

CCCXLIX.—*The Relative Directive Powers of Groups of the Forms RO and RR'N in Aromatic Substitution. Part VIII. The Nitration of 4-n-Butoxyanisole.*

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A STUDY of the nitration of 2-alkyloxyanisoles (Part I, Allan and Robinson, J., 1926, 376) showed that the directive powers of some alkyloxy-groups are in the order $\text{EtO} > n\text{-PrO} > n\text{-BuO} > \text{MeO}$, whilst in the nitration of 4-alkyloxyanisoles the order found was $n\text{-PrO} > \text{EtO} > \text{MeO}$ (Part III, Robinson and Smith, J., 1926, 392). We have now determined the directive power of the *n*-butoxy-group in the quinol series and it is appreciably greater (186) than that of the *n*-propoxy-group (180). In view of the high yields obtained in the nitrations, the fact that only two monosubstituted derivatives are possible, and the precautions observed in applying the method of thermal analysis, we have little doubt that this difference is real and lies beyond the limits of experimental error. The small fall in the directive powers in the pyrocatechol series in passing from *n*-PrO (128) to *n*-BuO (123) and the small corresponding rise (180—186) in the quinol series may now be disregarded, if desired, in favour of a comparison of EtO and *n*-BuO in both series. In the pyrocatechol series, we find $\text{EtO} = 135$ and $n\text{-BuO} = 123$, and in the quinol series, $\text{EtO} = 163$ and $n\text{-BuO} = 186$. A theoretical explanation embracing these phenomena was advanced in Part IV of this investigation (Allan, Oxford, Robinson, and Smith, J., 1926, 402), and the result for *n*-BuO is in agreement with its requirements.

EXPERIMENTAL.

Purification of Materials.—The methyl alcohol was free from acetone and distilled completely within 0.1° . The acetic acid was distilled and repeatedly frozen until the m. p. was $15.8\text{--}16.0^\circ$.

Pure nitric acid of constant b. p. was distilled (d 1.41). A good specimen of *n*-butyl alcohol was washed with dilute sulphuric acid and sodium bisulphite solution, and then boiled for 1.5 hours with 20% aqueous sodium hydroxide; it was separated, dried with potassium carbonate, and later with barium oxide. On distillation through an efficient column, a fraction, b. p. 117.6°/760 mm., d_4^{25} 0.8056, was obtained (Brunel, Creashaw, and Tobin, *J. Amer. Chem. Soc.*, 1921, 43, 561, give b. p. 117.71°/760 mm. and d_4^{25} 0.8057). This specimen was unchanged by further attempted purification, as mentioned below, and was employed in our work. The alcohol was converted into *n*-butyl salicylate and subsequently treated as described by Orton and Jones (*J.*, 1919, 115, 1198); the recovered material had b. p. 117.6°/762 mm. and d_4^{25} 0.8056; d_4^{20} 0.8094; d_4^{15} 0.8132; d_{14}^{14} 0.8141. A second portion was converted into *n*-butyl gallate, which crystallised readily from toluene in needles, m. p. 143—144° (Found: C, 58.3; H, 6.2. Calc. for $C_{11}H_{14}O_5$: C, 58.4; H, 6.2%). Subsequent to the completion of our work, we found that *n*-butyl gallate had been described by Christiansen (*J. Amer. Chem. Soc.*, 1926, 48, 1358), who gives the m. p. 133—134°. This derivative was hydrolysed by means of aqueous sodium hydroxide in an atmosphere of hydrogen, and the recovered alcohol had b. p. 117.5°/760 mm., d_4^{25} 0.8094. Commercial *n*-butyl alcohol (600 c.c.) esterified with gallic acid (250 g.) gave about 200 g. of the ester, m. p. 141—143°, and after one crystallisation from toluene the m. p. was 142—144°. The alcohol obtained on hydrolysis all distilled at 117.9—118.1°/769 mm. (117.6—117.8°/760 mm.) and had d_4^{25} 0.8099. This experiment seemed to show that the process of purification we contemplated was satisfactory, but it cannot be trusted in all circumstances, as the following observations clearly proved. In the first place, a mixture of *n*-propyl and *n*-butyl alcohols was esterified with gallic acid and the ester isolated had m. p. 148—149°, or by a different method, m. p. 150—151°. Recrystallisation from toluene gave a crop, m. p. 152—153°, and another, m. p. 151—153°. We then prepared *n*-propyl gallate, m. p. 147—148° (see below), and found that a mixture of equal quantities of *n*-propyl and *n*-butyl gallates, mixed dry, had m. p. 152—154°, with no sign of sintering at 143° or 147°. On cooling, the liquid crystallised at 145°; it then fused again at 152—154°. This is, therefore, an addition to the small number of recorded cases of binary mixtures that melt at a higher temperature than either of the components.

