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The Analysis of Aliphatic Amine Mixtures: Determination of Secondary Plus Tertiary Amines by the Azomethine–Acidimetric Method

BY CHARLES D. WAGNER, RUSSELL H. BROWN[1] AND EDWARD D. PETERS

Until recently, the analysis of mixtures of primary and secondary aliphatic amines has been dependent on relatively unsatisfactory methods involving the use of nitrous acid. Hawkins, Smith and Mitchell[2] recently reported that primary amines could be satisfactorily determined by measuring the amount of water produced in the reaction of benzaldehyde with the primary amine. However, the accuracy obtainable with the method is markedly decreased when large amounts of water are present, and for each determination measurements must be made of water content of the sample, water content of the reagent and solvent and the amount of water produced by the reaction. The effect on the determination when ammonia is present in the amine mixture is not reported.

The reaction of an aromatic aldehyde with an aliphatic primary amine has also been utilized in the procedure described below for the determination of secondary aliphatic amines

$$\text{ArCHO} + \text{RNH}_2 \longrightarrow \text{ArCH}{=}\text{NR} + \text{H}_2\text{O}$$

The azomethine formed is a much weaker base than the secondary amine, and differentiation in a non-aqueous potentiometric titration may then be accomplished. A typical titration curve is reproduced in Fig. 1, showing the first sharp end-point at the completion of titration of the secondary amine and the less distinct end-point when the azomethine is converted to its salt. Although the second end-point may be estimated with fair accuracy, primary amine is generally calculated more accurately by difference between a separate total base determination and the secondary amine determination.

The procedure seems to be applicable to all aliphatic amine mixtures. Tertiary amines do not react with the aldehyde, and therefore when present are determined along with secondary amine. Ammonia, in the absence of water, analyzes as primary amine as shown in Fig. 1. In the absence of ammonia, water in the sample does not interfere even in amounts up to 95%. When both ammonia and water are present in large quantities, the azomethine method may be applied to the amines from which ammonia has been removed in a manner similar to that originally described by Leone.[3] The perchloric acid titration of an acetic acid solution of an acetylated amine mixture,[4] the azomethine method, and the sodium cobaltinitrite precipitation method for the determination of ammonia[5] offer means for the complete analysis of a mixture containing tertiary amine, secondary amine, primary amine, and ammonia.

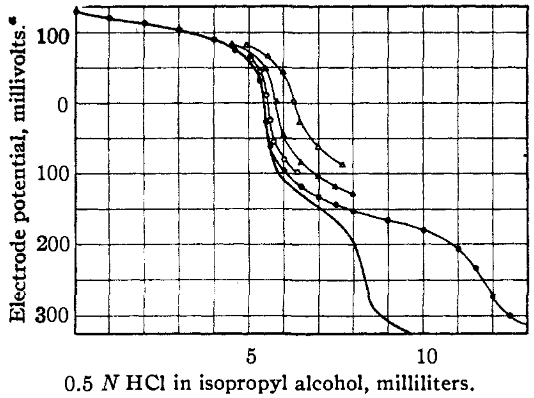

Fig. 1.—Effect of presence of ammonia and water on the azomethine titration curve. Samples contain 2.77 milliequivalents di-*n*-butylamine and 1.39 milliequivalents *n*-butylamine plus: —, typical titration curve, no additional components; -●-●-●-, 1.824 milliequivalents ammonia (6.3% by weight in sample); -O-O-O-, 0.370 milliequivalents ammonia + 5 g. water; -▲-▲-▲-, 0.925 milliequivalents ammonia + 5 g. water; -△-△-△-, 1.850 milliequivalents ammonia + 5 g. water.

[a] Zero on the electrode potential scale is equivalent approximately to a *p*H of 7 when the electrode system is used in aqueous solution.

Salicylaldehyde is the aromatic aldehyde recommended for use in the procedure. Although other common aromatic aldehydes behave similarly, the inflection points representing titration of secondary amine are not so definite, and in the presence of water the azomethines derived from most other aldehydes seem to hydrolyze more easily after the secondary amine is titrated. An additional advantage in the use of salicylaldehyde is its resistance to atmospheric oxidation, since the presence of a carboxylic acid would interfere in the titration by buffering the end-point. Salicylaldehyde also does not appear to react with certain secondary amines with which benzaldehyde does react under the conditions of the procedure.

