NOTES.

951. *A New Synthesis of 9-Acridones.*

By R. Ian Fryer, J. Earley, and L. H. Sternbach.

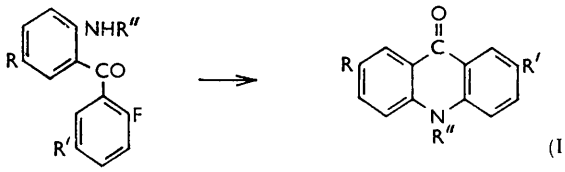
In connection with our studies of the synthesis of 5-phenyl-1,4-benzodiazepinones,[1] we have prepared a series of 2-amino-2′-fluorobenzophenones.[2] These compounds undergo internal nucleophilic exchange to give high yields of the corresponding 9-acridones. In contrast to substituted 2-amino-2′-chlorobenzophenones, which, as we have verified, do not cyclize under these conditions,[3] the fluorine is sufficiently activated by the *ortho*-carbonyl group to react readily with the aromatic amine.

Both solvent and catalyst affected the yield and it was determined that *NN*-dimethylformamide was the preferred solvent. The use of potassium carbonate as a catalyst significantly improved the yields of the 9-acridones in all cases. The catalytic effect of other salts was not investigated. *N*-Substituted 2-amino-2′-fluorobenzophenones were also easily cyclized by this method, although in *NN*-dimethylformamide only 2-chloro-9-acridone was obtained from the 5-chloro-2′-fluoro-2-toluene-*p*-sulphonamidobenzophenone. We were, however, able to obtain the desired 2-chloro-10-toluene-*p*-sulphonyl-9-acridone directly by using 2-ethoxyethanol as solvent.

Experimental.—M. p.s were determined microscopically on a hot stage and are corrected. The acridone structure of known compounds not directly compared with authentic samples was confirmed by a comparison of experimental and published ultraviolet spectra,[9] and by satisfactory analysis.

Cyclization of 2-amino-2′-fluorobenzophenones to 9-acridones. A typical procedure is described. A solution of 2-amino-2′-fluoro-5-nitrobenzophenone (1·0 g., 3·85 mmoles) and potassium carbonate (0·65 g., 4·75 mmoles) in *NN*-dimethylformamide (20 ml.) was refluxed for 17 hr., cooled, diluted to 100 ml. with water, and filtered. The precipitate was washed successively with water and boiling methanol, and was dried to give 2-nitro-9-acridone (0·8 g., 87%), m. p. >350°.

[1] Sternbach, Fryer, Metlesics, Reeder, Sach, Saucy, and Stempel, *J. Org. Chem.*, 1962, **27**, 3788.
[2] Sternbach, Fryer, Metlesics, Sach, and Stempel, *J. Org. Chem.*, 1962, **27**, 3781; Sternbach, Fryer, Keller, Metlesics, Sach, and Steiger, *J. Medicin. Chem.*, 1963, **6**, 261; Fryer, Brust, and Sternbach, preceding Paper.
[3] Kränzlein, *Ber.*, 1937, **70**, 1776.



(I) (II)

Benzophenone (I)			9-Acridone (II)				Yield	Reaction	
R	R′	R″	R	R′	R″	M. p.	(%)	solvent *	Ref.
H	H	H	H	H	H	354°	99	DMF	4
Cl	H	H	Cl	H	H	>350	95	DMF	5
NO_2	H	H	NO_2	H	H	>350	87 †	DMF	6
NO_2	NO_2	H	NO_2	NO_2	H	>350	100 †	DMF	7
NO_2	H	Me	NO_2	H	Me	285—287 ‡	82 †	DMF	8
Cl	H	Tos §	Cl	H	H	>350	100	DMF	5
Cl	H	Tos	Cl	H	Tos	172	40	$EtO{\cdot}C_2H_4{\cdot}OH$	—

* DMF = *NN*-dimethylformamide. † The physical properties and the infrared spectrum of this compound were identical with those of an authentic sample prepared as described in the literature. ‡ Lehmstedt and Hundertmark,[8] reported m. p. 276°. § Tos = p-$C_6H_4Me{\cdot}SO_2$.

2-*Chloro*-10-*toluene*-p-*sulphonyl*-9-*acridone*. A mixture of 5-chloro-2′-fluoro-2-toluene-*p*-sulphonamidobenzophenone (1·5 g., 3·7 mmoles) and potassium carbonate (0·65 g., 4·75 mmoles) in 2-ethoxyethanol (15 ml.) was heated under reflux for 5 hr. The solvent was removed under reduced pressure and the residue was partitioned between methylene chloride and water. The organic phase was separated, washed, dried, and evaporated to give yellow crystals (1·1 g.), m. p. 169—170°. Recrystallization from ethanol and treatment with charcoal gave the pure *product* (0·6 g., 40%) as white prisms, m. p. 171—172° (Found: C, 62·65; H, 4·0; N, 3·7. $C_{20}H_{14}ClNO_3S$ requires C, 62·6; H, 3·7; N, 3·65%).

Other reactions are recorded in the Table.

Department of Chemical Research, Research Division, Hoffmann-La Roche Inc., Nutley, New Jersey, U.S.A. [*Received, April 17th*, 1963.]

[4] Allen and McKee, *Org. Synth.*, Coll. Vol. II, p. 15.
[5] Ullmann, *Annalen*, 1907, **355**, 339.
[6] Albert and Ritchie, *J. Soc. Chem. Ind.*, 1941, **60**, 120.
[7] Bogert, Hirschfelder, and Lauffer, *Coll. Czech. Chem. Comm.*, 1930, **2**, 383.
[8] Lehmstedt and Hundertmark, *Ber.*, 1931, **64**, 2386.
[9] See Hershenson, " Ultraviolet and Visible Absorption Spectra," Academic Press Inc., New York, 1956, p. 8.

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952. *The Scope and Mechanism of Carbohydrate Osotriazole Formation. Part XI.* Some Aryltriazoles.*

By B. B. Bishay, H. El Khadem, and Z. M. El-Shafei.

Several compounds have been prepared from the corresponding osazones by the action of aqueous copper sulphate. The time of reaction (Table 1) again showed that electron-attracting groups inhibit triazole formation whilst electron-releasing ones facilitate it.[1] The tetra-acetates of the glucose arylosotriazoles were also prepared (Table 2).

Treatment of glucose *m*- and *p*-tolylosotriazole tetra-acetates with potassium permanganate yielded glucose *m*- and *p*-carboxyphenylosotriazole tetra-acetates, respectively, thus affording another method for their preparation. This reagent also converted glucose 2,5- and 3,4-dimethylphenylosotriazoles into 2-(2,5-dimethylphenyl)- and 2-(4-carboxy-3-methylphenyl)-1,2,3-triazole-4-carboxylic acid, respectively. In both cases, the methyl group *ortho* [2] and *meta* to the triazole ring resisted oxidation. Similarly, several new formyl derivatives have been prepared (Table 3).

* Part X, El Khadem, *J. Org. Chem.*, 1963, in the press.

[1] El Khadem, El-Shafei, and Meshreki, *J.*, 1961, 2957.
[2] El Khadem and El-Shafei, *J.*, 1959, 1655.

Experimental.—Osazones. These were prepared by heating glucose (10 g.) and the calculated amounts of the desired hydrazine hydrochloride and sodium acetate in water (400 ml.) on the water-bath for 2 hr., and, unless otherwise stated, were obtained as amorphous precipitates which were washed with water and used as such for the preparation of the osotriazoles.

Glucose 2,5-*dimethylphenylosazone.* Glucose (20 g.) was treated with 2,5-dimethylphenylhydrazine hydrochloride (60 g.) and sodium acetate as above. The *osazone* (25 g.) formed needles, m. p. 215—216° (decomp.) (from dilute ethanol), soluble in boiling ethanol or methanol and insoluble in ether or water (Found: N, 13·3. $C_{22}H_{30}N_4O_4$ requires N, 13·5%).

Galactose p-*acetamidophenylosazone.* Galactose (7 g.) was treated with *p*-acetamidophenylhydrazine hydrochloride (21 g.) and sodium acetate. The *osazone* (7 g.) formed needles, m. p. 165° (decomp.) (from dilute ethanol) (solubility as for the above osazone) (Found: C, 53·9; H, 6·2; N, 16·8. $C_{22}H_{28}N_6O_6,H_2O$ requires C, 53·9; H, 6·1; N, 17·1%).

Glucose arylosotriazoles (Table 1). A solution of the osazone (5 g.) in hot dioxan (100 ml.) was refluxed with copper sulphate (5 g.) in water (100 ml.), and the mixture filtered. To remove most of the dioxan, the filtrate was distilled until 100 ml. had been collected. The *osotriazole*, which separated when the residue cooled, was recrystallised from water–ethanol; it was soluble in ethanol or methanol and insoluble in water.

TABLE 1.

Glucose arylosotriazoles.

Subst. in Ph	Time (hr.)	Yield (%)	M. p.	Found (%) C	H	N	Formula	Required (%) C	H	N
p-CO·NH_2	4	21	223—225°	50·4	5·3	17·9	$C_{13}H_{16}N_4O_5$	51·1	5·2	18·2
o-Et	1	29	194	57·6	6·3	14·1	$C_{14}H_{19}N_3O_4$	57·3	6·5	14·3
p-Et	1	36	198	57·5	6·5	14·1	$C_{14}H_{19}N_3O_4$	57·3	6·5	14·3
3,4-Me_2 *	1·5	57	195	58·0	6·6	14·5	$C_{14}H_{19}N_3O_4$	57·3	6·5	14·3
3,5-Me_2 *	1·5	18	193	—	—	14·4	$C_{14}H_{19}N_3O_4$	—	—	14·3
2,5-Me_2 *	1·5	50	Amorphous	—	—	—	—	—	—	—
p-CH_2·CO_2H ...	0·75	38	220	52·1	5·4	13·4	$C_{14}H_{17}N_3O_6$	52·0	5·3	13·0

* Reaction was carried out without dioxan.

Glucose arylosotriazole tetra-acetates (Table 2). A solution of the osotriazole (2 g.) in dry pyridine (30 ml.) was treated with acetic anhydride (30 ml.), and the mixture left for 24 hr., poured on crushed ice, and extracted with ether. The ether layer was washed, dried, and evaporated. Unless otherwise stated, the products crystallised from dilute ethanol and were insoluble in water.

TABLE 2.

Glucose arylosotriazole tetra-acetates.

Subst. in Ph	Yield (%)	M. p.	Found (%) C	H	N	Formula	Required (%) C	H	N
o-Et	67	100°	57·5	5·6	8·9	$C_{22}H_{27}N_3O_8$	57·3	5·9	9·1
p-Et	67	102	56·8	5·9	8·5	$C_{22}H_{27}N_3O_8$	57·3	5·9	9·1
3,4-Me_2	67	105	57·2	5·8	9·6	$C_{22}H_{27}N_3O_8$	57·3	5·9	9·1
2,5-Me_2	67	101	—	—	9·6	$C_{22}H_{27}N_3O_8$	—	—	9·1
o-Me	62	79—80	56·6	5·6	9·8	$C_{21}H_{25}N_3O_8$	56·4	5·6	9·4
3,4-O·CH_2·O ...	67	98	52·5	4·8	9·1	$C_{21}H_{23}N_3O_{10}$	52·8	4·8	8·8

L-*Arabinose* p-*fluorophenylosotriazole triacetate* [Prepared by M. H. MESHREKI]. A solution of L-arabinose *p*-fluorophenylosotriazole in dry pyridine was treated with acetic anhydride; the *triacetate* crystallised from dilute ethanol as needles, m. p. 68—69° (solubility as for the other acetates) (Found: C, 53·9; H, 4·9; N, 11·0. $C_{17}H_{18}FN_3O_6$ requires C, 53·8; H, 4·7; N, 11·1%).

Glucose m-*carboxyphenylosotriazole tetra-acetate.* A boiling solution of glucose *m*-tolylosotriazole tetra-acetate[3] (2 g.) in 50% acetic acid (200 ml.) was treated with potassium permanganate (8 g.) until a pink colour persisted. The hot mixture was filtered, the filtrate decolorised with sulphur dioxde, and, to remove acetic acid, distilled until 100 ml. had been

collected. It was poured on ice, extracted with ether, and the extract treated with sodium hydrogen carbonate solution. The latter was acidified and the precipitate (0·5 g.) crystallised from water–ethanol in needles, m. p. and mixed m. p.[3] 174—175° (Found: C, 53·4; H, 4·8; N, 9·4. Calc for $C_{21}H_{23}N_3O_{10}$: C, 52·8; H, 4·8; N, 8·8%).

Glucose p-*carboxyphenylosotriazole tetra-acetate.* Glucose *p*-tolylosotriazole tetra-acetate[4] (2 g.) was treated with potassium permanganate, as above, yielding glucose *p*-carboxyphenylosotriazole tetra-acetate, m. p. and mixed m. p.[5] 165° (Found: C, 52·9; H, 4·7; N, 8·9. Calc. for $C_{21}H_{23}N_3O_{10}$: C, 52·8; H, 4·8; N, 8·8%).

Action of potassium permanganate on glucose o-*tolylosotriazole tetra-acetate.* A boiling solution of glucose *o*-tolylosotriazole tetra-acetate (2 g.) in 50% acetic acid was treated with potassium permanganate as for the *m*-isomer. Finally, the starting material was recovered unchanged.

2-(4-*Carboxy*-3-*methylphenyl*)-1,2,3-*triazole*-4-*carboxylic acid.* A boiling suspension of glucose 3,4-dimethylphenylosotriazole (1 g.) in water (100 ml.) was treated with potassium permanganate (4 g.) during 1·5 hr. The mixture was filtered, and the filtrate treated with sodium hydrogen sulphite and acidified. The *acid* (0·5 g.) crystallised from water–ethanol as needles, m. p. 309°, soluble in ethanol or methanol and insoluble in water (Found: C, 53·0; H, 3·9; N, 16·8. $C_{11}H_9N_3O_4$ requires C, 53·4; H, 3·6; N, 17·0%).

TABLE 3.

2-Aryl-4-formyl-1,2,3-triazoles.

