STUDIES IN THE RELATIONSHIP BETWEEN MOLECULAR STRUCTURE AND CHROMATOGRAPHIC BEHAVIOUR

XI. THE BEHAVIOUR OF SOME HALOGENATED PHENOLS AND SOME HALOGENO-; ALKYL-SUBSTITUTED PHENOLS ON CELLULOSE–POLYAMIDE THIN LAYERS*

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(Received August 17th, 1966)

INTRODUCTION

We have previously reported[1,2] that the removal of alkyl phenols from polyamide surfaces was related to the site of solvation of the phenolic molecule by the mobile phase. For non-aqueous eluents, the solvation site was the hydrophobic part of the molecule, while for aqueous eluents, the solvation site was the phenolic group. By comparing the orders of the R_F/R_M values obtained by chromatographing the same phenols on:

(i) alumina surfaces with non-aqueous eluents[3]
(ii) thin layers of cellulose impregnated with ethyl oleate using aqueous eluents[4]

we were able to substantiate our views on the role of the eluent in polyamide chromatography. We have also shown that the above mechanism can be used in explaining the results of other workers[5–7], while the supposed change in the nature of the polyamide from a polar surface to a non-polar one suggested by COPIUS-PEEREBOOM[8–10] cannot.

We have also suggested[2] that, in addition to the carbonyl oxygen atom of the polyamide surface engaging in hydrogen bonding with the phenolic group[1,2,11,12], it is possible for the hydrogen atoms of the amido group to act as proton donors to suitable acceptor sites, *e.g.* double bonds or ether oxygen atoms, present in substituent groups[2].

In recent papers[13,14], we have reviewed the work done in the field of paper and thin-layer chromatography of halogenated phenols and also reported the results of our studies on the behaviour of these compounds when they were chromatographed on thin layers of alumina[13] and by reversed-phase thin-layer chromatography[14].

Here, we have chromatographed a number of halogenated phenols and halogeno-alkyl-substituted phenols on thin layers of cellulose impregnated with polyamide[1,2], in order to assess the applicability of the MARTIN[15] additivity principle in relation

* For Parts I, II, IV, V, VI, VII, VIII, IX and X of this series, see refs. 17, 19, 18, 3, 4, 13, 14, 1 and 2, respectively.

to these compounds, and to study whether or not the effect of a group on the chromatographic behaviour of a molecule is independent of the rest of the molecule. This latter part of the MARTIN[15] postulate has been shown by PATAKI[16] to be invalid for amino acids chromatographed on silica gel thin layers, and by us for the halogenated phenols chromatographed on alumina[13], and by reversed-phase thin-layer chromatography[14]. It has also been shown to be invalid for nitrophenols chromatographed on alumina surfaces[17] and by reversed-phase thin-layer chromatography[18]. We will also present evidence to support the view that the hydrogen atom of the amido group of the polyamide can hydrogen bond with suitable acceptor sites in the phenolic molecule[2]. Further, except for the work of WANG[6] who failed to separate the 5 halogenophenols, *m*- and *p*-chloro-, *m*- and *p*-bromo-, and *p*-iodophenol, there is no reported use of polyamide as a substrate for the separation of halogenated phenols in the literature.

EXPERIMENTAL

A solution of polyamide (Nylon 66) in formic acid (0.13 g/ml) was prepared. This solution (11 ml) was added to cellulose powder (13.5 g of MN 300*) and well stirred. Formic acid (74 ml) was added with stirring to the mixture to give a slurry suitable for coating 5 glass plates (20 cm × 20 cm) using a Shandon applicator**, preset to give an applied layer of 0.3 mm thickness. The layers were dried for 24 h at a constant temperature of 25 ± 0.5°. They were then activated for 15 min at 80° after which they were cooled in an evacuated desiccator[1,2].

Eluent systems

These were:

(1) cyclohexane–acetic acid (93:7, v/v);

(2) aqueous acetic acid (10 %).

The purification of the components of the eluent systems has previously been described[1,17].

Application of the phenols

The phenols (1 μl of 0.25 % w/v solutions in suitable solvents) were applied to the layers using our multiple spotting technique[19] and the chromatograms were eluted by an ascending technique at a constant temperature of 25 ± 0.5° in our double saturation chamber[19]. After 2 h the eluent front had travelled a distance of 14.5 ± 0.5 cms.