Analytical Method

Reagents and Apparatus.—*Standard hydrochloric acid in isopropyl alcohol, 0.5 N,* is prepared by adding one volume of concentrated C. P. hydrochloric acid to isopropyl alcohol, diluting with the alcohol to 24 volumes, and standardizing against a standard base.

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[1] Present address: Department of Chemistry, Harvard University, Cambridge, Mass.

[2] W. Hawkins, D. M. Smith and J. Mitchell, Jr., THIS JOURNAL, **66**, 1662 (1944).

[3] P. Leone, *Gazz. chim. ital.*, **55**, 246 (1925).

[4] C. D. Wagner, R. H. Brown and E. D. Peters, THIS JOURNAL, **69**, 2609 (1947).

[5] K. G. Mizuch and A. Ya. Savchenko, *Org. Chem. Ind. U. S. S. R.*, **7**, 24 (1940).

TABLE I

APPLICATION OF AZOMETHINE METHOD TO KNOWN MIXTURES

Components in mixtures	1° Amine present eq. × 10^3	2° + 3° Amine present eq. × 10^3	2° + 3° Amine found eq. × 10^3	Error, %
Diethylamine and ethylamine	1.86	2.691	2.672	−0.7
Triethylamine, diethylamine and ethylamine[a]	3.72	4.56	4.60	+ .9
Di-*n*-butylamine and *n*-butylamine	2.75	2.756	2.742	− .5
Tri-*n*-butylamine, di-*n*-butylamine and *n*-butylamine[b]	2.75	5.36	5.30	−1.1
Di-*n*-amylamine[e] and *n*-amylamine	1.92	1.812	1.801	−0.6
Dimethylamine and *n*-butylamine	2.75	3.993	3.930	−1.6
Dioctylamine and *n*-amylamine	1.92	3.402	3.352	−1.5
Diisopropylamine[e] and isopropylamine[e]	4.226	3.983	4.000	+0.4
Diisobutylamine and isobutylamine	3.60	3.639	3.555	−2.3[c]
bis-(1,3-Dimethylbutyl)-amine[e] and 1,3-dimethylbutylamine[e]	3.44	3.480	3.525	+1.3
Dicyclohexylamine[e] and cyclohexylamine[e]	3.52	1.890	1.867	−1.2
Diisopropylamine[e] and β-phenylethylamine	2.645	3.949	3.934	−0.4
Diisopropylamine[e] and 1-isobutyl-3-methylbutylamine[e]	3.47	3.983	3.958	− .7
Piperidine and ethylamine	3.72	4.000	3.987	− .3
Diethanolamine and ethanolamine[d]	3.74	4.133	4.065	−1.6
Diallylamine[e] and allylamine[e]	3.92	3.884	3.901	+0.4
Dimethallylamine[e] and methallylamine[e]	4.26	3.807	3.788	− .5
Diethylenetriamine[e]	2.624	1.312	1.320	+ .6

[a] Triethylamine, 4.02 milliequivalents, and diethylamine, 0.538 milliequivalents. [b] Tributylamine, 3.88 milliequivalents, and dibutylamine, 1.48 milliequivalents. [c] Sample of diisobutylamine contained about 2.5% primary amine as shown by application of the azomethine method to the diisobutylamine sample itself. [d] Five ml. of water added to titration mixture and readings delayed after each addition of acid until further potential change due to hydrolysis of the diethanolamine–salicylaldehyde product was almost imperceptible. [e] Purified commercial and laboratory samples; all others are unpurified commercial samples obtained mainly from Eastman Kodak Company and Sharples Solvents Corporation.

The *salicylaldehyde* used should be a good grade free from salicylic acid.

The *sodium cobaltinitrite–sodium nitrite reagent* is prepared by dissolving 25 g. of sodium cobaltinitrite and 25 g. of sodium nitrite in water and diluting to 200 ml. Sodium cobaltinitrite satisfactory for use may be prepared as follows: One hundred and fifty grams of C. P. sodium nitrite and 50 g. of cobaltous nitrate hexahydrate are dissolved in 175 ml. of water in a one-liter conical flask. After adding in small portions, with shaking, 25 ml. of glacial acetic acid, the mixture is aerated with a strong current of air for one hour. Then ethyl alcohol (250 ml.) is added and the mixture is allowed to stand overnight. The precipitate is collected by suction filtration, washed thoroughly with ethyl alcohol, spread out to air dry for one hour, and stored in a brown bottle. The yellow solid should readily dissolve in water to produce a bright red, clear solution.

