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# Thin-layer chromatography of aromatic amines on cadmium sulphate-impregnated silica gel thin layers*

Aromatic amines are produced commercially either by the reduction of the corresponding nitro compounds or by the ammonolysis of halogenated compounds. The amines thus obtained are usually contaminated by their isomers (one or two of $o$-, $m$- and $p$-isomers) as unavoidable by-products of proceeding procedures. No further purification is generally carried out when the amines are used as intermediates for various industrial products, e.g. dyestuffs, medicines and perfumes. Such impurities, however, frequently have an appreciable influence on the characteristics of the finalproducts, e.g. shades of dyestuffs, or physiological action, e.g. commercial 1-naphthylamine contaminated with 2-naphthylamine[1].

Japanese Industrial Standards[2], in which the diazotization titration method is employed to determine the purities of aromatic amines, do not appear to provide any information about isomers in such products. Spectrometry[3-6] and colour reactions[7] have been used for the analysis of certain amines. These methods, however, which are based on characteristic absorbances of individual isomers, or the specific effects of the substituted group on chemical reactions, are also of limited use. Gas chromatography, though frequently used for amines[8-10], is not adequate for general use to separate aromatic amine isomers from each other. 2-Naphthylamine in commercial 1-naphthylamine, for example, was not determined by gas–liquid chromatography except by employing extremely long packed columns[8] or with tedious pretreatment, e.g. methylation[9] or acylation[9,10] of amino groups. Many attempts with paper chromatography[11-14] and thin-layer chromatography (TLC)[15-22] have also been made. But in none of them, except for nitroaniline isomers, have satisfactory conditions been found for the mutual separation of isomers on common layers and with common solvents[15,16,21]. Azo compounds[23,24] and amides[25], which are derived from amines to be analysed, or $\pi$-complexes[26,27] from polynitro compounds and amines, have been stated to give better separation than the original amines. According to the $R_F$ values reported, however, these methods still appear to be inadequate to yield good separations of minor amounts of an isomer from large quantities of other isomers.

This paper reports the results of an application of metallic salt-impregnated silica gel thin layers for the separation of aromatic amine isomers. Good separation of isomers has been achieved on cadmium sulphate-impregnated layers with acidic mobile phases.

## Experimental

Preparation of thin layers. The thin layers, 0.2 mm thick, were prepared from 1 part of Silica Gel G (E. Merck) and 2.1 parts of water or solution (or suspension) of a salt (0.5 part of salt in 2.1 parts of water). The plates were heated at 105° for 3 h and kept at room temperature overnight.

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TABLE I

COMPOSITIONS OF SOLVENTS USED

| Mobile phase | Solvent composition (v/v) | | | | | |
|---|---|---|---|---|---|---|
| | Benzene | Acetic acid | Methanol | Ethyl acetate | Isopropyl ether | Cyclo-hexane |
| S1 | 90 | 10 | | | | |
| S2 | 80 | 10 | 10 | | | |
| S3 | | 2 | | 25 | 25 | |
| S4 | 100 | | | | | |
| S5 | 50 | | | | | 50 |

*Samples.* All amines except *o*- and *p*-aminophenols and N,N-dimethyl-1-naphthylamine, were of reagent grade. *o*- and *p*-aminophenols were obtained from Nippon Junryo Yakuhin Co. Ltd. N,N-Dimethyl-1-naphthylamine was prepared by the usual methylation of 1-naphthylamine, and purified by vacuum distillation. Acetyl compounds were obtained from the corresponding amines by acylation and were recrystallized from methanol–water mixtures. All samples were spotted on the thin layers as methanolic solutions.

*Mobile phases and developing.* All solvents employed were of reagent grade. Mobile phase compositions are shown in Table I. Ascending development with 10 cm irrigation distance was employed.

*Detection.* Methods used were an exposure to gaseous nitrogen oxides followed by spraying of 1-naphthylamine solution[28] for general purpose, *p*-dimethylamino-benzaldehyde in methanol–acetic acid solution for primary amines and bromine vapour exposure followed by spraying of diphenylbenzidine solution[29] for acyl compounds.

