728. *Reactions of Disodium Pentacyanoamminoferrate with Aromatic Amines. Part IV.*[1] *The Preparation and Properties of Compounds containing the μ-p-Phenylenediaminebis(pentacyanoferrate) Ion.*

By E. F. G. Herington.

The reactions of an alkaline solution of disodium pentacyanoamminoferrate with *p*-aminophenol [2,3] and with aniline [2,4] have been investigated and this Note reports results with *p*-phenylenediamine. The reaction of disodium pentacyanoamminoferrate with *p*-phenylenediamine produced a dark blue solution exhibiting a single absorption band in the range 400—1000 mμ of half-width 150 mμ, with a maximum at 685 mμ. Paper electrophoresis showed that the solution contained mainly one anionic species and that the complex was only slightly decomposed after one week. Continuous-variation experiments with freshly prepared solutions, buffered with borax, indicated that the disodium salt reacted with *p*-phenylenediamine in the molar ratio 2 : 1. On mixing of solutions of *p*-phenylenediamine (0·001 mole in 20 ml.) and disodium pentacyanoamminoferrate (0·002 mole in 20 ml.) adjusted to pH 11·4, the pH fell to 8·4 and 0·0015 equivalent of sodium hydroxide was needed to restore the pH to 11·4. A purified sample of the zinc salt, which exhibited a strong band at 2093 cm.$^{-1}$ resembling in intensity and band-width that found in zinc ferrocyanide,[5] gave the correct analysis for $Zn_3[Fe(CN)_5{\cdot}HN{\cdot}C_6H_4{\cdot}NH{\cdot}Fe(CN)_5],4H_2O$. Reduction of the sodium salt with dithionite regenerated *p*-phenylenediamine.

It is suggested that the reaction can be represented by the equation

$$2Na_2[Fe(CN)_5{\cdot}NH_3] + H_2N{\cdot}C_6H_4{\cdot}NH_2 + 2NaOH = Na_6[Fe(CN)_5{\cdot}HN{\cdot}C_6H_4{\cdot}NH{\cdot}Fe(CN)_5] + 2NH_3 + 2H_2O$$

By the use of a spraying technique [3,4] it was established that the following salts of the complex anion are insoluble in dilute acetic acid; cupric, blue; silver, blue; zinc, violet blue; cadmium, blue; mercurous and mercuric, black; lead, blue; zirconium, blue; hafnium, blue; thorium, green blue; chromium, blue; uranyl, grey; manganese, brown; ferric, blue; cobalt, green; nickel, green; palladium, green.

Experimental.—Experiments were carried out as described earlier,[3,4] except that an ordinary glass electrode was used for the pH measurements.

Zinc μ-p-phenylenediaminebis(pentacyanoferrate). On to *p*-phenylenediamine (0·19 g.) was poured a solution containing disodium pentacyanoamminoferrate monohydrate (0·7 g.) in 0·1N-sodium hydroxide (5 ml.). The mixture was shaken for 30 min., then portions (2·5 ml.) were put on the upper ends of two Whatman's seed test papers. The papers were inserted into a preparative paper-electrophoresis apparatus,[4] current was passed, the resulting dark blue bands were cut out, and the material extracted from them with 0·1N-sodium hydroxide at room temperature. Zinc nitrate (3 ml.; M) was added to the resulting solution, and then glacial acetic acid (12 ml.). The blue precipitate was removed by centrifugation, and the gel was washed with water until the decanted liquid was neutral. The *zinc salt* was dried [NaOH, then $Mg(ClO_4)_2$ in a vacuum] [Found: C, 26·1; H, 1·9; N, 21·2; Zn, 26·0; Fe, 15·0. $Zn_3[Fe(CN)_5{\cdot}HN{\cdot}C_6H_4{\cdot}NH{\cdot}Fe(CN)_5],4H_2O$ requires C, 25·7; H, 1·9; N, 22·4; Zn, 26·3; Fe, 15·0%].

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[1] Part III, Herington, *J.*, 1958, 4771.
[2] Herington, *Nature*, 1955, **176**, 80.
[3] Herington, *J.*, 1956, 2747.
[4] Herington, *J.*, 1958, 4683.
[5] Herington and Kynaston, *J.*, 1955, 3555.

729. *Preparation of* 1-*Benzylpiperazine.*

By J. Cymerman Craig.

For the preparation of 1-monosubstituted, and thence of 1,4-unsymmetrically disubstituted piperazines it is usual to protect one of the nitrogen atoms by use of the 1-ethoxycarbonyl derivative.[1] The use of 1-benzylpiperazine hitherto required either fractional distillation,[2] often after long reaction, or 1-ethoxycarbonylpiperazine as intermediate.[3] We found[4] that 1 mol. each of hydrogen chloride and benzyl chloride gave a precipitate of piperazine dihydrochloride and a solution from which 1-benzylpiperazine could be obtained. A convenient preparation of 1-benzylpiperazine is now described, from 1 mol. each of piperazine, piperazine dihydrochloride, and benzyl chloride; 98% of the piperazine dihydrochloride is recovered, and the solution affords 4-benzylpiperazinium chloride in 93% yield.

The formulation of 4-benzylpiperazinium chloride is supported by its infrared spectrum (paraffin mull), which shows no absorption in the –NH region but bands at 2920 and 2810 cm.$^{-1}$ (NH_2^+ stretching) and 1600 cm.$^{-1}$ (NH_2^+ deformation).[5]

When kept in air or treated with carbon dioxide, 1-benzylpiperazine formed crystals which decomposed when heated or on attempted recrystallisation, regenerating the base. They liberated carbon dioxide in cold mineral acid, and gave analytical figures corresponding to 4-benzylpiperazinium carbonate $(Ph{\cdot}CH_2{\cdot}N<[CH_2{\cdot}CH_2]_2>NH_2^+)_2CO_3^{2-}$. However, their infrared spectrum (paraffin mull) was devoid of absorption at 878 or 1440 cm.$^{-1}$ (ionic carbonates[6,7]) but included OH absorption and a band at 1662 cm.$^{-1}$ given by hydrated inorganic salts[6,8] and presumably corresponding to the band at 1646 cm.$^{-1}$ shown[9] by liquid water at 20°. *E.g.*, sodium carbonate decahydrate (paraffin mull) had, in addition to the bands at 700 (w), 879 (s), and 1445 (s) cm.$^{-1}$, strong absorption at 1655 and 3220—3375 cm.$^{-1}$ which was absent in the anhydrous salt. The substance formed from 1-benzylpiperazine must therefore be 4-benzylpiperazinium 4-benzylpiperazine-1-carboxylate monohydrate (I), and this was confirmed by determination of the equivalent weight.

$$Ph{\cdot}CH_2{\cdot}N<[CH_2{\cdot}CH_2]_2>NH_2^+ \quad Ph{\cdot}CH_2{\cdot}N<[CH_2{\cdot}CH_2]_2>N{\cdot}CO_2^- \, H_2O \quad (I)$$

In its behaviour towards carbon dioxide, 1-benzylpiperazine thus resembles *N*-ethoxycarbonylethylenediamine[1] but differs from piperazine which forms the betaine $^+H_2N<[CH_2{\cdot}CH_2]_2>N{\cdot}CO_2^-$.[10]

For determination[5] of their infrared spectra, 1-methylpiperidinium and 1-ethylmorpholinium iodide and tetrahydro-1,4-thiazine hydriodide were prepared.

Experimental.—1-*Benzylpiperazine.* To a solution of piperazine dihydrochloride monohydrate (22·1 g., 0·125 mole) and piperazine hexahydrate (24·3 g., 0·125 mole) in absolute ethanol (50 c.c.) at 65° benzyl chloride (15·8 g., 0·125 mole) was added in 5 min. with stirring. After a further 25 minutes' stirring at 65°, the solution was cooled, kept at 0° for 30 min., and filtered. The solid was washed with ice-cold absolute ethanol and dried at 70°, giving recovered piperazine dihydrochloride (21·8 g., 98%) as needles, m. p. 310° (decomp.). Addition of 10N-absolute-alcoholic hydrogen chloride (25 c.c., 0·25 mole) at 0° to the combined filtrate and washings

[1] Moore, Boyle, and Thorn, *J.*, 1929, 39.
[2] Baltzly, Buck, Lorz, and Schon, *J. Amer. Chem. Soc.*, 1944, **66**, 263; Buck and Baltzly, U.S.P. 2,415,785, 2,415,786, 2,415,787; Wellcome Foundation, B.P. 578,342; Lutz and Shearer, *J. Org. Chem.* 1947, **12**, 771.
[3] Horrom, Freifelder, and Stone, *J. Amer. Chem. Soc.*, 1955, **77**, 753.
[4] Cymerman Craig, Rogers, and Tate, *Austral. J. Chem.*, 1956, **9**, 397.
[5] Stone, Craig, and Thompson, *J.*, 1958, 52; Heacock and Marion, *Canad. J. Chem.*, 1956, **34**, 1782.
[6] Miller and Wilkins, *Analyt. Chem.*, 1952, **24**, 1253.
[7] Underwood, Toribara, and Neuman, *J. Amer. Chem. Soc.*, 1955, **77**, 317; Gatehouse, Livingstone, and Nyholm, *J.*, 1958, 3137.
[8] Corbridge and Lowe, *J.*, 1954, 493.
[9] Fox and Martin, *Proc. Roy. Soc.*, 1940, *A*, **174**, 234.
[10] Majert and Schmidt, *Ber.*, 1890, **23**, 3718; Rosdalksy, *J. prakt. Chem.*, 1896, **53**, 19.

precipitated plates which were washed (with benzene) and dried at 70°, giving 1-benzylpiperazine dihydrochloride (29·0 g., 93%), m. p. 253—254° (sintering), then 279—280° (decomp.). Baltzly, Buck, Lorz, and Schon [2] give m. p. 253°.

A solution of this solid (29·0 g.) in water (50 c.c.) was basified to pH >12 with 5N-sodium hydroxide and extracted with chloroform, giving 1-benzylpiperazine (20 g., 91%), n_D^{25} 1·5468. With benzoyl chloride this gave 1-benzoyl-4-benzylpiperazine hydrochloride (91·5%), m. p. 245—245·5°. Baltzly, Buck, Lorz, and Schon [2] report m. p. 245°. Distillation of the base afforded pure 1-benzylpiperazine, b. p. 76—80°/1 mm., n_D^{16} 1·5485, n_D^{25} 1·5440 (lit.,[3] b. p. 89—96°/0·2 mm., n_D^{28} 1·5430).

4-Benzylpiperazinium chloride. (*a*) The filtrate from the recovered piperazine dihydrochloride obtained in the preparation of 1-benzylpiperazine described above gave, on removal of the solvent *in vacuo*, *4-benzylpiperazinium chloride*, plates (from absolute ethanol), m. p. 167—168° (Found: C, 61·65; H, 7·95; N, 12·75. $C_{11}H_{16}N_2$,HCl requires C, 62·1; H, 8·0; N, 13·15%). Treatment with ethanolic hydrogen chloride gave 1-benzylpiperazine dihydrochloride (m. p. and mixed m. p.). (*b*) 1-Benzylpiperazine in ether with ethanolic hydrogen chloride (1 mol.) afforded the same salt, m. p. and mixed m. p. 167·5—168°.

Reaction of 1-benzylpiperazine with carbon dioxide. (*a*) 1-Benzylpiperazine was rapidly transformed in air into *4-benzylpiperazinium 4-benzylpiperazine-1-carboxylate*, m. p. 99—100° (decomp.; rapid heating) [Found: C, 66·9, 66·6; H, 8·3, 8·2%; equiv. (potentiometric titration with 0·2N-NaOH in 33% alcohol), 404. $C_{23}H_{32}O_2N_4$,H_2O requires C, 66·65; H, 8·25%; equiv., 414]. The water of crystallisation was not removed by prolonged drying *in vacuo*. Infrared absorption maxima (paraffin mull) were at 3390 (s, asymm. OH stretching), sh 3270 (m, symm. associated OH stretching), 2920 and 2850 (s, NH_2^+ stretching), 1662 (m, OH deformation), 1616 (m, NH_2^+ deformation), 1526 and 1420 (s, CO_2^-), and 1000 cm.$^{-1}$ (s, OH deformation). In cold alcoholic hydrogen chloride it gave quantitatively 1-benzylpiperazine dihydrochloride (m. p. and mixed m. p.). (*b*) Ethereal 1-benzylpiperazine with carbon dioxide at room temperature gave the same product, m. p. and mixed m. p. 99—100° (decomp.) (Found: C, 66·65; H, 8·25%).

