187. *Experiments relating to the Synthesis of Homogeranic Acid.*

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Homogeranic acid (I; X = CO_2H) is obtained only in poor yield from *geranoyl chloride* by the Arndt–Eistert synthesis, and the production of the corresponding *cyanide* from geranyl chloride and cuprous cyanide is similarly inefficient. However, a novel and general method for synthesising allylic cyanides, *viz.*, allyl halide ⟶ allylmalonic ester ⟶ α-oximinoallylacetic acid ⟶ allyl cyanide, renders geranyl cyanide, and thence homogeranic acid, readily accessible. 1- and 3-Methylallyl cyanide and the hitherto difficultly obtainable cinnamyl cyanide have been prepared from the respective chlorides by the above method. The product from the condensation of 1-methylallyl chloride with sodiomalonic ester contains a small proportion of 3-*methylallylmalonic* ester; the relation of this finding to the S_N2' mechanism of allylic halide replacement (Hughes, *Trans. Faraday Soc.*, 1938, **34**, 185) is discussed.

Although no previous attempt to apply the Arndt–Eistert process

$$R{\cdot}CO_2H \longrightarrow R{\cdot}COCl \longrightarrow R{\cdot}CO{\cdot}CHN_2 \longrightarrow R{\cdot}CH_2{\cdot}CO_2H$$

to aliphatic αβ-unsaturated acids is on record, the successful conversion of several aromatic acids into substituted acetic acids and of an alicyclic βγ-unsaturated acid into the corresponding γδ-unsaturated acid by this method ("Organic Reactions", Wiley and Sons, N.Y., 1942, Vol. I, pp. 38 *et seq.*) gave reason to believe that the synthesis of homogeranic acid (I; X = CO_2H) from geranic acid (II; X = OH) could be realised without difficulty.

The first intermediate, *geranoyl chloride* (II; X = Cl), has not been described hitherto, but is readily prepared in good yield from the acid and thionyl chloride in the presence of pyridine, if particular care is exercised in purifying the thionyl chloride. Interaction of (II; X = Cl) with aqueous ammonia yields a geranamide (II; X = NH_2) mixture separable by fractional elution from alumina into two crystalline isomers. These are the compounds designated as geranamide-I and geranamide-II, respectively, by Caldwell and Jones (*J.*, 1946, 599), who first isolated them as rearrangement products from the action of Raney nickel on citral oxime. Comment on the structure of the compounds in the light of their infra-red spectra is made elsewhere (Barnard *et al.*, preceding paper). Notwithstanding the distinct preparative routes, the isolated mixtures contained the same relative proportion of isomers (5 : 1).

$CMe_2{:}CH{\cdot}CH_2{\cdot}CH_2{\cdot}CMe{:}CH{\cdot}CH_2X$ (I.) $\qquad$ $CMe_2{:}CH{\cdot}CH_2{\cdot}CH_2{\cdot}CMe{:}CH{\cdot}CO{\cdot}X$ (II.)

$CMe_2{:}CH{\cdot}CH_2{\cdot}CH_2{\cdot}CMeX{\cdot}CH{:}CH_2$ (III.)

The second stage of the projected synthesis also proceeds normally, to yield the liquid *diazomethyl* 2 : 6-*dimethylhepta*-1 : 5-*dienyl ketone* (II; X = CHN_2). The final stage, however, proved decidedly abnormal. Repeated attempts to rearrange the diazo-ketone to homogeranic acid (I; X = CO_2H) or to homogeranamide (I; X = $CO{\cdot}NH_2$) under the usual conditions using colloidal silver as catalyst gave only tar and much residual diazo-ketone. The possible catalytic activity of a variety of metallic compounds was then investigated. Although auric chloride proved to be an active catalyst for promoting the decomposition of the diazo-ketone in ethanol at room temperature, complex side-reactions greatly preponderated and, on hydrolysis, only 7% of *homogeranic acid* (I; X = CO_2H) was obtained.

Diazomethyl 2 : 6-dimethylhepta-1 : 5-dienyl ketone clearly possesses unusual stability, as is further emphasised by the fact that it can be distilled without appreciable decomposition at 0·05 mm. pressure from a bath at 100° (b. p. 87—88°). Although many diazo-ketones possess comparable thermal stability, few are resistant to the usual rearrangement procedures. The several indefinite interpretations of the mechanism of the rearrangement that have been propounded certainly offer no indication of any special function of the alkenyl substituent in the present example.

The limited success achieved forced our attention to preparative methods based on geranyl chloride. An inherent disadvantage of this approach is the possibility of allylic isomerism. This complication intrudes in three ways: (i) possible inhomogeneity of the terpenoid starting material or of an intermediate; (ii) similar inhomogeneity of the desired product even if its precursor were pure; and (iii) the analytical problem of identifying and characterising various isomers. The last of these, clearly of dominant importance, is now greatly facilitated by recent developments in the recording and interpretation of infra-red spectra (see Barnard *et al.*, *loc. cit.*).

