603. *The Scope and Mechanism of Carbohydrate Osotriazole Formation. Part VI.*[1] *The Apparent Dissociation Constant of Triazole Carboxylic Acids.*

By H. El Khadem.

It has been shown[1,2] that *o*-halogeno-phenylosotriazoles and -benzoic acids undergo dehalogenation by copper powder, it being suggested that the triazole ring acted as an electron-attracting group, rendering the *o*-halogen atom more reactive. To study the influence of substituents on the strength of triazolecarboxylic acids, the apparent dissociation constants of 2-*m*- and 2-*p*-carboxyphenyl-1,2,3-triazole and of some 2-arylphenyl-1,2,3-triazole-4-carboxylic acids have been determined and compared with those of substituted benzoic acids. The dissociation constants of a few triazolecarboxylic acids were determined previously,[3] but these did not include the 2-phenyl derivatives. Owing to the sparing solubility of the acids in water, their dissociation constants were determined in the solvent system 4 : 1 w/w Methylcellosolve–water.[4] The results are shown in the Table.

Acid	p*K*
2-*m*-Carboxyphenyl-1,2,3-triazole [1]	6·12
Glucose *m*-carboxyphenylosotriazole [2]	6·22
2-*p*-Carboxyphenyl-1,2,3-triazole [2]	6·24
Glucose *p*-carboxyphenylosotriazole [2]	6·31
2-Phenyl-1,2,3-triazole-4-carboxylic [5]	4·98
2-*m*-Chlorophenyl-1,2,3-triazole-4-carboxylic [1]	4·81
2-*p*-Chlorophenyl-1,2,3-triazole-4-carboxylic [1]	4·84
2-*m*-Bromophenyl-1,2,3-triazole-4-carboxylic [6]	4·83
2-*p*-Bromophenyl-1,2,3-triazole-4-carboxylic [5]	4·81
2-*m*-Iodophenyl-1,2,3-triazole-4-carboxylic [1]	4·84
2-*p*-Iodophenyl-1,2,3-triazole-4-carboxylic [1]	4·81
2-*m*-Methoxyphenyl-1,2,3-triazole-4-carboxylic [2]	4·98
2-*p*-Methoxyphenyl-1,2,3-triazole-4-carboxylic [2]	5·09
2-*p*-Nitrophenyl-1,2,3-triazole-4-carboxylic [7]	4·54
2-*m*-Carboxyphenyl-1,2,3-triazole-4-carboxylic [6]	4·93, 6·54
2-*p*-Carboxyphenyl-1,2,3-triazole-4-carboxylic [5]	4·72, 6·47

Experimental.—Preparation of the acids is described in the literature cited.

The apparent dissociation constants have been determined by titrating ~0·037M-solutions of the acids in 4 : 1 w/w Methylcellosolve–water with aqueous 0·1N-tetramethylammonium hydroxide. The apparent pH measured with a glass–calomel electrode system at half-neutralisation was recorded as p*K*. The results given are the mean of two determinations. The standard error of a single determination is 0·07 p*K* unit (95% level of significance).

Discussion.—From the measurements we find that 2-phenyltriazoles having a carboxy-group attached to the benzene ring have p*K* 6·12—6·31 and are thus stronger acids than benzoic acid [8] (p*K* 6·63). Thus, in the 2-phenyltriazole system there is an electron-shift towards the triazole ring, in harmony with our previous view.

Further, the p*K* values of triazole-3-carboxylic acids are 4·52—5·09 and are thus much stronger acids than the carboxyphenyl derivatives. It follows that the triazole ring is a much stronger electron-attracting group than the benzene ring.

A plot of p*K* against σ (determined from the equation $pK = 4{\cdot}98 - 0{\cdot}437\sigma$) is an approximate straight line. Comparison with the results for benzoic acid [8] shows similar

[1] Part V, *J.*, 1961, 2957.
[2] El Khadem, El-Shafei, and Mohammed, *J.*, 1960, 3993.
[3] Benson and Savell, *Chem. Rev.*, 1950, **46**, 1.
[4] Simon, *Helv. Chim. Acta*, 1958, **41**, 1835.
[5] El Khadem and El-Shafei, *J.*, 1958, 3117.
[6] El Khadem and El-Shafei, *J.*, 1959, 1655.
[7] Bischop, *Science*, 1953, **117**, 715.
[8] Simon, Lyssy, Mörikofer, and Heilbronner, "Zusammenstellung von scheinbaren Dissoziationskonstanten im Lösungsmittelsystem Methylcellosolve/Wasser," Juris-Verlag, Zürich, 1959, p. 5.

effects for substituents. The value of ρ in Hammett's equation,[9] determined from the slope of the plot for the triazole acids by the method of least squares, is only 0·45 (cf. 1·665 for substituted benzoic acids). This we attribute to the fact that the substituents here are separated from the carboxy-group by two ring systems, so that they will influence it only to a limited degree.

The author thanks Dr. W. Simon and Dr. P. F. Sommer for the dissociation-constant measurements.

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[9] Hammett, *J. Amer. Chem. Soc.*, 1937, **59**, 96.

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604. *Trisethylenediaminenickel*(II) *Thiosulphate as a Calibrant for Susceptibility Measurements by the Gouy Method.*

By N. F. CURTIS.

THE use of mercury tetrathiocyanatocobaltate, $HgCo(CNS)_4$, as a calibrant for magnetic susceptibility measurements by the Gouy method has been described by Nyholm and Figgis.[1] However, the susceptibility of this compound has been found to be too large for convenience in some applications. Thus, lateral displacement of the Gouy tube filled with this material, caused by field inhomogeneity, is troublesome for tubes of large diameter, or with the high field strengths which are desirable for measurements on compounds of low susceptibility. This is particularly serious in the narrow space usually available when temperature-controlling apparatus is fitted within the pole gap.

Trisethylenediaminenickel(II) thiosulphate has been found to be a satisfactory alternative in these circumstances, the force exerted by a magnetic field on a tube filled with this compound being approximately one-third of that exerted when the tube is filled with the mercury compound, and the lateral displacement effects are very much smaller. This complex, $Ni\ en_3S_2O_3$, is readily prepared, in a form which packs readily and uniformly in a Gouy tube and is unaffected by exposure to the atmosphere. In these respects it is much superior to crushed copper sulphate pentahydrate, which is often used as a calibrant of low susceptibility.

The magnetic susceptibility of five samples of $Ni\ en_3S_2O_3$, prepared under a variety of conditions, was determined at 25°, with three preparations of $HgCo(CNS)_4$ for calibration. In each case, the results quoted are the average of six measurements.

(a) *Calibration of Gouy tube.* [$10^3,W/\Delta w\ .\ \chi_g$ for $HgCo(CNS)_4$] 5·062 (±0·5%), 5·006 (±0·5%), 5·067 (±0·6%). Average 5·044 (±0·2%).

(b) *Susceptibility of* $Ni\ en_3S_2O_3$ $10^6\chi_g$. 10·76 (±0·3%), 10·72 (±0·5%), 10·83 (±0·7%), 10·81 (±0·6%), 10·99 (±0·9%). Average 10·82 (±0·4%).

The first sample, the preparation of which is described, gave particularly uniform results and was used for the measurements described in (c) and (d).

(c) *Temperature variation of susceptibility.* The susceptibility was measured at 1°, 25°, and 52°, with the same tube-full of $Ni\ en_3S_2O_3$. The average of four such series of measurements shows that, in the range studied, the compound obeys the Curie–Weiss law $\chi_g \propto [T-(43 \pm 5)]^{-1}$, T being in degrees absolute.

(d) *Variation of sample length.* To check the uniformity with which the compound packed in the sample tube, the susceptibility was measured with the Gouy tube filled to 8 cm., instead of the 12 cm. used for all other measurements. The determined value,

[1] Nyholm and Figgis, *J.*, 1958, 4190.

$\chi_g = 10{\cdot}82\ (\pm 0{\cdot}4\%) \times 10^{-6}$, agrees well with the value calculated from the measurements with 12 cm. sample length, for the same preparations of Ni $en_3S_2O_3$ and $HgCo(CNS)_4$, namely, $10{\cdot}79\ (\pm 0{\cdot}7\%) \times 10^{-6}$.

The gram-susceptibility at 25° is taken to be $10{\cdot}82\ (\pm 10) \times 10^{-6}$ (including the 0·5% uncertainty in the value of the susceptibility of the calibrant [1]).

Experimental.—Measurements were performed with a flat-bottomed Pyrex tube of 3·3 mm. diameter, suspended from the pan of an aperiodic semimicro-balance. The magnetic field was provided by an " Alcomax " permanent magnet of field strength about 7500 gauss, with pole-pieces 1 in. in diameter, and $\frac{3}{4}$ in. apart. During measurements the position of the Gouy tube in the magnetic field was maintained within 0·5 mm. by using the overlapping optical and rider ranges (both of 10 mg.), although variation in the force exerted by the magnetic field on the sample tube was negligible over the full optical range. The Gouy tube was surrounded by a double-walled glass jacket through which water from a thermostat bath was pumped. The temperature of the specimen was measured by means of a thermometer in this water jacket, preliminary measurements having shown that this gave a reliable indication of the temperature of the specimen at thermal equilibrium. Before the ice-water was circulated for the low-temperature measurements, the air was displaced from around the Gouy tube by means of a stream of dry nitrogen, to prevent condensation on the tube.

The Gouy tube was filled with the appropriate compound, which was compacted by repeatedly allowing the tube to fall from a height of about 2 in. on to wood. There was no systematic variation in results between measurements with the tube contents added in small portions, with compaction between additions (as described by Nyholm and Figgis), and those where the contents were compacted after the tube had been filled. The sample weight with Ni $en_3S_2O_3$ was about 0·8 g., and the force exerted by the magnetic field 17 mg. The figures for $HgCo(CNS)_4$ were 1·6 g. and 50 mg. respectively.

Preparation. To a vigorously boiling solution of " AnalaR " nickel nitrate hexahydrate (2 g.) and ethylenediamine hydrate (2 ml.) in water (50 ml.) was added a boiling solution of sodium thiosulphate pentahydrate (2 g.) in water (20 ml.). The whole was boiled for a minute and stirred vigorously as it cooled. The mauve crystals were filtered off from the cold solution, washed with cold water and then ethanol, and dried at 100° (Found: Ni, 16·7; C, 21·0; H, 6·9; N, 23·9. Calc. for $C_6H_{24}N_6NiO_3S_2$: Ni, 16·7; C, 20·5; H, 6·8; N, 23·9%). Before use, the crystals were vigorously agitated, to break up any crystal aggregates.

A sample (0·6 g.) showed no loss in weight when heated for several days at 110°, and this sample then showed no change in weight when exposed to the atmosphere for several days.

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605. *Tris-(2-hydroxyethyl) Isocyanurate.*

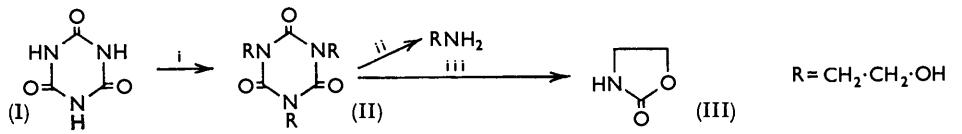
By A. A. SAYIGH and H. ULRICH.

CYANURIC ACID (I) has seldom been used as a nucleophilic reagent in reactions to yield isocyanurates containing functional groups. Recently,[1] however, and concurrently with our work a number of these compounds were reported. Thus tris-(2-hydroxyethyl) isocyanurate (II) was recently reported [1] to have been prepared from cyanuric acid and ethylene oxide. Previously, using the same reagents, we obtained only a mixture of products from which (II) could not be isolated.

The synthesis of the isocyanurate (II) in 83% yield by reaction of cyanuric acid and 2-chloroethanol in alkaline medium has been found to be convenient and reproducible,

[1] (*a*) U.S.S.R. Patent 118,042/1959 (*Chem. Abs.*, 1960, **53**, 21,673); (*b*) Frazer, Little, and Lloyd, *J. Org. Chem.*, 1960, **25**, 1944.

whereas previously known general methods [2] for the preparation of trialkyl isocyanurates could not be adapted to the synthesis of the hydroxyethyl compound (II).



i, RCl/HO⁻. ii, HO⁻. iii, Hot dimethylformamide.

