Aromatic Sulphonation. Part 55.[1] Reaction of Polyisopropylbenzenes with Concentrated Aqueous Sulphuric Acid

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The reaction of a number of polyisopropylbenzenes, mainly with 98.4% H_2SO_4 at 25°, has been studied. *m*- and *p*-di-isopropylbenzene undergo sulphonation; no side reactions have been observed. 1,2,3-Tri-isopropylbenzene with $ClSO_3H$ in CCl_4 at 0° yielded 80% 2,4,6-tri-isopropylbenzenesulphonyl chloride and small amounts of the 2,4,5-isomer. 1,3,5-Tri-isopropylbenzene with 98.4% H_2SO_4 led to the formation of 2,4,6-tri-isopropylbenzenesulphonic acid which is rapidly converted into the 2,4,5-isomer and 3,5-di-isopropylbenzenesulphonic acid. The ratio of formation of these compounds is 0.53 ± 0.05; their eventual ratio in the reaction mixture was, however, 1.0 ± 0.1. 1,2,4,5-Tetraisopropylbenzene with 9:1 (v/v) 98.4% H_2SO_4–CF_3CO_2H at 25° yielded initially the corresponding tetraisopropylbenzenesulphonic acid, but eventually 2,4,5-tri- and 3,5-di-isopropylbenzenesulphonic acid in the ratio 6.0 ± 0.6. Mechanisms for the formation of the various products obtained with 1,3,5-tri- and 1,2,4,5-tetra-isopropylbenzene are proposed.

RECENTLY we reported the sulphonation by sulphuric acid of the polymethyl-,[2] polyethyl-,[1,3] and poly-t-butylbenzenes.[4] In continuation we report the reaction of a number of polyisopropylbenzenes with sulphuric acid. The available information on sulphonation of these compounds is very limited.[5] Sulphonation *ortho* to a t-butyl group is rare.[4] From the literature it appeared, however, that sulphonation *ortho* to an isopropyl group, although difficult, does usually occur (to a minor extent) as observed in the sulphonation of *p*-di-isopropylbenzene with both oleum [5d] and chlorosulphuric acid,[5c] of *m*-di-isopropylbenzene with chlorosulphuric acid,[5c] of *p*-cymene with sulphuric acid,[5e] of *p*-isopropylbenzenesulphonic acid with oleum,[5g] and even of isopropylbenzene with sulphuric acid.[5f]

TABLE 1

Sulphonation of di-isopropylbenzenes and sulpho-derivatives

Substrate	Reagent	T/°C	t/day	Sulphonic acid or sulphonyl chloride product composition (%) 2-	4-	5-	4,6-di
$1,3\text{-}Pr^i_2C_6H_4$	98.2% H_2SO_4	25	0.02	<1	91.9	8.1	
	98.2% H_2SO_4	25	7.0	<1	75.0	8.3	16.7
	$ClSO_3H$–CCl_4	0		<1	91.2	8.8	
$1,4\text{-}Pr^i_2C_6H_4$	98.2% H_2SO_4	25	0.02	100			
	98.2% H_2SO_4	25	7.0	100			
$1,3\text{-}Pr^i_2C_6H_3\text{-}4\text{-}SO_3H$	104.4% H_2SO_4	25					>95
	$ClSO_3H$	62	0.7				77 [a]

[a] Yield of isolated bis(sulphonyl chloride).

During the present study it became apparent that some of the more overcrowded polyisopropylbenzenesulphonic acids are not stable in the sulphonation medium. Product formation in those cases was also studied.

RESULTS

The reactions of the polyisopropylbenzenes with sulphuric acid led to the formation of sulphonic acids, whereas those with excess of $ClSO_3H$ in CCl_4 [6] led to the formation of sulphonyl chlorides.

Di-isopropylbenzenes and their Sulphonic Acids.—The results of sulphonation of these substrates are given in Table 1. 2,4-Di-isopropylbenzenesulphonic acid in 104.4% H_2SO_4 suffers only a trace of dealkylation, whereas 2,5-di-isopropylbenzenesulphonic acid suffers substantial dealkylation. This is apparent from the specific n.m.r. absorptions at δ 2.21 (J 6.5 Hz) and 5.37br (s), assigned to (protonated) 1-methylethyl hydrogen sulphate.