Pure geraniol is entirely the primary allylic alcohol (I; X = OH). On treating it with

thionyl chloride and pyridine (Forster and Cardwell, *J.*, 1913, 1341), a product boiling over a range of about 20° is obtained (cf. Ruzicka, *Helv. Chim. Acta*, 1923, **6**, 492; Sutton, *J.*, 1944, 306), which gives analyses correct for the derived chloride and which infra-red spectroscopic analysis reveals to be a mixture of the primary (geranyl) (I; X = Cl) and the tertiary (linaloyl) (III; X = Cl) chloride in the ratio of roughly 5 to 1.* Separation of the isomers by fractionation is extremely difficult because of decomposition during the prolonged heating at the relatively high temperature needed. More rapid distillation at the lowest convenient pressure (*ca.* 0·2 mm.) effects some separation, the tail portions consisting of almost pure primary chloride. However, for reasons which will emerge, the use of the pure isomers offers no advantage in the present work.

Recent work by Lane, Fentress, and Sherwood (*J. Amer. Chem. Soc.*, 1944, **66**, 545) indicated that the conversion of an allylic halide into the carboxylic acid homologue *via* the nitrile offered not only the most direct, but a most favourable structural, route to homogeranic acid. These authors showed that the simpler analogues of the constituents of the geranyl chloride mixture, *viz.*, 1- and 3-methylallyl chloride, interact with cuprous cyanide so that, independently of the nature of the pure halide or of the composition of an isomeric mixture, the same equilibrium mixture of cyanides is formed (91·5% of crotyl, 8·5% of 1-methylallyl). Furthermore, when the mixture is hydrolysed by acid, the 1-methylallyl constituent behaves abnormally and the isolated acid is derived solely from the crotyl isomer. Once again, however, the extension to di-isoprenic derivatives of a method successful with simpler analogues was disappointing. Under the experimental conditions of Lane *et al.* (*loc. cit.*) and modifications thereof, the maximum yield of *geranyl cyanide* was no more than 11%, in marked contrast to the approximately 90% conversion obtained in the methylallyl system. As expected, isomeric heterogeneity of the product was indicated by a boiling range of 7° (cf. geranyl chloride), but in addition it appeared to be very slightly impure. Although this synthesis is therefore of little preparative value in the geranyl series, the present work corroborates the American authors' important findings concerning the formation of homogeneous hydrolytic products from isomeric mixtures of allylic nitriles. Alkaline hydrolysis converted the above geranyl cyanide into homogeneous homogeranic acid (I; X = CO_2H), which in turn has been converted *via* its *acid chloride* into crystalline *homogeranamide*, identical in melting point and infra-red spectrum with a specimen prepared from homogeranic acid isolated from the rearrangement of diazomethyl 2 : 6-dimethylhepta-1 : 5-dienyl ketone. A similarly identical specimen is obtained directly from the cyanide on mild hydrolysis with alkaline hydrogen peroxide, thus establishing that no double-bond displacement occurs during the relatively severe hydrolysis of the cyanide. The ultra-violet absorption spectrum also proves the absence of αβ-unsaturated conjugation in the acid.

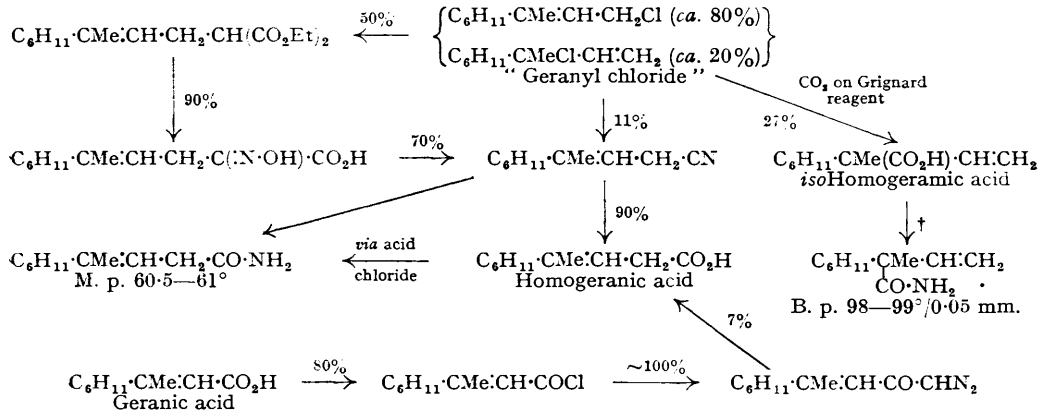
At this stage, when the possibility of finding an improved route to homogeranic acid seemed remote—especially as we had found in the meantime that carboxylation of geranylmagnesium chloride yields the tertiary allylic derivative (III; X = CO_2H) (see following paper)—Barry and Hartung (*J. Org. Chem.*, 1947, **12**, 460) described preparations of α-oximino-acids. One method involves a novel transformation of alkylmalonic esters. On treatment with an alkyl nitrite in alkaline solution, efficient oximation of these esters at the tertiary carbon atom is accompanied by simultaneous hydrolysis and decarboxylation of one carbethoxyl group, *i.e.*, $CHR(CO_2Et)_2 \longrightarrow HO{\cdot}N{:}CR{\cdot}CO_2H$. Now it is known that α-oximino-acids, while resistant to alkaline hydrolysis, tend to lose water and carbon dioxide in strongly acid solution with the formation of nitriles containing one less carbon atom (Bouveault and Loquin, *Bull. Soc. chim.*, 1904, **31**, 1142). Yields of the nitriles thus obtained are generally poor, and, in any case, the extension of this reaction to open-chain terpenoid compounds is restricted by the sensitivity of the latter towards mineral acids, but it seemed reasonable to expect that the mineral acid could be replaced with advantage by a powerful dehydrating agent. Experiment confirmed this; the addition of acetic anhydride to a solid α-oximino-acid caused almost explosive decomposition, but the use of low-boiling petroleum as a diluent gave a high yield of nitrile.

