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Electrochemical Sensors for Determination of Anticonvulsant Drug Gabapentin in Bulk Powder and Pharmaceutical Dosage Forms

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Three simple, sensitive and selective sensors for determination of gabapentin (GAB) have been fabricated and validated. Plastic membrane I, coated wire II and coated graphite rod III were constructed by the incorporation of gabapentin with phosphotungstic acid (PTA) in the presence of *o*-nitrophenyloctylether *o*-NPOE as electroactive material. The influence of several parameters such as (membrane composition, kind of plasticizer, type of ion-pair, pH of the test solution, soaking time and foreign ions on the potential of the sensors was investigated and optimized. The proposed sensors clarified Nernstain response with a mean calibration slope of 57.57±0.26, 59.57±0.31 and 55.07±0.91 mV dacade^{-1} over gabapentin concentration range $1.0x10^{-5}$ -$1.0x10^{-2}$, 5.0 $x10^{-6}$-$1.0x10^{-2}$and $1.0x10^{-5}$-$9.0x10^{-3}$ mol L^{-1} for sensor I, II and III respectively. The fabricated sensors showed high sensitivity with detection limit of $5.0x10^{-6}$, $2.5x10^{-6}$ and $4.6x10^{-6}$ mol L^{-1} for the above mentioned sensors, respectively. The recorded pH was 1.5-3.5 and the effect of common possible interfering species such as inorganic cations, sugars and amino acids was studied. The obtained results were statistically evaluated according to ICH guidelines.

Keywords: Plastic membrane; Coated wire electrode; Coated graphite rod; Ion-selective electrodes; Gabapentin; electrochemical sensors

1. INTRODUCTION

Gabapentin, 2-[1-(aminomethyl) cyclohexyl] acetic acid (Figure 1) is an anticonvulsant that is used for preventing seizures and for treating post herpetic neuralgia. The mechanism of action of

gabapentin is not known. Gabapentin structurally resembles the neurotransmitter gamma aminobutyric acid (GABA). It is possible that this similarity is related to gabapentin's mechanism of action. Gabapentin is used alone or in combination with other medications to treat seizures caused by epilepsy [1].

Figure 1. Chemical structure of gabapentin

The literature survey showed that gabapentin was determined by several analytical methods include high-performance liquid chromatography [2-3], liquid chromatography coupled with mass spectrometry [4], spectrophotometry [5, 6], capillary electrophoresis [7], voltammetry [8, 9], chemiluminescence [10] and potentiomerty [11, 12].

Although potentiomerty has some advantages over other techniques being easy, precise and accurate, few sensors have been constructed. In the present study new selective membrane electrodes, of three types: plastic membrane, coated wire and coated graphite electrodes have been constructed for the determination of gabapentin in pure form, pharmaceutical preparations and biological fluids.

2. EXPERIMENTAL

2.1. Apparatus

The electrochemical measurements were carried out with Jenway 3040 pH-mV meter (U.K.) with an indicator electrode in conjunction with double junction Ag/AgCl electrode (Orion 90-02) (Taiwan, R.O.C) containing 10 % w/v potassium nitrate in outer compartment. An Orion 91-02 glass-calomel combination electrode, (Taiwan, R.O.C) was used for pH adjustment.

2.2. Reagents and Materials

All chemicals used were of analytical grade, pure grade gabapentin was kindly supplied from EVA Pharm for medical applications, (Egypt). Conventin® Capsules labeled to contain 100 mg of gabapentin per capsules and Neuronyin® Capsules labeled to contain 400 mg gabapentin were

purchased from local drug stores. Poly (vinyl chloride) (PVC) high molecular weight and phosphotungstic acid 99.1 % were purchased from Aldrich, Germany. Ethanol 99.0 %, Acetone 99.9%, di-butyl phthalate (DBP) 99.0 %, di-octyl sebacate 99.0 %, o-nitrophenyl octyl ether 99.5 % and tetrahydrofuran (THF) 97.0% were provided by Fluka, Switzerland. Urine samples were obtained from healthy volunteers and serum samples (Multi-Serum Normal, Ranbdox Laboratories UK) were obtained from commercial sources.

2.3. Standard drug solution

Stock gabapentin solution $1.0x10^{-1}$ mol L^{-1} was freshly prepared daily by dissolving 0.428 g of the drug in 10.0 mL ethanol and complete to 100 mL using distilled water. Serial dilutions ($1.0x10^{-6}$-$1.0x10^{-2}$ mol L^{-1}) were obtained using distilled water.