1,3,5-*Tri-isopropylbenzene*.—Reaction of this substrate with 98.4% H_2SO_4 at 25° led to the formation of 2,4,6-tri-isopropylbenzenesulphonic acid. This compound is unstable under the reaction conditions and is rapidly converted into the 2,4,5-isomer and 3,5-di-isopropylbenzenesulphonic acid (Figure A). The initial ratio of these two compounds (*i.e.* their ratio of formation) is 0.53 ± 0.05, whereas the final ratio is 1.0 ± 0.1. The behaviour of 2,4,6-tri-isopropylbenzenesulphonic acid in 98.4% H_2SO_4 as 25° is similar (Figure B), the initial and final ratio of 2,4,5-tri- and 3,5-di-isopropylbenzenesulphonic acid being 0.46 ± 0.05 and 0.9 ± 0.1 respectively. It was shown independently that 2,4,5-tri-isopropylbenzenesulphonic acid in 98.4%

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[1] Part 54, A. Koeberg-Telder and H. Cerfontain, *J.C.S. Perkin II*, preceeding paper.

[2] A. J. Prinsen and H. Cerfontain, *Rec. Trav. chim.*, 1969, 88, 833; H. Cerfontain, A. Koeberg-Telder, C. Ris, and Z. R. H. Schaasberg-Nienhuis, *J.C.S. Perkin II*, 1975, 970.

[3] H. Cerfontain, Z. R. H. Nienhuis, and W. A. Zwart-Voorspuy, *J.C.S. Perkin II*, 1972, 2087.

[4] C. Ris and H. Cerfontain, *J.C.S. Perkin II*, 1975, 1438.

[5] (*a*) C. M. Suter, ' The Organic Chemistry of Sulphur,' Wiley, New York, 1944, ch. III; (*b*) C. M. Suter and A. W. Weston, ' Organic Reactions,' Wiley, New York, 1947, vol. III, ch. 4; (*c*) A. Newton, *J. Amer. Chem. Soc.*, 1943, **65**, 2439; (*d*) M. M. Morsumzade and I. K. Magamedov, *Azerb. khim. Zhur*, 1963, 143 (*Chem. Abs.*, 1964, **60**, 15763); (*e*) P. Kirjakka and V. Veijda, *Suomen Kemi.*, 1954, **27***B*, 49 (*Chem. Abs.*, 1955, **49**, 6163); (*f*) H. Cerfontain and Z. R. H. Schaasberg-Nienhuis, *J.C.S. Perkin II*, 1974, 536; (*g*) H. de Vries and H. Cerfontain, *Rec. Trav. chim.*, 1967, **86**, 873.

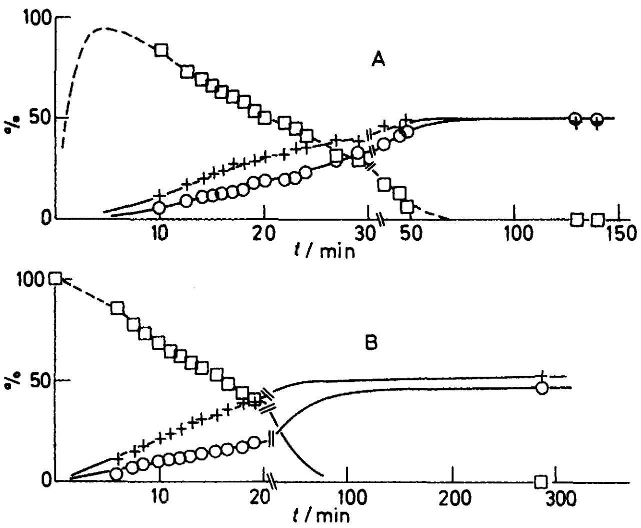
[6] E. H. Huntress and J. S. Autenrieth, *J. Amer. Chem. Soc.*, 1941, **63**, 3446.

