Scientific paper

Preparation and Characterization of a Diclofenac Sensitive Electrode Based on a PVC Matrix Membrane

Zholt Kormosh,[1]* Iryna Hunka[2] and Yaroslav Bazel[3]

[1] *Department of Analytical Chemistry, Volyn National University, Voli av., 13, 43021, Lutsk, Ukraine,*

[2] *Department of Analytical Chemistry, Volyn National University, Voli av., 13, 43021, Lutsk, Ukraine*

[3] *Department of Analytical Chemistry, Uzhgorod National University, Pidgirna str., 46, 88000 Uzhgorod, Ukraine*

[3] *Department of Analytical Chemistry, P. J. Safarik University, Moyzesova str., 11, 04154 Kosice, Slovakia*

** Corresponding author: E-mail: kormosh@univer.lutsk.ua*

Received: 28-05-2007

Abstract

A new diclofenac-selective electrode based on an ion associate of diclofenac with a basic dye BIK as a membrane carrier was developed. The electrode exhibits a good Nernstian slope of 60.0 ± 1.1 mV decade^{-1} and a linear range of $1.0 \cdot 10^{-4}$ to $5.0 \cdot 10^{-2}$ mol L^{-1} for diclofenac. The detection limit was $5.0 \cdot 10^{-5}$ mol L^{-1}. The electrode has a fast response time 2–3 s and can be used for more the four months. The selective coefficients were determined and this electrode can be used in the pH range of 7–11. The analytical results obtained by applying the proposed method compared very favorably with who's obtained by the Ukrainian Pharmacopoeia Standard procedure. This membrane electrode was successfully tested in for the determination of diclofenac in pharmaceuticals.

Keywords: Diclofenac; Ion-selective electrode; Potentiometry; Pharmaceutical analysis.

1. Introduction

Diclofenac sodium (Fig. 1 (a)) is a non-steroidal anti-inflammatory drug (NSAID) with analgesic, anti-inflammatory and antipyretic properties. These properties are primarily achieved by its ability to block the enzyme cyclooxygenase, but also by an additional direct effect on hyperalgesia due to the functional down regulation of sensitized peripheral pain receptors. The efficacy of diclofenac equals that of many newer and established NSAIDs. As an analgesic it has a fast onset and long duration of action. Compared to other NSAIDs, diclofenac is well tolerated and rarely produces gastrointestinal ulcerations or other serious side effects. Thus, diclofenac can be considered as one of few non-steroidal anti-inflammatory drugs of first choice used in the treatment of acute and chronic painful and inflammatory conditions.[1]

Several methods for the determination of diclofenac in pharmaceuticals and biological fluids have been reported. They include potentiometry,[2–4] chromatography,[1,5] fluorometry,[6–8] gravimetric,[9] spectrophotometric,[10–14] chemometric,[15–17] and others methods.[18–21]

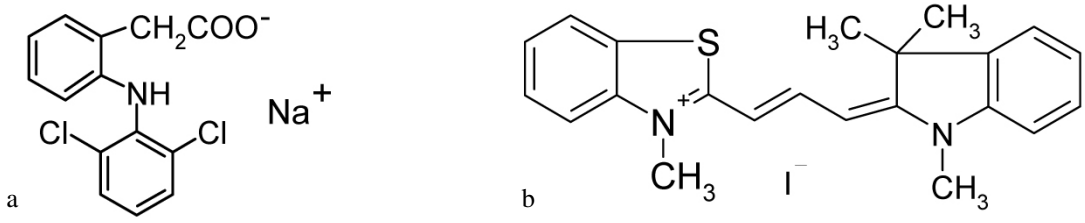

Figure 1: Structures of diclofenac sodium salt (1) and BIK (2).

The investigations of ion-selective electrodes (ISEs) have intensified recently. Many electrode types are commercially available from Beckman Instrument (USA), Coleman Instrument (USA), Corning Glass Instrument (UK), Orion Research Inc. (USA), Philips (Netherlands), Radelkis Electrochemical Instruments (Hungary), Radiometer (Denmark) etc. Wide applicability, small amounts of investigated substance, simplicity and usability not only place ISEs in the center of attention of the analytical chemistry but promote the use of them as an auxiliary means in physiological, medical, biological, geochemical studies and in monitoring the pollution state of the environment.[22–24]

