semicarbazone*, plates (from aqueous ethanol), m. p. 179—180·5° (Found: C, 62·7; H, 9·05. $C_{11}H_{19}ON_3$ requires C, 63·1; H, 9·15%)].

2-Allyl-3-methyl*cyclo*hex-2-enone (5 g.) was reduced in methanol over palladised barium sulphate to an uptake of 1 mol. hydrogen. Filtration and distillation gave 3-methyl-2-propyl-*cyclo*hex-2-enone (4·1 g., 81%), b. p. 108—110°/18 mm., n_D^{20} 1·4860 (semicarbazone, m. p. and mixed m. p. 179—180°).

2-*Butyl*-3-*methyl*cyclo*hex-2-enone* (57%), regenerated from the semicarbazone with aqueous oxalic acid,[18] had a bitter-sweet odour, b. p. 63°/0·1 mm., n_D^{20} 1·4875 (Found: C, 79·2; H, 11·0. $C_{11}H_{18}O$ requires C, 79·5; H, 10·9%). The *semicarbazone* separated as plates, m. p. 154·5—155·5°, from aqueous ethanol or ethyl acetate (Found: C, 64·7; H, 9·9. $C_{12}H_{21}ON_3$ requires

[18] Harper, *J.*, 1946, 892.

C, 64·5; H, 9·5%), and the 2 : 4-*dinitrophenylhydrazone* as red needles, m. p. 144°, from ethanol (Found: C, 58·2; H, 6·1. $C_{17}H_{22}O_4N_4$ requires C, 58·9; H, 6·4%).

2-*But*-cis-2′-*enyl*-3-*methyl*cyclo*hex*-2-*enone* (60%), b. p. 78—79°/0·2 mm., n_D^{20} 1·5070 (Found: C, 79·9; H, 9·85. $C_{11}H_{16}O$ requires C, 80·4; H, 9·85%). The *semicarbazone* crystallised from ethanol, m. p. 175—176° (Found: C, 65·3; H, 8·55. $C_{12}H_{19}ON_3$ requires C, 65·2; H, 8·65%), and the 2 : 4-*dinitrophenylhydrazone* as red laths, m. p. 147—149° (Found: C, 59·3; H, 5·8. $C_{17}H_{20}O_4N_4$ requires C, 59·3; H, 5·85%).

Ethyl 3-oxo-oct-6-enoate [6] (4·6 g.) was added to a cold, stirred solution of sodium (0·6 g.) in ethanol (15 ml.). After 30 min. the mixture was cooled to 0° and 4-diethylaminobutan-2-one methiodide [5] (7·0 g.) added in ethanol (15 ml.) during 30 min., then the whole was kept for 1 hr. at room temperature and refluxed for 3 hr. Next day the solvent was distilled off, the product isolated with ether and heated under reflux with 10% ethanolic potassium hydroxide (20 ml.) during 7 hr., and the solution then evaporated. The residue was acidified with dilute hydrochloric acid and heated at 50° for 1 hr. The decarboxylated product was isolated with ether and distilled, to give 2-but-*cis*-2′-enyl-3-methyl*cyclo*hex-2-enone (1·5 g., 37%), b. p. 79—80°/0·3 mm., n_D^{20} 1·5030, max. at 240 mμ (ε 11,300). The semicarbazone had m. p. and mixed m. p. 171—175° and the 2 : 4-dinitrophenylhydrazone m. p. and mixed m. p. 147—149°.

2-*But*-trans-2′-*enyl*-3-*methyl*cyclo*hex*-2-*enone* (45%) had a spicy odour, b. p. 72—75°/0·3 mm., n_D^{20} 1·5063 (Found: C, 80·0; H, 9·8. $C_{11}H_{16}O$ requires C, 80·5; H, 9·8%). The *semicarbazone* separated as needles (from ethyl acetate), m. p. 173—175° after softening at 168° (Found: C, 64·8; H, 8·7. $C_{12}H_{19}ON_3$ requires C, 65·1; H, 8·65%).

