948. *Dissociation Constants of Some Methylchlorobenzoic Acids in 71% Aqueous Ethanol: Further Examples of Steric Distortion.*

By G. M. Hoop and J. M. Tedder.

The dissociation constants of *o*-chloro-, 2-chloro-3-methyl-, and 2-chloro-5-methyl-benzoic acid in 71% aqueous ethanol have been determined by a conductivity method. 2-Chloro-3- proved to be twice as strong as 2-chloro-5-methylbenzoic acid and slightly stronger than *o*-chlorobenzoic acid, in accord with the concept of inhibition of mesomerism by steric distortion previously put forward. However, the dissociation constants of *p*-chloro-, 4-chloro-3-methyl-, and 4-chloro-3,5-dimethyl-benzoic acid in the same solvent reveal practically no steric effect.

In a previous paper[1] the dissociation constants of 1- and 3-halogeno-2-naphthoic acids were reported, and it was noted that the relative strengths of the acids (1- stronger than 3-halogeno-2-naphthoic) were contrary to that predicted by the simple electronic theory or by simple molecular-orbital calculation. It was suggested that this discrepancy could be accounted for by assuming that steric compression in the 1-halogeno-2-naphthoic acids bent the halogen atom out of the plane of the naphthalene ring system and so inhibited mesomerism. If so, it should be possible to detect similar effects in other *ortho*-substituted aromatic acids. Examination of the literature provides evidence of this phenomenon, although at first the data appear contradictory. It was emphasised previously that steric inhibition of mesomerism in aromatic compounds can occur in two forms. The simpler and most widely acknowledged occurs when an *ortho*-substituent prevents a group such as a carboxyl-, nitro-, or dimethylamino- from assuming the planar configuration for mesomerism. This effect explains the relatively high acidity of *ortho*-substituted benzoic acids.[3] It also (Table 1) explains why 2,5- is stronger than 2,3-dinitrobenzoic acid and why the 5-chloro- and 5-bromo-2-nitrobenzoic acid are stronger than the 3-halogeno-2-nitro-3-halogenobenzoic acids: in these examples the 3-substituent prevents the nitro-group from attaining a planar configuration. The less widely appreciated type of steric inhibition of mesomerism, which was invoked to explain the dissociation constants of the 1- and 3-halogeno-2-naphthoic acids, is also illustrated in Table 1, by the 2-halogeno-3-nitrobenzoic acids which are stronger than the 2-halogeno-5-nitrobenzoic acids: in these examples it seems probable that the halogen atom is bent out of the plane of the

Table 1.

Dissociation constants (10^5K) of some 2,3- and 2,5-disubstituted benzoic acids.[2,3]

2-Subst.	CH_3	NO_2	Cl	NO_2	Br	NO_2
3- or 5-Subst.	CH_3	NO_2	NO_2	Cl	NO_2	Br
2,3-Disubstd.	18·3	1300	870	440	1200	300
2,5-Disubstd.	10·5	2400	620	1500	910	1400

---

[1] Hoop and Tedder, preceding paper.

[2] Llandolt–Börnstein, Sixth Edition, Heidelberg, 1960.

[3] Dippy, Hughes, and Laxton, *J.*, 1954, 1470.

ring by the large groups on either side of it, and thus prevented from attaining the planar sp^2-configuration necessary for mesomerism. Finally, the difference in the acidities of 2,3- and 2,5-dimethylbenzoic acid suggests that some of the distortion may be in the plane of the benzene ring, *i.e.*, "sideways," so that the 2-methyl group obstructs the carboxyl group even more effectively.

The present work was initiated with the intention of finding further examples of steric distortion inhibiting mesomerism of halogen atoms attached to benzene rings. Table 2 lists the dissociation constants of *m*-toluic acid and its chloro-derivatives in 71% ethanol. It is very striking that 2-chloro-3-methylbenzoic acid turns out to be a stronger acid than *o*-chlorobenzoic acid, and the explanation that the adjacent methyl group distorts the molecule in such a way so as to restrict mesomerism seems the most probable. On the other hand, 2-chloro-5-methyl- is weaker than *o*-chloro-benzoic acid as expected (cf. benzoic acid and *m*-toluic acid).

