binary solid solutions is (irregularly) greater than that of a mechanical mixture of the two salts involved; each of the experimental curves lies above the straight lines of Fig. 2a of ref. 2. For the twelve binary points plotted the average algebraic deviation from the straight lines is +5.2 units (in the fourth decimal) while the experimental accuracy is claimed to be "about ±0.0001." The only negative deviation (0.5 unit) occurs on the curve **bc** (RbBr–KBr), which is itself the nearest to a straight line, with deviations +2, −0.5 and +1. For curve **ad** the deviations are +6, +5.5, +3; for **cd**, +10.5, +9, +0.5; and for **ab**, +9.5, +6, +9.5. The last two binary systems, each with a common cation, seem to differ most from strict additivity.

It is possible, of course, that the experimental uncertainty is much greater than 0.0001, and that the binary systems may still be taken as (practically) additive. However, even if the four edges of the surface are practically straight lines, the surface connecting them, which must be smooth and continuous if the solid phase is a single continuous solid solution, must nevertheless be a curved surface, since the four points **a**, **b**, **c** and **d** are not on the same plane, which would require **a** + **c** = **b** + **d**. Moreover, since at least the two sides **ab** and **cd** appear to be curved above their straight lines, the surface may be expected to be concave downward; this is apparent from the schematic diagram of Fig. 3. Finally, the curvature of the two diagonals of the surface, **ac**, and **bd**, will not be the same, and since **a** + **c** > **b** + **d**, the diagonal **ac** will be flatter, or more nearly a straight line, than the diagonal **bd**. This expected difference is apparent in the experimental data plotted in Figs. 3a and 4a of ref. 2. The refractive indexes parallel to the diagonal **ac** (Fig. 4a) fall, within what must be considered an uncertain experimental error, upon practically straight lines. Those parallel to the **bd** diagonal (Fig. 3a) are actually plotted on straight lines intersecting above the single straight line demanded by continuous additivity (the impossible conception pictured here as Fig. 2), but they may equally well be fitted by continuous curves concave downward.

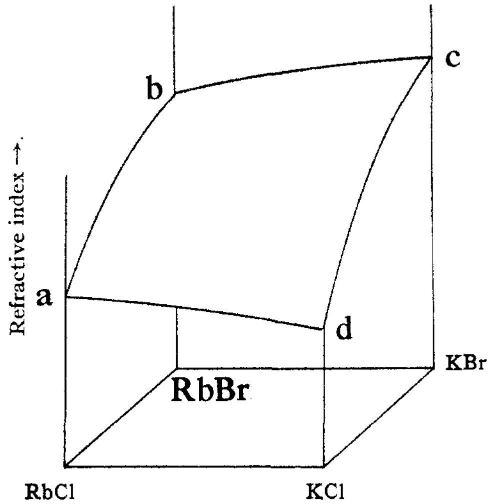

Fig. 3.—Schematic representation of the ternary refractive index surface.

In conclusion, it appears that all that can be done experimentally is to investigate the shape of the surface, which must be continuous if the ternary solid is continuous, and which may be expected beforehand, on the basis of the bounding binary curves, to be generally concave downward. On the question whether the solid is homogeneous or not, however, any observation of strict additivity with respect to adjacent pairs of binary solid solutions should be taken as indicating heterogeneity, or the presence of a mechanical mixture of such pairs of binary solids, and it would be the very opposite, or evidence of non-additivity, that would suggest a homogeneous ternary solid solution. Practically, the data are useful only in the usual sense that if the property measured varies smoothly over the entire surface the solid is a single phase, while if it varies with abrupt changes, as might be suggested by the unjustified intersecting straight lines of Fig. 3a of ref. 2, then it is heterogeneous. Within a somewhat uncertain experimental error all the data may apparently be fitted by smooth curves across the surface. On this basis, therefore, the data corroborate the thermal study and the X-ray analysis of the system indicating that the only solid formed is a continuous ternary solid solution of all four salts.

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The Reactivity of the Halogen in Some Halogenated Anilines

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RECEIVED MAY 5, 1952

In a previous report[1] it was shown that ortho halogen atoms increase the susceptibility of *p*-nitrosubstituted aryl halides toward substitution by nucleophilic reagents. This is no doubt due, mainly, to the unique behavior of halogens when attached to the benzene ring. Halogens have a large induction moment directed away from the ring and at the same time, owing to resonance, the electron density is the lowest at the meta carbon atoms. The over-all effect is to bring about activation for nucleophilic substitution, the order of which is $m > o > p$.