2.4. Preparation of ion-pair

The ion-pair was prepared by mixing 50 mL of $1.0x10^{-2}$ mol L^{-1} of phosphotungstic acid with an equimolar solution of gabapentin, stirred for 10 min. The resulting white precipitate was filtered through G_4 sintered glass crucible and washed thoroughly with distilled water then dried at room temperature for 24 h. The ion-pair should be stored in a desiccator.

2.5. Membrane composition

The percentages (w/w %) of the ion pair, PVC and plasticizer *o*-NPOE were varied until the optimum composition that exhibited the best performance characteristics was obtained. This was achieved by preparing the membrane by dissolving 1.25 mg of the ion pair, 41.25 mg PVC and 82.5 mg of *o*-NPOE, in 5.0 mL THF. The solution mixture was allowed to evaporate slowly at room temperature for 24 h in 3 cm petri dish.

2.6. Electrode construction

Plastic membrane electrode: A circular membrane was attached to a poly-ethylene tube (8 mm diameter) in electrode configuration by means of PVC-THF solution. A mixture containing equal volume of $1.0x10^{-3}$ gabapentin and $1.0x10^{-3}$ mol L^{-1} potassium chloride was used as internal reference solution in which the Ag/AgCl reference electrode was dipped. The constructed electrode was pre-conditioned after preparation by soaking for at least 24 h in $1.0x10^{-3}$ mol L^{-1} gabapentin and stored in the same solution. All potentiometric measurements were performed using the following cell assembly: Ag/AgCl / internal solution / membrane / test solution // KCl salt bridge // SCE.

Coated wire electrode: Pure aluminum wire of 4.0 cm length was tightly insulated by polyethylene tube and coated using the coating solution was described under (2.5. membrane composition). Prior to coating, the polished aluminum surface was washed with a detergent,

thoroughly rinsed with water, and dried with acetone. Afterwards, the aluminum wire was coated by quickly dipping it into the coating solution several times, and allowing the film left on the wire to dry for about 3 min. The prepared electrode was conditioned by soaking for 6 h in $1.0x10^{-3}$ mol L^{-1} gabapentin solution. All potentiometric measurements were performed using the following cell assembly: Al / membrane / test solution // KCl salt bridge // SCE.

Coated graphite electrode: A pure graphite rod 4.0 cm length and 4.0 mm diameter was insulated by tight polyethylene tube. The polished electrode surface was coated with the active membrane by dipping the exposed end into the coating solution that was described under (2.5. membrane composition), ten times and allowing the film left on graphite rod to dry in air for 1 min each time. The prepared electrode was preconditioned by soaking for 8 h in $1.0x10^{-3}$ mol L^{-1} gabapentin solution [13]. All potentiometric measurements were performed using the following cell assembly: Graphite rode/ membrane / test solution // KCl salt bridge // SCE.

2.7. Electrode Calibration

Direct calibration technique was used for the precondition sensors. Calibration of each prepared sensor was carried out by measuring the potential of $1.0x10^{-6}$-$1.0x10^{-2}$ mol L^{-1} gabapentin solutions, staring form low to high concentrations. The potential was plotted as a function of –log conc. of the drug for each prepared electrode.

2.8. Electrode Selectivity

Separate solution method [14] was used for the determination of the selectivity coefficients $K^{Pot}_{GabJ}{}^{z+}$ of the electrodes towards different cationic species. The following equation was applied.

$$\text{Log } K^{Pot}_{Gab}{}^{-}\, J^{z+} = (E_2 - E_1)/S + \log [\text{Gab.}] - \log [J^{z+}]^{1/z}$$

Where, E_1 is the electrode potential in $1.0x10^{-3}$ mol L^{-1} gabapentin solution. E_2 is the potential of the electrode in $1.0x10^{-3}$ mol L^{-1} solution of the interferent ion J^{z+} and S is the slope of the calibration plot.

2.9. Effect of pH

The influence of the pH on the potential of gabapentin fabricated sensors was investigated. The potential was recorded for the standard cell and varying the pH over range from 1-5 by adding small volumes of $1.0x10^{-1}$ mol L^{-1} of each sodium hydroxide or hydrochloric acid separately.

2.10. Standard Addition Method

Each prepared sensor was immersed into a sample of 50 mL with unknown concentration (ca. $1.0x10^{-4}$ mol L^{-1}) and the equilibrium potential of E_1 was recorded. Then small increments of standard gabapentin solution $1.0x10^{-1}$ mol L^{-1} were added into the testing solution and the equilibrium

potential of E_2 was obtained. From the change of ΔE (E_2-E_1) the concentration of the testing sample was determined [15].

