

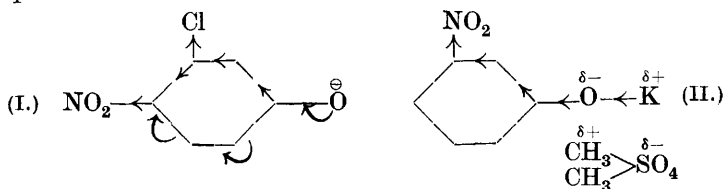
CCLXXVIII.—*The Methylation of Phenols by Methyl Sulphate. A Suggested Mechanism.*

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THE usual procedure for the methylation of phenols in aqueous alkaline solution by means of methyl sulphate (hereafter denoted by M) is very efficient for the cresols (70—80%) and moderately so for phenol (65%) and the nitrophenols (45—65%), but fails almost entirely with the chloronitrophenols and nitrocresols. For the methylation of the last-named compounds, Haworth and Lapworth (J., 1923, **123**, 2986) devised a special procedure (here

denoted H and L), viz., reaction in xylene in the presence of potassium carbonate.

A comparative quantitative investigation has been made of the methylation of a number of substituted phenols by both methods, and the following explanation of the results is offered. The M method being regarded as proceeding by initial attachment of methyl sulphate at the anionoid oxygen of the ionised phenol, it is clear that if the negative charge is not sufficiently localised (alternatively stated, if the oxygen electrons are insufficiently activated or mobile) no reaction can occur. This practically obtains in the case of the chloronitrophenols, where the combined alternating and general effects (Allan, Oxford, Robinson, and Smith, J., 1926, 401) [tautomeric and inductive effects (Ingold and Shaw, *ibid.*, p. 2918)], while promoting ionisation, cause a distribution and restraint of the negative charge (I) which inhibits the ability of the oxygen to attract the methyl sulphate. On the other hand, the H and L method reduces ionisation to a minimum, so that methylation must depend on the reaction between the methyl sulphate and the almost un-ionised potassium salt of the phenol at an incipient dipole, the formation of which will be enhanced by the nitro- and halogeno-substituents (II) but repressed by methyl groups. Double displacement will then be determined by the ability of the potassium to replace a methyl group in the methyl sulphate.



In the unsubstituted cresols the  $+I$  effect (Ingold and Shaw, *loc. cit.*) of the methyl group opposes ionisation and thus promotes localisation of the charge on the anionoid oxygen: the H and L method therefore fails entirely, and for the M method to succeed the methylation has to be performed in caustic alkaline solution to promote ionisation. From the chloro- and nitro-3-hydroxy-benzaldehydes, good yields of ethers are obtained only in aqueous sodium bicarbonate solution (Hodgson and Beard, J., 1926, 147): this shows the necessity for control of the ionisation, since methylation fails when caustic alkalis are used. For the methylation of *m*-nitrophenol, where only the  $-I$  effect can operate, the M and the H and L method are equally efficient, whereas for *o*- and *p*-nitrophenol, where the  $-I$  effect is reinforced by a  $-T$  effect,

the H and L method is the more productive. An anomalous case appears in *m*-nitro-*o*-cresol, where both methods fail. The combined  $-I$  effects in 4-fluoro-2 : 6-dichlorophenol are so great as almost to inhibit methylation by the M method, whereas from the bromo- and iodo-analogues fairly good yields of ethers are obtained ; and in contrast the H and L method almost fails in the case of 4-fluoro-2 : 6-di-iodophenol.

## EXPERIMENTAL.

*Method M.*—The phenol (1/10 g.-mol.), dissolved in cold 10% aqueous sodium hydroxide (50 c.c.), was stirred vigorously with methyl sulphate (12 c.c.) for 30 minutes; the mixture was then slowly warmed to 100° on the water-bath and kept there for 30 minutes. The resulting anisole was removed by steam distillation, dried, and weighed.

*Method H and L.*—The phenol (1/10 g.-mol.) was ground with anhydrous potassium carbonate (20 g.) and the mixture was suspended in xylene (50 c.c.) and boiled under reflux for 4 hours during the portionwise addition of methyl sulphate (12 c.c.). Fractional steam distillation removed first the xylene and afterwards the anisole, which was dried and weighed.

| Initial phenol.  | % Methylation<br>by H and L. | % Methylation<br>by M. |
|--|------------------------------|------------------------|
| Phenol .....   | Nil                          | 65                     |
| <i>o</i> -Cresol .....                                       | "                            | 71.4                   |
| <i>m</i> -Cresol .....                                       | "                            | 82.0                   |
| <i>p</i> -Cresol .....                                       | "                            | 71.3                   |
| <i>o</i> -Nitrophenol .....                                  | 71.5                         | 47.0                   |
| <i>m</i> -Nitrophenol .....                                  | 65.0                         | 65.0                   |
| <i>p</i> -Nitrophenol .....                                  | 79.6                         | 55.5                   |
| <i>o</i> -Chlorophenol .....                                 | 14.0                         | 72.5                   |
| <i>m</i> -Chlorophenol .....                                 | 28.0                         | 81.0                   |
| <i>p</i> -Chlorophenol .....                                 | 9.0                          | 81.0                   |
| 6-Chloro-2-nitrophenol .....                                 | 75.0                         | 19.5                   |
| 2-Chloro-4-nitrophenol .....                                 | 86.0                         | 8.0                    |
| 4-Chloro-2-nitrophenol .....                                 | 75.0                         | Nil                    |
| Insoluble sodium salt, 20%<br>yield in very dilute solution. |                              |                        |
| 5-Nitro- <i>o</i> -cresol .....                              | Nil                          | Nil                    |
| 2-Nitro- <i>p</i> -cresol .....                              | 73                           | 9                      |
| 6-Nitro- <i>o</i> -cresol .....                              | 41.5                         | 18                     |
| 4-Fluoro-2 : 6-di-iodophenol ...                             | 9.7                          | 40.0                   |
| 4-Fluoro-2 : 6-dibromophenol ...                             | 53.0                         | 53.0                   |
| 4-Fluoro-2 : 6-dichlorophenol ...                            | 60.0                         | 10.0                   |

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