The phenols were detected as yellow spots on a purple background by spraying the layers with alkaline potassium permanganate.

RESULTS

The results shown in Tables I-III are the mean of at least 4 runs on plates carrying an internal standard. The R_F values of the standards on these runs were reproducible to within ±0.01 R_F units of a pre-determined mean. The R_F values of the individual phenols were also reproducible to ± 0.01 R_F units.

* Macherey & Nagel, available from Camlab (Glass) Cambridge.

** Shandon Scientific, Pound Lane, London.

DISCUSSION

The two mobile phases used, cyclohexane–acetic acid and aqueous acetic acid are designated Systems 1 and 2, respectively.

It has already been stated that the phenols, adsorbed on to the polyamide surface by hydrogen bonds formed between the hydrogen atom of the phenolic group and the carbonyl oxygen atom of the amide group, are removed by solvation of the molecule; either of the hydrophobic part of the molecule by the non-aqueous mobile phase or the phenolic group by the aqueous phase[1,2]. For the halogenated phenols and the halogeno-; alkyl-substituted phenols the above mechanism may be influenced by a number of other factors, *viz.*:

Electronic effects. These may be either:

(i) the withdrawal of ring electrons by the electronegative halogen atoms, resulting in an increase in the strength of the phenolic/polyamide hydrogen bond, or

(ii) the mesomeric release of electrons from the lone pairs of electrons on the chlorine atoms, resulting in a decrease of the strength of the phenolic/substrate hydrogen bond.

Steric effects caused by changes in the sizes of the halogen atoms, and, in the case of the halogeno-alkyl-; substituted phenols, other groups substituted *ortho* to the phenolic group.

The possibility of internal hydrogen bonding between the phenolic hydrogen atom and a halogen atom in the 2-position.

The possibility of hydrogen bonding between the hydrogen atoms of the amino-groups of the substrate and the halogen atoms. It is probable that in either system, more than one of the above effects may operate simultaneously. These effects will be considered below.

(*a*) *Simple halogenated phenols*

For the homologous series of chlorinated phenols in System 1, the results (Table I) show that the compounds may be classified into three groups depending upon the number of *ortho* substituents present.

Where the molecule contains no substituent *ortho* to the phenolic group, the R_F values for the mono-substituted compounds are slightly higher than phenol, but for the di-substituted compounds the R_F values are slightly lower than those for the mono-compounds. This slight reduction in R_F values of the di-substituted compounds relative to the mono-compounds suggests some increase in the binding of the molecule to the substrate. Whether this is caused by an increase in the strength of the phenolic/substrate hydrogen bond as a result of the inductive effect of the chlorine atom, or whether it is caused by bonding of the chlorine atoms to the amido-hydrogen atoms has to be evaluated. Evidence will be presented below for the probability of the latter effect. The increase in R_F values for the monosubstituted compounds is probably a solvation effect.

The presence of an *o*-chlorine atom in the molecule, greatly increases the R_F value of this compound relative to that of phenol ($\Delta R_F = 0.365$). The addition of a further chlorine atom to the free *ortho* position of 2-chlorophenol to give 2,6-dichlorophenol results in a further increase in the R_F value. However, the change in the R_F value for the pair 2-chlorophenol to 2,6-dichlorophenol ($\Delta R_F = 0.105$) is much