2.11. Analytical Applications

2.11.1. Determination of gabapentin in capsules

The content of ten Conventin® or Neurontin® capsules was finely powdered. An accurate weight of the fine powdered. An accurate weight of the fine powder equivalent to 0.0428 g gabapentin was dissolved in 5.0 mL $1.0x10^{-2}$ mol L^{-1} hydrochloric acid and completes to mark with distilled water in a 25-mL volumetric flask to obtain a solution claimed to contain $1.0x10^{-2}$ mol L^{-1} gabapentin. Appropriate dilutions were carried out with water to obtain serial concentrations in the range of $1.0x10^{-6}$-$5.0x10^{-3}$ mol L^{-1} to be analyzed using the three mentioned sensors.

2.11.2. Content Uniformity Assay of gabapentin

The content uniformity assay was studied using two types of gabapentin capsules. The first one was Conventin® 100 mg/ Cap and Neurontin® 400 mg/Cap. To study the content uniformity assay, ten individual capsules of each type were placed in separate 100-mL beakers and dissolved in 100 mL of distilled water. The sensor(s) was directly immersed into 100 mL of drug sample for five times and should be washed with distilled water to reach steady potential between the individual measurements. The mean potential was used to evaluate the content uniformity from the calibration graph.

2.11.3. Application to Serum and Urine

Urine and serum pH was adjusted to pH 3 using $1.0x10^{-1}$ mol L^{-1} hydrochloric acid. 5.0 mL of adjusted urine or serum were transferred into small separatory funnel and then separately 5.0 mL of $1.0x10^{-5}$-$1.0x10^{-2}$ mol L^{-1} standard drug solution were added folloed by 20 mL toluene for urine or 20 mL diethylether for serum, each funnel was for 5.0 min and aqueous layer was transferred to a 50-mL volumetric flask and diluted to volume with distilled water. Apply above procedure as described under electrode calibration, using the urine and serum samples instead of standard drug solution.

3. RESULTS AND DISCUSSION

3.1. Optimization of membrane composition

The effect of membrane composition on the potentiometric response of the electrodes was investigated by varying the proportion of the membrane active phase to plasticizer and PVC ratio. In this study four membrane compositions were investigated and the results were summarized in Table 1. The results showed that the electrode(s) made by membrane of type (b) with 1.0 w% gabapentin-

phosphotungstate ion pair, 33.0 w% PVC and 66.0 w% *o*-NPOE exhibited the best performance characteristics (slope 57.57±0.264, 59.57±0.309 and 55.07±0.914 mV decade^{-1}) at 25 ^{o} C over gabapentin concentration range of 1.0x10^{-5}-1.0x10^{-2}, 5.0x10^{-6}-1.0x10^{-2} and 1.0x10^{-5}-9.0x10^{-3} mol L^{-1} for plastic membrane, coated wire and coated graphite electrodes respectively.

Table 1. Optimization of membrane composition (w/w %) for gabapentin sensors

Type of sensor	m	PVC w%	o-NPOE w%	Ion-pair w%	Slope	RSD%	r	Linear conc. range
Plastic membrane sensor	(a)	30.0	68.0	2.0	56.11	0.924	0.9995	1.0x10^{-5}-1.0x10^{-3}
	(b)	33.0	66.0	1.0	57.57	0.264	0.9998	1.0x10^{-5}-1.0x10^{-2}
	(c)	34.5	64.0	1.5	56.71	1.181	0.9997	1.0x10^{-5}-1.0x10^{-2}
Coated wire sensor	(a)	30.0	68.0	2.0	58.02	1.347	0.9997	1.0x10^{-5}-1.0x10^{-3}
	(b)	33.0	66.0	1.0	59.57	0.309	0.9998	5.0x10^{-6}-1.0x10^{-2}
	(c	34.5	64.0	1.5	57.64	0.117	0.9996	1.0x10^{-5}-1.0x10^{-2}
Coated graphite sensor	(a)	30.0	68.0	2.0	53.10	1.156	0.9997	1.0x10^{-5}-1.0x10^{-3}
	(b)	33.0	66.0	1.0	55.07	0.914	0.9997	1.0x10^{-5}-9.0x10^{-3}
	(c)	34.5	64.0	1.5	52.77	0.414	0.9996	9.0x10^{-4}-1.0x10^{-3}