Conversely one would expect deactivation, of the order $m > o > p$ for electrophilic substitution.[2]

The authors of the present paper have examined in a qualitative way, the behavior of *p*-iodoaniline, 3,4-diiodoaniline, 3,4,5-triiodoaniline and 2,6-dibromo-4-iodoaniline toward acid stannous chloride. The reaction is probably an electrophilic attack by hydrogen ion on nuclear carbon, the *p*-iodine being displaced as positive ion.[3] The presence of the

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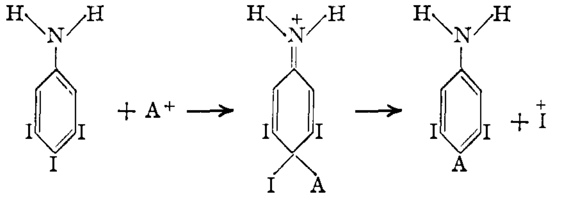
(1) R. B. Sandin and M. Liskear, THIS JOURNAL, **57**, 1304 (1935).

(2) For some recent interesting work and reviews on aromatic nucleophilic and electrophilic substitution reactions, see W. M. Schubert, THIS JOURNAL, **71**, 2639 (1949); E. Berliner, M. J. Quinn and P. J. Edgerton, *ibid.*, **72**, 5305 (1950); E. Berliner and L. C. Monack, *ibid.*, **74**, 1574 (1952); J. F. Bunnett and R. E. Zahler, *Chem. Revs.* **49**, 273 (1951); L. N. Ferguson, *ibid.*, **50**, 47 (1952).

(3) (a) B. H. Nicolet, *et al.*, THIS JOURNAL, **43**, 2081 (1921); **49**, 1796 (1927); **49**, 1801 (1927); **49**, 1805 (1927); **49**, 1810 (1927). (b) A. E. Remick, "Electronic Interpretations of Organic Chemistry," John Wiley and Sons, Inc., New York, N. Y., 1949, p. 408.

stannous chloride obviates the effects due to resubstitution and oxidation.

The results shown in Table I demonstrate the expected deactivation by *m*-halogen substituents. However, the introduction of one *o*-iodine atom increases the reactivity and a second *o*-iodine brings about a further increase in reactivity. The authors have considered that a plausible reason for the unexpected activation lies in the steric repulsion between adjacent halogens, which in turn favors the formation of intermediate (I).



(I) $\overset{+}{A} = \overset{+}{H}$

In the intermediate (I) A and iodine are not in the plane of the benzene ring. It is interesting to note in this connection that in *o*-dichloro- and *o*-dibromobenzene there is a 15° angle between the plane of the ring and the carbon–halogen bonds. However *p*-dibromobenzene is coplanar.[4]

The present authors believe that a steric activation by ortho halogens might also be of some importance in nucleophilic displacements, although in this case the steric effect is difficult to single out from other factors. Previous work[1] with piperidine as the nucleophilic reagent has shown steric deactivation due to steric hindrance of reagent approach. With a smaller entering group, steric deactivation would become less and electronic effects and steric activation (if any) would become important. However, the last two effects cannot be separated.[5]

Experimental

Materials.—3,4,5-Triiodoaniline,[6] m.p. 175°, 3,4-diiodoaniline,[7] m.p. 75°, *p*-iodoaniline,[8] m.p. 62–63°, and 2,6-dibromo-4-iodoaniline,[9] m.p. 147–148°, were prepared without difficulty and in good yield.

Reaction with Hydrochloric Acid and Stannous Chloride.—The method employed was similar to the one used by Nicolet[3a] and co-workers for the determination of so-called "positive" halogen. It was essential that the acid concentrations should be the same for all runs, since it is known that the rate of halogen removal is directly proportional to the acid concentration but is independent of the stannous chloride concentration.

In this work 0.001 mole of compound was dissolved in a boiling mixture of 50 cc. of glacial acetic acid and 10 cc. of concentrated hydrochloric acid. To this was added 0.025 mole of stannous chloride and the solution was refluxed for 15 minutes. On boiling, some hydrogen chloride was lost. However, since all experiments were carried on as nearly as possible under the same conditions, no attempt was made to avoid this loss.

