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SELECTIVE DEALKYLATIONS OF ARYL ALKYL ETHERS AND THIOETHERS BY SODIUM IN HMPA

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Abstract—The reaction of sodium with bis- and tris(alkoxy)benzenes in HMPA gives selectively the products of monodealkylation. The reaction proceeds through a dianion which fragments into an alkyl and an aryloxy anion. The positional selectivity of this fragmentation is governed by the structure of both the alkyl and aryloxy groups. With bis- and tris(alkoxy)benzenes which for symmetry reasons can afford aryloxy anions having the same basicity, the dealkylation involves exclusively the less substituted alkyl group. On the contrary, in the asymmetric terms, the positional selectivity of the dealkylation process is governed by the basicity of the aryloxy anion. On the basis of these concepts several efficient and synthetically useful reactions have been developed. In most cases the selectivity obtained in the present reactions is different from that observed with other previously developed methods which use sodium methoxide or sodium alkanethiolates in HMPA. It is shown that the appropriate choice of the reagent allows selective dealkylation of the desired alkoxy group of a poly(alkoxy)benzene.

The reaction of sodium with bis(alkylthio) benzenes in HMPA gives the bis(mercapto)benzenes. If the reduction is carried out with a solution of sodium in HMPA, the reaction gives instead the products of monodealkylation. This however is not selective. It is suggested that in the case of thioethers the dealkylation products originate from the fragmentation of the radical anions.

The dealkylation of aryl alkyl ethers is a synthetically important reaction and several methods have been developed in order to effect this process selectively without interfering with other functional groups.[1-5] Recently we have been involved in similar problems in the case of aryl alkyl sulphides for which we have described some new methods of selective dealkylation.[6-9] We have also reported that, with the appropriate choice of the reagent, it is possible to effect the selective cleavage of the C–O or the C–S bonds in methoxythioanisoles.[10] In connection with an investigation on the reactions of sodium methoxide and thiomethoxide with unactivated aryl halides[11,12] we observed that ethers and thioethers present different behaviour when they react with excess sodium in HMPA. With poly(alkylthio)benzenes complete dealkylation of all the alkylthio groups present in the molecule is obtained,[8] whereas with poly(alkoxy)benzenes the reaction does not proceed further after the dealkylation of the first alkoxy group has occurred.[12] Clearly the dealkylation of the two types of compounds proceed with different mechanisms.

In the present paper we report the results of an investigation concerning the reactions of bis- and tris(alkoxy)benzenes and bis(alkylthio)benzenes with sodium in HMPA. Experiments have been carried out in order to elucidate the mechanism of these reactions and to obtain information about the factors governing the selectivity of the process. The results of this work demonstrate that the reaction of the alkoxybenzenes with sodium can have important synthetic applications. The cleavage of the C–O bond by alkali metals in HMPA has been investigated previously by Normant and Cuvigny,[13] but their work was limited to aromatic substrates having only one ethereal function and therefore the effect of the nature of the alkyl group on the selectivity of the dealkylation reaction could not be observed. Some of the experiments described in this paper have been previously carried out by Birch,[14] using sodium in liquid ammonia; the results obtained in the two cases are substantially in agreement.

RESULTS

The reactions of *o*- (**1**), *m*- (**2**) and *p*-dimethoxybenzene (**3**) with 3 equivalents of sodium in HMPA at 100° afforded the sodium salts of the methoxyphenols (**4–6**), respectively (eqn 1). The phenols can be obtained in good yields (Table 1) by treatment with acid or the phenates can be directly used for further reactions. For example we have employed this procedure to obtain the methoxyphenyl i-propyl ethers (**7–9**), as well as the other i-propyl or benzyl derivatives reported below, by adding i-propyl iodide or benzyl chloride to the final mixtures (eqn 1).

$$\underset{\textbf{1-3}}{C_6H_4(OMe)_2} \xrightarrow{Na} \underset{\textbf{4-6}}{C_6H_4(OMe)ONa} \xrightarrow{Me_2CHI} \underset{\textbf{7-9}}{C_6H_4(OMe)OCHMe_2} \quad (1)$$

$$\underset{\textbf{7-9}}{C_6H_4(OMe)OCHMe_2} \xrightarrow{Na} \underset{\textbf{10-12}}{C_6H_4(OCHMe_2)ONa} \quad (2)$$

$$\underset{\textbf{13, 14}}{C_6H_4(OMe)OCH_2Ph} \xrightarrow{Na} \underset{\textbf{5, 6}}{C_6H_4(OMe)ONa} \quad (3)$$

The i-propyl derivatives (**7–9**), under similar conditions, suffered fragmentation of the OMe group to give the phenols (**10–12**) (Eq. 2) (Table 1). On the contrary, the *m*- (**13**) and *p*-methoxyphenyl benzyl ether (**14**) afforded the methoxyphenols (**5** and **6**) by cleavage of the 0-benzyl bond (eqn 3).