The following salts were prepared by standard methods: *1-methylpiperidinium*, needles (from ethanol), m. p. 121·5—122° (Found: C, 31·8; H, 6·15. $C_6H_{13}N$,HI requires C, 31·75; H, 6·2%), and *1-ethylmorpholinium iodide*, plates (from ethanol), m. p. 147—148° (Found: N, 5·5. $C_6H_{13}ON$,HI requires N, 5·75%); *tetrahydro-1,4-thiazine hydriodide*, cream plates (from ethanol), m. p. 156—157° (Found: N, 5·95. C_4H_9NS,HI requires N, 6·05%).

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730. *Isomer Ratios in the Nitration of 6-Acylamino-1,2,3,4-tetrahydronaphthalenes.*

By E. R. Ward and B. D. Pearson.

The present work arose out of attempts to improve the availability of 6-amino-7-nitro-1,2,3,4-tetrahydronaphthalene,[1] an essential intermediate in the synthesis of many 2,3-derivatives of tetralin and naphthalene, but is also of interest in relation to the reactivity of tetralin compounds to electrophilic reagents. Tetralin has the carbon skeleton of naphthalene, but it might be compared superficially to *o*-xylene though the steric situations in the two systems must differ. The Table presents data for the nitration of 6-acylamino-1,2,3,4-tetrahydronaphthalenes.

[1] Ward and Pearson, *J.*, 1959, 1676.

The yield given in the Table represents the yield of *N*-acylated compounds, isolated by chromatography, in relation to the amount of original amide. The probable accuracy of the chromatographic separation is $\pm 1\%$. The losses experienced with the acetyl derivative are normal in this type of experiment and are largely accounted for by hydrolysis, followed

Acyl	Conditions *	HNO_3 (mol.)	Yield (%)	Products: posn. of substn. & yields (%)
Acetyl	*A*, 50°	1	80	7(42); 5(38)
Acetyl	*A*, 50°	1·5	80	7(43); 5(34); 5,7(3)
Acetyl	*B*, 0°	1	96·5	8(87); 7(8); 5(1·5)
Tosyl	*C*, 35°	1	96	7(40); 5(53); 5,7(3)
Tosyl	*C*, 35°	1·2	94	7(36); 5(28); 5,7(30)

* A, acetic anhydride–nitric acid (*d* 1·42). *B*, Sulphuric acid (*d* 1·84)–nitric acid (*d* 1·42). *C*, Acetic acid–nitric acid (*d* 1·5).

by oxidation and/or diazotisation of the free amine. Experiments in which 6-acetamido-1,2,3,4-tetrahydro-5- and -7-nitronaphthalene were dissolved in the appropriate volume of acetic anhydride containing nitric acid (0·5 mol.) and left overnight showed that whilst the latter could be recovered almost quantitatively there was an 80% loss of the former (*ca.* 10% due to dinitration).

It is probable that for mononitration of both acylated derivatives the 5- is rather more reactive than the 7-position, this being obscured for the acetyl derivative by reason of the much greater losses of the 5- than of the 7-nitro-isomer (see above). It is difficult to account for this since there may be some steric hindrance from the "*peri*"-methylene group at the 5-position and one might expect the 7- to be more activated than the 5-position by electron-supply from the aliphatic ring (cf. Ingold [2]). However, in dinitration of the sulphonamido-compound it is clear that a "*peri*"-steric effect is operating whereby the tautomeric effect of the 5-nitro-group is reduced, so increasing the reactivity of the 5-nitro- relative to that of the 7-nitro-isomer. Under salt-forming conditions (cf. Ward *et al.*[3]) the acetyl compound is, as expected, predominantly substituted at the 8-position. Some reaction appears to occur through the unprotonated form, although the much lower reactivity of the 5- than of the 7-position may be partly accounted for by the much greater solubility of the 5-isomer, with relatively greater losses in isolation.

Schroeter [4] claimed that nitration of 5-acetamido-1,2,3,4-tetrahydronaphthalene in sulphuric acid produced a mixture of 6-, 7-, and 8-nitro-derivatives, the last greatly predominating (although even the yield of this was only *ca.* 45%). We were unable to repeat this work, finding that the yield of 8-nitro-isomer was much lower and that considerable dinitration occurred. However, working in acetic acid–acetic anhydride we obtained the 6-nitro-amide in *ca.* 45% yield. Attempts to carry out a quantitative study of this nitration were frustrated by our inability to separate either the mixed nitro-amides or the corresponding nitro-amines by column chromatography.

Experimental.—1,2,3,4-*Tetrahydro*-6-*toluene*-p-*sulphonamidonaphthalene.* Obtained in almost quantitative yield by refluxing 6-amino-1,2,3,4-tetrahydronaphthalene with toluene-*p*-sulphonyl chloride in pyridine for 7 hr., this *amide* had m. p. 135° (from ethanol) (Found: C, 67·1; H, 6·2. $C_{17}H_{19}O_2NS$ requires C, 67·7; H, 6·35%).

1,2,3,4-*Tetrahydro*-5-*nitro*-6-*toluene*-p-*sulphonamidonaphthalene*, prepared similarly and crystallised from acetic acid, had m. p. 156° (Found: C, 59·0, H, 5·2. $C_{17}H_{18}O_4N_2S$ requires C, 59·0; H, 5·4%).

Nitrations of 6-*acetamido*-1,2,3,4-*tetrahydronaphthalene.* (a) In acetic anhydride. To the amide (1 g.) suspended in acetic anhydride (1 c.c.) was slowly added a mixture of nitric acid (*d* 1·42; 0·34 c.c., 1 mol.) and acetic anhydride (0·34 c.c.), the temperature being kept just

[2] Ingold, "Structure and Mechanism in Organic Chemistry," Bell and Sons, London, 1953, pp. 256—257, 261—264.
[3] Ward, Coulson, and Wells, *J.*, 1957, 4816.
[4] Schroeter, *Annalen*, 1922, **426**, 1.

below 50°. The next day the mixture was extracted with benzene (2 × 30 c.c.), and the extract dried (Na_2CO_3–Na_2SO_4) and concentrated to 20 c.c. This was then chromatographed on alumina (2·5 × 25 cm.) prepared in benzene–ethyl acetate (20 : 1, v/v), the same solvent being used for elution. The lower yellow band yielded 6-acetamido-1,2,3,4-tetrahydro-7-nitronaphthalene (0·52 g. ,42%), m. p. 132—133° (Van Rij *et al.* [5] gives m. p. 134—135°), and the upper yellow band gave the 5-nitro-isomer (0·47 g., 38%), m. p. 127° (Schroeter [4] gives 128—129°). Larger amounts of nitric acid produced some 6-acetamido-1,2,3,4-tetrahydro-5,7-dinitronaphthalene, which stayed at the top of the column and was eluted by ethyl acetate.

(b) In sulphuric–nitric acid. A solution of the amide (4·0 g.) in sulphuric acid (*d* 1·84; 42 c.c.) was treated with nitric acid (*d* 1·42; 1·3 c.c., 1 mol.) at −5°. After being kept for 10 min. at 0° the mixture was poured on ice (*ca.* 800 g.), and the solid product was collected, washed with water, and dried (4·87 g., 98%). Paper chromatography by the method of Franc and Latinák [6] showed that all three possible monitrated isomers were present. The R_F values for a run of 22 cm. at 20° were: 5-nitro 0·79, 7-nitro 0·64, 8-nitro 0·88. All three isomers gave black spots under ultraviolet light but when kept for several days the spot for the 8-nitro-isomer became violet. The mixed amides were crystallised from benzene (*ca.* 40 c.c.) which yielded pure 8-nitroamide (3·59 g.). Chromatography of the residual liquor on alumina gave in order of elution, the 8-, 7-, and 5-nitro-compound.

Mono- and di-nitration of 6-p-*toluenesulphonamido*-1,2,3,4-*tetrahydronaphthalene*. (a) Mononitration. The amide (1 g.) in acetic acid (30 c.c.) at 35° was treated with a crystal of sodium nitrite, then nitric acid (*d* 1·5; 0·14 c.c.). The next day the mixture was added to ice–water, and the solids were collected, washed with water, dried (1·12 g.), and chromatographed in benzene (25 c.c.) on alumina (2·5 × 25 cm.), prepared in benzene–ethyl acetate (2 : 1, v/v). Elution by the latter solvent removed a yellow band (A); another yellow band (B) was eluted by ethyl acetate; the residual yellow band (C) was separated from the column and extracted with methanol (Soxhlet). Band A was the 7-nitro-amide (0·46 g.), m. p. 144—145° (Kuhn *et al.*[7] give 146°). Band B was the 5-nitro-amide (0·61 g., 53%), m. p. 154—155°. Band C was 1,2,3,4-*tetrahydro*-5,7-*dinitro*-6-*toluene*-p-*sulphonamidonaphthalene* (0·04 g.), m. p. 226° (Found: C, 52·0; H, 4·3. $C_{17}H_{17}O_6N_3S$ requires C, 52·2; H, 4·35%).

(b) Dinitration. To the amide (1 g.) in acetic acid (30 c.c.) at 60° was added a crystal of sodium nitrite and nitric acid (*d* 1·5; 0·31 c.c., 2·2 mol.). The mixture was allowed to cool to room temperature and next day the solid product was collected. Further amounts were obtained by concentration of the filtrate (total yield, 0·99 g., 76%). This was the 5,7-dinitro-compound, m. p. and mixed m. p. 225°. The residual filtrate poured on ice gave only a small amount of low-melting material.

Nitration of 5-*acetamido*-1,2,3,4-*tetrahydronaphthalene and the preparation of* 5-*amino*-1,2,3,4-*tetrahydro*-6-*nitronaphthalene* (with A. W. Bamford). 5-Amino-1,2,3,4-tetrahydronaphthalene (60 g.) was refluxed with acetic acid (200 c.c.) and acetic anhydride (650 c.c.) for 30 min., then treated, at 30—35°, with nitric acid (*d* 1·42; 82·5 c.c.), and 30 min. later added to ice–water. The solid products were collected, washed with water, and dried (75 g., 79%). These mixed amides (25 g.) were refluxed with 1 : 1 v/v (1·5 l.) benzene–light petroleum (b. p. 60—80°) for 1 hr. Filtration of the hot solution gave a small residue (0·7 g.), probably 5-acetamido-1,2,3,4-tetrahydro-6,8-dinitronaphthalene. The cooled filtrate deposited 5-acetamido-1,2,3,4-tetrahydro-6-nitronaphthalene, m. p. 184° (from ethanol) (Schroeter [4] gives m. p. 184—185°) (42·5 g., 45%). This was hydrolysed by refluxing it with 2 : 1 : 1 v/v ethanol–water–sulphuric acid (*d* 1·84) for 3 hr.; the amine was obtained by pouring the solution into water (yield 98%). Concentration of the original filtrate gave a brown solid (22 g.) hydrolysis of which gave only tar. Diazotisation of the above amine by the method of Hodgson and Turner,[8] followed by decomposition of the diazonium solution by addition to iodine dissolved in aqueous potassium iodide (underlaid by chloroform), gave, from the chloroform layer, almost pure 1,2,3,4-*tetrahydro*-5-*iodo*-6-*nitronaphthalene* (*ca.* 85%); purified by chromatography on alumina in benzene and crystallised from ethanol, this had m. p. 60° (Found: C, 39·8; H, 3·5. $C_{10}H_{10}O_2NI$ requires C, 39·6; H, 3·3%).

[5] Van Rij, Verkade, and Wepster, *Rec. trav. chim.*, 1951, **70**, 236.
[6] Franc and Latinák, *Chem. Listy*, 1955, **49**, 872; cf. Ward and Johnson, *J.*, 1959, 487; Telesz and Johnson, *J. Soc. Dyers and Colourists*, 1958, **74**, 858.
[7] Kuhn, Vetter, and Rzeppa, *Ber.*, 1937, **70**, 1302.
[8] Hodgson and Turner, *J.*, 1943, 86.

1,2,3,4-*Tetrahydro-5-iodo-8-nitronaphthalene*, prepared similarly (*ca.* 90%), had m. p. 57° (Found: C, 39·8; H, 3·3%). The iodine atom in this compound proved inert when the compound was refluxed in ethanol with, *e.g.*, dimethylamine or di-*n*-butylamine.

