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Solid-state PVC flow-through benzoate electrode*

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Abstract: A general construction procedure for conventional shape ion-selective electrodes based on a conductive support prepared with a mixture of a non-conductive epoxy and graphite was used in the preparation of a flow-through benzoate electrode to be used as potentiometric detector in flow injection analysis manifolds. The membranes were prepared from tetraoctylammonium benzoate in *o*-nitrophenyloctylether immobilized on PVC.

The results of the assessment of the tubular electrodes behaviour in low dispersion manifolds against that of conventional electrodes with the same membrane are reported.

Data obtained with a double-channel flow injection manifold incorporating these tubular detectors for benzoate determinations in several commercially available pharmaceutical preparations are also presented.

Keywords: *Flow injection analysis; benzoate tubular selective electrode; pharmaceutical preparations.*

Introduction

When the development and use of ion-selective electrodes (ISEs) first began, most researchers devoted their attention to inorganic ions. More recently, however, there has been great interest in organic species [1–3], namely those with pharmaceutical interest.

In many cases there are definitive advantages in using ISEs since they can be used for the direct determination of species in pharmaceutical formulations without the need for complex sample manipulations. The procedure is frequently limited to adjusting the pH and the ionic strength of the solutions in which the determinations are made.

These advantages become even more significant when potentiometry is used as the detection process in flow injection analysis (FIA) with the detector shaped so that it can be tightly joined to the manifold, thus leaving the system free from mechanical problems.

In this paper the general working characteristics and usage of a benzoate tubular detector that is similar to one that was designed previously for nitrate [4] and calcium [5], are reported.

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Experimental

Apparatus and electrodes

The tubular electrode potentials were measured with a potentiometer (Radiometer PHM-64) coupled to a plotter (Radiometer REC-61) by an interface (Radiometer REA-100). All the other measurements were made with a digital potentiometer (Crison 2002) with a ±0.1 mV sensitivity.

Orion 90-02-00 double-junction electrodes (of silver–silver chloride type) were used as reference (inner filling solution, Orion 90-00-02); outer filling solution, 0.033 M potassium sulphate). An Ingold glass electrode (ref. 10/402/3092) was used for the pH measurements.

The conventional electrodes without inner reference solution [6] and the tubular detectors [4] were constructed as previously described.

Figure 1 shows the flow injection manifolds used to evaluate the electrode response characteristics and the benzoate determinations in the pharmaceutical preparations.

Solutions were pumped with a Gilson Miniplus 2 peristaltic pump and samples were inserted with Rheodyne 5020 valve. Omnifit Teflon tubing (0.7 mm, i.d.) for connections and some auxiliary home-made devices, namely joints, grounding electrode and reference electrode, constructed as previously reported [7] were also used.

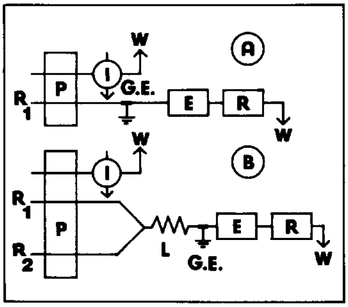

Figure 1
Flow injection manifold used in the tubular electrode evaluation (A) and in the determination of benzoate in pharmaceutical preparations (B): P, peristaltic pump; G.E., grounding electrode; I, injection valve; L, dilution coil (70 cm in length); E, tubular electrode; W, waste (gobal flow rate 6.4 ml cm^{-3}).

Reagents and materials

The water used in the preparation of all standards reagents solutions was de-ionized and distilled. All chemicals, except the following were of the best analytical grade available.

The tetraoctylammonium bromide (Fluka, ref. 88000), was purified by recrystallization from ethyl acetate.

The liquid ion exchanger, tetraoctylammonium benzoate in *o*-nitrophenyloctylether, was prepared by successive shaking (six times) of tetraoctylammonium bromide solution in *o*-nitrophenyloctylether (12%) with a 0.1 M sodium benzoate solution. The volume of the organic phase was increased by adding chloroform. After the last extraction process the organic phase was separated, and the chloroform evaporated by a current of dry nitrogen. The residual solution was kept over sodium sulphate.

Cocktails for the PVC-based sensor membranes consisted of liquid ion exchanger (electroactive component + *o*-nitrophenyloctylether), PVC and tetrahydrofuran in the amounts of 0.12 g, 0.51 g, and 18 cm^3.

Series of standard solutions, when necessary, were obtained by serial dilutions of a stock solutions prepared from the solid by weighing.