To obtain examples in which the relevant groups were not adjacent to the carboxyl group, 4 chloro-, 4-chloro-3-methyl-, and 4-chloro-3,5-dimethyl-benzoic acids were synthesised and examined (see Table 3): there is practically no steric effect in this case. The expected dissociation constants for 4-chloro-3-methyl- and for 4-chloro-3,5-dimethyl-benzoic acid can be calculated by using the Hammett equation[4] and assuming that σ-values are additive in polysubstituted compounds.[5] Computing ρ from the dissociation constants of benzoic and *p*-chlorobenzoic acid (Tables 2 and 3) give the values of $1{\cdot}2 \times 10^{-6}$ and $0{\cdot}9 \times 10^{-6}$ for 4-chloro-3-methyl- and 4-chloro-3,5-dimethyl-benzoic acid, respectively, at 25°, *i.e.*, values identical within experimental error with those found.

TABLE 2.

Dissociation constants (10^6K) of 2-chloro-3-methylbenzoic acid and some related methyl and chloromethylbenzoic acids in 71% aqueous ethanol.

X	Temp.	$2\text{-X-C}_6\text{H}_4\cdot\text{CO}_2\text{H}$	$2\text{-X,3-Me}\cdot\text{C}_6\text{H}_3\cdot\text{CO}_2\text{H}$	$2\text{-X,5-Me}\cdot\text{C}_6\text{H}_3\cdot\text{CO}_2\text{H}$
H	25°	0·58	0·44	0·44
H	31	0·6	0·45	0·45
H	40	0·58	0·44	0·44
Cl	25	7·3	7·9	3·5
Cl	31	7·1	7·8	3·4
Cl	40	6·7	7·2	3·2

TABLE 3.

Dissociation constants (10^6K) of *p*-chlorobenzoic acid and some related chloromethylbenzoic acids in 71% aqueous ethanol.

Temp.	$p\text{-Cl}\cdot\text{C}_6\text{H}_4\cdot\text{CO}_2\text{H}$	$3,4\text{-C}_6\text{H}_3\text{MeCl}\cdot\text{CO}_2\text{H}$	$3,5,4\text{-C}_6\text{H}_2\text{Me}_2\text{Cl}\cdot\text{CO}_2\text{H}$
25°	1·71	1·37	0·91
31	1·74	1·38	0·87
40	1·65	1·36	0·65

These results do not invalidate the concept of inhibition of mesomerism by steric distortion, but rather emphasise that "sideways" displacement in the plane of the ring may be as important as deflection out of the plane. In the 2,3-disubstituted benzoic acids this sideways distortion, or buttressing, is probably the important effect, a conclusion supported by the dissociation constant of 2,3-dimethylbenzoic acid discussed above. In the 1-halogeno-2-naphthoic acids the steric effect is greater, as expected, and distortion out of the plane of the ring is likely to be important.

2-Chloro-3-methylbenzoic acid was prepared from *m*-toluic acid by nitration, followed by reduction and a Sandmeyer reaction. 2-Chloro-5-methylbenzoic acid was prepared by a previously reported sequence from *p*-chlorotoluene. 4-Chloro-3-methylbenzoic acid was

---

[4] Hammett, "Physical Organic Chemistry," McGraw-Hill Book Co. Inc., New York, 1940, pp. 186—194.

[5] Jaffé, *Chem. Revs.*, 1953, **53**, 191.

prepared from *m*-toluidine *via* 4-chloro-3-methyl-aniline and -benzonitrile. 4-Chloro-3,5-dimethylbenzoic acid was prepared from mesitylene, by nitration, oxidation to 3,5-dimethyl-4-nitrobenzoic acid, reduction, and a Sandmeyer reaction.

EXPERIMENTAL

The dissociation constants were determined by a conductivity method, details of which were described previously.[1]

Benzoic, *p*-chlorobenzoic, and *m*-toluic acid were commercial materials repeatedly crystallised. An acid was considered pure when further recrystallisation failed to alter its specific conductivity.

2-Chloro-3-methylbenzoic Acid.—*m*-Toluic acid with fuming nitric acid yielded 3-methyl-2-nitrobenzoic acid [6] (m. p. 219—220°), which was reduced in ethanol with Raney nickel for 24 hr. at 75°/100 atm. of hydrogen, yielding 2-amino-3-methylbenzoic acid,[6] m. p. 171—172°. This (4·6 g.) was diazotised and treated with cuprous chloride in the usual way. The chloro-acid was recrystallised three times from aqueous acetone, to yield *2-chloro-3-methylbenzoic acid* (2·7 g.), m. p. 132° (Found: C, 56·9; H, 4·6; Cl, 20·3. $C_8H_7ClO_2$ requires C, 56·3; H, 4·1; Cl, 20·8%). The acid was recrystallised a further three times from benzene until its specific conductivity remained constant.