H_2SO_4 is quite stable; only traces of dealkylation are observed after 5 h.*

Reaction of 1,3,5-tri-isopropylbenzene with chlorosulphuric acid in CCl_4 at 0° yielded *ca.* 80% 2,4,6-tri-isopropylbenzenesulphonyl chloride and small amounts of both the corresponding 2,4,5-isomer and dealkylated sulphonic acids.

1,3,5-Tri-isopropylbenzene was sulphonated with 1.2 equiv. SO_3 in CCl_3F at 0°, and the reaction mixture subsequently poured into a mixture of chloroform and ice–water. From the aqueous layer after neutralization sodium 2,4,6-tri-isopropylbenzenesulphonate was isolated in a yield of 40%. The chloroform extract contained 10% of 2,4,5-tri-isopropylbenzenesulphonic anhydride.

1,2,4,5-*Tetraisopropylbenzene*.—Reaction of this substrate with 98.4% H_2SO_4 at 25° on a macroscale (see Experimental section) afforded after working up 80% crude potassium 2,4,5-tri-isopropylbenzenesulphonate. As was concluded from the ^1H n.m.r. spectrum of a microscale experiment, the reaction mixture after 120 h contained as main products 2,4,5-tri- and 3,5-di-isopropylbenzenesulphonic acid in the ratio 6.0 ± 0.6. Upon reaction with 98.4% H_2SO_4–CF_3CO_2H (9 : 1 v/v) the same main products were eventually obtained, but in the ratio 2.5 ± 0.3. With the same reagent and a short reaction time (0.2 h) the substrate conversion was found to be only 30% and the ^1H n.m.r. spectrum of the sulphuric acid phase then exhibited amongst others a singlet absorption at δ 7.76. This absorption was assigned to 2,3,5,6-tetraisopropylbenzenesulphonic acid after comparison with the chemical shifts of the aromatic hydrogen absorptions of the other polyisopropylbenzenesulphonic acids (Table 2) and the three tetraethylbenzenesulphonic acids.[1] Its content in the sulphuric acid phase amounted to 40% corresponding to a yield of 12%.



Reaction of 1,3,5-tri-isopropylbenzene (A) and sodium 2,4,6-tri-isopropylbenzenesulphonate (B) with 98.4% H_2SO_4 at 25°: □, 2,4,6-tri-isopropylbenzenesulphonic acid; ○, 2,4,5-tri-isopropylbenzenesulphonic acid; +, 3,5-di-isopropylbenzenesulphonic acid

Evidence for dealkylation of both 1,3,5-tri- and 1,2,4,5-tetra-isopropylbenzene in 98.4% H_2SO_4 came from the specific ^1H n.m.r. signals of the resulting 1-methylethyl hydrogen sulphate, δ (98.4% H_2SO_4) 5.60 (1 H, septet, *J* 6.5 Hz) and 1.93 (6 H, d, *J* 6.5 Hz).

DISCUSSION

Sulphonation of *m*-di-isopropylbenzene occurs mainly at the activated position 4, the remaining substitution being at position 5. The absence of substitution at the electronically activated 2-position reveals that substitution of a hydrogen which is *ortho* to two isopropyl groups is sterically strongly impeded. Sulphonation in between two isopropyl substituents does occur with 1,3,5-tri- and 1,2,4,5-tetra-isopropylbenzene where no other sulphodeprotonation can take place. The resulting sulphonic acids then are unstable in 98.4% H_2SO_4 and suffer isomerization and dealkylation.

The initial product in the sulphonation of 1,3,5-tri-isopropylbenzene is 2,4,6-tri-isopropylbenzenesulphonic acid, which is converted into 2,4,5-tri- and 3,5-di-isopropylbenzenesulphonic acid. The ratio in which these two acids are formed initially is constant, indicating that they are both formed directly from the 2,4,6-acid. The initial step (Scheme 1) is protonation of the 2,4,6-acid at position 1 forming the less strained σ-complex (1). This σ-complex then can undergo a sulpho or a hydrogen shift leading to (2) and (3) respectively. Complex (3) isomerizes by an isopropyl shift to (4) which because of the negative mesomeric effect of the sulpho-group is more stable than (3). Loss of a proton finally yields the 2,4,5-acid. Complex (2) suffers loss of an isopropyl cation to form 3,5-di-isopropylbenzenesulphonic acid rather than a 1,2-isopropyl shift which would lead to the undetected 2,3,5-tri-isopropylbenzenesulphonic acid, since the required σ-complex would have the sulpho-group (with its $-M$ effect) *ortho* to the ring protonated position. Dealkylation of the parent hydrocarbon can be ruled out as a mode of formation of 3,5-di-isopropylbenzenesulphonic acid, for *m*-di-isopropylbenzene yields predominantly 2,4-di-isopropylbenzenesulphonic acid (Table 1).