Ion associates (IA) are the most universal of electrode-active substances (EAS) in their functional properties because either a cation or an anion may be the potential-determining ion. It is well known that to build a membrane-electrode responsive to ion X^-, the salt R^+X^- should be incorporated into a non-volatile solvent, and the R^+ ion must be highly lipophilic. Another important factor of IAs is their solubility. It must be sufficiently low, otherwise the IAs would be quickly washed our from the membrane, but not too low to prevent obtaining a uniform membrane.[22–27]

Intense development of pharmaceutical industry creates the extraordinarily wide spectrum of pharmaceutical products. The above facts require the development of new fast and reliable methods of determination the components of both the matrix and admixtures in pharmaceutical preparations, objects of environment and new materials. The solution of this problem is possible by developing the new harmonized spectrophotometric and ionometric methods using ion associates with good chemical-analytical characteristics.

Reliable spectrophotometric methods using ion associates are known for a narrow circle of organic substanees. The ³î̂n-selective electrodes made with ion associates were suggested for the determination of some of the substances. As a rule, they were electrodes sensitive to inorganic anions. In literature, the number row row of ³î̂n-selective electrodes using ion associates is described for determination of organic cations, however, the analytical properties of such electrodes insufficient for their wide practical and industrial use. Therefore, are explation of the circle of the determinabble compouds by ionometric methods and the reation of new electrodes and spectrophotometric methods with the improved chemical-analytical characteristics is a promising task o current interest.

There are reports on the information efficiency of the use of ionic associates as analytical forms for the spectrophotometric analysis. Lately a systematization of such researches was attempted. That led to development of a number of new photometric, extraction-photometric and certain ionometric methods of the determination of elements in different objects. At the same time the ionometric methods for many ions are not developed, the literature information on the use of ionic associates in the pharmaceutical analysis is practically absent, in particular, for determination active ingredients etc. The non-extractive methods were paid little attention. Therefore a study of the conditions and patterns of the formation and behavior of ion associates and the development of new analytical forms and methods of analysis is a promising current challenge.

The attempts of using IAs of base dyes as electrode-active components of ISEs were reported but the literature data on such electrodes is scarce. Primarily, liquid electrodes were described where a solution of an IA in an organic solvent is the ion-sensitive membrane. However, the construction of such electrodes is quite complicated and far from perfect.[28,29] A more convenient version is plasticized electrodes which are liquid membranes set in a polymer matrix; commonly, PVC is used.

Potentiometric method with ion selective electrodes can provide valuable and straightforward means of assaying diclofenac in complex mixtures, as it makes possible the direct determination of ions in solution with high selectivity. Most ion selective electrodes are low-cost, their use and maintenance are very simple, and assay procedures involving such electrodes are generally simple and fast. These features, coupled with the reliability of the analytical information, make ion selective electrodes very attractive for the assay of pharmaceutical products.[30]

We have shown the possibility of creating ISEs using IAs of diclofenac with base dyes that were isolated in solid state. Such compounds satisfy primary requirements to the EAS: they are much better soluble in organic solvents compared to water and are capable of partial dissociation in the organic phase with the formation of the potential-determining ions.

In this work, the preparation of a simple and low-cost electrode based on ion associate of diclofenac with basic dye BIK is described. Basic dyes are often used as reagents for the extractive spectrophotometric and potentiometric determination of many species.[28,31,32] The BIK is known as reagent for extraction-photometry determination of some inorganic elements. However, the problem of determination organic substances through the basic dyes did not get proper attention in particular in pharmaceutical analysis. It is known some organic substances that have anionic nature can form IA complex with the basic dyes.[22] The given fact can be applied to diclofenac ionometric determination using a membrane sensor based on ion associate of diclofenac with BIK. Therefore it triggers a further interest in a detail study of conditions and peculiarities of creation of ionic associates of diclofenac with this base dye. The investigation of the experimental variables that contribute to the electrode response led to the development of a simple, selective and reliable method for diclofenac assaying. This trend of analytical chemistry is rather topical and holds much promise.

2. Experimental

All chemicals were of analytical-reagent grade. Distilled water was used to prepare all solution and in all experiments. Dibutyl phtalate (DBP), dibutyl sebacate (DBS), dioctyl phtalate (DOP), dinonyl phtalate (DNP), tricresyl phosphate (TCP), cyclohexanone (CHN), tetrahydrofuran (THF), high molecular weight polyvinylchloride (PVC) were obtained from Sigma-Aldrich. The 0.04 mol L^{-1} buffer solutions of pH 5.0–12.0 ranges were freshly prepared.