3.2. Nature and response characteristics of the electrode

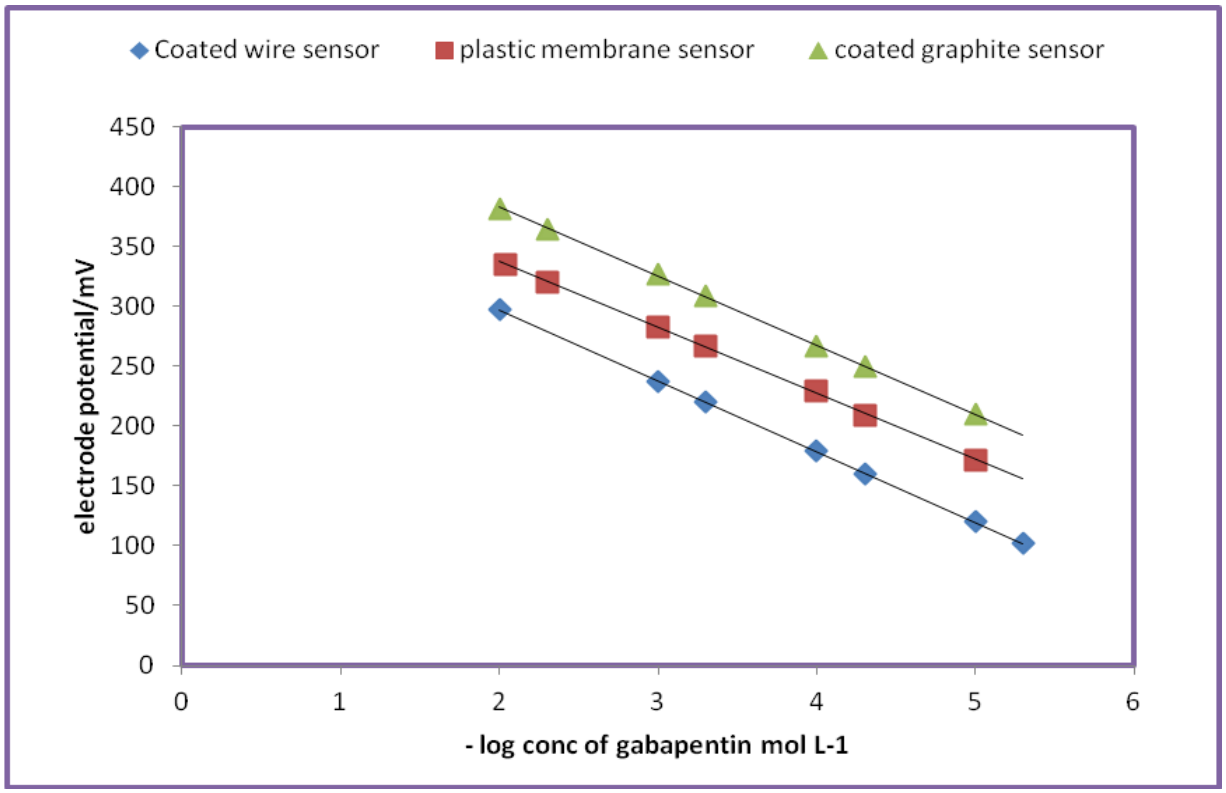

Figure 2. Typical calibration graphs of gabapentin sensors

Gabapentin-phosphotungstate ion-pair was prepared and tested as active material with *o*-NPOE as solvent mediator in a PVC membrane for gabapentin. The critical response characteristics of plastic membrane, coated wire and coated graphite electrodes were determined and results are summarized in Table 2. The electrode(s) exhibits a Nernstain response over the above indicated concentration ranges Figure 2.

3.3. Lifetime

The response time of the electrode(s) was tested for $1.0x10^{-6}$-$1.0x10^{-1}$ mol L^{-1} gabapentin solutions. The sequence of measurements was from low to high concentrations. The electrode(s) exhibited a fast dynamic response of 20, ≤ 15 *and* ≤ 35 *s* for a period of 25, 30 and 18 days for the three electrodes respectively, without significant change in the electrode(s) parameter Table 2.