Similarly the 1,3,5-trimethoxybenzene (**15**) gave the

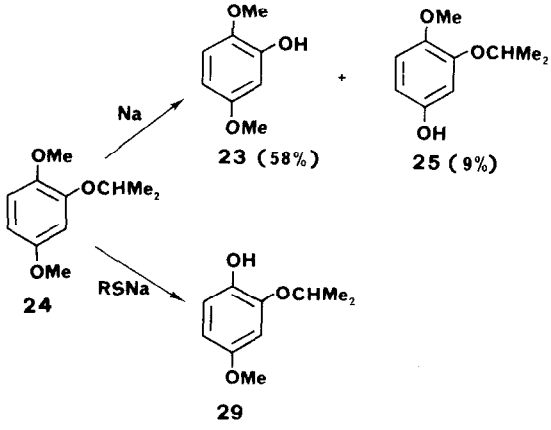
Table 1. Reactions of aryl alkyl ethers (0.01 mol) with sodium (3 equivalents) in HMPA (25 ml) at 100°

Starting Methoxybenzenes		Reaction Time hr	Phenols Produced		% Yields[a]
1	2-OMe	4	4	2-OMe	90
2	3-OMe	2.5	5	3-OMe	89
3	4-OMe	2	6	4-OMe	85
7	2-$OCHMe_2$	2	10	2-$OCHMe_2$	78
8	3-$OCHMe_2$	8	11	3-$OCHMe_2$	72
9	4-$OCHMe_2$	2	12	4-$OCHMe_2$	93
13	3-OCH_2Ph	2	5	3-OMe	92
14	4-OCH_2Ph	3	6	4-OMe	93
15	3,5-$(OMe)_2$	4	16	3,5-$(OMe)_2$	82
17	3-OMe,5-$OCHMe_2$	2	18	3-OMe,5-$OCHMe_2$	80
19	2,3-$(OMe)_2$	2	20	2,6-$(OMe)_2$	30
			21	2,3-$(OMe)_2$	30
22	2,4-$(OMe)_2$	2	23	2,5-$(OMe)_2$	65
24	2-$OCHMe_2$,4-OMe	1	23	2,5-$(OMe)_2$	58
			25	3-$OCHMe_2$,4-OMe	9
26	3-OMe,4-$OCHMe_2$	1.5	27	2-$OCHMe_2$,5-OMe	71
			28	3-OMe,4-$OCHMe_2$	4

[a] Calculated on isolated products after column chromatography.

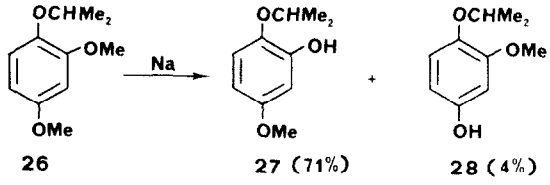
3,5-dimethoxyphenol (**16**) and the 3,5-dimethoxyphenyl i-propyl ether (**17**) gave the 3-methoxy, 5-(i-propoxy)phenol (**18**). In the case of the 1,2,3-trimethoxybenzene (**19**) the reaction was not selective, an equimolecular mixture of 2,6- (**20**) and 2,3-dimethoxyphenol (**21**) being obtained.

With the 1,2,4-trimethoxybenzene (**22**) a single product was obtained which was identified as the 2,5-dimethoxyphenol (**23**). This reaction was also employed to synthesize the i-propyl derivative (**24**) by addition of i-propyl iodide to the mixture. This compound, when treated with sodium, also suffered fragmentation from the 2 position to give **23**; this is the first case in which the elimination of the i-Pr is favoured in respect to that of the Me group. Also formed, as a by-product, was the phenol (**25**) derived from the fragmentation of the OMe group in the 4 position (Scheme 1). A similar behaviour



Scheme 1.

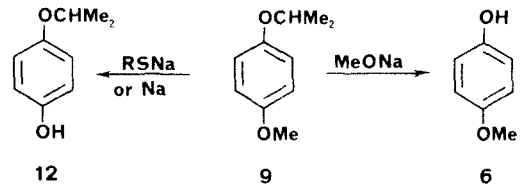
was shown by the 2,4-dimethoxyphenyl i-propyl ether (**26**) which gave **27** together with small amounts of **28** (Scheme 2). The results of these experiments are all



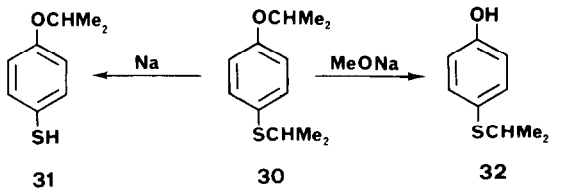
Scheme 2.

collected in Table 1. Selective monodealkylation of the bis(alkoxy)benzenes can be also effected using the sodium salt of the i-propanethiol. Thus, the *p*-methoxyphenyl i-propyl ether (**9**) gives the *p*-(i-propoxy)phenol (**12**) (95%) (Scheme 3), and 1,2,4-trimethoxybenzene (**22**), also in this case, gives the 2,5-dimethoxyphenol (**23**) (92%). On the contrary, the corresponding i-propyl derivative (**24**) reacts with Me_2CHSNa to give the 2-i-propoxy,4-methoxyphenol (**29**) (70%) (Scheme 1).

