641

行政院國家科學委員會專題研究計畫成果報告

乳液及洗髮精中 1-氧化 2-硫醇比定鋅與牙膏中單氟磷酸鈉測定方法之研究

Determination of Zinc 2-pyridinethiol-1-oxide in Skin Cream and Shampoo and Sodium Monofluorophosate in Toothhpaste

計畫編號：NSC 87- 2113- M- 041- 002

執行期限：86 年 8 月 1 日至 87 年 7 月 31 日

主持人： 王來好 嘉南藥理學院 醫藥化學系

0825

行政院國家科學委員會專題研究計畫成果報告

乳液及洗髮精中 1-氧化 2-硫醇比定鋅與牙膏中單氟磷酸鈉測定方法之研究

Determination of Zinc 2-pyridinethiol-1-oxide in Skin Cream and Shampoo and Sodium Monofluorophosate in Toothhpaste

計畫編號：NSC 87- 2113- M- 041- 002
執行期限：86 年 8 月 1 日至 87 年 7 月 31 日
主持人： 王來好 嘉南藥理學院 醫藥化學系

Determination of Zinc Pyrithione in Hair Care Products by Differenual Pulse Voltammetry

Lai-Hao Wang
Department of Applied Chemistry, Chia Nan College of Pharmacy and Science, Tainan, Taiwan 71710, R.O.C.

Summary

A simple electroanalytical method for the determination of zinc pyrithione (ZPT) in commercial cosmetic products has been developed using a metal oxide modified carbon paste electrode. Ingredients in cosmetic products did not interference in the determination of zinc pyrithione. A comparison is made between the detection limit of three kinds working electrodes (deposition of the nickel on glassy carbon electrode, carbon paste and metal oxides modified carbon paste electrodes). Comparison with results obtained from high performance liquid chromatography shows good agreement.

利用金屬氧化物修飾碳糊電極的電化學分析法，測定市售化妝品中 1-氧化 2-硫醇比定鋅(Zinc Pyrithione)的含量。並比較鎳電沉積玻璃碳電極、碳糊電極與金屬氧化物修飾碳糊電極等三種工作電極的偵測極限。將分析結果與液相層析法比較發現很一致。

關鍵詞：修飾碳糊電極、1-氧化 2-硫醇比定鋅

Introduction

The zinc and sodium pyrithiones (Omadine) are broad - spectrum antimicrobial agents , effective against both bacteria and fungi [1]. They were used as cosmetic preservatives by the late 1960s and the Procter and Gamble Co .discovered the antidandruff properties of zinc pyrithione (zinc 2 - pyridinethiol - N- oxide or ZPT). ZPT has been established as one of the most effective antidandruff ingredients for use in shampoo, conditioner, rinse and hairdressing formulations through various clinical studies [2]. In 1981 the Food and Drug Administration (FDA) reported that 29 formulations registered with the agency contained ZPT and 7 contained the sodium salt [3]. The Economic Community (EEC) Council Directive allows ZPT to be used in cosmetic products as a preservative,, in shampoos and conditioners as a antidandruff agent at a maximum concentration of 0.5 % and 1.0 %, respectively [4]. The toxicity of salts pyrithione by various routes of exposure has been studied extensively in several species of animals and has been described previously [5-16].

Several analytical methods for pyrithiones have appeared in the literature [17-30]. In general, they involve titration with Ti (Ⅲ) ion [17], thin-layer chromatography [4, 18-19], high-performance liquid chromatography [20-26] and polarography [27-30] procedures. Titrimetric methods suffer from a lack of selectivity for pyrthione and interferences in hair care products. Quantitative TLC analysis requires the use of a spectrodensitometry and ZPT decomposes in sunlight on TLC plates. Sodium pyrithione is difficult to Quantitate by means of TLC because they react with metals in the TLC plate. The normal-phase HPLC conditions in the on-line Cu (Ⅱ)complex formation technique can damage the analytical column in time. The direct reversed-phase HPLC analysis of ZPT is difficult owing to the interaction with reversed-phase packing materials or stainless-steel compounds of the liquid chromatography even if Zn(Ⅱ) is added to the mobile phase.

Although polarography offers greater specificity but is limited to the determination of 2-pyridinethiol and 2-pyridinethiol-N-oxide. ZPT is substantially insoluble in water and is present in aqueous-based products as a dispersion of fine solid particles. However, ZPT is soluble in 1 M hydrochloric acid or alkaline solution. ZPT dissolved in 1 M hydrochloric acid showed a degradation of 10 % immediately, 25 %after 24 hours and 93 % after 4 days of storage at room temperature in light-resistant container. ZPT is stable in alkaline solution [24]. In this work, the electrochemical oxidation of salts of pyrithione using a electrodeposition of nickel on glassy carbon electrode (GCE/Ni), carbon paste electrode (CPE) and metal oxides modified carbon paste electrode (CPE/M_xO_y) has been investigated in various alkaline solution by differential pulse voltammetry (DPV). The optimum experimental conditions for the determination of ZPT containing cosmetic samples are described in this paper.