Subst. in Ph	Yield (%)	M. p.	Found (%) C	Found (%) H	Found (%) N	Formula	Required (%) C	Required (%) H	Required (%) N
m-Me[2]	95	75°	64·4	5·3	22·6	$C_{10}H_9N_3O$	64·2	4·8	22·5
p-Me[4]	95	81	63·9	5·0	22·4	$C_{10}H_9N_3O$	64·2	4·8	22·5
p-Et *	59	53	—	—	21·2	$C_{11}H_{11}N_3O$	—	—	21·1
p-CO_2H[5]	95	278	55·0	3·7	18·8	$C_{10}H_7N_3O_3$	55·2	3·2	19·4
p-$CH_2{\cdot}CO_2H$ *	87	158	57·2	3·6	17·9	$C_{11}H_9N_3O_3$	57·1	3·9	18·2
p-NH·COMe[3]	87	230	57·6	4·7	24·4	$C_{11}H_{10}N_4O_2$	57·4	4·3	24·3
3,4-Me_2 *	95	99	65·9	5·4	21·4	$C_{11}H_{11}N_3O$	65·7	5·5	20·9
m-OMe[5]	95	76	58·9	4·5	20·3	$C_{10}H_9N_3O_2$	59·1	4·4	20·7
4-Me-3-NO_2[3]	87	135	—	—	24·4	$C_{10}H_8N_4O_3$	—	—	24·1
4-Br-3-Cl[1]	71	131	37·8	1·6	14·5	$C_9H_5ClBrN_3O$	37·7	1·7	14·7

* Table 1.

2-(2,5-*Dimethylphenyl*)-1,2,3-*triazole*-4-*carboxylic acid.* To a boiling suspension of glucose 2,5-dimethylphenylosotriazole (1 g.) in water (100 ml.), potassium permanganate (4 g.) was added, and the mixture refluxed for 1·5 hr. and treated as above. The *acid* (0·5 g.) was sublimed (170°/0·1 mm.), and then formed needles, m. p. 176° (from water–ethanol) (solubility as for the above acid) (Found: C, 61·3; H, 5·3; N, 19·0. $C_{11}H_{11}N_3O_2$ requires C, 60·9; H, 5·1; N, 19·3%).

2-*Aryl*-4-*formyl*-1,2,3-*triazoles* (Table 3). Glucose arylosotriazoles (1 mmole) were treated with periodic acid ($HIO_4,2H_2O$) (0·8 g., 3·5 mmoles) dissolved in water (10 ml.) and the mixture kept overnight at room temperature with occasional shaking. The crystals were filtered off, washed with water, and recrystallised from water–ethanol.

This work was supported by a grant from the U.A.R. Ministry for Scientific Research.

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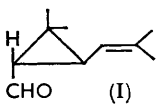
[*Received, February 25th,* 1963.]

[3] Bishay, El Khadem, El-Shafei, and Meshreki, *J.*, 1962, 3154.
[4] Hardegger and El Khadem, *Helv. Chim. Acta*, 1947, **30**, 1478.
[5] El Khadem, El-Shafei, and Mohammed, *J.*, 1960, 3993.

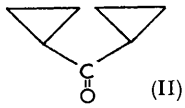
953. *Preparation of α-Cyclopropanealdehydes and Cyclopropyl Ketones.*

By L. Crombie and J. Crossley.

Manganese dioxide suspension at 20° has frequently been employed to oxidise α-unsaturated alcohols to α-unsaturated aldehydes and ketones: saturated alcohols are resistant.[1] We find that such oxidation satisfactorily converts α-cyclopropyl alcohols into aldehydes and ketones. This provides a convenient preparative method to some



(I)



(II)

inaccessible aldehydes. (±)-*trans*-Chrysanthemyl alcohol gave the (±)-*trans*-aldehyde (I and enantiomer) in 62% yield (isolated): the (±)-*cis*-aldehyde was formed in 59% yield (isolated). Cyclopropylmethyl alcohol and dicyclopropylmethyl alcohol gave the corresponding aldehyde and the ketone (II), respectively, in 61% and 51% yield (isolated as 2,4-dinitrophenylhydrazones).

Experimental.—(±)-trans- *and* (±)-cis-*Chrysanthemaldehyde.* (±)-*trans*-Chrysanthemyl alcohol, b. p. 59°/0·45 mm., n_D^{20} 1·4742 (Found: C, 78·0; H, 11·95. Calc. for $C_{10}H_{18}O$: C, 77·85; H, 11·75%), was made by reduction of methyl (±)-*trans*-chrysanthemate [2] with lithium aluminium hydride. Apparently, because of the formation of a complex insoluble in ether, the free acid is not reduced. (±)-*cis*-Chrysanthemyl alcohol [2] had b. p. 69°/0·3 mm., n_D^{18} 1·4767 (Found: C; 78·15; H, 11·95%). The (±)-*trans*-alcohol (1·08 g.) was shaken in light petroleum (b. p. 40—60°) with active manganese dioxide [3] (10 g.) for 16 hr. at 20°. After filtration, the manganese dioxide was washed with light petroleum, and the petroleum solutions were united, evaporated, and distilled, to give (±)-trans-*chrysanthemaldehyde* (I) (62%), b. p. 43—44°/0·1 mm., n_D^{19} 1·4776 (Found: C, 78·35; H, 10·7. $C_{10}H_{16}O$ requires C, 78·9; H, 10·6%), $\nu_{max.}$ (liquid) 1697 cm.$^{-1}$. The red 2,4-*dinitrophenylhydrazone* had m. p. 146—148° after chromatography (Found: C, 58·1; H, 6·2. $C_{16}H_{20}N_4O_4$ requires C, 57·8; H, 6·05%). The (±)-*cis*-alcohol (5 g.), shaken with active manganese dioxide (31 g.) in light petroleum (130 ml.) for 24 hr. at 20°, gave (±)-cis-*chrysanthemaldehyde* (59%), b. p. 63—64°/2 mm., n_D^{20} 1·4761 (Found: C, 78·35; H, 10·8%), $\nu_{max.}$ (liquid) 1695 cm.$^{-1}$. The *semicarbazone* had m. p. 177° (Found: C, 63·25; H, 9·3; N, 20·1. $C_{11}H_{19}N_3O$ requires C, 63·15; H, 9·15; N, 20·1%).

Oxidation of dicyclopropylmethyl alcohol and cyclopropylmethyl alcohol. Dicyclopropylmethyl alcohol [4] (1·0 g.) in n-pentane (80 ml.) was shaken with active manganese dioxide (10 g.) for 20 hr. at 20°. After centrifugation and washing, the pentane solutions were diluted to 175 ml., and 17·5 ml. was removed. Methanol (6 ml.), 2,4-dinitrophenylhydrazine (0·23 g.), and one drop of concentrated hydrochloric acid were added to the aliquot part, and the mixture was refluxed (20 min.). The 2,4-dinitrophenylhydrazone was isolated crude by evaporation and chromatographed from chloroform on bentonite—kieselguhr (1 : 4) to give, after crystallisation from ethanol, dicyclopropyl ketone 2,4-dinitrophenylhydrazone [4] (56%), m. p. and mixed m. p. 191—192°. When dicyclopropylmethyl alcohol was similarly treated with 2,4-dinitrophenylhydrazine reagent in a blank experiment, no dicyclopropylmethyl ketone 2,4-dinitrophenylhydrazone formed, indicating that this reagent did not cause oxidation.

[1] Ball, Goodwin, and Morton, *Biochem. J.*, 1948, **42**, 516; Evans, *Quart. Rev.*, 1959, **13**, 61.
[2] Inouye and Ohno, *Bull. Agric. Chem. Soc. Japan*, 1956, **20**, 25; Matsui, Yamashita, Miyano, Kitamura, Suzuki, and Hamuro, *ibid.*, p. 89.
[3] Attenburrow, Cameron, Chapman, Evans, Hems, Jansen, and Walker, *J.*, 1952, 1094.
[4] Curtis and Hart, *J. Amer. Chem. Soc.*, 1956, **78**, 112.

Cyclopropylmethyl alcohol (1·0 g.) similarly gave cyclopropanealdehyde 2,4-dinitrophenylhydrazone, red crystals (from ethanol) (61%), m. p. 185—187° (lit.,[5] 185·5—186·5°).

We thank Mr. C. M. Smith for preliminary experiments. One of us (J. C.) is grateful for a D.S.I.R. post-graduate award.

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[5] Smith and Roger, *J. Amer. Chem. Soc.*, 1951, **73**, 4047.

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954. *Amides of Vegetable Origin. Part XI.* Acetylenic Amides Related to Neoherculin.*

By L. CROMBIE and M. MANZOOR-I-KHUDA.

IN connection with synthetic work on stereoisomers of the natural lipid amide, neoherculin (α-sanshoöl), *N*-isobutyldodeca-*trans*-2,*cis*-6,*trans*-8,*trans*-10-tetraenamide (I),[1] the preparation of the enetriynes (II) and (III) and the dienediynes (IV) and (V) has been carried out. All four are crystalline. The two enetriynes were made by oxidative cross-coupling between *N*-isobutylhepta-2,6-diynamide (VI) and *cis*- and *trans*-pent-3-en-1-yne. The tetrayne-bisamide (VII) was formed as a by-product. Similar cross-coupling between

$Me\cdot\overset{t}{C}H{=}\overset{t}{C}H\cdot\overset{c}{C}H{=}CH\cdot[CH_2]_2\cdot\overset{t}{C}H{=}CH\cdot CO\cdot NHBu^i$	(I)
$Me\cdot CH{=}CH\cdot C{\equiv}C\cdot C{\equiv}C\cdot[CH_2]_2\cdot C{\equiv}C\cdot CO\cdot NHBu^i$	(II = *trans*-10; III = *cis*-10)
$Me\cdot CH{=}CH\cdot C{\equiv}C\cdot C{\equiv}C\cdot[CH_2]_2\cdot CH{=}CH\cdot CO\cdot NHBu^i$	(IV = *trans*-2,*trans*-10; V = *trans*-2,*cis*-10)
$HC{\equiv}C\cdot[CH_2]_2\cdot C{\equiv}C\cdot CO\cdot NHBu^i$	(VI)
$Bu^i\cdot NH\cdot CO\cdot C{\equiv}C\cdot[CH_2]_2\cdot C{\equiv}C\cdot C{\equiv}C\cdot[CH_2]_2\cdot C{\equiv}C\cdot CO\cdot NHBu^i$	(VII)
$HC{\equiv}C\cdot[CH_2]_2\cdot CH{=}CH\cdot CO\cdot NHBu$	(VIII)
$Bu\cdot NH\cdot CO\cdot\overset{t}{C}H{=}CH\cdot[CH_2]_2\cdot C{\equiv}C\cdot C{\equiv}C\cdot[CH_2]_2\cdot\overset{t}{C}H{=}CH\cdot CO\cdot NHBu^i$	(IX)

trans-*N*-isobutylhept-2-en-6-ynamide (VIII) and *cis*- and *trans*-pent-3-en-1-yne gave the dienediynes, with the dienediyne-bisamide (IX) as a by-product. A preliminary examination of the partial hydrogenation of these amides has been made with a view to making stereoisomers of amide (I), but it has proved difficult to isolate products of assured homogeneity. The extreme instability of the tetraenes produced (cf. neoherculin [1]) has greatly hampered their purification.[2]

Experimental.—N-Isobutylhepta-2,6-diynamide and *N-isobutylhept*-trans-2-*en*-6-*ynamide*. Hepta-2,6-diynoic acid [3] (2 g.) and thionyl chloride (2·1 g.) were kept at 100° for 20 min. The excess of thionyl chloride was removed *in vacuo* and the acid chloride in dry ether (50 ml.) was added to isobutylamine (2·6 g.) in ether (50 ml.). Working up gave N-*isobutylhepta*-2,6-*diynamide* (VI) (1·21 g.), needles, m. p. 59° [from light petroleum (b. p. 40—60°)] (Found: C, 74·3; H, 8·5. $C_{11}H_{15}NO$ requires C, 74·55; H, 8·55%). There was end-absorption in the ultraviolet region (ε 2800 and 600 at 239·5 and 252 mμ), and the compound had $\nu_{max.}$ (mull) 3236, 3077, 1626, 1546 (amide), 3279 (HC≡C), 2260, 2234 (C≡C str) cm.$^{-1}$. Hept-*trans*-2-en-6-ynoic acid [3] (0·55 g.) similarly gave N-*isobutylhept*-trans-2-*en*-6-*ynamide* (VIII) (0·45 g.), needles, m. p. 58° (Found: C, 73·4; H, 9·5. $C_{11}H_{17}NO$ requires C, 73·7; H, 9·55%). There

* Part X, *J.*, 1963, 4970.

[1] Crombie, *J.*, 1955, 995; Crombie and Tayler, *J.*, 1957, 2760.
[2] Manzoor-i-Khuda, Ph.D. Thesis, University of London, 1958.
[3] (*a*) Shaw and Whiting, *J.*, 1955, 999; (*b*) Crombie and Manzoor-i-Khuda, *J.*, 1957, 2767.

was end-absorption in the ultraviolet region (ε 4730 and 1790 at 239·5 and 252 mμ). On microhydrogenation the enyne absorbed 2·9 mol. of hydrogen. It had $\nu_{max.}$ 3268, 3067, 1626, 1550 (amide), 2126 (C≡C) 1669, 970 (*trans*-CH=CH) cm.$^{-1}$.

N-*Isobutyldodec*-cis- *and* -trans-10-*ene*-2,6,8-*triynamide*. *N*-Isobutylhept-2,6-diynamide (400 mg.) and pent-*cis*-3-en-1-yne (480 mg.) [3b,4] in methanol (8 ml.) were added to ammonium chloride (1·84 g.) and cuprous chloride (0·74 g.) in 0·08N-hydrochloric acid (8 ml.). After cooling, the mixture was shaken under oxygen for 24 hr. The product was acidified and extracted with ether. The ether extract was freed from suspended solid by filtration. After crystallisation from chloroform containing a little light petroleum (b. p. 40—60°), NN′-*di-isobutyltetradec*-2,6,8,12-*tetrayne*-1,14-*diamide* (VII) (51 mg.), m. p. 187—188°, was obtained (Found: C, 74·85; H, 8·05. $C_{22}H_{28}N_2O_2$ requires C, 74·95; H, 8·0%). It had end-absorption in the ultraviolet region which covered the weak diyne spectrum, and $\nu_{max.}$ (mull) 3279, 3049, 1626, 1534 (amide), 2269, 2238 (C≡C) cm.$^{-1}$. On microhydrogenation the diamide absorbed 7·95 mol. of hydrogen. The ethereal solution was evaporated and the residue, on crystallisation from ether–pentane, gave needles (206 mg.), m. p. 69—71°. Chromatography on alumina from chloroform, and further crystallisation, gave N-*isobutyldodec*-cis-10-*ene*-2,6,8-*triynamide* (III), plates or needles, m. p. 71—72° (Found: C, 79·65; H, 8·1. $C_{16}H_{19}NO$ requires C, 79·65; H, 7·95; N, 5·8%). On microhydrogenation 7·1 mol. of hydrogen were absorbed. The amide, which became pink in light, had $\lambda_{max.}$ (in EtOH) 239·5, 252, 266, and 282 mμ (ε 6800, 13,900, 19,500, and 15,000), and $\nu_{max.}$ (mull) 3279, 3049, 1629, 1536 (amide) 2239, 2265 (C≡C) and 711 (*cis*-CH=CH, def.) cm.$^{-1}$.