2-*But*-2′-*ynyl*-3-*methyl*cyclo*hex*-2-*enone* (from but-2-ynyl chloride [6]) (30% overall), b. p. 98—100°/0·3 mm., n_D^{20} 1·5186 (Found: C, 79·8; H, 8·7. $C_{11}H_{14}O$ requires C, 81·4; H, 8·7%) [*semicarbazone* (from ethanol), m. p. 222—223° (Found: C, 65·4; H, 7·45. $C_{12}H_{17}ON_3$ requires C, 65·7; H, 7·8%)].

3-*Methyl*-2-*pentyl*cyclo*hex*-2-*enone* (54% from undistilled keto-ester), regenerated from the semicarbazone,[18] had b. p. 125°/11 mm., n_D^{20} 1·4857 (Found: C, 79·5; H, 11·4. $C_{12}H_{20}O$ requires C, 80·0; H, 11·4%). The *semicarbazone* formed plates, m. p. 149—150·5°, from aqueous ethanol (Found: C, 65·8; H, 9·7. $C_{13}H_{23}ON_3$ requires C, 65·8; H, 9·8%), and the 2 : 4-*dinitrophenylhydrazone* red plates, m. p. 109°, from ethanol (Found: C, 59·8; H, 6·7; N, 14·9. $C_{18}H_{24}O_4N_4$ requires C, 60·0; H, 6·7; N, 15·5%).

3-*Methyl*-2-*pent*-trans-2′-*enyl*cyclo*hex*-2-*enone* (from pent-*trans*-2-enyl bromide [7]) (54% overall), b. p. 90—91°/0·1 mm., n_D^{20} 1·5020 (Found: C, 80·4; H, 10·3. $C_{12}H_{18}O$ requires C, 80·8; H, 10·2%). The *semicarbazone* separated as needles (from aqueous ethanol), m. p. 159·5—161·5° (Found: C, 66·45; H, 8·8. $C_{13}H_{21}ON_3$ requires C, 66·3; H, 9·0%), and the 2 : 4-*dinitrophenylhydrazone* as red needles (from ethanol), m. p. 118° (Found: C, 60·8; H, 6·1. $C_{18}H_{22}O_4N_4$ requires C, 60·3; H, 6·2%).

3-*Methyl*-2-(*penta*-trans-2 : 4-*dienyl*)cyclo*hex*-2-*enone* (from penta-*trans*-2 : 4-dienyl chloride,[9] b. p. 74—76°/175 mm., n_D^{20} 1·4920) (44% overall), b. p. 95—97°/0·25 mm., n_D^{20} 1·5372 (Found: C, 81·3; H, 9·5. $C_{12}H_{16}O$ requires C, 81·8; H, 9·2%). The *semicarbazone* formed yellow prisms, m. p. 143·5—145·5°, from aqueous ethanol (Found: C, 66·6; H, 8·3. $C_{13}H_{19}ON_3$ requires C, 66·9; H, 8·3%). The maleic anhydride adduct separated from benzene, during 10 days at room temperature, as needles, m. p. 130—165°. Crystallisation from ethyl acetate raised the m. p. to 168—178° but did not sharpen it.

3-*Methyl*-2-(*pent*-trans-2-*en*-4-*ynyl*)cyclo*hex*-2-*enone* (40% from undistilled keto-ester), b. p. 85—86°/0·05 mm., 108—112°/0·2 mm., n_D^{20} 1·5408 (Found: C, 81·5; H, 8·1. $C_{12}H_{14}O$ requires C, 82·7; H, 8·1%). The *semicarbazone* separated as yellow prisms, m. p. 164—167° (decomp.), from aqueous ethanol (Found: C, 66·9; H, 7·3. $C_{13}H_{17}ON_3$ requires C, 67·5; H, 7·4%), and the 2 : 4-*dinitrophenylhydrazone* as red needles (from ethanol), m. p. 145·5—146·5° (Found: C, 60·6; H, 4·9. $C_{18}H_{18}O_4N_4$ requires C, 61·0; H, 5·1%).

3-*Methyl*-2-(*pent*-4-*en*-2-*ynyl*)cyclo*hex*-2-*enone* (from pent-4-en-2-ynyl chloride [8]) (15% overall), b. p. 100—101°/0·2 mm., n_D^{20} 1·5354 (Found: C, 80·5; H, 8·35. $C_{12}H_{14}O$ requires C, 82·7; H, 8·1%) [*semicarbazone* (from ethanol), m. p. 203·5—204·5° (Found: C, 67·4; H, 7·35. $C_{13}H_{17}ON_3$ requires C, 67·5; H, 7·4%)].

