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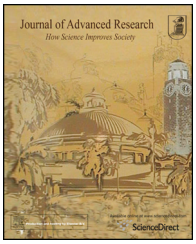

ORIGINAL ARTICLE

Mixed ion-exchanger chemically modified carbon paste ion-selective electrodes for determination of triprolidine hydrochloride

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KEYWORDS

Chemically modified carbon paste ion-selective electrode;
Triprolidine hydrochloride;
Potentiometeric determination;
Flow injection analysis;
Standard addition method

Abstract Triprolidine hydrochloride (TpCl) ion-selective carbon paste electrodes were constructed using Tp-TPB/Tp-CoN and Tp-TPB/Tp-PTA as ion-exchangers. The two electrodes revealed Nernstian responses with slopes of 58.4 and 58.1 mV decade^{-1} at 25 °C in the ranges 6×10^{-6}–1×10^{-2} and 2×10^{-5}–1×10^{-2} M for Tp-TPB/Tp-CoN and Tp-TPB/Tp-PTA, respectively. The potentials of these electrodes were independent of pH in the ranges of 2.5–7.0 and 4.5–7.0, and detection limits were 6×10^{-6} and 1×10^{-5} M for Tp-TPB/Tp-CoN and Tp-TPB/Tp-PTA, respectively. The electrodes showed a very good selectivity for TpCl with respect to a large number of inorganic cations and compounds. The standard addition, potentiometric titration methods and FIA were applied to the determination of TpCl in pure solutions and pharmaceutical preparations. The results obtained were in close agreement with those found by the official method. The mean recovery values were 100.91% and 97.92% with low coefficient of variation values of 0.94%, and 0.56% in pure solutions, 99.82% and 98.53% with coefficient of variation values of 2.20%, and 0.73% for Actifed tablet and Actifed syrup, respectively, using the Tp-TPB/Tp-CoN electrode, and 98.85%, and 99.18% with coefficient of variation values of 0.48% and 0.85% for Actifed tablet and Actifed syrup, respectively, using the Tp-TPB/Tp-PTA electrode.

Introduction

Triprolidine hydrochloride (TpCl), Fig. 1, is a sedating antihistamine with antimuscarinic and mild sedative effects. It is used for the symptomatic relief of allergic conditions, including urticaria and rhinitis, and in pruritic skin disorders. It is also often used in combination with pseudoephedrine hydrochloride for rhinitis and in other preparations for the symptomatic treatment of coughs and common cold. Triprolidine hydrochloride has also been applied topically to the skin, though (as with other antihistamines) there is a risk of sensitisation [1].

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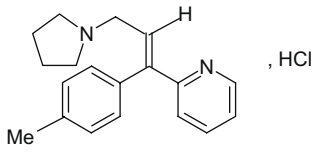

Figure 1 Triprolidine hydrochloride structure.

Several methods for the determination of triprolidine hydrochloride have been reported in comprehensive reviews. Most of these methods have been applied for determination in pure state and pharmaceutical preparations; these include high performance liquid chromatography HPLC [2–5], ultraviolet derivative spectrophotometry [6–8], and colorimetric [9–11], polarographic [12] and potentiometric [13,14] methods. For the single components and in combination with pseudoephedrine hydrochloride preparations, the official method as described in the USP 28 (2005), involves HPLC measurements, while European Pharmacopoeia (2002) recommended non-aqueous potentiometric titration.

Experimental

Reagents and materials

All chemicals and reagents used throughout this work were of analytical-reagent grade and solutions were made with doubly distilled water. Graphite powder, dioctylphthalate (DOP), dipropylphthalate (DPP), dibutylphthalate (DBP), sodium cobaltinitrite (NaCoN) and phosphotungstic acid (PTA) were supplied by Aldrich and sodium tetraphenylborate (NaTPB) was obtained from Fluka Chemical Co.

Triprolidine hydrochloride (TpCl) and pseudoephedrine hydrochloride (PsCl) (which is found as a mixture with TpCl in tablet and syrup), were kindly supplied by Glaxo Wellcome Co. for pharmaceuticals, Cairo, Egypt, and TpCl was used as a working standard. The purity of TpCl was found to be 99.86% according to USP 2005. Its commercial preparation, Actifed tablets, labelled to contain 2.5 mg of TpCl/tablet and Actifed syrup (1.25 mg/5 ml) were manufactured by Glaxo Wellcome Co. Egypt. Na, K, Li, Ni, Zn, Ca, Mg, Co, Fe, Cr and Se salt solutions (1000 $\mu g\ ml^{-1}$) were obtained from Merck. Glucose anhydrous, lactose monohydrate, L-serine, L-lysine, L-threonine, methionine, L-alanine were obtained from Aldrich.