Aqueous alkaline hydrolysis gave ethanolamine, and heating in dimethylformamide at 150—155° converted (II) into oxazolidone (III). The latter was identified by its infrared spectrum which was identical with that of a sample prepared according to Fränkel and Cornelius's method.[3]

Experimental.—Tris-(2-hydroxyethyl) isocyanurate (II). A suspension of cyanuric acid (65 g.) in water (748 ml.) containing sodium hydroxide (14·4 g.) was stirred vigorously and heated to 90—95°; a cold solution of 2-chloroethanol (290 g.) and sodium hydroxide (80 g.) in water (390 g.) was added dropwise during 6—8 hr., the temperature being kept at 95°. The resulting clear solution (pH 8·6—9·1) was set aside overnight, and then concentrated *in vacuo* (steam-bath). The resulting oil and solid were extracted with boiling isopropyl alcohol or dioxan (5 × 100 ml.); the combined extracts were filtered hot, cooled to 8°, and filtered again to give the solid product. Concentration (to *ca.* 75 ml.) of the mother liquor *in vacuo* and cooling overnight to 8° gave a precipitate which was collected. The combined solids were washed with cold isopropyl alcohol (50 ml.) and dried. The product (II) (109 g.; 83% yield) had m. p. 135—136° (lit.,[1a] 134—136°) (Found: C, 41·7; H, 5·9; N, 16·2. Calc. for $C_9H_{15}N_3O_6$: C, 41·4; H, 5·8; N, 16·1). Its infrared spectrum in potassium bromide is identical with that of an authentic sample: * 2·95s, 3·07m, 3·35w, 3·45w, 5·95vs, 6·85vs, 7·35m, 7·55m, 7·85w, 7·95w, 8·68w, 9·47m, 9·65m, 10·1w, 11·05w, 11·25w, 11·65w, 13·05m, 13·41w μ.

Oxazolidone (III). The isocyanurate (II) (10 g.) was heated in dimethylformamide (100 ml.) at 150—155° for 6 hr. The infrared spectrum of the solution was identical with that of a dimethylformamide solution containing the oxazolidone (III), prepared according to Fränkel and Cornelius.[3]

We thank Mr. F. J. Geremia for experimental assistance.

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* Kindly supplied by Allied Chemical Corporation, Nitrogen Division, Hopewell, Virginia, U.S.A.

[2] Biilmann and Bjerrum, *Ber.*, 1917, **50**, 503; Bortnick, Luskin, Hurwitz, and Rytina, *J. Amer. Chem. Soc.*, 1956, **78**, 4358; U.S.P. 2,536,849/1959.
[3] Fränkel and Cornelius, *Ber.*, 1918, **51**, 1654.

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606. *The Preparation of* o-(4-*Phenylbuta*-1,3-*dienyl*)*phenylboronic Anhydride.*

By P. M. MAITLIS.

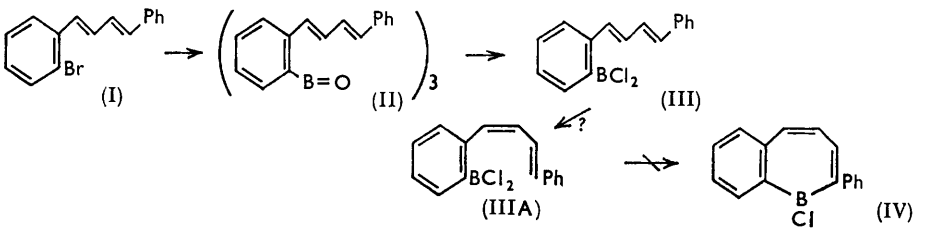
THE seven-membered fully conjugated borepin ring is of theoretical interest as it should be aromatic. Our attempts to synthesise a derivative containing it from the boronic anhydride (II) have, however, failed.

1-*o*-Bromophenyl-4-phenyl-1,3-butadiene (I) was prepared in 33% yield from *o*-bromophenylacetic acid and cinnamaldehyde by Huggins and Yokley's method.[1] An alternative

[1] Huggins and Yokley, *J. Amer. Chem. Soc.*, 1942, **64**, 1160.

preparation, by the action of the salt from triphenylphosphine and *o*-bromobenzyl bromide on cinnamaldehyde in the presence of lithium ethoxide,[2] while more convenient, gave lower yields.

Treating of the bromo-compound (I) with a small excess of butyl-lithium, followed by butyl metaborate, gave the anhydride (II) in 12% yield. The only other product was *trans-trans*-1,4-diphenylbuta-1,3-diene (34%; identified by its m. p. and infrared spectrum), presumably obtained by hydrolysis of the unchanged lithio-compound. Attempts to improve the yield by using longer reaction times or by using the boron trifluoride–ether complex or butyl orthoborate in place of the butyl metaborate were unsuccessful. The isolation of *trans-trans*-diphenylbutadiene from this reaction suggests that both the bromo-



compound (I) and the boronic anhydride (II) have the same conformation since the reactions involved should not involve changes about the double bonds. This is supported by the absence of a band in the infrared spectra of these compounds which could be ascribed to a *cis*-ethylenic bond and by the presence of a strong band at *ca.* 10·19 μ which is characteristic of *trans*-ethylenic bonds.[3]

On treatment of boronic anhydrides with an excess of boron trichloride, exchange of oxygen with chlorine occurs;[4] it was hoped that the boronic anhydride (II) would thus afford the boron dichloride (III) and since, in the presence of catalysts such as boron halides, double bonds isomerise easily, that this would isomerise to the *cis-trans*-form (IIIA), which has the right conformation for cyclisation. Cyclisation should then occur easily by a Friedel–Crafts-type reaction[4] in the presence of catalyst, or even without it, if the resultant seven-membered ring were sufficiently stable. However, though boron trichloride in benzene caused the insoluble boronic anhydride (II) to dissolve, presumably with the formation of (III), cyclisation did not occur since only the starting material (II) was recovered from the reaction mixture. Addition of a small amount of aluminium chloride caused vigorous evolution of hydrogen chloride but gave only tars. Other attempts gave similar results.

Experimental.—1-*o*-*Bromophenyl*-4-*phenylbuta*-1,3-*diene* (I). A mixture of *o*-bromophenylacetic acid[6] (31·5 g.), freshly distilled cinnamaldehyde (13·0 ml.), acetic anhydride (21 ml.), and lead oxide (17 g.) was refluxed for 5 hr., then cooled and diluted with 25% acetic acid (500 ml.). A sticky solid was precipitated which was extracted with benzene. The extract was washed with dilute sodium carbonate solution, dried (Na_2CO_3), and evaporated to leave an oil, which on addition of ethanol gave pale yellow needles of 1-*o*-*bromophenyl*-4-*phenylbuta*-1,3-*diene* (7·2 g., 33%), m. p. 107—108° (Found: C, 67·1; H, 4·3; Br, 28·3. $C_{16}H_{13}Br$ requires C, 67·4; H, 4·6; Br, 28·1%).

o-(4-*Phenylbuta*-1,3-*dienyl*)*phenylboronic anhydride* (II). A solution of 1-*o*-bromophenyl-4-phenylbuta-1,3-diene (I) (7 g., 0·0247 mole) in benzene (50 ml.) was treated during 1 hr. at

[2] McDonald and Campbell, *J. Org. Chem.*, 1959, **24**, 1969.
[3] Bellamy, "Infra-red Spectra of Complex Molecules," J. Wiley and Sons, Inc., New York, 1954, p. 40.
[4] Gerrard and Lappert, *Chem. Rev.*, 1958, 58, 1107, and references therein.
[5] Dewar, Kubba, and Pettit, *J.*, 1958, 3073; Dewar and Dietz, *J.*, 1959, 2728; 1960, 1344.
[6] Misra and Shukla, *J. Indian Chem. Soc.*, 1951, **28**, 480.

0—10° with ethereal butyl-lithium (0·0337 mole). A solid was slowly precipitated that redissolved on addition of ethereal butyl metaborate (3·0 g. in 30 ml.) at 0°. The resultant greenish solution was refluxed for 1 hr. and left overnight, then hydrolysed with dilute hydrochloric acid. The benzene layer was dried and evaporated to leave an oil. This was chromatographed on alumina; elution with light petroleum gave *trans-trans*-1,4-diphenylbuta-1,3-diene (1·5 g., 34%), m. p. 151° (lit.,[7] 152—153°; infrared spectrum identical with that quoted [7]) (Found: C, 93·3; H, 6·8. Calc. for $C_{16}H_{14}$: C, 93·2; H, 6·8%). Elution with a large volume of chloroform for several hours gave a total of 0·7 g. (12%) of the *boronic anhydride* (II), m. p. 231° [Found: C, 82·2; H, 5·8; B, 4·6. $(C_{16}H_{13}BO)_3$ requires C, 82·8; H, 5·6; B, 4·7%], insoluble in nearly all solvents but recrystallising from a large volume of light petroleum (b. p. 100—120°). This was only very sparingly soluble in aqueous sodium hydroxide. The ultraviolet spectrum was very similar to that of *trans-trans*-1,4-diphenylbuta-1,3-diene,[8] with peaks at 332 (log ε 3·60) and 236 mμ (log ε 3·00), shoulders at *ca.* 350 (log ε 3·40) and 315 mμ (log ε 3·55), and troughs at 255 (log ε 2·30) and 220 mμ (log ε 2·85).

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[7] Zechmeister, *J. Amer. Chem. Soc.*, 1948, **70**, 1938; *Acta Chem. Scand.*, 1954, **8**, 1421.
[8] Friedel and Orchin, " Ulta-violet Spectra of Aromatic Compounds," J. Wiley and Sons, Inc., New York, 1951.

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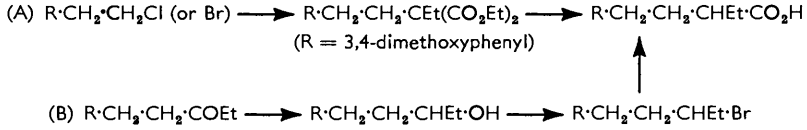
607. *Some Experiments Based on Veratraldehyde.*

By K. W. BENTLEY and S. F. DYKE.

IN the course of other work a quantity of α-ethyl-γ-(3,4-dimethoxyphenyl)butyric acid was required, and we report two attempts to synthesise this compound, which though unsuccessful, afforded several interesting compounds.

The most obvious route to the acid involved the sequence A:



3,4-Dimethoxyphenethyl alcohol, prepared by reduction of methyl homoveratrate,[1] gave the related bromide in only 30% yield on treatment with phosphorus tribromide, but afforded the chloride in 80% yield with thionyl chloride. (These halides were further characterised by bromination to the 2-bromo-4,5-dimethoxyphenethyl halides.) Condensation of the chloride with diethyl ethylmalonate yielded only polymeric material, presumably as a result of base-catalysed elimination of hydrogen chloride followed by polymerisation of the resulting styrene.

A second route is summarised in scheme B. The bromide in this series would not react with magnesium to form the Grignard reagent, and attempts to prepare from it the related nitrile yielded only dark viscous oils.

The ketone was prepared by two routes. The condensation product of veratraldehyde and ethyl methyl ketone, which was formed in greater amount under the alkaline conditions, was hydrogenated to a saturated ketone, whose infrared spectrum was identical with that

[1] Barash and Osbond, *J.*, 1959, 2162.

of the product obtained from β-(3,4-dimethoxyphenyl)propionyl chloride and diethylcadmium.

Experimental.—All melting points are uncorrected.

3,4-*Dimethoxyphenethyl alcohol.* Barash and Osbond's method [1] was modified slightly. The product was obtained as white crystals, m. p. 45—47° (from ether) (lit.,[1] m. p. 45—46·5°).

3,4-*Dimethylphenethyl bromide.* This was prepared essentially by Shigehiko Sugasawa's method.[2] The product was obtained as a pale yellow oil, b. p. 114—122°/0·2 mm., which slowly solidified. Crystallisation from ethanol then gave white needles, m. p. 67—68° (lit.,[2] b. p. 130—131°/0·3 mm.; m. p. 47—50°).