The proposed mechanism predicts that the same products are obtained and in the same ratio on starting with 1,3,5-tri-isopropylbenzene and the 2,4,6-tri-isopropylbenzenesulphonic acid, as is in fact observed.

An alternative explanation for the constant initial ratio in which the 2,4,5-tri- and 3,5-di-isopropylbenzenesulphonic acid are formed would be that the 1,3,5-tri-isopropylbenzene and the 2,4,6-acid are in an equilibrium which lies strongly to the right hand side † with direct and exclusive formation of (3) and (2) from 1,3,5-tri-isopropylbenzene and 2,4,6-tri-isopropylbenzenesulphonic acid respectively.

The eventual ratio in which 2,4,5-tri- and 3,5-di-isopropylbenzenesulphonic acid are present is significantly greater than the intial ratio of their formation. This may be explained in terms of a slow isopropylation of the

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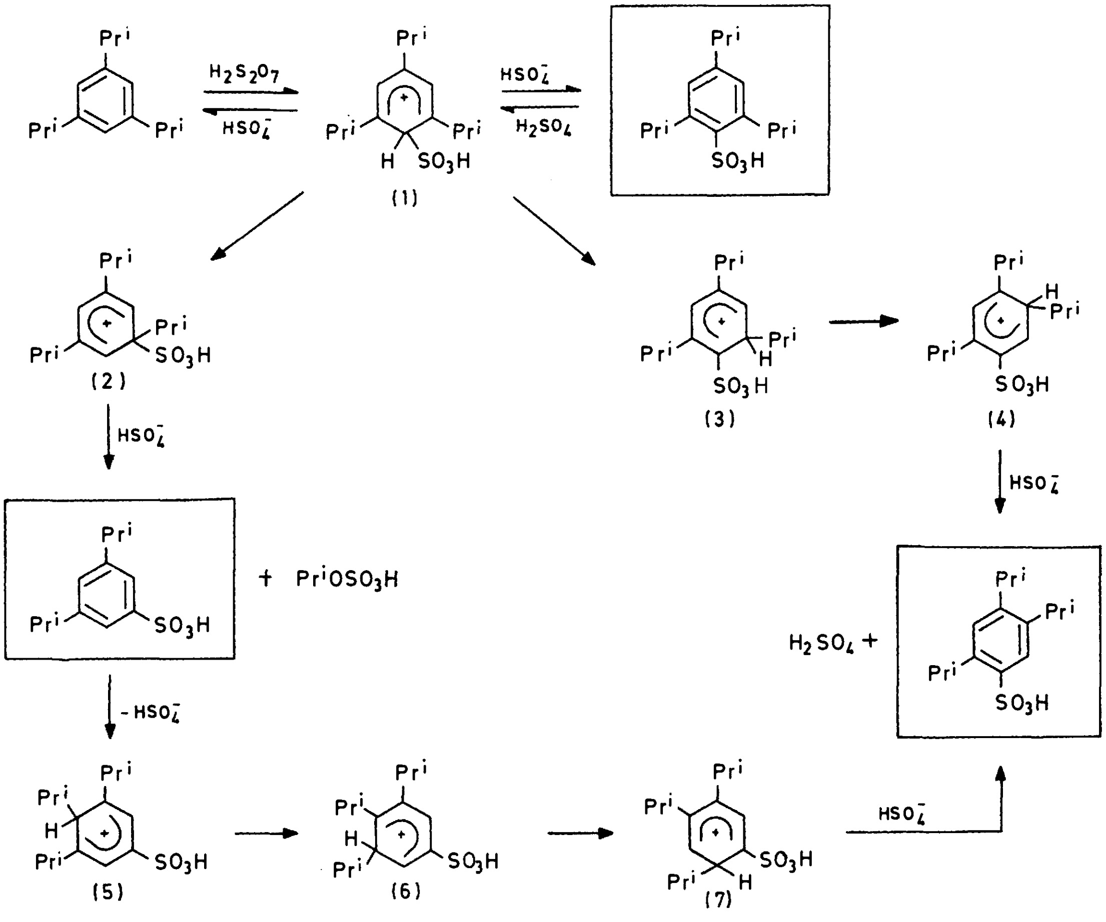
* Reaction of 2,4,5-tri-isopropylbenzenesulphonic acid with the much stronger acid trifluoromethanesulphonic acid yielded within 0.1 h 2,4-di-isopropylbenzenesulphonic acid almost quantitatively.