In a similar fashion *N*-isobutylhept-2,6-diynamide (560 mg.) and pent-*trans*-3-en-1-yne [3b,4] (700 mg.) gave the symmetrically coupled diamide (78 mg., m. p. 185—187°) and N-*isobutyldodec*-trans-10-*ene*-2,6,8-*triynamide* (II) (506 mg.), m. p. 112—113° (from ether–pentane) (Found: C, 79·2; H, 7·8; N, 5·7%). On microhydrogenation 6·7 mol. of hydrogen were absorbed. The amide had $\lambda_{max.}$ (in EtOH) 239, 252, 266, and 282 mμ (ε 9800, 14,000, 19,500, and 14,800) and $\nu_{max.}$ (mull) 3226, 3021, 1628, 1536 (amide), 2229, 2254 (C≡C) and 942 (*trans*-CH=CH, def.) cm.$^{-1}$.

N-*Isobutyldodec*-trans-2,cis-10- *and* -trans-2,trans-10-*diene*-6,8-*diynamide*. *N*-Isobutylhept-*trans*-2-en-6-ynamide (200 mg.) and pent-*cis*-3-en-1-yne (230 mg.) were oxidatively cross-coupled as above, to give symmetrically coupled product and crossed-coupled product. The first (deca-*cis*-2,*cis*-8-diene-4,6-diyne was eliminated in the working up), NN′-*di-isobutyltetradec*-trans-2,trans-12-*diene*-6,8-*diyne*-1,14-*diamide* (IX) (37 mg.), had m. p. 232—234° (Found: C, 74·0; H, 8·85. $C_{22}H_{32}N_2O_2$ requires C, 74·1; H, 9·05%), $\nu_{max.}$ (mull) 3268, 3049, 1621, 1541 (amide), 1669, 963 (*trans*-CH=CH) cm.$^{-1}$. The cross-coupled product, N-*isobutyldodec*-trans-2, cis-10-*diene*-6,8-*diynamide* (V) (136 mg.), formed needles (from ether–light petroleum or chloroform–light petroleum), m. p. 73—74° (Found: C, 78·55; H, 8·5. $C_{16}H_{21}NO$ requires C, 78·95; H, 8·7%). The amide became pink in light. On microhydrogenation it absorbed 5·9 mol. of hydrogen. It had $\lambda_{max.}$ (in EtOH) 239·5, 252, 266, and 282 mμ (ε 8700, 14,600, 19,700, and 14,700), $\nu_{max.}$ (mull) 3289, 3058, 1623, 1543 (amide), 2252 (C≡C), 1669 (*trans*-2,str.), 968 (*trans*-2, def.) and 711 (*cis*-10, def.).

When *N*-isobutylhept-*trans*-2-en-6-ynamide (200 mg.) and pent-*trans*-2-en-4-yne (250 mg.) were oxidatively cross-coupled the symmetrically coupled product above (29 mg.; m. p. 232—234°) was obtained, together with the cross-coupled product, N-*isobutyldodec*-trans-2,trans-10-*diene*-6,8-*diynamide* (IV) (130 mg.), plates, m. p. 133—134° (from chloroform–ether–light petroleum) (Found: N, 5·75. $C_{16}H_{21}NO$ requires N, 5·75%). On microhydrogenation 5·9 mol. of hydrogen were absorbed. The amide had $\lambda_{max.}$ (in EtOH) 239, 252, 266, 282 mμ (ε 10,900, 15,800, 20,000, 15,200), $\nu_{max.}$ (mull) 3268, 3058, 1623, 1546 (amide), 2249, 2153 (C≡C), 1667 (*trans*-2,str.), 968 (*trans*-2, def.) and 941 (*trans*-10, def., acetylene conj.) cm.$^{-1}$.

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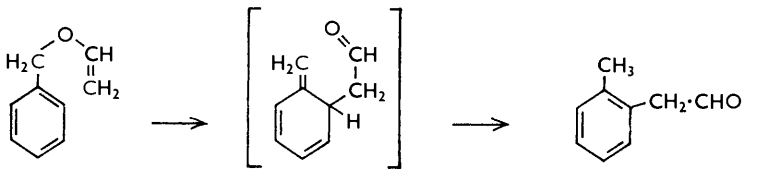
[*Received, February 28th*, 1963.]

[4] Allan and Whiting, *J.*, 1953, 3314; Crombie, Krasinski, and Manzoor-i-Khuda, *J.*, 1963, 4970.

955. *Thermal Rearrangement of Arylmethyl Vinyl Ethers.*

By A. W. Burgstahler, L. K. Gibbons, and I. C. Nordin.

In connection with studies on the Claisen rearrangement of allyl vinyl ethers to allyl-substituted acetaldehydes,[1] we became interested in the possibility of extending this type of transformation to arylmethyl vinyl ethers. For example, benzyl vinyl ether, by analogy with the conversion of allyl phenyl ether into *o*-allylphenol, might be expected to rearrange to *o*-tolylacetaldehyde:



In the present work, the thermal rearrangement of benzyl vinyl ether, 1- and 2-naphthylmethyl vinyl ether, 9-anthrylmethyl vinyl ether, and 9-phenanthrylmethyl vinyl ether has been investigated. These ethers were conveniently prepared from the corresponding arylmethanols by the vinyl transetherification technique of Watanabe and Conlon [2] or by Reppe's [3] method.

Benzyl vinyl ether either did not rearrange or merely polymerised in diglyme or decalin solution in sealed tubes at 225—260°. At still higher temperatures (270—300°) a mixture of polymeric and high-boiling products was formed in which the only detectable aldehydic product was a small amount of benzaldehyde. On the other hand, in the presence of di-t-butyl peroxide, rearrangement occurred at *ca.* 170°, but then the aldehydic product was largely β-phenylpropionaldehyde.

From these results it is clear that the thermal rearrangement of benzyl vinyl ether, at least in the liquid phase or in solution, does not proceed by the Claisen pathway. Instead, the formation of β-phenylpropionaldehyde points to a free-radical scission–recombination mechanism of the type established by Elkobaisi and Hickinbottom [4] for the thermal rearrangement of benzyl phenyl ether. The generation of benzyl radicals would be expected to yield β-phenylpropionaldehyde by the chain sequence:

$$Ph{\cdot}CH_2{\cdot} + CH_2{:}CH{\cdot}O{\cdot}CH_2Ph \longrightarrow Ph{\cdot}CH_2{\cdot}CH_2{\cdot}\dot{C}H{\cdot}O{\cdot}CH_2Ph \longrightarrow Ph{\cdot}CH_2{\cdot}CH_2{\cdot}CHO + Ph{\cdot}CH_2{\cdot}$$

The formation of 1,2-diphenylethane by the coupling of two benzyl radicals and the production of carbon monoxide by free-radical attack on the β-phenylpropionaldehyde might also be expected. In fact, both of these products were observed, together with considerable polymer. However, since our main interest lay in obtaining a Claisen-type rearrangement of an arylmethyl vinyl ether, only a qualitative examination of the foregoing reaction was made. Further investigation was centred on the rearrangement of polynuclear arylmethyl vinyl ethers, it being thought that a greater degree of double-bond character [5] at the reaction site in the aromatic ring might promote the Claisen process.

Accordingly, the thermal rearrangement of 1- and 2-naphthylmethyl, 9-anthrylmethyl, and 9-phenanthrylmethyl vinyl ether was examined. In the absence of di-t-butyl peroxide, rearrangement of these ethers to aldehydic products occurred in low yields at 230—270°. However, as with the peroxide-initiated rearrangement of benzyl vinyl ether, these aldehydes proved to be mainly the corresponding β-arylpropionaldehydes,

[1] Burgstahler and Nordin, *J. Amer. Chem. Soc.*, 1961, **83**, 198.
[2] Watanabe and Conlon, *J. Amer. Chem. Soc.*, 1957, **79**, 2828.
[3] Reppe, D.R.P. 550,403; U.S.P. 1,941,108; *Chem. Abs.*, 1934, **28**, 1357.
[4] Elkobaisi and Hickinbottom, *J.*, 1960, 1286.
[5] Pauling, " The Nature of the Chemical Bond," Cornell Univ. Press, Ithaca, New York, 3rd edn., 1960, p. 200.

together with which were formed the corresponding 1,2-diarylethanes and varying amounts of carbon monoxide. Moreover, in the presence of di-t-butyl peroxide the reaction proceeded at *ca.* 170°, and in higher yield, but when the rearrangement was attempted in dimethyl- or diethyl-aniline (free-radical inhibiting solvents which are generally useful in Claisen rearrangements) no aldehydic products were formed. It can be concluded, therefore, that Claisen rearrangement of an arylmethyl vinyl ether with interruption of ring aromaticity is not favoured, even in polynuclear aromatic systems.

Finally, as a test of the behaviour of a vinylogous arylmethyl vinyl ether, the rearrangement of cinnamyl vinyl ether was examined. In this case, as in the well-known related rearrangement of cinnamyl phenyl ether to 2-1′-phenylallylphenol, the normal Claisen rearrangement took place, and 3-phenylpent-4-enal was obtained in more than 70% yield. Thus, when a true allylic system is present, even when substituted by an aryl group, the ordinary Claisen rearrangement occurs in preference to the free-radical chain process observed in the rearrangement of arylmethyl vinyl ethers.

Experimental.—Preparation of arylmethyl vinyl ethers. In a typical vinylation (based on Watanabe and Conlon's procedure B [2]) recrystallised [1] mercuric acetate (2 g.) was added to a solution of benzyl alcohol (20 g.) in purified [1] ethyl vinyl ether (200 ml.). The resulting solution was refluxed for 10 hr., treated with additional mercuric acetate (1 g.), and refluxed for another 5 hr. It was then extracted twice with cold 10% potassium carbonate solution, dried (K_2CO_3), and concentrated under reduced pressure. Distillation of the oily residue from sodium yielded benzyl vinyl ether (15 g.; 60%), b. p. 85—87°/21 mm., n_D^{20} 1·5193, $\nu_{max.}$ ($CHCl_3$) 1640, 1610, and 1200 cm.$^{-1}$. This ether was also obtained by direct vinylation of benzyl alcohol with acetylene by Reppe's method,[3] but the yield was only 15%.

1-Naphthylmethanol (m. p. 59—61°) [6] and 2-naphthylmethanol (m. p. 80·5—82°) [7] were prepared in 95% yield by reduction of the corresponding ethyl naphthoate with lithium aluminium hydride. 1-Naphthylmethyl vinyl ether [b. p. 74—75°/0·05 mm., n_D^{20} 1·6069; $\nu_{max.}$ ($CHCl_3$) 1640, 1610, and 1200 cm.$^{-1}$] was obtained from the corresponding carbinol in 62% yield by the Watanabe–Conlon method.[2] 2-Naphthylmethyl vinyl ether was prepared similarly, and obtained as a solid [m. p. 37—38°; $\nu_{max.}$ ($CHCl_3$) 1640, 1610, and 1200 cm.$^{-1}$], which was purified by elution from basic alumina (Woelm, activity grade 1) with benzene–light petroleum (b. p. 40—50°) and recrystallisation from methanol.

Similar vinylation of 9-anthrylmethanol (m. p. 162—164°) [8] furnished *9-anthrylmethyl vinyl ether* (61% yield) which, after chromatography and crystallisation from benzene–light petroleum, was obtained as light yellow needles, m. p. 112—113°; $\nu_{max.}$ ($CHCl_3$) 1640, 1610, and 1195 cm.$^{-1}$ (Found: C, 87·3; H, 6·2. $C_{17}H_{14}O$ requires C, 87·15; H, 6·0%). In the same manner, *9-phenanthrylmethyl vinyl ether* was prepared in 74% yield from 9-phenanthrylmethanol (m. p. 151—152°).[9] After chromatography, it crystallised from ethanol as needles, m. p. 81—82°; $\nu_{max.}$ ($CHCl_3$) 1640, 1610, and 1195 cm.$^{-1}$ (Found: C, 87·2; H, 6·0%).

Thermal rearrangements. (*a*) *Benzyl vinyl ether.* When heated at 245° for 6—8 hr. in diglyme (diethylene glycol dimethyl ether) under nitrogen in a sealed tube, benzyl vinyl ether was recovered essentially unchanged. At 280° the solution darkened and, after 12 hr., a small amount of benzaldehyde [identified by infrared (i.r.) spectrum and as the 2,4-dinitrophenylhydrazone], was recovered in the fraction boiling below 100°/25 mm. Most of the product, however, consisted of a non-volatile residue which was not examined further.

In the presence of di-t-butyl peroxide (0·3 g.), the rearrangement of benzyl vinyl ether (2·0 g.), in diglyme or without solvent, occurred at 170° and was judged to be complete in 30—40 hr., on the basis of the disappearance of the vinyl ether peaks at 1640, 1610, and 1200 cm.$^{-1}$ in the i.r. spectrum. Below 170° the reaction was inconveniently slow. The spectrum of the product showed aldehyde absorption at 2720 and 1725 cm.$^{-1}$, but no aldehyde could be isolated by distillation at reduced pressure. Accordingly, the viscous brown product from another run was digested with four 5-ml. portions of 90% ethanol, and the contents of the combined extracts were stirred with an excess of silver oxide in aqueous ethanol at pH 9—9·5

[6] Ziegler, *Ber.*, 1921, **54**, 737.
[7] Bamberger and Boekman, *Ber.*, 1887, **20**, 1115.
[8] Hunter, Buck, Gubitz, and Bolen, *J. Org. Chem.*, 1956, **21**, 1512.
[9] Mosettig and van de Kamp, *J. Amer. Chem. Soc.*, 1933, **55**, 2995.

and 40° for 30 hr. Separation of the acidic product, by extraction with ether, furnished β-phenylpropionic acid (*ca.* 50 mg.), identified by i.r. spectrum and as the *S*-benzylthiouronium salt). Elution of the neutral fraction from basic alumina (Woelm, activity grade 1), with light petroleum, gave 1,2-diphenylethane (*ca.* 100 mg.), m. p. 50—51° (lit.,[10] m. p. 50—51°). During the rearrangement, *ca.* 20 ml. of a gas was evolved, which was identified as carbon monoxide by absorption into acidic copper(II) chloride solution. No oxygen or carbon dioxide was produced.