Results and discussion

Choice of analytical method

Pyrithione exists in tautomeric form (thiol and thione). At or below pH 3 the prevailing form is the thione .The thiol form appears as the pH is raised, the equivalence point being about 7.6. Between pH 7.6 and about 10.0 the thiol form (or its salts) is relatively stable, but above pH 10 it is rather easily oxidized to the sulfimic acid anion [3]. In order to arrive at the optimum conditions for Pyrithiones determination, there are several factors such as pH, supporting electrolyte and working electrode which should be considered. The oxidation of ZPT in 0.1 M tetraburylammonium hydroxide was studied at a GCE/Ni, CPE and CPE /M_xO_y and the results were given in Table 1. The detection limits (three times the standard deviation) were given in Table 2. It was found that CPE/SnO_2 exhibited a pronounced electrocatalytic effect. From Table 1, the peak current of CPE/SnO_2 is higher than the other electrodes and From Table 2, the CPE/SnO_2 has lower

detection limits than the other electrodes. Parts A and B of Figure 1 and 2 compare the cyclic voltammograms of the CPE/SnO_2 in 0.1 M tetrabutylammonium hydroxide + 1.2 mM Pyrithiones solution with that of the CPE. The CV studies indicate that the characteristics of the Tin(IV) oxide modified CPE are similar to that of unmodified CPE. The .Tin(IV) oxide modified CPE exhibit more catalytic activity. The peak potential for the Tin(IV) oxide modified CPE is more in the positive direction with respect to the CPE. Therefore, the CPE/SnO_2 was chosen for use in the determination of ZPT in cosmetic products. ZPT oxidation was performed using several electrodes containing different weight percentage of SnO_2/graphite (in the range 0.0 to 15 %) and shown in Table 3. Tin(IV) oxide (2.5 %) was used for incorporation of graphite powder, because the peak current of ZPT (8 and 16 mol L^{-1}) was the largest using this procedure. Comparative tests of various pH and supporting electrolytes were shown in Table 4. The height of the ZPT wave in solutions of 0.1 M tetrabutylammonium hydroxide was found to be much higher than in the other supporting electrolytes.

Reproducibility and accuracy

Determination of the concentration of ZPT was accomplished by means of a standard addition procedure as shown in Figures 3 and 4. The peak height of the wave at +0.620 V increases linearly with the concentration of added ZPT. The calibration graphs obtained by plotting the peak current against the concentration of ZPT show good linearity over the range 1.6 ~32.0 mg L^{-1}, and the regression equations being y = 163 + 41 x (correlation coefficient r = 0.9993). The relative standard deviation value was 4.3 %. Recovery tests were carried out on cosmetic products to evaluate the reproducibility and accuracy of the proposed DPV method. Three cosmetic products were spiked with the amounts reported in Table 5 and subjected to the whole procedure. As shown in Table 5, excellent recoveries and precision were observed (recoveries ranging from 101±1.5 % to 102±3.1 %).

Determination of ZPT in cosmetic products

The effect of the ingredients in cosmetic products on the determination of ZPT was investigated. As shown in Table 6, no interference effects were observed. The proposed DPV method was applied to the determination of ZPT in shampoo, conditioner, rinse and hairdressing products. A representative DPV voltammogram of a commercial shampoo is shown in Figure 5. Analytical results are given in Table 7. These results agreed with those obtained by a high performance liquid chromatographic method.

Financial support of this work by the National Science Council of the Republic of China is gratefully acknowledged.

References

[1] J. D.Nelson, and G. A. Hyde, *Cosm. & Toil*, **96** (1981), 87.

[2] A.Babar, C. Kawilarang, A .J .Cutie and F. M.. Plakogiannis, *Drug Devel and Indus. pharm.* 11 (1985), 1507.

[3] Jon. J. Kabara , *Cosmetic and Drug Preservation Principles and Pratices* , Marcel Dekker , INC. (1984) p.117.

[4] N. DE. Kruijf, M. A. H. Rijk, L. A. Pranoto – Soetardhi, and A. Schouten , *J. Chromatogr.*, 410 (1987), 395 .

[5] T. Okumura , S. Hayashi, F. Tokiwa, and S. Horin, *Cosmet. Perfum.* 90 (1975), 101.

[6] G. A. Nolen, L. F. Parrick, and T. A. Dierckman, *Toxicol. Appl. Pharmacol.*, **31**, (1975) , 430 .

[7] C. D. Klaassen, *Toxicol. Appl. Pharmacol.*, 35 (1976), 581.

[8] J. H. Wedig, G. L. Kennedy, D. H. Jenkins, R.Henderson and M. L. Keplinger, *Toxicol. Appl. Pharmacol.*, 36 (1976), 255 .

[9] M. D. Adams, J. H. Wedig, R. L. Jordan, L. W. Smith, R. Henderson, and J. F. Borzelleca , *Toxicol. Appl. Pharmacol*, 36 (1976), 323 .

[10] J. H. Wedig, C. Mitoma, R. A. Howd , and D. W. Thomas, *Toxicol. Appl. Pharmacol.*, 43 (1978), 373 .

[11] W. B. Gibson, and G. Calvin, *Toxicol. Appl. Pharmacol.*, 43 (1978), 425 .

[12] G. G. Cloyd, M. Wyman, J.A. Shadduck, M. J. Winrow, and G. R. Johnson, *Toxicol. Appl. Pharmacol.*, 45 (1978), 771.