2-*Bromo*-3,4-*dimethoxyphenethyl bromide.* A mixture of the above ethyl bromide (16 g.) in glacial acetic acid (75 ml.) containing sodium acetate (20 g.) was cooled in ice, and bromine (10·5 g.) in glacial acetic acid (20 ml.) was added during 2 hr. The mixture was poured into water, and the precipitate extracted with chloroform. The extract was washed with aqueous sodium dithionite solution, water, 5% sodium hydrogen carbonate solution and water, then dried (Na_2SO_4). Evaporation of the solvent left a pale orange oil, which slowly solidified. Crystallisation from ethanol then yielded 2-*bromo*-3,4-*dimethoxyphenethyl bromide* as fluffy white needles, m. p. 68—69° (Found: C, 31·8; H, 3·8; Br, 49·3. $C_{10}H_{12}Br_2O_2$ requires C, 31·7; H, 3·7; Br, 49·4%).

3,4-*Dimethoxyphenethyl chloride.* 3,4-Dimethoxyphenethyl alcohol (10 g.) in dry chloroform (50 ml.) was cooled in ice, and thionyl chloride (10 g.) in chloroform (20 ml.) was added slowly. When the vigorous evolution of hydrogen chloride ceased, the mixture was heated under reflux for 2 hr. The resulting pale brown solution was evaporated, and the residual oil was distilled under reduced pressure. The fraction (8·8 g.) of b. p. 114—116°/0·3 mm. was collected; it slowly gave clusters of elongated prisms of 3,4-dimethoxyphenethyl chloride, m. p. 52—53° (Barash and Osbond [1] give b. p. 126°/0·3 mm.) (Found: C, 60·0; H, 6·6. Calc. for $C_{10}H_{13}ClO_2$: C, 59·9; H, 6·5%).

2-*Bromo*-3,4-*dimethoxyphenethyl chloride.* This was prepared essentially as for 2-bromo-3,4-dimethoxyphenethyl bromide. The *bromoethyl chloride* was obtained from ethanol as white needles, m. p. 59—61° (Found: C, 43·1; H, 4·5; Br, 28·5; Cl, 12·5. $C_{10}H_{12}BrClO_2$ requires C, 43·0; H, 4·3; Br, 28·7; Cl, 12·75%).

β-(3,4-*Dimethoxyphenyl*)*propionic acid.* The corresponding cinnamic acid (obtained by a modification of the method in *Organic Syntheses* [3]) was reduced with sodium amalgam to yield the propionic acid as white needles (from water), m. p. 100—102° (lit.[4] m. p. 98°) (Found: C, 62·6; H, 6·9. Calc. for $C_{11}H_{14}O_4$: C, 62·9; H, 6·7%).

3,4-*Dimethoxyphenethyl ethyl ketone.* (*a*) From β-(3,4-dimethoxyphenyl)propionic acid. Cadmium chloride (18·5 g.) was added in one lot under nitrogen to ethylmagnesium bromide (from 4·85 g. of magnesium) in ether, and the mixture was stirred for 30 min.; Gilman's Grignard reagent test [5] was then negative. The ether was evaporated and benzene (250 ml.) was added, followed by β-(3,4-dimethoxyphenylpropionyl chloride (b. p. 139—140°/0·1 mm.; 23·0 g.) in benzene (75 ml.) during 2 min. Some heat was evolved; the mixture was stirred and heated on a water-bath for 2 hr. The complex was decomposed with 2N-sulphuric acid, the layers were separated, and the aqueous layer was extracted with benzene (2 × 150 ml.). The combined benzene solutions were washed with water, sodium hydrogen carbonate solution, and water, dried (Na_2SO_4), and evaporated to a yellow oil (21·3 g.). This was distilled and the fraction of b. p. 132—136°/0·1 mm. was collected. The infrared spectrum of this material, 3,4-dimethoxyphenethyl ethyl ketone showed a broad intense band with maximum at 1712 cm.$^{-1}$. The 2,4-*dinitrophenylhydrazone* was obtained from ethanol as orange, fluffy needles, m. p. 139—140° (Found: C, 56·4; H, 5·5; N, 13·8. $C_{19}H_{22}N_4O_6$ requires C, 56·7; H, 5·5; N, 13·9%). The *oxime* crystallised from ethanol as white rods, m. p. 119—120° (Found: C, 65·9; H, 8·3; N, 5·7. $C_{13}H_{19}NO_3$ requires C, 65·9; H, 8·0; N, 5·9%).

(*b*) From veratraldehyde. (i) 2-(3,4-Dimethoxyphenyl)vinyl ethyl ketone. Veratraldehyde (140 g.) was dissolved in methanol (413 ml.), and water (650 ml.) and ethyl methyl ketone

[2] Shigehiko Sugasawa, *J. Pharm. Soc. Japan*, 1937, **57**, 296.
[3] Koo, Fish, Walker, and Blake, *Org. Synth.*, 1951, **31**, 35.
[4] Kindler and Li, *Ber.*, 1941, **74**, 321.
[5] Gilman and Schulze, *J. Amer. Chem. Soc.*, 1925, **47**, 2002.

(122 g.) were added, followed by 2N-sodium hydroxide (54 ml.). The mixture was shaken for 5 min., then kept at room temperature for 48 hr. The yellow solid was extracted with ether, and the ethereal solution dried (Na_2SO_4) and evaporated to a yellow oil (154 g.) which slowly solidified. This was distilled: the first fraction, b. p. 108—110°/0·3 mm., was unchanged veratraldehyde (30 g.), m. p. 40—43°. After a small intermediate fraction, the main fraction, b. p. 150—153°/0·3 mm., was collected (104 g.). Crystallisation from ethanol gave white rods, m. p. 83—84°, of 2-(3,4-*dimethoxyphenyl*)*vinyl ethyl ketone* (Found: C, 70·7; H, 7·4. $C_{13}H_{16}O_3$ requires C, 70·9; H, 7·3%).

(ii) 3,4-Dimethoxyphenethyl ethyl ketone. The unsaturated ketone (2·5 g.) in methanol (75 ml.) was shaken, at room temperature and atmospheric pressure, with hydrogen and palladised strontium carbonate (1·0 g.). Theoretical uptake of hydrogen (254 ml. at N.T.P. for 1 mole) occurred during 15 min., and absorption of gas ceased abruptly. The filtrate from the catalyst was evaporated to an oil. The melting-points of the 2,4-dinitrophenylhydrazone and the oxime of this material were undepressed on admixture with the corresponding derivatives of the ketone prepared from β-(3,4-dimethoxyphenyl)propionic acid.

1-(3,4-*Dimethoxyphenethyl*)*propanol*. (a) From 3,4-dimethoxyphenethyl ethyl ketone. The ketone (10 g.) in ether (70 ml.) was added to a stirred slurry of lithium aluminium hydride (2 g.) in ether (100 ml.) during 30 min. After 3 hr. the excess of lithium aluminium hydride was decomposed with dilute hydrochloric acid, and the complex with concentrated hydrochloric acid. The ether layer was separated and the aqueous layer was extracted with ether (2 × 50 ml.). The combined ethereal solutions were washed with water, dried (Na_2SO_4) and evaporated to an oil (9·5 g.) which slowly solidified. Crystallisation from light petroleum (b. p. 60—80°) gave white crystals, m. p. 36—38°, of 1-(3,4-*dimethoxyphenethyl*)*propanol* (Found: C, 69·4; H, 9·1. $C_{13}H_{20}O_3$ requires C, 69·6; H, 9·0%). The 3,5-*dinitrobenzoate* was obtained from ethanol as yellow prisms, m. p. 97—98° (Found: C, 57·1; H, 5·3; N, 6·7. $C_{20}H_{22}N_2O_8$ requires C, 57·4; H, 5·3; N, 6·7%).

(b) From 2-(3,4-dimethoxyphenyl)vinyl ethyl ketone. The unsaturated ketone (10 g.) in benzene (50 ml.) was added to a slurry of lithium aluminium hydride (3·5 g.) in ether (100 ml.). The mixture was warmed at 50° for 3 hr., and the product isolated as above. The infrared spectra of the two specimens were identical.

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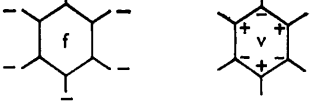
608. *Substitution Patterns of Monosubstituted Benzene Derivatives.*

By W. GERRARD, E. F. MOONEY, and H. A. WILLIS.

RANDLE and WHIFFEN [1] laid a firm foundation for the method of indicating the position of substituents in the benzene ring by using the so-called " substitution patterns " in the 800—625 cm.$^{-1}$ region. These authors assign the two prominent bands in the mono-substitution pattern to the $B_2\gamma$C–H mode or " umbrella " vibration (I) (751 ± 15 cm.$^{-1}$) and the $B_2\phi$C–H mode (II) (697 ± 11 cm.$^{-1}$). (The signs + and — indicate out-of-plane positions of the atoms.) They consider that these frequencies are substantially independent

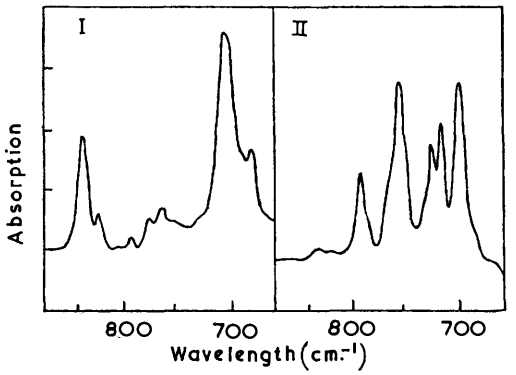


(I) (II)

of the group X. Bellamy [2] states that these bands may be influenced by electronic effects but gives little detail, while Kross, Fassel, and Margoshes [3] observe disturbance of the accepted pattern when X is a deactivating group such as NO_2 or CO_2H.

[1] Randle and Whiffen, " Molecular Spectroscopy," Institute of Petroleum, London, 1955, p. 111.
[2] Bellamy, " Infra-red Spectra of Complex Molecules," Methuen, London, 1959, p. 79.
[3] Kross, Fassel, and Margoshes, *J. Amer. Chem. Soc.*, 1956, **78**, 1332.

During our study of phenylborazole and phenylboroxole derivatives [4] it was observed that the expected substituent patterns were not obtained. No significant band near 750 cm.$^{-1}$ was found, and the striking feature in this substitution region was the very intense band centred on 705 cm.$^{-1}$. In search of the cause of the loss of the substitution pattern we re-examined many compounds with electrophilic substituents, including those previously recorded by Kross *et al.*[3] These authors illustrate the spectra of several benzoic acid derivatives, in which the high-frequency band (I; 750 cm.$^{-1}$) is very weak or absent, but in every case a low-frequency band at 710 cm.$^{-1}$ was remarkably strong; no comment was made upon this very intense band, which is the major feature of the spectra. We have examined sixteen benzoate esters, benzoic anhydride, benzoic acid and its sodium and ammonium salts, and all these show a very intense broad band in the region of 710 cm.$^{-1}$ (Table 1). When R = phenyl or phenyl-substituted alkyl or alkenyl the normal monosubstitution pattern and the " modified " pattern were superimposed.



*Infrared spectra of tri-*B*-chlorotri-*N*-phenylborazole,* (I) *as Nujol mull and* (II) *as* CS_2 *solution.*

That the modification of the substitution pattern is due to electronic interaction is clearly shown in the case of tri-*B*-chlorotri-*N*-phenylborazole, since in carbon disulphide this borazole shows the normal substitution pattern together with the doublet of the borazole ring-deformation mode. We suggest that this recovery of the normal substitution pattern is due to complex formation between carbon disulphide and the borazole derivative in which the electron-deficiency of boron is now compensated by an external co-ordination.

TABLE 1. *Substitution patterns of benzoyl derivatives,* PhCO·Y.[a]

Y	Bands (cm.$^{-1}$)	Y	Bands (cm.$^{-1}$)	Y	Bands (cm.$^{-1}$)
MeO–	One strong band 712—714	PhO–	705, 752, 692 §	$-O^-NH_4^+$	722
EtO–		Ph·CH_2·O–	713, 752, 698 §	Ph–	710
Pr^nO–		Ph·CH_2·CH_2·O–	714, 752, 701 §	Me–	763, 693
Pr^iO–		Ph·CH=CH·O–	712, 747, 692 §	H	746, 690
Bu^nO–		*o*-Me·C_6H_4·O–	708, 751 *		
Bu^iO–		*p*-Me·C_6H_4·O–	707, 805 †		
Am^iO–		–OH	712		
$C_6H_{11}O$–		Ph·CO·O	709		
Citronellyl–		$-O^-Na^+$	714		
Polyethylene glycol					

* *ortho*-Band of *o*-Me·C_6H_4 group. † *para*-Band of *p*-Me·C_6H_4 group. § Monosubstitution bands of unperturbed nucleus.