Sodium methoxide also reacts with bis(alkoxy)benzenes to give the monodealkylated products but with different selectivity; in this case in fact the cleavage



Scheme 3.



Scheme 4.

occurs at the 0-i-propyl bond. Thus compound **9** when treated with MeONa gives the 4-methoxyphenol (**6**) (65%) (Scheme 3). Sodium methoxide also discriminates between the 0-i-Pr and the S-i-Pr bonds. Thus, the 4-(i-propylthio) phenyl i-propyl ether (**30**) when treated with MeONa gives the 4-(i-propylthio)phenol (**32**) (75%) (Scheme 4). Selective cleavage of the S-i-Pr bond can be effected by treatment with sodium; under these conditions compound **30** affords the thiophenol **31** (70%).

The reactions of *p*-bis(alkylthio)benzenes (**33**) with sodium in HMPA afforded the *p*-bis(mercapto)benzene (**34**).[8] Moreover, if sodium is first allowed to react with HMPA and the bis-thioether is then added to the resulting mixture, the reaction gives selectively the monodealkylated products. Thus the *p*-bis(ethylthio)benzene (**33**: R_1=R_2=Et) afforded the *p*-(ethylthio)thiophenol (**35**: R_2=Et); this was isolated and identified as the bissulphide **39** (90%). If, however the two alkyl groups are different a mixture of the two thiophenols (**35** and **36**) is obtained (Scheme 5). In order to investigate the effect of the alkyl group on the fragmentation of the S–R bond the bissulphides (**37–40**) were allowed to react with the solution of sodium in HMPA and the ratio of the two thiophenols formed was determined. For this purpose it was found more convenient to reconvert the thiophenols (**35** and **36**) to the bissulphides by adding an appropriate alkyl iodide to the final mixtures. Quantitative analyses were then effected by gas chromatography. Thus, the mixture from **37**, after treatment with EtI, afforded **39** and **38** in the ratio of 1.5:1. From **38**, after treatment with MeI, **39** and **37** were obtained in the ratio of 1.4:1. From **39**, after treatment with Me_2CHI, **37** and **38** were formed in the ratio of 1.05:1. Thus the easiness of fragmentation follows the order $Me_2CH > Et \simeq Me$ (1.5:1.05:1). In the case of compound **40** the fragmentation occured exclusively at the S-benzyl bond to give the *p*-(methylthio)thiophenol (**35**: R_2=Me) which was isolated and identified as the bissulphide (**39**) after treatment with ethyl iodide.

DISCUSSION

The reaction with sodium in HMPA represents a synthetically useful method to effect the monodealkylation of aryl alkyl ethers and thioethers. Sodium phenoxides and thiophenoxides respectively are obtained in good yields and these can be directly used for further reactions or can be treated with acids to give phenols and thiophenols. In previous work[8,10] we observed that this reaction occurs more easily with thioethers than with ethers. Moreover, the results described in this paper indicate that with ethers the monodealkylation process is highly selective whereas with thioethers it is generally not selective. We suggest that the observed different behaviour of these two classes of compounds can be explained assuming that different mechanisms are operating in the two cases.

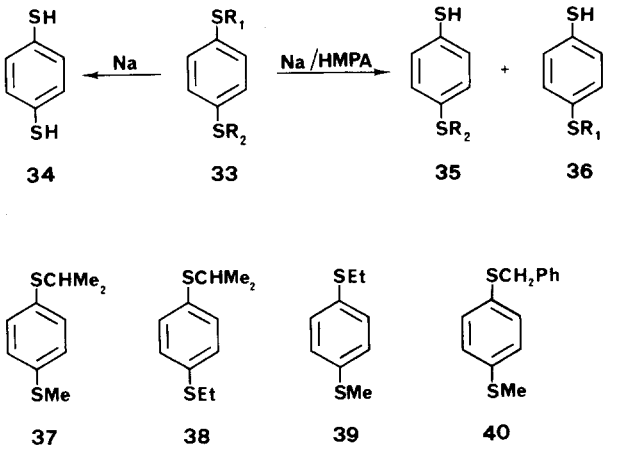
It can be assumed that from the interaction of an aryl alkyl ether or thioether with sodium an electron transfer occurs to give a radical anion. This can fragment to an alkyl radical and a phenoxy or thiophenoxy anion (eqn 4)[15] or it can accept another electron to give a dianion which then fragments into two anions (eqn 5):