Stock solutions, 10^{-2} M of PTA, NaCoN and NaTPB were prepared by dissolving the accurately weighed amounts of the pure solid in doubly distilled water. Solutions of sodium hydroxide and hydrochloric acid of concentrations within the range 0.1–1.0 M were used for adjusting the pH of the medium, while 0.5 M NaCl solution was used for adjusting the ionic strength. Solutions (10^{-2} M) of TpCl and NaTPB were prepared in doubly distilled water, stored in dark bottles and kept in the refrigerator for not more than 10 days.

Apparatus

Potentiometric and pH measurements were carried out using a digital HANNA meter, Model 211. A saturated calomel electrode (SCE) was used as the external reference. The electrochemical system of the TpCl carbon paste electrodes would be represented as carbon paste electrode/test solution/saturated calomel electrode. A circulator thermostat Model C-100 (Cambridge, England) was used to control the temperature. The FIA system was as has been previously described [15]. The elemental analysis of the recognition elements was performed at the Micro-Analytical Center, Cairo University.

Preparation of Tp-TPB, Tp-CoN ion-pairs and Tp-PTA ion associate

The precipitate of Tp-TPB and Tp-CoN ion-pairs were prepared by mixing aqueous solutions containing equimolar amounts of NaTPB or NaCoN and TpCl; the Tp-PTA ion associate was prepared by mixing 150 ml of 10^{-2} M of the TpCl with 50 ml of 10^{-2} M of PTA. The obtained precipitate was filtered, washed thoroughly with distilled water until it became chloride-free and dried at room temperature. The composition of the ion-pair was confirmed by elemental analysis and found to be 1:1 (Tp-TPB) and (Tp-CoN) and 1:3 (Tp-PTA).

Preparation of electrodes

Tp-TPB/Tp-CoN and Tp-TPB/Tp-PTA carbon paste electrodes were prepared by mixing either Tp-TPB (2–5% w/w) with Tp-CoN (5% w/w), or 5% w/w Tp-TPB with 2–5% w/w Tp-PTA and spectroscopic graphite powder, (1–2 μm). DOP was used as a pasting liquid (ratio graphite powder to pasting liquid was 1:1 (w/w)) in an agate mortar until it was uniformly wetted. The mixture was used for filling the electrode body and the electrode surface was polished using a filter paper to obtain a shiny surface. It was then used directly for potentiometric measurements without preconditioning.

Selectivity of the electrodes

The selectivity coefficients of the electrodes were evaluated by the matched potential method [16].

Construction of calibration graphs

Suitable increments of standard TpCl solution were transferred to a 50-ml standard measuring flask in the concentration range 1.0×10^{-6}–1.0×10^{-2} M. The volume was completed to the mark with bi-distilled water and subjected to potentiometric measurements using the carbon paste and saturated calomel electrodes. The potential readings of the stirred solutions were measured at (25 ± 1 °C), after each addition. The values were plotted versus the negative logarithmic value of the drug concentration, pTpCl (−log [TpCl]). The constructed calibration graphs were used for subsequent measurements of unknown TpCl test solutions.

Standard addition method

TpCl was determined using the prepared electrodes by the standard addition method [16]. Small increments of standard TpCl solution (0.01 M) were added to 50-ml aliquot of samples of various concentrations (at the appropriate pH value). The change in potential (at 25 ± 1 °C) was recorded for each increment and used to calculate the concentration of TpCl in the sample solution.

Potentiometric titration

An aliquot of TpCl, pure or sample (tablets and syrup) solution containing 3.32–9.96 mg TpCl was transferred into a 100-ml titration vessel and diluted to about 50 ml with water, then titrated potentiometrically with a standard solution of 0.01 M TPB. The volume of the titrant at equivalence point was obtained using the differential method.