TABLE I

HALOGENATED PHENOLS

Key	*Phenol*	*System 1*		*System 2*	
		R_F	R_M	R_F	R_M
1	Phenol	0.160	+0.720	0.620	−0.213
2	2-Chloro-	0.525	−0.043	0.360	+0.250
3	3-Chloro-	0.195	+0.616	0.330	+0.308
4	4-Chloro-	0.185	+0.644	0.340	+0.288
5	2,3-Dichloro-	0.455	+0.079	0.180	+0.659
6	2,4-Dichloro-	0.455	+0.079	0.175	+0.673
7	2,5-Dichloro-	0.440	+0.105	0.170	+0.679
8	2,6-Dichloro-	0.630	−0.231	0.260	+0.454
9	3,4-Dichloro-	0.170	+0.689	0.130	+0.826
10	3,5-Dichloro-	0.170	+0.689	0.115	+0.886
11	2,4,5-Trichloro-	0.380	+0.213	0.060	+1.158
12	2,4,6-Trichloro-	0.590	−0.158	0.090	+1.005
13	2,3,4,6-Tetrachloro-	0.520	−0.035	0.025	−1.601
14	2,3,4,5,6-Pentachloro-	0.475	+0.043	0.00	—
15	2-Fluoro-	0.450	+0.087	0.540	+0.070
16	3-Fluoro-	0.165	+0.704	0.480	+0.035
17	4-Fluoro-	0.150	+0.750	0.490	+0.017
18	2-Bromo-	0.555	−0.096	0.270	+0.432
19	3-Bromo-	0.230	+0.525	0.240	+0.501
20	4-Bromo-	0.215	+0.562	0.250	+0.477
21	2-Iodo-	0.605	−0.185	0.220	+0.550
22	3-Iodo-	0.245	+0.489	0.170	+0.689
23	4-Iodo-	0.230	+0.525	0.180	+0.659
24	2,4-Dibromo-	0.500	0.000	0.095	+0.979
25	3,5-Dibromo-	0.200	+0.602	0.050	+1.279
26	2,4,6-Tribromo-	0.705	−0.379	0.040	+1.380
27	2,4,6-Tri-iodo-	0.715	−0.399	0.000	—
28	2,4-Di-iodo-6-chloro-	0.615	−0.203	0.010	+1.996
29	2,6-Di-iodo-4-chloro-	0.700	−0.368	0.020	+1.690
30	2,6-Di-iodo-4-bromo-	0.710	−0.389	0.000	—

smaller. This suggests that more than one of above factors are operating. BAKER AND KAEDING[20] have shown that in the formation of an internal hydrogen bond between the phenolic hydrogen atom and a halogen atom, orbital repulsion between the O–H bonding orbital and the lone pair orbital of the halogen atom results in a twisting of the chelate system from the plane of the phenyl nucleus. Thus in the migration of the 2-chlorophenol the high R_F value relative to phenol may result from:

(i) an electronic effect, the formation of a competing internal hydrogen bond reducing the availability of the phenolic hydrogen atom for bonding with the polyamide surface;

(ii) two steric effects, (a) the presence of the chlorine atom preventing access of the phenolic group to the surface, (b) the twisting effect of the chelate system holding the hydrophobic part of the molecule away from the surface and into the interface of the mobile phase, thus enhancing the solvation of the hydrophobic part of the molecule by the non-aqueous mobile phase.

In the case of 2,6-dichlorophenol these factors will already be operating so that the addition of the second chlorine atom will influence the R_F value mainly through the first steric effect, *i.e.* by further screening the phenolic group from the

polyamide surface. It is possible that the second chlorine atom may interact electronically by increasing the acidity of the phenolic hydrogen atom and hence the strength of the hydrogen bond, so reducing the R_F values. Alternatively, the second chlorine atom may hydrogen bond with the surface *via* the hydrogen atoms of the amido group. BAKER AND KAEDING[20] have shown that in 2,6-dihalogenophenols, the halogen atoms in the 2- and 6-positions compete for the phenolic hydrogen atom so that the internal hydrogen bond is not localised on one halogen atom. This effect suggests that the internal hydrogen bond is weakened rather than strengthened by the presence of the second *ortho*-halogen atom and thus it is possible that the electronic effect of the second chlorine atom results in external hydrogen bonding with the polyamide surface. In this latter respect, the behaviour of the chlorinated phenols on polyamide surfaces parallels their behaviour on alumina surfaces[13], where hydrogen bonding between the chlorine atoms and the hydroxylated alumina surface occurred. In each of the groups, mono-*ortho*-, and di-*ortho*-substituted chlorophenols, a further increase in the number of chlorine atoms in the molecule causes a reduction in R_F values relative to the 2-, and 2,6-chlorophenols, respectively.