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731. *The Periodate Oxidation of 2-Deoxyglycosides: Structure of 1-(2-Deoxy-D-galactosyl)benzimidazole.*

By R. J. FERRIER and W. G. OVEREND.

RECENTLY, syntheses have been described of 1-glycosylbenzimidazoles [1] and of 2-polyhydroxyalkylbenzimidazoles [2] derived from 2-deoxy-sugars. Attempts to establish the structures of these compounds by measuring periodate uptake were unsuccessful when the determinations were made by titrating with sodium arsenite the iodine liberated by excess of periodate.[3] Likewise, estimations on simple alkyl and aryl 2-deoxyglycosides resulted in values in excess of theory for the consumption of oxidant.[3] These anomalous results were obtained owing to iodination of the methylene group in the oxidation products. It has now been established that the spectrophotometric method for the determination of periodate as reported by Aspinall and Ferrier [4] can be used successfully with deoxy-sugar derivatives. Results obtained by this method are shown in the Experimental Section. It can be noted that methyl 2-deoxy-α-D-glucoside is oxidised more rapidly than methyl α-D-glucoside.

Condensation of crude tri-*O*-acetyl-2-deoxy-D-galactosyl bromide with benzimidazolylsilver in xylene gives, after deacetylation, a lævorotatory form (*A*) of 1-(2-deoxy-D-galactosyl)benzimidazole ($[\alpha]_D$ −18·9°). On the other hand the triacetyldeoxygalactosyl bromide with an excess of benzimidazole in dioxan at 100° affords finally only a small amount of compound (*A*), and the main product is a dextrorotatory isomer (*B*) ($[\alpha]_D$ +21·6°).[1] These compounds, which are interconvertible, were considered to be α- and β-isomers although the size of the sugar ring in each compound was not established. They were oxidised by 0·004M-periodate at 21°, and it was found by the spectrophotometric procedure that both consumed 1 mole of oxidant per mole of glycoside. (Control experiments indicated that a small correction for the absorption by the benzimidazole portion of the molecule was necessary.) By the oxidation of each compound negligible quantities of formaldehyde were produced. Consequently both isomers (*A*) and (*B*) possess a pyranosyl ring: this supports the contention that they are α- and β-isomers.

Experimental.—All compounds were oxidised with 1·5—2·0 molar equivalents of 0·004M-sodium periodate at 20—21°. Periodate uptake was followed spectrophotometrically by Aspinall and Ferrier's method: [4]

(i) *Methyl 2-deoxy-α-D-glucoside.*

Time (hr.)	0·33	1·0	2·0	3·5	6
Periodate uptake (mol.)	0·59	0·85	1·01	1·04	1·14

(ii) 1-(2-*Deoxy-D-galactosyl*)*benzimidazole* (B).

Time (hr.)	0·33	1·0	2·0	3·5
Periodate uptake (mol.)	0·91	0·96	1·08	1·11

(iii) 1-(2-*Deoxy-D-galactosyl*)*benzimidazole* (A).

Time (hr.)	0·25	1·0	2·0
Periodate uptake (mol.)	0·92	0·98	0·99

[1] Cleaver, Foster, and Overend, *J.*, 1959, 409.
[2] *Idem*, *J.*, 1957, 3961.
[3] Cleaver, Foster, Hedgley, and Overend, *J.*, 1959, 2578.
[4] Aspinall and Ferrier, *Chem. and Ind.*, 1957, 1216.

The formaldehyde produced by the oxidation of isomers (*A*) and (*B*) was estimated by O'Dea and Gibbons's method [5] except that excess of periodate was destroyed with stannous chloride instead of lead dithionate. The complete oxidation of each compound yielded 0·08 mol. of formaldehyde per mol. of benzimidazole deoxyglycoside.

(iv) *Other derivatives.* Periodate uptake was estimated after 2 hours' oxidation.

Compound	Periodate uptake (mol.)	Theoretical uptake (mol.)
Methyl 2-deoxy-α-D-galactopyranoside	1·04	1·00
Methyl 2-deoxy-α-D-glucopyranoside	1·01	1·00
Phenyl 2-deoxy-α-D-glucopyranoside	1·00	1·00
Methyl α-D-glucopyranoside	0·6	2·0
2-Deoxy-D-glucitol	2·8	3·0

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BIRKBECK COLLEGE, LONDON, W.C.1.

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[5] O'Dea and Gibbons, *Biochem. J.*, 1953, **55**, 580.

732. p-*Bisphenylmercuribenzene.*

By M. MALNAR and D. GRDENIĆ.

IN connection with other work we needed *p*-bisphenylmercuribenzene. Of the several methods for its preparation we chose the Grignard reaction of *p*-bisbromomagnesiobenzene with phenylmercuric bromide.

The difficulty of obtaining the dimagnesium compound is already known.[1] We chose Houben's method [2] but later found that the amount of magnesium dissolved could be increased by prolonging the period of heating and by reducing the quantity of solvent. Nevertheless, the yield of *p*-bisphenylmercuribenzene was never higher than 16% of the theoretical amount. The main product was an insoluble polymer.

Experimental.—A solution of *p*-dibromobenzene (5·2 g.) in dry ether (15 ml.) was slowly added to magnesium turnings (1·08 g.) in stirred dry ether (15 ml.). The reaction was started with methyl iodide and thereafter maintained by the portionwise addition of half of the dibromobenzene solution. The other half was then added and the mixture refluxed for 24 hr. The solution was then diluted with ether (35 ml.), finely powdered phenylmercury bromide (15·8 g.) added, and the stirred mixture refluxed for 10 hr. After addition of water (50 ml.) and 10% hydrochloric acid (15 ml.) the cream-coloured precipitate was dried and extracted several times with hot toluene. From the toluene solution a yellowish powder was deposited (2·3 g.) which after recrystallization from toluene had m. p. 143° (Found: C, 35·0; H, 2·7; Hg, 63·4. $C_{18}H_{14}Hg_2$ requires C, 34·2; H, 2·2; Hg, 63·55%).

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ZAGREB, YUGOSLAVIA.

[*Received, April 6th*, 1959.]

[1] Yoffe and Nesmeyanov, "A Handbook of Organomagnesium Compounds" (in Russian), Vol. I—III, The Academy of Sciences of the U.S.S.R., Leningrad, 1950; Lukeš and Prelog, *Chem. Listy*, 1930, **24**, 277; Millar and Heaney, *Quart. Rev.*, 1957, **11**, 109.

[2] Houben, *Ber.*, 1905, **38**, 3796.

733. *Aromatic Reactivity. Part VII.* Additivity of Effects of Methyl Substituents in Protodesilylation.*

By C. Eaborn and R. C. Moore.

We have measured the rates of cleavage of the tolyl- and xylyl-trimethylsilanes and of phenyl- and mesityl-trimethylsilane by aqueous-methanolic perchloric acid. Several acid concentrations must be used to cover the range of compounds, but by a stepwise procedure the reactivity, $k_{rel.}$, of each compound relative to that of phenyltrimethylsilane can be derived. The results are shown in the Table, which includes values of $k_{rel.}$(calc.) (*i.e.*, the reactivity of a xylyl or mesityl compound calculated on the assumption that the effects of the methyl groups, as revealed in the tolyl compounds, are additive). Agreement between $k_{rel.}$ and $k_{rel.}$(calc.) is excellent except for the 2,6-Me_2-, 2,4,6-Me_3-, and 2,3-Me_2-compounds, which are more reactive than expected because of release of steric strain on going from ground state to transition state.[1,2] In the case of the 2,3-Me_2-compound a " buttressing effect " is involved.[1]

The conclusions are very similar to those based on cleavage by toluene-*p*-sulphonic or hydrochloric acid in acetic acid–water.[1,2] †

Cleavage of substituted phenyltrimethylsilanes at 50·0°.

Subst.	$[HClO_4]$ [a] (M)	10^3k_1 (min.$^{-1}$)	$k_{rel.}$	$k_{rel.}$ (calc.)	Subst.	$[HClO_4]$ [a] (M)	10^3k_1 (min.$^{-1}$)	$k_{rel.}$	$k_{rel.}$ (calc.)
None ...	7·54	0·63	1	—	2,3-Me_2 ...	6·16	20·00	71·9	43·6
2-Me ...	7·54	11·50	18·3	—		3·08	2·86	—	—
	6·16	5·08	—	—	2,4-Me_2 ...	6·16	116	422	417
3-Me ...	7·54	1·50	2·38	—		3·08	16·8		
4-Me ...	6·16	6·35	22·8	—	2,6-Me_2 ...	3·08	138	3530	335
3,5-Me_2...	6·16	1·67	6·00	5·70		0·640	11·7	—	—
2,5-Me_2...	6·16	11·94	42·9	43·6	2,4,6-Me_3	0·640	176	53,000	7640
	3·08	1·68	—	—		0·103	21·4	—	—
3,4-Me_2...	6·16	15·61	56·1	54·3					
	3·08	2·19	—	—					

[a] Concn. of aqueous acid, 2 vol. of which were added to 5 vol. of a solution of the organosilane in methanol.

Experimental.—The xylyltrimethylsilanes, $Me_2C_6H_3{\cdot}SiMe_3$, were mainly prepared from the chloroxylenes, trimethylchlorosilane, and sodium in boiling toluene. After fractional distillation they had the following properties: 3,4-Me_2, b. p. 211·8°, n_D^{20} 1·4995; 2,3-Me_2, b. p. 218°, n_D^{20} 1·5106; 2,4-Me_2, b. p. 215—216°, n_D^{20} 1·5050; 2,6-Me_2, b. p. 224—226°, n_D^{20} 1·5179; 2,5-Me_2, b. p. 208—209°, n_D^{20} 1·5056. The 3,5-Me_2-compound, b. p. 210°, n_D^{20} 1·4950, and the 2,4,6-Me_3-compound, b. p. 237°, were prepared from the aryl bromides. The mesityl compound could not be obtained free from an impurity, but this did not interfere with the rate measurements, identical rates being obtained with samples from different preparations and from different fractions in the distillations.

The method of measuring rates has been described.[3] The molar concentration of the silane in methanol (before addition of acid) and (in parentheses) the wave lengths (in mμ) used were as follows: 2,4,6-Me_3, 0·0037 (277); 3,5-Me_2, 0·0022 (279); 2,5-Me_2, 0·0016 (280); 3,4-Me_2, 0·003 (277); 2,3-Me_2, 0·003 (277); 2,6-Me_2, 0·003 (278); *o*-Me, 0·01 (278); *m*-Me, 0·01 (278); *p*-Me, 0·01 (273); unsubstituted compound, 0·012 (270).

We thank Imperial Chemical Industries Limited for a grant towards the cost of chemicals.

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* Part VI, *J.*, 1959, 3034.

† In absence of information on cleavage of tolyltrimethylsilanes in such media, de la Mare analysed data for xylyltrimethylsilanes by use of figures for bromination of toluene by a positive species, and concluded wrongly that the 2,3-Me_2-compound was only normally reactive.[2]

[1] Benkeser and Krysiak, *J. Amer. Chem. Soc.*, 1954, **76**, 6353; Benkeser, Hickner, Hoke, and Thomas, *ibid.*, 1958, **80**, 5289.

[2] de la Mare, " Progress in Stereochemistry," edited by Klyne and de la Mare, Butterworths Scientific Publications, London, 1958, Vol. II, pp. 73—75.

[3] Eaborn, *J.*, 1956, 4858.

734. *Substituent Effects in Fluorene Compounds. Part II.* Substituted 9-Fluorenones in Oxime Formation.*

By J. D. Dickinson and C. Eaborn.

We have measured the rates of reaction of some 2- and 3-substituted 9-fluorenones with excess of hydroxylamine hydrochloride in "70% methanol" containing sodium acetate and acetic acid. The results are shown in the Table as pseudo-first-order rate constants k_1. The rates, $k_{rel.}$, relative to that of the unsubstituted compound are also listed, along with the apparent activation energies, E, derived from measurements at 50·0° and 40·0°.