*Results and discussion*

$R_F$ values of some primary amines on silica gel layers impregnated with various metallic salts and on cadmium sulphate-impregnated layers are shown in Tables II

TABLE II

$R_F$ VALUES OF AROMATIC AMINES ON LAYERS IMPREGNATED WITH VARIOUS METALLIC SALTS

| Amines | $R_F \times 100$ | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Without impreg-nation | | CdSO₄ impreg-nation | | ZnSO₄ impreg-nation | | BaSO₄ impreg-nation | | CaSO₄ impreg-nation | | Al₂(SO₄)₃ impreg-nation | | CuSO₄ impreg-nation | |
| | S1 | S3 | S1 | S3 | S1 | S3 | S1 | S3 | S1 | S3 | S1 | S3 | S1 | S3 |
| o-Toluidine | 36 | 69 | 12 | 65[b] | 12[a] | 59[a] | 16 | 72 | 23[b] | 74 | 2 | 33[a] | 9 | 49 |
| m-Toluidine | 27 | 68 | 9 | 32[b] | 12[a] | 55[a] | 14[b] | 70[b] | 17[b] | 74 | 4 | 28[a] | 6 | 34[a] |
| p-Toluidine | 20 | 57 | 7 | 12 | 4[a] | 25[a] | 9[b] | 62[b] | 12[b] | 66[b] | 3 | 11[a] | 2 | 7[a] |
| α-Naphthylamine | 35 | 77 | 33[b] | 75[a] | 24[b] | 78 | 32 | 73[b] | 37 | 83 | 18[a] | 68[a] | 24[b] | 73[b] |
| β-Naphthylamine | 21 | 74 | 13 | 30 | 11[b] | 73 | 18 | 69[b] | 22 | 80 | 12[a] | 51[a] | 11[a] | 60[a] |

[a] Tailing.
[b] Slight tailing.

TABLE III

$R_F$ VALUES OF AROMATIC AMINES ON CADMIUM SULPHATE-IMPREGNATED LAYERS

A = non-impregnated layer; B = CdSO$_4$-impregnated layer.

| Amines | $pK_a$ | $R_F \times 100$ | | | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | | S1 | | S2 | | S3 | | S4 | | S5 | |
| | | A | B | A | B | A | B | A | B | A | B |
| o-Toluidine | 4.38 | 36 | 12 | 62 | 45 | 69 | 65[b] | 38 | 23 | 13 | 11 |
| m-Toluidine | 4.67 | 27 | 9 | 55 | 32 | 68 | 32[b] | 31 | 15[a] | 10 | 10 |
| p-Toluidine | 5.07 | 20 | 7 | 48 | 22 | 57 | 12 | 29 | 12[a] | 9 | 5 |
| o-Nitroaniline | 0.28 | 44 | 61 | 62 | 70 | 71 | 85 | 37 | 43 | 22[c] | 25[c] |
| m-Nitroaniline | 2.45 | 37 | 51 | 60 | 63 | 67 | 82 | 25 | 23 | 11[c] | 14[c] |
| p-Nitroaniline | 0.98 | 34 | 51 | 58 | 61 | 63 | 79 | 19 | 21 | 5[c] | 8[c] |
| o-Chloroaniline | 2.62 | 62 | 61 | 68 | 75 | 76 | 91 | 56 | 46 | 38[c] | 44[c] |
| m-Chloroaniline | 3.32 | 51 | 30 | 58 | 57 | 69 | 86 | 46 | 32 | 22[c] | 20[c] |
| p-Chloroaniline | 3.81 | 34 | 15 | 51 | 29 | 68 | 78 | 21 | 22 | 15[c] | 12[c] |
| o-Aminophenol | 4.72 | 1 | 2 | 27 | 11 | 58 | 29 | 2 | — | — | — |
| m-Aminophenol | 4.17 | 2 | 1 | 27 | 11 | 50 | 24 | 1 | — | — | — |
| p-Aminophenol | 5.50 | 1 | 0 | 12 | 4 | 18 | 3 | 1 | — | — | — |
| o-Aminobenzoic acid | 2.11 | 40 | 42 | 45 | 50 | 63 | 65 | 2 | — | — | — |
| m-Aminobenzoic acid | 3.12 | 6 | 3 | 32 | 16 | 55 | 18 | 0 | — | — | — |
| p-Aminobenzoic acid | 2.41 | 31 | 36 | 41 | 38 | 58 | 64 | 0 | — | — | — |
| o-Anisidine | 4.51 | 22 | 9 | 56 | 34[b] | 70 | 41[a] | — | — | — | — |
| m-Anisidine | 4.21 | 20 | 5 | 55 | 24 | 62 | 27[a] | — | — | — | — |
| p-Anisidine | 5.30 | 7 | 0 | 27 | 9[a] | 33 | 1 | — | — | — | — |
| α-Naphthylamine | 3.99 | 35 | 30[b] | 58 | 35[b] | 77 | 75[a] | 23 | 36 | 12 | 17 |
| β-Naphthylamine | 4.11 | 21 | 13 | 54 | 17 | 74 | 30 | 22 | 27 | 9 | 11 |

