The Micro-determination of Picric Acid in Picrates

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Three methods for the determination of picric acid in organic picrates, on a micro scale, have been examined. Neither Bolliger's method of titration with methylene blue, nor the method of titration with sodium hydroxide, is of universal application. The macro method of Busch and Blume, involving precipitation with nitron, gives satisfactory results on a micro scale, and is applicable to all the compounds examined. The solubility of the precipitate and the effect of chloride on its purity have also been examined.

Bolliger[1] has described a micro method for the determination of picrates by titration with methylene blue. It is also claimed[2] that picrates can be titrated with sodium hydroxide, with ethyl bis-2:4-dinitrophenylacetate[3] as indicator, but no experimental details have been given. A macro-gravimetric method involving precipitation with nitron has been described by Busch and Blume[4] and recommended by Cope and Barab,[5] who reviewed the literature up to 1917.

Preliminary experiments carried out in this laboratory some years ago suggested that this last method might be successfully adapted to a micro scale, and the work here described was undertaken to substantiate this and to assess the relative merits of the three methods.

When this work was nearing completion, a further method, described by Stöhr and Scheibl,[6,7] came to our notice. In this, the picric acid is reduced to picramic acid, which is determined colorimetrically. The results quoted, given in terms of the molecular weights of the parent compounds, are within about ± 10 per cent. of the theoretical values.

Determination with methylene blue

The procedure followed was essentially that of Bolliger.[1]

Reagents—

Methylene blue, 0·01 N—Dissolve 3·8 g of methylene blue in water and make up to 1000 ml. Store over a few ml of chloroform in a dark bottle.

Methylene blue, 0·001 N—Dilute the above stock solution as required.

Chloroform—Analytical-reagent grade.

Pyridine—Analytical-reagent grade.

Procedure—

Weigh 3 to 6 mg of the sample into a 50-ml separating funnel. Dissolve it in 5 drops of pyridine and add 4 to 5 ml of water and 20 ml of chloroform. Titrate with 0·001 *N* methylene blue, shaking after each addition to extract the colour into the chloroform. Replace the chloroform when it becomes saturated with methylene-blue picrate. Replace the chloroform more frequently near the end-point, which is reached when addition of methylene blue produces in the aqueous phase a blue colour that is not extractable with chloroform.

Standardise the methylene blue against pure picric acid.

Determination with sodium hydroxide

It is said[2] that picrates can be titrated with standard sodium hydroxide, with ethyl bis-2:4-dinitrophenylacetate[3] as indicator.

With 0·01 *N* sodium hydroxide and pure picric acid, the end-points were very vague in aqueous solution, but there was a great improvement on dissolving the sample in a mixture of equal volumes of acetone and alcohol, the solvent in which it is recommended that the indicator should be made up.[2] The use of more than 5 ml of solvent also rendered the end-point indistinct.

Reagents—

Solvent—Acetone and ethanol (1 + 1).
Indicator—Ethyl bis-2:4-dinitrophenylacetate, 1 per cent. solution, in the above solvent.
Sodium hydroxide, 0·01 N.

Procedure—

Dissolve 20 to 30 mg of the sample in 3 to 5 ml of solvent. Add 3 or 4 drops of the indicator and titrate with 0·01 *N* sodium hydroxide to a pale green colour. (The colour will revert to yellow on standing, owing to absorption of carbon dioxide.) Standardise the sodium hydroxide against pure picric acid.

1 ml of 0·01 *N* sodium hydroxide ≡ 2·291 mg of picric acid.

Determination with nitron

Nitron (2:5:6-triphenyl-2:3:5:6-tetra-aza*bicyclo*[2:1:1]hex-3-ene) was first made by Busch[8] and later used by him for the determination of picric acid on a macro scale.[4] It is of interest, in view of the fact that nitron nitrate is more soluble than the picrate, to note that Utz[9] determined picric acid by a two-stage oxidation to nitrate, followed by precipitation as nitron nitrate. The method here described was adapted from that given by Busch and Blume.[4]

Reagents—

Nitron reagent—A 5 per cent. w/v solution of nitron in 5 per cent. v/v acetic acid. Filter this solution before use.
Sulphuric acid, 2 N.

