Procedure for the Simultaneous Determination of Tartaric and Citric Acids and Total Carbonate by Potentiometric Titrimetry and Its Application to Antacid Analysis

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The application of a linear algebraic method to the potentiometric titration of a mixture of tartaric and citric acids and sodium carbonate and sodium hydrogen carbonate (previously treated with strong acid), permits the determination of the concentration of each individual acid and the total equivalent of carbonate in antacids. It is also possible to determine individual concentrations of sodium carbonate and sodium hydrogen carbonate by combining the results of the described titration with the acidimetric titration of a sample previously treated with an excess of strong base.

Keywords: *Citric acid determination; tartaric acid determination; total carbonate determination; antacid analysis; potentiometric titrimetry*

Antacids are drugs that are used to reduce the acidity of the stomach and relieve the symptoms of occasional indigestion.[1] Tartaric acid, citric acid, sodium hydrogen carbonate and sodium carbonate are components of some types of common antacid formulations.

The analysis of the components of these pharmaceutical preparations has involved a gravimetric procedure followed by titration for the determination of tartaric acid,[2] a gravimetric method for the determination of citric acid[3] and a gasometric method for the determination of carbonate.[2] Recently, a method involving the use of cationic and anionic resins and titration of the respective eluates for the determination of sodium citrate and sodium hydrogen carbonate in antacids has been described by Tan and Szopa.[4]

Determining these components individually is time consuming and it was, therefore, the objective of this work to develop a method that allows the simultaneous determination of tartaric and citric acids and the total equivalent carbonate with one titration. However, the titration curve produced in the base potentiometric titration of a mixture of hydrochloric, tartaric and citric acids (resulting from the treatment of a sample of antacid with an excess of strong acid) is unsuitable for the determination of these acids by a conventional procedure and it is necessary to make use of special calculation methods. Several mathematical and graphical methods have been developed for the evaluation of titration data and these have been discussed by Ivaska[5] and also summarised by Ivaska and Nagypal.[6]

In addition Ivaska and Nagypal have also derived a general expression involving the transformation of titration curves of mixtures of weak acids in a system of linear equations, which permits the evaluation of the concentration of the acids present in the mixtures. This method was applied to our titration data using a computer program written by Ivaska and Nagypal for this purpose.

The possibility of using the same calculation method[6] for the acid potentiometric titration of a drug treated with a strong base for the determination of the individual concentrations of sodium carbonate and sodium hydrogen carbonate was also studied.

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Experimental

All reagents used in the preparation of solutions were of analytical-reagent grade. Standardisation of solutions was carried out by the usual methods.

All solutions to be titrated were made 1.0 M in sodium nitrate. The titrant was 0.1 M sodium hydroxide solution which was also made 1.0 M in sodium nitrate.

The pH measurements were carried out using a Micronal B-375 pH meter, a Metrohm EA109 glass electrode and an Orion double-junction reference electrode. The outer chamber of the reference electrode was filled with a saturated solution of potassium chloride. The titrant was added with a Metrohm EA 457 microburette. During the titration, carbon dioxide-free nitrogen was bubbled into the solution.

The hydrogen ion concentration was calculated from e.m.f. measurements using the equation

$$E = E^{\circ\prime} + 59.16 \log [H^+] + E_j$$

where E_j, the junction potential, is given by the equation

$$E_j = j_H [H^+] + j_{OH} [OH^-]$$

The values of the parameters $E^{\circ\prime}$, j_H and j_{OH} (the proportionality constants that relate the junction potential, E_i, with the concentration of hydrogen and hydroxyl ions, respectively) and K_w (the ionic product of water) were determined by the titration of a solution of hydrochloric acid, 1.0 M in sodium nitrate, with a solution of sodium hydroxide also 1.0 M in sodium nitrate, in accordance with the procedure of Pehrsson *et al.*[7]

The pK_a values, necessary for the calculation of the concentration of the acids, were evaluated from the titration data of the respective acid with sodium hydroxide, both solutions being 1.0 M in sodium nitrate. The results from the titration of sodium carbonate solution with hydrochloric acid were utilised for determining the pK_a values of the carbonic acid.