A convenient and satisfactory apparatus for use in the titration is a direct-reading *titrometer*, such as the Beckman Model M or the Precision-Shell instrument,[6] equipped with glass and calomel electrodes and a 10-ml. buret graduated in intervals of 0.05 ml.

Procedure.—A sample containing about four milliequivalents of secondary amine is added to 80 ml. of methanol and 5 ml. of salicylaldehyde contained in a titration beaker. The beaker is covered with a watch glass, the contents swirled to mix, and allowed to stand at room temperature for thirty minutes. The mixture is then titrated potentiometrically using standard 0.5 *N* hydrochloric acid in isopropyl alcohol. The secondary (plus tertiary) amine content is then calculated as equivalent to the acid used in titrating to the first end-point. Primary amine content may be calculated by difference utilizing a separate total base determination.

When ammonia is present, it may be removed from the amines and determined as follows: The sample, containing 15 to 20 milliequivalents of amine, is neutralized with hydrochloric acid in an ice-bath, diluted to about 25 ml. with water, and 25 ml. of the cobaltinitrite reagent is added. The mixture is allowed to stand one and one-half hours in ice, 40 ml. of methyl cellosolve is added, and after half an hour more in ice the mixture containing the yellow sodium diammonium cobaltinitrite precipitate is filtered by suction through an asbestos filter. After the precipitate is washed thoroughly with 50 ml. of 50% ice-cold methyl cellosolve, it, together with the asbestos, is transferred to a distilling flask, an excess of sodium hydroxide solution is added and the liberated ammonia is distilled in the usual manner into boric acid and titrated. If both water and ammonia are present in the original sample in large amounts, so that direct analysis for secondary amine is not possible, the ammonia may be removed as above and the amines in the filtrate recovered and analyzed. In order to recover the amines, the filtrate is transferred immediately after the filtration to a distilling flask, an excess of sodium hydroxide is added, and 50 ml. of distillate containing the liberated amines is received in 45 ml. of cold methanol. A 10–15 ml. aliquot of the methanol solution diluted to 100 ml. may then be used in the azomethine procedure for primary and secondary amine determination.

Experimental

Solutions of aliphatic amines in isopropyl alcohol (approximately 0.4 *N*) were prepared and standardized against standard acid. The method was then applied to mixtures of known amounts of primary and secondary amines or primary, secondary and tertiary amines. Results are tabulated in Table I. For purposes of calculation, it is assumed that the titratable nitrogen in a primary amine sample is all primary amino nitrogen, that in a secondary amine is all secondary amino nitrogen, etc.

Discussion

The values obtained seem to agree well with the theoretical values. In a total of 41 separate determinations on the above amine mixtures, the

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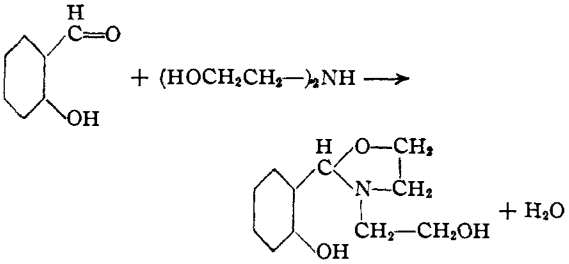
[6] C. J. Penther and F. B. Rolfson, *Ind. Eng. Chem., Anal. Ed.*, **15**, 337 (1943).

average error amounted to ±0.7% of the quantity of secondary amine present, as indicated by previous acidimetric standardization of the secondary amine solution. Curves obtained with the allylamines, methallylamines, ethanolamines, diethylene triamine, dimethylamine plus butylamine, and piperidine plus ethylamine exhibited end-points which were somewhat less sharp than in the case of other amines, but results were nevertheless clear cut.

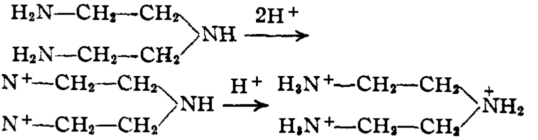
Experiments on a diethanolamine–ethanolamine mixture indicated that the diethanolamine had reacted with salicylaldehyde to form a compound of basicity similar to that of an azomethine. The compound formed is probably an oxazolidine, as Hawkins, Smith, and Mitchell[2] have suggested in the case of the similar reaction between benzaldehyde and diethanolamine.