The freshly prepared aqueous standard solutions ($1 \cdot 10^{-7} - 5 \cdot 10^{-2}$ mol L^{-1}) of diclofenac were prepared in 0.04 mol L^{-1} of buffer solution (for the study of effect of pH) for analytical purposes. Buffer solutions (pH 5.0–12.0*)* were prepared by mixing corresponding amounts of 0.04 mol L^{-1} H_3BO_3, 0.04 mol L^{-1} CH_3COOH, 0.04 mol L^{-1} H_3PO_4 and 0.2 mol L^{-1} NaOH. The ionic strength was adjusted with 0.1 mol L^{-1} KCl.

An ion associate of diclofenac with BIK (Fig. 1 (b)) was preparing by mixing of equal quantities of $1 \cdot 10^{-2}$ mol L^{-1} diclofenac sodium and $1 \cdot 10^{-2}$ mol L^{-1} of basic dye (BIK). The solution was settled during 2 hours and the sediment of ion associate was filtered (quantitative rapid filter paper). This residue was treated with 50 ml cold distilled water. The filter paper containing the precipitate was dried for 24 h at room temperature. This ion associate of diclofenac with BIK was used as an electrode active substance for preparing membrane of ion-selective electrode for diclofenac determination.

The general procedure to prepare the membrane electrodes was to mix thoroughly 0.1 g of powdered PVC and necessary amount of ion associate of diclofenac and BIK with necessary volume of a plasticizer in 5 ml cyclohexanone (in some cases tetrahydrofuran).

The resulting mixture was transferred into a glass dish of 2.5 cm diameter. The solvent was evaporated slowly at room temperature. The thickness of the membrane after drying was 0.5 mm. The diclofenac membrane of 5 mm diameter was cut out and glued to the polyethylene tube by using 10% solution of PVC. A solution $1.0 \cdot 10^{-2}$ mol L^{-1} (in some cases $5.0 \cdot 10^{-2}$ mol L^{-1}) of sodium diclofenac was used as internal reference solution.

The analytical products were purchased locally or directly from the manufacturers, and all were tested prior to the listed expiration date. Four pharmaceutical formulations containing sodium diclofenac salt and other components were analyzed with a diclofenac-sensitive electrode.

A freshly prepared $5 \cdot 10^{-2}$ mol L^{-1} aqueous solution of diclofenac (standard substance) was used as the stock solution. Next solutions (50 ml $1 \cdot 10^{-2} - 1 \cdot 10^{-7}$ mol L^{-1}) of diclofenac were prepared by suitable dilution of the stock solution with water. The ion strength of the final solutions used for the potentiometric determination was kept constant at 0.1 mol L^{-1} using potassium chloride solution.

All emf measurements were carried out with the following cell assembly. An I-160 M model pH/mV meter with Ag–AgCl reference electrode was used for the measurements of potential difference at 25.0 ± 1.0 °C. The standard procedure of the Ukrainian State Pharmacopeia employed for the assay of diclofenac in pharmaceuticals utilizes a potentiometric titration method using 0.1 mol L^{-1} hydrochloric acid in glacial acetic acid medium.[1]

3. Results and Discussion

It is well-know that the nature of the plasticizer plays a fundamental role in determining the potentiometric characteristics of an electrode. Of five different plasticizers employed dibutyl phthalate, dibutyl sebacate, dioctyl phthalate, dinonyl phthalate, tricresyl phosphate, the membrane prepared with DBP showed the best response characteristics (Fig. 2). This membrane consists of 9% ion associate of diclofenac with BIK, 36% DBP, and 45% PVC. The electrode response to diclofenac has the sensitivity of 60 mV decade^{-1} over the range $1 \cdot 10^{-4} - 5 \cdot 10^{-2}$ mol L^{-1} at pH 7–11, and the detection limit[33] of $5.0 \cdot 10^{-5}$ mol L^{-1} (Table 1). Therefore this membrane was used for detailed measurements. The following electrochemical cell was used:

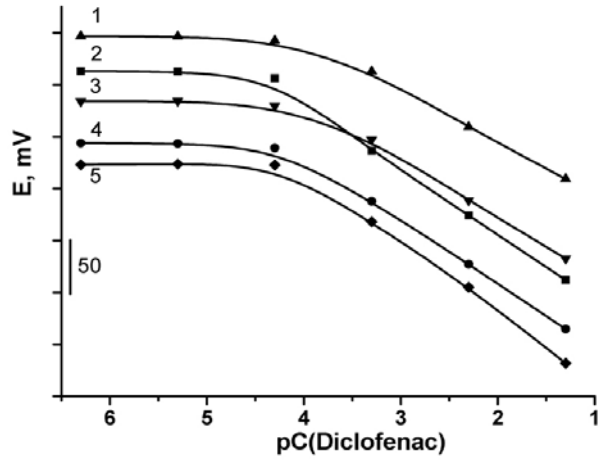

Figure 2: Effect of the nature of the plasticizers on the response of the proposed electrode (1 – DNP, 2 – DBS, 3 – DOP, 4 – DBP, 5 – TCP were used; pH 8).