[a] There was only one strong band, at 712—714 cm.$^{-1}$, when Y was MeO, EtO, Pr^nO, Pr^iO, Bu^nO, Bu^iO, Pr^i·$[CH_2]_2$·O, C_6H_{11}·O, or citronellyl, and for polyethylene glycol.

The bands obtained are shown in Table 2. In tri-*B*-phenylborazole and phenylboronic anhydride, which do not form 1 : 3 complexes with nucleophiles, there is no significant difference between the spectra recorded for a Nujol mull and a carbon disulphide solution,

[4] Beck, Gerrard, Mooney, and Pratt, unpublished work.

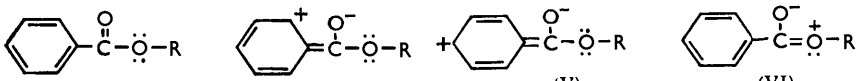
but in both cases the strong band at 708—705 cm.$^{-1}$ is present. The electronic effect is further exemplified by consideration of benzophenone, acetophenone, and benzaldehyde (Y = Ph, Me, and H respectively; Table 1). With the last two compounds, for which the normal substitution pattern is obtained, the methyl group and the hydrogen atom compensate for the $-E$ effect of the carbonyl group, so that the aromatic ring is virtually

TABLE 2. *Infrared bands (cm.$^{-1}$) of boron compounds.*

Compound	Nujol mull	CS_2 soln.
$(ClBNPh)_3$ *	759w, 704s, 690sh, 683m	754s, 724m, 715m, 701s
$(PhBNH)_3$	762w, 700s	708s (705s in tetrahydrofuran)
$(PhBO)_3$	764w, 706s	763w, 707s

* Cf. Figure.

unaffected. By a similar argument it can be seen that the alkoxy-oxygen atom plays little or no part in compensating for the $-E$ effect of the carbonyl group, that canonical forms of the type (VI) make little contribution to the structure, and that (IV) and (V) are the major canonical structures to be considered.



(III) (IV) (V) (VI)

We have observed similar effects in the substitution patterns of ring-substituted benzoate esters and acids and substituted phenylborazoles, and these results will be discussed in another paper.

Experimental.—The purity of the benzoic acid derivatives used was checked by the usual analytical methods. The borazole derivatives and phenylboronic anhydride were prepared by standard methods. The spectra were recorded as capillary films or Nujol mulls and, where stated, in solution. 0·5 mm. cells were used in a Perkin–Elmer 137 spectrometer. The calibration was checked with polystyrene, polyethylene, and ammonia.

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609. *Synthesis of 7-Fluoroflavone and Related Compounds.**

By C. T. CHANG and F. C. CHEN.

IN continuation of the synthesis of 7-halogenoflavones,[1] 7-fluoro-flavone and -flavonol and the 4′-methoxy-compounds were conveniently prepared as described previously,[1] from *m*-fluorophenyl acetate [2] by the steps shown. 7-Fluoro-4′-methoxyflavanone was also obtained by cyclization of the corresponding chalcone in phosphoric or pyrophosphoric acid, but the 7-fluoroflavanone was not available.

Experimental.—Microanalyses were by Dr. E. Aoyagi, Miike Branch, Mitsui Chemical Laboratory, Ohmuda, Japan.

4-Fluoro-2-hydroxyacetophenone (I). *m*-Fluorophenyl acetate (10 g.) and anhydrous aluminium chloride were heated at 160—170° for 2 hr., then decomposed with hydrochloric acid and steam-distilled, giving the *ketone* (8·8 g.), m. p. 24° (Found: C, 61·55; H, 4·7. $C_8H_7FO_2$ requires C, 61·9; H, 4·55%).

4′-Fluoro-2′-hydroxychalcone (II; R = H). To a cooled mixture of the above ketone (1 g.)

* Preliminary report see *J. Formosan Sci.*, 1958, **12**, 149.

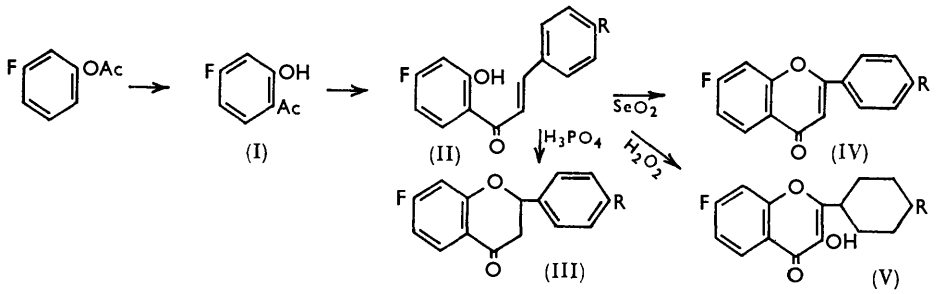
[1] Chang and Chen, *J.*, 1958, 146.

[2] Chen, Chang, Hsu, and Lin, *J. Formosan Sci.*, 1954, **8**, 23.

and benzaldehyde (1·5 g.) in alcohol (10 c.c.) was added cold 60% aqueous potassium hydroxide (5 c.c.). The mixture was treated as stated in the previous paper,[1] giving yellow needles (1·1 g.) of the *chalcone*, m. p. 110—111° (Found: C, 74·2; H, 4·5. $C_{15}H_{11}FO_2$ requires C, 74·4; H, 4·6%).

4'-Fluoro-2'-hydroxy-4-methoxychalcone (II; R = OMe). The above ketone (I) was treated similarly with anisaldehyde, giving the *chalcone* as yellow needles (72%), m. p. 143—144° (Found: C, 70·5; H, 5·0. $C_{16}H_{13}FO_3$ requires C, 70·6; H, 4·8%).

7-Fluoro-4'-methoxyflavanone (III; R = OMe). A solution of 4'-fluoro-2'-hydroxy-4-methoxychalcone (1 g.) and phosphoric acid (*d* 1·75; 5 c.c.) in alcohol (100 c.c.) was refluxed for 72 hr. Concentration afforded a small amount of the *flavanone* as colourless needles, m. p. 90—90·5° (Found: C, 70·9; H, 5·0. $C_{16}H_{13}FO_3$ requires C, 70·6; H, 4·8%).



7-Fluoroflavone (IV; R = H). A mixture of 4'-fluoro-2'-hydroxychalcone (1 g.), selenium dioxide (1 g.), and pentyl alcohol (20 c.c.) was refluxed for 10 hr., giving colourless needles of the *flavone* (0·5 g.), m. p. 101—102° (Found: C, 75·45; H, 4·2. $C_{15}H_9FO_2$ requires C, 75·0; H, 3·8%).

7-Fluoro-4'-methoxyflavone (IV; R = OMe), prepared from 4'-fluoro-2'-hydroxy-4-methoxychalcone (1·5 g.), selenium dioxide (1·5 g.), and pentyl alcohol (30 c.c.), formed colourless needles (1·2 g.), m. p. 220—222° (Found: C, 70·95; H, 4·2. $C_{16}H_{11}FO_3$ requires C, 71·1; H, 4·1%).

7-Fluoroflavonol (V; R = H). 4'-Fluoro-2'-hydroxychalcone (1 g.), methanol (35 c.c.), 16% aqueous sodium hydroxide (10 c.c.), and 15% hydrogen peroxide (10 c.c.) were treated as described in the previous paper,[1] giving the *flavonol* as pale yellow needles (0·8 g.), m. p. 166—167° (Found: C, 70·0; H, 3·5. $C_{15}H_7FO_3$ requires C, 70·3; H, 3·5%).

7-Fluoro-4'-methoxyflavonol (V; R = OMe), prepared from 4'-fluoro-2'-hydroxy-4-methoxychalcone (1·5 g.) by a similar reaction, formed pale yellow needles (1·2 g.), m. p. 200—201° (Found: C, 66·9; H, 4·1. $C_{16}H_{11}O_4F$ requires C, 67·1; H, 3·9%).

Acetates of 7-halogenoflavonols. The 7-halogenoflavonols with acetic anhydride and sodium acetate gave 7-fluoro- (89%), m. p. 115—116°, 7-chloro- (88%), m. p. 122·5—123·5°, 7-bromo- (90%), m. p. 142—143°, and 7-iodo-flavonol acetate (89%), m. p. 152—153°. Similarly were prepared 7-fluoro-4'-methoxy- (83%), m. p. 143—144°, 7-chloro-4'-methoxy- (75%), m. p. 176·5—177·5°, 7-bromo-4'-methoxy- (80%), m. p. 185—186°, and 7-iodo-4'-methoxy-flavonol acetate (82%), m. p. 174·5—176°. All these formed colourless needles.

The authors express their gratitude to Professor T. S. Wheeler (Dublin), President S. L. Chien (this University), and Professor E. Sebe (University of Kumamoto, Japan) for their interest and encouragement, to Mr. T. Ueng for technical assistance, and to the Asia Foundation and to the National Council on Science Development for financial support.

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610. *Crystallographic Examination of the α- and β-Anomers of D-Galactose.*

By B. Sheldrick.

Of the two known forms of D-galactose, the more readily obtainable α-form crystallises as a monohydrate from water and in an anhydrous form from alcohol. The latter has m. p. about 170°; its solution has an initial specific rotation of about +144° and mutarotates to +80°. The β-form [1] has an initial specific rotation of about +52° and mutarotates to +80°.

Unit-cell dimensions were published by Cox *et al.*[2] for " α-D-galactose " (obtained by the method of Riiber *et al.*[3]) and by Braekken *et al.*[4] for " stable *trans*-β-α-galactose." More recently, Werner [5] found that the interplanar spacings calculated from the published figures corresponded with the spacings obtained from a powder photograph, not of α-D-galactose, but of β-D-galactose and he suggested that Cox *et al.* had measured crystals of β-D-galactose in error. This matter has been investigated at the request of Professor E. G. Cox and Dr. T. H. Goodwin.

α- and β-Galactose have been prepared, their identities confirmed by measurement of specific rotations, and their cell dimensions measured on single crystals. The cell dimensions of α-galactose obtained were different from those given by Cox *et al.*, whereas the results for β-galactose were almost identical with those given by Cox *et al.* for α-galactose. However, large prismatic crystals found in the samples of α-galactose prepared by the method of Riiber *et al.*[3] were characterised, by microscopy and *X*-ray diffraction, not as a second crystal form of α-galactose, but as β-galactose. The fact that this can occur is now believed to have been the cause for the discrepancy.

Riiber *et al.*[3] state that E. Berner measured some crystals of β-galactose and found them to be monoclinic with axial angle $\beta = 106° 25'$ and axial ratios $a : b : c = 0{\cdot}827 : 1 : 0{\cdot}75$. These had crystallised from an aqueous solution and may, therefore, be hydrated. (There is a misprint in the reference which Braekken *et al.*[4] give to this work, the date being given as 1928 instead of 1929.)

Experimental.—*α-Galactose* (cf. Riiber *et al.*[3]). D-Galactose (10 g.) was dissolved in water (8 ml.) on a water-bath, hot absolute alcohol (120 ml.) was added, and the mixture allowed to cool slowly. The alcohol produced a heavy precipitate of microcrystalline α-galactose, which was filtered off; afterwards, on cooling, a mass of small plate-like crystals containing numerous aggregates appeared. These were not suitable for examination and a further crystallisation was carried out as follows:

D-Galactose (10 g.) was dissolved in water (12 ml.) on a water-bath, hot absolute alcohol (300 ml.) was added, and the mixture allowed to cool slowly. The crystals obtained were washed with alcohol and allowed to dry in the air. They were large and mostly intergrown, but all alike. They were similar in shape and appearance to those described by Ost [6] and a sample, dissolved in water, gave a mutarotation which confirmed that this material was α-galactose. Initially $[\alpha]_D^{21{\cdot}0}$ was +130° (Hudson and Janowsky [1] give $[\alpha]_D^{20}$ +144°).