2-Chloro-5-methylbenzoic Acid.—2-Chloro-5-methylacetophenone, b. p. 238—241°, was prepared from *p*-chlorotoluene, acetyl chloride, and aluminium chloride in carbon disulphide. With alkaline permanganate it yielded 2-chloro-5-methylbenzoic acid, which after two recrystallisations from aqueous acetone had m. p. 167°.[7] The acid was recrystallised a further three times from benzene, its specific conductivity then remaining constant (Found: C, 56·3; H, 4·3; Cl, 21·0%.

4-Chloro-3-methylbenzoic Acid.—4-Chloro-3-methylaniline, m. p. 80—81°, was prepared by the chlorination of *N*-acetyl-*m*-toluidine followed by hydrolysis.[8] The chlorotoluidine (17·5 g.) was heated with 5N-hydrochloric acid (100 c.c.) for 30 min. and the resulting suspension cooled to 0°. Sodium nitrite (9 g. in 30 c.c. of water) was added dropwise to the cold suspension. The resulting diazonium salt solution was added slowly to a heated (60—70°) solution of potassium tetracyanocuprate [from copper sulphate (31 g.), potassium cyanide (31 g.), and water (162 c.c.)]. The combined solutions were heated at 100° for a further 40 min., then cooled and extracted with ether. Evaporation of the ether left an oil which was distilled (b. p. 235—242°). *4-Chloro-3-methylbenzonitrile* recrystallised from light petroleum (b. p. 40—60°) as yellow needles (3·4 g.), m. p. 60—61° (Found: C, 62·6; H, 4·2; N, 9·7. C_8H_6ClN requires C, 63·3; H, 4·0; N, 9·2%). It was hydrolysed by aqueous alkali to 4-chloro-3-methylbenzoic acid that recrystallised from aqueous acetone (charcoal) as white needles, m. p. 209° [9] (Found: C, 56·2; H, 4·5; Cl, 20·5%.

4-Chloro-3,5-dimethylbenzoic Acid.—Mesitylene was nitrated and the 1,3,5-trimethyl-2-nitrobenzene was oxidised with chromic acid to 3,5-dimethyl-4-nitrobenzoic acid, m. p. 212—215°.[10] This acid (7·8 g.) was reduced in alcohol (200 c.c.) for 12 hr. at 65°/100 atm. of hydrogen in the presence of Raney nickel (2 g.). Most of the alcohol was distilled off and the residue treated with water. The precipitated *4-amino-3,5-dimethylbenzoic acid,* when recrystallised from ethanol, had m. p. 244° (6·6 g.) (Found: C, 65·1; H, 7·0; N, 8·6. $C_9H_{11}NO_2$ requires C, 65·5; H, 6·7; N, 8·5%). This acid (6·5 g.) was dissolved in 5N-hydrochloric acid (70 c.c.) and cooled. Aqueous sodium nitrite (2·8 g. in 15 c.c. of water) was added dropwise. The diazonium salt solution was added slowly to aqueous cuprous chloride solution at 80°. The mixture was heated for a further 30 min. at 100° and then cooled. The white precipitate of *4-chloro-3,5-dimethylbenzoic acid* was filtered off and recrystallised from aqueous acetone as white needles (4·1 g.), m. p. 211° (Found: C, 58·7; H, 5·4; Cl, 19·2. $C_9H_9ClO_2$ requires C, 58·5; H, 4·9; Cl, 19·6%).

Conductivity Measurements.—Measurements were made by using a transformer ratio-arm bridge (a Wayne-Kerr universal bridge) with a " magic eye " as detector. The procedure

---

[6] Wheeler and Hoffman, *Amer. Chem. J.*, 1910, **44**, 507.

[7] Claus, *J. prakt. Chem.*, 1892, **46**, 26.

[8] Reverdin and Crépieux, *Ber.*, 1900, **33**, 2503.

[9] Claus, *J. prakt. Chem.*, 1891, (2), **43**, 357.

[10] Schmitz, *Annalen*, 1879, **193**, 168; cf. also Jacobsen, *Ber.*, 1878, **11**, 2054.

was as described previously. Readings were made for solutions of three different concentrations for each acid, each at 25°, 31°, and 40°. The values for benzoic and *o*-chlorobenzoic acid in Table 2 are taken from previous work.

The authors express their gratitute to Dr. P. A. H. Wyatt for his assistance with the conductivity measurements and for much advice. They thank Mr. W. Higgins for experimental work and the D.S.I.R. for an award of a maintenance grant (to G. M. H.).

THE UNIVERSITY, SHEFFIELD, 10.

[*Received, March* 22*nd*, 1962.]