at 105° and kept in a desiccator, was used and the procedure of McBride[14] followed. Portions of the ferrous sulfate solution to be standardized were diluted with 150 to 200 cc. of recently boiled water and 10 cc. of 6 M sulfuric acid and the ferrous ion titrated with a standard permanganate solution. All volumetric apparatus used was standardized. Approximately the same rate of flow of the permanganate was used when titrating the ferrous sulfate with a volume buret as in the standardization of the permanganate. The volume of permanganate solution required was corrected in both titrations by subtracting the amount necessary to produce a visible color in blank determinations.

Summary

The practical limits of acidity for the electrometric titration of dichromic acid with ferrous sulfate have been determined.

The amount of ferrous sulfate required to titrate a given amount of dichromic acid varies with the concentration of the latter.

Dissolved air has a negligible effect on the titration.

Hydrofluoric acid in sufficient concentration reduces the amount of ferrous sulfate required by about 0.1%.

When the ferrous sulfate solution was standardized by means of a standard permanganate solution the amount required to titrate a known amount of dichromate in 0.01 N solution of the latter was about 4 parts in a thousand higher than the calculated.

When the dichromate concentration was 0.003 N the amount of ferrous sulfate required was about 0.1% higher than the calculated.

The titration of ferrous ion with a potassium dichromate solution gives results which agree with those obtained with the reverse titration.

NEWPORT, RHODE ISLAND

THE USE OF THE NEWER INDICATORS IN TITRATIONS OF ALKALOIDS

By WILLIAM J. McGILL

Not since Kippenberger's study[1] of the adaptability of certain indicators for alkaloidal titrations has there been any extended or systematic work on this subject.[2] The indicators recommended in the United States, British, French, and German pharmacopeias have been selected, it seems, principally with a view to the sharpness of the end-points they afford in the titration rather than because they give a marked color change at or near the correct end-point of the titration.

[14] McBride, THIS JOURNAL, **34**, 415 (1912).

[1] Kippenberger, Z. anal. Chem., **39**, 201 (1900).

[2] An article discussing the use of the newer indicators in alkaloidal titrations, based on data obtained by colorimetric methods has been published by Evers, Pharm. J., 1921, 470 and is reprinted in the J. Am. Pharm. Assoc., **10**, 676 (1921).

According to the theoretical considerations set forth by Noyes,[3] and Bjerrum,[4] *"the end-point in any titration with a given indicator is reached when the hydrogen-ion concentration in the titrated solution attains a definite value, and the end-point is determined solely by that concentration. This definite value varies with the ionization-constant of the indicator, and with the proportion of the indicator transformed."* The term *"indicator-function"* has been used by Noyes[3] to designate this value.

By making use of the optimum values of the indicator function for different types of titrations, it is possible to designate the indicator which will give the most accurate results in any titration, entirely on theoretical grounds.[5] The most desirable indicator for use in a particular acidimetric titration may also be determined empirically, using experimental methods, and best by the use of the hydrogen electrode. It is necessary only to measure the hydrogen-ion concentration of the titrated solution at the correct end-point, and then to select the indicator whose optimum value for the indicator function lies closest to this figure.

The indirect method of titrating alkaloids is now ordinarily employed, and the titrated solution of an alkaloid thus contains, in addition to the alkaloidal salt and its dissociation products, the inorganic salt formed as a result of the reaction of the standard alkali and acid used and the dissociation products of this salt. The amount present is usually small, particularly if not too great an excess of acid has been added over the theoretical quantity necessary to dissolve the alkaloid. Experimental data given later will show that the "neutral-salt" effect due to this factor has little influence on the hydrogen-ion concentration, and for our purposes may be disregarded.

Briefly, the method used in finding the hydrogen-ion concentration of a titrated alkaloidal solution was to measure, by means of the potentiometer, the concentration afforded by an aqueous solution of the corresponding pure alkaloidal salt, in various dilutions. In titrating alkaloidal solutions the dilution may run from 0.02 to 0.002 N, and the experimental results lead us to believe that within this range, dilution has only a slight effect on the hydrogen-ion concentration of the solution.

Quinine

The indicators usually suggested for the titration of the cinchona alkaloids and cinchona residues are methyl orange, methyl red, and hematoxylin. The last, in the hands of most workers, gives a very unsatisfactory end-point. From the table which follows it can be seen that both methyl orange, which gives its most pronounced color change at P_H 4.0

[3] Noyes, THIS JOURNAL, **32**, 815 (1910).

[4] Bjerrum, "Sammlung Chem. u. Chem.-Tech. Vorträge," **21**, 1 (1914–15).

[5] Ref. 3, p. 861.

to 4.2, and methyl red, which changes color at P_H 5.4–5.6, will give results in the titration of the cinchona alkaloids that are too high.

TABLE I

SÖRENSEN VALUES FOR CINCHONA ALKALOID SOLUTIONS

Dilution	Quinine hydrochloride	Quinine hydrochloride in presence of neutral salt Conc. of NaCl		Cinchonine hydrochloride
N	P_H	N	P_H	P_H
0.1	5.96	...	..	..
0.02	5.98	0.02	5.98	5.71
0.01	5.98	0.01	5.98	..
0.002	6.01	0.002	6.02	5.77

Bromocresol purple, one of the sulfonphthalein indicators, gives its first visible color-change at P_H 6.0, and consequently should give more accurate results with quinine than methyl red.