A powder photograph of this α-galactose was obtained and the spacing calculated from it corresponded to the spacing given by Werner for α-galactose.

Single-crystal *X*-ray photographs, taken on a Weissenberg camera, showed the space group to be $P2_12_12_1$ and the cell dimensions to be: $a = 15{\cdot}78 \pm 0{\cdot}03$; $b = 7{\cdot}85 \pm 0{\cdot}02$; $c = 5{\cdot}92 \pm 0{\cdot}02$ Å. The density, measured by suspension in tetrachloroethane–tetrachloroethylene, was $1{\cdot}60_1$ g./ml. This gave a cell weight of 706 and a molecular weight of 177 (Calc. for $C_6H_{12}O_6$: *M*, 180). The α-galactose examined was therefore anhydrous.

[1] Hudson and Janowsky, *J. Amer. Chem. Soc.*, 1917, **39**, 1021.
[2] Cox, Goodwin, and Wagstaff, *J.*, 1935, 978.
[3] Riiber, Minsaas, and Lyche, *J.*, 1929, 2173.
[4] Braekken, Koren, and Sørensen, *Z. Krist.*, 1934, **88**, 205.
[5] Werner, *Mikrochem.*, 1952, **39**, 133.
[6] Ost, *Z. analyt. Chem.*, 1890, **29**, 651.

The crystal faces present were {011} in addition to {100}, {010} and {001}.

β-*Galactose* (cf. Hudson and Janowsky [1]). D-Galactose (8 g.) was dissolved in hot water, cooled to 0°, and poured, with stirring, into absolute alcohol (200 ml.) previously cooled in ice–salt. The crystals produced were washed quickly with cold alcohol and allowed to dry. They were prismatic, quite different from the flat plates of the α-form, and had faces of the type {201} and {210}. A sample mutarotated in water in the direction required for β-galactose, and a powder photograph gave spacings in agreement with those given by Werner for β-galactose.

Single-crystal *X*-ray photographs, taken on a Weissenberg camera, showed the space group to be $P2_12_12_1$ and the cell dimensions to be: $a = 12{\cdot}67 \pm 0{\cdot}03$; $b = 7{\cdot}77 \pm 0{\cdot}02$; $c = 7{\cdot}68 \pm 0{\cdot}02$ Å. The cell dimensions given by Cox *et al.*,[2] supposedly for α-galactose, were: $a = 12{\cdot}68$; $b = 7{\cdot}78$; $c = 7{\cdot}71$ Å.

The density was $1{\cdot}61_3$ g./ml., which gave a cell weight of 727 and $M = 182$; hence this β-galactose was anhydrous.

Microscopic examination of the first batch of α-galactose prepared by the method of Riiber *et al.* showed that it contained some large prismatic crystals, usually at the centre of aggregates of the smaller, plate-like crystals. Riiber *et al.* themselves noted this fact. Some of these prismatic crystals were separated and measured. Single-crystal *X*-ray rotation photographs showed them to have the cell dimensions of β-galactose. Measurement of the interfacial angles confirmed the presence of faces of the types {201}, {110}, and {210}.

The author thanks Professor E. G. Cox for his suggestions and provision of facilities for this work, and Dr. J. H. Robertson for his advice.

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611. *Hydrolysis of* N-*Acylphosphoramidic Acids. Part IV.*[1] N-*Benzenesulphonylphosphoramidic Acid.*

By M. Halmann, A. Lapidot, and David Samuel.

N-Substituted phosphoramidic acids are hydrolysed in aqueous solution to phosphoric acid and an amide or amine. Previous papers in this series have shown that the rates of hydrolysis are maximal at about pH 4.[1,2] At this pH the compounds are mostly in the monoanion form, indicating that an acidic proton is required for solvolysis, as has been suggested for monoalkyl phosphates.[3] In the more acid range, below pH 1, *N*-substituted phosphoramidic acids show differences in rate and in the effect of acids, depending on the substituting group. Hydrolyses of phenyl, *p*-methoxyphenyl, and unsubstituted phosphoramidic acids $R{\cdot}NH{\cdot}PO(OH)_2$ are strongly catalysed by acids,[4] whereas the *N*-acylphosphoramidic acids investigated, *i.e.*, those with a carbonyl or phosphoryl group adjacent to the nitrogen atom, are not susceptible to acid catalysis. It was suggested [1] that this may be due to the marked polarity of the carbonyl and phosphoryl groups which causes withdrawal of negative charge from the nitrogen of the phosphoramidic acid and makes it less susceptible to protonation. This interpretation was supported by the observation that the *N*-acylphosphoramidic acids, phosphourethane $C_2H_5{\cdot}CO{\cdot}NH{\cdot}PO(OH)_2$, and diphenyl *N*-dihydroxyphosphinylphosphoramidate $(PhO)_2PO{\cdot}NH{\cdot}PO(OH)_2$ are hydrolysed at the same rates in water and in deuterium oxide, presumably since there is no protonation of nitrogen in acid solution (to form the conjugate acid). We have now tested this hypothesis by examining the hydrolysis of another phosphoramidic acid with a highly polar acyl group, benzenesulphonyl, in the presence of acid and also in D_2O.

[1] Part III, Halmann, Lapidot, and Samuel, *J.*, 1960, 4672.
[2] (*a*) Lapidot and Halmann, *J.*, 1958, 1713; (*b*) Halmann and Lapidot, *J.*, 1960, 419.
[3] Westheimer, *Chem. Soc. Spec. Publ.*, No. 8, 1957, p. 1; Vernon, *ibid.*, p. 17.
[4] Chanley and Feageson, *J. Amer. Chem. Soc.*, 1958, **80**, 2686; Winnick and Scott, *Arch. Biochem. Biophys.*, 1947, **12**, 201; Rathler and Rosenberg, *ibid.*, 1956, **65**, 319.

N-Benzenesulphonylphosphoramidic acid,[5] $Ph{\cdot}SO_2{\cdot}NH{\cdot}PO(OH)_2$, was found to hydrolyse smoothly to benzenesulphonamide and phosphoric acid. The rates of hydrolysis determined at various pH's and temperatures are summarised in Table 1. From the temperature-dependence of the rate of hydrolysis, the energy and entropy of activation at pH 4 were calculated: $\Delta E^* = 26{\cdot}1$ kcal./mole; $\Delta S^* = +0{\cdot}56$ e.u. These values are very

TABLE 1. *Hydrolysis of* N-*benzenesulphonylphosphoramidic acid* [10^4k (*obs.*) (*sec.*$^{-1}$)].

Solvent	$HClO_4$ 8·3M	$HClO_4$ 5·8M	KHP * 0·05M	DB * 0·05M	$Na_2B_4O_7$ 0·5M
pH			4·02	7·4	9·07
60·0°	1·13	1·32	8·9	0·94	0·013
50·0°			3·31		
37·0°			0·55		

* KPH = KH phthalate. DB = diethyl barbiturate.

similar to those found for other phosphoramidic acids.[1,2] The rates of hydrolysis in water and in deuterium oxide were determined at pH 4 and in 0·1M-sulphuric acid (or deuterosulphuric acid) at 50° and at 60°. The results are given in Table 2.

Table 1 shows that at 60° there is a maximum in the rate at pH 4, as with other substituted phosphoramidic acids. The dissociation constants of *N*-benzenesulphonylphosphoramidic acid at 25° were $K_1 = (1{\cdot}49 \pm 0{\cdot}09) \times 10^{-4}$, $K_2 = (7{\cdot}72 \pm 0{\cdot}12) \times 10^{-8}$, indicating again that the monoanion is the active species in hydrolysis. On the other hand, as shown in Table 1, there is *no* catalysis by acids even in 8M-perchloric acid. This is due to prevention of protonation on the amido-nitrogen by the very polar sulphonyl group. It is further confirmed by the total absence of a deuterium isotope effect on hydrolysis shown in Table 2.

From these results and those of previous papers in this series,[1,2,4] the susceptibility to acid catalysis is seen to decrease in the order, $Ar{\cdot}NH{\cdot}PO(OH)_2$, $Ph{\cdot}CO{\cdot}NH{\cdot}PO(OH)_2$, $EtO_2C{\cdot}NH{\cdot}PO(OH)_2$, $(PhO)_2PO{\cdot}NH{\cdot}PO(OH)_2$, $Ph{\cdot}SO_2{\cdot}NH{\cdot}PO(OH)_2$. *N*-Benzoylphos-

TABLE 2. *Solvolysis of* N-*benzenesulphonylphosphoramidate in water and* D_2O [10^4k (*obs.*) (*sec.*$^{-1}$)].

Solvent	Temp.	H_2O	D_2O
K H Phthalate (0·05M)	50·0°	3·31 ± 0·01	3·36 ± 0·02
Sulphuric acid (0·1M)	60·0°	5·65 ± 0·03	5·65 ± 0·01

phoramidic acid will undergo acid catalysis in very concentrated acid, possibly because the phenyl group reduces the electron-deficiency at the carbonyl-carbon atom. In the *N*-benzenesulphonyl compound, however, it appears that the polarity of the sulphonyl group is such that the phenyl group has no effect and acid catalysis is prevented even at very high acidities (8M).

Experimental.—*N*-Benzenesulphonylphosphoramidic acid was prepared according to directions of Kirsanov and Abrazhanova [5] and after two washings with anhydrous ether had m. p. 149—150° (Found: P, 13·15. Calc. for $C_6H_8NO_5PS$: P, 13·1%). The dissociation constants at 25° were determined by the Henderson equation, $pK = -\log [H^+][B + H^+]/(C - [B + H^+])$, from the titration curve with sodium hydroxide; a Radiometer glass electrode pH-meter was used.

The products of hydrolysis were benzenesulphonamide, m. p. 156°, and phosphoric acid (yield, determined colorimetrically, 100 ± 1%).

Kinetic experiments. The *N*-benzenesulphonylphosphoramidic acid (20—30 mg.) in aqueous buffer or acid solution (25 ml.) was kept in a thermostat and at intervals, aliquot parts were withdrawn for determination of phosphate by Fiske and Subbarow's method.[6] Runs were

[5] Kirsanov and Abrazhanova, *Sbornik Statei Obshchei Khim.*, 1953, **2**, 1048.
[6] Fiske and Subbarow, *J. Biol. Chem.*, 1925, **66**, 375.

made at least in duplicate and rate constants were calculated for first-order reactions. D_2O containing sulphuric acid (0·1M) was prepared from deuterosulphuric acid (Fluka) and deuterium oxide (Norsk-Hydro).

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612. *A Simple Synthesis of αβ-Dialkylacrylic Acids.*

By ISRAEL SHAHAK.

IT has been found [1] that β-alkyl-α-fluoroacrylic acids can be prepared easily and in good yield by condensation of aldehydes with diethyl α-fluoro-oxaloacetate without isolation of any of the intermediate compounds or even the keto-ester itself:

$$R{\cdot}CHO + EtO_2C{\cdot}CO{\cdot}CHF{\cdot}CO_2Et \longrightarrow R{\cdot}CH{:}CF{\cdot}CO_2H$$

It seemed worthwhile to apply the same principle to the synthesis of αβ-dialkylated acrylic acids from diethyl α-alkyloxaloacetates. This has been achieved, with overall yields of 70—75% based on the initial ester. The systems studied were ethyl propionate with benzaldehyde and heptaldehyde, and ethyl butyrate with heptaldehyde. For comparison the condensation of ethyl α-ethoxalyl-propionate, -butyrate, and -phenylacetate with benzaldehyde was investigated; *i.e.*, in these cases the intermediate derivative was isolated. The yields in the condensation with benzaldehyde were of the order of 90%.

The keto-esters used here were less reactive than diethyl α-fluoro-oxaloacetate: whilst the latter reacted in ether or tetrahydrofuran, boiling xylene or dibutyl ether (about 140°) had to be used in the present cases.