$$\text{Ag}\,|\text{AgCl}|\text{KCl}_{(satd)}\,|\,\text{test solution}\,|\,\text{membrane}\,|\,\text{internal solution}\,|\,\text{internal reference electrode}$$

with varying $[DCF^-]$ $[DCF^-] = 1 \cdot 10^{-2}$ mol L^{-1}

The content of ion associate diclofenac with BIK on the response of the proposed electrodes was investigated. Among the 2%, 5%, 9%, 15%, 20%, 25%, of different content of ion associate, which were used some significant

Table 1: Effect of plasticizer on the response of diclofenac sensitive electrode (the content of ion associate 9%; response time 2–3 s; pH 8)

Plasticizer, 45%	Slope, mV pC^{-1}	Linear range, mol L^{-1}	Detection limit, mol L^{-1}
DNP	51.0 ±1.2	$5 \cdot 10^{-4}$–$5 \cdot 10^{-2}$	$1.0 \cdot 10^{-4}$
DOP	67.0 ±1.0	$5 \cdot 10^{-4}$–$5 \cdot 10^{-2}$	$8.5 \cdot 10^{-5}$
DBP	60.0 ±1.1	$1 \cdot 10^{-4}$–$5 \cdot 10^{-2}$	$5.0 \cdot 10^{-5}$
TCP	74.0 ±1.0	$1 \cdot 10^{-4}$–$5 \cdot 10^{-2}$	$7.0 \cdot 10^{-5}$
DBS	65.0 ±1.0	$5 \cdot 10^{-5}$–$5 \cdot 10^{-2}$	$4.0 \cdot 10^{-5}$

Table 2: Effect of content of ion associate and the concentration of the background electrolyte on the response of diclofenac sensitive electrode (DBP as a plasticizer was used; response time 2–3 s; pH 8)

Content ofion ion associate, %	The background electrolyte (0.1 mol L^{-1} KCl)			The background electrolyte (0.5 mol L^{-1} KCl)		
	Slope, mV pC^{-1}	Linear range, mol L^{-1}	Detection limit, mol L^{-1}	Slope, mV pC^{-1}	Linear range, mol L^{-1}	Detection limit, mol L^{-1}
2	57.0	1×10^{-4}–$5 \cdot 10^{-2}$	$4.0 \cdot 10^{-5}$	57.0	$1 \cdot 10^{-4}$–$5 \cdot 10^{-2}$	$3.0 \cdot 10^{-5}$
5	60.0	1×10^{-4}–$5 \cdot 10^{-2}$	$3.0 \cdot 10^{-5}$	59.0	$1 \cdot 10^{-4}$–$5 \cdot 10^{-2}$	$5.0 \cdot 10^{-5}$
9	60.0	1×10^{-4}–$5 \cdot 10^{-2}$	$5.0 \cdot 10^{-5}$	60.0	$1 \cdot 10^{-4}$–$5 \cdot 10^{-2}$	$5.0 \cdot 10^{-5}$
15	59.0	1×10^{-4}–$5 \cdot 10^{-2}$	$6.0 \cdot 10^{-5}$	60.0	$1 \cdot 10^{-4}$–$5 \cdot 10^{-2}$	$7.0 \cdot 10^{-5}$
20	60.0	1×10^{-4}–$5 \cdot 10^{-2}$	$5.0 \cdot 10^{-5}$	58.0	$1 \cdot 10^{-4}$–$5 \cdot 10^{-2}$	$5.0 \cdot 10^{-5}$
25	62.0	1×10^{-4}–$5 \cdot 10^{-2}$	$5.0 \cdot 10^{-5}$	61.0	$1 \cdot 10^{-4}$–$5 \cdot 10^{-2}$	$5.0 \cdot 10^{-5}$

difference on the potential response was founded. The best result was shown by electrode with dibutyl phthalate as a plasticizer and 9% of ion associate content used (Table 2).