For the monochlorophenols in System 2, chlorination of the phenol results in a lowering of the R_F values relative to phenol. However, the value of the 2-chlorophenol is higher than those of the 3- and 4-isomers. This behaviour is similar to that observed for these compounds in our reversed phase thin-layer system[14]. The formation of the internal hydrogen bond in 2-chlorophenol gives this compound a higher R_F value than the 3- and 4-isomers, but because of orbital repulsion[20] this hydrogen bond is relatively easily broken under the influence of the polar mobile phase. This breaking of the hydrogen bond means that it is possible for both the phenolic group and the 2-chlorine atom, to be solvated by the mobile phase, but the degree of solvation is less than that of the free phenol.

For the remaining members of the homologous series, further chlorination of the nucleus results in a decrease in the R_F values of the compounds relative to that of phenol. However, the *ortho* effect is still apparent. Thus for the dichlorophenols, all of which have lower R_F values than their mono-homologues the 2,6-dichloro isomer has the highest R_F value; this is followed by the 3-dichloro isomer containing a single *ortho* group, while the dichloro isomers without an *ortho* group have the lowest R_F values. The value for the 2,4,5-trichlorophenol is also lower than that of 2,4,6-trichlorophenol. Thus it can be seen that the R_F values for the homologous series of chlorinated phenols follow approximately the MARTIN[15] additivity principle, subject to positional effects as described by BARK AND GRAHAM[21-23] for nuclear methylated, and nuclear chlorinated phenoxyacetic acids. Further, the order of R_F values for the chlorinated phenols in this system is the same as that observed by us for these compounds when they were chromatographed by reversed-phase thin-layer chromatography[14]. This confirms our views that removal of these phenols from the stationary phase is a consequence of solvation of the phenolic group by the mobile phase. The higher R_F values for the *ortho*-chlorinated phenols are a result of the *ortho*-chlorine atoms presenting additional solvation sites at the same end of the molecule as the phenolic group.

The values for the mono-halogenated compounds are of interest in separating the steric effects from the internal hydrogen bonding effect, the latter being regarded as being made up partly of an electrostatic effect and partly of a charge transfer effect.

BAKER AND KAEDING[20] have determined the relative strengths of the internal hydrogen bonds in *ortho*-halogenated phenols from the absorbance ratios for the hydrogen bonds formed between the 2 *ortho*-halogen atoms in unsymmetrical 2,6-dihalogenophenols. They found the strengths to increase in the order:

$$I < F < Br < Cl.$$

They suggested that the reason for this order is related to two factors:

(a) the optimum interacting distance between the phenolic group and the halogen atom;

(b) the increase in the orbital–orbital repulsion energy between the O–H bonding orbital and the donated lone pair of electrons.

The balance between the optimum interaction distance and the minimum repulsion interaction was reached in the chlorinated compound and hence this forms the strongest hydrogen bond. The decreasing strength of the internal hydrogen bond

$$Cl < Br < I$$

was a result of the increase in the orbital–orbital repulsion, which was of greater significance than the expected bond strengthening as a result of the closer approach of the larger halogen atoms to the phenolic group. The relative weakness of the internal hydrogen bond in 2-fluorophenol was attributed to the small size of the fluorine atom. This increases the interaction distance between the fluorine atom and the phenolic group to give a longer range, and hence weaker bond.

If the chromatographic behaviour of the 2-monohalogenated phenols is dependent solely upon the strengths of the internal hydrogen bonds, and hence on electrostatic and charge transfer effects we would expect the R_F values for these compounds to follow the order of hydrogen bond strengths. However, from Table I, it can be seen that for System 1, the R_F values increase in the order:

$$F < Cl < Br < I,$$

while in System II, they decrease in the order:

$$F < Cl < Br < I,$$

i.e. they change in the order of the sizes of the halogen atoms. This suggests that the steric effect on chromatographic behaviour is greater than the electronic effect. This is in accord with our previous findings for other substituted phenols[1–4,13,14,18,19]. However, it should be recalled that MARCINKIEWICZ and co-workers[24] were of the opinion that the chromatographic behaviour of substituted phenols was best explained in terms of electronic effects rather than steric effects. MARCINKIEWICZ AND GREEN[25] found all three isomers of each halogenated phenol to have identical R_F values in reversed-phase paper chromatography, thus failing to detect an *ortho* effect in these compounds.

