# 216. *Azo-indicators with a Quaternary Ammonium Group.*

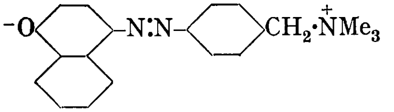
By G. Spencer Hartley.

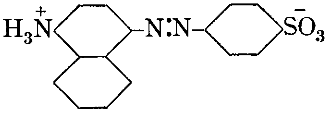
If acidimetric indicators are to be used in aqueous solutions containing long paraffin-chain cations or positively charged colloids, it is desirable (Hartley, *Trans. Faraday Soc.*, 1934, **30**, 444) that their colour-ions should have a resultant positive charge in both the acid and the alkaline form. Among commercially available compounds, the choice is at present restricted to those of the di- or tri-amino-(or alkylamino-)triphenylmethane class, or compounds of the quinoline-blue (Colour Index, 1924, No. 806) type. The former cover only the very acid range and, in some cases (*e.g.*, crystal-violet), show complex fading phenomena (Adams and Rosenstein, *J. Amer. Chem. Soc.*, 1914, **36**, 1452), which are sufficiently rapid to make their use inconvenient. The latter are too unstable to be of utility.

During the work referred to, the author prepared some azo-indicators from a specimen of β-*p*-nitrophenylethyltrimethylammonium iodide kindly supplied by Dr. E. D. Hughes, to whom he is also indebted for valuable advice. These compounds were satisfactory, and means of preparing analogous ones from a more readily available material were, therefore, sought.

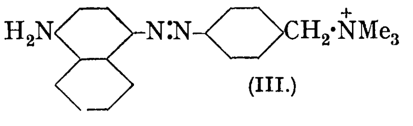
It is believed that the compounds described, which are very easily prepared, may have considerable interest apart from the particular purpose for which they were designed. Another application for one of them, in moving-boundary transport-number measurements (Samis, *Trans. Faraday Soc.*, 1937, **33**, 469), has already been described. In the study of hydrogen-ion-controlled reactions and equilibria (particularly biochemical), increasing attention must be paid to salt effects if satisfactory progress is to be made. These effects are functions mainly of the valency-type of the ions concerned (Guggenheim and Schindler, *J. Amer. Chem. Soc.*, 1934, **38**, 543) and it is desirable, therefore, to extend, as do the compounds described, the range of valency-type available in indicators. Finally, these compounds, in common with other quaternary ammonium salts, have a higher solubility than most other salts of corresponding complexity. This is particularly marked in the case of one " zwitterionic " indicator prepared, the compound (I) being far more soluble in cold alkaline water than is necessary for indicator work. Its counterpart (II), with reversed signs (we make no attempt here to represent the actual location of the labile charge), is so sparingly soluble that it is precipitated when a solution of the sodium salt, in concentration such as is used in indicator work, is acidified. It is for this reason that $\alpha$-naphthylamineazo-compounds have been little used as indicators. The ion (III) forms very soluble salts and thus renders more available the yellow–purple colour change of the $\alpha$-naphthylamineazo-group (between $p_H$ *ca.* 3·5—5·5).

(I.)





(II.)



(III.)

The quaternary ammonium indicators described are neither more nor less stable than other azo-indicators. They are easily decolorised by reducing agents, but are otherwise permanent, except that the naphthylamine compounds fade in a few hours at 100°.

## EXPERIMENTAL.

*p*-Nitrobenzyl chloride was the starting material. From this, the *p*-aminobenzyltrimethylammonium ion was prepared, diazotised in the usual way in acid solution, and coupled with various aromatic amines. Reduction of the nitro-group could not be made the first step in the preparation, as only tarry condensation products were obtained. If, however, the chloride is first replaced by quaternary nitrogen, reduction may then be effected by any of the usual agents in acid solution. Of these, iron was found most convenient.

It was found that trimethylamine and nitrobenzyl chloride unite very readily, and special solvents, such as nitromethane, were unnecessary. The procedure adopted was to dissolve the nitrobenzyl chloride in about 3 times its weight of acetone, and then to add (as 33% aqueous solution) trimethylamine in about 50% excess of the theoretical quantity. The initially cloudy mixture became clear after a few minutes' shaking. Heat was evolved, but insufficient to necessitate external cooling. The mixture was kept until a sample remained clear when the amine and acetone were boiled off. A little water was then added to the bulk, and the amine and acetone driven off by heating, a few drops of hydrochloric acid being added when the amine odour had disappeared, to reduce possible hydrolysis of the quaternary ammonium salt. The resulting aqueous solution of *p*-nitrobenzyltrimethylammonium chloride was yellow but quite clear. The iodide could be precipitated in pale yellow plates by addition of excess of potassium iodide, but separation of this compound was not considered necessary in the main preparation.

To the solution of nitro-salt (about $M$), prepared as above, 5% of the theoretical amount of hydrochloric acid was added, and then, in small quantities and with constant stirring, iron filings. Since the reaction was very vigorous and evolved considerable heat, each addition of iron was delayed until the temperature of the reaction mixture had fallen below 70°. Cessation of rise of temperature on further addition of iron was taken to indicate the end of the reaction. A slight excess of ammonia was then added, and air blown through the mixture to oxidise ferrous to ferric hydroxide. The filtrate, diluted by washing to about $M/3$ (assuming 100% yields), was red, but gave no test for iron in any circumstances, the colour being presumably due to an organic by-product. Diazotisation of the amino-salt was carried out directly in this solution after addition of nitric acid.