The above ketones, particularly the acetylenic ketones, generally gave low analyses for carbon. The analogous *cyclo*pentenones behaved similarly.[18]

Selective Hydrogenation of 3-*Methyl*-2-(*pent*-4-*en*-2-*ynyl*)cyclo*hex*-2-*enone*.—This ketone (550

mg.) was shaken in ethyl acetate (15 ml.) with lead-poisoned palladised calcium carbonate [19] (100 mg.) and quinoline (250 mg.) under hydrogen to an uptake of 0·96 mol. Filtration and fractional distillation gave impure 3-*methyl*-2-(*penta*-cis-2 : 4-*dienyl*)cyclo*hex*-2-*enone* (250 mg., 46%), b. p. 95—96°/0·1 mm., n_D^{20} 1·5196 (Found : C, 79·7; H, 9·1. $C_{12}H_{16}O$ requires C, 81·8; H, 9·15%), for light absorption see the Table. Prepared in pyridine–ethanol, the semicarbazone separated as an oil, but on cold storage in ethanol a few crystals separated and on recrystallisation had m. p. 168—170°, after softening at 155°, for light absorption see the Table. The 2 : 4-*dinitrophenylhydrazone*, after passage through activated alumina in benzene and crystallisation from aqueous ethanol, had m. p. 118—120° [Found (on 1·3 mg.) : C, 58·4; H, 5·9. $C_{18}H_{20}O_4N_4$ requires C, 60·6; H, 5·7%].

Selective Hydrogenation of 3-*Methyl*-2-(*pent*-trans-2-*en*-4-*ynyl*)cyclo*hex*-2-*enone*.—This ketone (1·84 g.) was shaken in ethyl acetate with palladised calcium carbonate (not Lindlar) (50 mg.) under hydrogen to an uptake of 1·0 mol. Filtration and fractional distillation at 0·05 mm., gave fractions (i) b. p. 64—67° (0·52 g.), n_D^{20} 1·514, (ii) b. p. 73—74° (0·65 g.), n_D^{20} 1·528, and (iii) b. p. 74—77° (0·35 g.), n_D^{20} 1·535. Fraction (ii) was converted into the semicarbazone and recrystallised from aqueous ethanol, forming yellow prisms, m. p. 143·5—145°, max. at 232, 271 mμ (ε 19,300, 24,000) (Found : C, 66·35; H, 8·3. Calc. for $C_{13}H_{19}ON_3$: C, 66·9; H, 8·3%). Regeneration of the ketone from the semicarbazone (250 mg.) with oxalic acid [18] and fractional distillation gave impure 3-methyl-2-(penta-*trans*-2 : 4-dienyl)*cyclo*hex-2-enone (50 mg.), b. p. 77°/0·05 mm., n_D^{20} 1·520, max. at 232 mμ (ε 15,850) (Found : C, 79·5; H, 10·0. Calc. for $C_{12}H_{16}O$: C, 81·8; H, 9·2%). The 2 : 4-*dinitrophenylhydrazone* separated as red needles (from ethanol), m. p. 126° after softening at 117° (Found : C, 59·8; H, 5·7. $C_{18}H_{20}O_4N_4$ requires C, 60·7; H, 5·6%).

Selective Hydrogenation of Pent-trans-2-*en*-4-*ynol*.—This alcohol [20] (9·4 g.) was shaken in ethyl acetate with palladised calcium carbonate (0·5 g.) under hydrogen to an uptake of 0·95 mol. After filtration and evaporation the product was fractionally distilled. Fractions (5·1 g.) having b. p. 52—55°/12 mm., n_D^{20} 1·475—1·486, were converted into penta-*trans*-2 : 4-dienyl chloride [9] (3·0 g.), b. p. 70—72°/170 mm., n_D^{20} 1·488, and thence (cf. p. 1086) into impure 3-methyl-2-(penta-*trans*-2 : 4-dienyl)*cyclo*hex-2-enone (2·34 g.), b. p. 98—103°/0·2 mm., n_D^{20} 1·536. The semicarbazone separated as yellow prisms (from 2-ethoxyethanol), whose m. p. 136—146° did not sharpen on recrystallisation, max. at 231, 270 mμ (ε 25,700, 20,400) (Found : C, 66·9; H, 8·3. Calc. for $C_{13}H_{19}ON_3$: C, 66·9; H, 8·2%).