Analysis of TpCl in pharmaceutical formulations

Pharmaceutical formulation solutions: For tablets, twenty tablets were accurately weighed and finely powdered. The required amount of powder was weighed, dissolved in about 30 ml bi-distilled water, filtered in a 50 ml-volumetric flask and after pH adjustment, volume was completed with bi-distilled water. The standard addition and potentiometric titration methods were then applied.

For syrup, the required volume of syrup was transferred to a 50 ml measuring flask. The volume was completed to the mark with bi-distilled water. The procedures were then completed as mentioned previously for tablets.

Results and discussion

It is well known that organic amines and quaternary ammonium compounds react with TPB, CoN and PTA to form stable ion-pair complexes. This is related to the relatively low limits of detection obtained with TpCl.

Composition of the electrodes

The carbon paste electrodes of mixed ion-exchanger (5% Tp-TPB and 5% Tp-CoN) and (5% Tp-TPB and 5% Tp-PTA) exhibit the best performance in terms of calibration slope, detection limit and linear range for TpCl. The electrodes display slopes of 58.4 mV and 58.1 concentration decade^{-1} in the concentration range 6×10^{-6}–1×10^{-2} M and 1×10^{-5}–1×10^{-2} M, and detection limits 6×10^{-6} and 1×10^{-5} M, respectively for determination of TpCl. It can be seen from the results in Table 1, which summarises the response characteristics of the triprolidine mixed ion-exchanger ion-selective electrodes, that mixed electrodes can be used within the concentration range 1×10^{-5}–1×10^{-2} and 6×10^{-6}–1×10^{-2} M TpCl.

Table 1 Response characteristics of the Tp electrodes.

Parameters	Tp-TPB/Tp-CoN	Tp-TPB/Tp-PTA
Electrodes (w/w%)	(5% TpCoN + 5% Tp-TPB, 45% graphite, 45% DOP)	(5% TpPTA + 5% TpTPB, 45% graphite, 45% DOP)
Slope (mV/decade)	58.4 ± 0.5	58.1 ± 0.7
Correlation coefficient	0.992	0.986
Limit of detection (M)	6×10^{-6}	1×10^{-5}
Linear range (M)	6×10^{-6}–1×10^{-2}	1×10^{-5}–1×10^{-2}
Working pH range	2.5–7.0	3.5–7.5
Response time (s)	⩽6	⩽8
Life span (days)	17	85

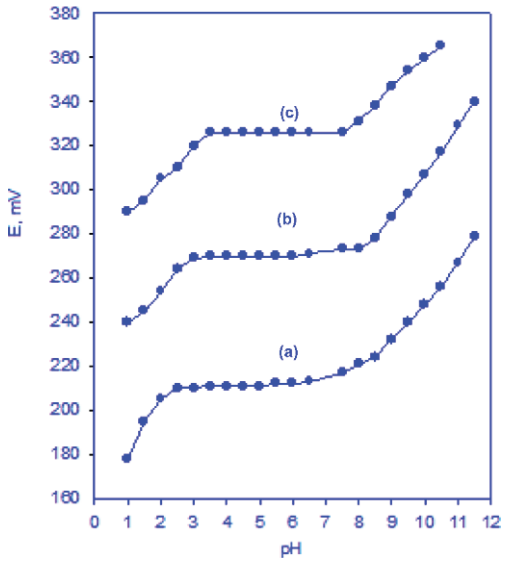

Figure 2 Effect of pH on 10^{-4} (a) 10^{-3} (b) 10^{-2} M (c) TpCl solutions on the potential response of Tp-TPB/Tp-PTA/CMCP electrode.

Effect of the pH

The effect of pH on the potential values of the TpCl electrode system were tested by measuring the EMF of the cell in the tested solution in which the pH was varied by adding HCl and/or NaOH solution (each 0.1–1.0 M). Representative curves for Tp-TPB/Tp-PTA electrode are shown in Fig. 2. The results indicate that the electrode showed no response to the pH changes in the range 2.5–7.0 for Tp-TPB/Tp-CoN and 3.5–7.5 for Tp-TPB/Tp-PTA electrodes. At pH values lower than 3.0, the electrodes become H^+-sensitive and the potential decreased gradually with a slope ~20 mV/decade. This can be related to the interference of hydronium ion, while the increase that takes place at pH higher than 7.5 with slope ~17 mV/decade can probably be attributed to the formation of the free triprolidine base in the solution leading to a decrease in the concentration of Tp cation and interference of the OH ions.