[13] A. R. Jeffcoat, W. B. Gibson, P. A. Rodriguez, T. S. Turan, P. F. Hughes, and M. E. Twine, *Toxicol. Appl..Pharmacol.* 56 (1980), 141.

[14] I. K. Genji, and O. M. Kikuhiko, *J. Soc. Cosmet. Chem.*, 34 (1983), 1.

[15] A. B. G.. Lausdown, *Fd. Chem. Toxi.*,, 29 (1991), 57..

[16] N. P. Skoulis, and S. J. Barbee, *J. Appl. Toxicol.*, 13 (1993), 283 .

[17] S. Oliveri – Vigh, and H. L. Karageozian, *Anal. Chem.*, 48 (1976), 1001.

[18] R. T. Brooks, and P. D. Sternglanz, *Anal. Chem.*, 31 (1959), 561.

[19] M. D. Seymour, and D. L. Bailey, *J. Chromatogr.*, 206 (1981), 301.

[20] H. Cheng and R. R. Gadde, *J. Chromatogr.*,. 291 (1984), 434.

[21] D. Valdez, and J. C. Reier, *J. Lig. Chromatogr.*, 10 (1987), 2133.

[22] Y. H. Kondoh and S. S. Takand, *J. Chromatogr.*,. 408 (1987),255.

[23] R . J .Fenn , and M . T . Alexander , *J . Lig .Chromtogr* . 11 (1988) , 3403 .

[24] N . Dekruijf , A . Schouten , M .A . H . Rijk and L .A .Pranoto - Soetardhi , *J . Chromatogr* . 469 (1989) , 317 .

[25] N . J Keiko , and Y . U . Toshiko , *J . Chromatogr* . 502 (1990) , 379 .

[26] N.Ferioli , C . Rustichelli , F . Vezzalini , and G . Gamberini , *Chromatographia* , 40 (1995) , 669.

[27] D . A . Csejka , S .T . Nakos , and E . W . Bubord , *Anal . Chem .* 47 (1975) , 322 .

[28] J . T . Stock , and R .E . Larsn , *Anal . Chim . Acta* . 138 (1982) ,371 .

[29] J . M .Fernandez , Alvarez , and M . R . Smyth , Hnalyst . 114 (1989) , 371 .

[30] I . Pardo , M . Angulo , R .M .Galvin , and J . M . Rodriguez Mellado , *Electo . Acta* . 41 (1996) , 133 .

Table 1 Comparative voltammetric characteristics of deposition of the nickel on glassy carbon and metal oxides modified carbon paste electrodes

modified electrodes	E (V)	Concentration [mg L^{-1}]	
		8.0	16.0
		$i_p \times 10^3$ (nA)	
GCE/Ni	0.664	280	592
CPE	0.680	190	373
CPE/SnO_2	0.620	505	1004
CPE/γ -Al_2O_3	0.656	379	770
CPE/ZrO_2	0.632	388	779
CPE/CoO	nm	nm	nm
CPE/Pb_2O_3	0.652	430	877
CPE/CeO_2	0.640	351	775

nm: zp not measured at this modified electrode

Table 2 Detection limits of zinc pyrithione at deposition of the nickel on glassy carbon, carbon paste and metal oxides modified carbon paste electrodes

Electrodes	ZPT [mg L^{-1}]
GCE/Ni	2.32
CPE	3.01
CPE/SnO_2	0.068
CPE/γ-Al_2O_3	2.50
CPE/ZrO_2	2.38
CPE/Pb_2O_3	1.77
CPE/Ce_2O_2	2.81

Table 3. Effect of weight percentage of stannic oxide incorporation of graphite in the composite electrode on the differential pulse voltammetry peak current of zinc pyrithione.

SnO_2/graphite (W/W, %)	$i_p \times 10^{-1}$ (nA)	
	8.0 mg L^{-1}	16.0 mg L^{-1}
0.0	190	373
2.5	505	1004
5.0	447	866
7.5	254	540
15.0	237	445

Table 4. Effect of pH and supporting electrolytes on the differential pulse voltammetry peak current of zinc pyrithione for the stannic oxide modified carbon paste electrode.

supporting electrolytes	pH	Concentration [mg L^{-1}]			
		1.6	3.2	6.4	
		$i_p \times 10^{-1}$ (nA)			
Robinson buffer	10.26	61.5	117.1	222.7	
0.15 M Ammonia	10.54	nm	138.6	265.3	
0.1 M Bu_4NOH	12.47	97.0	233.0	464.0	

nm: zp not measured at this pH and supporting electrolytes

Table 5 Recovery of zinc pyrithione Added to Commercaial Shampoos and Rinses by DPV

	Added (mg L^{-1})	Found (mg L^{-1}) N= 3[a]	Recovery (%)
Shampoo	8.00	8.10	101(1.8%) [b]
Shampoo and conditioner	10.00	10.17	102(301%)
Rinse	5.00	5.05	101(1.5%)

[a] Number of determinations. [b] Relative standard deviation.