Ethyl geranylmalonate [I; X = $CH(CO_2Et)_2$] was prepared in 50% yield † by condensing sodiomalonic ester with the geranyl chloride mixture (cf. above) and was structurally homogeneous (see below); with amyl nitrite it gave *α-oximinogeranylacetic* (1-*oximino*-4 : 8-*dimethyl*-n-*deca*-3 : 7-*dienoic*) *acid* [I; X = $C(:NOH){\cdot}CO_2H$] in 90% yield. On crystallisation from aqueous

* This ratio is determined by the conditions of reaction and of subsequent isolation; it is not to be regarded as reflecting the free-energy difference between the isomers.

† The yields in this and the analogous condensations referred to later are typical for the experimental conditions employed; they may not be the highest possible.

acetone, metastable and stable forms were obtained (presumably *syn-* and *anti*-oxime isomers); the former reverted readily to the latter on subsequent recrystallisation. Smooth decomposition ensued on adding acetic anhydride to a suspension of this acid in light petroleum. The product, isolated in 70% yield, was homogeneous and analytically pure (cf. p. 927), and yielded derivatives identical with those prepared from the geranyl cyanide which had been synthesised much less satisfactorily from cuprous cyanide and geranyl chloride. The annexed reaction scheme summarises the inter-relationships of the compounds studied and records the yields of those reactions of preparative significance.



† See following paper.

The alkylated malonic ester route to cyanides provides a new method for ascending a homologous series which is especially useful for fairly reactive halides. The difficulty experienced with direct halide–cyanide exchange in these cases arises from the fact that the cyanide ion is too weak a base to initiate a bimolecular (S_N2) reaction which can compete successfully with solvolysis of the halide by the hydroxylic solvent, whose presence is demanded by solubility considerations. The heterogeneous cuprous cyanide system introduces other factors which may, or, as with geranyl chloride, may not, contribute to successful interaction. The ethyl malonate anion is not only a sufficiently powerful base to engage in effective nucleophilic attack in a hydroxylic medium, but also yields a product of unique functional character. To test the response of other allylic compounds to this synthesis, the conversion of cinnamyl chloride and of 1- and 3-methylallyl chloride into the respective cyanides has been investigated.

Ethyl cinnamylmalonate reacted with *n*-butyl nitrite in alkaline ethanol to give *α-oximino-cinnamylacetic* (*1-oximino-4-phenylpent-3-enoic*) *acid* (83%). This acid is dehydrated and decarboxylated extremely easily. Even repeated recrystallisation from aqueous ethanol suffices to effect complete conversion into cinnamyl cyanide, although this is effected more expeditiously in bulk by treating a light-petroleum suspension with acetic anhydride as described previously. The one preparation of this nitrile recorded (Borsche and Niemann, *Ber.*, 1936, **69**, 1993) gives a poor yield. Hydrolysis of the nitrile with alcoholic potash yielded 79% of the expected phenyl*iso*crotonic acid, Ph·CH:CH·CH_2·CO_2H (Buchner and Dessaver, *Ber.*, 1892, **25**, 1155; Fittig and Jagne, *Annalen*, 1883, **216**, 98).