Effect of temperature on the electrode potential

The thermal stability of the cells and electrodes was studied following the method of a previously reported investigation using the following equation [17]:

$$E^{\circ}_{\text{cell}} = E^{\circ}_{25^{\circ}\text{C}} + (dE^{\circ}/dt)(t-25)$$

Plots of (E°) versus $(t-25)$ gave a straight line. The slope of the line was taken as the thermal coefficient of the electrode. The small values $(dE^{\circ}/dt)_{\text{elec}}$, amounting to 0.0046 and 0.0033 for Tp-TPB/Tp-PTA and Tp-TPB/Tp-CoN electrodes, reveal the high thermal stability of the studied electrodes within the temperature range studied.

Selectivity

The influence of some inorganic cations, sugars and amino acids on the Tp electrodes and different excipients and

Table 2 Selectivity coefficient ($-\log K^{pot}_{Drug,J^{z+}}$) values for Tp-CMCPE.

Interferent	Tp-TPB/Tp-CoN	Tp-TPB/Tp-PTA
Na^+	1.5	0.05
K^+	1.7	0.07
Li^+	2.06	1.92
Ni^{2+}	4.66	3.88
Zn^{+2}	3.83	1.55
Ca^{2+}	4.17	1.59
Mg^{2+}	3.96	1.59
Co^{2+}	4.12	1.41
Fe^{3+}	4.84	1.85
Cr^{3+}	4.6	1.88
Se^{IV}	5.27	5.09
Glucose anhydrous	2.03	2.29
Lactose monohydrate	2.17	2.26
L-Serine	2.1	2.07
L-Lysine	3.7	2.29
Threonine	4.13	2.5
Methionine	4.91	2.03
L-Alanine	4.1	2.5
PsCl	8.84	8.8

PsCl: Pseudoephedrine hydrochloride.

Table 3 Effect of soaking time on Tp-CMCPEs.

Soaking time	Slope (mV/decade)	Linear range (M)	Response time (t_{resp}) (s)
Tp-TPB/Tp-PTA electrode			
1 h	59.1 ± 0.8	1×10^{-5}–1×10^{-2}	⩽8
24	58.7 ± 0.8	1×10^{-5}–1×10^{-2}	⩽8
5 days	58.3 ± 0.6	1×10^{-5}–1×10^{-2}	⩽8
6	58.5 ± 0.9	2×10^{-5}–1×10^{-2}	⩽8
7	58.7 ± 1.1	6×10^{-5}–1×10^{-2}	⩽8
14	59.5 ± 0.6	6×10^{-5}–1×10^{-2}	⩽8
24	61.0 ± 0.5	1×10^{-5}–1×10^{-2}	⩽5
30	60.0 ± 0.3	1×10^{-5}–1×10^{-2}	⩽5
43	60.0 ± 0.8	1×10^{-5}–1×10^{-2}	⩽5
50	57.6 ± 0.6	2×10^{-5}–1×10^{-2}	⩽5
70	55.3 ± 0.9	1×10^{-5}–1×10^{-2}	⩽5
85	53.3 ± 1.1	1×10^{-5}–1×10^{-2}	⩽5
90	51.0 ± 0.7	2×10^{-5}–1×10^{-2}	⩽5
Tp-TPB/Tp-CoN			
6 h	62.3 ± 0.5	6×10^{-5}–1×10^{-2}	⩽5
4 days	57.4 ± 0.5	6×10^{-5}–1×10^{-2}	⩽5
5	54.7 ± 0.3	6×10^{-5}–1×10^{-2}	⩽5
10	55.2 ± 0.8	6×10^{-5}–1×10^{-2}	⩽5
17	54.7 ± 0.3	6×10^{-5}–1×10^{-2}	⩽5
20	50.9 ± 0.3	6×10^{-5}–1×10^{-2}	⩽5
27	46.2 ± 0.6	6×10^{-5}–1×10^{-2}	⩽5