(*b*) 1- *and* 2-*Naphthylmethyl vinyl ether.* When 1- and 2-naphthylmethyl vinyl ether were heated in decalin at 275° for 5 hr., the vinyl ether peaks of the i.r. spectrum disappeared, but only weak absorption at 1725 cm.$^{-1}$ was produced and no aldehydic material could be isolated. In the presence of di-t-butyl peroxide at 170° 1-naphthylmethyl vinyl ether gave $<1\%$ yield of β-1-naphthylpropionaldehyde (identified by oxidation with silver oxide to the corresponding acid,[11] m. p. 153—155°). Although 2-naphthylmethyl vinyl ether reacted in the presence of di-t-butyl peroxide at 170°, the yield of aldehydic product was too small for convenient purification.

(*c*) 9-*Anthrylmethyl vinyl ether.* A solution of this ether (0·5 g.) and a few crystals of quinol in decalin (10 ml.) was heated at 250° under nitrogen, in a sealed tube, for 5 hr. After removal of the decalin by distillation under reduced pressure, a viscous dark brown residue remained, from which 0·2 g. of an insoluble solid was obtained by trituration with ethanol. On recrystallisation from toluene this formed light yellow needles of 1,2-di-9-anthrylethane, m. p. 318—320° (lit.,[12] m. p. 310°), $\nu_{max.}$ (KBr) 885, 840, 790, 735, and 725 cm.$^{-1}$ (Found: C, 94·0; H, 6·0. Calc. for $C_{30}H_{22}$: C, 94·2; H, 5·8%).

Treatment of the ethanol-soluble residue with silver oxide at pH 9·5 for 2 days at 45° gave β-9-anthrylpropionic acid (15 mg.) as pale yellow needles (from ethanol), m. p. and mixed m. p 191—193° (Found: C, 81·0; H, 5·6. Calc. for $C_{17}H_{14}O_2$: C, 81·6; H, 5·6%). The u.v. spectrum in ethanol was almost identical with that of 9-methylanthracene.[13] Authentic β-9-anthrylpropionic acid, m. p. 195—196°,[14] was prepared by the malonic ester synthesis from 9-bromomethylanthracene.

When rearrangement of the ether (0·5 g.) was conducted at 170° in the presence of di-t-butyl peroxide (0·3 g.), the vinyl ether peaks of the i.r. spectrum disappeared after 6 hr. However, the aldehyde peaks at 2720 and 1725 cm.$^{-1}$ were comparatively weak, and efforts to obtain the above acid by oxidation of the product with silver oxide were unsuccessful. On the other hand, use of only trace amounts of di-t-butyl peroxide failed to promote rearrangement at 170°, and in dimethyl- or diethyl-aniline the vinyl ether was unchanged after 5 hr. at 270°.

(*d*) 9-*Phenanthrylmethyl vinyl ether.* This ether (0·5 g.) and a few crystals of quinol were heated at 230° in decalin in a sealed tube for 8 hr.; the i.r. spectrum then indicated the presence of aldehydic material and the absence of vinyl ether. After removal of the decalin the ethanol-insoluble portion (0·2 g.) of the rearrangement product crystallised from dimethylformamide as small cubes, m. p. 252—256°, $\nu_{max.}$ (KBr) 885, 775, 750, 745, and 725 cm.$^{-1}$. This substance was identified as 1,2-di-9-phenanthrylethane by comparison with a sample (m. p. and mixed m. p. 251—256°) prepared by the method of Bachmann and Kloetzel.[15]

Treatment of the ethanol-soluble portion of the rearrangement product with 2,4-dinitrophenylhydrazine afforded a deep yellow derivative, tentatively identified as the *dinitrophenylhydrazone* of β-9-phenanthrylpropionaldehyde. After purification, by elution from alumina with benzene–light petroleum and crystallisation from the same solvent pair, this derivative had m. p. 211—212° (Found: C, 66·3; H, 4·6; N, 13·85. $C_{23}H_{18}N_4O_4$ requires C, 66·65; H, 4·4; N, 13·5%).

In another experiment, the ethanol-soluble product from the rearrangement of 9-phenanthrylmethyl vinyl ether (1·3 g.) in decalin, in the presence of di-t-butyl peroxide, gave on oxidation with silver oxide β-9-phenanthrylpropionic acid (0·21 g.), m. p. and mixed [15] m. p. 173—174° (Found: C, 81·0; H, 5·45. Calc. for $C_{17}H_{14}O_2$: C, 81·6; H, 5·6%). Esterification

[10] Fuson, *J. Amer. Chem. Soc.*, 1926, **48**, 2681.
[11] Fieser and Gates, *J. Amer. Chem. Soc.*, 1940, **62**, 2335.
[12] Beckwith and Waters, *J.*, 1956, 1108.
[13] Barnett, Cook, and Ellison, *J.*, 1928, 885.
[14] Daub and Doyle, *J. Amer. Chem. Soc.*, 1952, **74**, 4449.
[15] Bachmann and Kloetzel, *J. Amer. Chem. Soc.*, 1937, **59**, 2207.

with diazomethane gave the methyl ester, m. p. and mixed m. p. 69—70° (lit.,[15] m. p. 72—73°) (from methanol). For further identification, the ester was reduced with lithium aluminium hydride in refluxing ether to yield 3-9′-phenanthrylpropan-1-ol, m. p. and mixed m. p. 89—90° (from ligroin). The u.v. spectra of these derivatives of the rearrangement product showed $\lambda_{max.}$ (EtOH) 252, 277, 285, 297, 317, 325, 332, 340, and 349 mμ, identical with those in the spectrum of 9-methylphenanthrene.[16]

Preparation and rearrangement of cinnamyl vinyl ether. A solution of cinnamyl alcohol (5 g., m. p. 33—35°) and recrystallised [1] mercuric acetate (0·4 g.) in ethyl vinyl ether (50 ml.) was refluxed for 3 days. After addition of anhydrous potassium carbonate (5 g.) and evaporation of the ethyl vinyl ether, the mixture was taken up in light petroleum and the resulting solution was passed through a 1·5 × 20 cm. column of basic alumina. Two distillations gave cinnamyl vinyl ether (2·2 g.), b. p. 117—119°/26 mm., n_D^{20} 1·5060, $\nu_{max.}$ (CCl_4) 1640, 1610, and 1195 cm.$^{-1}$. For rearrangement, the ether (1·1 g.) was heated under nitrogen in diglyme (10 ml.) in a sealed tube at 190° for 6 hr. Dilution of the solution with water (75 ml.), extraction with light petroleum, and distillation afforded 3-phenylpent-4-enal (0·83 g., 75%), b. p. 120—121°/25 mm., $\nu_{max.}$ (CCl_4) 2720, 1725, and 915 cm.$^{-1}$; *2,4-dinitrophenylhydrazone*, yellow plates (from ethanol), m. p. 107—108° (Found: C, 60·1; H, 4·6; N, 16·3. $C_{17}H_{16}N_4O_4$ requires C, 60·0; H, 4·7; N, 16·5%). Hydrogenation of the aldehyde over palladium–charcoal gave 3-phenylpentanal [b. p. 124—126°/26 mm.], 2,4-dinitrophenylhydrazone, yellow plates (from ethanol), m. p. 105—107°.

By treatment with silver oxide in aqueous ethanol, 3-phenylpent-4-enal was converted into 3-phenylpent-4-enoic acid, a colourless oil; benzylamine salt, m. p. 102—103° (lit.,[17] m. p. 97—98°). Hydrogenation of the acid over palladium–charcoal gave 3-phenylpentanoic acid, m p. 60—61° (lit., m. p. 63°; [18] 58° [17]), after crystallisation from light petroleum. The benzylamine salt, from ethyl acetate, had m. p. 108—110° (lit.,[17] m. p. 96·5°).

This work was supported in part by a fellowship (to A. W. B.) from the Alfred P. Sloan Foundation and by a grant from the Petroleum Research Fund administered by the American Chemical Society.

Department of Chemistry, The University of Kansas,
Lawrence, Kansas, U.S.A. [*Received, March 19th*, 1963.]

[16] Greenhow, McNeil, and White, *J.*, 1952, 986.
[17] Campbell and Young, *J. Amer. Chem. Soc.*, 1949, **71**, 296.
[18] Barltrop, Acheson, Philpott, MacPhee, and Hunt, *J.*, 1956, 2938.

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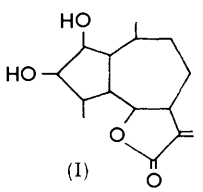
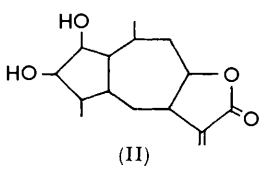
956. *The Revised Structure of Geigerinin.*

By J. P. de Villiers and K. Pachler.

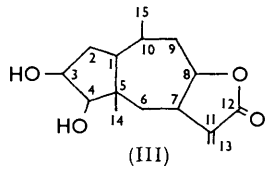
Two isomeric guaianolide structures (I) and (II), have been suggested for geigerinin,[1] a sesquiterpenoid lactone from *Geigeria aspera* Harv. Both structures are in full agreement with the chemistry of geigerinin, but they do not fit in with its nuclear magnetic resonance (n.m.r.) spectra, which can be accommodated by structure (III).



(I)



(II)



(III)

Experimental.—The spectra of geigerinin diacetate, the most suitable derivative, were recorded in deuterochloroform solution (~5 mol. %) on a Varian A60 high-resolution nuclear magnetic resonance spectrometer, with tetramethylsilane (τ = 10) as internal standard.

[1] de Villiers, *J.*, 1959, 2412.

As no explicit analysis of complicated patterns has been done, spin–spin interactions quoted refer to splittings only. The accuracy of the coupling constants is estimated to be $\pm 0{\cdot}2$ c./sec. and of τ values $\pm 0{\cdot}01$ p.p.m.

The n.m.r. data for geigerinin diacetate.

Proton	Position in (III)	τ	Multiplicity	Coupling constants (c./sec.)
$C\dot{C}H_2$	13	3·83, 4·56	AX	$\Delta\nu = 43{\cdot}2$. $J_{AX} = 3{\cdot}25$
CH·OAc	4	~4·7	ABXY	$\Delta\nu \sim 17$, $J_{AB} = 6{\cdot}7$
CH·OAc	3	~4·9		$J_{AX} = J_{AY} = 0$, $J_{BX} \neq J_{BY} \neq 0$
Angular H	8	5·75	Octet	$J_1 = 11{\cdot}2$, $J_2 = 9{\cdot}0$, $J_3 = 3{\cdot}2$
O·CO·CH_3	3 or 4	7·86	Singlet	
O·CO·CH_3	4 or 3	7·94	Singlet	
C·CH_3	14	8·95	Singlet	
CH·CH_3	15	9·01	Doublet	$J = 5{\cdot}3$

Discussion.—The presence of an AX system [2] due to the vinylidene group, of two acetoxy-groups with a proton on each carbon carrying an acetoxy-group, of two *C*-methyl groups and of a proton on the carbon carrying the lactonised hydroxyl groups, is in agreement with the previously suggested structures (I) and (II).

One of the *C*-methyl groups is, however, bound to a quaternary carbon, and the protons of the two carbons carrying the acetoxy-groups form an ABXY system, showing that one of the carbons with an acetoxy-group is adjacent to a methylene group. The AB coupling of this system (6·7 c./sec.) suggests that the two acetoxy-groups are in the *cis*-configuration (dihedral H–H angle ~0°).[3] The analysis of the proton on the carbon carrying the lactonised hydroxyl function furthermore established that the lactone is closed on to position 8, as in (II) or (III). The resonance pattern of this proton shows three splittings, which can be assigned to a large *cis*-coupling to the hydrogen on C-7, a large axial–axial, and an axial–equatorial interaction with the C-9 methylene protons.

The above n.m.r. evidence, and the previously reported chemistry,[1] support structure (III). This requires the migration of the methyl group from the 4 to the 5 position during the biosynthesis of the sesquiterpenoid. The formation of chamazulene during dehydrogenation can be explained by a reverse migration of the methyl group.

The new structure for geigerinin is analogous to structures recently advanced for parthenin and ambrosin,[4] and tenulin,[5] all of which had previously been considered to be guaianolides. In the tenulin series, the presence of the methyl group at position 5 has been confirmed, independently of n.m.r. spectra, by an *X*-ray study of bromoisotenulin.[6]

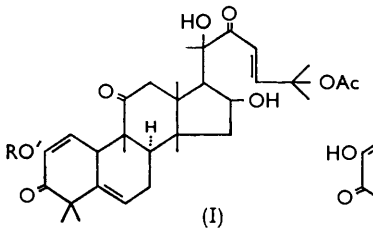
National Chemical Research Laboratory,
South African Council for Scientific and Industrial Research,
Pretoria, South Africa. [*Received, March 11th*, 1963.]

[2] Pople, Schneider, and Bernstein, " High Resolution Nuclear Magnetic Resonance," McGraw-Hill Book Co., Inc., New York, 1959.
[3] Lemieux, Kullnig, Bernstein, and Schneider, *J. Amer. Chem. Soc.*, 1957, **79**, 1005.
[4] Herz, Watanabe, Miyazaki, and Kishida, *J. Amer. Chem. Soc.*, 1962, **84**, 2601.
[5] Herz, Rohde, Rabindran, Jayaraman, and Viswanathan, *J. Amer. Chem. Soc.*, 1962, **84**, 3857.
[6] Rogers and Mazur-ul-Haque, *Proc. Chem. Soc.*, 1963, 92.

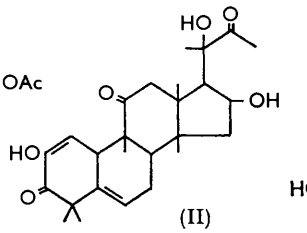
957. *Constituents of the Fruit of* Citrullus colocynthis.

By H. El Khadem and M. M. A. Abdel Rahman.