Ethyl (*1-methylallyl*)*malonate* and crotylmalonate (cf. Eccott and Linstead, *J.*, 1929, 2153, and Linstead and Rydon, *J.*, 1934, 1995) were prepared from the respective chlorides in >50% yields. Since Linstead *et al.*'s samples of crotyl bromide were unquestionably heterogeneous (Winstein and Young, *J. Amer. Chem. Soc.*, 1936, **58**, 104), some doubt exists concerning the purity of these products, but, for reasons referred to below, contamination with the 1-methylallyl isomer was probably inappreciable. To free the derived esters from traces of ethyl malonate, however, very careful fractionation was necessary. The purified esters were transformed in the usual way into 1-oximino-2-methylpent-3-enoic and 1-oximinohex-3-enoic acid, crystalline solids, which were dehydrated directly in ethereal solution without isolation. The cyanides were obtained in high yield, were apparently homogeneous, and exhibited physical constants in close agreement with those reported by Lane, Fentress, and Sherwood (*loc. cit.*), but were found to evolve hydrogen cyanide on distillation and were therefore not obtained analytically pure. The

cause of this slight decomposition (possibly an impurity) was not further investigated as the synthetic route was considered to be sufficiently demonstrated.

Certain further observations on the sodiomalonic ester condensations deserve mention. First, 1-methylallyl chloride reacts much more slowly than its 3-methyl isomer, in accord with the quantitative data of Young and Andrews (*J. Amer. Chem. Soc.*, 1944, **66**, 421) and of Catchpole and Hughes (*J.*, 1948, 4) on the related bimolecular substitutions with ethoxide ions. Since these authors have also established that the halides undergo unimolecular solvolysis at similar rates, it follows that under conditions where both modes of halide replacement occur the production of the primary allylic malonic ester is favoured. This is undoubtedly the principal reason why the geranyl chloride (p. 928) and crotyl bromide (p. 928) mixtures yield products containing inappreciable proportions of the secondary allylic derivative. Secondly, while the malonic ester isolated from 3-methylallyl chloride possessed *entirely* the allylic structure of the parent halide, in the 1-methylallyl series this was only *mainly* so. From the crude (1-methylallyl)malonic ester was separated a small amount of a mixed ester fraction, the analysis of which indicated that about 3% of the 3-methylallyl isomer had been formed. From such product composition data alone, it is impossible, of course, to draw conclusions about the reaction mechanism, but this finding suggests the operation of the long-forecast (Hughes, *loc. cit.*), but experimentally elusive (cf. Catchpole, Hughes, and Ingold, *J.*, 1948, 8), S_N2' reaction :

S_N2 S_N2'

During the preparation of this paper, Kepner, Winstein, and Young (*J. Amer. Chem. Soc.*, 1949, **71**, 115) reported an investigation designed expressly to detect the S_N2' mechanism if operative in the reactions just considered and in the analogous condensations with 1- and 3-ethylallyl chloride. The composition of the derived malonic esters was not examined directly; instead, these were successively hydrogenated, hydrolysed, and decarboxylated, the resulting straight-chain saturated acids fractionated, and the distillates converted in portions into the benzylamine salts, whose isomeric compositions were ascertained by melting-point comparisons. By this laborious procedure, applied apparently to a single experiment, the product obtained from 1-methylallyl chloride in boiling ethanol was found to contain $10 \pm 3\%$ of 3-methylallylmalonic ester—an estimate in reasonable agreement with our value based on partial separation and analytical identification of the rearranged ester, which also refers to one experiment and is probably somewhat low. With 1-ethylallyl chloride, rearrangement occurs to a greater extent ($23 \pm 3\%$), and this is attributed to decreased S_N2 reactivity arising from increased steric hindrance to the approach of the malonate ion at the α-carbon atom. In the tertiary allylic (linalyl) chloride (III; X = Cl), this steric situation is greatly emphasised and will be an additional factor contributing to the formation of homogeneous geranylmalonic ester [I; X = $CH(CO_2Et)_2$] from the isomeric chloride mixture (cf. above). By accessory rate measurements, Kepner *et al.* further showed (i) that the condensation is a bimolecular reaction, of the first-order with respect to both allyl chloride and malonate ion, and (ii) that it proceeds much faster than unimolecular solvolysis of the chloride. On this evidence, they naturally deduce that the production of the rearranged ester from the 1-alkylallyl chlorides definitely establishes the existence of the S_N2' mechanism.

Experimental.

The absence of selective infra-red absorption at the frequencies 910 and 990, 965, and 835 $cm.^{-1}$, or at small recognisable displacements therefrom, is taken as characterising the absence of $CH_2{:}CHR$, *trans*-$CHR{:}CHR'$, and $CRR'{:}CHR''$, respectively. The experimental basis for the analytical use of infra-red spectroscopy in this sense is presented and discussed elsewhere (Barnard *et al.*, *loc. cit.*).

The micro-analyses recorded in this and the following papers were carried out in the Analytical Department of these laboratories under the direction of Dr. W. T. Chambers.

Geranic Acid.—Oxidation of commercially pure citral by alkaline silver oxide, essentially according to Semmler's directions (*Ber.*, 1890, **23**, 3556), gave a product (65%) which after careful fractionation had b. p. 99—100°/0·1 mm., n_D^{20} 1·4876.