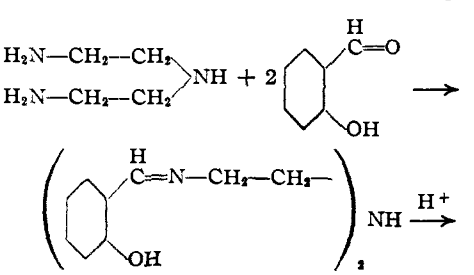
This compound is apparently more easily hydrolyzed than the azomethine, for after 5 ml. of water is added to the reaction mixture, the compound readily hydrolyzes as acid is added during the titration, and differentiation between primary and secondary amine is thus accomplished.

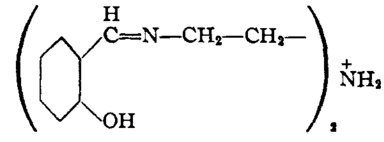
The behavior of diethylenetriamine with the azomethine method is interesting, since the compound has two primary amino groups and one secondary amine group on the same molecule. On direct titration, as illustrated in Fig. 2, the principal end-point indicates only two of the three amino groups act as fairly strong bases, the third being much weaker. After treatment with salicylaldehyde, only one amino group per molecule is measurably basic. We may postulate that the following equations explain the facts

(1)



(2)





In a simple acidimetric titration (equation 1) the presence of two positive charges, probably at the terminal primary amino groups, greatly decreases the basicity of the third amino nitrogen. In the presence of salicylaldehyde (equation 2), the two primary amine groups are rendered less basic by azomethine formation leaving the secondary amino group free to act as a rather strong base.

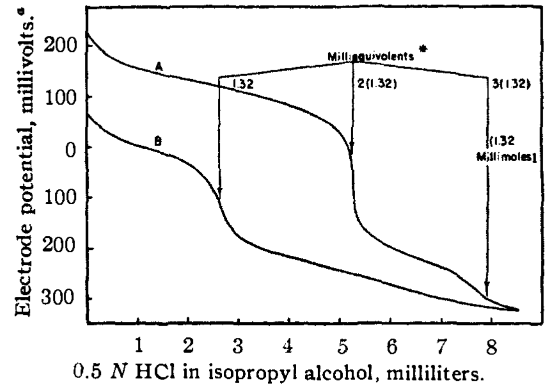
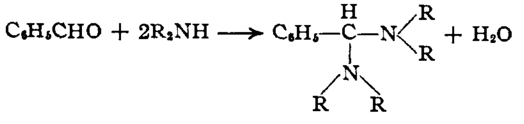


Fig. 2.—Azomethine titration of diethylenetriamine: A, acidimetric titration in methanol; B, acidimetric titration in methanol after treatment with salicylaldehyde.

[*] Based on 97% purity.

[a] Zero on electrode potential scale is approximately equivalent to a pH of 7 when the electrode system is used in aqueous solution.

When benzaldehyde was used in some determinations in place of salicylaldehyde, low results were obtained in the cases of di-*n*-amylamine, di-*n*-butylamine, diethylamine and particularly dimethylamine and piperidine. The latter two compounds analyzed to be only ten to thirty per cent. of the expected value. Since the second end-point corresponding to total base agreed with theory in each case, it seems evident that these secondary amines reacted to form compounds with basicities similar to that of the azomethines. Piperidine is known to condense with benzaldehyde to form N,N-benzaldipiperidine.[2] It is probable, therefore, that reactions with the straight chain secondary amines occur to varying extents, depending on the length of the alkyl chains, in the following manner



Secondary amines with branched chains did not exhibit this behavior, a fact undoubtedly due to steric hindrance. The observation by Hawkins, Smith and Mitchell[2] that a slight amount of water was produced in the reaction of benzaldehyde with diethyl- and di-*n*-butylamines may have been due to partial reaction between the secondary amines and the benzaldehyde, and not to presence of primary amine impurities.

Application to Mixtures Containing Ammonia.—Application of the method to known mixtures of di-*n*-butylamine, *n*-butylamine, and ammonia indicated that the secondary amine could be determined accurately in the presence of up to at least 7% ammonia by weight. In the presence of much water, however, high results were obtained when large amounts of ammonia were also present, as illustrated in Fig. 1.

The validity of the procedure to be applied to samples containing both ammonia and water was tested as follows: Known mixtures containing ammonia, a primary amine, or a primary amine plus a secondary amine, were neutralized with hydrochloric acid and the ammonium ions were removed and determined by precipitation with the cobaltinitrite reagent. The filtrate in each case was made basic with sodium hydroxide and the liberated amines were distilled into methanol and determined by acidimetric titration in the cases of single amines or by acidimetric titration plus the azomethine procedure when both primary and secondary amines were present. Typical results on several of such mixtures are tabulated in Table II. The ammonia separation is not applicable in the presence of methylamine, since the methylammonium cobaltinitrite precipitate is apparently not very soluble.