Procedure—

Dissolve 8 to 10 mg of the sample in 10 ml of water. Add 2 or 3 drops of 2 *N* sulphuric acid and 1 ml of nitron reagent. Heat the solution on a steam-bath for 5 minutes and set it aside for at least 2 hours. Collect the precipitate on a sintered-glass filter of porosity 4 with the aid of a syphon tube,[10] transferring the precipitate with water only, and dry it at 105° C.

1 mg of nitron picrate ≡ 0·4231 mg of picric acid.

Solubility of nitron picrate

Busch and Blume[4] stated that even if picric acid is at as great a dilution as 1 in 250,000, a precipitate is still formed. Cope and Barab[5] incorrectly assumed this to mean that the solubility of nitron picrate is 1 in 250,000. (They have made the same mistake in translation for the other limiting dilutions quoted by Busch.) We find the solubility of nitron picrate, under the conditions of determination, to be of the order of 1 in 800,000. We had at our disposal no direct method of determining such a low solubility and hence the following method was adopted. Ten millilitres each of a series of dilute aqueous picric acid solutions were treated with 2 drops of 2 *N* sulphuric acid and 1 ml of nitron reagent. After being heated on the steam-bath for 5 minutes they were set aside, and the formation of any precipitate was noted. The results are shown in Table I.

It appears from these results that, under our conditions, approximately 6 μg of picric acid will remain in solution, equivalent to 14 μg of nitron picrate. These figures are equivalent to solubilities of 1 in 1,800,000 for picric acid, or 1 in 800,000 for nitron picrate.

Busch and Blume[4] also stated that the precipitate is almost insoluble in alcohol and gave

a result for a solution in 50 per cent. alcohol that is only slightly low (found by them, 63·44 per cent.; required, 63·96 per cent. of picric acid). Under our conditions it was at once apparent that the solubility is far too great to permit the use of alcohol in micro work, and quantitative determinations showed that the solubility of nitron picrate in ethanol, at room temperature, is about 0·4 mg per ml.

TABLE I

PRECIPITATION OF DILUTE PICRIC ACID SOLUTIONS WITH NITRON

Amount of picric acid present, μg	
20	Precipitate formed within 15 minutes
13	Precipitate formed within 30 minutes
10	Precipitate formed within 1 hour
7	Precipitate formed within 2 hours
6·5	Very slight precipitate after 3 hours
6	No precipitate after 24 hours; slight trace after 72 hours

EFFECT OF OTHER ANIONS

Previous workers have given lists of anions that may or may not interfere with the precipitation. Busch and Blume[4] state that bromide, iodide, chlorate, perchlorate, nitrite, nitrate and chromate must be absent. Visser[11] claims that oxalate and salicylate interfere, but that sulphate, chloride, formate, acetate, borate, benzoate, tartrate, citrate and phosphate do not.

There appears, however, to be some doubt about the effect of chloride. Dealing with its effect on the precipitation of nitron nitrate, Busch[12] found that the presence of a small amount of chloride (giving a solution 0·05 *N* with respect to chloride) gave a precipitate slightly contaminated with chloride. Flagg[13] states that "results obtained in the presence

TABLE II

COMPARISON OF RESULTS

Picrate of	Picric acid required, %	Picric acid found with: Methylene blue, %	Sodium hydroxide, %	Nitron, %
(Picric acid)	100·0	—	—	99·8
Naphthalene	64·1	63·8	64·1	63·8
2-Methylnaphthalene	61·7	61·9	62·5	61·3
1-Naphthol	61·35	61·2	61·3	61·05
4-Acetylpyridine (R)	65·4	65·2	65·1	64·55
3-Dimethylamino-2-methyl-1:1-diphenylpropane (R)	47·5	44·0 to 45·2	10·0	46·8
3-Dibutylaminopropylamine (dipicrate) (R)	71·1	68·0 to 69·3	31·6	70·5
Triethylamine	69·35	65·6 to 68·6	14·7	69·0
Ammonia	93·1	93·2	7·2	93·0