The calculation of pK_a values was carried out using the computer program developed by Ivaska and Nagypal.[6] In this instance the input data are the initial volume of solution, the concentrations of the acid and titrant, the ionic product of water and the pairs of values of titrant volume and pH. The constants obtained are constants in terms of concentration (stoicheiometric constant) in this ionic medium.[8]

Procedure for the Titration of Antacid

Transfer about 5 g of antacid sample into a 500-ml calibrated flask and dissolve the sample in doubly distilled water. To a 30-ml aliquot, add 30 ml of 0.1 M hydrochloric acid, boil for 1 min and transfer into a 250-ml calibrated flask containing sodium nitrate to make the final solution 1.0 M in sodium nitrate. Transfer 30 ml of this solution into the titration flask and titrate.

Procedure for the Reverse Titration of Antacid

Transfer 0.5 g of antacid sample into a 500-ml calibrated flask, dissolve in 50 ml of 0.1 N sodium hydroxide solution, add sodium nitrate in order to make the final solution 1.0 M in this salt and dilute to the mark with boiled water. Transfer 30 ml of this solution into the titration flask and titrate with 0.1 M hydrochloric acid. During the titration, carbon dioxide-free nitrogen is bubbled into the solution.

The concentrations of the acids in the mixtures were determined using the same computer program developed by Ivaska and Nagypal.[6] In this instance the input data are the initial volume of solution, the concentration of titrant, the ionic product of water, the pairs of values of titrant volume and pH and the pK_a values of the acids determined in separate experiments. About 25 points were employed in the calculations; however, as noted by Ivaska and Nagypal[6] it is important that points in the pH range of p$K \pm 0.5$ are included in the calculations.

Table 1. pK_a values (with their standard deviations) for tartaric, citric and carbonic acids. Temperature = 25.0 °C and μ = 1.0 M ($NaNO_3$)

Acid	pK_1	pK_2	pK_3
Tartaric* ..	2.718 ± 0.002	3.659 ± 0.004	
Citric*	2.759 ± 0.009	4.051 ± 0.005	5.122 ± 0.007
Carbonic† ..	5.899 ± 0.026	9.260 ± 0.001	

* Results are the means of six determinations.
† Results are the means of three determinations.

The procedure based on precipitation as potassium hydrogen tartrate was utilised to confirm the concentration of the tartaric acid.[2] The citric acid content was confirmed by gravimetry in the form of pentabromoacetone.[3] The total carbonate was confirmed by precipitation with barium chloride, dissolution in 0.1 M hydrochloric acid and titration with 0.1 M sodium hydroxide solution. Before titration the solution was boiled in order to eliminate carbon dioxide.

Results and Discussions

The pK_a values obtained for tartaric, citric and carbonic acid are presented in Table 1. The pK_a values for carbonic acid were obtained from the titration results of sodium carbonate with hydrochloric acid as described under Experimental.

Table 2 shows the results obtained for the base potentiometric titration of a mixture of tartaric, citric and hydrochloric acids. The result for the hydrochloric acid content is important because the result of its determination is used for the calculation of the carbonate content of antacids. The results obtained for an alkalimetric titration of a mixture containing tartaric and citric acids, sodium carbonate and sodium hydrogen carbonate, previously treated with a known amount of hydrochloric acid, are also shown in Table 2. The composition of this synthetic mixture resembles those of actual samples of antacids. The concentration of carbonate in terms of equivalents per litre was calculated from the difference between the amount of hydrochloric acid added and the amount found in the titration. This value effectively corresponds to the neutralising power of the mixture. The accuracy attained for determination of the three components of the mixture is reasonably satisfactory (considering the complexity of the mixture).