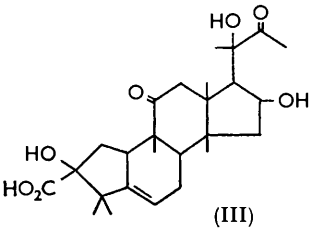
A glycoside isolated from a chloroform extract of the defatted fruit of *Citrullus colocynthis* is responsible for its anti-cancer activity.[1] We are studying the constituents of the pulp and peel of *Citrullus colocynthis* and the structure of this anti-cancer glucoside. Material removed in chloroform yields, on extraction with ether, the glucoside (I; R = D-glucopyranosyl) and its aglycone (α-elaterin) (I; R = H), as well as a dihydric alcohol, citrullol.[2] The glucoside, like α-elaterin,[3] has infrared bands 3570 and 3450 (OH), 1725 (Ac), 1685 (C:C·CO), and 1660, 1625, and 1415 (diosphenol) cm.$^{-1}$. It contained one acetyl group and gave on acetylation a penta-acetate having six acetyl groups, as expected for an α-elaterin glucoside. Three mols. of periodate were consumed, two by the sugar residue and one by the aglycone part.[4] One mol. of formic acid and no formaldehyde were produced, suggesting that the sugar residue was present in the pyranose form. This was



(I)



(II)



(III)

confirmed by gas chromatography of the methylated sugar obtained by methanolysis of the methylated glucoside, which showed the presence of methyl 2,3,4,6-tetra-*O*-methyl-α- and -β-D-glucopyranoside. The glucoside was not hydrolysed by emulsin, but acid hydrolysis liberated one mol. of D-glucose and an amorphous aglycone. The latter consumed one mol. of periodate and on acetylation yielded elateridin diacetate.[3] The aglycone, like α-elaterin and elateridin, was converted by boiling alkali into ecballic acid [3] (III) which is formed by a benzilic acid rearrangement of ring A and rupture of the side-chain of ring D. The glucoside on similar treatment, followed by acid hydrolysis, yielded a ketone (II) by rupture of the side-chain attached to ring D, but with no benzilic acid rearrangement in ring A. This ketone (II) had infrared bands 3450 (OH), 1700 (C=O), and 1660, 1625, and 1415 (diosphenol) cm.$^{-1}$. Like the aglycone and α-elaterin it gave a colour with ferric chloride whereas the glycoside and ecballic acid did not, denoting that the diosphenol group present in ring A was responsible for the colour and that the glucoside had the sugar residue attached to the 2-hydroxyl group, as shown in structure (I). We believe the glucoside to be identical with Walz's colocynthin.[5]

Two alcohols were isolated from the peel of *Citrullus colocynthis* and are under investigation.

Experimental.—Infrared absorption spectra were measured on Zeiss U.R. 10 and Perkin-Elmer model 13 spectrophotometers, and ultraviolet absorption spectra on a Unicam S.P. 500 spectrophotometer. Acetyl numbers were determined by the method of Kunz and Hudson,[6] and periodate oxidations as described earlier.[7]

Isolation and purification of the glucoside. Powdered, dried pulp of *Citrullus colocynthis*

[1] Lavie, Willner, Belkin, and Hardy, *Acta Unio Intern. Contra Cancerum*, 1959, **15**, 177.
[2] Power and Moore, *J.*, 1910, 99.
[3] Lavie and Szinai, *J. Amer. Chem. Soc.*, 1958, **80**, 707; Lavie, Shvo, Gottlieb, and Glotter, *J. Org. Chem.*, 1962, **27**, 4546.
[4] Lavie, Shvo, and Willner, *J. Amer. Chem. Soc.*, 1959, **81**, 3062.
[5] Walz, *N. Jahrb. Pharm.*, 1858, **9**, 16, 225; 1861, **16**, 10.
[6] Kunz and Hudson, *J. Amer. Chem. Soc.*, 1926, **48**, 1982.
[7] El Khadem and Megahed, *J.*, 1956. 3956.

(3 kg.) was defatted with light petroleum (b. p. 60—80°), then extracted with chloroform, and the dark brown extract was concentrated and dried. The product (500 g.) was continuously extracted with ether, which after 0·5 hr. started to deposit yellow crystals, m. p. 148—152°. These were collected daily and washed with ether (total yield, 72 g.), dissolved in ethanol, filtered from a colourless insoluble portion (mainly citrullol), recovered by evaporation, mixed with kieselguhr, and extracted once more with ether (Soxhlet). A bitter, yellow crystalline glucoside separated in the flask and was purified by repeated Soxhlet extractions with ether until a thin-layer chromatogram on silica gel with chloroform–water as solvent showed only one spot on spraying with sulphuric acid. The *glucoside* had m. p. 158—160°, $[\alpha]_D$ +50° (*c* 0·4 in EtOH), $\lambda_{max.}$ 234—236 mμ (log ε 4·11), and $\nu_{max.}$ 3570, 3450, 1725, 1685, 1625, 1425, 1415, 1390, 1370, 1250, 1220, 1120, and 1070 cm.$^{-1}$, and was soluble in ethanol, acetone, or chloroform and slightly insoluble in ether or water (Found: C, 60·0, 60·2; H, 7·7, 7·8; Ac, 3·6. $C_{38}H_{54}O_{13},2H_2O$ requires C, 60·5; H, 7·7; 1Ac, 5·7%). It consumed 3·2 mol. of sodium periodate and liberated 1·4 mol. of formic acid and no formaldehyde.

With acetic anhydride in pyridine the glucoside gave its penta-acetyl derivative, $\nu_{max.}$ 3430, 1740, 1725, 1680, 1652, 1440, 1420, 1365, 1215, 1120, 1030, 990, 890, and 960 cm.$^{-1}$ (Found: C, 61·8; H, 7·1; Ac, 25·0. $C_{48}H_{64}O_{18}$ requires C, 62·1; H, 6·9; 6Ac, 27·8%).

Hydrolysis of the glucoside. The glucoside (2 g.) in ethanol (5 ml.) was heated with 5% sulphuric acid (50 ml.) for 4 hr. at 100°. The amorphous aglycone which separated was filtered off, washed with water, and dried in a vacuum; it consumed 0·9 mol. of sodium periodate, liberating no formaldehyde.

After removal of the aglycone, the hydrolysate was neutralised with barium carbonate and passed through a cation-exchange resin, then continuously extracted with ether (to remove the last traces of aglycone) and evaporated to dryness in a vacuum. The colourless gummy sugar obtained slowly crystallised and had m. p. 80° alone or mixed with D-glucose monohydrate and $[\alpha]_D$ +30 (*c* 1·0 in H_2O). One-dimensional paper chromatograms developed with the upper layer of butanol–ethanol–water (4 : 1 : 5) and sprayed with 10% ammonium molybdate [8] showed one spot (glucose). Other portions of glucose from the hydrolysate gave the phenylosazone, m. p. 210°, and *p*-nitrophenylhydrazone, m. p. 189° (mixed m. p.s). Estimation of glucose in the glucoside hydrolysate by Jendrassik and Polgar's method [9] indicated 1·2 mol. of glucose.

Methylation of the glucoside. The glucoside (5 g.) in methanol (50 ml.) was treatd with 5% ethereal diazomethane (300 ml.) and left overnight to evaporate at room temperature. The residue was taken up in acetone (15 ml.) and treated with dimethyl sulphate (10 g.) and 30% sodium hydroxide solution. The methylated glucoside was then taken up in chloroform, washed with water, and remethylated after removal of the chloroform. The product (MeO, 12·3%) was refluxed with 1% methanolic hydrogen chloride for 2 hr., then neutralised with silver carbonate. The mixture was filtered, treated with water to precipitate the methylated aglycone, filtered again, and evaporated to dryness. The product distilled (120°/0·4 mm.) and was subjected to vapour-phase chromatography on butane-1,4-diol succinate polyester at 175° and on *m*-di-(*m*-phenoxyphenoxy)benzene at 200°. Peaks corresponding to methyl 2,3,4,6-tetra-*O*-methyl-α- and -β-D-glucopyranoside were obtained as well as a small amount of less fully methylated material.

Aglycone acetate. The aglycone with acetic anhydride in pyridine gave elateridin diacetate as needles (from ethanol), m. p. and mixed m. p. 137—140° (Found: C, 67·6; H, 7·8; Ac, 14·4. Calc. for $C_{34}H_{46}O_9$: C, 68·2; H, 7·7; 2Ac, 14·4%).

Ecballic acid. The aglycone (2 g.) was boiled with 2% sodium hydroxide solution (160 ml.) under reflux for 3 hr. Cooling and acidifying the solution with hydrochloric acid gave a pale yellow gelatinous precipitate, which was filtered off and washed with water. The filtrate and washings were continuously extracted with ether, and the extract dried and evaporated, giving ecballic acid that, crystallised from methanol–water, had m. p. and mixed m. p. 260° (Found: C, 66·4; H, 7·8. Calc. for $C_{26}H_{38}O_7,\frac{1}{2}H_2O$: C, 66·2; H, 8·3%).

Methyl ketone from the glucoside. The glucoside (2 g.) was boiled with 2% sodium hydroxide solution (200 ml.) for 2·5 hr. Acidification and warming with dilute hydrochloric acid gave a yellow precipitate which was collected and washed with water. This *ketone* (II) crystallised

[8] El Khadem and Hanessian, *Analyt. Chem.*, 1958, **30**, 1965.
[9] Jendrassik and Polgar, *Biochem. Z.*, 1940, **304**, 271.

from ethanol in yellow prisms, m. p. 268—269° (Found: C, 70·9; H, 7·7; O, 20·9. $C_{26}H_{36}O_6$ requires C, 70·3; H, 8·1; O, 21·6%).

Isolation of α-elaterin. On concentration of the ethereal mother-liquor which deposited the glucoside and addition of ethanol, colourless crystals separated which crystallised from ethanol in hexagonal crystals. It had m. p. and mixed m. p. 236—238° and its ultraviolet and infrared spectra were identical with those of authentic α-elaterin (Found: C, 69·0; H, 7·9; O, 23·0. Calc. for $C_{32}H_{44}O_8$: C, 69·0; H, 7·8; O, 23·0%).

Isolation of the higher alcohol. Powdered dried peel (6·3 kg.) was defatted with light petroleum (b. p. 60—80°), and the green petroleum extract concentrated to 500 ml.; a greenish wax was precipitated. It was purified by repeated crystallisations from methanol, followed by saponification with alcoholic potassium hydroxide and sublimation at 240°/0·2 mm. The pure alcohol had m. p. 72—76° and $\nu_{max.}$ 3360, 1720, 1305, 1240, 1165, 1100, 1070, 1065, 1050, 965, and 905 cm.$^{-1}$, and was soluble in methanol, ethanol, chloroform, carbon tetrachloride, and ethyl acetate (Found: C, 82·0, 81·7, 82·1; H, 14·0, 14·0, 14·1. Calc. for $C_{27}H_{56}O$: C, 81·7; H, 14·2%). Its acetate (from ethanol) had m. p. 62—64° (Found: C, 80·1; H, 13·5. Calc. for $C_{29}H_{58}O_2$: C, 79·5; H, 13·3%).

Isolation of citrullol. (*A*) Citrullol was obtained from the alcohol-insoluble portion of the glucoside by repeated crystallisations from ethanol. It had m. p. 282—283° (Found: C, 72·5; H, 10·3; O, 17·1. Calc. for $C_{22}H_{38}O_4$: C, 72·1; H, 10·4; O, 17·5%).

(*B*) The dried defatted peel was extracted with hot ethanol and the extract concentrated to 1 l. Crystals separated during the concentration, and were collected, washed with water, and crystallised from ethanol. A further amount of citrullol was obtained by concentrating the alcoholic extract to 500 ml., treating it with water (300 ml.), and crystallising the precipitate from ethanol. Citrullol had m. p. and mixed m. p. 282—283° (Found: C, 71·6; H, 10·3; O, 17·6%). With acetic anhydride in pyridine it gave a *diacetate*, needles (from ethanol), m. p. 162° (Found: C, 69·7; H, 9·2. $C_{26}H_{42}O_6$ requires C, 69·3; H, 9·4%).

The authors thank Dr. G. O. Aspinall, University of Edinburgh, for carrying out and interpreting the vapour-phase chromatograms, and Professor F. G. Baddar, University of Ein Shams, for measuring the infrared spectra.

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[*Received, March 19th*, 1963.]

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958. *The Critical Temperatures of Covalent Fluorides.*

By D. C-H. CHENG and J. C. MCCOUBREY.

A NUMBER of newly measured (cf. ref. 1) critical temperatures for fluorocarbons and other fluorides are recorded in the Table together with values of the critical pressure calculated by Lydersen's group method.[2] For completeness a number of measured critical temperatures and critical pressures have been added from the literature.

The results in the Table serve to extend the generalisation that the critical temperatures of covalent fluorinated compounds of quite high molecular weight are remarkably low, the phosphonitrilic fluorides apparently behaving in a very similar way to fluorocarbons. They show that the effect of introducing a double bond into fluorocarbons is small but positive (*ca.* 5°). The introduction of a dipole moment in the monohydrofluorocarbons appears to increase T_c by about 20° over the value for the perfluoro-compound. This may be compared with the increase [5] of 70° in T_c which occurs on passing [3] from tetrafluoromethane to fluoroform and demonstrates the dilution of such dipole moments when these arise in longer chains.

Simple molecules such as inert gases or methane have intermolecular forces which can

[1] Cheng, McCoubrey, and Phillips, *Trans. Faraday Soc.*, 1962, **58**, 224.
[2] Hougan, Watson, and Regatz, " Chemical Process Principles. Part I," Wiley, New York, 1954.
[3] Minnesota Mining and Manufacturing Co., leaflet on Fluorocarbons.