The compounds marked (R) were research compounds that had previously given satisfactory elementary analyses. The remainder were prepared by us and had melting points in agreement with the literature values.

of chlorides are generally high, presumably because of co-precipitation." On the other hand, Booth[14] found that up to 100 ml of *N* hydrochloric acid did not interfere.

We have investigated the effect of chloride and find that it depends on the concentration of both reagents. If nitron reagent is added dropwise to 10 ml of dilute hydrochloric acid, a gelatinous precipitate is formed at concentrations greater than 0·2 *N* with respect to hydrochloric acid. On the other hand, if 1 ml of nitron reagent is diluted with 10 ml of water, no immediate precipitate is obtained by adding 35 ml of 2 *N* hydrochloric acid, although clusters of white needles are deposited if the solution is set aside for several hours. The addition of more than 0·1 ml of concentrated acid gives a gel, as described by Busch,[8] which slowly crystallises as white needles, m.p. 225° C, with decomposition and previous shrinking (Busch gives m.p. 242° C). (Found on material dried at 110° C *in vacuo*: C, 68·65 per cent.; H, 4·6 per cent. Calculated for $C_{20}H_{16}N_4.HCl$: C, 68·8 per cent.; H, 4·9 per cent.) The dried

substance is hygroscopic (loss at 110° C *in vacuo* after exposure to the atmosphere for 24 hours is 6·6 per cent.). It is evident, therefore, that chloride should be absent.

Results

Results by the three methods are shown in Table II.

Discussion

The methylene-blue method gave low and erratic results for three of the compounds examined (see Table II), owing, it was suspected, to the compounds themselves being extracted by the chloroform. To check this, 1 mg of each of the compounds examined was shaken with 2 drops of pyridine, 1 ml of water and 1 ml of chloroform. It was seen that the five compounds that gave good results were all extracted slightly by chloroform. Picric acid itself was extracted to about the same extent, and it seemed therefore that the results were good by a compensation of errors. The three compounds that gave low results were all extracted to a far greater extent; with 3-dibutylaminopropylamine picrate the intensity of colour was about the same in both phases. Attempts to overcome the extraction effect by adding methylene blue to within 1 ml of the calculated end-point before replacing the chloroform gave results that were slightly improved but still not satisfactory. Bolliger[1] appreciated that some substances would be more soluble in chloroform than in water, as he suggested that substances not readily soluble in water should be dissolved in chloroform, but he did not mention the possible effect on his results, which are, in general, slightly low.

The sodium hydroxide method gave good results for the picrates of neutral or weakly basic compounds, but not for those of strong bases. This is not unexpected, as the method is merely an acid - base titration. The procedure described above, with relatively large sample weights, is obviously capable of refinement, but owing to the inherent limitations of the method it was not further investigated.

The nitron method is applicable to all the compounds examined, but the results are, in general, about 0·4 per cent. low. If a correction is made for the solubility of the precipitate, as found above, they are only increased by about 0·07 per cent. It is evident, therefore, that either the solubility error is greater than is indicated by the figures in Table I, or there is another, undetected, source of error. The uncorrected results are sufficiently accurate for most purposes, but if greater accuracy is required, an empirical correction, based on results with pure picric acid or a reference picrate, can be applied.

Conclusions

The nitron method is the only one of the three examined that is applicable to all the compounds used, and it has the additional advantage of being an absolute method, since no standardisation is required. In general, therefore, it would be the method of choice. The simple and rapid sodium hydroxide titration would be preferable, however, if analyses were required for a series of picrates known to be derived from non-basic substances.

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