additives which may have been present in the pharmaceutical preparations were investigated. The selectivity coefficients were determined by the separate solution method (SSM) and matched potential method (MPM) [16]. None of the investigated species interfered, as shown by the very small values of $-\log K^{pot}_{Drug,J^{z+}}$ as shown in Table 2. This reflects a very high selectivity of the investigated electrodes towards Tp ion. Inorganic cations do not interfere because of the differences in ionic size, mobility and permeability as compared with Tp^+. The high selectivity of amino acids can be attributed to the differences in polarity and to the lipophilic nature of their molecules relative to Tp ion. The mechanism of selectivity is mainly based on the stereospecificity and electrostatic environment, and is dependent on how much fitting is present between the locations of the lipophilicity sites in two competing species in the bathing solution side and those present in the receptor of the ion-exchanger [18]. The electrodes exhibit good tolerance towards the common excipients of the tablets, i.e., glucose and lactose. The tolerance of interference of pseudoephedrine hydrochloride is very small.

The use of π-coordinating soft carriers for the preparation of ion-selective electrodes for aromatic cations indicated that tetraparachlorophenylborate (TpClPB) revealed the best sensitivity amongst the other electrodes of the same type. The use of *o*-nitrophenyloctyl ether (*o*-NPOE) as plasticiser gives a better discrimination of alkali metal cations than dioctylsebasate (DOS) [19,20].

Effect of soaking

Freshly prepared mixed ion-exchanger electrodes can be used without soaking in dilute solution of TpCl. The effect of soaking time on the performance of the carbon paste electrode surfaces was studied by measuring the slope of the calibration graphs for variable intervals of time starting from 1 h reaching to 3 months. The slope of the calibration graph for the Tp-TPB/Tp-PTA electrode remained near Nernstian for about 85 days and was found to be 53.3 ± 1.1 mV/concentration decade, before decreasing gradually to reach about 51.0 ± 0.7 mV/concentration decade after 90 days. Meanwhile, in the case of the Tp-TPB/Tp-CoN electrode, the slope reached 50.9 ± 0.3 mV/concentration decade after 20 days, then decreased gradually to reach about 46.2 ± 0.6 mV/ concentration decade after 17 days.

The results listed in Table 3 indicate that the life span (t) is 85 days for the Tp-TPB/Tp-PTA electrode, and 17 days for the Tp-TPB-Tp/Tp-CoN electrode. It is obvious that after cutting and polishing the electrode surface, the slopes of the electrodes increase again to reach about 58.0 mV/concentration decade.

Response time

The response time [21] of each electrode was tested by measuring the time required to achieve a steady state potential (within ±1 mV) after successive immersion of the electrode in a series of its respective ion solution, each having a 10-fold increase in concentration from 1×10^{-5} M to 1.0×10^{-2} M. The electrodes gave steady potentials within 5–8 s using Tp-TPB/Tp-CoN and Tp-TPB/Tp-PTA electrodes. The potential readings remained constant, to within ±1 mV, for at least 4 min. Typical potential–time plots for the response characteristics of Tp-TPB/Tp-CoN electrode are shown in Fig. 3.

Analytical applications

The investigated electrodes can be used in the determination of Tp ion in pure solutions and in pharmaceutical preparations by (i) direct potentiometry, (ii) potentiometric titration, (iii) standard addition, and (iv) flow injection analysis. Student *t*- and *F*-tests (at 95% confidence level) were applied [22].

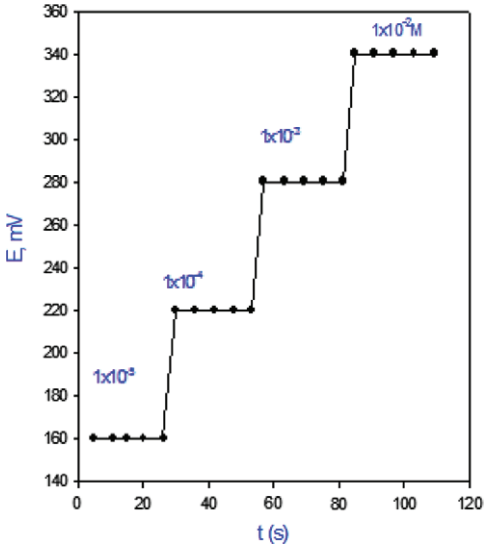

Figure 3 Potential–time plot for the response of Tp-TPB/Tp-CoN electrode.

Table 4 Evaluation of the precision of the standard addition and potentiometric titration methods.