4-*Bromo*-3 : 5 : 5-*trimethyl*cyclo*hex*-2-*enone*.—*iso*Phorone (13·8 g., 0·1 mol.) and freshly recrystallised *N*-bromosuccinimide (17·8 g., 0·1 mol.) were heated under reflux in carbon tetrachloride (30 ml.). Reaction commenced after 10 min. and was complete in a further 20 min. The ice-cooled suspension was filtered from succinimide (9·7 g., 98%), and the solvent removed at 30° by a water-pump. The residue (21 g.) was dissolved in light petroleum (20 ml.; b. p. 60—80°) and kept at 0°. Next day the crystals were collected and recrystallised from light petroleum, to give 4-*bromo*-3 : 5 : 5-*trimethyl*cyclo*hex*-2-*enone* (10·8 g., 50%), m. p. 48—49·5° (Found : C, 49·8; H, 5·9; Br, 36·5. $C_9H_{13}OBr$ requires C, 49·8; H, 6·0; Br, 36·8%). The bromo-ketone distilled without decomposition (b. p. 70°/0·1 mm.) and resolidified. If the whole product was distilled before crystallisation appreciable decomposition occurred.

4-*Acetoxy*-3 : 5 : 5-*trimethyl*cyclo*hex*-2-*enone*.—The crystalline bromo-ketone (19·6 g., 0·09 mol.) and dry silver acetate (20 g., 0·12 mol.) were stirred in glacial acetic acid (80 ml.) at 90° during 3 hr. The cooled suspension was filtered from silver bromide (19·5 g., 90%), the filtrate concentrated under reduced pressure, and the product taken into ether, washed, dried ($MgSO_4$), and distilled, to give 4-*acetoxy*-3 : 5 : 5-*trimethyl*cyclo*hex*-2-*enone* (5·5 g., 31%), b. p. 92—95°/0·5 mm., n_D^{20} 1·5128, max. at 229 mμ (ε 9650) (Found : C, 68·9; H, 8·35. $C_{11}H_{16}O_3$ requires C, 67·3; H, 8·2%). The 2 : 4-*dinitrophenylhydrazone*, crystallised from ethanol, had m. p. 152·5—154° (Found : C, 54·8; H, 5·45. $C_{17}H_{20}O_6N_4$ requires C, 54·2; H, 5·4%).

4-(±)-trans-*Chrysanthemoyloxy*-3 : 5 : 5-*trimethyl*cyclo*hex*-2-*enone*.—The crystalline bromo-ketone (1·0 g.) and silver (±)-*trans*-chrysanthemate [12] (1·2 g.) were heated under reflux in xylene during 30 min. [no reaction occurred in benzene, light petroleum (b. p. 60—80°), or carbon tetrachloride]. Filtration and distillation gave the *ester* (0·8 g., 56%), b. p. 132—133°/0·1 mm., n_D^{20} 1·5005, max. at 210 mμ (ε 13,800) (Found : C, 75·3; H, 9·55. $C_{19}H_{28}O_3$ requires C, 75·0; H, 9·25%).

[19] Lindlar, *Helv. Chim. Acta*, 1952, **35**, 446.
[20] Haynes, Heilbron, Jones, and Sondheimer, *J.*, 1947, 1583.