Table 2. Critical response characteristics of gabapentin sensors

Parametera	Plastic membrane sensor	Coated wire sensor	Coated graphite sensor
Slope (mV decade^{-1})	57.57±0.264	59.57±0.309	55.07±0.914
Intercept	497.99	416.78	447.62
Correlation coefficient r.	0.9998	0.9998	0.9997
Linear range (mol L^{-1})	$1.0x10^{-5}$-$1.0x10^{-2}$	$5.0x10^{-6}$-$1.0x10^{-2}$	$1.0x10^{-5}$-$9.0x10^{-3}$
LOD (mol L^{-1})	$5.0\ x10^{-6}$	$2.5\ x10^{-6}$	$4.7x10^{-6}$
Response time (s)	20	≤ 15	≤ 35
Working pH range	1.5-3.5	1.5-3.5	1.5-3.5
Lifetime /day	25	30	18
Accuracy (%)	99.36	99.64	99.38
Standard deviation	0.662	0.612	0.468
Repeatability (CVw %)	0.718	0.725	0.606
Between day variability	0.929	0.811	0.829
Robustnessb	100.0±0.116	99.97±0.819	99.96±0.227
Ruggednessc	99.98±0.627	99.87±0.144	99.97±0.531

[a] Mean of three measurements

[b] A small variation in method parameters were studied using buffer solution pH

[c] Comparing the results by those obtained by different sensors assemblies using (Orion 420 A)

3.4. Effect of plasticizer

Three plasticizers, DBP, o-NPOE and DOP were used to examine the optimization of the membrane. The plasticizer content ratios were 68.0, 66.0 and 64.0 w% with PVC contents of 30.0, 33.0 and 34.5 w% and gabapentin-phosphotungstate contents of 2.0, 1.0 and 1.5 w%. The typical

potential responses of the electrodes constructed with the three plasticizers were given in Figure 3, which indicated that o-NPOE was the most efficient plasticizer.

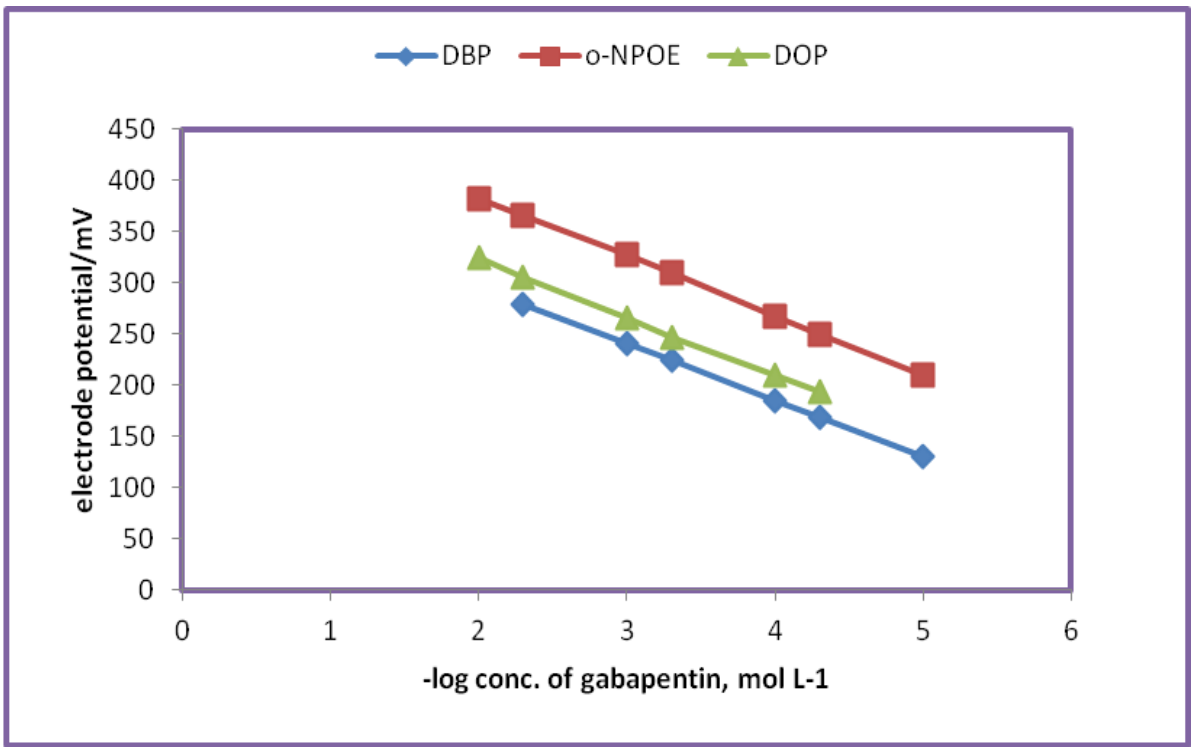

Figure 3. Effect of type of plasticizer on electrode potential using gabapentin sensors

3.5. Effect of soaking time

The optimum soaking time in $1.0x10^{-3}$ mol L^{-1} drug solution was found to be 24, 6 and 6 h at which the slope of the calibration curves were 57.57±0.264, 57.57±0.309 and 55.07±0.914 mV $decade^{-1}$ at 25°C for plastic membrane, coated wire and coated graphite respectively.