Sample	Standard addition method		Official method (USP) [23]
Electrodes	Tp-TPB/Tp-PTA	Tp-TPB/Tp-CoN	
Actifed tablet 1.25 mg/tablet			
X ± SE	98.41 ± 0.39	98.12 ± 0.30	98.60 ± 0.29
F-value	1.52	1.11	
t-value	1.48	0.84	
Actifed syrup 2.5 mg/5 ml			
X ± SE	99.58 ± 0.43	99.94 ± 0.39	98.60 ± 0.29
F-value	1.85	1.52	
t-value	0.90	1.48	
	Potentiometric titration method		Official method (USP) [21]
Actifed tablet 1.25 mg/tablet			
X ± SE	98.85 ± 0.32	99.82 ± 0.53	98.60 ± 0.29
F-value	1.72	2.90	
t-value	0.10	1.10	
Actifed syrup 2.5 mg/5 ml			
X ± SE	99.18 ± 0.39	98.85 ± 0.21	98.60 ± 0.29
F-value	1.53	2.23	
t-Value	0.60	0.52	

X ± SE: Recovery ± standard error, *F*-tabulated is 9.28 at 95% confidence limit.
t-Tabulated is 2.447 at 95% confidence limit and 6 degrees of freedom.

The results show that the calculated *t*- and *F*-values did not exceed the theoretical values. The determination of TpCl in tablets and syrup was carried out using the standard addition and the potentiometric titration techniques. The mean recoveries in tablets and syrup were 98.12% and 99.94%, 98.41% and 99.58%, respectively, using Tp-TPB/Tp-CoN and Tp-TPB/Tp-PTA electrodes applying standard addition technique; the mean recoveries in tablets and syrup were 99.83% and 98.85%, 98.53% and 99.18%, respectively, using Tp-TPB/Tp-CoN and Tp-TPB/Tp-PTA electrodes applying potentiometric titrations, as shown in Table 4.

Flow injection analysis

Optimisation of FIA conditions

Flow injection analysis (FIA) has become a widely used methodology due to its versatility, high sampling frequency and minimum sample treatment necessary prior to injection into the system, reduced time of analysis and low consumption of reagents compared to the conventional manual procedure [24].

FIA parameters were optimised in order to obtain the best signal sensitivity and sampling rate under low dispersion conditions. The dispersion coefficients ranged from 1.56 to 1.60, i.e., limited dispersion that aids optimum sensitivity and fast response of the electrodes. The effect of sample size and flow rate on the performance of each electrode's response was assessed by injecting volumes between 20 and 500 µl of 10^{-3} M TpCl at different flow rates. The sample loop of size 150 µl and flow rate of 12.5 ml/min were found to be the optimum and used throughout this work. Fig. 4 shows the recordings (a) and calibration graph (b) using the Tp-TPB/Tp-CoN electrode under FIA conditions.

Electrode response in FIA

In potentiometric detection, the electrode potential depends on the activity of the main ion sensed. It is considered a principle advantage of this detection method that in flow measurements the dependence is semi-logarithmic over a wide analyte activity range according to the Nickolsky-Eisenman equation. However, the main unfavourable feature of this detection is the slow response of electrode potential to concentration change.

This occurs when low concentrations are measured and depends on the state of the electrode surface at the interface with the measured solution [25]. This slow response is a good reason for the super-Nernstian sensitivities observed in FI measurements using the investigated electrodes at different flow rates. An increase in the slope of the calibration plots in FIA was observed compared to batch measurements, where the potential is measured in conditions close to the equilibrium at membrane solution interface [18]. The slopes of the calibration graphs were 65.50 ± 1.2 and 75.00 ± 0.7 mV/decade in FIA compared to 58.40 ± 0.5 and 58.10 ± 0.7 mV/decade in batch conditions using Tp-TPB/Tp-CoN and Tp-TPB/Tp-PTA electrodes, respectively. The usable concentration range of the electrode in FIA was found to be 1×10^{-4}–1×10^{-2} M and 1×10^{-5}–1×10^{-2} M with detection limits 1.6×10^{-5} and 3.9×10^{-5} M using Tp-TPB/Tp-PTA and Tp-TPB/Tp-CoN electrodes, respectively. The super-Nernstian slope and lower sensitivities of the electrodes in FIA compared to batch mode may be attributed to many factors, including the mass transport rate, the non-uniformity of the concentration profile at the electrode surface, the sample dispersion, and the effect of contact time between the sample solution and the electrode surface [26]. In general, this behaviour is similar to that previously reported [18].