The dependence of the electrode potential response on the pH was studied over the pH range of 5–12. The ion strength of the test solution was adjusted using 0.1 mol L^{-1} KCl. The potentials pH profile for $1 \cdot 10^{-3}$ and $1 \cdot 10^{-2}$ mol L^{-1} of diclofenac concentrations shown in Fig. 3 indicates that the potential remains constant over the pH ranges of 7–11. For pH values below 7, progressive formation and precipitation of free diclofenac acid is formed.[3] For pH > 11, the hydroxide ion interferes with the electrode response.

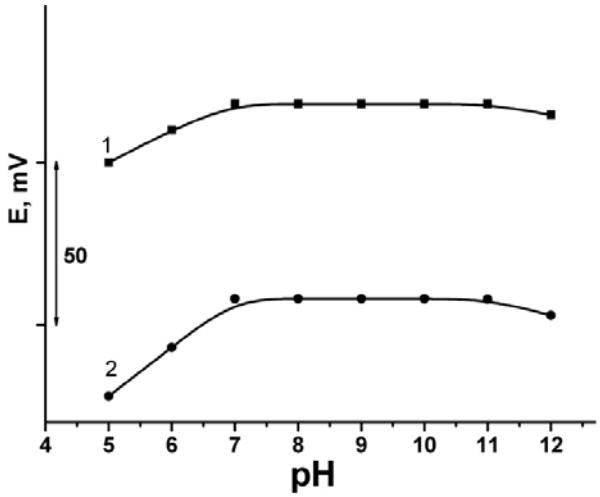

Figure 3: Effect of the pH of test solution on the potential response of the diclofenac ion selective electrode (1 – pC 3, 2 – pC 2).

The effect of internal solution concentration on the potential response electrode was investigated. The concentration of sodium diclofenac $1 \cdot 10^{-2}$ and $5 \cdot 10^{-2}$ mol L^{-1} was used. It was found that the concentration variation of the internal solution does not show any significant difference in the corresponding potential response, but the overall emf of the used cell was changed. No variation in the slope and detection was observed, on taking dilute internal reference solution hence $1 \cdot 10^{-2}$ mol L^{-1} diclofenac sodium was used as an internal solution for smooth functioning of the electrode membrane.

The dynamic response time of a membrane electrode is an important factor for analytical application.[30,33] The response time of electrode was recorded by changing the sodium diclofenac concentration over a concentration range of $1 \cdot 10^{-7} - 5 \cdot 10^{-2}$ M. It was found that the electrode reaches its equilibrium response in 2–3 s. A lifetime of the electrodes like that are 16–20 weeks. These electrodes can be used more for the 100 measurements. The slope and dynamic range of the electrode during this period remained unchanged.

The reproducibility of the electrode was also examined by immersing the electrode alternatively in $1 \cdot 10^{-2}$ mol L^{-1} and $5 \cdot 10^{-2}$ mol L^{-1} of sodium diclofenac solutions.

The emf response of the membrane at varying concentration of diclofenac indicates a rectilinear range from $1 \cdot 10^{-4}$ to $5 \cdot 10^{-2}$ mol L^{-1}. The slope of the calibration curve was 60 mV $decade^{-1}$ of sodium diclofenac concentration. The detection limit, as determined from the intersection of the two linear segments of the calibration graph, was $5 \cdot 10^{-5}$ mol L^{-1}.

The selectivity is an important characteristic of the electrode, which decides whether a target species concen-

tration can be estimated accurately by using the proposed electrode or not. The selectivity coefficients of the electrode were determined using separate solution method.[30,33] The potentiometric selectivity for membrane diclofenac selectivity electrode $-\lg K^{pot}_{DCF,I^-}$ were determined, for a number of anions and cations. No interference from ions such as Ca^{2+}, SO_4^{2-}, PO_4^{3-}, tartrate, citrate etc was recorded.

The analysis of current literature data leads to a conclusion that the major factors that determine the electrode characteristics of plasticized ISEs are: the nature and the concentration of EAS, the polymer matrix and the solvent (plasticizer). If an ISE is paired with a comparison electrode and immersed into the investigated solution, the EMF of such an electrochemical cell follows the equation:

$$E = E^\circ \pm \frac{RT}{Z_m F} \ln \left[a_m + \sum_s K_{m-s} (a_s)^{Zm/Zs} \right] \quad (1)$$

where (+) stands for cation, (–) stands for anion; a_m, a_s are the activities of the principal and the interfering ions; z_m, z_s are the change of the charge of respective ions; K_{m-s} is the selectivity coefficient.