n-Butyl bromide was prepared by the method of Kamm and Marvel (*J. Amer. Chem. Soc.*, 1920, 42, 299) and had b. p. 101.2°/759 mm., d_4^{20} 1.2764.

n-Propyl Gallate.—A mixture of propyl alcohol (50 c.c.), sulphuric acid (1 c.c.), and gallic acid (17 g.) was boiled under reflux for 4 hours (in the case of *n*-butyl gallate, the period of heating should not exceed 3 hours) and then concentrated somewhat by distillation under diminished pressure. The residue crystallised, and was thoroughly washed with water and dried at 80°. The almost colourless crystals were practically pure and the substance crystallised from water in long needles, m. p. 147—148° (Found: C, 56·7; H, 5·7. $C_{10}H_{12}O_5$ requires C, 56·6; H, 5·7%). This ester is rather more readily soluble in water than is *n*-butyl gallate, whilst it is the more sparingly soluble of the two in toluene.

2-Nitro-4-*n*-butoxyanisole.—Potassium (3·9 g.) was dissolved in methyl alcohol (100 c.c.), and after the successive introduction of 3-nitro-4-methoxyphenol (16·9 g.) (Part III, *loc. cit.*) and *n*-butyl bromide (15 c.c.), the mixture was refluxed for 3 hours; as the colour was still red, a further 5 c.c. of butyl bromide were added and the boiling was continued for 2 hours. The greater part of the solvent was removed by distillation under diminished pressure, and an ethereal solution of the residue was twice washed with aqueous sodium carbonate, thrice with water, and then dried. After removal of the ether, the yellow oil distilled at 143°/1 mm. and had f. p. 12·4°, m. p. 12·5° (yield, 17 g. or 76%). After one recrystallisation from methyl alcohol at -15° (the filter was cooled by a jacket containing a mixture of solid carbon dioxide and ether) and removal of the adherent solvent at 110° in a vacuum, the values observed were: f. p. 13·1°, m. p. 13·25°, n_D^{14} 1·5382 (Found: C, 58·6; H, 6·7. $C_{11}H_{15}O_4N$ requires C, 58·7; H, 6·7%). The f. p. and m. p. were not raised by a further recrystallisation. A second preparation (yield, 81%) had f. p. 12·6°, m. p. 12·7°, raised on recrystallisation to the constant values 13·15° and 13·20°, respectively; n_D^{14} 1·5382.

3-Nitro-4-*n*-butoxyanisole.—A solution of potassium (7·8 g., 0·92 mol.) in *n*-butyl alcohol (100 c.c.) and 2-nitro-4-methoxyphenol (33·8 g., 1 mol.) (Part III, *loc. cit.*) were mixed, and after the addition of *n*-butyl bromide (21 c.c.) the mixture was refluxed for 20 hours with the gradual further addition of *n*-butyl bromide (29 c.c.). After cooling, the brown liquid was decanted from the potassium bromide, which was washed with a little butyl alcohol, and the solvent completely removed by distillation under diminished pressure. An ethereal solution of the residue was washed with aqueous sodium carbonate and water, then dried and distilled. A pale yellow oil (18·75 g.), b. p. 137°/1 mm., was obtained and 2-nitro-4-methoxyphenol (11·5 g.) was recovered from the alkaline extracts. A second preparation on half the scale gave a rather larger yield (53% calculated on the potassium) of an identical