Table 6 Effect of ingredients of cosmenc products on the determination of zinc pyrithione

Ingredient	Ingredient Added (mg L^{-1})	ZP Present (mg L^{-1})	ZP Found (mg L^{-1})	ZP Recovery (%)
Sodium lauryl sulfate	80	8.00	7.81	97.6
Sodium lauryl ether sulfate	800	8.00	7.94	99.2
Ammonium lauryl sulfate	80	8.00	8.09	101.2
Ammonium lauryl ether sulfate	120	8.00	8.12	101.6
Trimethylstearylammonium chloride	800	8.00	8.02	100.3
Coconut monoethanolamide	720	8.00	8.23	102..9
Brij 35	800	8.00	8.25	103.5
Triton-X 100	800	8.00	7.98	99.7
Tween 60	800	8.00	7.82	97.7
Monoethanolamine	720	8.00	8.01	100.0
Diethanolamine	800	8.00	8.18	102.0
Triethanolamine	720	8.13	8.01	101.7
Ceryl alcohol	800	8.00	8.06	101.0
Dimethione	800	8.00	8.03	100.3

Table 7 Analytical results for the determination of zinc pyrithione in commercial shampoos, conditioner and rinses by DPV and HPLC

	Concentration (w/w, %)	
	DPV	HPLC
	N=5 [a]	
Shampoo A	0.488(4.0%)[b]	0.486(4.1%)
Shampoo B	1.294(4.9%)	1.562(4.5%)
Shampoo C	0.474(3.3%)	0.476(1.7%)
Shampoo D	0.230(1.7%)	0.234(1.9%)
Shampoo and conditioner A	0.758(5.0%)	0.761(4.2%)
Shampoo and conditioner B	1.012(5.0%)	1.016(5.0%)
Shampoo and conditioner C	0.953(2.4%)	0.943(0.4%)
Rinse	0.226(2.6%)	0.209(2.1%)

[a] Number of determinations [b] Relative standard deviation.

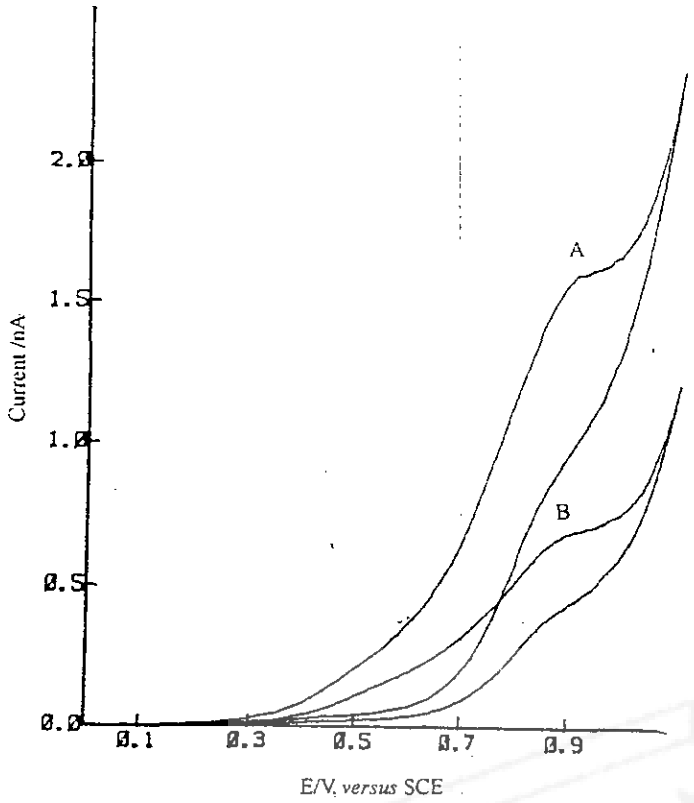

Fig. 1. Cyclic voltammograms of zinc pyrithione in 0.1 M tetrabutylammonium hydroxide(pH 12.47) + 1.2 mM zinc pyrithione, (A) 2.5% Tin(IV) oxide modified CPE , (B) CPE , scan rate 50 mV/s,.Initial potential 0.0V, final potential 1.1 V.