The selectivity coefficients of created ISEs were determined by the mixed solutions technique [30] based on the EMF measurements of the solutions where the interfering ion concentration remains constant, whereas the principal ion concentration varies. Having determined the activity of the anions of interest a_m (by the point where the values of the logarithmic expressions in Eq. 1 are equal) and knowing the activity of foreign ions a_s, the selectivity coefficients were calculated as $K_{m-s} = a_m/a_s$:

$$K_{m-s} = a_m/a_s \quad (2)$$

We have established the relation between the equation parameter of the some interfering ions and the selectivity coefficients (Fig. 4). The plot shows that the interfering effect in the given system increases with the anion equation parameter ($-\Delta G_{aq}$). Obtained data show that the selectivity of an ISE depends on the extraction and ion-exchange equilibria of the distribution of the ion being determined.

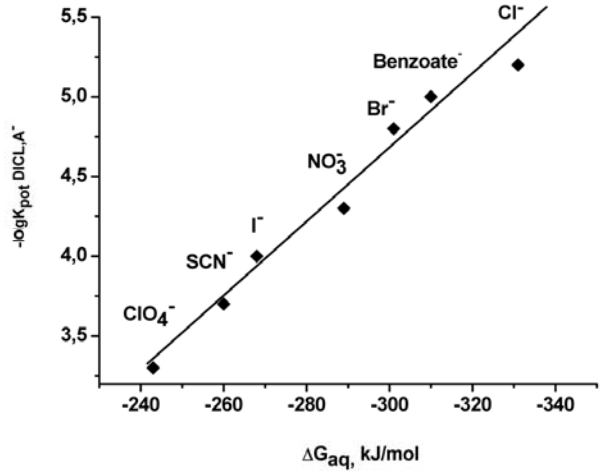

Figure 4: The relation between the equation parameter of the some interfering ions and the selectivity coefficients

One can see from the data given in Table 3 that many investigated ion do not interfere with the proposed ion selective electrode diclofenac with BIK by the matched potential method. In this method, the selectivity coefficient is defined by the ratio of the activity of the primary ion relative to an interfering ion, when they generate identical potentials in the same reference solution. Both monovalent ions are treated in the same manner and the valence of the ions does not influence the selectivity coefficient.[22]

In Table 4, the selectivity coefficients of the proposed membrane electrode for some interfering ions are compared with the corresponding values previously reported for diclofenac ion selective electrodes.[2–4] A comparison of the proposed electrode with reported electrodes presented in Table 3 and in Table 4 indicates that the selectivity coefficients of the proposed electrode are similar or somewhat better than those reported for diclofenac ion selective electrodes.

On the basis of experimental results we have shown the successful applicability of the new membrane electrode based on ion associate diclofenac with BIK for determining diclofenac in pharmaceutical formulas. In Table 5 the result for determining of diclofenac amount in some

Table 3: Comparison of the analytical performance of the proposed electrode with the reported diclofenac ion selective electrodes

Membrane	pH	Slope, mV decade^{-1}	Linear range, mol L^{-1}	Detection limit, mol L^{-1}	Resp. time, s	Life time weeks
Iron(II)–Phtalocyanine,[4]	7.2	–61.0 ± 1.0 –55.0 ± 1.0	$9 \cdot 10^{-6}$–$1 \cdot 10^{-2}$ $6 \cdot 10^{-6}$–$1 \cdot 10^{-2}$	$5.4 \cdot 10^{-6}$ $4.4 \cdot 10^{-6}$	<10	16 <5
Complex diclofenac with HDPB,[2]	6–9	–59.0 ± 1.0	$1 \cdot 10^{-5}$ – $6 \cdot 10^{-2}$	$4.0 \cdot 10^{-6}$	<10	>3
Pt|$Hg_2(DFC)_2$|graphite,[3]	7	–58.1 ± 0.8	$5 \cdot 10^{-5}$ – $1 \cdot 10^{-2}$	$3.2 \cdot 10^{-5}$	10–30	20
Ion associate diclofenac with BIK, [this work]	7–11	–60.0 ± 1.1	$1 \cdot 10^{-4}$ – $5 \cdot 10^{-2}$	$5.0 \cdot 10^{-5}$	2–3	16–20

Table 4: Comparison of the selectivity coefficients of the proposed electrode with the reported diclofenac ion selective electrodes (membrane No 1 was used)