Geranoyl Chloride.—Distilled thionyl chloride with geranic acid in the presence of pyridine gave much tar and practically none of the desired product. However, by the use of specially purified thionyl chloride under the same conditions, good yields were readily obtained. To an ice-cooled and stirred mixture of

geranic acid (50 g.), anhydrous pyridine (23·7 g.), and anhydrous ether (150 ml.) was slowly added thionyl chloride (28·7 ml.), freshly purified by successive distillation from quinoline and linseed oil. After filtration from the precipitated pyridine hydrochloride, the filtrate was refluxed for 1 hour. Removal of solvent and fractionation of the residue gave *geranoyl chloride* (81%) as a colourless liquid, b. p. 77—78°/0·3 mm., n_D^{20} 1·4963, d_D^{20} 0·9955 (Found: C, 64·6; H, 8·3; Cl, 18·7. $C_{10}H_{15}OCl$ requires C, 64·4; H, 8·1; Cl, 19·0%).

Isomeric Geranamides.—Geranoyl chloride (7 g.), added slowly to stirred 20% aqueous ammonia (15 ml.) at 0°, yielded an oil (5 g.), which was separated into geranamide-I (1·83 g.) and geranamide-II (0·36 g.) by the chromatographic procedure described by Caldwell and Jones (*loc. cit.*). The isomer-I crystallised from light petroleum (b. p. 60—80°) in long needles, m. p. 67·8—68·4° (Found: C, 71·8; H, 10·3; N, 8·3. Calc. for $C_{10}H_{17}ON$: C, 71·8; H, 10·3; N, 8·4%); the amide-II separated from the same solvent in lustrous plates, m. p. 61·6—61·9° (Found: N, 8·5%).

Diazomethyl 2 : 6-*Dimethylhepta*-1 : 5-*dienyl Ketone.*—Geranoyl chloride (45 g.) in ether (130 ml.) was added slowly, with efficient stirring, to a solution of diazomethane (from 139 g. of *N*-nitrosomethylurea) in ether (900 ml.) cooled to −10°. After being kept at 0° for 48 hours and at 20° for 1 hour, the reaction mixture was filtered, and the ether and excess of diazomethane were removed under reduced pressure at 26—28°. The residual diazo-ketone (46 g.) was an orange oil, b. p. 87—88°/0·05 mm., n_D^{20} 1·5395 (Found: C, 69·0; H, 8·6; N, 14·9. $C_{11}H_{16}ON_2$ requires C, 68·7; H, 8·4; N, 14·6%). Light-absorption measurements in ethanol showed intense bands at 2560 (ε = 11,000) and 3000 A. (ε = 10,250).

Rearrangement of Diazomethyl 2 : 6-*Dimethylhepta*-1 : 5-*dienyl Ketone.*—Attempted Wolff rearrangement of the diazoketone in (*a*) aqueous dioxan solution at 55° and 80°, (*b*) aqueous dioxan saturated with ammonia at 60° or under reflux, and (*c*) ethanol saturated with ammonia at room temperature or under reflux, in the presence of silver oxide or colloidal silver, produced only some tar; much unchanged diazo-ketone was recovered. In a wide survey of possible catalysts for the rearrangement of the diazo-ketone as a 10% solution in ethanol, positive promotion (as shown by nitrogen evolution) was found only with silver oxide and colloidal silver (slightly active) and with auric chloride (highly active).

Homogeranic Acid.—To a solution of diazomethyl 2 : 6-dimethylhepta-1 : 5-dienyl ketone (35 g.) in ethanol (400 ml.) and water (20 ml.) at 50°, a saturated solution of auric chloride (0·4 g.) in ethanol was added at such a rate that nitrogen evolution was approx. 30 c.c./min. After gas evolution had ceased, potassium hydroxide (12 g.) was added to the red, turbid solution, which was refluxed for 3 hours, filtered, and evaporated to 100 c.c. under reduced pressure. Water (400 ml.) was added, and the solution extracted with ether and then acidified with concentrated hydrochloric acid (20 ml.). *Homogeranic acid* separated as an oil which, dried (Na_2SO_4) and fractionated, had b. p. 110—110·5°/0·1 mm., n_D^{20} 1·4743 [Found: C, 72·5; H, 9·8%; $\equiv$, 1·97 (catalytic hydrogenation). $C_{11}H_{18}O_2$ requires C, 72·5; H, 9·9%; $\equiv$, 2·0]. Yield, 2·5 g.

Homogeranamide.—Homogeranic acid (2 g.) in ether (3 ml.) was treated with pyridine (1 g.) and thionyl chloride (1·4 ml.) at 0°; after dilution further with ether and filtration, homogeranic acid chloride, b. p. 68—71°/0·1 mm., was obtained by evaporation. Interaction of this chloride with ammonia in ethanol, and isolation of the product in the usual way, gave an oil which rapidly solidified at room temperature. Recrystallisation from light petroleum (b. p. 40—60°) yielded *homogeranamide* as white platelets, m. p. 60·5—61° (Found: C, 72·8; H, 10·6; N, 7·9. $C_{11}H_{19}ON$ requires C, 72·9; H, 10·6; N, 7·8%). Fractional elution from alumina following the procedure used for separating the isomeric geranamides indicated homogeneity of the amide. Its infra-red spectrum indicates that the olefinic unsaturation is of the type $R_2C{:}CHR$.