It will be noticed that our observed *ortho* (and hence steric) effect is greater in System 1 than in System 2. This is in accord with our findings for the alkylphenols,

TABLE IIa

CHLORO-ALKYL-SUBSTITUTED PHENOLS

Key	*Phenol*	*System 1*		*System 2*	
		R_F	R_M	R_F	R_M
1	Phenol	0.160	+0.720	0.620	−0.213
4	4-Chloro-	0.185	+0.644	0.340	+0.288
31	4-Chloro-3-methyl-	0.320	+0.327	0.220	+0.550
32	4-Chloro-2,3-dimethyl-	0.520	−0.035	0.125	+0.845
33	4-Chloro-2,5-dimethyl-	0.400	+0.176	0.135	+0.867
34	4-Chloro-2,6-dimethyl-	0.550	−0.087	0.170	+0.689
35	4-Chloro-3,5-dimethyl-	0.310	+0.348	0.140	+0.789
36	4-Chloro-2,3,5-trimethyl-	0.410	+0.158	0.060	+1.195
37	4-Chloro-3-methyl-5-ethyl-	0.430	+0.123	0.060	+1.195
2	2-Chloro-	0.525	−0.043	0.360	+0.250
38	2-Chloro-4,5-dimethyl-	0.620	−0.213	0.180	+0.659
6	2,4-Dichloro-	0.455	+0.079	0.175	+0.673
39	2,4-Dichloro-6-methyl-	0.860	−0.788	0.000	—
40	2,4-Dichloro-3,5-dimethyl-	0.620	−0.213	0.030	+1.510
41	2,4-Dichloro-3,6-dimethyl-	0.890	−0.907	0.000	—
8	2,6-Dichloro-	0.630	−0.231	0.260	+0.454
42	2,6-Dichloro-4-methyl-	0.710	−0.389	0.155	+0.737
43	2,6-Dichloro-3,4-dimethyl-	0.750	−0.478	0.080	+1.061
12	2,4,6-Trichloro-	0.590	−0.158	0.090	+1.005
44	2,4,6-Trichloro-3-methyl-	0.700	−0.368	0.045	+1.328
45	2,4,6-Trichloro-3,5-dimethyl-	0.750	−0.478	0.000	—
46	2,4,6-Trichloro-3-methyl-5-ethyl-	0.840	−0.721	0.000	—

chromatographed in these systems. This supports our views[1,2] on the mechanism of chromatography on polyamide layers. In System 1, the *ortho*-halogen atom sterically hinders the approach of the phenolic group to the polyamide surface, and hence enables the hydrophobic part of these compounds to be more easily solvated by the non-aqueous mobile phase. In System 2, the halogen atoms hinder solvation of the phenolic group by the mobile phase.

The 3- and 4-mono-halogenated phenols show an increase in R_F value with an increase in the size of the halogen atoms in System 1, thus paralleling the behaviour of these compounds on alumina surfaces[3]. They also show a decrease in R_F values with the increase in the sizes of the halogen atoms in System 2. This behaviour is again similar to the behaviour of these compounds in reversed-phase thin-layer chromatography[4]. The polyhalogenated phenols behave in a similar manner to their polychlorinated analogues in both systems, subject to variations in R_F values which may be related to the influence of the sizes of the halogen atoms. Their behaviour in Systems 1 and 2 are comparable to their behaviour on alumina surfaces[3] and on reversed-phase thin-layer chromatograms[4]. This additional correlation again supports our views[1,2] on the mechanisms of chromatography on polyamide surfaces—as opposed to the suggested duality of behaviour of the polyamide surface[8–10].

(*b*) *Chloro-alkyl-substituted phenols*

The results for the chloro-alkylphenols are shown in Table IIa.

The addition of one or more alkyl groups to the parent chlorophenols increases the R_F values relative to the parent in System 1 and decreases them in System 2.

This is to be expected from the behaviour of the simple alkylphenols, observed by us[2], when these latter compounds were chromatographed in the same system. It is also noted that the positional effects observed for the simple alkylphenols[2] are also transferred to these compounds. This suggests that, subject to these positional effects, the MARTIN[15] additivity principle is operating. However, attempts to calculate R_F values for the chloro-alkyl-substituted phenols from the values for the chlorinated phenols reported here, and from the values for the alkylphenols previously reported[2] shows that the calculated R_F values are higher than the experimental values in System 1, and lower in System 2. This supports the previously expressed view[13,14,16–18,26,27] that the effect of the addition of a group to the molecule is not independent of the group already substituted in the molecule as proposed by MARTIN[15].