The products were identified by comparison with authentic specimens; in one instance, the substituted acrylic acid was hydrogenated to the known corresponding saturated acid. The ultraviolet spectra of ethyl 2-methyl- ($\lambda_{max.}$ 221 mμ; log ε 4·08) and 2-ethyl-non-2-enoate ($\lambda_{max.}$ 220 mμ; log ε 4·00) (both in ethanol) also showed that the acids obtained were αβ-unsaturated; their spectrum is that of crotonic acid,[2] but shifted bathochromically by the β-alkyl groups. In the infrared spectra of the two compounds, the carbonyl absorption was at 1707 cm.$^{-1}$, that of the C=C double bond at 1661 cm.$^{-1}$.

The condensation of α-alkyloxaloacetates with formaldehyde [3] and aromatic aldehydes [4] has been studied before, but only up to the first step of β-ethoxycarbonyl-α-oxo-γ-butyrolactones (hydrogen or aryl in β-position).

Experimental.—Ethyl α-methylcinnamate. (*a*) Diethyl oxalate (15 g.) and ethyl propionate (10·2 g.) were added successively to a suspension of sodium hydride (2·4 g.) or sodium ethoxide (6·8 g.) in dibutyl ether or xylene (150 ml.); after 1 hr. at 50°, the mixture was heated at 70°/35 mm. until the ethanol had distilled off and the b. p. of dibutyl ether (or xylene) had been reached. Usually, the enolate of ethyl α-ethoxalylpropionate separated. After 30 min. at 50°, freshly distilled benzaldehyde (10·6 g.) was added and the mixture refluxed for 1 hr. The enolate disappeared, and the product gradually crystallized. The mixture was poured into water, and the organic layer washed with 7% sodium carbonate solution and water, dried, and concentrated at 35 mm. The residual ester (12 g., 63%) distilled at 124—125°/1 mm. Its hydrolysis gave α-methylcinnamic acid, m. p. and mixed m. p. 81°.[5] This acid was further hydrogenated in

[1] Bergmann and Shahak, *J.*, in the press.
[2] Hausser, Kuhn, Smakula, and Hoffer, *Z. phys. Chem.*, 1935, *B*, **29**, 371.
[3] Schinz and Hinder, *Helv. Chim. Acta*, 1947, **30**, 1349.
[4] Labib, *Compt. rend.*, 1957, **244**, 2396.
[5] Raikov, *Ber.*, 1887, **20**, 3396.

the presence of platinum oxide as catalyst to α-methyl-β-phenylpropionic acid, b. p. 142°/2 mm., m. p. 36° [6] (amide, m. p. 110°).

(*b*) From ethyl α-ethoxalylpropionate [7] (20·2 g.) and sodium hydride (2·4 g.), the enolate was prepared in xylene (150 ml.). When all the sodium hydride had reacted, benzaldehyde (10·6 g.) was added and the preparation continued as above. The yield of the ester was 18·5 g. (97%).

Ethyl α-ethylcinnamate. (*a*) This ester was prepared analogously, from ethyl butyrate, diethyl oxalate, and benzaldehyde, the yield being 15 g. (74%), and the b. p. 122—123°/1 mm. Hydrolysis gave the known *trans*-α-ethylcinnamic acid,[8] m. p. 104°.

(*b*) When ethyl α-ethoxalylbutyrate [9] (21·6 g.) was employed in xylene (150 ml.), ethyl α-ethylcinnamate was obtained in 94% yield (19 g.).

Ethyl 2-methylnon-2-enoate, obtained in 93% yield from ethyl propionate and heptaldehyde, had b. p. 93—95°/2 mm. (Found: C, 72·9; H, 11·3. $C_{12}H_{22}O_2$ requires C, 72·7; H, 11·1%).

Ethyl 2-ethylnon-2-enoate, prepared in 95% yield from ethyl butyrate and heptaldehyde, had b. p. 95—98°/2 mm. (Found: C, 73·2; H, 11·6. $C_{13}H_{24}O_2$ requires C, 73·6; H, 11·3%).

Ethyl α-phenylcinnamate. (*a*) As described above, ethyl phenylacetate (18·4 g.) and diethyl oxalate (15 g.) were condensed by means of sodium hydride (2·4 g.) in dibutyl ether (500 ml.), and benzaldehyde (10·6 g.) was added. The ester (20·5 g., 81%) boiled at 163—165°/1 mm. Hydrolysis gave *trans*-α-phenylcinnamic acid,[10] m. p. 172°.

(*b*) Ethyl sodio-α-ethoxyalyl-α-phenylacetate [11] (28·6 g.) was suspended in xylene (150 ml.), benzaldehyde (10·6 g.) added, and the mixture refluxed for 1 hr. The yield of ethyl α-phenylcinnamate was 91% (23 g.).

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[*Received, January 30th*, 1961.]

[6] Conrad and Bischoff, *Annalen*, 1880, **204**, 194.
[7] *Org. Synth.*, Coll. Vol. II, p. 272.
[8] Claisen, *Ber.*, 1890, **23**, 976.
[9] Adickes and Andresen, *Annalen*, 1943, **555**, 41.
[10] Mueller, *Ber.*, 1893, **26**, 659.
[11] Wislicenus, *Ber.*, 1894, **27**, 1092.

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613. *Degradative Studies of Peptides and Proteins. Part VI.*[1] *The Cyclisation and Degradation of N-Phenylthiocarbamoylsarcosine Derivatives.*

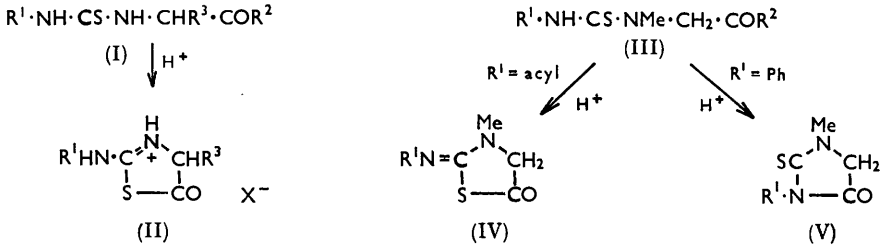
By D. T. ELMORE.

IT has been shown that anhydrous acids degrade *N*-phenyl- and *N*-acyl-thiocarbamoyl-peptides (I; R^1 = Ph or acyl) to salts of 2-anilino- and 2-acylamino-thiazol-5-ones (II; R^1 = Ph or acyl) respectively.[2,3] Since, however, *N*-acylthiocarbamoyl derivatives of sarcosine (III; R^1 = acyl) afford 2-acylimino-3-methylthiazolid-5-ones (IV; R^1 = acyl),[1] we decided to study the degradation of *N*-phenylthiocarbamoylsarcosine derivatives (III; R^1 = Ph). The amide and benzylamide of *N*-phenylthiocarbamoylsarcosine (III; R^1 = Ph, R^2 = NH_2 or $NH{\cdot}CH_2Ph$) were synthesised from phenyl isothiocyanate and the corresponding sarcosine derivatives. Cyclisation occurred with astonishing ease, either on brief warming or on treatment with cold trifluoroacetic acid. The product in both cases was 1-methyl-3-phenyl-2-thiohydantoin (V; R^1 = Ph), identical with a synthetic sample;[4] there was no sign of an intermediate 2-anilino-3-methylthiazolid-5-one. Rearrangement of *N*-substituted 2-iminothiazolid-5-ones to 2-thiohydantoins is probably facilitated by a high electron-density on the imino-nitrogen atom. Since this is diminished by resonance with the adjacent carbonyl group in 2-acyliminothiazolid-5-ones, the relative stability of

[1] Part V, Elmore, *J.*, 1959, 3152.
[2] Edman, *Nature*, 1956, **177**, 667; *Acta Chem. Scand.*, 1956, **10**, 761.
[3] Elmore and Toseland, *J.*, 1957, 2460.
[4] Cook and Cox, *J.*, 1949, 2342.

the latter and the absence of a corresponding intermediate in the degradation of *N*-phenylthiocarbamoylsarcosine derivatives can be explained.

It is of interest to note that a strong " thioureide " band at 1518 cm.$^{-1}$ is present in the



infrared spectrum of 1-methyl-3-phenyl-2-thiohydantoin. This is additional evidence in support of the suggestion [5] that this feature of the spectra of compounds containing the >N·C:S system is not due solely to a δNH frequency.

Experimental.—N-*Phenylthiocarbamoylsarcosine amide.* Sarcosine amide (from 3·72 g. of the hydrogen sulphate [6]) in a mixture of dry ether (5 c.c.) and chloroform (5 c.c.) was treated with phenyl isothiocyanate (2·70 g.) in ether (5 c.c.). The crystalline N-*phenylthiocarbamoyl derivative* (3·97 g.), which separated, had m. p. 156—158° (decomp.) (Found: C, 53·6; H, 5·55; N, 19·05. $C_{10}H_{13}N_3OS$ requires C, 53·8; H, 5·9; N, 18·8%). In warm ethanol, acetonitrile, or cold pyridine, ammonia was evolved. From ethanol, 1-methyl-3-phenyl-2-thiohydantoin was obtained, m. p. and mixed m. p. 160·5—161·0°. 1-Methyl-3-phenyl-2-thiohydantoin in methanol had $\lambda_{max.}$ 266·5 (ε 14,100) and 235 (ε 10,700), $\lambda_{min.}$ 248 (ε 8600) and 222—226 mμ (ε 10,200).[7]

N-*Phenylthiocarbamoylsarcosine benzylamide.* Sarcosine benzylamide (from 2·60 g. of the hydrobromide [1]) in ether (20 c.c.) was treated with phenyl isothiocyanate (1·35 g.) in ether (20 c.c.). The *product* (3·06 g.), after crystallisation from ethanol with the minimum of heating, had m. p. 128—129° (Found: C, 65·3; H, 6·4; N, 13·7. $C_{17}H_{19}N_3OS$ requires C, 65·1; H, 6·1; N, 13·4%). On one occasion, attempted recrystallisation of the crude product afforded 1-methyl-3-phenyl-2-thiohydantoin, m. p. and mixed m. p. 160—161°. The benzylamide (0·626 g.) was left in trifluoroacetic acid (2 c.c.) for 40 hr. After evaporation, addition of water afforded the thiohydantoin (0·350 g.), which had m. p. and mixed m. p. 160·5—161·0° after recrystallisation.

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[*Received, February 2nd,* 1961.]

[5] Elmore, *J.*, 1958, 3489.
[6] Cook and Cox, *J.*, 1949, 2334.
[7] Edward and Nielsen, *J.*, 1957, 1014.

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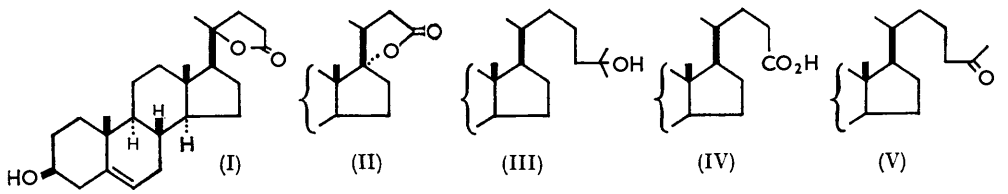
614. *Hydroxylation of 5α,6β-Dibromocholestan-3β-yl Acetate by Chromic Acid.*

By A. L. J. BECKWITH.

OXIDATION of 5α,6β-dibromocholestane-3β-yl acetate, the key reaction in the preparation of steroid hormones from cholesterol, has been the subject of numerous investigations.[1] The major products obtained after debromination and hydrolysis are 3β-hydroxyandrost-5-en-17-one (2—8%) and 3β-hydroxypregn-5-en-20-one, but a number of other products, most of which are formed by oxidative degradation of the side chain, have also been isolated. It has been suggested [1,2] that the initial step is a hydroxylation, occurring most

[1] See Fieser and Fieser, " Steroids," Reinhold Publ. Corp., New York, 1959, pp. 508—511.
[2] Billeter and Miescher, *Helv. Chim. Acta*, 1947, **30**, 1409.

readily at tertiary positions, a hypothesis supported by the formation of the lactone (I) of 3β,20ξ-dihydroxychol-5-enoic acid.[2,3] Similarly, oxidation of sitosterol acetate dibromide yields the lactone (II) of 3β,17α-dihydroxy-23-norchol-5-enoic acid.[4]



(I) (II) (III) (IV) (V)

Additional evidence for a mechanism involving hydroxylation has now been obtained. After debromination and hydrolysis of the crude product from oxidation of 5α,6β-dibromocholestan-3β-yl acetate with chromium trioxide in acetic acid [5] the neutral fraction was distributed between hexane and 92% aqueous methanol. The material from the polar phase, when chromatographed on alumina, yielded cholest-5-ene-3β,25-diol (III) which was identified by preparation of the mono- and the di-acetate.[6] A very small amount of an unidentified triol, $C_{27}H_{46}O_3$, was also isolated.