Geraniol.—"Geraniol Q" (Boake Roberts & Co.), purified through its calcium chloride addition compound and then fractionated, had b. p. 112·5—113·5°/13 mm., n_D^{20} 1·4765. Yield, approx. 60%. Its infra-red spectrum is incompatible with the presence of $CH_2{:}CHR$ groups, and therefore establishes its identity as the homogeneous primary allylic alcohol (I; X = OH).

Geranyl Chloride.—To a mixture of geraniol (200 g.), pyridine (110 g.), and anhydrous ether (200 ml.), thionyl chloride (170 g.) was slowly added with vigorous stirring and ice-cooling (cf. Forster and Cardwell, *loc. cit.*). After being kept for several hours at room temperature, the mixture was stirred with ice-water (3 l.), and the upper layer separated, washed with dilute sodium hydroxide solution until alkaline and then with water, and finally dried ($CaCl_2$). On fractionation through a 35-cm. Vigreux column, the product always exhibited a continuous boiling range, 50—105°/11 mm. or 25—55°/0·2 mm.; only the fraction, b. p. 85—105°/11 mm. or 45—55°/0·2 mm., n_D^{20} 1·4728—1·4790 (beginning and end of fraction), gave correct analytical figures for geranyl chloride (Found: Cl, 20·1—20·5. Calc. for $C_{10}H_{17}Cl$: Cl, 20·6%).

On dividing the chloride during fractionation into several fractions of increasing b. p., it was found by infra-red spectroscopy that the lower-boiling fractions contained considerable amounts of the isomeric tertiary chloride (linalyl chloride; III; X = Cl), the proportion decreasing with increasing b. p. until the fraction of highest b. p. was practically pure primary chloride (I; X = Cl). As is usual with allylic chlorides, the isomeric composition of these fractions changed on long storage or on heating them in a vacuum for a shorter period.

A freshly prepared sample of geranyl chloride, distilled at 0·2 mm. and of the boiling range given above, contains approx. 20% of the tertiary isomer (see footnote p. 927).

Geranyl Cyanide.—On mixing geranyl chloride (54 g.), pyridine (30 g.), and anhydrous cuprous cyanide (30 g.), heat was evolved and a pasty mass resulted; the paste liquefied on raising of the temperature to about 75°. After being maintained at this temperature for 2 hours, and at 100° for 0·5 hour, the dark syrup was poured rapidly into ether. The insoluble matter was separated, washed with ether, and the combined extracts were worked up in the usual way. The main product (30 g.) was a halogen- and nitrogen-free liquid, b. p. 45—87°/0·1 mm., and there was a much smaller amount (5 g.) of material, b. p. 87—94°/0·2 mm. Refractionation of the latter yielded a pleasant-smelling, very pale yellow oil, b. p. 90—91°/0·2 mm., n_D^{20} 1·4701, evidently slightly impure *geranyl cyanide* (Found: C, 79·7; H, 10·5; N, 7·8. $C_{11}H_{17}N$ requires C, 81·0; H, 10·5; N, 8·6%).

Hydrolysis of Geranyl Cyanide.—Geranyl cyanide (5 g.) was refluxed for 6 hours with 20% aqueous ethanol (80 ml.) containing potassium hydroxide (5 g.); no more ammonia was then evolved. The resulting acid (2·6 g.), b. p. 108—9°/0·05 mm., n_D^{20} 1·4744 (Found : C, 72·3; H, 10·0. Calc. for $C_{11}H_{18}O_2$: C, 72·5; H, 9·9%), was identical with the homogeranic acid previously isolated, and gave, *via* its acid chloride, homogeranamide m. p. 59—59·5°, mixed m. p. 60·0—60·5°.

Geranyl cyanide (3·5 g.) was dissolved in ethanol (20 ml.) containing sodium hydroxide (1 ml.; 6N.), and 30% hydrogen peroxide (9 ml.) was added. Rapid effervescence occurred with the intermediate formation of a crystalline complex which subsequently re-dissolved. The solution was kept at 50° for 4 hours, and a crystalline product (3 g.) then isolated by ether-extraction. Several recrystallisations from light petroleum (b. p. 40—60°) yielded pure homogeranamide, m. p. 60·0—60·5°.