Compound	Measured T_c °C	Measured or estimated p_c (atm.) (Lydersen [2])	Deviation parameter ω
CF_4	−47·3° [3]	42·1	0·23 [3]
PF_3	−2·1 [4]	42·7 [4]	0·20 [4]
$CF_3{\cdot}CF_3$	19·7 [5]	31·2	0·26 [5]
$CF_3{\cdot}CF_2{\cdot}CF_2{\cdot}CF_3$	113·3 [6]	23 [6]	0·39 [6]
$CF_3{\cdot}CF_2{\cdot}CF_2{\cdot}CF_2{\cdot}CHF_2$	170·8	18·2	(0·4)
$CF_3{\cdot}CF_2{\cdot}CF_2{\cdot}CF_2{\cdot}CF_2{\cdot}CF_3$	176·4	15·3	0·49 [7]
$CF_2{:}CF{\cdot}CF_2{\cdot}CF_2{\cdot}CF_2{\cdot}CF_3$	181·2 *	16·5	(0·4)
$CF_3{\cdot}CF_2{\cdot}CF_2{\cdot}CF_2{\cdot}CF_2{\cdot}CHF_2$	198·6	15·7	(0·4)
$CF_3{\cdot}CF_2{\cdot}CF_2{\cdot}CF_2{\cdot}CF_2{\cdot}CF_2{\cdot}CF_3$	201·7 [8]	16 [8]	0·56 [5]
$CF_2{:}CF{\cdot}CF_2{\cdot}CF_2{\cdot}CF_2{\cdot}CF_2{\cdot}CF_3$	205·0 *	14·5	(0·45)
$CF_3{\cdot}CF_2{\cdot}CF_2{\cdot}CF_2{\cdot}CF_2{\cdot}CF_2{\cdot}CHF_2$	222·6	13·8	(0·45)
cyclo-C_6F_{12}	184·0 [9]	19·2	0·42 [9]
cyclo-C_6F_{10}	188·6	21·3	(0·38)
cyclo-$C_6F_{11}H$	204·5	19·9	~0·3)
cyclo-$C_6F_{11}{\cdot}CF_3$	213·5 [9, 6]	15·8	0·47 [9]
C_6F_6	242·7	27·4	0·48 [10]
$C_{10}F_8$	399·9 †	20·2	(0·8)
$(PNF_2)_3$	187·7	—	0·67 [10, 11]
$(PNF_2)_4$	223·2	—	0·86 [10, 11]
$(PNF_2)_5$	250·8 *	—	0·75 [10, 11]

* Slight decomposition appeared to occur; T_c obtained by extrapolation to zero time. † Slight decomposition appeared to occur; no change in T_c with time.

be described accurately by an intermolecular potential of the form [12] $\phi(r) = \varepsilon f(\sigma/r)$, where ε is an energy parameter, σ a length parameter, and r the distance between molecular centres. Only these molecules accurately obey the well-known principle of corresponding states.

Pitzer *et al.*[13] showed that a wider form of this principle may be enunciated in which properties such as the reduced vapour pressure p/p_c, when plotted against reduced temperature T/T_c, give, not a single curve as required by simple theory, but a recognisable family of curves. The difference between ln p/p_c at $T/T_c = 0{\cdot}7$ for a test substance and that for an inert gas has been designated as a significant measure, ω, of the departure of the operative intermolecular potential from the inert-gas potential. Values of $\omega > 0$ arise from increases in the steepness and narrowness of the central potential or from orientation-dependent interactions which also narrow the potential-energy curve.

Values of ω have been calculated by the methods of Pitzer *et al.* and are shown in Table 1 to be very large for fluorides. Where possible the ω values are obtained from the measured entropies of vaporisation: in other cases, approximate values can be calculated by using the Lydersen critical pressure and the existing vapour-pressure data. The differences (ω fluoride − ω hydride) show an interesting constancy for the series C_1 (0·21), C_2 (0·16), n-C_4 (0·20), n-C_6 (0·19), n-C_7 (0·21), cyclo-C_6 (0·20) (data for the hydrocarbon being taken from Project 44 [14] as previously discussed by McCoubrey [15]), suggesting that there is little change in the intermolecular forces on passing from a hydrocarbon to its corresponding fluorocarbon, other than the difference arising from the more important part played by the peripheral atoms in the fluorocarbon interaction.[16]

[4] Tennessee Valley Authority, Chemical Engineering Report No. 8, 1950.
[5] Pace and Aston, *J. Amer. Chem. Soc.*, 1948, **70**, 566.
[6] Fowler, Hamilton, Kasper, Weber, Durford, and Anderson, *Ind. Eng. Chem.*, 1947, **39**, 375.
[7] Dunlap, Murphy, and Bedford, *J. Amer. Chem. Soc.*, 1958, **80**, 83.
[8] Oliver and Grisard, *J. Amer. Chem. Soc.*, 1951, **73**, 1688.
[9] Rowlinson and Thacker, *Trans. Faraday Soc.*, 1957, **53**, 1.
[10] Albright and Wilson (Mfg.) Ltd., unpublished results.
[11] Chapman, Paine, Paddock, Searle, and Smith, *J.*, 1960, 3608.
[12] Hirschfelder, Curtiss, and Bird, "Molecular Theory of Gases and Liquids," Wiley, New York 1954.
[13] Pitzer, Lippmann, Curl, Huggins, and Petersen, *J. Amer. Chem. Soc.*, 1955, **77**, 3433.
[14] A.P.I. Project 44, Nat. Bureau Standards.
[15] McCoubrey, *Fuel*, 1956, **35**, 343.
[16] Rowlinson, *Austral. J. Chem.*, 1954, **7**, 397.

To test this we examine the ratio

$$\frac{T_c \text{ (fluorocarbon)}}{T_c \text{ (hydrocarbon)}} = \frac{xT_c(CF_3) + yT_c(CF_2)}{xT_c(CH_3) + yT_c(CH_2)},$$

the quantities x and y being the number of relevant groups in the molecule.

Comparison of the potentials for the inert gases and methane suggests plausible values to be $T_c(CH_3) = 0{\cdot}9T_c(CH_4)$, and $T_c(CH_2) = 0{\cdot}8T_c(CH_4)$.

Inserting these values in the equation and using experimental critical temperatures for C_2, n-C_4, n-C_6, n-C_7 and cyclo-C_6 compounds, we obtain the parameters $T_c(CF_3)$ to be $0{\cdot}73$, $T_c(CF_4)$ and $T_c(CF_2)$ to be $0{\cdot}57T_c(CF_4)$.

These values are further consistent with the physical picture that the peripheral atoms are dominant in fluorocarbon potentials since the values of T_c for CF_4, CF_3, and CF_2 are roughly in the ratio 4 : 3 : 2.

It seems clear that the covalent fluorides have intermolecular forces which are dominated by the fluorine atoms, these atoms largely screening the intermolecular forces between the molecular cores, which serve mainly to determine the geometrical arrangement.

Experimental.—Measurements of critical temperatures have been made by the "disappearing meniscus" method in sealed tubes. Details of the present experimental arrangements have been described previously.[1] Temperatures were measured either on mercury in glass thermometers, checked against N.P.L.-calibrated thermometers, or on a calibrated thermocouple, which had been thoroughly proved by being used to measure the critical temperatures of standard hydrocarbons within 0·1—0·2°.

Materials. The following samples were kindly given to us by Imperial Chemical Industries Limited, General Chemicals Division (the measured atmospheric boiling temperatures are recorded in parentheses): perfluorohexane (56·6°), 1*H*-undecafluoropentane, 1*H*-tridecafluorohexane (71·5°), 1*H*-pentadecafluoroheptane (86·8°/768 mm.), perfluorocyclohexene (53·0°/768 mm.), and undecafluorocyclohexane (a glass at room temperatures).

These materials have been shown by nuclear magnetic resonance typically to contain up to 5—10% of impurities which are other fluorocarbons of comparable chain length and are therefore unlikely to cause any serious error ($<$1—2°) in the critical temperatures.

Samples of perfluorobenzene (80·6°) and perfluoronaphthalene were kindly given to us by the Imperial Smelting Corporation. The benzene was stated to be 99% pure and the naphthalene 90%, though the latter was probably better than the figure quoted.

The phosphonitrilic fluorides were kindly supplied by Albright and Wilson (Mfg.) Limited. They were shown by infrared analysis to be pure, apart from a trace of solvent (nitrobenzene) which was removed by bulb-to-bulb fractionation *in vacuo*. The atmospheric b. p. of the trimer, tetramer, and pentamer are reported by Albright and Wilson as 50·9°, 89·7°, and 119·3° (extrapolated), respectively, for materials of similar purity.

We are grateful to Dr. L. Pratt for the nuclear magnetic resonance analyses. One of us (D. C-H. C.) is indebted to the Department of Scientific and Industrial Research for a Research Studentship.

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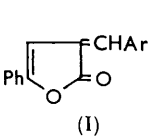
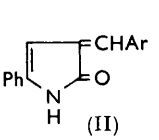
[*Received, March 20th,* 1963.]

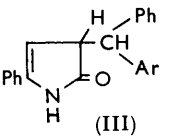
959. *Preparation and Reactions of 4-Arylidene-5-oxo-2-phenyl-2-pyrrolines.*

By Y. S. Rao and R. Filler.

Several reactions of 4-arylidene-5-oxo-2-phenyl-2-pyrrolines (II) have been studied. These new conjugated γ-lactams are prepared in 70—80% yield from the corresponding butenolides (I) in a one-step process, by reaction with aqueous ammonia in the presence of potassium carbonate, in much the same manner as 5-oxazolones are converted into 5-imidazolones.[1] The reactions of the lactones (I) have been explored extensively [2-5] and the *N*-benzyl analogue of the pyrroline (IIa) has been prepared from (Ia) by a two-step procedure.

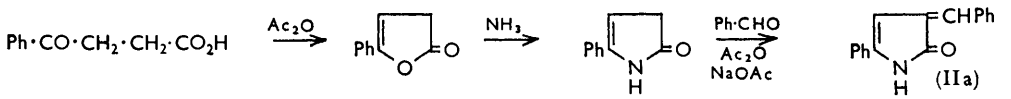

(I)


(II)


(III)

Ar = (a) Ph,
(b) o-Cl·C$_6$H$_4$,
(c) p-Cl·C$_6$H$_4$.

Compound (IIa) shows $\nu_{max.}$ 3240 (>NH) and 1675 cm.$^{-1}$ (lactam CO), and the maxima at 410, 308, and 258 mμ are in agreement with data for the *N*-benzyl-lactam.[2] The structure of the pyrroline (IIa) was confirmed by (*a*) liberation of ammonia and isolation of 2-phenacylcinnamic acid on treatment with alcoholic alkali, and (*b*) its preparation by an alternative route:



It reacted with benzene in the presence of anhydrous aluminium chloride to give the 1,4-addition product, 4-diphenylmethyl-5-oxo-2-phenyl-2-pyrroline (IIIa) in 20% conversion. Much of the starting material was recovered. The structure of (IIIa) was established by hydrolysis with alcoholic sodium hydroxide to give ammonia and α-phenacyl-ββ-diphenylpropionic acid; it was also identical with a sample prepared from α-diphenylmethyl-γ-phenylbut-2-enolide.[4] This behaviour of the lactam was in marked contrast to that of the butenolides, which, under similar conditions, undergo intramolecular alkylation.[5] With phenylmagnesium bromide, compounds (IIa—c) gave 1,4-addition products exclusively, in 70—75% yield.

Experimental.—M. p.s were determined on a Fisher-Johns block. Infrared spectra were obtained on a Perkin-Elmer 21 spectrophotometer for dichloromethane solutions, and ultraviolet spectra on a Beckman DK-2 spectrophotometer for ethanol solutions.

α-Arylidene-γ-phenylbut-2-enolides (I). These were prepared as previously described.[2]

Conversion of butenolides into 4-arylidene-5-oxo-2-phenyl-2-pyrrolines (II). The butenolide (5 g.) was mixed with water (12·5 ml.), 95% ethanol (25 ml.), and concentrated aqueous ammonia (5 g.), and the mixture refluxed for ½ hr. Concentrated aqueous ammonia (25 ml.) and potassium carbonate (5 g.) were added and heating continued for 1 hr. during which time more ammonia was added. The orange-red product was washed with hot water and alcohol and crystallised from ethanol–benzene. The following compounds were prepared: *4-benzylidene-5-oxo-2-phenyl-2-pyrroline* (IIa) (80%), m. p. 227° (decomp.) (Found: C, 82·35; H, 5·5. $C_{17}H_{13}NO$ requires C, 82·55; H, 5·3%); *4-o-chlorobenzylidene-5-oxo-2-phenyl-2-pyrroline* (IIb) (75%), m. p. 203° (decomp.) (Found: C, 72·35; H, 4·4. $C_{17}H_{12}ClNO$ requires C, 72·75; H,

[1] Williams and Ronzio, *J. Amer. Chem. Soc.*, 1946, **68**, 647.
[2] Filler and Hebron, *J. Amer. Chem. Soc.*, 1959, **81**, 391.
[3] Filler, Mark, and Piask, *J. Org. Chem.*, 1959, **24**, 1780.
[4] Filler, Piasek, and Mark, *J. Org. Chem.*, 1961, **26**, 2659.
[5] Filler and Leipold, *J. Org. Chem.*, 1962, **27**, 4440.

4·3%); 4-p-*chlorobenzylidene*-5-*oxo*-2-*phenyl*-2-*pyrroline* (IIc) (70%), m. p. 223° (decomp.) (Found: C, 72·3; H, 4·35%).

Alkaline hydrolysis of 4-*benzylidene*-5-*oxo*-2-*phenyl*-2-*pyrroline* (IIa). To the compound (0·5 g.) was added 6N-sodium hydroxide (20 ml.) in alcohol and the mixture was heated under reflux for 3 hr. during which time ammonia was evolved. The mixture was acidified with 20% hydrochloric acid, and the product filtered off and dried to give 2-phenacylcinnamic acid, m. p. and mixed m. p. 173° (0·4 g.) (from ethyl acetate).

γ-Phenylbut-2-*enolide*. β-Benzoylpropionic acid (10 g.) was mixed with acetic anhydride (10 ml.) and the mixture was heated on a hot plate for 1½ hr. The red oily product was steam-distilled, to give the butenolide (1·4 g.), m. p. 91°. The remaining oil was extracted with ether, and the solution yielded starting material (4·0 g.).

5-*Oxo*-2-*phenyl*-2-*pyrroline*. The butenolide (0·5 g.) was converted into the pyrroline by the procedure described earlier. The red oil had $\nu_{max.}$ 3240 and 1705 cm.$^{-1}$ (γ-lactam C=O).

Conversion of 5-*oxo*-2-*phenylpyrroline into compound* (IIa). The above pyrroline (0·4 g.) was heated with benzaldehyde (0·5 ml.), acetic anhydride (2 ml.), and sodium acetate (0·25 g.) for ½ hr. The mixture was left overnight in the refrigerator and then poured into water. The orange solid gave the product (0·2 g.), m. p. 226—227° (from ethanol–benzene), identical with compound (IIa) above.

Reaction of compound (IIa) *with benzene under Friedel–Crafts conditions*. A mixture of anhydrous aluminium chloride (2·2 g.) and dry benzene (50 ml.) was cooled to 10° and stirred for 1 hr. in a nitrogen atmosphere. To this mixture, at 10—20°, was added dropwise 4-benzylidene-5-oxo-2-phenyl-2-pyrroline (1·0 g.) in dry benzene (50 ml.). The mixture turned deep orange. When all the pyrroline had been added, stirring was continued for a further 3 hr. at room temperature and the complex decomposed with dilute hydrochloric acid (100 ml.) to form two clear layers. Unused starting material (0·6 g.) remained suspended in the aqueous layer. The benzene layer was washed with water and dried ($MgSO_4$), and the benzene removed, to give a pale yellow material (IIIa) (0·2 g.), m. p. 237°, $\nu_{max.}$ 3240 and 1705 cm.$^{-1}$ (>NH and C=O).