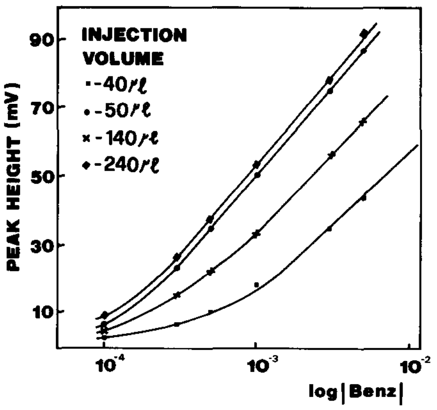

Figure 2
Recorder output obtained from a single-channel manifold for several benzoate solutions.

Results and Discussion

Calibration parameters

The response characteristics of the benzoate tubular electrode, when incorporated in the FIA manifold, were assessed on the basis of successive calibration curves, obtained from the recorder output (Fig. 2).

The characteristics of intrinsic response were assessed with a low dispersion single-channel manifold with a carrier of a solution 0.033 M in borax and sodium sulphate; the pH and ionic strength of the samples were adjusted to be also 0.033 M in borax and sodium sulphate. In this manner, it was attempted to minimize the influence of the flow system parameters on the values of the tubular electrodes potential.

Using the double-channel manifold, the detector behaviour was studied in a system designed to determine benzoate in pharmaceutical preparations where the sample flows through one channel, and the solution that adjusts the ionic strength and the pH flows through the other, until the point where they joined together. The influence of various flow system parameters in the electrode response, namely the injection volume, the length of the reaction coil and the flow rate, was studied. The results obtained with the tubular benzoate detector were in good agreement with those obtained earlier with another tubular electrode based on a mobile carrier sensor [4] where the response of the electrode is basically dependent on the injection volume because of its influence on dispersion.

The results obtained with the tubular detector when different amounts of the sample were injected in the double-channel manifold are shown in Fig. 3. A decrease in the volume injected lead to an increase in both the lower limit of the linear response and the value estimated for the limit of detection. This effect was also accompanied by a decrease in the slopes of the calibration curves. A similar, but less marked, behaviour was obtained with the single-channel system.

On the basis of these results injection volumes of approximately 140 μl for both systems and an overall stream of 6.4 ml min^{-1} were chosen. For the double-channel system, both channels contributed equally to the total flow rate. Under these conditions, the response and the return to the baseline were so rapid that up to 120 samples per hour could be achieved.

The general working characteristics of the tubular electrode when used as a detector in both of the aforementioned systems, as well as the results obtained with a conventional shaped electrode under batch conditions, are presented in Table 1.

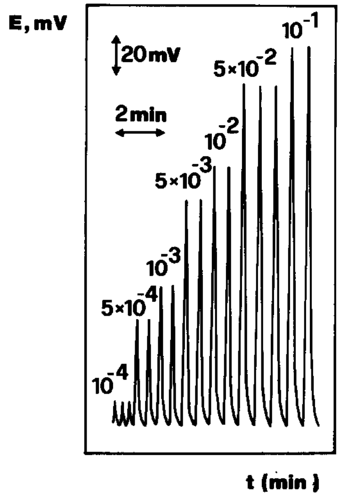

Figure 3
Calibration curves obtained with several injection volumes in a single-channel manifold.

Table 1
General performances of the tubular detector and the conventional electrode

		FIA manifold	
	Conventional electrode	Single-channel	Double-channel
LLLR (M)*	5×10^{-4}	1×10^{-4}	3×10^{-4}
LLD (M)†	1×10^{-4}	7×10^{-5}	1×10^{-4}
Slope (mV/decade)	62	57	55

*Lower limit of linear response.
†Lower limit of detection.

The results obtained with the single-channel manifold were very similar to those of the conventional electrode although the values for the lower limits of linear response (LLLR) and detection (LLD) were slightly lower. This was most probably due to the effective and continuous rinsing of the membrane by the carrier.

In the double-channel system, as expected, there was an increase in LLLR and LLD values when these were compared with those obtained with the single-channel manifold, since the concentration of benzoate in the sample plug had been reduced by the increased dispersion.

Effect of the pH

The effect of the pH on the potential of the tubular electrode (Fig. 4) was determined in the single-channel manifold with a 0.033 M sodium sulphate carrier using the procedures described elsewhere [8]. The results show that, for several benzoate concentrations tested, there was a large pH interval from approximately 7 to 12 units in which there were only slight variations in the potential. The amplitude and localization of these platforms were similar to those obtained with conventional electrodes without an inner reference solution.