Coupling with aromatic amines proceeded most quickly when the reaction mixture was nearly neutralised with ammonia. After being kept for 24 hours, the mixture was made definitely alkaline with ammonia, and extracted several times with benzene to remove free amine and any by-products not ionised in alkaline solution. In most cases, crystalline indicator nitrate was already present in the aqueous layer, but more complete precipitation was ensured by adding a large excess of ammonium nitrate and keeping the mixture cold for 24 hours. The nitrates (less soluble than the chlorides and preferable in use to the iodides) were recrystallised several times from hot water. The yields of once-recrystallised products were 50—70% of the theoretical for the amount of nitrobenzyl chloride used.

A small amount of brown gummy material made the first filtration slow, but disappeared in recrystallisation. A cleaner first precipitate was obtained in a preparation when the amino-salt was isolated as iodide (and reconverted into nitrate by silver nitrate solution) before diazotisation. This salt is, however, extremely soluble in water, and its isolation therefore very wasteful.

Mononitrates were obtained in this way from coupling with the following amines. The appearance of the salts, colour changes of the solutions (alkaline first), and the approximate $p_H$ values for the half-changed condition are given. The indicators cover a range of about one $p_H$ unit on either side of this value and are usable in concentrations between $10^{-5}$ and $10^{-6}N$.

| Amine. | Appearance. | Colour change. | $p_H$. |
|---|---|---|---|
| (1) Dimethylaniline | Bright orange-red plates | Orange-yellow ⟶ bright pink | 3·3 |
| (2) α-Naphthylamine | Small dark purple plates | Orange-yellow ⟶ purple-red | 4·5 |
| (3) Dimethyl-α-naphthylamine | Very fine, bright red precipitate, which could not be removed by filtration, but was centrifuged | Similar to (2) | |
| (4) β-Naphthylamine | Fine, bright red precipitate | Yellow ⟶ red | 1·3 |

No salt could be isolated from the reaction mixture when *m*-phenylenediamine was used, and a sample of the mixture showed a very indefinite colour change.

The constitution of these compounds is obvious from the method of formation, the cations in the salts and in alkaline solution having formulæ similar to (III). The following confirmatory observations were made.

(*a*) No colour was extracted from alkaline solution by benzene. It would be were the *strong* basic group not present.

(*b*) After warming with alcoholic potash and dilution with water, a benzene extract had a yellow colour, the quaternary group having been hydrolysed to amine and alcohol.

(*c*) The salts were more soluble in acid than in alkaline solution, indicating further ionisation.

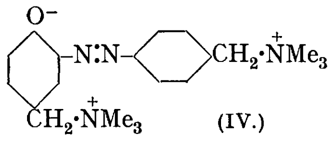
(*d*) The colour in buffer solution was not displaced by addition of a small amount of cetylpyridinium chloride (for significance, see Hartley, *loc. cit.*).

(*e*) Addition of neutral salt (*e.g.*, potassium chloride) to solutions in acetate–acetic acid buffers displaced the colour towards that of the acid form, which is, therefore, the more highly charged (cf. Guggenheim and Schindler, *loc. cit.*).

(*f*) A conductimetric titration of the dimethylaniline *compound* was made by adding successive weighed amounts of the solid to a *N*/100-nitric acid solution in a conductivity vessel (Found : equiv. as a base, 385 ± 5%. $NMe_2\cdot C_6H_4\cdot N{:}N\cdot C_6H_4\cdot CH_2\cdot NMe_3NO_3$ requires equiv., 359).

(*g*) A sample of *iodide* was prepared from the nitrate of the dimethylaniline compound by recrystallising it twice from excess of potassium iodide solution and twice from water. An acid solution of this was titrated against silver nitrate electrometrically (Found : I, 28·9. $NMe_2\cdot C_6H_4\cdot N{:}N\cdot C_6H_4\cdot CH_2\cdot NMe_3I$ requires I, 30·0%).

By coupling the diazotised amino-salt with diphenylamine or benzylaniline, other indicators could doubtless be made which would be useful at lower $p_H$ values than are those described. We were guided in our choice of amines by an endeavour to make indicators which could be used in the more generally important range of $p_H > 6$. In this we were not successful, and an attempt was therefore made to prepare a compound of another type, also having, but by a different mechanism, a resultant positive charge in alkaline solution. Two equal portions of the amino-salt solution were treated with nitrite. One was then heated, to replace the amino- by a hydroxyl group, made alkaline, and cooled, and the other solution was added. A dark brown colour developed, presumably due to the ion (IV), but no anion could be found to give a precipitate with it. The behaviour of a diluted solution of the reaction mixture, however, confirmed formula (IV). Tests (*a*)—(*e*) [but with a phosphate buffer in (*d*) and (*e*)] gave the same results as before. The colour change was from darker (alkaline) to lighter (acid) yellow in the range $p_H$ 7—8, as would be expected for a phenolic azo-compound. The colour faded completely in strong acid solution and could not be restored. In other respects the compound appeared normally stable.



(IV.)

For the purpose of comparison with other zwitterionic indicators, one was prepared from the diazotised amino-salt by coupling with α-naphthol in alkaline solution. The high solubility of the internal salt (I) precipitated from the reaction mixture has already been mentioned. It could conveniently be recrystallised from hot water. The solution was red when alkaline and orange-yellow when acid, the half-change point being about $p_H$ 8·5.

THE SIR WILLIAM RAMSAY LABORATORIES OF INORGANIC AND PHYSICAL CHEMISTRY,
UNIVERSITY COLLEGE, LONDON.
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