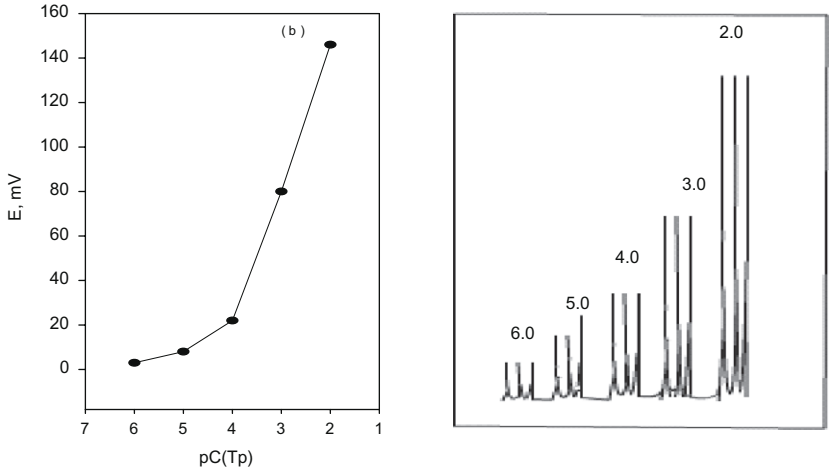

Figure 4 Recordings (a) and calibration graph (b) for Tp-TPB/Tp-PTA electrode under FIA conditions.

Table 5 Statistical treatment of the FIA data for the determination of TpCl using Tp-TPB/Tp-PTA electrode in comparison with reference method [23].

		CMCPE	
Sample	Reference method	Batch	FIA
Pure solution			
X ± SE	98.60 ± 0.36	97.92 ± 0.03	100.9 ± 0.05
F-value		4.22	4.56
t-Value		2.27	2.85
Actifed tablet 2.5 mg/tablet			
X ± SE	98.60 ± 0.36	98.85 ± 0.32	101.7 ± 0.03
F-value		1.72	3.96
t-Value		2.56	3.78

X ± SE: Recovery ± standard error, *F*-tabulated is 9.28 at 95% confidence limit.
t-Tabulated equals 3.143 at 99% confidence limit and 6 degrees of freedom.

Analytical applications using FIA

In FIA conditions the peak heights comparison is the best method for TpCl determination in its pure state or pharmaceutical preparations. Table 5 shows where the peaks obtained from series of different concentrations of TpCl are compared with those obtained by a standard series of the drug measured under the same conditions of flow rate, sample volume, pH and temperature. The percentage recovery can be obtained as the ratio of the peak heights and thus the concentrations can be calculated.

Conclusion

Triprolidine-tetraphenylborate/Cobalti-nitrite and triprolidine-tetraphenylborate/phosphotungstic acid carbon paste electrodes offer variable techniques for the determination of TpCl in pure solutions and in pharmaceutical preparations. The electrodes eliminate the prior separation steps that are usually necessary in other methods. The proposed sensors show high sensitivity (lower limit of detection, 6×10^{-6} and 1×10^{-5} M in batch and 1.6×10^{-5}, 3.9×10^{-5} M in FIA), the electrodes exhibit linear response with slope of 58.1 and 58.4 mV/concentration decade over concentration ranges from 6×10^{-6}–1×10^{-2} to 1×10^{-5}–1×10^{-2} M in batch and 1×10^{-5}–1×10^{-2} and 1×10^{-5}–1×10^{-2} M mV/concentration decade in FIA, a fast response time (5–8 s), long life span (17–85 days) and a wide pH range (2.5–7.5). Meanwhile, in case of Tp-TPB carbon paste electrode without mixing with any other ion-exchanger, the electrode was shown to exhibit a linear response with a slope of 54.32 mV/concentration decade over concentration range from 3.84×10^{-5} to 1×10^{-2} M in batch [14] with detection limit 1.78×10^{-5} M. Its life span was 40 days and pH range was 4.7–8.5.

We recommend the use of mixed ion-exchanger ion-selective electrodes for TpCl determination. Additionally, the proposed techniques have the advantages of simplicity, high selectivity, reduced analysis time and economy.

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