product, and both specimens, after being crystallised thrice from methyl alcohol at -50° , gave long, yellow needles, which, after separation and complete removal of adhering solvent at 110° in a vacuum, had m. p. -9.7° , $n_D^{14.0}$ 1.5358 (Found: C, 58.6; H, 6.8. $C_{11}H_{15}O_4N$ requires C, 58.7; H, 6.7%). The m. p.'s were determined as follows: the substance in a tube was cooled to -20° and stirred until crystallisation began; it was then placed in an air-jacket fitted into a transparent Dewar vessel containing brine at -12° . While the cold bath was stirred occasionally and the nitro-compound regularly (and vigorously on account of the viscosity of the material), the temperature gradually rose until the thermometer in the nitro-compound registered -9.7° and remained steady for some minutes.

Mixtures of 3-Nitro-4-n-butoxyanisole and 2-Nitro-4-n-butoxyanisole.—The mixtures were rather viscous below 0° , and reproducible values could only be obtained over the composition range given below. It was found that characteristic values could best be assigned by taking the mean of the f. p. and m. p. of each mixture. A series of 4–6 determinations was made in each case as in the example: Composition, 94.3% of 2-nitro-4-n-butoxyanisole; f. p.'s, 11.40° , 11.30° , 11.35° , 11.40° ; m. p.'s, 11.50° , 11.50° , 11.45° , 11.45° ; mean, 11.42° . It was found necessary to eliminate water from the mixtures every 2–3 hours and also after any operation involving dismantling. The water did not actually depress the f. p.'s, but it retarded crystallisation. It was evaporated at $110^{\circ}/20$ mm. in a stream of dry air introduced through a fine tube; care was taken not to lose any of the material adhering to this tube or to the silver wire stirrer and thermometer—during temporary removal, these details were protected from dust. For the determination of the f. p.'s and m. p.'s, the apparatus mentioned above was employed; the temperature of the bath in the Dewar vessel could be raised or lowered by admission of water at different temperatures from reservoirs. In the first place, the m. p. was roughly determined while the bath was kept at a temperature 0.5 – 1° lower than that of the nitro-compound. The tube was then removed from the air-jacket and allowed to warm until almost all the solid had melted; it was then cooled to 2° below the m. p. and stirred to initiate crystallisation. After the tube was replaced in the apparatus, the bath was kept at 1° below the m. p., and the f. p. determined. As a rule, the temperature remained constant for some minutes. The temperature of the bath was then raised to about 0.5° below the f. p. and stirring continued, so that heat might enter and cause the mixture to melt. In this way, the temperature of the mixture usually rose 0.1 – 0.15° and remained steady at the m. p. until

almost all the solid had disappeared; a sudden rise supervened. The following f. p.-m. p. means were determined, the first number of each pair indicating the % of the 2-nitro-isomeride in the mixture: 100, 13.20°; 94.3, 11.42°; 86.4, 9.12°; 82.65, 7.88°; 79.58, 6.95°; 77.08, 6.00°; 73.77, 4.90°; 71.94, 4.09°; 69.06, 3.00°. The corresponding graph is a smooth curve.

4-n-Butoxyanisole.—Pure quinol monomethyl ether (6.2 g.) was added to a solution of sodium *n*-butoxide (from 1.15 g. of sodium) in *n*-butyl alcohol (30 c.c.), and after the introduction of *n*-butyl bromide (6.5 c.c.) the mixture was refluxed for 2 hours. After removal of the solvent at 50–70° in a vacuum, the product was steam-distilled and crystallised in contact with ice-water (yield, 7.6 g. or 85%). The substance crystallised from methyl alcohol containing a little water in large, pearly plates, m. p. 24.5–25.5° (Found: C, 73.4; H, 9.1. $C_{11}H_{16}O_2$ requires C, 73.3; H, 8.9%). This ether was also satisfactorily obtained by the use of sodium methoxide in acetone solution.