TABLE II

ANALYSES OF MIXTURES CONTAINING AMMONIA BY PRECIPITATION OF AMMONIA AND DETERMINATION OF AMINES RECOVERED AFTER THE AMMONIA SEPARATION

	Ammonia, grams		Primary amine, grams		Secondary amine, grams	
Amines in sample	Present	Found	Present	Found	Present	Found
n-Butyl	0.0148	0.014	7.22	7.10		
Allyl	.0205	.0199	1.89	1.84		
Ethyl	.0205	.0208	1.175	1.155		
Cyclohexyl	.0204	.0202	2.56	2.49		
Isopropyl and	.0138	.0135	0.0979	0.0947	3.24	3.20
diisopropyl	.0691	.0675	.326	.323	0.810	0.799
Di-*n*-butyl and *n*-butyl	.1232	.1199	.822	.776[a]	2.015	1.922[a]

[a] Recovery of higher-boiling amines is not complete by the prescribed distillation procedure.

Acknowledgment.—The authors wish to thank Dr. L. Lykken for his helpful advice, especially in connection with the electrometric aspects of this work.

Summary

1. A new acidimetric method of general applicability has been developed for the determination of secondary aliphatic amines in the presence of primary amines and ammonia. The method depends upon the fact that salicylaldehyde reacts quantitatively with primary amines and ammonia to form compounds of decreased basicity.

2. With this method tertiary amines analyze as secondary amines, since neither type reacts with salicylaldehyde. Ammonia in the absence of water reacts like a primary amine and does not interfere with the secondary amine determination. Water in the absence of ammonia has no effect on the analysis.

3. Ammonia in a mixture with aliphatic amines may be determined by precipitation with sodium cobaltinitrite followed by distillation of ammonia from the precipitate decomposed with alkali. Tertiary amines in such mixtures may be readily determined by acetylating the mixture and titrating the mixture with perchloric acid in acetic acid. Therefore, with the aid of a total base determination, all four components of a mixture containing tertiary amine, secondary amine, primary amine, and ammonia may be quickly and accurately determined using acidimetric procedures.

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[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, THE UNIVERSITY OF TEXAS]

Allylic Chlorides. III. Preparation of the 1,3-Dichloro-2-methyl-1-propenes

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In the course of current studies on the influence of geometrical configuration on chemical reactivity[2,3] it became desirable to prepare both pure *cis* and pure *trans* 1,3-dichloro-2-methyl-1-propene. The synthesis of these dichlorides has been attempted by the chlorination of both isobutylene and methallyl chloride,[4] dehydration of 1,3-dichloro-2-methyl-2-propanol,[4b] pyrolysis of 1,2,3-trichloro-2-methylpropane[5] and by the dehydrochlorination of 1,2,3-trichloro-2-methylpropane by the action of quinoline.[6] In every case either only one isomer was formed or the mixture of isomers produced was not resolved. It has, however, been suggested by Mooradian and Cloke[7] that this might be accomplished through the hydroxyl derivatives.

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(1) Present address: Magnolia Petroleum Co., Dallas, Texas.

(2) Hatch and Roberts, THIS JOURNAL, **68**, 1196 (1946).

(3) Hatch, Gordon and Russ, paper presented at the Texas Regional Meeting of the American Chemical Society, Dallas, Texas, December 13, 1946.

(4) (a) Burgin, Engs, Groll and Hearne, *Ind. Eng. Chem.*, **31**, 1413 (1939); (b) D'yakonov, *J. Gen. Chem. U. S. S. R.*, **10**, 402 (1940); (c) Burgin, Hearne and Rust, *Ind. Eng. Chem.*, **33**, 385 (1941); (d) Suter and Bordwell, THIS JOURNAL, **65**, 507 (1943); (e) Pogorshelski, *J. Russ. Phys.-Chem. Soc.*, **36**, 1129 (1904).

(5) Rogers and Nelson, THIS JOURNAL, **58**, 1029 (1936).

(6) Mooradian and Cloke, *ibid.*, **68**, 785 (1946).

(7) Mooradian and Cloke, *ibid.*, **67**, 942 (1945).