† With 1,3,5-trimethylbenzene the existence of an equilibrium between the hydrocarbon and its sulphonic acid has been clearly demonstrated.[7]

[7] M. Kilpatrick, M. W. Meyer, and M. L. Kilpatrick, *J. Phys. Chem.*, 1961, **65**, 1189; M. I. Vinnik and L. D. Abramovich, *Bull. Akad. Nauk S.S.S.R., Ser. Khim.*, 1972, 789.

3,5-acid by 1-methylethylhydrogen sulphate *para* to the sulpho-group *via* the σ-complexes (5)—(7). Alkylation *ortho* to the sulpho-group also leads *via* similar types of rearrangement to the 2,4,5-acid.

The initial product of the reaction of 1,2,4,5-tetraisopropylbenzene with 98.4% H_2SO_4 is 2,3,5,6-tetraisopropylbenzenesulphonic acid formed from the substrate by direct sulphodeprotonation. The eventual main product is 2,4,5-tri-isopropylbenzenesulphonic acid. Its formation from the tetraisopropylbenzenesulphonic acid may be explained (Scheme 2) in terms of protonation of the sulphonic acid at position 1 forming the substantially less strained σ-complex (8). A sulpho-group shift, whether directly or *via* the parent hydrocarbon, leads to (9) which by loss of an isopropyl cation yields 2,4,5-tri-isopropylbenzenesulphonic acid. Alternatively the conversion of 2,3,5,6-tetra- into 2,4,5-tri-isopropylbenzenesulphonic acid may proceed by successive protiodesulphonation, protiodealkylation, and sulphodeprotonation of the resulting 1,2,4-tri-isopropylbenzene. The first proposal is similar to that advanced for the conversion of 2,4,5-tri- into 3,5-di-isopropylbenzenesulphonic acid (Scheme 1). The mode of formation of 3,5-di-isopropylbenzenesulphonic acid in the 1,2,4,5-tetraisopropylbenzene system is less obvious. It may be formed by sulphodeprotonation of the parent hydrocarbon followed by dealkylation of the two isopropyl groups adjacent to the sulpho-group, or, if 1,2,4-tri-isopropylbenzene occurs as an intermediate, by sulphonation of this hydrocarbon at the 6-position and subsequent protiodealkylation.



SCHEME 1

Of related interest is the behaviour of 1,3,5-tri- and 1,2,4,5-tetra-isopropyl-benzene in the presence of methanesulphonic acid at 180°.[8] The former hydrocarbon yields an equilibrium mixture of 1,3,5-tri-isopropylbenzene and 1,3- and 1,4-di-isopropylbenzene. 1,2,4,5-Tetraisopropylbenzene yields 1,2,4- and 1,3,5-tri-isopropylbenzene (with the 1,2,4-isomer being only present in the initial stages of the reaction), and 1,3- and 1,4-di-isopropylbenzene.[8b]

The behaviour of symmetrical tri-isopropylbenzene with sulphonation reagents is intermediate between the corresponding trimethyl-,[7] triethyl-,[1] and trineopentylbenzene [9] on the one hand, and tri-t-butylbenzene [4] on the other. The first three hydrocarbons in concentrated aqueous sulphuric acid at 25° yield the 2,4,6-trialkylbenzenesulpho-derivatives which are stable in the sulphonating medium, whereas the latter hydrocarbon in