The formation of the diol (III) in relatively high yield (2%, calculated on unrecovered cholesterol) indicates that it is possibly a precursor of the previously isolated products, 3β-hydroxychol-5-enoic acid [5,7] (IV) and 3β-hydroxy-27-norcholest-5-en-25-one [8] (V), both of which may be formed by dehydration of the tertiary alcohol followed by oxidation of the double bond. The ready hydroxylation at the 25-position is in accord with the formation of cholest-5-ene-3β,25-diol by aerial oxidation of cholesterol.[9]

Experimental.—3β-Acetoxy-5α,6β-dibromocholestane (28 g.) was oxidised with chromium trioxide (48 g.) in acetic acid.[5] After debromination with zinc dust (30 g.) in acetic acid (200 ml.) the crude product, dissolved in ether, was extracted with 2N-aqueous sodium hydroxide. Acidification of the aqueous extract yielded a mixture of acids (2·8 g.). Evaporation of the ethereal solution afforded a gum (13·7 g.) which was heated under reflux with potassium hydroxide (10 g.) in methanol (250 ml.) for 2 hr. Cholesterol (7·4 g.), which crystallised from the cooled reaction mixture, was collected and the filtrate and washings were evaporated. The residue (4·9 g.) was distributed between hexane and 92% methanol (3 × 60 ml. of each solvent) in separatory funnels, and the methanol-soluble material (1·76 g.) was chromatographed on alumina. Gradient elution with ether–hexane gave the following fractions:

(i) Cholest-5-ene-3β,25-diol (180 mg.) which crystallised from ether–hexane in prisms, m. p. 178—180°, $[\alpha]_D^{20}$ −38° (lit.,[5] m. p. 177—179°, 181·5—182·5°, $[\alpha]_D^{19}$ −39·3°, $[\alpha]_D^{25}$ −38·6°) (Found: C, 80·4; H, 11·5. Calc. for $C_{27}H_{46}O_2$: C, 80·5; H, 11·5%). The monoacetate prepared by treatment of the diol with pyridine and acetic anhydride at 0° formed needles (from methanol), m. p. 140—142°, $[\alpha]_D^{20}$ −42° (lit.,[5] m. p. 138—140°, 140—141°, $[\alpha]_D^{19}$ −40·4°, $[\alpha]_D^{25}$ −42·1°) (Found: C, 78·0; H, 10·8. Calc. for $C_{29}H_{48}O_3$: C, 78·3; H, 10·9%). Acetylation of the monoacetate with the same reagents under reflux yielded the diacetate which crystallised from methanol in plates, m. p. 119—120°, $[\alpha]_D^{25}$ −35° (lit.,[5] m. p. 119·5—120°, $[\alpha]_D^{25}$ −35·5°) (Found: C, 76·5; H, 10·6. Calc. for $C_{31}H_{50}O_4$: C, 76·5; H, 10·4%). Treatment of the diol with pyridine and benzoyl chloride at 100° for 1 hr. afforded the *dibenzoate*, laths (from ethanol), m. p. 100—102°, $[\alpha]_D^{20}$ −10° (Found: C, 80·7; H, 9·0. $C_{41}H_{54}O_4$ requires

[3] Miescher and Fischer, *Helv. Chim. Acta*, 1939, **22**, 155; Billeter and Miescher, *ibid.*, 1949, **32**, 564; Ryer and Gebert, *J. Amer. Chem. Soc.*, 1952, **74**, 4336.
[4] Ryer and Gebert, *J. Amer. Chem. Soc.*, 1952, **74**, 41.
[5] Wallis and Fernholz, *J. Amer. Chem. Soc.*, 1935, **57**, 1504.
[6] Ryer, Gebert, and Murrill, *J. Amer. Chem. Soc.*, 1950, **72**, 4247; Dauben and Bradlow, *ibid.*, p. 4248.
[7] Ruzicka and Wettstein, *Helv. Chim. Acta*, 1935, **18**, 986.
[8] Ruzicka and Fischer, *Helv. Chim. Acta*, 1937, **20**, 1291.
[9] Fieser, Huang, and Bhattacharyya, *J. Org. Chem.*, 1957, **22**, 1380; Beckwith, *Proc. Chem. Soc.* 1958, 194.

C, 80·6; H, 8·9%). A similar benzoylation at 0° yielded a *monobenzoate*, as rods (from hexane), m. p. 176—178°, $[\alpha]_D^{25}$ −13° (Found: C, 80·4; H, 9·8. $C_{34}H_{50}O_3$ requires C, 80·6; H, 9·9%).

(ii) An unidentified *triol* (65 mg.) which crystallised from aqueous methanol in plates, m. p. 192° (Found: C, 77·1; H, 11·0. $C_{27}H_{46}O_3$ requires C, 77·45; H, 11·1%). The *diacetate* crystallised from aqueous methanol in rods, m. p. 137° (Found: C, 74·0; H, 10·1. $C_{31}H_{50}O_5$ requires C, 74·1; H, 10·0%).

(iii) Cholestane-3β,5α,6β-triol (18 mg.), identical with an authentic specimen.

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615. *The Reaction of Dialkyl Phosphites and Trialkyl Phosphates with Sodium* NN-*Diethyldithiocarbamate.*

By T. D. SMITH.

As part of a study of salts of organic phosphorus acids the reaction of dialkyl phosphites with salts of *NN*-diethyldithiocarbamic acid was investigated. This may be represented as: $PHO(OR)_2 + NEt_2{\cdot}CS{\cdot}SNa \longrightarrow PHO(OR){\cdot}ONa + NEt_2{\cdot}CS_2R$. With dimethyl phosphite the reaction was complete within minutes, but for higher alkyl phosphites required some hours. Zinc diethyldithiocarbamate yielded zinc monoalkyl phosphites and the corresponding ester of diethyldithiocarbamate, though reaction, even in the case of dimethyl phosphite, required a higher temperature.

It has been noted in the alkylation of thiourea [1] that trialkyl phosphates are as effective alkylating agents as dialkyl phosphites. Reaction of trialkyl phosphates with sodium diethyldithiocarbamate gave the sodium dialkyl phosphate and the diethyldithiocarbamate ester. Again reaction with trimethyl phosphate was complete within minutes, but higher alkyl phosphates required prolonged heating at 100°.

General methods for the preparation of esters of dialkylthiocarbamic acids include treatment of the aqueous sodium salt with alkyl halides [2] and reaction of the free acid with a compound having an activated C–C double bond to which the dithiocarbamic acid adds.[3] The present work establishes a further method for the preparation of the n-alkyl esters. Sodium monoalkyl phosphites have been obtained by treatment of the dialkyl phosphites with 1 mol. of sodium hydroxide in aqueous alcohol followed by evaporation in a vacuum.[4] Alternatively treatment of sodium dialkyl phosphites with 1 mol. of water in dry alcohol results in good yields of the sodium monoalkyl phosphites. Reaction of dialkyl phosphites with sodium diethyldithiocarbamate results in a convenient preparation of the sodium salt of the monoalkyl phosphite in good yield.

Experimental.—Sodium *NN*-diethyldithiocarbamate (0·5 mole) was heated at 100° with the dialkyl phosphite (0·5 mole) for 4 hr. during which there was no loss in weight though during the early stages an ammoniacal odour developed. The mixture separated into two phases, completion of reaction being noted by treating samples of both phases with an aqueous solution of cupric chloride which detects extremely small quantities of diethyldithiocarbamate. When an excess of dialkyl phosphite was used the remaining dialkyl phosphite appeared almost completely in the upper phase. The lower phase was separated and treated with 200 ml. of acetone; the sodium monoalkyl phosphite separated. After filtration the residue was washed with dry ether and the salt recrystallised from ethanol.

The filtrate was evaporated to remove acetone, and the residue combined with the upper phase and washed with 10% aqueous potassium carbonate (2 × 200 ml.). The ester was finally

[1] Smith and Parker, *J.*, 1961, **442**.
[2] Campbell and Tyson, *Ind. Eng. Chem.*, 1953, **45**, 125.
[3] Hook, Beegle, and Wystrach, U.S.P. 2,786,866.
[4] Nylen, *Svensk Kem. Tidskr.*, 1936, **48**, 2.

washed with hot water and distilled at low pressure.[2] The salient features of the various syntheses are detailed in the annexed Table. From dimethyl phosphite the sodium salt was

Product	Yield (%)	M. p.	Found (%) C	H	P or S	N	Required (%) C	H	P or S	N
$NaBuHPO_4$	69	177°	33·0	6·9	22·1		33·1	6·9	22·1	
$NaEtHPO_4$	71	183	20·3	5·0	26·4		20·6	5·2	26·7	
$NEt_2 \cdot CS_2Bu$	64		53·1	9·4	30·9	6·8	52·7	9·3	31·2	6·8
$NEt_2 \cdot CS_2Et$	79		47·5	8·5	36·0	7·85	47·45	8·5	33·2	7·9
$NEt_2 \cdot CS_2Me$	94		43·9	8·0	39·1	8·55	44·2	8·0	39·3	8·6

obtained as a very hygroscopic solid. Of the trialkyl phosphates used trimethyl phosphate reacted most readily, though in all cases the reaction was carried out under reflux with a small flame.

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[*Received, February 23rd*, 1961.]

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616. *Interaction between Selenium Oxychloride and the Trichlorides of Boron and Aluminium.*

By M. J. FRAZER.

MANY metal and non-metal chlorides dissolve in selenium oxychloride,[1] and these solutions have been of interest in connection with theories of acid and base behaviour in aprotic solvents.[2] Only a few solid solvates ($SnCl_4,2X$;[3,4] $SbCl_5,X$;[4] $ZrCl_4,2X$;[5] where $X = SeOCl_2$) have been isolated; but the solids isolated from selenium oxychloride solutions of phosphorus trichloride and pentachloride,[6] silicon tetrachloride,[3] and titanium tetrachloride [3] contain selenium tetrachloride.

Selenium oxychloride, when mixed with boron trichloride or aluminium trichloride in methylene chloride, gave a precipitate, which analysis indicated to be either the addition compound $2MCl_3,3SeOCl_2$ or the products of the reaction: $2MCl_3 + 3SeOCl_2 \longrightarrow M_2O_3 + 3SeCl_4$, where M = B or Al. The precipitate was formed immediately with boron trichloride but more slowly in the second experiment, probably owing to the insolubility of aluminium chloride in methylene chloride. Vacuum-sublimation of the precipitates gave selenium tetrachloride and a residue of boric or aluminium oxide. Additional evidence that there was reaction and not formation of an addition compound came from the infrared spectra of the original precipitates, which did not show bands in the region from 800—975 cm.$^{-1}$ which have been attributed to the Se=O bond in selenium oxychloride and its complexes.[3] Absorption bands between 1400 and 1180 cm.$^{-1}$ in the boron trichloride experiment, and continuous absorption between 900 and 650 cm.$^{-1}$ in the aluminium trichloride experiment, indicated the formation of metal–oxygen links.

Experimental.—Selenium oxychloride (10·38 g., 2 mol.) and boron trichloride (1 mol.) were mixed in methylene chloride (50 c.c.) at −80°. There was immediate formation of a white precipitate (11·40 g.) which was filtered off, washed with methylene chloride, and dried at 10 mm. (Found: B, 3·0; Cl, 58·6; Se, 33·1%). Evaporation of the filtrate gave selenium oxychloride (0·45 mol.) (Found: Cl, 42·2. Calc. for Cl_2OSe: Cl, 42·7%). Sublimation of the precipitate at 10 mm. gave selenium tetrachloride (9·9 g., 95%), m. p. 304° (Found: Cl, 64·0;

[1] Wise, *J. Amer. Chem. Soc.*, 1923, **45**, 1233.
[2] Smith, *Chem. Rev.*, 1938, **23**, 165.
[3] Sheldon and Tyree, *J. Amer. Chem. Soc.*, 1959, **81**, 2290.
[4] Agerman, Andersson, Lindqvist, and Zackrisson, *Acta Chem. Scand.*, 1958, **12**, 477.
[5] Gutmann and Himml, *Z. anorg. Chem.*, 1956, **287**, 199.
[6] Lenher, *J. Amer. Chem. Soc.*, 1922, **44**, 1664.