$$ArXR \xrightarrow{e} ArXR^{\cdot} \rightarrow ArX^{-} + R\cdot \qquad (4)$$

$$ArXR^{\cdot} \xrightarrow{e} ArXR^{=} \rightarrow ArX^{-} + R^{-} \qquad (5)$$

X = O, S

In both cases, when different alkoxy or thioalkoxy groups are present in the molecule, the problem of the selectivity of the dealkylation process intervenes. A reasonable way of approaching this problem seems to be that of looking at the relative stabilities of the species which result from the fragmentation. Thus, if radical anions are the reactive intermediates, the two factors governing the selectivity of the process (eqn 6) will be the basicity of the two possible phenoxy or thiophenoxy anions ($Ar(RX)X^{-}$ and $Ar(XR_1)X^{-}$) and the stability of the two alkyl radicals ($R_1\cdot$ and $R\cdot$). Similarly, if the



Scheme 5.

dianions are the reactive intermediates, one has to compare the basicity of the two phenoxy or thiophenoxy anions and the stability of the two alkyl anions (R_1^- and R^-) (eqn 7).

$$Ar(XR)XR_1^{\cdot} \rightarrow Ar(XR)X^- + R_1\cdot \quad \text{or} \quad Ar(XR_1)X^- + R\cdot \tag{6}$$

$$Ar(XR)XR_1^{\cdot -} \rightarrow Ar(XR)X^- + R_1^- \quad \text{or} \quad Ar(XR_1)X^- + R^-. \tag{7}$$

This problem is greatly simplified when dealing with bissulphides like **37–40** and bis(alkoxy)benzenes like **7–9**, **13**, **14** or the symmetric tris(alkoxy)benzene (**17**), because in these cases it can be reasonably assumed that the differences between the two possible anions, $Ar(XR)X^-$ and $Ar(XR_1)X^-$, are negligible and therefore the only important factor is the relative stability of the two alkyl radical or anions, R and R_1.

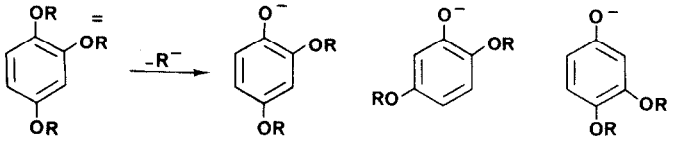
From the foregoing discussion it can be concluded that the results obtained in the present work indicate that the dealkylation of the sulphides occurs *via* the radical anions whereas that of the ethers occurs *via* the dianions. In fact, from the reactions of the bissulphides (**37–39**) with a solution of sodium in HMPA one observes that the dealkylation is not selective and that the i-Pr group is eliminated slightly more easily than the Et or the Me groups (1.5:1.05:1). This result can be expected on the basis of the accepted relative stabilities of the alkyl radicals. It follows that in the case of the bissulphides the dealkylation with sodium will not be selective unless one of the alkyl group gives a radical which has considerable greater stability than the other. This is what occurs with the *p*-(methylthio)phenyl benzyl sulphide (**40**) which gives exclusively the *p*-(methylthio)thiophenol (**35**: R_2=Me) because a stable benzyl radical can be eliminated.[16]

A completely different picture emerges from the reactions of the ethers (**7–9**) and **17** with sodium in HMPA. In agreement with the results obtained by Birch in liquid ammonia,[14] in this case the reactions are completely selective and the Me group is eliminated more easily than the i-Pr group. This can be explained on the basis of the greater stability of the Me in respect to the i-Pr anion. In our opinion these results strongly support the hypothesis that in the case of the ethers the reactive intermediates are the dianions as suggested in previous work.[13,14,17] Although the results obtained with the methoxyphenyl benzyl ethers, (**13** and **14**), could be explained in a similar way, we suggest that in these cases the reaction can proceed with a different mechanism. In **13** and **14**, in fact, in view of the greater electron affinity of the benzyl ring in respect to the bis(alkoxy)phenyl ring, it seems more reasonable to assume that the electron is transferred to the benzyl nucleus to give the radical anion $MeOC_6H_4OCH_2C_6H_5^{\cdot}$ which can directly fragment without taking up another electron.