Nitration of 4-n-Butoxyanisole.—*4-n*-Butoxyanisole (2.0 g.), dissolved in acetic acid (4 c.c.), was nitrated by means of nitric acid (1.03 g.) in acetic acid (1 c.c.), and the product isolated as in the case of the nitration of *4-n*-propoxyanisole (Part III, *loc. cit.*). The products were, however, washed with sodium carbonate instead of with the bicarbonate in order to avoid effervescence; yields, (a) 96.4%, (b) 97.2%, (c) 97.4% (Found: N, 6.2. Calc.: N, 6.2%). Specimens (c) and (d) were isolated without the aid of methyl alcohol, the washed oil being siphoned through a Pregl micro-filter into the freezing-point tube. Specimen (b) was orange-yellow and was not further examined, whilst (c) was specially prepared for analysis; (a), (c), (d), and (e) were clear, pure yellow oils. The following table displays the results; 6–8 determinations of each f. p. and m. p. were made.

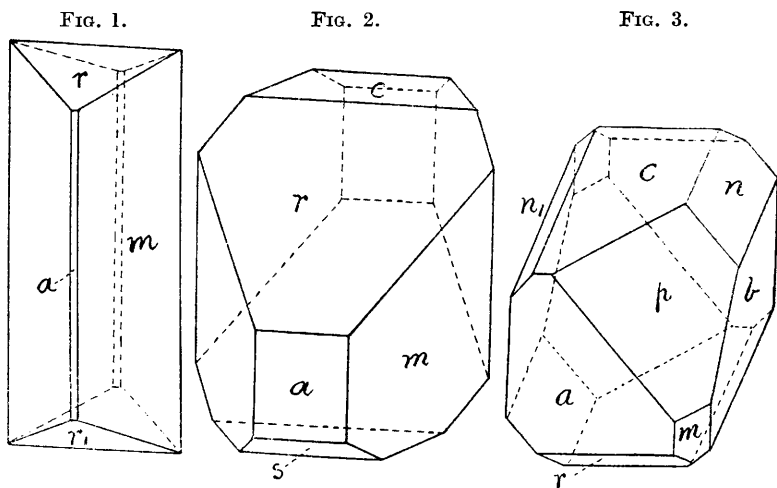
Specimen.	Mixture taken, g.	2-Nitro-isomeride added, g.	F. p. (mean).	M. p. (mean).	Mean.	% of 2-nitro-isomeride indicated.	% of 3-nitro-isomeride in nitration product.
(a)	1.0052	1.4758	4.72°	4.88°	4.80°	73.7	64.9
		1.9920	6.41	6.53	6.47	78.3	64.7
(c)	0.5993	1.0141	5.46	5.59	5.53	75.7	65.4
		1.3133	6.82	6.98	6.90	79.6	65.1
(d)	0.5027	0.8216	5.35	5.46	5.41	75.35	64.9
							Mean 65.0

Hence the directive power of *n*-BuO is 186 (MeO = 100).

In order to determine the effect of the process of isolation on the composition of the nitration product the following experiment was carried out. The product (d) (1.25 g.) was dissolved in acetic acid (3 c.c.), cooled to 0°, and a mixture of acetic acid (3 c.c.) and nitric

acid (0.7 g.) added. The concentrations of the nitro-compounds were then exactly half of those at the end of a normal nitration, and dilution and washing were carried out in the normal way. When the last water layer had been removed, the entire process was repeated; the specimen was thus subjected to a process which should produce four times the normal change. The weight of re-washed oil was 1.172 g. (loss, 6.24% or 1.6% for the normal process). 0.5029 G. of this with 2-nitro-4-*n*-butoxyanisole (0.8215 g.) had f. p. 5.37°, m. p. 5.48°, mean, 5.42°. Hence the loss is mechanical and involves no change in composition.