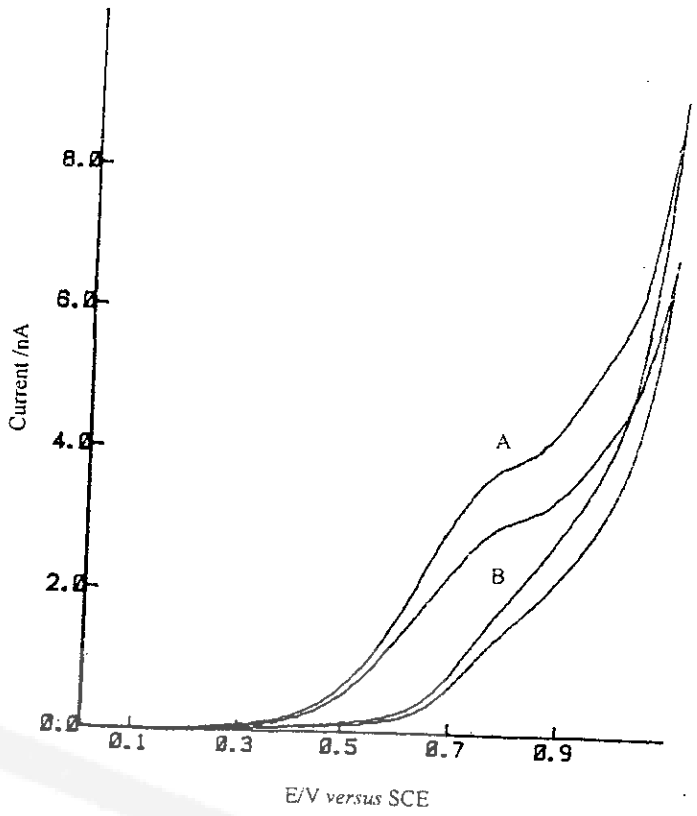

Fig. 2. Cyclic voltammograms of sodium pyrithione in 0.1 M tetrabutylammonium hydroxide(pH 12.47) + 1.2 mM sodium pyrithione, (A) 2.5% Tin(IV) oxide modified CPE , (B) CPE , scan rate 50 mV/s,.Initial potential 0.0V, final potential 1.1 V.

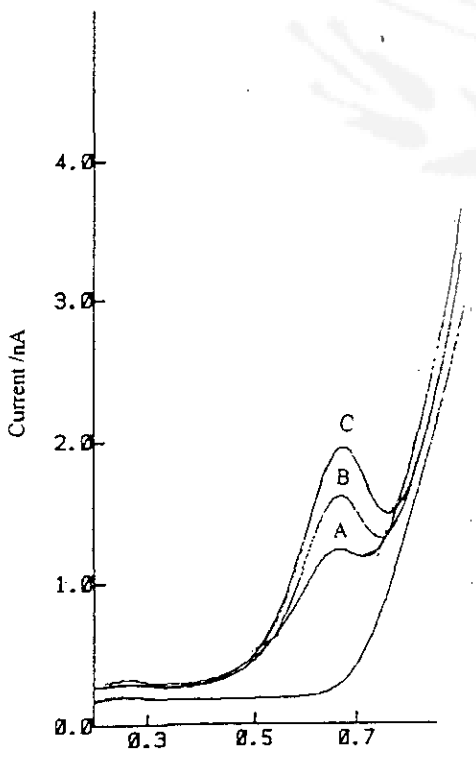

Fig 3 DPV obtained to produce calibration graph for zinc pyrithione (ZPT) at a CPE. Peak A) 0.676 V, 1.17 (E2) nA (8 ppm ZPT added); B) 0.672 V, 2.77 (E2) nA (12 ppm ZPT added);C) 0.676 V, 4.18 (E2) nA (16 ppm ZPT added) Scan rate 4 mV/s, pulse height 0.05 V, Initial potential 0.2 V final potential 0.85 V

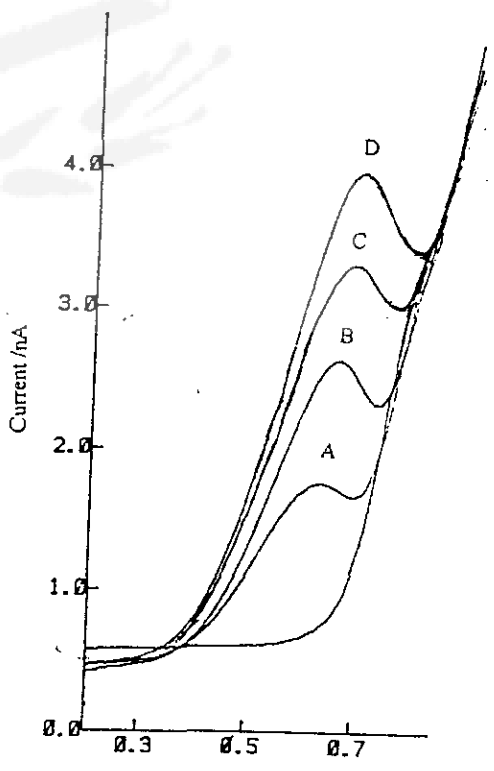

Fig.4. DPV obtained to produce calibration graph for zinc pyrithione (ZPT) at a Tin(IV) oxide modified CPE Peak A) 0.620 V, 5.05 (E2) nA (8 ppm ZPT added), B) 0.612 V, 8.05 (E2) nA (16 ppm ZPT added);C) 0.620 V, 1.132 (E3) nA (24 ppm ZPT added), D) 0.628 V, 1.488 (E3) nA (32 ppmZPT added). Scan rate 4 mV/s, pulse