The simple considerations made above for the bis-(**7-9**) and the tris(alkoxy)benzene (**17**) can no longer be applied to the 1,2,4-tris(alkoxy)benzenes, (**22**, **24** and **26**). In these cases in fact the three possible aryloxy anions, (**42–44**), which can result from the fragmentation of the dianion (**41**) are very different. This means that now both the basicity of the aryloxy anions and the stability of the alkyl anions must be taken into consideration. The results obtained with compounds **22**, **24** and **26** indicate that the fragmentation always occurs at the alkoxy group in the 2 position, to give **43**, whether this is a OMe or an i-OPr group. A small amount of **44** is obtained in the case of **24** and, to a less extent, of **26**. Clearly, the stability of the alkyl anions is no longer the more important factor which governs the selectivity of the dealkylation reaction. If one considers the electronic effect of the alkoxy group the anion **43** is very likely more basic than the other two. It can therefore be suggested that the process is now governed by the basicity of the aryloxy anions which overcomes the effect of the stability of the alkyl anions. In the case of **24** these two effects act in opposite directions and in fact a small amount of the demethylated product **25** is also formed.[18]

The suggestion that the dealkylation of thioethers occurs through the radical anions whereas that of the ethers occurs through the dianions implies that the fragmentation of $ArOR^{\cdot}$ is slower than the further reduction to the dianion and that the reverse is true for the $ArSR^{\cdot}$. Since it seems reasonable to assume that the addition of one electron to a radical anion cannot be a very fast process it follows that $ArOR^{\cdot}$ should be more persistent than $ArSR^{\cdot}$. Evidence is available in the literature which supports this hypothesis. From the results of some ESR investigations it can be concluded that, whereas $ArSR^{\cdot}$ are very elusive,[17,19] the radical anions of ethers can be easily produced and studied.[17] In molecules which contain both an OR and an SR function the reaction should occur through the radical anion and give rise to the dealkylation of the SR group. In fact the reaction of the *p*-(i-propylthio)phenyl i-propyl ether (**30**) with sodium in HMPA gives selectively the thiophenol (**31**) demonstrating that the thioethereal function is more easily reduced than the ethereal function. Similar conclusions were also reached from the results of the reactions of methoxythioanisoles with sodium.[10]

In previous work we have shown that selective dealkylations of ethers and thioethers can also be effected using the sodium salts of alkanethiols or sodium methoxide. It has been suggested that with RSNa the dealkylation is the result of an S_N2 reaction,[6,10,11] while with MeONa the dealkylation occurs *via* an elimination reaction.[9] Thus, with RSNa the reaction will involve the less substituted alkyl group and with MeONa the more substituted. The practical utility of these reactions is examplified by the results obtained with compounds **22**, **9**, **24** and **30**. With the 1,2,4-trimethoxybenzene (**22**) the reaction occurs selectively at the 2 position to give **23**; in this case therefore one obtains the same compound



41 **42** **43** **44**

Scheme 6.

which is formed from the reaction with sodium. The same occurs with compound **9** in which the substitution involves the OMe group to give the phenol **12** (Scheme 3). On the contrary with the i-Pr derivative (**24**) the dealkylation occurs at the OMe group in the 1 position and the phenol **29** is obtained. It is noteworthy that this compound could not be obtained from the reaction with sodium.

The use of sodium methoxide allows to effect the selective dealkylation at the i-Pr group of the methoxyphenyl i-propyl ethers. Similar results were obtained from the reaction of the (methylthio)phenyl i-propyl sulphides with MeONa.[9] Thus compound **9** gives the *p*-methoxyphenol **12** (Scheme 3). A further interesting result is obtained from the reaction of the *p*-(i-propylthio)phenyl i-propyl ether (**30**) with MeONa which gives the *p*-(i-propylthio)phenol **32** (Scheme 4). Thus when both an $SCHMe_2$ and an $OCHMe_2$ functions are present the elimination occurs selectively at the $OCHMe_2$ group to give the aryloxy anion. A similar selectivity was also observed in the S_NAr reactions of methoxythiophenols with RSNa from which (methylthio)phenols were obtained.[10] Probably the same effects which govern the selectivity of the substitution reaction[10] are also operating in the elimination process.

Thus the three methods of dealkylation described (i.e. the reactions with Na, RSNa or MeONa) are complementary and the appropriate choice of the reagent permits selective dealkylation of the desired alkoxy or thioalkoxy group from aromatic substrates containing two or more different OR groups, two different SR groups[7,9,16] or an OR and an SR group.

The selectivity observed in these reactions are very likely due to the use of HMPA, a solvent which greatly enhances the nucleophilicity of nucleophiles and the basicity of bases; moreover in HMPA also the electron transfer reactions occur very easily. It must be said that the dealkylations with sodium can also be effected in liquid ammonia;[14] however, it seems that HMPA is a superior medium (for instance, **12** is obtained from **9** in 93% yields whereas in ammonia the yield was only 2.5%[14]) and moreover the reactions are more easily carried out and worked up.