Crystallographic Measurements.—Mr. H. E. Buckley of the Crystallography Department of this University submits the following reports relating to substances described in Part III (*loc. cit.*).



2-Nitro-4-methoxyphenol. The crystals (Fig. 1) are of a short-prismatic habit and deep orange colour. Symmetry: Monoclinic (pseudo-orthorhombic). $a : b : c = 1.0234 : 1 : 0.5732$; $\beta = 90^\circ$. Forms developed: $m(110)$, $r(101)$, $r_1(10\bar{1})$, $a(100)$, and occasionally $l(210)$, $n(120)$, $s(320)$, and $t(230)$.

	Angles observed.		Calc.	
110—110	91°	21' (8)	—	—
110—101	70°	1'	—	—
100—101	60°	44'	60°	45'
110—320	11°	32'	11°	21'
110—210	18°	35'	18°	34½'

Cleavage parallel to $r(101)$ perfect.

Double refraction appears to be very strong, the interference figure being practically in the plane of cleavage 101. There is a slight pleochroism, varying from orange through yellow to pale green.

2-Nitro-4-ethoxyanisole (Fig. 2). Symmetry: Monoclinic [hohedral]. $a : b : c = 1.431 : 1 : 1.569$; $\beta = 77^\circ 23'$. Forms developed: $a = 100$, $c = 001$, $r = 101$, $s = 10\bar{1}$, $m = 110$, and $p = 111$ (infrequent).

	Angles observed.	No. measured.	Limits.	Calc.
100—001	$77^\circ 2\frac{1}{2}'$	7	$76^\circ 58' - 77^\circ 8'$	—
100—110	$53^\circ 42'$	11	$53^\circ 35' - 53^\circ 58'$	—
101—001	$35^\circ 52\frac{1}{2}'$	6	$35^\circ 48' - 35^\circ 56'$	—
101—100	$41^\circ 10'$	6	$40^\circ 59' - 41^\circ 16'$	$41^\circ 10'$
100— $10\bar{1}$	$55^\circ 40'$	6	$55^\circ 36' - 55^\circ 47'$	$55^\circ 39'$
110— $10\bar{1}$	$70^\circ 26'$	7	$70^\circ 14' - 70^\circ 34'$	$70^\circ 30\frac{1}{2}'$
110—101	$63^\circ 26\frac{1}{2}'$	11	$63^\circ 10' - 63^\circ 44'$	$63^\circ 32'$
110—001	$82^\circ 18'$	8	$82^\circ 6' - 82^\circ 36'$	$82^\circ 26'$
001—111	$50^\circ 57'$	3	$50^\circ 41' - 51^\circ 15'$	$51^\circ 10'$

2-Nitro-4-n-propoxyanisole. System: Triclinic (pinacoidal). $a : b : c = 0.7831 : 1 : 1.030$; $\alpha = 92^\circ 54'$, $\beta = 55^\circ 32'$, $\gamma = 87^\circ 12'$. Forms developed: $a = 100$, $b = 010$, $c = 001$, $m = 110$, $r = 10\bar{1}$, $n = 011$, $n_1 = 0\bar{1}1$, and $p = 111$. The habit is often tabular on the 111 face (Fig. 3).

Angular elements.	Observed.	No. measured.	Limits.
$a-p$ (100—111)	$31^\circ 3'$	4	$31^\circ 0' - 31^\circ 5'$
$a-b$ (100—010)	$88^\circ 33'$	3	—
$a-c$ (100—001)	$55^\circ 48'$	8	$55^\circ 34' - 56^\circ 11'$
$n-p$ (011—111)	$31^\circ 58'$	4	$31^\circ 56' - 32^\circ 3'$
$n-b$ (011—010)	$50^\circ 35'$	4	$50^\circ 33' - 50^\circ 39'$

The crystals are of considerable interest in that they exhibit remarkably well their anorthic optical properties. The first mean line, which varies a little for different colours, is nearly normal to 111, on which the crystal is tabular, and the optic axial plane for the sodium yellow line is turned through practically a right angle from that for the mercury violet line.