The results for the determination of tartaric and citric acids and total equivalents of carbonate in a sample of antacid are presented in Table 3. The titration curve of the solution resulting from the treatment of antacid with hydrochloric acid is presented in Fig. 1. Examination of the curve reveals that it is unsuitable for the determination of each acid present in the

Table 2. Results of titrations of two mixtures of tartaric acid, citric acid, sodium carbonate, sodium hydrogen carbonate and a strong acid (HCl). Temperature = 25 °C and μ = 1.0 M ($NaNO_3$)

Mixture	Acid	Concentration/ 10^{-3} M			
		Taken	Found	S.d.	Error, %
I	Tartaric acid	3.915	3.914	0.009	0.0
	Citric acid	3.310	3.246	0.009	−1.9
	Hydrochloric acid	6.450	6.548	0.008	+1.5
II	Tartaric acid	2.242	2.212	0.001	−1.3
	Citric acid	1.111	1.102	0.042	−0.8
	Hydrochloric acid	12.04	3.514	0.005	
	Total carbonate/ equiv. l⁻¹	8.586	8.526	0.005	−0.7

* Results are the means of four determinations.

Table 3. Results of the titration of antacid samples. Temperature = 25 °C and μ = 1.0 M ($NaNO_3$)

Antacid component	Concentration/ 10^{-3} mol g⁻¹		Difference, %
	Potentiometric*	Other methods	
Tartaric acid	1.908 (0.006)	1.910	−0.1
Citric acid	0.784 (0.003)	0.767	+2.2
Total carbonate/equiv. l⁻¹ ..	7.480 (0.015)	—	—
Total carbonate†/mol g⁻¹ ..	6.554 (0.071)	6.756	−3.1
Sodium hydrogen carbonate‡	5.628 (0.101)	—	—
Sodium carbonate‡	0.926 (0.072)	—	—

* Results are the means of four determinations; values in parentheses are standard deviations.
† Concentration determined by reverse titration.
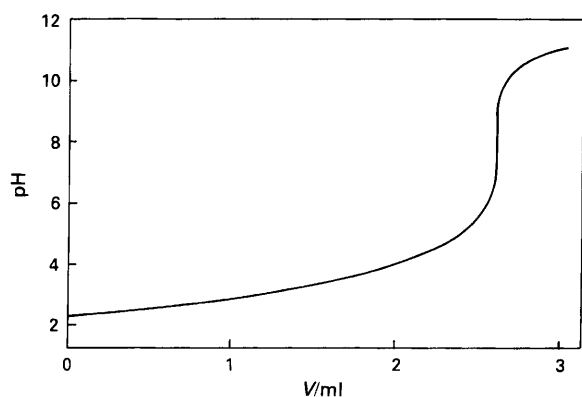‡ The individual concentration of Na_2CO_3 and $NaHCO_3$ have been calculated by equations (1) and (2).

Fig. 1. Potentiometric titration curve of a solution resulting from the treatment of antacid with an excess of hydrochloric acid with sodium hydroxide solution.

of sodium hydroxide solution) with hydrochloric acid. The computer program developed by Ivaska and Nagypal[6] was again used. The results obtained for the total number of moles of carbonate were compared with those of an independent method, involving the precipitation of carbonate with barium chloride, dissolution of the precipitate with hydrochloric acid and titration with an excess of strong acid.

The results for individual concentrations of carbonate and hydrogen carbonate in the sample (shown in Table 3) were calculated using the equations

$$n_1 = [HCO_3^-] + [CO_3^{2-}] \qquad .. \quad .. \quad (1)$$

$$n_2 = [HCO_3^-] + 2[CO_3^{2-}] \qquad .. \quad .. \quad (2)$$

where n_1 is the total number of moles of carbonate and n_2 represents the total number of equivalents of carbonate in the sample.

Tentative calculations of the concentration of tartaric and citric acids using the data of the acidimetric titration were carried out. In this instance it was possible to obtain good results for tartaric acid but the results for citric acid were unsatisfactory. For this reason it was concluded that alkalimetric titration is preferable for the determination of these acids. Further, an alkalimetric titration is capable of determining in one titration the content of tartaric and citric acids and total equivalents of carbonate with reasonable accuracy; the total equivalents of carbonate is an important parameter as it represents the effective neutralising power of an antacid.

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