Ethyl Geranylmalonate.—Redistilled ethyl malonate (126 g.) was added during 30 minutes to a hot solution of sodium (17·8 g.) in anhydrous ethanol (750 ml.). Geranyl chloride (138 g.) was then added with vigorous stirring at a rate sufficient to keep the solution gently refluxing. Heating was continued until the mixture was neutral to moist litmus (2 hours), whereafter most of the ethanol was removed by distillation. The oil obtained by pouring the residue into water gave, on fractionation, much low-boiling material together with the desired product (100 g.), b. p. 126—129°/0·2 mm., n_D^{20} 1·4610 (Found : C, 68·9; H, 9·6. Calc. for $C_{17}H_{28}O_4$: C, 68·9; H, 9·5%). The infra-red spectrum indicates the absence of $CH_2{:}CHR$ groups, and thus identifies the product as a primary allylic geranyl derivative.

α-Oximinogeranylacetic Acid.—Sodium (7·8 g.) was dissolved in ethanol (200 ml.), and ethyl geranylmalonate (100 g.) added slowly at 0°; *n*-amyl nitrite (43 g.) was then added dropwise with vigorous stirring. After removal of the ethanol under reduced pressure at 30°, the red residue was mixed with crushed ice (130 g.), acidified with 25% aqueous sulphuric acid (100 ml.), and extracted with ether. The ethereal extract was washed with 10% sodium hydroxide solution (6 × 50 ml.) until colourless and the aqueous solution thus obtained heated for 15 minutes on the steam-bath, the dissolved ether being distilled off. On acidification at 0°, a yellow solid (62 g.) was precipitated which was dried in a vacuum. Crystallisation was effected most readily by dissolution in boiling acetone, addition of water to cause slight turbidity, and then storage at 0°. *α-Oximinogeranylacetic* (*1-oximino-4 : 8-dimethyl-*n*-deca-3 : 7-dienoic*) *acid* was first obtained as colourless platelets, m. p. 138—139°, but the m. p. decreased with successive crystallisations to a constant value of 102·0—102·2°, the crystalline form now being needles (Found : C, 64·0; H, 8·1; N, 6·2%; equiv., 222. $C_{12}H_{19}O_3N$ requires C, 63·9; H, 8·5; N, 6·2%; equiv., 225).

Dehydration of α-Oximinogeranylacetic Acid.—The finely powdered, crude product (87 g.) was suspended in light petroleum (b. p. 60—80°; 200 ml.), and acetic anhydride (100 ml.) added slowly with stirring. Carbon dioxide was smoothly liberated, and the heat of reaction was sufficient to induce gentle boiling. The resulting solution was stirred with water for 2 hours and the undissolved oil worked up in the usual manner and fractionated. The product (43 g.), b. p. 81—82°/0·1 mm., n_D^{20} 1·4698, appeared to be identical with the geranyl cyanide obtained previously (Found : C, 80·8; H, 10·3; N, 8·4%). Hydrolysis with alkaline hydrogen peroxide yielded a crystalline amide, m. p. 60·0—60·5° alone or mixed with the original homogeranamide.

Homogeranic Acid.—Geranyl cyanide, obtained *via* the oximino-acid derivative, was hydrolysed with alcoholic potassium hydroxide solution as described previously, and an acid isolated, in 90% yield, identical with the original homogeranic acid (p. 930), b. p. 110—110·5°/0·1 mm., n_D^{20} 1·4743 (Found : C, 72·4; H, 9·9%). The infra-red spectrum of this acid indicates that olefinic unsaturation is only of the type $R_2C{:}CHR$, thus confirming that no shift of the double bond accompanies the hydrolysis. The absence of side reactions during the latter process is further confirmed by the fact that samples of homogeranamide prepared from the acid and by mild hydrolysis of the cyanide exhibited identical light absorption in the ultra-violet region.

Ethyl Cinnamylmalonate.—Under the above experimental conditions, cinnamyl chloride (142 g.) reacted with ethyl sodiomalonate (from 164 g. of ethyl malonate) to give *ethyl cinnamylmalonate* (130 g.), b. p. 137—140°/0·1 mm., n_D^{20} 1·5139 (Found : C, 69·4; H, 7·1. $C_{16}H_{20}O_4$ requires C, 69·5; H, 7·3%). Its infra-red spectrum establishes the absence of isomer containing the $CH_2{:}CHR$ grouping.

α-Oximinocinnamylacetic Acid.—Treatment of ethyl cinnamylmalonate (119 g.) with *n*-amyl nitrite in the manner already described yielded *α-oximinocinnamylacetic* (*1-oximino-4-phenylpent-3-enoic*) *acid* (73 g.), which crystallised from aqueous ethanol in white needles, m. p. 132—133·5°. On further recrystallisations, the m. p. steadily decreased until ultimately complete conversion into cinnamyl cyanide was realised.

Cinnamyl Cyanide.—Dehydration of crude α-oximinocinnamylacetic acid (67 g.) with acetic anhydride gave cinnamyl cyanide, m. p. 59·1—59·3° (after recrystallisation from aqueous ethanol) (Found : C, 83·8; H, 6·0; N, 9·9. Calc. for $C_{10}H_9N$: C, 83·9; H, 6·3; N, 9·8%).