The effect of the addition of alkyl groups to the parent chlorophenols in System 1 is similar to that observed for the same compounds chromatographed on alumina surfaces[13], while in System 2, it is similar to their observed behaviour on reversed-phase thin-layer chromatograms[14], once again supporting our views of the mechanism of chromatography of phenolic substances on polyamide surfaces with non-aqueous or aqueous systems[1,2].

The effects of the position of the substituents relative to the phenolic group and relative to each other have been referred to above, they are further emphasised by a comparison of the R_F values of some isomeric chloro-alkylphenols (Table IIb). For the monochloro-dimethyl isomers, the values depend not only on the number of *ortho* substituents, but also on the nature of the *ortho* substituent. Thus the single *o*-chloro- group has a greater effect than the di-*ortho*-methyl- groups. This is probably caused by the dual effects of internal hydrogen bonding and steric inhibition for the former compound in System 1, and the enhanced solubility of the molecule in the mobile phase in System 2. In System 1, it has also been shown that the 6-chloro-substituent has a much smaller effect on the R_F values than either a 2-chloro- or a 6-methyl- substituent. This is seen in the results for the isomeric pairs 2,4-dichloro-6-methyl- and 2,6-dichloro-4-methyl-; 2,4-dichloro-3,6,dimethyl- and 2,6-dichloro-3,4-dimethylphenols.

(*c*) *Bromo-alkyl-substituted phenols*

The results for the bromo-alkyl-substituted phenols are given in Table III. The patterns of behaviour of these compounds are the ones expected from the behaviour of the simple bromophenols and the simple alkylphenols[2].

For System 1, the addition of alkyl groups to the 4-position of 2-bromophenol has the expected result of increasing the R_F values of these compounds, the increase depending upon the size of the group added. The addition of comparable groups to the 6-position of 2,4-dibromophenol also increases the R_F values, compared with that of 2,4-dibromophenol. However, for the last mentioned group, the compounds all migrated to the eluent front, so that structural relations could not be studied. The positional effects are seen in the values for the isomeric pairs 2,4-dibromo-6-methyl- and 2,6-dibromo-4-methyl-; and 2,4-dibromo-6-*tert.*-butyl- and 2,6-dibromo-4-*tert.*-butylphenols. By a comparison of the results in Tables IIa and III, the effects of the sizes of the chlorine and bromine atoms can be seen.

For System 2, the results are entirely as expected, an increase in the degree of substitution in the molecule brings about a reduction in R_F values. Though mi-

TABLE IIb

A COMPARISON OF THE R_F VALUES FOR SOME ISOMERIC CHLORO-ALKYL-SUBSTITUTED PHENOLS

Key	*Phenol*	*System 1*		*System 2*	
		R_F	R_M	R_F	R_M
33	4-Chloro-2,5-dimethyl-	0.400	+0.176	0.135	+0.867
38	2-Chloro-4,5-dimethyl-	0.620	—0.213	0.180	+0.659
34	4-Chloro-2,6-dimethyl-	0.550	—0.087	0.170	+0.689
39	2,4-Dichloro-6-methyl-	0.860	—0.788	0.000	—
42	2,6-Dichloro-4-methyl-	0.710	—0.389	0.155	+0.737
41	2,4-Dichloro-3,6-dimethyl-	0.890	—0.907	0.000	—
43	2,6-Dichloro-3,4-dimethyl-	0.750	—0.478	0.080	+1.061

gration of the compounds in most cases is too small to permit a discussion of behaviour in relation to structure, it can be said that the behaviour of the compounds again supports the proposed mechanism of chromatographic behaviour. That the 2,4-dibromo-6-methylphenol has a lower R_F value than the isomeric 2,6-dibromo-4-methylphenol is expected.

It is once again found that the general effects of adding alkyl groups to bromophenols in System 1 are similar to those observed for the same compounds chromatographed on alumina[13] surfaces, and for System 2, to those for these compounds chromatographed by reversed-phase thin layers[14].