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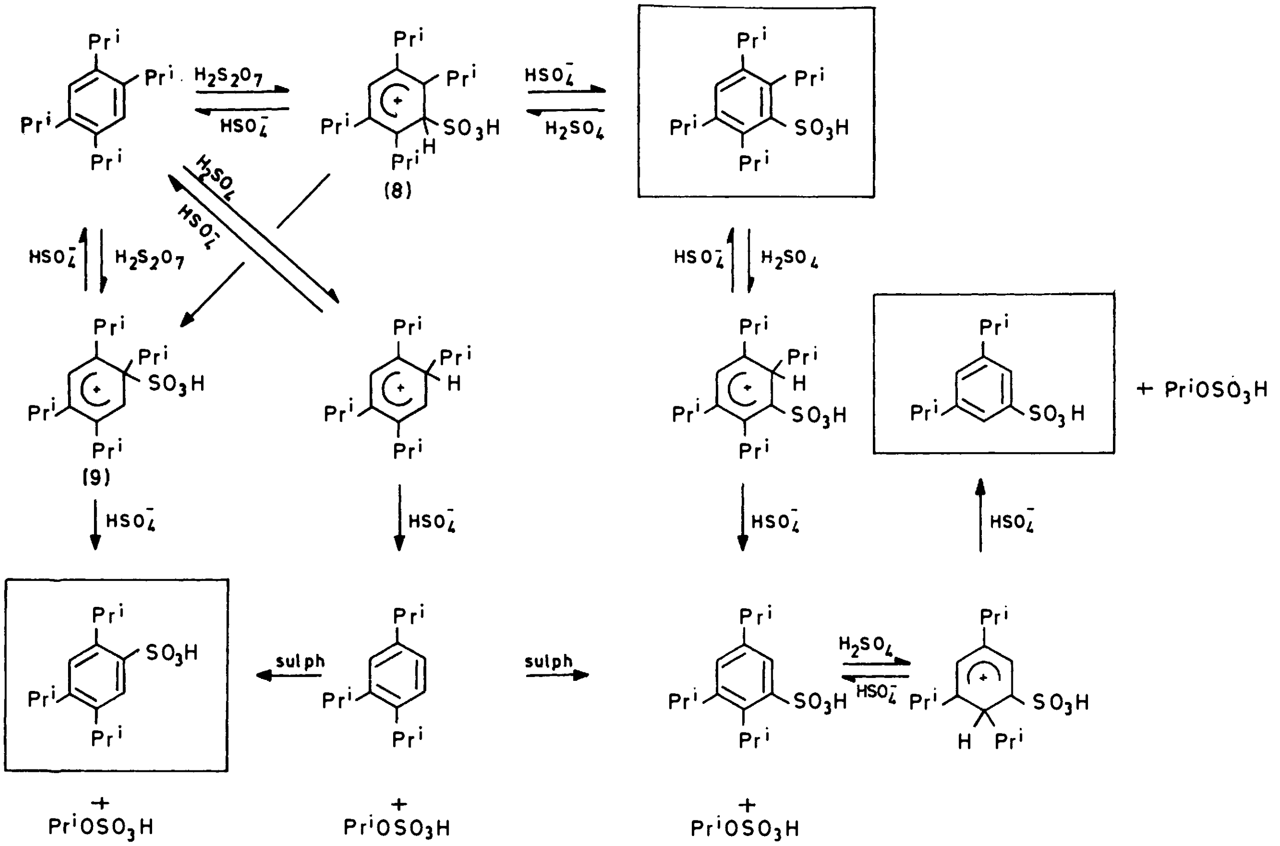
[8] (*a*) E. G. Willard and H. Cerfontain, *Rec. Trav. chim.*, 1973, **92**, 739; (*b*) E. G. Willard, unpublished results.

[9] C. Ris, Thesis (in English), University of Amsterdam, 1973, ch. 6; C. Ris, Z. R. H. Schaasberg-Nienhuis, and H. Cerfontain, *Tetrahedron*, 1973, **29**, 3168.

this sulphonating medium yields 3,5-di-t-butylbenzenesulphonic acid.