	Ion	Iron(II)-Phtalocyanine,[4]	Complex diclofenac with HDPB,[2]	Pt|$Hg_2(DFC)_2$| graphite,[3]	Present work
$-\log K_{pot}$ DCF,I^-	Cl^-	2.3	2.6	0.36	*
	Br^-	3.3	3.3	–	4,8
	I^-	2.9	–	–	4.0
	IO_3^-	3.3	–	–	–
	NO_2^-	3.2	–	–	–
	NO_3^-	2.0	2.3	*	4.3
	SO_4^{2-}	3.0	–	3.9	*
	SCN^-	3.5	–	–	3,7
	PO_4^{3-}	3.8	–	–	*
	oxalate	3.8	–	2.1	–
	tartrate	3.6	–	–	*
	citrate	3.8	–	–	*
	benzoate	3.3	–	2.1	5.0
	salicilate	2.7	–	2.0	4.7
	phthalate	3.3	–	2.1	–
	Mg^{2+}	–	3.2	–	5.1
	Ca^{2+}	–	3.1	–	*
	Na^+	–	1.3	–	5.1
	K^+	–	3.0	–	5.0
	perchlorate	–	–	*	3.3
	formiate	–	–	3.7	–
	acetate	–	–	2.9	–

* – no interference

Table 5: Diclofenac quantities in pharmaceuticals as determined by the proposed membrane electrode and potentiometric titration method

Sample	Label amount, mg	Found by proposed Electrode (with DBP)		Found by potentiometric Titration [1]	
		mg	RSD (%) (n = 5)	mg	RSD (%) (n = 5)
Dicloran® CP	100.0 $tablet^{-1}$	101.2 ± 1.3	1.0	101.7 ± 1.4	1.1
Dicloberl retard	100.0 $capsule^{-1}$	99.6 ± 1.5	1.2	100.1 ± 1.2	1.0
Sodium Diclofenac	25.0 $capsule^{-1}$	25.1 ± 0.5	1.6	25.2 ± 0.4	1.0
Naclofen	75.0 $ampoule^{-1}$	74.8 ± 1.2	1.3	74.7 ± 0.6	1.0

pharmaceuticals are shown. The results are in satisfactory agreement with the labeled amounts.

The influence of the concentration of the background electrolyte on the main characteristics of the proposed electrode was studied (Table 2). The nature and the concentration of the background electrolyte are very important in the measurement of the electrode potential. Its anion must not compete with the potential-determining anion for the position in the membrane. Recalling that the anion selectivity series corresponds with the equation parameter of the respective anions, the best background electrolyte is the KCl solution (Cl^- anion has the lowest equation parameter: ΔG_{aq} = –331 kJ/mol). Obtained results are presented in the Table. One can see minor changes in the slope and the linearity of the electrode function as well as the sensitivity of the determination.

4. Conclusions

The presented method with a membrane electrode based on ion associate of diclofenac with BIK for determination of diclofenac in pharmaceutical preparations is simple, rapid and low cost. This data obtained provide the evidence that the new membrane electrode can be used as an effective way of testing the amounts of diclofenac in pharmaceutical formulations.

5. Acknowledgements

This work was supported by the International Vishegrad Fund (No 997015). J. B. is thankful for support from MVTS Grant Mad/Ukr/SR/UPJS07 and Scientific Grant

Agency of the Ministry Education of the SR (VEGA 1/4450/07).