Substituent	2-CN	2-NO_2	2-Br	2-NHAc	2-MeO	None
10^2[NH_2·OH,HCl] (M) [a]	9·20	4·56	4·56	9·20	9·20	4·56
10^2k_1 (50°) (min.$^{-1}$)	3·46	1·13	0·87	1·94	1·88	0·694
$k_{rel.}$	1·99	1·63	1·25	1·11	1·08	1
E (kcal./mole)	10·1	10·3	8·5	9·7	9·9	9·0

Substituent	None	2-HO	2-Me	3-Br	3-Me	3-MeO
10^2[NH_2·OH,HCl] (M) [a]	9·20	9·20	9·20	9·20	9·20	9·20
10^2k_1 (50°) (min.$^{-1}$)	1·74	1·74	1·74	1·71	1·24	0·590
$k_{rel.}$	1	1·00	1·00	0·98	0·71	0·339
E (kcal./mole)	—	10·1	10·4	9·6	10·0	11·4

[a] Calc. by assuming volume additivity on mixing of aqueous and methanolic solutions (see Experimental section).

The variations in E are too small to warrant discussion. The pattern of substituent effects is very similar to that observed for benzophenones,[1] if 2- and 3-substituents in fluorenone are regarded as equivalent to *meta*- and *para*-substituents, respectively, in benzophenone. In neither case do the simple Hammett σ-constants represent the effects of the substituents, for reasons we have previously discussed.[1] A point of interest is that the 2-methoxy-group activates fluorenone slightly, while the 2-methyl group deactivates slightly and the 3-methoxy-group more strongly. It thus seems that tautomeric eletron-release from the 2-methoxy-group is not significantly transmitted to the 9-position through the unsubstituted ring (see Part I).

Fluorene is 16·7 times as reactive as benzophenone in oxime formation at 50°. This is consistent with Price and Hammett's observation that the more rigid the structure of a ketone the more reactive it is in carbonyl-addition reactions,[2] but it should be noted that the reactivity difference largely arises from a lower activation energy in the case of fluorenone, not from a more favourable activation entropy as might be expected if rigidity is the important factor. With both fluorenones and benzophenones the reaction is facilitated by electron-withdrawing substituents, and the higher reactivity of fluorenone probably originates in the well-known electron affinity of the cyclopentadiene system.

Experimental.—The preparation of the fluorenones has been described.[3]

Three volumes of stock aqueous hydroxylamine hydrochloride (0·613 or 0·304M) were made up to 10 volumes with methanol. The solution thus obtained was added to an equal volume of a solution of the fluorenone (of concentration shown in the Table below) in "70% methanol"

Subst.	Concn. (g./l.)	λ (mμ)	Subst.	Concn. (g./l.)	λ (mμ)	Subst.	Concn. (g./l.)	λ (mμ)
H	0·47	330	2-Me	0·23	330	2-NHAc ...	0·48	380
2-Br	0·81	360	2-HO	0·42	330	2-CN	0·17	333
2-NO_2 ...	0·070	370	3-Me	0·13	335	3-Br	0·28	335
2-MeO ...	0·54	330	3-MeO ...	0·087	345	—	—	—

(3 vol. of water made up to 10 vol. with methanol) containing sodium acetate and glacial acetic acid (both 0·2M). The reaction was followed spectrophotometrically at the wavelengths (λ)

* Part I, *J.*, 1959, 3574.

[1] Dickinson and Eaborn, *J.*, 1959, 3036.
[2] Price and Hammett, *J. Amer. Chem. Soc.*, 1941, **63**, 2387.
[3] Dickinson and Eaborn, *J.*, 1959, 2337.

shown in the Table, as previously described.[1] Rate constants were reproducible to within 2%.

In the medium used with benzophenone (for which the aqueous hydroxylamine hydrochloride was 4·20M) [1] the rate constant for fluorenone was 0·150 min.$^{-1}$ at 50°.

THE UNIVERSITY, LEICESTER. [*Received, April 10th,* 1959.]

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735. *Synthesis of α-Azido-γ-butyrolactone and its Reduction to α-Amino-compounds.*

By MAX FRANKEL, Y. KNOBLER, and T. SHERADSKY.

γ-BUTYROLACTONE has been used extensively in the synthesis of α-amino-acids, and several methods have been found to introduce into it the α-amino-group.

Snyder *et al.*[1] worked out a procedure for the α-amination of butyrolactone by way of α-acetyl-γ-butyrolactone and α-hydroxyimino-γ-butyrolactone, and for hydrogenation of the last to 2,5-di-(2-hydroxyethyl)-3,6-dioxopiperazine.

Livak *et al.*[2] prepared α-bromo-γ-butyrolactone and introduced the α-amino-group by means of aqueous ammonia, with α-amino-γ-hydroxybutyramide as intermediate which has to be hydrolysed. The α-amino-γ-butyrolactone was isolated as hydrobromide in the laborious process of separating it from inorganic salts formed, or it was converted into a water-insoluble derivative, the α-benzamido-γ-butyrolactone [3] or the α-benzyloxycarbonylamino-γ-butyrolactone.[3]

Introduction of the α-amino-group without opening of the lactone ring was effected by treating α-bromo-γ-butyrolactone with a molar quantity of potassium phthalimide,[4,5] and the water-insoluble α-phthalimido-γ-butyrolactone was obtained directly.

In continuation, the present work utilises the azido-group for the α-amination of γ-butyrolactone. α-Bromo-γ-butyrolactone with sodium azide in ethanolic solution gave α-azido-γ-butyrolactone in 70—80% yield. The azido-group was transformed into the α-amino-group by acidolytic or catalytic reduction; this was effected, according to the conditions employed, with conservation or opening the lactone ring.

Treating α-azido-γ-butyrolactone with 24% solution of hydrogen bromide in acetic acid precipitated α-amino-γ-butyrolactone hydrobromide in 70% yield. Similar treatment with hydrogen iodide gave the hydriodide, but yields were only 40—50%.

Catalytic reduction of α-azido-γ-butyrolactone with palladium black in the presence of hydrogen chloride afforded α-amino-γ-butyrolactone hydrochloride in 75% yield; in ethanol–water, in the presence of a base, the simultaneous reduction and opening of the lactone ring led to homoserine (α-amino-γ-hydroxybutyric acid); with sodium hydroxide as base the yield was only about 40%, with triethylamine 80%.

When catalytic reduction of the azido-lactone in absolute ethanolic solution was followed by long refluxing the aminolactone dimerised,[2,3,6] giving 2,5-di-(2-hydroxyethyl)-3,6-dioxopiperazine in 60% yield.

Unlike other α-aminated γ-butyrolactones, *e.g.*, α-benzamido- and α-phthalimido-γ-butyrolactone which are converted into α-amino-γ-iodobutyric acid hydriodide by refluxing with concentrated hydriodic acid,[7] the α-azido-γ-butyrolactone gave the corresponding γ-iodo-compound in a very poor yield. Treatment of the α-azido-γ-butyrolactone with amino-acid derivatives failed to yield a peptide linkage, as is given by α-benzamido- and α-benzyloxycarbonylamino-γ-butyrolactone.[7]

[1] Snyder, Andreen, Cannon, and Peters, *J. Amer. Chem. Soc.*, 1942, **64**, 2082.
[2] Livak, Britton, Vanderweele, and Murray, *ibid.*, 1945, **67**, 2218.
[3] Knobler and Frankel, *J.*, 1958, 1629.
[4] Frankel, Knobler, and Sheradsky, *Bull. Res. Council Israel*, 1958, **7**, *A*, 173.
[5] Talbot, Gaudry, and Berlinguet, *Canad. J. Chem.*, 1958, **36**, 593.
[6] Fischer and Blumenthal, *Ber.*, 1907, **40**, 106.
[7] Unpublished results.

All these preparations, including those of α-azido-γ-butyrolactone, the salts of α-amino-γ-butyrolactone, homoserine, and 2,5-di-(2-hydroxyethyl)-3,6-dioxopiperazine, are very convenient and proceed smoothly.

Experimental.—*α-Azido-γ-butyrolacone.* α-Bromo-γ-butyrolactone (33 g.) and sodium azide (14·5 g.) were refluxed in ethanol (200 ml.) for 5 hr., and the solution was filtered and concentrated *in vacuo*. Water (100 ml.) was added to the residue, and the lower layer was taken up in chloroform (70 ml.). The aqueous layer was extracted twice with chloroform (70 ml.), and the combined chloroform extracts were washed with water, dried (Na_2SO_4), and evaporated. The *azido-lactone* (16·8 g. 67%) had b. p. 83—85°/0·3 mm., n^{20} 1·4827, d^{20} 1·3861 (Found: C, 38·0; H, 4·1. $C_4H_5O_2N_3$ requires C, 37·8; H, 3·9%).

During distillation the azide may explode if the bath-temperature exceeds 150°. Slight decomposition occurs on prolonged storage.

Undistilled azido-lactone can be used for the following steps, but yields are lower.

α-Amino-γ-butyrolactone hydrobromide. To α-azido-γ-butyrolactone (6·35 g.) a 24% solution of dry hydrogen bromide in acetic acid (100 ml.) was added, in portions with shaking. The temperature rose to 50—60° and evolution of nitrogen occurred. Then the mixture was stirred for 4 hr., during which the amino-lactone hydrobromide was precipitated. Next morning it was collected and washed with ether. A second crop was obtained by evaporating the filtrate *in vacuo* and washing the residue with ethanol and ether. The lactone (6·8 g., 70%) melted at 223—224° (Found: N, 7·7; Br, 44·4. Calc. for $C_4H_8O_2NBr$: N, 7·7; Br, 43·9%).

α-Amino-γ-butyrolactone hydrochloride. α-Azido-γ-butyrolactone (3·2 g.) was dissolved in acetic acid (40 ml.), and hydrochloric acid (5 ml.) and palladium black (50 mg.) were added. The mixture was hydrogenated at 30—35°/2 atm. for 4 hr. The catalyst was removed and the acetic acid evaporated *in vacuo*. The oily residue crystallised on addition of a little dry ethanol. It (2·75 g. 78%) melted at 199—201° (Found: N, 9·9. Calc. for $C_4H_8O_2NCl$: N, 10·2%).

α-Amino-γ-hydroxybutyric acid (*homoserine*). α-Azido-γ-butyrolactone (6·35 g.) in ethanol (20 ml.) and water (20 ml.) containing triethylamine (5 ml.) and palladium black (100 mg.) was hydrogenated. The catalyst was removed, and acetone (100 ml.) was added. The precipitated acid (4·9 g. 82%) recrystallised from water–acetone and melted at 184—185° [Found: N (Van Slyke), 11·7. Calc. for $C_4H_9O_3N$: N, 11·8%].

2,5-*Di*-(2-*hydroxyethyl*)-3,6-*dioxopiperazine.* α-Azido-γ-butyrolactone (6·35 g.) in absolute ethanol (50 ml.) with palladium black (100 mg.) was hydrogenated. The catalyst was removed, and the ethanolic solution was refluxed for 24 hr. The product (3 g., 60%) crystallised (m. p. 185—186°; ninhydrin reaction negative) [Found: N (Kjeldahl), 13·6; N (Van Slyke), 0·0. Calc. for $C_8H_{14}O_4N_2$: N, 13·9%].

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736. *The Reactions of Boron Halides with Anhydrous Sulphuric Acid: Boron Tri(hydrogen sulphate) and Tetra(hydrogen sulphato)boric Acid.*

By N. N. GREENWOOD and A. THOMPSON.