TABLE II

TITRATION OF CINCHONA ALKALOIDS

Indicator	Quinine Present	Found	Cinchonine Present	Found
	G.	G.	G.	G.
Methyl red	0.9385	0.9492	0.2434	0.2448
	0.2436	0.2553	0.1622	0.1662
	0.5512	0.5624	0.2374	0.2402
	0.3120	0.3218	0.2311	0.2398
	0.2348	0.2526	0.2276	0.2321
	0.1586	0.1632	....	....
Bromocresol purple	0.2398	0.2412	0.2656	0.2633
	0.3610	0.3615	0.3562	0.3546
	0.2722	0.2718	0.2136	0.2124
	0.1545	0.1560	0.2096	0.2078

In the titration of cinchona residues with bromocresol purple, the end-point is not more definitely marked than that given by methyl red.

TABLE III

TITRATION OF MORPHINE

Dilution	Sörensen values	Present	Titration Found Methyl red	Found Bromophenol blue
N	P_H		G.	G.
0.1	3.98	0.2	0.1980	0.2015
0.01	3.99	0.2	0.1960	0.2012
0.004	3.99	0.2	0.1980	0.1998
0.002	4.00	0.2	0.1982	0.1998
...	..	0.2	....	0.1998
...	..	0.2	....	0.1980

Cochineal and methyl red, both ordinarily used in morphine titration, give their most pronounced color changes at P_H 5.4–5.8, so that results obtained with these indicators will always be too low.

Bromophenol blue gives a very satisfactory end-point with opium residues, titrating to the first tinge of blue in the solution.

TABLE IV

TITRATION OF ATROPINE

Dilution N	Sörensen values P_H	Bromophenol blue		Methyl red	
		Present G.	Found G.	Present G.	Found G.
0.1	3.8	0.1367	0.1362	0.1424	0.1396
0.02	3.81	0.2055	0.2045	0.1764	0.1740
0.01	3.81	0.1686	0.1712	0.1140	0.1127
0.002	3.84	0.1830	0.1821	0.1320	0.1284
. . .	. .	0.1708	0.1689	. . . .	. . . .
. . .	. .	0.1728	0.1732	. . . .	. . . .
. . .	. .	0.1588	0.1590	. . . .	. . . .
. . .	. .	0.1256	0.1249	. . . .	. . . .

It will be seen that methyl red or cochineal should give too low results in atropine titrations, and this is substantiated by experimental results. Bromophenol blue gives very good results in the titration of residues from mydriatic drugs, the correct end-point coming where the first blue tinge appears in the solution.

TABLE V

TITRATION OF STRYCHNINE

Dilution N	Sörensen values hydrochloride P_H	Bromocresol purple		Methyl red	
		Present G.	Found G.	Present G.	Found G.
0.02	5.42	0.0756	0.0755	0.0408	0.0393
0.01	5.44	0.0500	0.0491	0.0596	0.0601
0.002	5.45	0.1041	0.1032	. . . .	. . . .

From these values, it is apparent that methyl red can best be used in the titration of strychnine.

Discussion

From an inspection of the results obtained in the titrations carried out with different indicators, it is seen that in the case of morphine, atropine and quinine the indicators usually recommended for use in volumetric determinations of these alkaloids give results not nearly so accurate as should be theoretically obtained. Thus, in the case of morphine, the average error using methyl red amounted to 1.4%. Using bromophenol blue, whose optimum indicator function more nearly corresponds to the hydrogen-ion concentration afforded by morphine salts, the average error is only 0.5% and in some cases is as low as 0.1%. Even methyl orange does not give as good results, because an inspection of the ionization constant of this indicator will show that it is necessary that it be much

more than 25% transformed before the color change corresponding to the hydrogen-ion concentration at the correct end-point for a morphine titration is reached.   According to Noyes,[3] the best transformation value for an indicator lies between 5 and 25%.

The conflicting values for the dissociation constants of alkaloids, given in the literature, preclude anything more than an approximate comparison of the optimum value for the indicator function obtained by calculation, and that determined empirically, for any particular titration.

Summary

1.   The Sörensen values of various alkaloidal salts in aqueous solution have been determined by the potentiometer method.   From these values the indicator giving the most accurate results in titrations of the corresponding alkaloid has been selected and experimental results are given to justify the selection.

2.   The greater accuracy of some of the sulfonphthalein indicators in alkaloidal titrations has been pointed out.

ANN ARBOR, MICHIGAN

THE DIFFUSION OF HYDROGEN AND HELIUM THROUGH SILICA GLASS AND OTHER GLASSES[1]

BY G. A. WILLIAMS AND J. B. FERGUSON

Introduction

Villard,[2] in 1900, noted that gas leaked into an evacuated silica glass vessel when the latter was heated over a Bunsen flame to 1000° and because he found that this gas would diffuse readily through platinum, he concluded that it was hydrogen. His work was followed by that of other investigators; Jaquerot and Perrot,[3] Berthelot,[4] Richardson and Richardson,[5] Bodenstein and Kranendieck,[6] Mayer[7] and Wüstner.[8]

The probable permeability of our modern water-clear silica glass can hardly be predicted from these results.   Several reasons may be assigned for this, such as the qualitative nature of most of the work; the discrepancies between the observations of the various workers and the fact that

[1] Presented in part at the Rochester meeting of the American Chemical Society. April, 1921.

[2] Villard, *Compt. rend.*, 130, 1752 (1900).

[3] Jaquerot and Perrot, *Arch. sci. phys. nat. Geneve*, [4] 20, 128 (1905).

[4] Berthelot, *Compt. rend.*, 140, 821 (1905).

[5] Richardson and Richardson, *Phil. Mag.*, 22, 704 (1911).

[6] Bodenstein and Kranendieck, *Nernst-Festschrift*, 1912, 100.

[7] Mayer, *Phys. Rev.*, 6, 283 (1915).

[8] Wüstner, *Ann. Physik*, 46, 1095 (1915).