6. References

1. R. Roœkar, V. Kmetec, *J. Chromatog. B*, **2003**, *788*, 57–64.
2. M. Shamsipur, F. Jalali, S.Ershad, *J. Pharm. Biomed. Anal.,* **2005**, *37*, 943–947.
3. A. O. Santini, H.R. Pezza, L. Pezza, *Talanta*, **2006**, *68*, 636–642.
4. S. S. M. Hassan, W. H. Mahmoud, M. A. F. Elmosallany, M. H. Almazzooqi, *J. Pharm. Biomed. Anal.,* **2005**, *39*, 315–321.
5. C. Arcelloni, R. Lanzi, S. Pedercini, G. Molteny, at all, *J. Chromatog. B*, **2001**, *763*, 195–200.
6. J. A. Arancibia, M. A. Boldrini, G. M. Escandar, *Talanta*, **2000**, *52*, 261–268.
7. P. C. Damiani, M. Bearzotti, M. A. Cabezón, A. C. Olivieri, *J. Pharm. Biomed. Anal,* **1999**, *20*, 587–590.
8. L. A. Carreira, M. Rizk, Y. El-Shabrawy, N.A. Zakhari, S.S. Toubar, *J. Pharm. Biomed. Anal,* **1995**, *13*, 1331–1337.
9. M. Tubino and R. L. de Souza, *J. AOAC Intern*, **2005**, *88*, 1684–1687.
10. R. L. de Souza, M. Tubino, *J. Braz. Chem. Soc,* **2005**, *16*, 1068–1073.
11. J. C. Botello and G.Pérez Caballero, *Talanta*, **1995**, *42*, 105–108.
12. S. Agatonović-Kuštrin, Lj. Živanović, M. Zečević, D. Radulović, *J. Pharm. Biom. Anal*, **1997**, *16*, 147–158.
13. A. A. Matin, M. A. Farajzadeh, A. Joyuban, *IL Farmaco,* **2005**, *60*, 855–858.
14. C. S. P. Sastry, A. S. R. Prasad Tipirneni and M.V. Suryanarayana, *Analyst,* **1989**, *114*, 513–515.
15. M. M. Sena, Z. F. Chaudhry, C. H. Collins, R.J. Poppi, *J. Pharm. Biom. Anal*, **2004**, *36*, 743–749.
16. J. Ghasemi, A. Niazi, S. Ghobadi, *J. Chin. Chem. Soc,* **2005**, *52*, 1049–1054.
17. J. Chasemi, A. Niazi, S. Ghobadi, *Pharm. Chem. J*., **2005**, *39*, 671–765.
18. M. Tubino, R. Leandro de Souza, *Talanta*, **2006**, *68*, 776–780.
19. M. L. Ferńandez de Córdova, P. Ortega Barrales, A. Molina Díaz, *Anal. Chem. Acta*, **1998**, *369*, 263–268.
20. M. S. Garcßa, M. I. Albero, C. Sanchez-Pedreño, J. Molina, *J. Pharm. Biom. Anal.*, **1998**, *17*, 267–273.
21. S. Mazurek, R. Szostak, *J. Pharm. Biom. Anal.*, **2006**, *40*, 1235–1242.
22. R. Durst, *Ion-selective electrodes*, Mir, Moscow, 1972.
23. N. Lakshminarayah, *Membrane electrodes*, Chemistry, Leningrad, 1979.
24. J. Koryta, K. Štulík, *Ion-selective electrodes*, Mir, Moscow, 1989.
25. O. M. Petrukhin, *Ion-selective electrodes*. Znannya, Moscow, 1986.
26. G. E. Baiulescu and V. V. Cosofret, *Application of ion-selective membrane electrodes in the organic analysis*, Ellis Horwood Ltd, 1977.
27. K. Vytras, *J. Pharm. Biomed. Anal.,* **1989**, *7*, 789–812.
28. Y. R. Bazel, *Journal of Analytical Chemistry,* **2002**, *57*, 1066–1070.
29. K. Cammann, *Work with ion-selective electrodes*, Mir, Moscow, 1980.
30. E. Bakker, P. Buhlmann, E. Pretsch, *Chem. Rev*, **1997**, *97*, 3083–3132.
31. Zh. O. Kormosh, I. P. Hunka, Y. R. Bazel, *Methods and objects of chemical analysis,* **2007**, *2*, 76–81 (www.achem.univ.kiev.ua/moca/3/9.htm)
32. Zh. Kormosh, I. Hunka, Y. Bazel, Chin. Chem. Lett., **2007**, *18*, 1103–1106.
33. E. Bakker, E. Pretsch, P. Buhlmann, *Anal. Chem*, **2000**, *72*, 1127–1133.

Povzetek

Razvili smo novo diclofenac-selektivno elektrodo, ki deluje na podlagi tvorbe ionskega asociata med diclofenacom in alkalnim barvilom BIK, kot membranskim nosilcem. Elektroda izkazuje Nernstov naklon 60,0 ± 1.1 mV na dekado in področje linearnosti od $1.0 \cdot 10^{-4}$ do $5.0 \cdot 10^{-2}$ mol L^{-1}. Za diclofenac je bila dosežena spodnja meja detekcije $5.0 \cdot 10^{-5}$ mol L^{-1}. Elektroda za katero smo določili koeficiente selektivnosti deluje optimalno v območju pH 7–11, ima hiter odzivni čas 2–3 s in jo lahko uporabljamo dalj kot štiri mesece. Opisano membransko elektrodo smo uspešno testirali za določevanje diclofenaca v zdravilih. Rezultati analiz z razvito elektrodo se dobro ujemajo z rezultati standardnega postopka po ukrajinski farmakopeji.