Se, 35·3. Calc. for Cl_4Se: Cl, 64·2; Se, 35·8%), and a residue (0·9 g.) (Found: B, 30·5. Calc. for B_2O_3: 31·0%).

Aluminium trichloride (1 mol.) was suspended in a mixture of selenium oxychloride (2·50 g., 2 mol.) and methylene chloride (40 c.c.). The mixture was shaken at 20° for 6 hr. Filtration then gave a white powder (2·9 g.) which was washed with methylene chloride and dried at 10 mm. (Found: Cl, 55·1; Se, 30·8%). Evaporation of the filtrate gave selenium oxychloride (0·43 mol.) (Found: Cl, 42·3%). Sublimation of the precipitate at 10 mm. gave the tetrachloride (2·2 g., 88%), m. p. 304° (Found: Cl, 63·9; Se, 35·3%), and a residue of aluminium oxide (0·3 g.) (Found: Al, 52·5. Calc. for Al_2O_3: Al, 52·9%).

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617. *An Aldobiouronic Acid Isolated from* Fagara xanthoxyloides *Gum.*

By F. G. TORTO.

EVIDENCE has been presented [1] for the occurrence of galactose, arabinose, and 4-*O*-methylglucuronic acid in the gum exuded by *Fagara xanthoxyloides* (Lam). Paper-chromatographic examination of the products of partial hydrolysis of the gum reveals the presence of an aldobiouronic acid, composed of galactose and 4-*O*-methylglucuronic acid residues, as well as a slow moving oligosaccharide (or oligosaccharides) composed of galactose and glucuronic acid residues.

Hydrolysis of the polysaccharide with 0·5N-sulphuric acid, followed by precipitation of the neutralised hydrolysate with methanol, gave a mixture of barium salts, from which the barium aldobiouronate was isolated by large-scale paper-chromatography as a white hygroscopic powder, $[\alpha]_D^{24}$ +86°.

The aldobiouronic acid was converted into a neutral disaccharide by reduction of the methyl ester methyl glycoside with potassium borohydride. Methylation of the disaccharide gave a derivative which on acid hydrolysis gave 2,3,6-tri-*O*-methylgalactose and 2,3,4,6-tetra-*O*-methylglucose. The aldobiouronic acid is therefore 4-*O*-(4-*O*-methyl-α-D-glucuronosyl)-D-galactose, the anomeric configuration following from the optical rotation. This aldobiouronic is a component of gum myrrh.[2] A 4-*O*-(4-*O*-methyl-D-glucuronosyl)-D-galactose occurs in gums of Khaya species.[3,4]

Experimental.—Paper chromatograms were run in (*a*) ethyl acetate–acetic acid–formic acid–water (18 : 3 : 1 : 4) or (*b*) butanol–ethanol–water (5 : 1 : 4; upper phase). Sugars were detected with *p*-anisidine phosphate or aqueous ammonium molybdate. R_{gal} and R_G values are relative to the rates of migration of galactose and 2,3,4,6-tetra-*O*-methylglucose, respectively.

Isolation of aldobiouronic acid. Crude gum (60 g.) was heated in 0·5N-sulphuric acid (600 ml.) at 100° for 14 hr. The filtered solution was neutralised with barium carbonate, and then filtered, and the filtrate concentrated under reduced pressure to a light syrup (100 ml.), which was poured with stirring into methanol (1800 ml.). The precipitated barium salts were collected on a sintered-glass filter, washed thoroughly with methanol, and dried ($CaCl_2$) in a vacuum (yield 4·8 g.). On a paper chromatogram the product gave two spots, R_{gal} 0·69 and 0·23, as well as a trace of galactose. The same pattern of spots was obtained from a hydrolysate of a specimen of gum carefully purified by precipitation in acidified methanol.

[1] Torto, *Nature*, 1957, **180**, 864.
[2] Jones and Nunn, *J.*, 1955, 3001.
[3] Aspinall, Hirst, and Matheson, *J.*, 1956, 989.
[4] Aspinall, Johnston, and Stephen, *J.*, 1960, 4918.

A sample of the mixed barium salts was completely hydrolysed by 2N-sulphuric in a sealed tube at 100° for 24 hr. The neutralised solution, de-ionised with IR-120 H, gave galactose, glucuronic acid, glucurone, and 4-*O*-methylglucuronic acid on a chromatogram.

Large-scale paper-chromatography of the mixed barium salts (1 g.) gave barium aldobiouronate as a white hygroscopic powder (350 mg.), $[\alpha]_D^{24}$ +86° ± 1° (*c*, 0·5 in water) (Found: Ba, 15·8; OMe, 6·1. Calc. for $C_{26}H_{42}O_{24}Ba$: Ba, 15·7; 2OMe, 7·1%). Prolonged chromatography (90 hr.) with solvent (*a*) indicated that the material was homogeneous. Upon complete hydrolysis with 2N-sulphuric acid, it gave galactose and 4-*O*-methylglucuronic acid on the chromatogram. Only 4-*O*-methylglucuronic acid was detected in the hydrolysate of a specimen oxidised for several days with bromine water.

Isolation of 4-O-*methylglucuronic acid.* A portion of the mixed barium salts (0·9 g.) was treated with N-sulphuric acid (50 ml.), the mixture filtered, and the filtrate heated in a sealed tube at 100° for 18 hr. The filtered solution was neutralised with IR-4B resin, and the resin collected and washed till the washings were non-reducing. The uronic acids were recovered by stirring the resin with successive portions of dilute sulphuric acid till a slight excess of sulphuric acid was present. The combined solutions were treated with barium acetate till sulphate free. Barium sulphate was removed by filtration and the filtrate concentrated to a syrup, from which 4-*O*-methylglucuronic acid (20 mg.) was isolated by chromatography on large sheets of paper. The product was refluxed with 1% methanolic hydrogen chloride (10 ml.) and then neutralised with silver carbonate. The filtered solution was evaporated under reduced pressure to a syrup which was treated with concentrated ammonia (5 ml.) and kept at 0° for 24 hr. The solvent was evaporated, leaving a syrup which crystallised. The product was recrystallised several times from ethanol giving plates of the amide of methyl 4-*O*-methyl-α-D-glucuronoside, m. p. 232—233° (lit.,[2] 232°), $[\alpha]_D^{21}$ +145° (*c* 0·5 in water).

Identification of the aldobiouronic acid. Barium aldobiouronate (250 mg.) was refluxed with 1·8% methanolic hydrogen chloride (50 ml.) for 7 hr., neutralised with silver carbonate, and filtered. The filtrate was evaporated to dryness, the residue dissolved in water (5 ml.), and the solution added slowly to one of potassium borohydride (150 mg.) in water (2 ml.). After 2 hr., the excess of borohydride was destroyed by the addition of dilute acetic acid, the solution de-ionised with IR-120 H and IR-45 resins, and evaporated under reduced pressure to dryness. The syrup obtained was methylated three times with methyl sulphate and sodium hydroxide, and the product (after extraction of the acidified mixture with chloroform) was further methylated twice with methyl iodide and silver oxide, giving a yellow syrup (200 mg.), n_D^{26} 1·465 (Found: OMe, 54·9. Calc. for $C_{20}H_{38}O_{11}$: OMe, 54·6%). This material was hydrolysed with N-sulphuric acid (10 ml.) at 100° for 18 hr. The neutralised hydrolysate ($BaCO_3$), was extracted with chloroform, and the chloroform removed, giving a syrup (130 mg.) which was separated on Whatman 3MM paper into two fractions. The first fraction (35 mg.) had m. p. and mixed m. p. (with 2,3,4,6-tetra-*O*-methylglucose) 84°, $[\alpha]_D^{22}$ +83° (*c*, 0·5 in water). It was converted into the anilide, m. p. and mixed m. p. 137—138°. The second fraction (28 mg.), R_G (solvent *b*) 0·71, $[\alpha]_D^{21}$ +87° (*c*, 0·5 in water), was oxidised with bromine water (4 days). The product, isolated in the usual way, was recrystallised from ether–light petroleum, giving needles of 2,3,6-tri-*O*-methylgalactofuranolactone, m. p. 98—99° (lit.,[2] 98—99°), $[\alpha]_D^{22}$ −40°.

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618. *Some New Polydentate Arsenic Ligands.*

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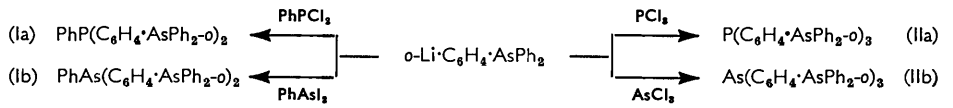
WHILE several bidentate phosphorus and arsenic ligands are known, only two tridentate ligands of these donor atoms, $CH_3{\cdot}As(CH_2{\cdot}CH_2{\cdot}CH_2{\cdot}AsMe_2)_2$ and $Ph{\cdot}P(C_6H_4{\cdot}PEt_2\text{-}o)_2$ have been reported.[1,2] Furthermore, no tetradentate ligands of the heavy Group VB elements have been reported. We report here the preparation of two tridentate (Ia and b)

[1] Barclay and Nyholm, *Chem. and Ind.*, 1953, 378.
[2] Hart, *J.*, 1960, 3324.

and two tetradentate ligands of phosphorus and arsenic (IIa and b), by the methods indicated in the scheme.



The compounds form white crystals, stable in air, and moderately soluble in aromatic hydrocarbons from which they can be recrystallised. Their complex-forming properties are being investigated.

Experimental.—o-*Diphenylarsinophenyl-lithium.* This was prepared by the method of Cochran *et al.*[3] The stoicheiometric amount of butyl-lithium was used to prevent the formation of undesirable by-products.

Bis-(o-*diphenylarsinophenyl*)*phenylphosphine* (Ia). Dichlorophenylphosphine (13 g.) in light petroleum (50 c.c.) was gradually added to the above lithium derivative (from 27 g. of *o*-bromophenyldiphenylarsine) in a nitrogen atmosphere. After hydrolysis the yellowish *product* was filtered off and recrystallised from anisole, yielding white crystals (8·5 g.), m. p. 238—240° (Found: C, 70·3; H, 4·4; As, 20·9; P, 4·7. $C_{42}H_{33}As_2P$ requires C, 70·6; H, 4·1; As, 21·0; P, 4·3%).

Bis-(o-*diphenylarsinophenyl*)*phenylarsine* (Ib). Di-iodophenylarsine (12·63 g.) in dry ether (30 c.c.) was added dropwise to the lithium derivative (from 23·96 g. of *o*-bromophenyldiphenylarsine). After hydrolysis and recrystallisation from tetrahydrofurfuryl alcohol the *product* formed white crystals, m. p. 235—236° (8 g.) (Found: C, 65·8; H, 4·6; As, 29·2. $C_{42}H_{33}As_3$ requires C, 66·2; H, 4·4; As, 29·5%).

Tris-(o-*diphenylarsinophenyl*)*phosphine* (IIa). This was prepared and purified as was its analogue (Ia). *o*-Bromophenyldiphenylarsine (25 g.) and phosphorus trichloride (2·2 c.c.) yielded a *product* (5·2 g.), m. p. 238—238·5° (Found: C, 67·8; H, 4·4; As, 24·0. $C_{54}H_{42}As_3P$ requires C, 68·5; H, 4·5; As, 23·7%).

Tris-(o-*diphenylarsinophenyl*)*arsine* (IIb) was prepared and purified analogously. *o*-Bromophenyldiphenylarsine (23·3 g.) and arsenic trichloride (1·69 c.c.) yielded the product (10 g.), m. p. 239—240° (Found: C, 65·7; H, 4·6; As, 30·2. $C_{54}H_{42}As_4$ requires C, 65·5; H, 4·3; As, 30·2%).

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[3] Cochran, Hart, and Mann, *J.*, 1957, 2816.