IT has been suggested [1] that boron trifluoride forms a 1 : 1 addition compound with sulphuric acid but there is no evidence for this in the literature. Davy [2] observed that sulphuric acid absorbed 50 times its volume of gaseous boron trifluoride, which corresponds to the composition $H_2SO_4,0{\cdot}123BF_3$, and Paushkin [3] formulated the saturated solution as $BF_3 + 2\frac{1}{2}H_2SO_4$, *i.e.*, $H_2SO_4,0{\cdot}4BF_3$. We find that a saturated solution of boron trifluoride in anhydrous sulphuric acid contains less than 3 moles % of the gas, *i.e.*, $H_2SO_4,0{\cdot}028BF_3$, and explain the earlier observations as due to the presence of water in the sulphuric acid. Thus, Davy's acid had a specific gravity of 1·85, corresponding to

[1] Booth and Martin, "Boron Trifluoride and its Derivatives," John Wiley and Sons, Inc., 1949, pp. 56, 168.
[2] Davy, *Phil. Trans.*, 1812, **102**, 352.
[3] Paushkin, *Zhur. priklad. Khim.*, 1948, **21**, 1199.

approximately 98% by weight of sulphuric acid or, on a molar basis, $H_2SO_4,0{\cdot}11H_2O$; formation in solution of the 1 : 1 compound BF_3,H_2O would therefore account for almost all the gas absorbed. Likewise, the acid used in Paushkin's experiments was stated to be 94—100%.[4] The lower value is equivalent to $H_2SO_4,0{\cdot}35H_2O$, so that combination of boron trifluoride with this water again accounts for most of the gas absorbed. The absence of appreciable interaction between boron trifluoride and sulphuric acid is surprising in view of (*a*) the ease with which the related electron acceptor sulphur trioxide dissolves to give oleums from which pyrosulphuric acid, H_2SO_4,SO_3, can be crystallized, and (*b*) the existence of compounds such as M_2SO_4,BF_3 analogous to the pyrosulphates.[5]

The conductivity of anhydrous sulphuric acid at 25° is $1{\cdot}044 \times 10^{-2}$ ohm^{-1} cm.$^{-1}$.[6] Using acid of conductivity $4{\cdot}36 \times 10^{-2}$ ohm^{-1} cm.$^{-1}$, Topchiev and Paushkin found that boron trifluoride lowered this conductivity to $3{\cdot}57 \times 10^{-2}$ ohm^{-1} cm.$^{-1}$, a factor of 0·82.[4] In our experience the effect is even more marked with pure acid, and a saturated solution (2·9 moles % of boron trifluoride) had a conductivity only 0·53 that of the solvent acid. This reduction in conductivity is presumably due to a partial suppression of the proton-switch conduction mechanism in a manner similar to that encountered in the boron trifluoride–phosphoric acid system.[7]

Boron trichloride, in contrast to the trifluoride, reacts vigorously with anhydrous sulphuric acid according to the equation

$$BCl_3 + 3H_2SO_4 = B(HSO_4)_3 + 3HCl \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

Boron tri(hydrogen sulphate) was obtained as a white deliquescent powder which did not melt when heated in a sealed tube to 240°. It was readily soluble in anhydrous sulphuric acid and an equimolar solution set to a moist solid at room temperature:

$$B(HSO_4)_3 + H_2SO_4 = HB(HSO_4)_4 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

A solid of the same composition was obtained directly by reaction of sulphuric acid with the calculated amount of boron trichloride:

$$BCl_3 + 4H_2SO_4 = HB(HSO_4)_4 + 3HCl \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

The compound decomposed into a liquid with some evolution of gas when heated. In this instability it resembles other anhydrous acids of tetraco-ordinated boron, *e.g.*, fluoroboric acid, HBF_4, and boron trifluoride monohydrate, HBF_3OH.

No reaction between boron trichloride and sulphuric acid has been reported previously but, when the gas was condensed with sulphur trioxide at −80°, an unstable compound $BCl_3,2SO_3$ was formed which can be formulated as di(chlorosulphonato)boron chloride, $BCl(O{\cdot}SO_2Cl)_2$.[8] Boron tri(hydrogen sulphate) has been reported as the product of the reaction of boric oxide with sulphuric acid.[9] The white, hygroscopic solid had the correct analysis but melted at about 215° in contrast to our product which was infusible at 240°. The compound has also been postulated to exist in dilute solutions of boric oxide in sulphuric acid [10] but more recent cryoscopic and conductometric work on very dilute solutions of boric oxide and boric acid in sulphuric acid and oleum favours the formation of tetra(hydrogen sulphato)boric acid in these solutions.[11] The compound was not isolated at that time however.

Experimental.—Boron trifluoride (Imperial Smelting Co.) and boron trichloride (B.D.H.) were used after a preliminary fractionation. The preparation of anhydrous sulphuric acid [6] and the design of the conductivity cell [12] have previously been described.

[4] Topchiev, Paushkin, Vishnyakova, and Kurashov, *Doklady Akad. Nauk, S.S.S.R.*, 1951, **80**, 611.
[5] Baumgarten and Müller, *Ber.*, 1936, **69**, 2688; Baumgarten and Hennig, *ibid.*, 1939, **72**, 1743.
[6] Greenwood and Thompson, *J.*, 1959, 3474.
[7] *Idem, ibid.*, p. 3493.
[8] Luchinski, *Zhur. obshchei Khim.*, 1941, **11**, 884.
[9] D'Arcy, *J.*, 1889, **55**, 155.
[10] Hantzsch, *Z. phys. Chem.*, 1908, **61**, 257.
[11] Flowers, Gillespie, and Oubridge, *J.*, 1956, 1925.
[12] Greenwood, Martin, and Emeléus, *J.*, 1951, 1328.

Boron tri(hydrogen sulphate). Excess of boron trichloride was condensed at −80° from a vacuum line on to a known weight of sulphuric acid in a reaction vessel fitted with a spring-loaded tap. The contents were allowed to warm slowly to room temperature and, as the sulphuric acid melted, a highly exothermic reaction ensued with considerable frothing. The reaction vessel was then evacuated and reweighed. Equation 1 requires that 1 g. of H_2SO_4 yield 1·027 g. of $B(HSO_4)_3$; our yield was 1·027 g. The gases evolved in the reaction contained no sulphur and, after fractionation, proved to be hydrogen chloride (*M*, 34·9—38·0) and the unchanged excess of boron trichloride. The solution obtained by hydrolysis of the *product* contained boron and sulphate but no chloride. It was titrated with 0·1N-sodium hydroxide to the methyl orange end-point to determine sulphuric acid and then, in the presence of mannitol, to the phenolphthalein end-point to determine boric acid [Found: B, 3·6; SO_4, 93·2. $B(HSO_4)_3$ requires B, 3·6; SO_4, 95·4%].

Tetra(hydrogen sulphato)boric acid. Addition of an equimolar amount of boron tri(hydrogen sulphate) to anhydrous sulphuric acid resulted in a moist solid of indefinite m. p. which decomposed on being heated. Reaction of one mole of boron trichloride with four moles of sulphuric acid gave the theoretical weight of *product* according to equation (3); it contained only a trace of chlorine [Found: B, 2·76; SO_4, 94. $HB(HSO_4)_4$ requires B, 2·77; SO_4, 96%].

THE UNIVERSITY, NOTTINGHAM. [*Received, April 29th,* 1959.]

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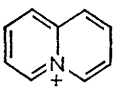
737. *A Molecular Orbital Calculation of the Ultraviolet Absorption Spectrum of the Quinolizinium Cation.*

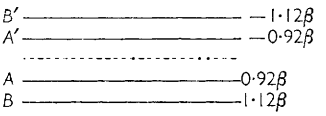
By T. E. PEACOCK.

THE quinolizinium cation (I) and naphthalene are isoelectronic and, because they possess the same framework it is reasonable to expect that their electronic spectra will be related.

The electronic spectrum has been calculated by the methods of previous papers,[1-3] in which we use the SCF (self-consistent field) molecular orbitals of the hydrocarbon parent (*i.e.*, naphthalene) in order to calculate the spectrum of the heterocyclic derivative.

The spectrum of naphthalene, which has the symmetry D_{2h}, has already been discussed in detail.[2,4] The energies of its two highest occupied and two lowest unoccupied SCF molecular orbitals, and their symmetry symbols, are:

(I) 



The quinolizinium cation has the reduced symmetry C_{2v}. The ground state function Φ_0 and the functions of the excited configurations $\Phi(A \longrightarrow A')$, $\Phi(B \longrightarrow B')$, $\Phi(A \longrightarrow B')$, $\Phi(B \longrightarrow A')$ are grouped according to symmetry under C_{2v} in Table 1. Here, for instance, $\Phi(A \longrightarrow A')$ is the singlet function in which the configuration is $(A)^1(A')^1$ instead of $(A)^2$.

TABLE 1.

Symmetry	*A*	*B*
Function	Φ_0	$\Phi(A \longrightarrow B')$
	$\Phi(B \longrightarrow B')$	$\Phi(B \longrightarrow A')$
	$\Phi(A \longrightarrow A')$	

Since there are excited functions of the same symmetry as the ground-state function, mixing will be allowed and is adequate to describe the effect of the substituent on the charge distribution without any revision of the basic orbitals.[1]

[1] McWeeny, *Proc. Phys. Soc.*, 1957, *A*, **70**, 593.
[2] Peacock, *Proc. Phys. Soc.*, 1957, *A*, **70**, 645.
[3] Peacock, *J.*, 1959, 2308.
[4] Peacock, *J.*, 1959, 3421.

The general interpretation of the so-called α, *p*, β, and β′ bands of an alternant hydrocarbon [5] and its heterocyclic derivatives [3,6,7] in terms of the mixing of the configurational functions discussed above, is now well known.

The value of the framework parameter for the doubly-charged nitrogen ion was chosen to reproduce Brown and Penfold's [8] charge distribution for $CH_2{\cdot}NH_2^+$: this value is 3·0β where β is the SCF value of the C–C resonance integral in benzene. At first sight this value is somewhat high, but this is due to the atom's being doubly ionized and requiring a substantial proportion of the π electrons (about 1·5) in order to screen its large framework charge. This value agrees closely with that determined experimentally.[9] The other parameters and the two-electron integrals were given the same values as in previous work.[2,6]

Results.—The calculated transition energies and oscillator strengths for the quinolizinium ion are given in Table 2, and the wave functions for the ground state and excited states in Table 3.

TABLE 2.

State and symmetry	Transition energy ($\tilde{\nu}$)	Predicted oscillator strength	Observed band ($\tilde{\nu}$)	State and symmetry	Transition energy ($\tilde{\nu}$)	Predicted oscillator strength	Observed band ($\tilde{\nu}$)
	Naphthalene				Quinolizinium *		
$\alpha(B_3)$	35,900	0	32,300	$\alpha(B)$	34,900	0·314	30,300
$p(B_2)$	36,600	0·208	36,500	$p(A)$	41,300	0·228	44,000
$\beta(B_3)$	51,000	2·213	45,200	$\beta(B)$	60,700	2·160	
$\beta'(B_2)$	53,700	1·040	59,700	$\beta'(A)$	63,000	1·200	

* Experimental values taken from Jones and Glover.[10]

TABLE 3.

$$\Psi_0 = 0{\cdot}960\,\Phi_0 - 0{\cdot}100\,\Phi(A \longrightarrow A') + 0{\cdot}257\,\Phi(B \longrightarrow B')$$
$$\Psi_\alpha = 0{\cdot}951\,\Phi(A \longrightarrow B') - 0{\cdot}310\,\Phi(B \longrightarrow A')$$
$$\Psi_p = -0{\cdot}003\,\Phi_0 + 0{\cdot}928\,\Phi(A \longrightarrow A') + 0{\cdot}371\,\Phi(B \longrightarrow B')$$
$$\Psi_\beta = 0{\cdot}310\,\Phi(A \longrightarrow B') + 0{\cdot}951\,\Phi(B \longrightarrow A')$$
$$\Psi_{\beta'} = -0{\cdot}278\,\Phi_0 - 0{\cdot}341\,\Phi(A \longrightarrow A') + 0{\cdot}898\,\Phi(B \longrightarrow B')$$

Discussion.—The results account satisfactorily for the observed shifts and intensity changes of the main bands:

α *Band.* Theory predicts a bathochromic shift of 1000 $\tilde{\nu}$, which compares with the experimentally determined shift of 2000 $\tilde{\nu}$ (the agreement is quite good bearing in mind the difficulties which occur in determining the centre of the observed bands). The intensity is much higher than in naphthalene and this is predicted.

p Band. A hypsochromic shift of 4700 $\tilde{\nu}$ is predicted. The observed value is 7500 $\tilde{\nu}$. Again bearing in mind the uncertainty of the experimental value the agreement is quite good. The intensity of this band is predicted to be almost unchanged on substitution, which is observed.

In the quinolizinium ion the α and *p* bands are predicted to have comparable intensities—in contrast with the situation in naphthalene. This is in fact observed.

β *and* β′ *Bands.* These are predicted to occur at 60,700 $\tilde{\nu}$ and 63,000 $\tilde{\nu}$ and are as yet unobserved.

The author thanks Dr. R. McWeeny for his interest and the Ramsay Memorial Fellowship Trust for a Fellowship.