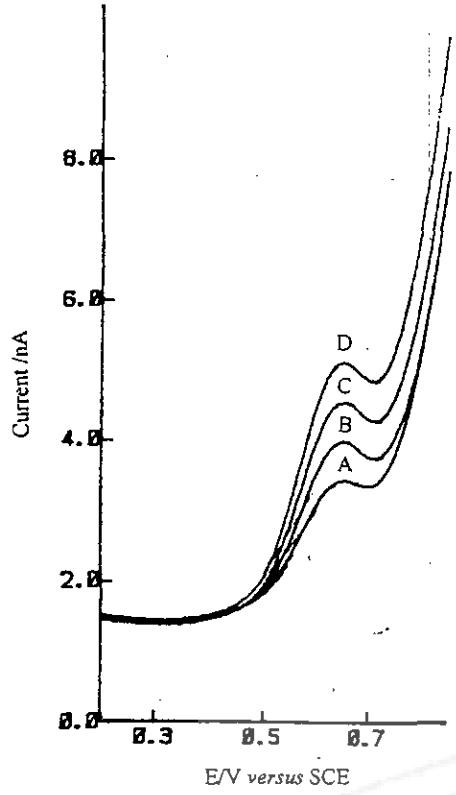

Fig. 5. DPV for zinc pyrithione (ZPT) from commercial shampoo at a Tin(IV) oxide modified CPE. Peak A) 0.648 V, 5.10 (E2) nA (0 ppm ZPT added); B) 0.652 V, 7.94 (E2) nA (8 ppm ZPTadded); C) 0.652 V, 1.024 (E3) nA (16 ppm ZPTadded); D) 0.652 V, 1.286. (E3) nA (24 ppm ZPT added). Scan rate 4 mV/s, pulse height 0.05 V. Initial potential 0.2 V, final potential 0.85 V.

Simultaneous Quantitative Determination of Fluorine and Sodium Monofluorophosphate in Oral Hygiene Products

Lai-Hao Wang

Department of Applied Chemistry, Chia Nan College of Pharmacy and Science, Tainan, Taiwan, 71710, R. O. C.

Synosis

Ion chromatography method for simultaneous quantitative determination of fluorine and sodium monofluorophosphate in oral hygiene products is described. The liquid chromatography system consisted of a IC A1 polymethacrylate- based anion exchanger and carbonate buffer(pH 9.85) as the mobile phase with a conductive detector. Various excipient ions were investigated with respect to their interferences with the determination of fluoride. Comparison with results obtained from fluoride-ion electrode show good agreement.

利用離子層析法同時測定口腔製品(牙膏與漱口水)中氟離子與單氟磷酸鈉含量，將分析結果與氟離子選擇電極法比較，發現很一致。

關鍵詞：口腔製品、氟離子、單氟磷酸鈉

Introduction

The epidemiologic and experimental evidence concerned with the relationship of fluoride to dental caries suggests that fluoride solutions applied to the external surfaces of teeth may decrease their susceptibility to caries attack. The first two papers on the effect of topical application of fluorides were made by Bibby and Chenye in 1942 [1]. Fluorine derivatives including sodium fluoride , stannous fluoride and sodium monofluorophosphate (MFP, Na_2PO_3F) are incorporated into dentifrices or mouthwashes as chemtherapeutic agents [1,2]. However, fluoride is absorbed into the blood from the gastrointestinal tract. It is then mostly deposited in bone or excreted in urine [3]. The acute and chronic toxicity values (LD_{50} values in the rat and mouse) of sodium fluoride, stannous fluoride and MFP have been investigated. The toxicity of stannous fluoride is similar to that of the sodium fluoride. The stannous fluoride and sodium fluoride are more toxic than MFP by factors of 1.4-3.0 [3]. The Food and Drug Administration (FDA) has promulgated regulations for safe and effective oral hygiene productions. Anticaries active agents in dentifrices were 0.22 %, 0.40 % and 0.76 % for sodium fluoride, stannous fluoride and MFP, respectively. The final product containing 0.02 % fluoride ion in oral rinses was based on *in vitro* data as well as clinical trials[3]. A mutagenicity study on three fluorine derivatives selected from the cosmetic guidelines of the Council of the European Communities (27 July 1976)[4]. Stannous fluoride was slightly mutagenic in the Ames test. Today, over 90% of the dentifrices sold in the Taiwan contain fluoride from one of two major source (sodium fluoride and MFP). There are reports that a mixture of sodium fluoride and MFP is superior in efficacy to MFP alone in a dentifrice base[3]. Dentifrices with mixed fluoride systems been marked. Quantitative determination of fluoride and MFP are important for quality control and stability evaluation of these products.

Gas chromatography[5-7], fluoride- ion electrode[5,7,8], high liquid chromatographic[9] and ion chromatographic[10,11] techniques have been used to determine fluoride derivatives in toothpastes. Gas chromatographic methods involve the chromatographic analysis of trimethyl fluorosilane resulting from the reaction of trimethyl chlorosilane with fluonde ions in the toothpaste. Fluoride- ion electrode used only for the determination of soluble fluoride derivatives. However, MFP is solubie in water to the extent of 42 % saturation and slowly hydrolyzed in the presence of hydrochioric acid. These methods are laborious and time consuming. The use of high-performance liquid chromatography required a postcolumn detection system in order to analyse orthophosphate, diphosphate, triphosphate and cyclo-triphosphate in MFP samples[9]. Ion chromatographic methods for direct determination of MFP in toothpaste have been reported [10,11]. However, oral hygiene formulation commonly contain abrasive(phosphate) , antibacterial agent(cetylpyridium chloride) ,astringent salts(zinc chloride) ,and surfactant (sodium laury sulfate) . These excipient anion ions were found not to be ideal for resolving fluoride and phosphate in pH 5.3-5.7. This present paper describes the application of various pH to separate rapidly and efficiently the peaks of interest. The results were compared with those obtained with a fluoride-ion electrode method.