EXPERIMENTAL

Commercial HMPA was used without further purification. Sodium methanethiolate[6] and NaOMe[9] were prepared as described in previous work. Reaction products were identified by comparison of their physical and spectral properties with those reported in the literature and by ^{1}H-NMR spectra. NMR spectra were recorded, in $CDCl_3$ solns, on a 90 MHz Varian EM 390 instrument.[20] GLC analyses were carried out on a Hewlett-Packard 5830 A chromatograph with a 20 in. 10% UCW 982 column. The 3,5-dinitrobenzoates were prepared from 3,5-dinitrobenzoyl chloride and the phenols in pyridine and were purified by crystallization from EtOH.

Starting products. The dimethoxy- (**1–3**) and the trimethoxybenzenes (**15**, **19** and **22**) were commercial products. The methoxyphenyl i-propyl ethers and the methoxyphenyl benzyl ethers were prepared according to the following general procedure. To a soln of the appropriate dimethoxy- or trimethoxybenzene (0.01 mol) in HMPA (25 ml), stirred under N_2 at 100°, small pieces of Na (3 equivs) were added. The progress of the reaction was monitored by TLC. When the starting products were completely consumed (2–5 hr) the mixture was cooled to room temp. and i-PrI or benzyl chloride (0.015 mol) was added dropwise. The resulting clear soln was poured into water and extracted with ether. After the usual work up the residue was purified by column chromatography using a 98:2 mixture of petroleum ether and ethyl ether as eluant. The following products were obtained in this way with the yields indicated in parentheses.

o-*Methoxyphenyl i-propyl ether* (**7**) (75%). Oil (Lit.[14] b.p. 98–100°/2 mm). δ 6.8 (m, 4H), 4.4 (spt, 1H), 3.75 (s, 3H), 1.3 (d, 6H).

m-*Methoxyphenyl i-propyl ether* (**8**) (89%). Oil. δ 7.25–6.95 (m, 1H), 6.6–6.35 (m, 3H), 4.5 (spt, 1H), 3.75 (s, 3H), 1.3 (d, 6H).

p-*Methoxyphenyl i-propyl ether* (**9**) (65%). Oil (Lit.[21] b.p. 103°/12 mm). δ 6.7 (s, 4H), 4.35 (spt, 1H), 3.7 (s, 3H), 1.25 (d, 6H).

m-*Methoxyphenyl benzyl ether* (**13**) (76%). B.p. 104–5°/10^{-1} mm. δ 7.4–6.9 (m, 6H), 6.55–6.30 (m, 3H), 5.85 (s, 2H), 3.55 (s, 3H).

p-*Methoxyphenyl benzyl ether* (**14**) (78%). M.p. 68–70°. δ 7.5–7.3 (m, 5H), 7.0–6.6 (AA'BB', 4H), 5.0 (s, 2H), 3.75 (s, 3H).

3,5-*Dimethoxyphenyl i-propyl ether* (**17**) (62%). Oil. δ 6.0 (s, 3H), 4.45 (spt, 1H), 3.7 (s, 6H), 1.3 (d, 6H).

2.5-*Dimethoxyphenyl i-propyl ether* (**24**) (63%). Oil. δ 6.75 (d, 1H, J = 8.5 Hz), 6.45 (d, 1H, J = 2.7 Hz), 6.35 (dd, 1H, J = 8.5 and 2.7 Hz), 4.45 (spt, 1H), 3.75 (s, 3H), 3.7 (s, 3H), 1.35 (d, 6H).

2,4-*Dimethoxyphenyl i-propyl ether* (**26**) (60%). Oil. This compound was obtained by dissolving 2,4-dimethoxyphenol[22] (0.01 mol) in HMPA, containing NaOMe (0.012 mol), and then adding i-PrI (0.015 mol), δ 6.75 (d, 1H, J = 8.5 Hz), 6.4 (d, 1H, J = 2.7 Hz), 6.3 (dd, 1H, J = 8.5 and 2.7 Hz), 4.35 (spt, 1H), 3.75 (s, 3H), 3.65 (s, 3H), 1.25 (d, 6H).

p-(*i-Propylthio)phenyl i-propyl ether* (**30**) (86%). Oil. A soln of *p*-chlorophenyl methyl sulphide[9] (0.008 mol) and NaOMe (0.047 mol) in HMPA (25 ml) was stirred at 100°, under N_2, for 15 hr. The mixture contained *p*-methoxythioanisole, contamined by traces of *p*-(methylthio)phenol. To this soln sodium isopropanethiolate (0.02 mol) was added. After 4 hr the mixture was constituted by *p*-(methylthio)phenol.[10] To this soln small pieces of Na (0.04 equivalents) were added. After 3 hr the mixture contained only the Na salt of the mercaptophenol.[10] After cooling at room temp, i-PrI (0.03 mol) was added and the mixture was worked up in the usual way. The residue was purified by column chromatography to give pure **30**. δ 7.3 (d, 2H), 6.75 (d, 2H), 4.45 (spt, 1H), 3.15 (spt, 1H), 1.3 (d, 6H), 1.2 (d, 6H).