Hydrolysis of 4-*Bromo*-3 : 5 : 5-*trimethyl*cyclo*hex*-2-*enone*.—The crystalline bromo-ketone (5·4 g.) was stirred in aqueous sodium carbonate (5·3 g. in 50 ml.) at room temperature for 12 hr. and then at 50° for 4 hr. After cooling, the neutral product was extracted with ether, washed with 5% sodium hydroxide, dried, and distilled, to give impure 4-*hydroxy*-3 : 5 : 5-*trimethyl*cyclo*hex*-2-*enone* (1·5 g., 39%), b. p. 68—70°/0·1 mm., n_D^{20} 1·5170, max. at 225 mμ (ε 9050) (Found : C, 73·7; H, 9·1. $C_9H_{14}O_2$ requires C, 70·1; H, 9·15%). Acidification of the sodium hydroxide washings and crystallisation of the solid from light petroleum (b. p. 60—80°) gave 3 : 4 : 5-trimethylphenol, m. p. 106—107°, max. at 206, 279 mμ (ε 18,700, 2200) (Found : C, 79·3; H, 8·75. Calc. for $C_9H_{12}O$: C, 79·4; H, 8·9%). The literature [21] gives m. p. 106° for 3 : 4 : 5-trimethylphenol; no other trimethylphenol has a m. p. above 100°. 3 : 4 : 5-*Trimethylphenyl* 3 : 5-*dinitrobenzoate* separated from light petroleum (b. p. 60—80°) as needles, m. p. 195° (Found : C, 58·0; H, 4·3. $C_{16}H_{14}O_6N_2$ requires C, 58·2; H, 4·3%). Esterification of 3 : 4 : 5-trimethylphenol (0·8 g.) with (±)-*trans*-chrysanthemoyl chloride [1] (1·0 g.) in pyridine–benzene gave 3 : 4 : 5-*trimethylphenyl* (±)-trans-*chrysanthemate* (1·2 g., 75%), prisms (from methanol), m. p. 66—67·5°, max. at 210 mμ (ε 25,000) (Found : C, 79·8; H, 9·35. $C_{19}H_{26}O_3$ requires C, 79·9; H, 9·15%).

Hydrolysis of 4-*Acetoxy*-3 : 5 : 5-*trimethyl*cyclo*hex*-2-*enone*.—The acetoxy-ketone (2·5 g.) was dissolved in 1 : 1 aqueous-methanolic potassium hydroxide (0·7 g. in 20 ml.) and left at room temperature during 50 hr. After evaporation the product was isolated with ether and distilled (0·8 g.; b. p. 70—72°/0·1 mm., n_D^{20} 1·519). The 3 : 5-dinitrobenzoate, prepared in the usual manner from this oil, had m. p. and mixed m. p. 195—196°, when admixed with 3 : 4 : 5-trimethylphenyl 3 : 5-dinitrobenzoate.

Ethyl 3-*Allyl*-4-*methyl*-2-*oxo*cyclo*hex*-2-*enecarboxylate*.—2-Allyl-3-methyl*cyclo*hex-2-enone (5·5 g.) in dry ether (5 ml.) was added during 20 min. to a stirred, gently boiling suspension of sodium hydride (1·92 g.) in ethyl carbonate (9·5 g.) and ether (20 ml.) under nitrogen. After a further 4 hr. moist ether was added and the suspension poured on ice (50 g.) and glacial acetic acid (6·5 g.). The oil was taken up in more ether, washed with sodium hydrogen carbonate, dried, and fractionally distilled. The *ester* produced (4·20 g., 52%) had b. p. 115—116°/0·05 mm., n_D^{20} 1·5022 (Found : C, 70·25; H, 8·55. $C_{13}H_{18}O_3$ requires C, 70·2; H, 8·2%), and gave a deep purple ferric colour.

Ethyl 3-*Allyl*-1-*chloro*-4-*methyl*-2-*oxo*cyclo*hex*-2-*enecarboxylate*.—The above keto-ester (11·5 g.) was added dropwise to a suspension of powdered sodium (1·15 g.) under ether (30 ml.). Next day toluene-*p*-sulphonyl chloride (9·5 g.) in ether (30 ml.) was added, causing a heavy white precipitate. After 1 hour's refluxing water was added to dissolve the solid, and the organic product extracted with ether. The extracts were washed with sodium hydrogen carbonate, dried, and fractionally distilled. Solid separated from the higher-boiling fractions but the desired *ethyl* 3-*allyl*-1-*chloro*-4-*methyl*-2-*oxo*cyclo*hex*-2-*enecarboxylate* (1·25 g.) was obtained as a liquid, b. p. 104—105°/0·05 mm., n_D^{20} 1·500 (Found : C, 61·7; H, 7·0; Cl, 13·3. $C_{13}H_{17}O_3Cl$ requires C, 60·8; H, 6·7; Cl, 13·8%).

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[21] Beilstein, " Handbuch der organischen Chemie," 4th Edn., E II 6, p. 480.