After refluxing, the reaction mixture was made alkaline, extracted with carbon tetrachloride and steam distilled. The reaction mixture thus freed from organic material was acidified with sulfuric acid and treated with excess ferric chloride. The liberated iodine was steam distilled into a cold solution of potassium iodide in water, and was then titrated with standard sodium thiosulfate. The percentage of iodine removed for each compound is shown in Table I. The authors make no claim to great quantitative accuracy.

TABLE I

	Substance	*p*-Iodine removed by $HCl-SnCl_2$, %
I	2,6-Dibromo-4-iodoaniline[a]	23
II	*p*-Iodoaniline	41
III	3,4-Diiodoaniline[b]	52
IV	3,4,5-Triiodoaniline[c]	99

[a] 2,4,6-Triiodoaniline was not used because *o*-iodine is also displaced. [b] *m*-Iodoaniline was isolated as the acetyl derivative, m.p. 119–120°. [c] 3,5-Diiodoaniline, m.p. 105°, recovered.

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[4] O. Bastiansen and O. Hassel, *Acta Chem. Scand.*, *1*, 489 (1947); *C. A.*, **42**, 2484 (1948).

[5] In the careful work by Spitzer and Wheland, THIS JOURNAL, **62**, 2995 (1940), it has been shown that in the reactions with piperidine the ratio of the velocity constants for *p*-nitrobromobenzene and 2-bromo-5-nitro-*m*-xylene is about 160:1, while, in the reactions with hydroxide ion, the ratio is only about 11:1. Thus the total deactivation due to the two methyl groups ortho to the bromine atom has been reduced by the use of the smaller reagent molecule.

[6] L. Kalb, F. Schweizer, H. Zellner and E. Berthold, *Ber.*, **59**, 1860 (1926).

[7] P. Brenans, *Compt. rend.*, **136**, 1077 (1903).

[8] R. Q. Brewster, "Organic Syntheses," Coll. Vol. II, John Wiley and Sons, Inc., 1943, p. 347.

[9] J. J. Sudborough and J. V. Lakhumalani, *J. Chem. Soc.*, **111**, 41 (1917).

Steroidal Sapogenins. IV.[1] Hydrolysis of Steroidal Saponins[2]

BY EDWARD S. ROTHMAN, MONROE E. WALL AND HENRY A. WALENS

RECEIVED MARCH 10, 1952

Steroidal sapogenins are recognized as excellent sources for sex hormones and may be important precursors for cortisone synthesis.[3] The sapogenins are not found free, but occur in a combined glucosidal form which can be cleaved by the use of strong hydrochloric acid. Consequently, the yield of sapogenin depends on the completeness of the acid hydrolysis of the precursor saponins. The question of yield has not been clearly elucidated by previous workers. Jurs and Noller[4] hydrolyzed a purified saponin precursor of tigogenin (isoallospirostan-3β-ol) using 1.4 *N* hydrochloric acid for 72 hours. Marker, *et al.*,[5] hydrolyzed crude alcoholic plant extracts with 2 *N* hydrochloric acid for 2–3 hours. In neither case was it shown that the hydrolysis conditions were optimal.

We have studied the acid hydrolysis of a number of different saponins. The results are summarized in Table I. Several important facts can be deduced from the data. All the saponins tested were rapidly hydrolyzed with 4 *N* hydrochloric acid, yielding in most cases 90% of the total sapogenin found, in 1–2 hours. Hydrolysis occurred very rapidly when 6 *N* acid was used, cleavage taking place within 10 minutes with the two saponins tested.

Hydrolysis of the different saponins with 2 *N* acid resulted in variable hydrolysis rates. In all cases, the time to reach 90% hydrolysis was much

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[1] Paper III, E. S. Rothman, M. E. Wall and C. R. Eddy, THIS JOURNAL, **74**, 4013 (1952).

[2] Not copyrighted.

[3] For pertinent references of papers by Marker, *et al.*, THIS JOURNAL, (1940–1947), and Djerassi, Rosenkranz, *et al.*, THIS JOURNAL, (1950–1952).

[4] P. C. Jurs and C. R. Noller, *ibid.*, **58**, 1251 (1936).

[5] R. E. Marker, *et al.*, *ibid.*, **69**, 2167 (1947).