[a] Tailing.
[b] Slight tailing.
[c] Multiple development (twice).

and III, respectively. $R_F$ values of unsubstituted amines on thin layers, either with or without metallic salt impregnation, in any of the mobile phases employed, generally increased in the order p-, m-, o-isomers. $R_s$ values of m- and p-isomers, obtained from the $R_F$ values of o- or a-isomers on cadmium sulphate-impregnated layers (B), however, were less than those on nonimpregnated layers (A) with a few exceptional cases. Better mutual separation of amine isomers was thus achieved on B.

In acidic mobile phases, as shown in Figs. 1 and 2, differences in the $R'_m$ values[30] of primary amines between both layers, A and B, seem to bear some relationship to the basicities of the amines.

$R_F$ values of some N,N-dimethylamines and acyl derivatives are shown in Table IV. Cadmium sulphate impregnation was found to be less effective for the former and not for the latter.

The special adsorption phenomena on metallic salt-impregnated layers should be caused by the well-known complex formation[31] between metallic salts and amines, and the relationship between the basicities of amines and $R'_m$ differences between
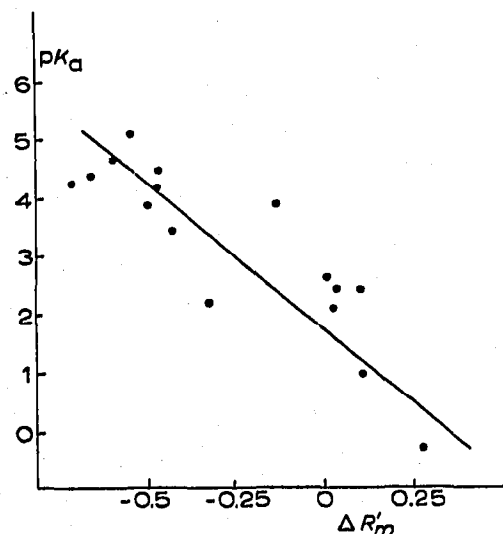
Fig. 1. Relationships between $pK_a$ values and $R'_m$ differences on layers A and B of aromatic amines. Solvent S1: benzene–acetic acid (9:1).
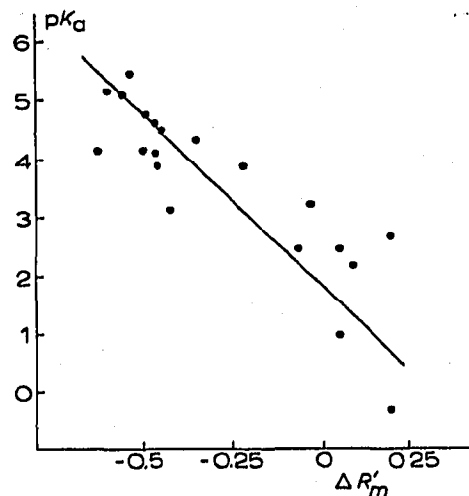
Fig. 2. Relationships between $pK_a$ values and $R'_m$ differences on layers A and B of aromatic amines. Solvent S2: benzene–methanol–acetic acid (8:1:1).