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[5] Dewar and Longuet-Higgins, *Proc. Phys. Soc.*, 1954, *A*, **67**, 795.
[6] McWeeny and Peacock, *Proc. Phys. Soc.*, 1957, *A*, **70**, 41.
[7] Peacock, *Nature*, 1957, **179**, 684.
[8] Brown and Penfold, *Trans. Faraday Soc.*, 1957, **53**, 397.
[9] Mason, *J.*, 1958, 674.
[10] Jones and Glover, *J.*, 1958, 3021.

738. *Pyrimidine Reactions. Part II.* 2-Ethoxy-4-, and 4-Ethoxy-2-hydroxy-5-nitropyrimidine.*

By D. J. Brown.

2,4-Dichloro-5-nitropyrimidine [1] was converted by sodium ethoxide in anhydrous ethanol into 2,4-diethoxy-5-nitropyrimidine. This product corresponds to that made by nitrating 2,4-diethoxypyrimidine [2] and by other means.[3] When one mol. of water was initially present in the ethanol used, little diethoxynitropyrimidine resulted, but in its place there appeared two isomeric ethoxyhydroxypyrimidines and a little 5-nitrouracil. The best yield of the isomers was obtained by using 2·8 moles of sodium ethoxide per mole of dichloro-compound, and almost the same mixture resulted by similar partial hydrolysis of the diethoxy-derivative in the presence of 1 mol. of sodium ethoxide.

The structure of each isomer was found by amination. The 4-ethoxy-compound gave 5-nitrocytosine, and the 2-ethoxy-compound gave 5-nitroisocytosine. These amines were identified with authentic materials [4,5] by paper chromatography, pK_a determination, and ultraviolet and infrared spectra.

Inspection of the Table of spectra, along the lines now familiar from work by Marshall and Walker [6] and others,[7,8] suggests that 5-nitrouracil exists in aqueous solution predominantly as 1,2,3,4-tetrahydro-5-nitro-2,4-dioxopyrimidine.

5-Nitropyrimidine derivative	pK_a, spread, and concn.	pH	Ultraviolet spectra $\lambda_{max.}$ (mμ)	log ε
2,4-Diethoxy	—	7·0	296, 251	3·96, 3·78
2-Ethoxy-4-hydroxy	—	2·5	314, 238,[a] 225 [a]	3·89, 3·76, 3·83
anion	4·88 ± 0·05 (M/400)	7·0	341, 250,[a] 230	3·97, 3·74, 3·95
4-Ethoxy-2-hydroxy	—	4·5	298, 260	3·88, 3·90
anion	*ca.* 6·6 (M/400)	9·5	335, 266, 232	4·14, 3·61, 3·76
2,4-Dihydroxy [b]	—	3·3	298, 237	3·95, 3·82
anion	5·55 ± 0·03 (M/1000) [c]	7·7	341, 258, 229	4·13, 3·68, 3·78
dianion	11·3			
2-Amino-4-hydroxy	—	4·5	338, 254, 232	4·15, 3·70, 3·72
anion	6·70 ± 0·02 (M/1000)	9·5	353, 245	4·10, 3·75
4-Amino-2-hydroxy	—	5·0	317, 251,[a] 223	3·94, 3·90. 4·18
anion	7·34 ± 0·03 (M/1000)	9·5	353, 253, 214	4·21, 3·78, 406
1,2,3,4-Tetrahydro-1,3-dimethyl-2,4-dioxo [d]	—	7·0	309, 239	3·95, 3·79

[a] Inflexion. [b] Prep.: see ref. 9. [c] Cf. ref. 10: 5·3 and 11·7 by spectrophotometric means. [d] Prep.: see ref. 11.

Experimental.—*2,4-Diethoxy-5-nitropyrimidine.* 2,4-Dichloro-5-nitropyrimidine [1] (1 g.) and sodium ethoxide [from sodium (0·3 g.) and anhydrous ethanol (20 ml.)] were kept at 25° for 2 hr. Carbon dioxide was introduced, and the filtered solution evaporated to dryness in a vacuum. Sublimation (45°/0·05 mm.) of the residue gave 53% of the product, m. p. 42—3° (lit., 45°) (Found: C, 45·2; H, 5·15; OEt, 41·2. Calc. for $C_8H_{11}O_4N_3$: C, 45·1; H, 5·2; OEt, 42·2%).

2-Ethoxy-4- and 4-ethoxy-2-hydroxy-5-nitropyrimidine. 2,4-Dichloro-5-nitropyrimidine (5·82 g.) and sodium ethoxide [from sodium (1·93 g.) and anhydrous ethanol (140 ml.)] with water (0·54 ml.) were refluxed for 20 min. The filtered solution was evaporated to dryness under reduced pressure at 30°, and the solid dissolved in hot ethanol (85 ml.). After refrigeration for

* Part I, *J.*, 1956, 2312.

[1] Whittaker, *J.*, 1951, 1565.
[2] Rabinowitz and Gurin, *J. Amer. Chem. Soc.*, 1953, **75**, 5758.
[3] Takahashi, Naito, and Inoue, *Chem. Pharm. Bull.* (*Japan*), 1958, **6**, 334.
[4] Johns, *Amer. Chem. J.*, 1911, **45**, 79.
[5] Johnson and Johns, *Amer. Chem. J.*, 1905, **34**, 554.
[6] Marshall and Walker, *J.*, 1951, 1004.
[7] Brown and Short, *J.*, 1953, 331.
[8] Albert and Barlin, *J.*, 1959, in the press.
[9] Brown, *J. Appl. Chem.*, 1952, **2**, 239.
[10] Shugar and Fox, *Biochim. Biophys. Acta*, 1952, **9**, 199.
[11] Brown, Hoerger, and Mason, *J.*, 1955, 211.

at least 1 day, the solid was dissolved in water (16 ml.) at 40°, the solution adjusted to pH 2—3, and the product (1·1 g.) recrystallised from water (16 parts) to give colourless needles of the 2-*ethoxy-isomer*, m. p. 165—166° (Found: C, 38·7; H, 3·6; OEt, 24·8. $C_6H_7O_4N_3$ requires C, 38·9; H, 3·8; OEt, 24·35%). The residue from evaporation of the ethanolic filtrate was triturated with water (12 ml.). Sublimation (45°/0·05 mm.) of the insoluble material gave the diethoxy-derivative (1·4 g.), m. p. 42—43°. Adjustment of the aqueous solution to pH 2—3, and recrystallization of the resulting solid from water (40 ml.), gave irregular plates (0·86 g.) of the 4-*ethoxy-isomer*, m. p. 198—199° (Found: C, 38·9; H, 3·7; OEt, 24·8%).

Partial hydrolysis of 2,4-*diethoxy*-5-*nitropyrimidine.* The 2,4-diethoxy-compound (6·4 g.) was treated as above for 30 min., except that sodium (0·69 g.) was used. There resulted 2-ethoxy-isomer (1·6 g.), 4-ethoxy-isomer (0·95 g.), and unchanged material (0·03 g.).

5-*Nitrocytosine and* 5-*nitroisocytosine.* Each ethoxy-isomer (0·5 g.) was heated at 100° for 1 hr. with 6·5% alcoholic ammonia (4 ml.). After evaporation to dryness, the solid was triturated with 7·5N-acetic acid (5 ml.) to free the nitrocytosine (85%) and nitroisocytosine (50%), which recrystallised from water (respectively 350 and 80 parts).

I thank Mr. J. Harper for painstaking experiments, Mr. F. Robinson and Mr. D. Light for physical measurements, and Dr. J. E. Fildes and staff for analyses.

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739. *The Stability Constants of Some Metal Chelates of* ortho-*Aminophenols.*

By PETER SIMS.

IT has been suggested [1] that certain *ortho*-aminophenols are carcinogenic because of their ability to chelate with metals in the body. An attempt has been made, therefore, to measure the stability constants of some of these compounds: 3-hydroxyanthranilic acid and 2-amino-4,5-dimethylphenol (which are known carcinogens [1,2]) and 2-aminophenol (which is not a carcinogen).

Albert's methods [3,4] for the calculation of the stability constants have been applied to those parts of the titrations where consistent results were obtained. Because of the low solubilities of the aminophenols and of the chelate complexes in water, titrations were carried out on 0·001M solutions of the aminophenols (or of their hydrochlorides) but even

Stability constants of chelates of o-*aminophenols* (*at* 20°).

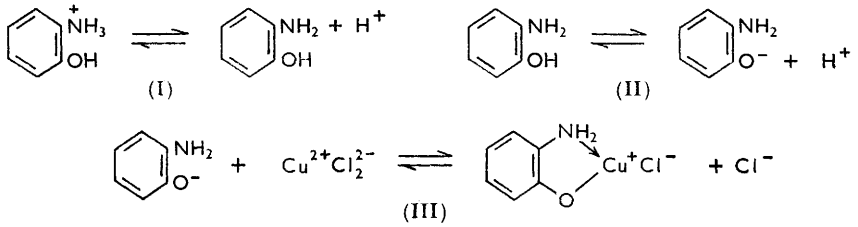
			Cu^{2+}		Fe^{2+}	Ni^{2+}		Co^{2+}	Cd^{2+}	Mn^{2+}
	pK_a	$pK_{a'}$	K_1	K_2	K_1	K_1	K_2	K_1	K_1	K_1
3-Hydroxyanthranilic acid *	10·09 ± 0·02	5·20 ± 0·01	—	—	7·7	5·1	3·6	4·4	4·3	3·4
2-Amino-4,5-dimethylphenol hydrochloride	10·40 ± 0·06	5·28 ± 0·04	9·9	—	—	5·9	4·8	5·3	4·9	3·6
2-Aminophenol hydrochloride	9·99 ± 0·02	4·86 ± 0·04	8·8	7·3	8·0	5·4	—	4·7	4·3	3·6

* Albert (personal communication) reports pK_a 5·21 ± 0·01 and 10·11 ± 0·03 for 3-hydroxyanthranilic acid at 20°, and values of 5·07 and 3·31 for the stability constants of the complex of this acid with Ni^{2+}.

at these low concentrations precipitation of the complexes began at values of $\bar{n}$ of 0·8 or above for 2-amino-4,5-dimethylphenol and 2-aminophenol and at 0·6 and above for 3-hydroxanthranilic acid. Values for K_2 are recorded where precipitation did not occur below $\bar{n} = 1·5$. The pK_a values for the aminophenols presumably refer to the equilibria (I) and (II). A third pK_a of about 2·5 for 3-hydroxyanthranilic acid could not be measured exactly because of difficulties due to insolubility, but it is presumably that of the acid–base equilibrium involving the carboxyl group. K_1 is the equilibrium constant of reactions such as (III). Except in the presence of cupric or ferrous ions, the titration curves of the

[1] Boyland and Watson, *Nature*, 1956, **177**, 837.
[2] Allen, Boyland, Dukes, Horning, and Watson, *Brit. J. Cancer*, 1957, **11**, 212.
[3] Albert, *Biochem. J.*, 1950, **47**, 531.
[4] *Idem, ibid.*, 1952, **50**, 690.

hydrochlorides of 2-aminophenol and 2-amino-4,5-dimethylphenol with the metallic ions followed closely the titration curves in their absence until one equivalent of alkali had been added. 3-Hydroxyanthranilic acid behaved in the same way: presumably one of the functional groups (possibly carboxyl) is not involved in chelate formation. With cupric and ferrous ions complex formation began with all aminophenols during the addition of



the first equivalent of alkali. Ferric ions chelate strongly with all three aminophenols but, because of the low solubility of the complexes, the stability constants could not be measured, and the titration curves in the presence of Mg^{2+} ions closely followed those obtained in the absence of metallic ions. The order of stability of the chelates of the various metals follows that described by Irving and Williams [5] except that the position of the ferrous chelates is anomalous and the values of K_1 are higher than expected. This may be due to oxidation of ferrous to ferric ions, although *o*-aminophenols might be expected to act as reducing agents.

Albert [3] has pointed out that the success of a chelating agent in competing for a particular metallic ion depends on K_a as well as on the stability constants. This is reflected in the value of $\bar{n}$ at a given pH, and in particular at the pH of the animal cell. As the values of K_a and K_1 of the three aminophenols do not differ widely among themselves, little differences in the values of $\bar{n}$ at, say, pH 7·5, for each aminophenol with a particular metallic ion would be expected. For example, 3-hydroxyanthranilic acid, 2-amino-4,5-dimethylphenol, and 2-aminophenol in the presence of Ni^{2+} ions have values for $\bar{n}$ of 0·45, 0·20, and 0·37 respectively at this pH.