EXPERIMENTAL

Materials.—The hydrocarbons were commercial high purity products; 1,2,4,5-tetraisopropylbenzene (Aldrich) was recrystallized from pentane. The sodium salts of 2,4-di- and 2,4,6-tri-isopropylbenzenesulphonate were obtained from the corresponding hydrocarbons according to the method of Huntress and Autenrieth.[6] Potassium 2,4,5-tri-isopropylbenzenesulphonate was obtained by reaction of 1,2,4,5-tetraisopropylbenzene (20 g) with 98.4% H_2SO_4 (200 ml) at 25° until a homogeneous mixture was obtained. This was then poured onto ice and subsequently neutralized with potassium hydroxide. Sodium 4,6-di-isopropylbenzene-1,3-disulphonate was obtained by reaction of sodium 2,4-di-isopropylbenzenesulphonate with an excess of chlorosulphuric acid overnight at 62° and subsequent work-up.[6] The sulphonate salts were purified by recrystallization from aqueous ethanol.



SCHEME 2

TABLE 2

Chemical shifts of polyisopropylbenzenes and their sulphonation products

Compound	Solvent	δ (p.p.m.)												
		2-	3-	4-	5-	6-H	2-	3-	4-	5-C*H*Me$_2$	2-	3-	4-	5-CH(C*H*$_3$)$_2$
1,3-$Pr^i{}_2C_6H_4$	$CDCl_3$	7.1	—7.05—7.2—					2.89				1.24		
1,4-$Pr^i{}_2C_6H_4$	$CDCl_3$	7.13						2.85					1.22	
1,3,5-$Pr^i{}_3C_6H_3$	$CDCl_3$	6.92						2.87				1.25		
1,2,4,5-$Pr^i{}_4C_6H_2$	CCl_4		6.98				3.17				1.20			
2,4-$Pr^i{}_2C_6H_3SO_3H$	CF_3SO_3H		7.73		7.46	8.04	3.7		3.18		1.49		1.43	
2,4-$Pr^i{}_2C_6H_3SO_3H$	98.4% H_2SO_4		7.91		7.68	8.28	4.05		3.39		1.73		1.67	
2,5-$Pr^i{}_2C_6H_3SO_3H$	98.4% H_2SO_4		8.22	8.02		8.02	4.05			3.38	1.73			1.66
3,5-$Pr^i{}_2C_6H_3SO_3H$	98.4% H_2SO_4	8.05		7.94										
4,6-$Pr^i{}_2C_6H_2$-1,3-$(SO_3H)_2$	98.4% H_2SO_4	8.98			8.33				4.18				1.80	
2,4,5-$Pr^i{}_3C_6H_2SO_3H$	98.4% H_2SO_4		7.93			8.18	3.99		3.72	3.72	1.72		1.66	1.66
2,4,5-$Pr^i{}_3C_6H_2SO_2Cl$	CCl_4		6.92			7.16	4.3		—3.0—		1.36		—1.32—	
(2,4,5-$Pr^i{}_3C_6H_2SO_2)_2O$	CCl_4		6.82			7.21	4.13		2.82	2.80	1.26		—1.24—	
2,4,6-$Pr^i{}_3C_6H_2SO_3H$	98.4% H_2SO_4		7.70				4.26		3.3					
2,4,6-$Pr^i{}_3C_6H_2SO_3Na$	D_2O		7.13				4.20		2.8		1.21		1.12	
2,4,6-$Pr^i{}_3C_6H_2SO_2Cl$	CCl_4		7.21				4.27		2.94		1.32		1.29	
2,3,5,6-$Pr^i{}_4C_6HSO_3H$	98.4% H_2SO_4–CF_3CO_2H (9 : 1 v/v)			7.76										

Sulphonation Procedures.—For the sulphuric acid reactions 3 wt % of the substrate was shaken with the sulphuric acid solvent at 25° until it had dissolved and the mixture was left at 25° for the desired time. Sulphonation with chlorosulphuric acid in CCl_4 has been described.[6]

Analysis.—The structural assignments of the products were made by ^{1}H n.m.r. as outlined before.[1] The ^{1}H n.m.r. data are collected in Table 2.

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