both layers also seem to support this assumption. However, the results of the following additional experiments suggest that the mechanism is more complicated. $p$-Toluidine was treated with $CdSO_4$ and $CuSO_4$ in water, S1, S3 and S4 (see Table I), and the products were collected as precipitates. The amine formed a 1:2 complex with $CuSO_4$, though the complex was a little unstable in acidic media, in all cases. (N contents: 7.25, 5.38, 5.25 and 7.10%, respectively; theoretical N in $CuSO_4(C_7H_9N)_2$

TABLE IV

$R_F$ VALUES OF N-SUBSTITUTED AROMATIC AMINES AND AMIDES ON CADMIUM SULPHATE-IMPREGNATED LAYERS

| Amines and amides | $pK_a$ | $R_F \times 100$ | | | |
|---|---|---|---|---|---|
| | | S1 | | S3 | |
| | | A | B | A | B |
| N,N-Dimethyl-o-toluidine | 5.86 | 8 | 8 | 72 | 41[a] |
| N,N-Dimethyl-m-toluidine | 4.66 | 12 | 7 | 73 | 41[a] |
| N,N-Dimethyl-p-toluidine | 5.50 | 10 | 8 | 70 | 41[a] |
| N,N-Dimethyl-α-naphthylamine | 4.88 | 22 | 16 | 75 | 71[a] |
| N,N-Dimethyl-β-naphthylamine | —— | 21 | 12 | 72 | 64[a] |
| Aceto-o-toluidide | | 29 | 37 | 48 | 50 |
| Aceto-m-toluidide | | 29 | 35 | 53 | 59 |
| Aceto-p-toluidide | | 29 | 35 | 52 | 54 |
| Aceto-α-naphthylamide | | 22 | 49 | 50 | 64 |
| Aceto-β-naphthylamide | | 19 | 44 | 53 | 59 |

[a] Tailing.

$= 7.48\%$.) In contrast, the amine produced a stable 1:2 complex with $CdSO_4$ only in water. (N contents: 6.67, 2.91, 0.57 and 0.0%, respectively; theoretical N in $CdSO_4(C_7H_9N)_2 = 6.62\%$.) As shown in Tables II and III, on the other hand, an apparent depression of the $R_F$ values of the amine by $CdSO_4$ impregnation was observed with any of the mobile phases. The amine on $CuSO_4$-impregnated layers, which was expected to produce a more stable complex compound on the layer, behaved similarly with respect to the $R_F$ values, but produced severely tailed spots. Formation of a stable complex on the layers therefore seems to be non-essential or rather harmful to obtain good separation of the amines. It can be assumed that much weaker bonding, probably by the simple electron donation from nitrogen to metal atom, is essential for good separation.

Studies on the infrared (IR) spectra of the metallic salt–amine complexes were also made. A strong red shift of bands assigned to the C–N stretching mode was observed on both complexes ($1267$ cm$^{-1}$ for toluidine, $1159$ cm$^{-1}$ for the $CuSO_4$ complex, and $1241$ and $1060$ cm$^{-1}$ for the $CdSO_4$ complex). Such a shift may indicate that the formation of the complexes is not only due to the ordinary electron donation from the amino nitrogen to the metal atom as is the case[32] between transition metals and 8-aminoquinoline in which a red shift of less than $30$ cm$^{-1}$ was observed, but also to other factors, such as $\pi$-electron donation from the aromatic ring and steric effects. Because of the lack of further information regarding IR spectra of such compounds, however, detailed studies on the structure of the complexes will be left for further investigations.

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