Experimental.—Materials. 3-Hydroxyanthranilic acid was prepared by Spada and Gavioli's method [6] and purified as described by Hegedüs.[7] 2-Amino-4,5-dimethylphenol, prepared by the persulphate oxidation of 3,4,1-xylidine,[8] and 2-aminophenol were purified by sublimation and converted into the hydrochlorides by saturating solutions in ether with dry hydrogen chloride.

The metallic ions were added in the form of the following "AnalaR" salts: Fe^{2+}, Co^{2+}, Mn^{2+}, and Mg^{2+} as sulphates, Ni^{2+} and Co^{2+} as the nitrates, and Cu^{2+} as the chloride.

Titrations. 5×10^{-5} mole of the aminophenol and $2{\cdot}5 \times 10^{-5}$ mole of the metallic salt, in boiled-out distilled water (45 ml.), were titrated with 0·01N-potassium hydroxide (carbonate free), added in 0·5 ml. portions, the pH of the solution being measured after each addition of alkali on a Pye Universal pH meter with a lithium-glass electrode and a calomel electrode. The titration vessel was immersed in a bath at 20° ± 0·1°, and the contents were stirred by means of a stream of purified nitrogen. pK_a was measured in the same way in the absence of metallic ions.

I thank Professor Adrien Albert for a discussion and Professor E. Boyland for his interest. This work was supported by grants to this Institute from the British Empire Cancer Campaign, the Jane Coffin Childs Memorial Fund for Medical Research, the Anna Fuller Fund, and the National Cancer Institute of the National Institutes of Health, U.S. Public Health Service.

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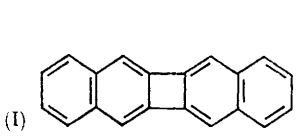
THE INSTITUTE OF CANCER RESEARCH: ROYAL CANCER HOSPITAL,
LONDON, S.W.3. [*Received, May 26th*, 1959.]

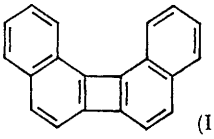
[5] Irving and Williams, *J.*, 1953, 3192.
[6] Spada and Gavioli, *Boll. scient. Fac. chim. ind. Bologna*, 1950, **8**, 101.
[7] Hegedüs, *Helv. Chim. Acta*, 1951, **34**, 611.
[8] Sims, *J.*, 1958, 44.

740. 2,3:6,7-*Dibenzodiphenylene.*

By R. F. Curtis.

Recently,[1] it was emphasised that 2,3:6,7-dibenzodiphenylene (I) shows unusual properties compared with 1,2:7,8-dibenzodiphenylene [2] (II). In particular, the melting point (372°) is very high and the compound is extraordinarily stable (sublimation unchanged at 350°). In contrast, 1,2:7,8-dibenzodiphenylene (II) (m. p. 137—139°) decomposes easily. Since it was impossible to determine the molecular weight of 2,3:6,7-dibenzodiphenylene these large differences might be attributed to a structure of higher molecular weight than that appropriate for (I), especially as only a low yield of 2,2′-dinaphthyl was obtained on reduction.


(I)


(II)

The mass spectrum of the compound has now been determined. This clearly shows a molecular weight of 252 ($C_{20}H_{12}$) and a breakdown pattern indicative of a diphenylene nucleus.

Thus the dibenzodiphenylenes (I) and (II) must contain major contributions from the structures shown, with cyclobutadienoid character predominant in (II) and notably absent from (I).

The mass spectrum was kindly determined by Imperial Chemical Industries Limited (Dyestuffs Division).

University College of Swansea,
Singleton Park, Swansea.

[*Received, May 28th,* 1959.]

[1] Curtis and Viswanath, *J.*, 1959, 1670.
[2] Cava and Stucker, *J. Amer. Chem. Soc.*, 1955, **77**, 6022.

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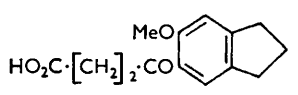
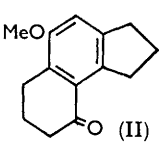
741. 6-*Hydroxy*-4,5-*benzindane.*

By David W. Mathieson and V. S. Gandhi.

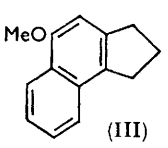
5-Methoxyindane has been condensed with succinic anhydride in presence of aluminium chloride to yield the propionic acid (I). Oxidation of this gave 5-methoxyindane-6-carboxylic acid whence demethylation yielded the known 5-hydroxyindane-6-carboxylic acid.[1] The position of attack on 5-methoxyindane under Friedel–Crafts conditions is thus demonstrated and is to be compared with production of 6-acetyl-5-hydroxyindane obtained on Fries rearrangement of 5-acetoxyindane.[2]



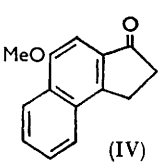
(I)



(II)



(III)



(IV)

Clemmensen reduction of the acid (I) followed by cyclisation with anhydrous hydrogen fluoride furnished the tetrahydrobenzindanone (II). A second reduction with amalgamated zinc followed by selenium dehydrogenation then yielded 6-methoxy-4,5-benzindane

[1] Prelog, Meltzer, and Jeger, *Helv. Chim. Acta*, 1947, **30**, 675.
[2] Wilson Baker, *J.*, 1937, 476.

(III), whose constitution was confirmed by comparison with a sample obtained on Clemmensen reduction of the known [3] 6-methoxy-1-oxo-4,5-benzindane (IV).

Demethylation of the 6-methoxy-compound (III) gave 6-hydroxy-4,5-benzindane. The m. p. of this phenol is in accord with that of a sample isolated by Kruber [4] from coal tar by sulphonation followed by potash fusion.

Experimental.—*γ-(5-Methoxy-6-indanyl)-γ-oxobutyric acid* (I). Aluminium chloride (27 g.) was added with stirring to 5-methoxyindane (15 g.) and succinic anhydride (12 g.) in ethylene dichloride (100 ml.) and the mixture kept overnight. Next morning it was decomposed with ice and dilute hydrochloric acid. Solvent was removed by steam distillation and the residual solid purified *via* its sodium salt. The *acid* crystallised from ethanol in needles, m. p. 181—182·5° (Found: C, 67·9; H, 6·6; OMe, 12·6. $C_{14}H_{16}O_4$ requires C, 67·7; H, 6·5; OMe, 12·5%).

Oxidation by means of alkaline sodium hypochlorite afforded 5-methoxyindane-6-carboxylic acid, m. p. 106°. This was demethylated with hydrogen bromide in acetic acid to give 5-hydroxyindane-6-carboxylic acid, m. p. 195° (Prelog, Meltzer, and Jeger [1] give m. p. 195—196°).

γ-(5-Methoxy-6-indanyl)butyric acid. To amalgamated zinc wool (40 g.) and water (80 ml.) there was added in order, concentrated hydrochloric acid (120 ml.) and *γ*-(5-methoxy-6-indanyl)-*γ*-oxobutyric acid (20 g.) in toluene (120 ml.). The mixture was refluxed for 48 hr., additions of concentrated hydrochloric acid (5—10 ml.) being made every 12 hr. The dried toluene layer yielded a solid (17·8 g., 94%) which was recrystallised from light petroleum (b. p. 60—80°), forming stout needles, m. p. 82—83°, of the *acid* (Found: C, 72·2; H, 7·7. $C_{14}H_{18}O_3$ requires C, 71·8; H, 7·7%).

1′,2′,3′,4′-Tetrahydro-6-methoxy-4′-oxo-4,5-benzindane (II). *γ*-(5-Methoxy-6-indanyl)butyric acid (10 g.) was kept for 3 days in anhydrous hydrogen fluoride. Evaporation of the hydrogen fluoride gave a residue which was washed in ether with sodium carbonate solution to remove any unchanged acid. The ethereal solution yielded a neutral residue (8·8 g., 95%) which was recrystallised from ethanol, giving a felted mass of needles, m. p. 81·5° of the *benzindanone* (Found: C, 77·9; H, 7·5; MeO, 14·4. $C_{14}H_{16}O_2$ requires C, 77·7; H, 7·4; MeO, 14·3%); $\lambda_{max.}$ 227 mμ (ε 17,460), 258 mμ (ε 3808). The *semicarbazone* crystallised from ethyl alcohol in needles, m. p. 218—219° (Found: C, 65·5; H, 7·1; N, 15·3. $C_{15}H_{19}O_2N_3$ requires C, 65·9; H, 7·0; N, 15·4%). The 2 : 4-*dinitrophenylhydrazone* crystallised from xylene in crimson needles, m. p. 259—260° (Found: C, 60·8; H, 5·5; N, 14·2. $C_{20}H_{20}O_5N_4$ requires C, 60·6; H, 5·1; N, 14·1%).

1′,2′,3′,4′-Tetrahydro-6-methoxy-4,5-benzindane. To amalgamated zinc wool (10 g.) and water (20 ml.) were added concentrated hydrochloric acid (15 ml.) and 1′,2′,3′,4′-tetrahydro-6-methoxy-4′-oxo-4,5-benzindane (5 g.) in toluene (30 ml.). The mixture was refluxed for 48 hr., small additions of concentrated hydrochloric acid being made every 12 hr. After working up in the usual way there resulted a yellow oil (4·48 g., 96%), b. p. 110—120°/0·5 mm. This *benzindane* crystallised from light petroleum (b. p. 40—60°) in needles, m. p. 68° (Found: C, 82·9; H, 8·9; OMe, 15·4. $C_{14}H_{18}O$ requires C, 83·1; H, 8·9; OMe, 15·3%); $\lambda_{max.}$ 284 mμ (ε 2650), 333—334 mμ (ε 413). The *picrate* crystallised from ethanol in orange-red needles, m. p. 96—98° (Found: C, 55·8; H, 4·9; N, 9·7. $C_{20}H_{21}O_8N_3$ requires C, 55·7; H, 4·9; N, 9·8%).

6-Methoxy-4,5-benzindane (III). (*a*) The tetrahydro-compound (3 g.) was heated to 200° for 4 hr. with an equal weight of 30% palladium–charcoal, a stream of carbon dioxide being passed through the flask. After cooling, the residue was extracted with ether. The pale yellow oil was purified by passing the derived picrate through alumina, and the low-melting solid obtained was crystallised from light petroleum (b. p. 40°) at −40°. Colourless needles, m. p. 39·5°, of the *benzindane* (III) resulted (Found: C, 84·7; H, 7·2; MeO, 15·2. $C_{14}H_{14}O$ requires C, 84·8; H, 7·1; MeO, 15·7%); $\lambda_{max.}$ 241 mμ (ε 35,330), 303 mμ (ε 5283). The *picrate* crystallised in dark red needles, m. p. 154—155°, from ethanol (Found: C, 56·2; H, 4·0; N, 9·8. $C_{20}H_{17}O_8N_3$ requires C, 56·2; H, 4·0; N, 9·8%). (*b*) A mixture of 6-methoxy-1-oxo-4,5-benzindane (5 g.) in toluene (30 ml.) and zinc amalgam (10 g.) in concentrated hydrochloric acid (30 ml.) and water (20 ml.) was heated under reflux for 48 hr. The ether-soluble portion of the product was a pale yellow oil, b. p. 140—150°/0·1 mm. (39%), which solidified on cooling and was purified by passing the picrate through alumina. Crystallisation from light petroleum

[3] Robinson and Martin, *J.*, 1943, 798.
[4] Kruber, *Ber.*, 1932, **65**, 1382.

(b. p. 40°) at −40° gave needles, m. p. 39° giving no depression on admixture with a sample obtained by method (*a*); $\lambda_{max.}$ 241 mμ (ε 37,360), 303 mμ (ε 5564). The picrate crystallised from ethanol in dark red needles, m. p. 150—151° giving no depression on admixture with a sample prepared as described under (*a*).

6-*Hydroxy*-4,5-*benzindane* (IV). 6-Methoxy-4,5-benzindane (850 mg.) was refluxed with 60% aqueous hydrobromic acid (4 ml.) and acetic acid (7 ml.) for 4 hr. Most of the solvent was removed *in vacuo*, and phenolic material removed by washing an ethereal solution of the residue with sodium hydroxide. The non-phenolic fraction (405 mg.) was again demethylated. The combined sodium hydroxide extracts yielded a solid (320 mg.) (40%), purified by passing an ethereal solution through a short column of charcoal. The sample was sublimed at 75—85°/0·1 mm., then crystallised from light petroleum (b. p. 60—80°) to give yellow needles, m. p. 120—121° (Kruber [4] records m. p. 122°) (Found: C, 84·7; H, 6·7. Calc. for $C_{13}H_{12}O$: C, 84·8; H, 6·5%).