Results and discussion

Optimization of the mobile phase

Dentifrices or mouthwashes, containing anions include the fluoride, MFP, phosphate and chloride in many commercial ingredients, and sulfate as an impurity in some anionic surfactants. The mixture of anions to separate in short run times is difficult. Separation and quantification of fluoride and monofluorophosphate (FPO_3^{2-}) was interference free in the wide range of separation conditions selected. At the elevated mobile phase pH value, a HPO_4^{2-} peak was shifted away from the FPO_3^{2-} peak. Carbonate buffer with 11.00 gave good separations of F^- and FPO_3^{2-} but the overall analysis time was considered longer than with pH 9.85. The carbonate buffer(pH 9.85) contained a mixture of 0.94 m mole Na_2CO_3 and 0.31 m mole $NaHCO_3$. This the CO_3^{2-} concentration helped achieve a larger resolution between FPO_3^{2-} and SO_4^{2-}. Chloride was also eluted in a chromatographic region free of interference from other ion peaks. The retention times were 2.683, 5.448, 8.473 and 11.393 min. for F^-, Cl^-, FPO_3^{2-} and SO_4^{2-}, respectively. Optimization of CO_3^{2-} concentration and the eluent pH for maximum resolution at minimum total run time resulted in the eluent described in experimental section. A chromatogram of a mixture standard solution produced with this eluent is shown in Figure 1. Under these conditions separation was fast, reproducible and free from interferences from other components of the sample.

Reproducibility and Accuracy

Determination of the concentration of the various chemtherapeutic agents was accomplished by means of a calibration graph. The calibration graphs were linear for two chemtherapeutic agents over the range of concentration used (5.0 ~ 40.0 mg L^{-1}). The correlation coefficients were within the range 0.9990 ~ 0.9998. Recovery test were carried out on oral hygiene products to evaluate the reproducibility and accuracy of the proposed ion chromatography (IC) method. Four toothpastes and mouthwashes were spiked with the amounts reported in Table 1 and subjected to the whole procedure. As shown in Table 1, excellent recoveries and precision were observed(recoveries ranging from 97.3 % to 103.5 %).

Application to oral hygiene productions

The proposed IC method was applied to the determination of chemtherapeutic agents in oral hygiene productions (.toothpastes and mouthwashes).A representative chromatogram of a commercial toothpaste is shown in Figure 2. Analytical results are given in Table 2. These results agreed with those obtained by a fluoride-ion electrode method, which was carried with a TISAB Ⅱ solution, after treatment with hydrochloride acid hydrolysis.

samples without the need for MFP acid hydrolysis. The direct determination of fluoride not onlyoffers more precise than indirect determination but also saves more time, and its applicability to actual samples.

Acknowledgement

Financial support of this work by the National Science Council of the Republic of China is gratefully acknowledged.

References

(1). Gershon, S. D., and Pader, M., " Dentifrice", in *Cosmetics Science and Technology*, 2 nd ed., M. S. Balsam and E. Sagarin, Eds. (Wiley-Interscience, New York 1972) Vol. 1, pp 440～447.

(2) Verling, M. V. " Dentifrice", in *The Chemistry and Manufacture of Cosmetics*, 2 nd ed., M. G. deNavarre, PhC., B. S., M. S., (Continental press, Orlando, Florida, 1975) Vol 2, pp 450～453.

(3) Pader, M. " *Oral Hygiene Products and Practice*" Marcel Dekker, Inc. 1988, pp 406～407.

(4) Gocke, E. King, M. T. Eckhardt, K., and Wild, D., Mutagenicity of cosmetics ingredients licensed by the European Communities, *Mutat. Res.*, **90**, 91～109 (1981).

(5) Wayne, D. C., An investigation of methods proposed for the analysis of the various forms of fluoride in toothpaste, *Aust. Dent. J.* 26, 299～303 (1981).

(6) Ma, M. S., and Chen, W. J., Determination of active fluoride content in toothpaste by gas chromatography. *Riyong Huaxue Gongh*, 2, 78～80 (1988).

(7) Emil, S., Anica, P., Adolf, K., and Mirko, P., Quantitative determination of fluoride in toothpastes, *J. High. Resolut. Chromatogr.*, **16**, 243～246 (1993).

(8) Liu, D. Y., Determination of fluoride content in toothpaste by ion-selective electrode. *Riyong Huaxue Gongh*, 3, 155～158 (1992)

(9) Norimass, Y., Sachiko, N., Tetsuya, N., Nobuyuki, U., Hiroki, K., and Akira, T., Determination of monofluorophosphate, orthphosphate, and polyphosphates by high-performance liquid chromatography with a photodiode array detector, *Anal. Chem.* **64**, 1499～1501(1992)

(10) Jeffrey, J. P., Audrey, E. H. and Geoffrey, J. B., Determination of fluoride and monofluorophosphate in toothpaste by ion chromatography, *J. chromatogr.* **367**, 423～ 427 (1986)).

(11) Jeseph, H. T. and Thomas, A. B., Determination of potassium nitrate and sodium monofluorophosphate in the presence phosphate and sulfate by high-resolution ion chromatography, *J. chromatogr.* **410**, 494～ 499 (1987).