This further emphasises our view[1,2] that the reversal of the order of R_F values on changing from a non-aqueous eluent system to an aqueous system in chromatography of phenols on polyamide surfaces is a consequence of altering the site of solvation of the molecule chromatographed. For non-aqueous eluent systems, this is the hydrophobic part of the molecule; for aqueous systems, it is the phenolic group.

TABLE III

BROMO-ALKYL-SUBSTITUTED PHENOLS

Key	*Phenol*	*System 1*		*System 2*	
		R_F	R_M	R_F	R_M
1	Phenol	0.160	+0.720	0.620	—0.213
47	2-Bromo-4-methyl-	0.600	—0.176	0.080	+1.061
48	2-Bromo-4-cyclohexyl-	0.880	—0.867	0.000	—
49	2-Bromo-4-phenyl-	0.600	—0.176	0.040	+1.380
50	2-Bromo-3,4,6-trimethyl-	1.000	—	0.000	—
51	2-Bromo-3-methyl-4,6-di-*tert.*-butyl-	1.000	—	0.000	—
52	2,4-Dibromo-5-methyl-	0.940	—1.194	0.055	+1.234
53	2,4-Dibromo-6-methyl-	1.000	—	0.040	+1.380
54	2,4-Dibromo-6-*tert.*-butyl-	1.000	—	0.000	—
55	2,4-Dibromo-6-cyclohexyl-	1.000	—	0.000	—
56	2,4-Dibromo-6-phenyl-	0.980	—1.699	0.000	—
57	2,4-Dibromo-3,6-dimethyl-	1.000	—	0.020	+1.690
58	2,4-Dibromo-5,6-dimethyl-	1.000	—	0.040	+1.380
59	2,4-Dibromo-3,5,6-trimethyl-	1.000	—	0.000	—
60	2,6-Dibromo-4-methyl-	0.790	—0.575	0.080	+1.061
61	2,6-Dibromo-4-*tert.*-butyl-	0.980	—1.699	0.000	—

We do not consider it possible for the nature of the eluent to alter the nature of the polyamide surface from a polar one to a nonpolar one[8–10].

CONCLUSION

The order of migration of halogenated phenols and halogeno-; alkyl-substituted phenols chromatographed on a polyamide surface is related to the site of solvation of the phenol by the mobile phase; the non-aqueous eluents solvate the hydrophobic part of the molecule, while the aqueous eluent solvates the phenolic group. These views are substantiated by a comparison of the migration order of these phenols in the systems studied with the orders obtained for the same compounds when they were chromatographed on alumina surfaces and by reversed-phase thin-layer chromatography.

By comparing the chromatographic behaviour of the *ortho*-halogenated phenols with the strengths of the internal hydrogen bond strengths obtained for these compounds from infra-red spectroscopic studies, it is apparent that steric factors influence their chromatographic behaviour more than electronic factors. That the latter are not entirely absent, however, is evidenced by the change in R_F values of polyhalogenated phenols resulting from the formation of hydrogen bonds between the halogen atoms and the hydrogen atoms of the polyamide amido-groups.

In the poly substituted compounds, the MARTIN additivity principle is seen to be approximately valid, subject to positional effects. For *ortho*-substituted phenols, however, the R_F values are dependent upon the nature of the group or groups in the *ortho* positions.

ACKNOWLEDGEMENTS

For the gift of some of the phenols used in this study we thank: Coalite & Chemical Products Ltd., Bolsover, Nr. Chesterfield, and R. Graesser Ltd., Sandicroft, Chester. For the gift of Nylon 66 we thank: Dr. R. LODGE, British Nylon Spinners, Pontypool, Monmouth. We also thank Prof. L. HUNTER for useful discussion.

SUMMARY

Sixty halogenated phenols and halogeno-; alkyl-substituted phenols have been chromatographed on thin layers of cellulose impregnated with polyamide (Nylon 66), in a non-aqueous eluent and in an aqueous eluent. The order of migration of the compounds is related to the site of solvation of the molecule by the mobile phase. The solvation site being the hydrophobic part of the molecule for the non-aqueous eluent and the phenolic group for the aqueous eluent. Steric effects appear to play a greater part in the migration of the compounds than do electronic effects; though the latter do contribute to the system. The position of substituents in the molecule and also the nature of the substituents are also shown to affect the R_F values.

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