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742. *Experiments Relating to Phthiocerol. Part IV.*[1] *Synthesis of 7-Methoxy-6-methylnonanoic Acid.*

By F. K. DRAYSON and N. POLGAR.

6-METHYL-7-OXONONANOIC ACID [1] was converted, by means of diazomethane, into its methyl ester which, on reduction with sodium borohydride in tetrahydrofuran, gave the hydroxy-ester. Methylation of the latter by repeated treatment with methyl iodide–silver oxide gave the methoxy-ester which on hydrolysis afforded the methoxy-acid. Comparison of the infrared spectra of the methoxy-ester and the methyl ester derived from the C_{11} oxidation product of phthiocerol showed close agreement. Moreover, Professor Ställberg-Stenhagen, of Göteborg, kindly subjected these methyl esters to gas chromatography, and found that, within the experimental error, they had the same gas-chromatographic retention time.

Experimental.—Petrol refers to light petroleum (b. p. 40—60°).

Methyl 7-*hydroxy*-6-*methylnonanoate*. 6-Methyl-7-oxononanoic acid [1] was converted, by means of diazomethane, into its *methyl* ester which distilled at 160—180° (bath)/17 mm., and had n_D^{23} 1·4368 (Found: C, 65·9; H, 10·0. $C_{11}H_{20}O_3$ requires C, 66·0; H, 10·0%). This ester (1·02 g.) in dry tetrahydrofuran (20 c.c.) was added dropwise to a solution of sodium borohydride (0·2 g.) in tetrahydrofuran (40 c.c.) during 6 hr., the mixture being stirred mechanically throughout. Most of the tetrahydrofuran was then removed by distillation, and the residue, after acidification with dilute sulphuric acid, was extracted with ether. Distillation of the dried ($MgSO_4$) extract gave *methyl* 7-*hydroxy*-6-*methylnonanoate* (0·95 g.), b. p. 160—190° (bath)/12 mm., n_D^{18} 1·4476 (Found: C, 65·2; H, 10·8. $C_{11}H_{22}O_3$ requires C, 65·3; H, 10·9%).

7-*Methoxy*-6-*methylnonanoic acid*. The hydroxy-ester (3·4 g.) was refluxed with methyl iodide (15 c.c.) and silver oxide (8 g.; prepared according to the directions of Busch *et al.*;[3] added in small portions) for 8 hr. The mixture was filtered while hot, and the silver salts were extracted repeatedly with boiling chloroform. The filtrate and washings were then evaporated. After three more methylations by the same procedure, the product was chromatographed in petrol on alumina (200 g.; Spence, type H, washed with 50% aqueous acetic acid, then dried at 175° for 36 hr.; activity II on Brockmann and Schodder's scale [4]) prepared in petrol. Elution with petrol afforded *methyl* 7-*methoxy*-6-*methylnonanoate* (1·6 g.) which distilled at 160—175° (bath)/20 mm., and had n_D^{23} 1·4339 (Found: C, 66·5; H, 11·3. $C_{12}H_{24}O_3$ requires C, 66·7; H, 11·1%). Further elution with petrol–benzene (1 : 1) yielded unchanged methyl 7-hydroxy-6-methylnonanoate.

The methoxy-ester was hydrolysed by refluxing 5% aqueous-ethanolic (1 : 1) potassium

[1] Part III, Drayson, Lewis, and Polgar, *J.*, 1958, 430.
[2] Hall, Lewis, and Polgar, *J.*, 1955, 3971.
[3] Busch, Clark, Genung, Schroeder, and Evans, *J. Org. Chem.*, 1936, **1**, 1.
[4] Brockmann and Schodder, *Ber.*, 1941, **74**, 73.

hydroxide for 1 hr. Dilution with water, followed by acidification with hydrochloric acid and ether-extraction, afforded *7-methoxy-6-methylnonanoic acid*, b. p. 180—200° (bath)/18 mm., n_D^{20} 1·4458 (Found: C, 65·4; H, 11·1. $C_{11}H_{22}O_3$ requires C, 65·3; H, 11·0%). The *S-benzylthiuronium salt* crystallised from 50% aqueous ethanol as plates, m. p. 141—143° (Found: C, 62·2; H, 8·4; S, 8·4. $C_{19}H_{32}O_3N_2S$ requires C, 62·0; H, 8·7; S, 8·7%). Hall *et al.*[2] give m. p. 137—139° for the *S*-benzylthiuronium salt of the stereoisomer arising on oxidation of phthiocerol.

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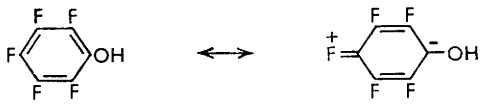
Dyson Perrins Laboratory, Oxford University. [*Received, May 29th*, 1959.]

743. *Polyfluoroarenes. Part II.*[1] *The Ionisation Constant of Pentafluorophenol.*

By J. M. Birchall and R. N. Haszeldine.

The replacement of hydrogen by fluorine in an alcohol causes a marked increase in ionisation constant, *e.g.*, $CH_3{\cdot}CH_2{\cdot}OH$, $K_a = 3 \times 10^{-16}$ (in water); $CF_3{\cdot}CH_2{\cdot}OH$, $K_a = 4{\cdot}8 \times 10^{-12}$ (in 50% aqueous ethanol).[2,3] The synthesis and properties of pentafluorophenol [1] suggest that the perfluoroarene ring exhibits distinct conjugation of the double bonds, in contrast to hexafluorobuta-1,3-diene.

The ionisation constant of pentafluorophenol, now determined as $K_a = 3{\cdot}0 \times 10^{-6}$ at 25°, is distinctly greater than that for phenol ($K_a = 1{\cdot}3 \times 10^{-10}$) [4] or the fluoro-alcohol $(C_3F_7)_2CH{\cdot}OH$ ($K_a = 30 \times 10^{-12}$),[3] and approaches that of benzoic acid, thus indicating the effect of conjugation in the ring. It also reveals the extent to which back-co-ordination with electron-release from fluorine, *e.g.*,



offsets the inductive effect of the aryl fluorine, since pentachlorophenol [5] is more acidic, with $K_a = 5{\cdot}5 \times 10^{-6}$. Fluoro-alcohols are more acidic than the corresponding chloro-alcohols [$CF_3{\cdot}CH_2{\cdot}OH$, $K_a = 4{\cdot}8 \times 10^{-12}$; $CCl_3{\cdot}CH_2{\cdot}OH$, $K_a = 1{\cdot}6 \times 10^{-12}$; $(CF_3)_2CH{\cdot}OH$, $K_a = 50 \times 10^{-12}$; $(CCl_3)_2CH{\cdot}OH$, $K_a = 7 \times 10^{-12}$].[3]

Electron-release by fluorine has been noted earlier in monofluoro-aromatic compounds [K_a for *p*-fluorophenol,[6] $1{\cdot}1 \times 10^{-10}$; *p*-chlorophenol,[7] $4{\cdot}2 \times 10^{-10}$; *p*-fluorobenzoic acid,[8] $7{\cdot}2 \times 10^{-5}$; *p*-chlorobenzoic acid,[9] $10{\cdot}3 \times 10^{-5}$; benzoic acid,[10] $6{\cdot}3 \times 10^{-5}$], but it is now clear that polyfluoroarenes show the same effect.

Experimental.—The ionisation constant for pentafluorophenol [1] was determined by measurement of the pH of an aqueous solution, titrated against aqueous sodium hydroxide, at the half-neutralisation point; [6] application of the Henderson equation gives pH = pK_a. Solutions were 0·01N in carbonate-free distilled water and 50 ml. aliquot portions were titrated; pH measurements (Model 23A Electronic Instruments Ltd. pH meter with glass electrode) were reproducible to ±0·01 unit. Repeated determinations gave pK_a = 5·53, whence $K_a = 2{\cdot}95 \times 10^{-6}$.

Manchester College of Science and Technology. [*Received, June 1st*, 1959.]

[1] Part I, *J.*, 1959, 13.
[2] Danner and Hildebrand, *J. Amer. Chem. Soc.*, 1922, **44**, 2824.
[3] Haszeldine, *J.*, 1953, 1757, and unpublished results.
[4] Walker and Cormack, *J.*, 1900, **77**, 18.
[5] Tiessens, *Rec. Trav. chim.*, 1931, **50**, 112.
[6] Bennett, Brooks, and Glasstone, *J.*, 1935, 1821.
[7] Judson and Kilpatrick, *J. Amer. Chem. Soc.*, 1949, **71**, 3110.
[8] Dippy, Williams, and Lewis, *J.*, 1935, 343.
[9] Briegleb and Bieber, *Z. Electrochem.*, 1951, **55**, 250.
[10] Dippy and Williams, *J.*, 1934, 1888.

744. *Measurement of the Conductance of Electrolytes.*

By W. S. METCALF.

THE resistance of an electrolyte is usually measured by using some modification of the Wheatstone bridge such as that of Fig. 1. The resistance R_2 and capacitance C_2 of the test cell are balanced by the variable resistance R_1 and a variable capacitance C_1 in *parallel* with it. However the capacitance of the test cell resides mainly on the surface of the electrodes as a layer of undischarged ions and is in *series* with the resistance R_2 of the electrolyte.[1] The reactance of the electrolyte cell is thus of the form C_2'–R_2–C_2''.

The conditions of balance require

$$R_1 = R_2\left(1 + \frac{1}{\omega^2 R_2^2 C_2^2}\right); \quad C_1 = \frac{C_2}{(1 + \omega^2 R_2^2 C_2^2)}$$

where $1/C_2 = 1/C_2' + 1/C_2''$. Both R_1 and C_1 depend on both R_2 and C_2 and on the frequency. As R_2 changes, as is the case when the rate of a reaction is followed by a change of conductance, C_1 must be continually adjusted to maintain the bridge in balance. At low frequencies (50 cycles per sec.), C_1 is inconveniently large.

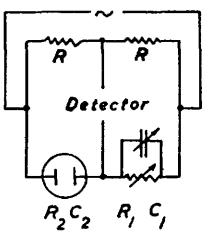


Fig. 1

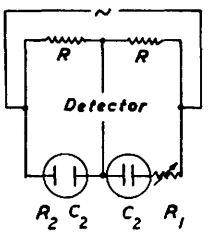


Fig. 2

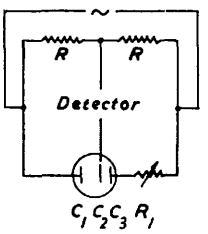


Fig. 3

If C_1 is put in series with R_1 its value at balance should be independent of R_2 and of frequency. This arrangement is simpler to manipulate, and more suited to automatic recording and control equipment.

The capacity of the cell can be balanced by that of a similar cell of the same electrolyte with electrodes of the same size but closer together, as in Fig. 2. At balance R_1 is proportional to the specific conductance of the electrolyte.

Experimentally, it is simpler to adopt the arrangement of Fig. 3. Three similar electrodes,[2] of which one pair are more closely spaced than the others, are sealed into the same glass cell.

The specific resistance of the electrolyte is proportional to R_1 at balance, and the constant of proportionality (" cell constant ") is measured in the conventional way.

If C_1, C_2, C_3 are the surface capacities of the electrodes and R_{12}, R_{23}, R_{31} are the inter-electrode resistances, the conditions for balance are

$$R_1 = \frac{R_{31}(R_{12} - R_{23})}{R_{12} + R_{23} + R_{31}}; \quad C_1 = C_3$$

A highly sensitive yet simple instrument for use at 50 cycles per sec. can be made with short bright platinum wire electrodes. If the electrodes are platinised the duration of the plating process can be controlled to secure the precise equivalence of C_1 and C_3.

This arrangement of three electrodes has proved suitable in equipment (made and tested by the Industrial Development Division of this University) for the automatic recording and control of the conductance of an alkaline solution for cleaning milk bottles. The capacity balance changes very little as the electrodes become contaminated with grease, and no separate automatic capacity balance is required.

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[1] Feates, Ives, and Pryor, *J. Electrochem. Soc.*, 1956, **103**, 580.
[2] Shedlovsky, *J. Amer. Chem. Soc.*, 1930, **52**, 1806.