The bissulphides (**33**: $R_1 = R_2 = Et$),[23] (**36**,[24] **38**[24] and **39**)[9] were prepared as described in the literature. The synthesis of **40** is described below.

p-(*Methylthio)phenyl benzyl sulphide* (**40**). A soln of *p*-bis(methylthio)benzene[8] (0.01 mol) and MeSNa (0.015 mol) in HMPA (25 ml) was kept at 100°, under N_2, for 3 hr. The mixture contained *p*-(methylthio)thiophenol.[7,9] After cooling at room temp, benzyl chloride (0.012 mol) was added and the resulting mixture was worked up as usual. The solid residue was purified by column chromatography to give pure **40** (95%) m.p. 69–71°. δ 7.35–7.0 (m, 9H), 4.05 (s, 2H), 2.4 (s, 3H).

Reactions of alkoxybenzenes with sodium in HMPA

To a soln of the alkoxybenzene (0.01 mol) in HMPA (25 ml), stirred under N_2 at 100°, small pieces of Na (3 equivs) were added. The progress of the reaction was monitored by TLC. When the starting compound was completely consumed, the mixture was cooled, poured into dil HCl and extracted with ethyl ether. The residue obtained after the usual work up was chromatographed through a silica gel column using a mixture of light petroleum and ethyl ether (9:1) as eluant.

The products obtained are indicated in the Results section. Reaction times and yields of phenols produced are collected in Table 1. Physical and NMR data of the phenols obtained (with the exception of the methoxyphenols (**4**, **5**, **6**, **16**, **20** and **21**) which are commercial products) are reported below.

o-(*i-Propoxy)phenol* (**10**). Oil (Lit.[14] 100–102°/11 mm). δ 7.0–6.7 (m, 4H), 5.75 (s, 1H), 4.5 (spt, 1H), 1.3 (d, 6H). 3,5-*Dinitrobenzoate*, m.p. 115–6°. δ 9.25 (m, 3H), 7.35–6.75 (AA'BB', 4H), 4.55 (spt, 1H), 1.3 (d, 6H).

m-(*i-Propoxy)phenol* (**11**). Oil (Lit.[25] 122–125°/3.5 mm). δ 7.2–6.9 (m, 1H), 6.6–6.3 (m, 3H), 6.2 br (s, 1H), 4.45 (spt, 1H), 1.25 (d, 6H). 3,5-*Dinitrobenzoate*, m.p. 132–4°. δ 9.3 (s, 3H), 7.5–7.3 (m, 1H), 6.95–6.7 (m, 3H), 4.55 (spt, 1H), 1.35 (d, 6H).

p-(*i-Propoxy)phenol* (**12**). Oil (Lit.[26] 117°/4 mm). δ 6.6 (s, 4H),

6.2 br (s, 1H), 4.4 (spt, 1H), 1.3 (d, 6H). 3,5-*Dinitrobenzoate*, m.p. 138–141°. δ 9.25 (s, 3H), 7.2–6.7 (AA'BB', 4H), 4.5 (spt, 1H), 1.35 (d, 6H).

3-*Methoxy*,5-(*i-propoxy*)*phenol* (**18**). Oil. δ 6.55 br (s, 1H), 6.0 (s, 3H), 4.4 (spt, 1H), 3.7 (s, 3H), 1.3 (d, 6H), 3,5-*Dinitrobenzoate*, m.p. 108–109°. δ 9.25 (s, 3H), 6.3 (s, 3H), 4.5 (spt, 1H), 3.8 (s, 3H), 1.35 (d, 6H).

2,5-*Dimethoxyphenol* (**23**). Oil (Lit.[5] b.p. 131°/12 mm). δ 6.65 (d, 1H, J = 8.5 Hz), 6.5 (d, 1H, J = 2.7 Hz), 6.3 (dd, 1H, J = 8.5 and 2.7 Hz), 5.4 (s, 1H), 3.75 (s, 3H), 3.65 (s, 1H). *Acetate*, m.p. 63–4° (Lit.[5] m.p. 62°). δ 6.9–6.55 (m, 3H), 3.75 (s, 3H), 3.65 (s, 3H), 2.25 (s, 3H). 3,5-*Dinitrobenzoate*, m.p. 136–138°. δ 9.25–9.15 (m, 3H), 7.0–6.65 (m, 3H), 3.75 (s, 6H).