3-Phenylisocrotonic Acid.—Hydrolysis of cinnamyl cyanide (10 g.) by refluxing it with alcoholic potassium hydroxide solution until ammonia was no longer liberated (24 hours) produced 3-phenyl*iso*-crotonic acid (9 g.), m. p. 87—87·5° (after recrystallisation from aqueous ethanol) (Found : C, 74·2; H, 6·3%; equiv., 163. Calc. for $C_{10}H_{10}O_2$: C, 74·1; H, 6·2%; equiv., 162).

Crotonyl Alcohol.—Meerwein–Pondorff–Verley reduction of crotonaldehyde gave a product having b. p. 120·0—120·6°/760 mm., n_D^{20} 1·4295.

1- and 3-Methylallyl Chloride.—Crotyl alcohol (161 g.) was dissolved in anhydrous ether (200 ml.), and purified thionyl chloride (357 g.) slowly added with stirring at 0°. After refluxing for 1 hour the mixture was cooled to 0° and ice-water added. The ethereal layer was separated, washed with sodium carbonate solution until alkaline and then with water, and dried ($CaCl_2$). On careful fractionation through a Fenske-type column, separation of the isomeric chlorides was achieved without difficulty, but gave 1-methylallyl chloride (61 g.), b. p. 63·0—63·9°/759 mm., n_D^{20} 1·4159, and 3-methylallyl chloride (59·5 g.), b. p. 82·9—83·9°/759 mm., n_D^{20} 1·4357.

Ethyl α-3-Methylallylmalonate (*Pent-3-ene-1 : 1-dicarboxylate*).—Ethyl malonate (115 g.) was alkylated with 3-methylallyl chloride (59 g.) in the usual way; the reaction was complete in 4 hours. Fractionation of the product through a 30-cm. Vigreux column at 0·05 mm. gave fractions with steadily

increasing *n*, but the use of an efficient packed column gave, after a small fore-run (7 g.) (mainly ethyl malonate), a homogeneous distillate (77 g.), b. p. 120·0—120·5°/15 mm., n_D^{20} 1·4362 (Found : C, 61·6; H, 8·6. Calc. for $C_{11}H_{18}O_4$: C, 61·7; H, 8·5%). Its infra-red spectrum reveals that olefinic unsaturation is solely of the type RCH:CHR.

Ethyl α-1-*Methylallylmalonate* (2-*Methylbut*-3-*ene*-1 : 1-*dicarboxylate*).—Ethyl malonate (115 g.) was converted into the sodio-derivative and alkylated with 1-methylallyl chloride (61 g.). The reaction proceeded slowly : after refluxing for 10 hours the mixture was still alkaline to moist litmus and an odour of the chloride remained. However, isolation of the product after this time, followed by efficient fractionation, gave the required *malonate* (83 g.), b. p. 113·0—113·8°/16 mm., n_D^{20} 1·4333 (Found : C, 61·6; H, 8·5. $C_{11}H_{18}O_4$ requires C, 61·7; H, 8·4%). Infra-red spectroscopic examination showed that the olefinic unsaturation was purely of the type CH_2:CHR. Also isolated was a small amount (3 g.) of a higher-boiling fraction, b. p. 115·5—121°/16·5 mm., n_D^{20} 1·4342—1·4354, which could not be purified further by fractionation; its infra-red spectrum showed it to be a mixture of 3- and 1-methylallylmalonate in the ratio of 3 : 1.

3-*Methylallyl Cyanide*.—Ethyl α-3-methylallylmalonate (76 g.) was dissolved in sodium ethoxide solution (from 8·2 g. of sodium and 250 ml. of ethanol) and converted into 1-oximinohex-3-enoic acid by the slow addition of *n*-butyl nitrite (41 g.). The crude crystalline product was dissolved in ether (200 ml.) and dried (Na_2SO_4), and the solution refluxed for 4 hours while acetic anhydride (70 ml.) was slowly added. The product was stirred with water for 1 hour, and the ethereal layer washed successively with sodium carbonate solution and water, dried (Na_2SO_4), and fractionated through a 20-cm. column packed with glass helices. The cyanide (19·6 g.) had b. p. 142·0—143·0°/763 mm., n_D^{20} 1·4220. During the fractionation, a slight evolution of hydrogen cyanide was detected, and this is perhaps reflected in the analytical figures (Found : C, 73·8; H, 9·0; N, 16·9. Calc. for C_5H_7N : C, 74·1; H, 8·6; N, 17·2%).

1-*Methylallyl Cyanide*.—By the above procedure, ethyl 1-methylallylmalonate (82 g.) was converted to 1-oximino-2-methylpen-3-enoic acid, which, without isolation, was dehydrated to 1-methylallyl cyanide. Again, evidence of hydrogen cyanide evolution was observed during the fractionation of the nitrile (20·1 g.), which had b. p. 124·0—124·1°/760 mm., n_D^{20} 1·4058 (Found : N, 16·9%).

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