Reaction of 4-*arylidene*-5-*oxo*-2-*phenyl*-2-*pyrrolines* (II) *with phenylmagnesium bromide*. To magnesium metal (0·3 g.) in anhydrous ether (15 ml.) was added dropwise bromobenzene (1·5 ml.) in ether (10 ml.). The mixture was heated under reflux, and compound (II) (1 g.) in ether (50 ml.) was added in portions during 2 hr. The mixture was refluxed for an additional 2 hr. and decomposed with 8% sulphuric acid. The ether layer was washed with water and dried ($MgSO_4$), and the ether evaporated by air-blowing, to give a solid, which was crystallised from ethanol–benzene. The following compounds were prepared: 4-*diphenylmethyl*-5-*oxo*-2-*phenyl*-2-*pyrroline* (IIIa) (75%), m. p. 237° (decomp.) (Found: C, 85·05; H, 5·85. $C_{23}H_{19}NO$ requires C, 84·9; H, 5·85%); 4-2′-*chlorodiphenyl*-5-*oxo*-2-*phenyl*-2-*pyrroline* (IIIb) (70%), m. p. 197° (decomp.) (Found: C, 76·55; H, 5·0. $C_{23}H_{18}ClNO$ requires C, 76·8; H, 5·0%); 4-4′-*chlorodiphenylmethyl*-5-*oxo*-2-*phenyl*-2-*pyrroline* (IIIc) (65%), m. p. 219° (decomp.) (Found: C, 76·9; H, 5·1%).

Alternative preparation of 4-*diphenylmethyl*-5-*oxo*-2-*phenyl*-2-*pyrroline*. 2-Diphenylmethyl-4-phenylbut-2-enolide [4] (0·5 g.) was treated with ammonia and potassium carbonate, as described above. The product, m. p. 237°, was identical with compound (IIIa). It was hydrolysed with sodium hydroxide to give, after acidification, α-phenacyl-ββ-diphenylpropionic acid, m. p. and mixed m. p.[4] 186°.

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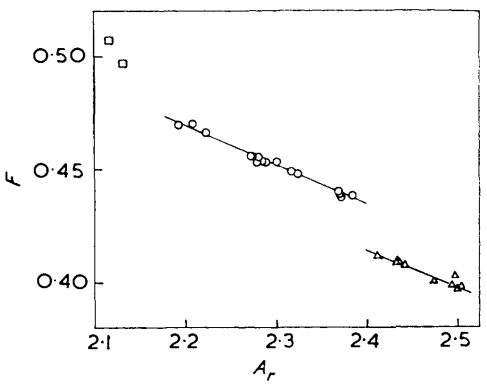
[*Received, March 29th*, 1963.]

960. *Fluoranthene-like Hydrocarbons:* MO–LCAO *Study of Electronic Spectra, Charge-transfer Spectra, and Polarographic Reduction.*

By R. Zahradník, J. Michl, and J. Koutecký.

The simple Hückel MO–LCAO method has been used to calculate orbital energies and molecular orbitals for thirty-nine fluoranthene-like hydrocarbons (*e.g.*, fluoranthene, rubicene, and their benzo-derivatives). The assignment of the longest-wavelength intense bands in the electronic spectra of these hydrocarbons [1] to the *p*-bands, by analogy with structurally similar benzenoid hydrocarbons, is supported by semi-empirical CI calculations on fluoranthene itself (for the method and parameters used, see ref. 2). This calculation predicts a weak absorption at 373 mμ ($f = 0{\cdot}02$) and a stronger one at 346 mμ ($f = 0{\cdot}6$), arising from L_a and L_b transitions into states in which the predominant configurations are $2\rightarrow1'$ and $1\rightarrow1'$, respectively. A shoulder near 380 mμ and an intense band at 359 mμ are observed experimentally.[1] Excitation energies estimated from the positions of the first intense bands can be correlated closely with theoretical values of the $N\rightarrow V_1$



Free valency, F, plotted against atomic localisation energy A_r. Positions of class 0, 1, and 2 denoted by △, ○, and □, respectively.[5]

transition energies. The regression line is close to that of benzenoid hydrocarbons, in agreement with results from the CI calculations, which show that the electron repulsion contributes roughly the same amount to the excitation energy of the $1\rightarrow1'$ transition in fluoranthene and in benzenoid hydrocarbons. Also, there is a significant correlation between the energies of the highest occupied molecular orbitals and the charge-transfer excitation energies of the complexes with trinitrofluorenone studied by Lepley.[3] An especially close correlation has been found between the half-wave potentials of cathodic waves of the hydrocarbons reported by Bergman [4] and the energies of the lowest free molecular orbitals. The Table summarises the results and contains, for comparison, a survey of analogous data for benzenoid hydrocarbons.

Further, the following reactivity indices have been calculated for a selected group of representatives: electron density, free valency, Wheland's atomic localisation energies, and exact and approximate superdelocalisabilities. A fair correlation has been found between localisation energies (A_e, A_r, and A_n) and the corresponding superdelocalisabilities

[1] Clar, "Aromatische Kohlenwasserstoffe," Springer, Berlin, 1952; Clar and Willicks, *Annalen*, 1956, **601**, 193; *Chem. Ber.*, 1956, **89**, 743; *J.*, 1958, 942; Zander, *Chem. Ber.*, 1959, **92**, 2740; Lang *et al.*, *Chem. Ber.*, 1956, **89**, 2734; 1957, **90**, 2888, 2894; 1961, **94**, 523, 1075, 1871; 1962, **95**, 973.
[2] Koutecký, Paldus, and Zahradník, *J. Chem. Phys.*, 1962, **36**, 3129; see also Heilbronner and Murrell, *J.*, 1962, 2611.
[3] Lepley, *J. Amer. Chem. Soc.*, 1962, **84**, 3577.
[4] Bergman, *Trans. Faraday Soc.*, 1954, **50**, 829; 1956, **52**, 690.
[5] Koutecký, Zahradník, and Čížek, *Trans. Faraday Soc.*, 1961, **57**, 169.

(S_e, S_r, and S_n) for positions belonging to the same class (for definition, see ref. 5). The same is true of the dependence of free valency on radical localisation energy and radical superdelocalisability (see Figure). The other indices are only rather loosely inter-related.

Constants of regression lines, $y = ax + b$.

	y	x	Hydrocarbons *	No compds. studied	a	b	r †
Electronic spectra	$10^3\nu$ (cm.$^{-1}$)	$E(N\rightarrow V_1)$ (β)	F	28	22·58	5·80	0·957
			B [2]	34	19·13	10·44	0·983
p-bands							
Charge-transfer spectra	$10^3\nu$ (cm.$^{-1}$)	HOMO (β) ‡	F	6	29·57	4·91	0·934
			B [3]	18	24·78	7·78	0·976
Polarographic cathodic waves	$E_{\frac{1}{2}}$ (v)	LFMO (β) §	F	12	2·682	−0·329	0·991
			B [6]	40	2·405	−0·420	0·965

* F = Fluoranthene-like; B = Benzenoid. † Correlation coefficient. ‡ Highest occupied molecular orbital. § Lowest free molecular orbital.

This treatment appears helpful in view of the known difficulty in selecting suitable reactivity indices for compounds other than benzenoid hydrocarbons.

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PRAGUE, CZECHOSLOVAKIA. [*Received, March 29th*, 1963.]

[6] Zahradník, Párkányi, unpublished results (cf. Streitwieser, " Molecular Orbital Theory for Organic Chemists," Wiley, New York, 1961).

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961. *Biaryls. Part IV.*[1] *Ullmann Reactions with* o-*Dihalogenonaphthalenes: Synthesis of a Dinitro*-2,3:6,7-*dibenzobiphenylene.*

By E. R. WARD and J. E. MARRIOTT.

WARD and PEARSON [1] obtained 2,3:6,7-dibenzobiphenylene by refluxing 2-bromo-3-iodonaphthalene with copper bronze in dimethylformamide (cf. Dobbie, Fox, and Gauge; [2] Mascarelli and Gatti [3]), thus potentially providing the simplest route to aromatic derivatives of cyclobutadiene. Corbett and Holt [4] used the method to prepare a dimethyldinitrobiphenylene in 40% yield from 3,4-dibromo-5-nitrotoluene. Unfortunately *o*-dihalogenonaphthalenes are not easy to synthesise but new techniques we have devised for carrying out relevant diazo-decompositions [5] have provided some starting materials. From 2,3-dibromo-1-nitronaphthalene or 3-bromo-2-iodo-1-nitronaphthalene we obtained a dinitro-2,3:6,7-dibenzobiphenylene in 1—3% yield, insufficient being available for orientation. It must have been the 1,5- or 1,8-dinitro-derivative and was not identical with a product (insufficient for analysis) that we obtained on attempted dinitration of the parent hydrocarbon. The new dibenzobiphenylene gave an ultraviolet spectrum with peaks in the 350—450 mμ region, characteristic of the cyclobutadiene system, although much of the fine structure is lost (cf. Ward and Pearson [6]). The dibenzobiphenylene fluoresced in benzene as does the parent hydrocarbon, thus making possible its isolation by column chromatography.

2,3-Dibromonaphthalene failed to react; no identifiable material could be isolated

[1] Part III, Ward and Pearson, *J.*, 1961, 515.
[2] Dobbie, Fox, and Gauge, *J.*, 1913, 36.
[3] Mascarelli and Gatti, *Gazzetta*, 1953, **63**, 561.
[4] Corbett and Holt, *J.*, 1961, 4261.
[5] Ward and Marriott, *J.*, 1963, 2151.
[6] Ward and Pearson, *J.*, 1959, 1676.

from syntheses involving 1,3-dibromo-2-iodonaphthalene or 3-bromo-2-iodo-1,6-dinitronaphthalene, and no 1,2:7,8- or 1,2:5,6-dibenzobiphenylene was obtained from 1-bromo-2-iodonaphthalene (in view of the known instability of the 1,2:7,8-isomer [7] it is very doubtful whether it would survive the severe reaction conditions). As 2,3-di-iodonaphthalene was commercially available we made a detailed study of the preparation from this of 2,3:6,7-dibenzobiphenylene but could not raise the yield above *ca.* 1%. Working in alternative solvents such as pyridine or sulphonane, and direct pyrolysis by gradual heating to 400° during 3 hours of the molten dihalogeno-compound with copper bronze, failed to give any dibenzobiphenylene; nor was the yield improved by working under nitrogen or using copper bronze freshly activated by iodine in acetone.[8] Attempts to detect the suggested naphthalyne intermediate by carrying out the reaction in dimethylformamide in the presence of furan gave no detectable adduct (cf. Wittig and Pohmer [9]). Owing to the difficulties in separating anything but the dibenzobiphenylene from the tarry reaction residues no by-products other than naphthalene were detected and this only in a reaction in dimethylformamide prolonged for 4 days, which gave the usual yield of dibenzobiphenylene but also gave naphthalene in *ca.* 70% yield.

Wittig and Herwig [10] obtained biphenylene in very high yield by pyrolysis of the mercury complex which is formed quantitatively when mercuric chloride reacts with 2,2′-dilithiobiphenyl in ether. Attempts to synthesise 2,3:6,7-dibenzobiphenylene by a similar route were abandoned when we were unable to convert 2,2′-binaphthyl- [11] or 5,5′,6,6′,7,7′,8,8′-octahydrobinaphthyl-3,3′-diamine [6] into the required dibromo-intermediates by Sandmeyer reactions. Ward and Pearson,[6] by reaction of 1-bromo-2-iodonaphthalene with magnesium, obtained a hydrocarbon which may have been 1,2:5,6-dibenzobiphenylene. Attempts to confirm this by an alternative synthesis were frustrated when we failed to isolate 5,6,7,8-tetrahydro-1′,3-dinitro-2,2′-binaphthyl from a crossed Ullmann reaction between 2-iodo-1-nitronaphthalene and 1,2,3,4-tetrahydro-6-iodo-7-nitronaphthalene.

Experimental.—Reactions of dihalogenonaphthalenes with copper bronze in dimethylformamide. (*a*) 2,3-Di-iodonaphthalene [12] (25 g.) was refluxed in dimethylformamide (100 ml.) with freshly activated copper bronze (25 g.) for 85 hr., then filtered hot. The cooled filtrate deposited a yellow solid which was collected (180 mg.) and extracted with hot benzene (50 ml.; Soxhlet). The cooled extract gave pure 2,3:6,7-dibenzobiphenylene (80 mg., 1%), m. p. 373—376°. The residual dimethylformamide solution was poured on ice and next day the brown solids were collected, washed with water, dried, and extracted with hot benzene (3 × 30 ml.). The cooled combined extract was chromatographed on alumina (25 × 3 cm.), and elution by benzene removed a bright yellow band. Evaporation of this eluate gave orange plates (7·8 g.), m. p. 45—50°, which could not be crystallised from solvents. However, steam-distillation gave a white waxy solid (6·0 g.), m. p. 57°, which after two crystallisations from aqueous ethanol gave pure naphthalene. The residue from the steam-distillation was an intractable tar. Further elution of the column gave only a tar (42 mg.).

(*b*) 2,3-Dibromo-1-nitronaphthalene (1 g.) was refluxed with copper bronze (1 g.) in dimethylformamide (10 ml.) for 6 hr., then the mixture was filtered and poured on ice. The next day the solids were collected, washed with water, dried, and extracted with benzene (150 ml.; Soxhlet). The extract was passed through alumina (15 × 2·5 cm.), and the green fluorescent eluate evaporated, to yield a tarry brown solid (0·433 g.). From benzene–hexane this gave a presumed (1·5- or 1,8-)*dinitro*-2,3:6,7-*dibenzobiphenylene* as golden needles (45 mg.), m. p. 350°, raised to 384° (sublimes rapidly above 370°) by a similar crystallisation (yield, 11 mg., 2·2%) (Found: C, 69·0; H, 3·05; N, 8·7. $C_{20}H_{10}N_2O_4$ requires C, 70·2; H, 3·0; N, 8·2%), $\lambda_{max.}$

[7] Cava and Stucker, *J. Amer. Chem. Soc.*, 1955, **77**, 6022.
[8] Kleiderer and Adams, *J. Amer. Chem. Soc.*, 1933, **55**, 4219.
[9] Wittig and Pohmer, *Angew. Chem.*, 1955, **67**, 348.
[10] Wittig and Herwig, *Chem. Ber.*, 1954, **85**, 1511.
[11] Curtis and Viswanath, *J.*, 1959, 1670.
[12] Fundamental Research Co., unpublished work.