3-(*i-Propoxy*), 4-*methoxyphenol* (**25**). Oil. δ 6.7 (d, 1H, J = 8.5 Hz), 6.45 (d, 1H, J = 2.7 Hz), 6.3 (dd, 1H, J = 8.5 and 2.7 Hz), 5.35 br (s, 1H), 4.4 (spt, 1H), 3.75 (s, 3H), 1.35 (d, 6H). 3,5-*Dinitrobenzoate*, m.p. 100–102°. δ 9.25 (s, 3H), 6.95–6.7 (m, 3H), 4.5 (spt, 1H), 3.9 (s, 3H), 1.4 (d, 6H).

2 (*i-Propoxy*), 5-*methoxyphenol* (**27**). Oil. δ 6.8 (d, 1H, J = 8.5 Hz), 6.55 (d, 1H, J = 2.7 Hz), 6.35 (dd, 1H, J = 8.5 and 2.7 Hz), 5.85 (s, 1H), 4.4 (spt, 1H), 3.7 (s, 3H), 1.35 (d, 6H). 3, 5 - *Dinitrobenzoate*, m.p. 154–155°. δ 9.25 (s, 3H), 7.05–6.65 (m, 3H), 4.4 (spt, 1H), 3.75 (s, 3H), 1.25 (d, 6H).

3-*Methoxy*-4-(*i-propoxy*)*phenol* (**28**). Oil. δ 6.7 (d, 1H, J = 8.5 Hz), 6.5 (d, 1H, J = 2.7 Hz), 6.3 (dd, 1H, J = 8.5 and 2.7 Hz), 5.85 (s, 1H), 4.4 (spt, 1H), 3.7 (s, 3H), 1.35 (d, 6H). 3,5 - *benzoate*, m.p. 151–152°. δ 9.25 (s, 3H), 7.0–6.65 (m, 3H), 4.5 (spt, 1H), 3.85 (s, 3H), 1.35 (d, 6H).

p-(*i-Propoxy*)*thiophenol* (**31**). Oil. δ 7.2 and 6.75 (AA'BB', 4H), 4.45 (spt, 1H), 3.3 (s, 1H), 1.3 (d, 6H).

Reactions of alkoxybenzenes with sodium i-propanethiolate in HMPA

A soln of the alkoxybenzene (0.01 mol) and sodium i-propanethiolate (0.012 mol) in HMPA (25 ml) was stirred, under N_2, at 100° for 5 hr. The progress of the reaction was monitored by TLC. The mixture was poured into dil HCl and worked up in the usual way. The residue was purified by column chromatography. The phenols (**12** and **23**) were obtained from **9** and **22** respectively (Results section). The following phenol, **29**, was obtained from **24**:

2-(*i-Propoxy*)-4-*methoxyphenol* (**29**). Oil. δ 6.7 (s, 1H, J = 8.5 Hz), 6.45 (d, 1H, J = 2.7 Hz), 6.3 (dd, 1H, J = 8.5 and 2.7 Hz), 5.35 (s, 1H), 4.5 (spt, 1H), 3.7 (s, 3H), 1.35 (d, 6H). 3,5-*Dinitrobenzoate*, m.p. 146–148°. δ 9.25 (m, 3H), 7.05 (d, 1H, J = 8.5 Hz),, 6.55 (d, 1H, J = 2.7 Hz), 6.45 (dd, 1H, J = 8.5 and 2.7 Hz), 4.5 (spt, 1H), 3.8 (s, 3H), 1.25 (d, 6H).

Reactions of alkoxybenzenes with sodium methoxide in HMPA

A soln of the alkoxybenzene (0.01 mol) and NaOMe (0.05 mol) in HMPA (25 ml) was stirred, under N_2, at 100° for 24 hr. The progress of the reaction was monitored by TLC. The mixture was poured on dil HCl and worked up in the usual way. The residue was purified by column chromatography. The phenol **6** was obtained from **9** and the following phenol, **32** was obtained from **30** (Results section):

p-(*i-Propylthio*)*phenol* (**32**). Oil. δ 7.3 and 6.75 (AA'BB', 4H), 5.7 br (s, 1H), 3.2 (spt, 1H), 1.25 (d, 6H). 3,5-*Dinitrobenzoate*, m.p. 101–102°. δ 9.25 (s, 3H), 7.45 and 7.15 (AA'BB', 4H), 3.4 (spt, 1H), 1.35 (d, 6H).

Reactions of bis(alkylthio)benzenes with sodium in HMPA

Small pieces of Na (*ca* 4–5 equivs) were added with stirring to HMPA (15 ml) kept under N_2 at 100°. To the resulting brown soln the bis(alkylthio)benzene (0.01 mol), dissolved in the minimum amount of HMPA, was added dropwise. The progress of the reaction was monitored by NMR (the reaction times were of the order of 24 hr). When the starting product was completely consumed the appropriate alkyl iodide (0.01 mol) was added (Results section) and the mixture was worked up in the usual way. The ratios of the two new bis(alkylthio)benzenes so formed were determined by GLC. The results of these experiments are described in the Results section.

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