With a view to applying the double-channel system to determinations of pharmaceutical preparations, tests were also performed to assess the effectiveness of introducing a borax solution through a side channel. It was found that the potential was not affected by the pH of the sample solutions in the range from 4 to 9 units.

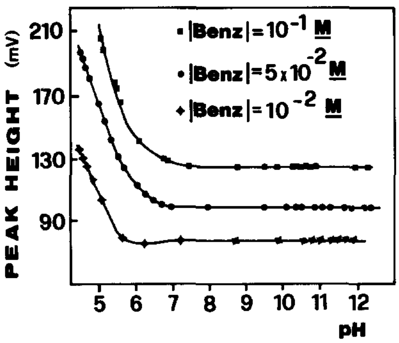

Figure 4
Potential response of the tubular electrodes at various pH values and different benzoate levels.

Selectivity of the potentiometric detectors

The potentiometric selectivity coefficients were determined for certain anions by means of the mixed solution method [9] with a constant interfering ion concentration and with varied benzoate concentrations within the 10^{-4} and 10^{-1} M range.

Table 2 gives the values obtained with the tubular detectors in comparison to those of the conventional electrodes without an inner reference solution under static conditions by the separate solution method.

The results confirmed that nitrate and chloride are species that must be taken into account given their high degree of interference, which is not surprising considering the type of sensor used. On the other hand, the potentiometric selectivity coefficients of the electrode to sulphate, were such as to suggest that the former may be used as an electrolyte for the carrier solution.

The interference of *o*-methoxyphenol (guaiacol) and 3-(*o*-methoxyphenoxy)-1,2-propenodiol (guaiacol glyceryl ether), compounds often present in benzoate-containing pharmaceutical preparations, was also studied. However, their potentiometric selectivity coefficients indicated that there is nothing to fear from the presence of these compounds.

Response stability and lifetime

The aforementioned characteristics of the tubular detectors were assessed on the basis of the repeated tracing of the calibration curves throughout the lifetime of the electrodes.

Table 2
Tubular and conventional electrodes potentiometric selectivity coefficient (log K^{pot})*

Interferent	Tubular†	Conventional‡
Sulphate	−1.70 (0.03)	−1.53 (0.09)
Chloride	+0.92 (0.08)	+0.83 (0.01)
Nitrate	+0.85 (0.07)	+0.88 (0.01)
o-Methoxyphenol	−0.70 (0.02)	—
3-(*o*-Methoxyphenoxy)-1,2-propanediol	−1.52 (0.05)	—

*Standard deviation of three determinations, in parentheses.

†Mixed solution method with the interference concentration fixed respectively to 10^{-2} M for sulphate and chloride, 5×10^{-3} M for nitrate and parametoxiphenol, and 10^{-3} M for 3-(*o*-methoxyphenoxy)-1,2-propanediol.

‡Values are average of two determinations with three electrodes obtained by the separated solution method.

The majority of the units were fully functional over more than 5 months of constant use (at least 4 days a week). The units were discarded when they presented slopes of <10% of their initial value.

Reproducibility during a working day was good, with no variations greater than ±0.5 mV between several calibration curves. This characteristic remained constant even after tests where the electrodes were put into contact with anionic interference solutions.

The response stability of the tubular detectors was also studied by the repeated injection (20 times) of the same benzoate solution at a concentration within the linear response zone. The relative standard deviation of the peak values (in mV) never exceeded 0.22 mV.

No special maintenance was necessary for these tubular detectors and furthermore, they may be stored in air between runs.

Benzoate determinations in medicinal syrups

The double-channel manifold (Fig. 1B) was used for benzoate determinations in medicinal syrups. The pharmaceutical preparations were first diluted with water before proceeding with the determinations, due to their high viscosities. Table 3 gives the results of the benzoate analysis of several commercially available pharmaceutical preparations, as well as their recovery percentages.

Table 3
Benzoate determination by FIA in some commercially available pharmaceutical preparations

Commercial name	Found (% w/w)	% Recovery
Codeisan	0.49	101
Gadipulmina	5.4	106
Tossil	2.2	98
Xarope Celsus	0.71	94
Xarope Labsan	1.9	100

Conclusions

The tubular detector shows good working characteristics, the most noteworthy of which are long lifetimes and excellent response stability. The latter makes it most useful for ion determinations in pharmaceutical preparations since it does not require systematic calibrations of the detection system.

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