(log ε in parentheses) 254·5 (4·58), 262·5 (4·64), 291·5 (4·32), 330 (4·42), 417 (4·06), and 446 mμ (4·21). 3-Bromo-2-iodo-1-nitronaphthalene, treated similarly, gave yellow needles (26 mg., 2·8%), m. p. 345—350° (sublimes above 320°), which when twice crystallised from benzene–light petroleum (b. p. 40—60°), formed yellow needles, m. p. 370—373° (Found: C, 68·7; H, 3·0; N, 8·7%), whose ultraviolet spectrum had only very minor differences from that of the above compound.

The authors thank Dr. J. Hyman (Fundamental Research Co., Berkeley, California) for gifts of chemicals.

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962. *Isolation of β-Sitostenone from* Quassia amara.

By D. LAVIE and I. A. KAYE.

β-SITOSTEROL has been isolated from numerous plant sources and is frequently accompanied by its glucoside [1] and reduction product, β-sitostanol [2] (another reduction product, sitostene, has been isolated in one instance,[3] together with the parent sterol, from the pods and seeds of *Gleditschia horrida*). Since none of the oxidation products of β-sitosterol has thus far been identified in Nature, it is of interest that we find the components of *Quassia amara* wood to include sitost-4-en-3-one (β-sitostenone) and β-sitosterol. The ketone was identical with a synthetic sample [2] prepared by oxidation of β-sitosterol. It is conceivable that β-sitostenone is often associated with the phytosterol but has escaped detection till now (Heilbron *et al.*[4] isolated, from plantation rubber, β-sitosterol and an αβ-unsaturated ketone, as its 2,4-dinitrophenylhydrazone; the latter's m. p. was similar to that of β-sitostenone 2,4-dinitrophenylhydrazone). It is noteworthy that, among animal sterols, the analogous cholest-4-en-3-one has been found as a companion of cholesterol in several lipoid extracts.[5]

Added in proof.—In a study on the composition of the wood of a tree from the genus *Cabralia*, obtained from Brazil, both β-sitosterol and β-sitostenone have been isolated. This strengthens the assumption that these substances may be fairly wide-spread in Nature.

Experimental.—M. p.s are corrected and were determined in soft-glass capillaries in an electrothermal m. p. block. Thin-layer chromatograms were conducted on Merck's kieselgel G; in chromatographic fractionations Merck's acid-washed alumina was used. Specific rotations were measured at 21° for chloroform solutions. The ultraviolet absorption spectrum was measured for 95% ethanol solutions with a Cary model 14 recording spectrophotometer. Infrared spectra were recorded on a Perkin-Elmer Infracord model 137 spectrometer.

To the black viscous oil (100 g.), obtained as a residue by the extraction of *Quassia amara* wood with benzene and from which the bulk of the quassin had been removed, was added isopropyl ether (800 ml.). Next morning the finely divided brown precipitate was separated by filtration and washed exhaustively with isopropyl ether. The solid (24·58 g.) consisted mainly of quassin and neoquassin which were identified by comparison of their infrared spectra and chromatoplates [developed with ethyl acetate–methanol (99 : 1)] with those of authentic samples. The isopropyl ether was evaporated from the filtrate, leaving a dark amber viscous oil (43·68 g.) which was dissolved in benzene and chromatographed on alumina (2 kg.). The column was eluted with the following solvents in succession: benzene (5 l.), benzene–ether (3 : 1) (4 l.), benzene–ether (1 : 1) (6 l.), ether–chloroform (1 : 1) (1·8 l.), chloroform (16 l.), and

[1] Van der Horn, *Rec. Trav. chim.*, 1929, **48**, 726.
[2] Ives and O'Neil, *Canad. J. Chem.*, 1958, **36**, 434.
[3] Kitasawa, *J. Pharm. Soc. Japan*, 1953, **73**, 658.
[4] Heilbron, Jones, Roberts, and Wilkinson, *J.*, 1941, 344.
[5] Elsevier's "Encyclopedia of Organic Chemistry," ed. Josephy and Radt, Elsevier, Amsterdam, Series III, 1959, 14 Supplement, p. 2424.

chloroform–methanol as follows: 99·5 : 0·5 (2·4 l.), 99 : 1 (2·4 l.), 98·5 : 1·5 (2·4 l.), 97·5 : 2·5 (2·4 l.), and 95 : 5 (6·2 l.). Several of the residues from the first benzene–ether (1 : 1) fractions which crystallised were combined and recrystallised several times from methanol, then having m. p. 137·5—138·5°, $[\alpha]_D$ −35·3° (*c* 1·53) (Found: C, 81·8; H, 11·8. Calc. for $C_{29}H_{58}O,\frac{1}{2}H_2O$: C, 82·2; H, 12·1%). These physical constants are in good agreement with those reported for β-sitosterol.[6] The acetate, prepared by the method of Beylert and Sarett,[7] was purified by filtration in benzene through alumina and had m. p. 132·5—133·5° (from benzene), $[\alpha]_D$ −41·3° (*c* 1·62) [Found: C, 81·5; H, 11·2%; *M* (Rast), 470. Calc. for $C_{31}H_{52}O_2$: C, 81·5; H, 11·5%; *M*, 457]. The *p*-nitrobenzoate, purified in a similar fashion, had m. p. 188·5—190·5° (clear at 214°) (from acetone), $[\alpha]_D$ −6·0° (*c* 1·51). Thin-layer chromatoplates of the esters (benzene–hexane, 1 : 1) and of the parent sterol (benzene–ether, 1 : 1) gave single spots.

The middle benzene–ether (3 : 1) fractions were combined and chromatographed on alumina (400 g.). The material eluted with hexane–ether (3 : 1) was rechromatographed on alumina; the fractions obtained with hexane–ether (8 : 2) were combined and, recrystallised twice from ether–methanol, had m. p. 92—94°. Recrystallisation left much to be desired inasmuch as the substance tends to separate as an oil. However, slow evaporation of a solution in a large volume of ether–methanol yielded needles, m. p. 95—96·5°, $[\alpha]_D$ +81·3° (*c* 2·78), $\lambda_{max.}$ 241 mμ (ε 16,400), $\nu_{max.}$ (in KBr) 1680 and 1622 cm.$^{-1}$. Its infrared spectrum was superimposable on that of authentic β-sitostenone, prepared by the oxidation of β-sitosterol;[2] both gave single spots of identical R_F value on chromatoplates (benzene–ether, 1 : 1). The 2,4-dinitrophenylhydrazone formed a red powder, m. p. 235—236·5° (from ethyl acetate); the semicarbazone had m. p. 234—235°.

The major component of the mixture eluted from the column with chloroform was neoquassin.

One of the authors (I. A. K., on leave of absence from Brooklyn College of The City University of New York) thanks the National Cancer Institute of the National Institutes of Health, U.S. Public Health Service, for a Fellowship. Grateful acknowledgment is made to the Plantex Chemical and Pharmaceutical Works, Ltd., Nathanya, Israel, for the crude extract of *Quassia amara* wood.

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Rehovoth, Israel. [*Received, April 18th*, 1963.]

[6] Ref. 5, p. 2467.
[7] Beylert and Sarett, *J. Amer. Chem. Soc.*, 1952, **74**, 1408.

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963. *The Synthesis and Separation of a Mixture of* 1-*Aziridin*-1′-*ylbut*-3-*en*-2-*ol and* 2-*Aziridin*-1′-*ylbut*-3-*en*-1-*ol.*

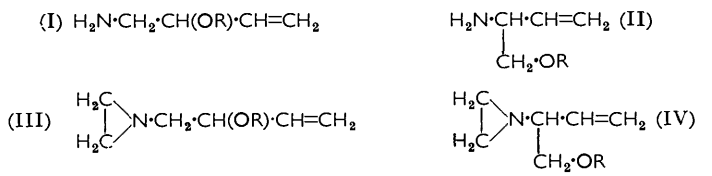
By G. A. Stein, N. Trenner, A. Zambito, B. Arison, B. Powell, W. Jankowski, and E. M. Chamberlin.

Ettlinger,[1] in studying the reaction of ammonia with butadiene monoxide, isolated two products (I and II; R = H). Vierling and his co-workers [2] studied the same reaction, but used aziridine in place of ammonia and reported the product to be the secondary alcohol (III; R = H). We have examined the product from aziridine and butadiene monoxide by means of nuclear magnetic resonance (n.m.r.) spectroscopy, which led us to suspect that the product was a mixture of products (III and IV; R = H).

The 60 Mc. n.m.r. spectrum of the product in carbon tetrachloride showed a pair of doublets at τ 7·83 (*J* ~6) arising from the hydrogen on the carbon linked to nitrogen and at τ 6·49 (*J* ~7) arising from the hydrogen on a primary alcohol group which could only be present in structure (IV). These doublets were in a ratio of 3 : 2.

[1] Ettlinger, *J. Amer. Chem. Soc.*, 1950, **72**, 4792.
[2] Vierling, Oettel, and Wilhelm, G.P. 1,004,614; B.P. 783,728 (*Chem. Abs.*, 1958, **52**, 10,201).

Separation was achieved by distillation *in vacuo* through a 24-plate Oldershaw column, the two n.m.r. doublets being of diagnostic value in assessing the purity of fractions and the proportion of the isomers therein. The acetates of the pure isomers were also prepared,



though the usual methods of acetylation led to opening of the aziridine ring. *O*-Acetylation was accomplished by reaction with keten in inert solvents such as ether or hydrocarbons, preferably n-hexane. Staab and Rohr [3] reported preparation of a number of esters, including the acetates of the isomeric mixture (III and IV; R = H), but were unable to separate the isomeric alcohols.

Experimental.—*1-Aziridin-1′-ylbut-3-en-2-ol* (III; R = H) *and* *2-Aziridin-1′-ylbut-3-en-1-ol* (IV; R = H). (Caution: This reaction is prone to violent polymerisation and scrupulous attention to the treatment of the apparatus as described below is recommended.)

All the apparatus used was rinsed with 6N-ammonia and then washed well with distilled water. The distilled water used in the reaction was scrubbed with a stream of nitrogen for 30 min. just before use to remove dissolved carbon dioxide. The reaction was carried out in a nitrogen atmosphere in a system protected by a soda-lime tube.

To a vigorously stirred mixture of butadiene monoxide (1·6 kg., 22·8 moles) and water (206 ml., 11·4 moles) was added, during 1 hr., a solution of aziridine (" high purity; " b. p. 55—57°; Chemirad Corp.) (1·96 kg., 45·6 moles) in water (206 ml., 11·4 moles). The temperature was kept at 10—15° during the addition and for an additional 6 hr. The ice-bath was replaced by a Dewar flask filled with ice, and the reaction mixture was stirred at 0—3° for 5 days and then set aside at 0—5° for 2 days. The low-boiling materials were removed by distillation in a vacuum until the pot-temperature reached 40°/10 mm. The residue was then distilled through an 8″ Vigreux column to give the mixed isomers (III and IV; R = H) (1·44 kg., 58·2%), b. p. 58—59°/4 mm., n_D^{27} 1·487. N.m.r. spectroscopy indicated a 3 : 2 ratio (III) : (IV) (Found: C, 63·8; H, 9·7; N, 12·7. Calc. for $C_6H_{11}NO$: C, 63·7; H, 9·8; N, 12·4%).

The mixture (2·976 kg.) was distilled in a nitrogen atmosphere through a 24-plate (2″ × 36″) all-glass Oldershaw column. An automatic liquid-dividing head, controlled by a flexopulse ratio timer to give a reflux ratio of 15 : 1, was used. Twenty-three fractions of ~130 g. each were collected at a rate of 15 g./hr. The fractions were analysed by infrared and n.m.r. spectroscopy. Fractions 2—12 were pure secondary *alcohol* (III; R = H) (1346 g.), b. p. 67·5°/5 mm., n_D^{26} 1·4686 (Found: C, 63·8; H, 9·7; N, 12·5%). Fractions 17—25 were pure primary *alcohol* (IV; R = H) (683 g.), b. p. 73·5°/5 mm., n_D^{26} 1·4701 (Found: C, 63·8; H, 9·7; N, 12·5%).

The alcohol (III; R = H), in n-hexane (b. p. 60—71°; 20 ml./g.), was stirred at the b. p. (~60°) while keten was passed under the surface until reaction was complete as determined by passing the exit gases into a solution of 1 drop of 2·5N-sodium hydroxide, 3 drops of 1% ethanolic phenolphthalein, and 10 ml. of water: decoloration time was compared with that of a blank. A 20—30% excess of keten was added. There was a 5—8° drop in temperature when the reaction was complete (the time required for a 100-g. batch was ~3 hr.). The hexane solution was cooled to room temperature, filtered from polymeric material, saturated with dry ammonia, refrigerated overnight, filtered again to remove polymer, and evaporated in a vacuum at 40°. The crude oily residue was dissolved in n-hexane (10 ml./g.), washed three times with saturated aqueous sodium dithionite (1 ml./3 ml. of oil), and dried (Na_2SO_4). The solvent was removed under a vacuum at 40°. These treatments removed colour and stabilised the product. The oil was then distilled in a vacuum, in a nitrogen atmosphere through a 12″

[3] Staab and Rohr, *Chem. Ber.*, 1962, **95**, 1298.

Vigreux column, giving the *acetate* (80%), b. p. 48°/1 mm., n_D^{23} 1·4462 (no infrared hydroxyl band) (Found: C, 61·8; H, 8·5; N, 9·0. $C_8H_{13}NO_2$ requires C, 61·9; H, 8·4; N, 9·0%).

The alcohol (IV; R = H) was converted similarly in 90% yield into its *acetate* (IV; R = Ac), b. p. 47·5° mm., n_D^{23} 1·4445 (no infrared hydroxyl band) (Found: C, 61·75; H, 8·2; N, 8·7%).

The authors are indebted to Mr. R. N. Boos and his staff for analytical data and to Mr. Robert Walker for the infrared spectra. The technical assistance of Mr. Malcolm Ryder in carrying out the fractional distillation is gratefully acknowledged. This work was supported by the Cancer Chemotherapy National Service Center, National Cancer Institute, National Institutes of Health.

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Rahway, New Jersey, U.S.A. [*Received, April 29th,* 1963.]