Table 1 Recovery and reproducibility in the analysis of toothpastes and mouthwashes by ion chromatography.

	Sodium fluoride			Sodium monofluorophosphate		
	Added ($mg\ L^{-1}$)	Found ($mg\ L^{-1}$)	Recovery (%)	Added ($mg\ L^{-1}$)	Found ($mg\ L^{-1}$)	Recovery (%)
	N = 5[a]			N = 5[a]		
Toothpaste A	2.00	2.07	103.5(1.4)[b]	5.00	5.10	102.0(2.3)
Toothpaste B	----	----	--------	5.00	5.07	101.5(5.0)
Mouthwashes A	5.00	4.87	97.3(3.3)	----	----	------
Mouthwashes B	4.00	3.99	99.8(1.3)	----	----	-----

Table 2 Analytical results for the determination of fluoride and monofluorophosphate in commercial toothpastes and mouthwashes by ion chromatography (IC) and fluoride-ion selective electrode

	Concentration [w/w, %]		
	IC		F^- electrode
	F^-	FPO_3^{2-}	Total F^-
	N = 5[a]		N = 6[a]
Toothpaste 1	-----	0.075 (4.3 %)[b]	0.074 (2.5 %)
Toothpaste 2	0.244 (1.1%)	0.129 (1.4 %)	0.376 (5.0 %)
Toothpaste 3	0.245 (0.7%)	0.386 (2.4 %)	0.632 (2.2 %)
Toothpaste 4	0.369 (3.3%)	0.239 (4.1 %)	0.605 (2.3 %)
Toothpaste 5	0.390 (5.0%)	0.231 (4.0 %)	0.620 (0.5 %)
Toothpaste 6	0.314 (3.7%)	0.360 (4.4 %)	0.669 (4.4 %)
Toothpaste 7	0.245 (2.0%)	0.239 (4.4 %)	0.474 (0.76 %)
Toothpaste 8	0.144 (0.9%)	0.467 (5.1 %)	0.618 (0.7 %)
Toothpaste 9	0.211 (2.4%)	0.355 (3.7 %)	0.588 (1.8 %)
Toothpaste 10	-------	0.667 (2.5 %)	0.675 (3.9 %)
Toothpaste 11	------	1.09 (3.6 %)	1.055 (5.6 %)
Toothpaste 12	0.064 (5.3%)	0.690 (5.5 %)	0.768 (1.6 %)
Mouthwash 1	0.021 (1.2%)	-------	0.028 (1.5 %)
Mouthwash 2	0.068 (2.8%)	-------	0.070 (2.6 %)

[a] Number of determinations

[b] Relative standard deviation

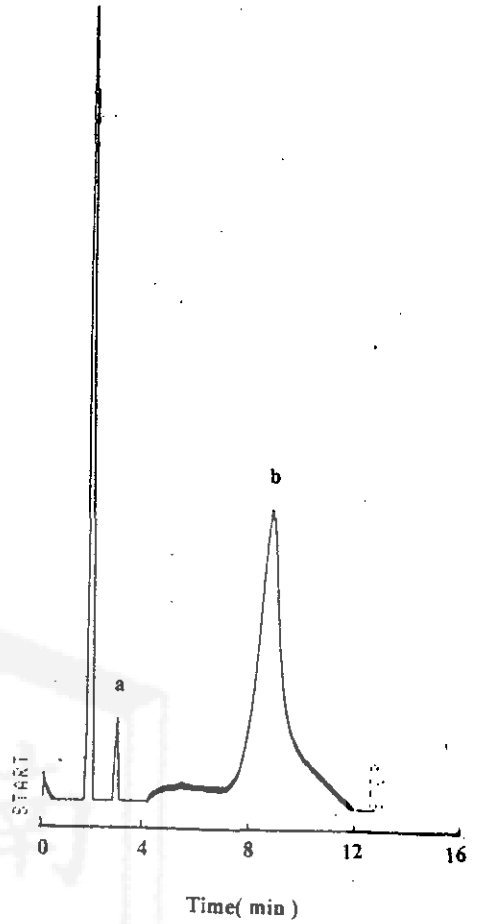

Fig. 1. Chromatogram of standard using sodium carbonate buffer (pH 9.85)Mobile phase. Peaks: a = fluoride(25 mg/L); b = monofluorophosphate (30 mg/L).

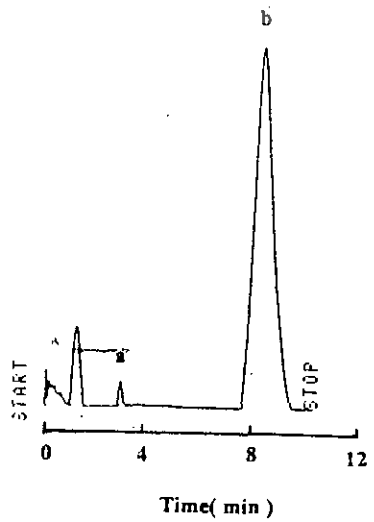

Fig. 2. Chromatogram of typical toothpaste using sodium carbonate buffer (pH 9.85)Mobile phase. Peaks: a = fluoride; b = monofluorophosphate.