3.6. Regeneration of the electrode

The regeneration of the gabapentin membrane was successfully achieved by soaking the exhausted electrode(s) for 24 h in a solution of $1.0x10^{-2}$ mol L^{-1} phosphotungstic acid, followed by soaking for 3 h in $1.0x10^{-2}$ mol L^{-1} gabapentin solution.

Figures 4, 5 and 6 clarified that the slopes of the calibration graphs of exhausted electrode(s) (55.74, 55.56 and 51.63 mV $decade^{-1}$) were decreased than those after regeneration (slopes 57.20, 57.57 and 53.58 mV $decade^{-1}$) for the three electrodes respectively. It was found that the lifespan of the regenerated electrode(s) is limited to 3-4 h due to the ease of leaching of the lipophilic salts from the gel layer at the electrode(s) surface compared with those that are attached homogeneously to the PVC network through the solvent mediator.

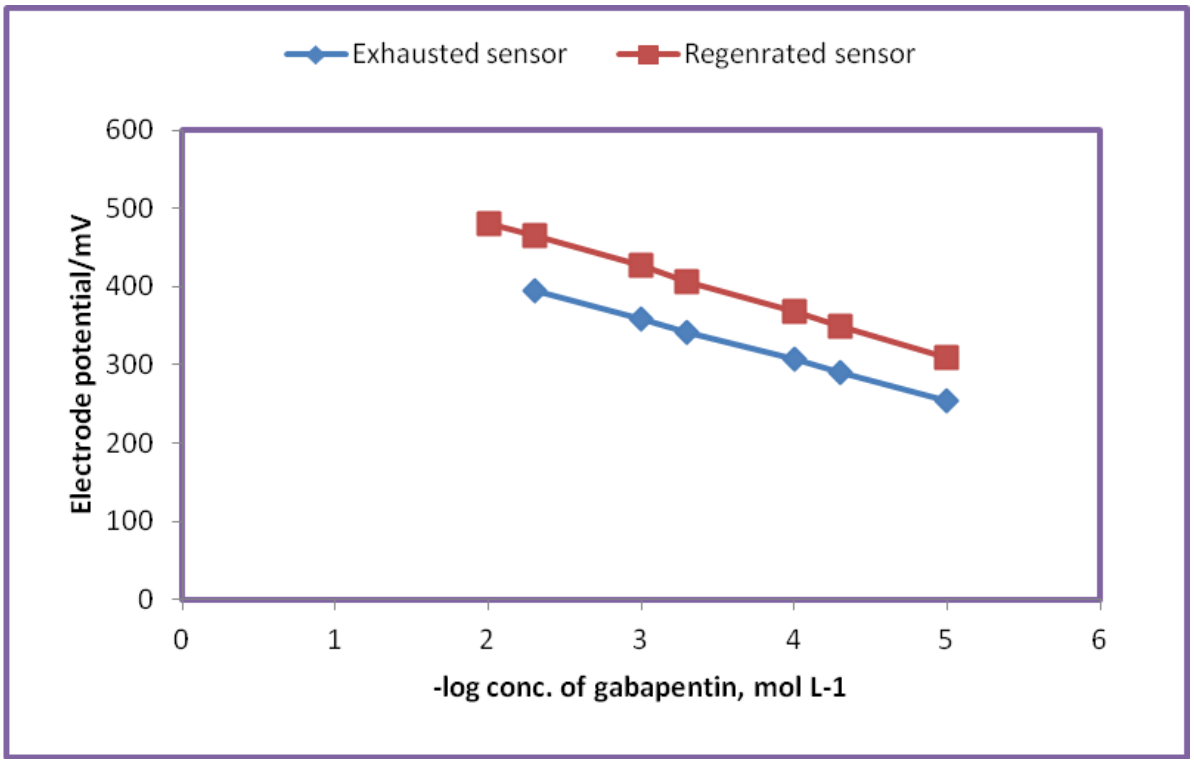

Figure 4. Regeneration of gabapentin-phosphotungstate plastic membrane sensor

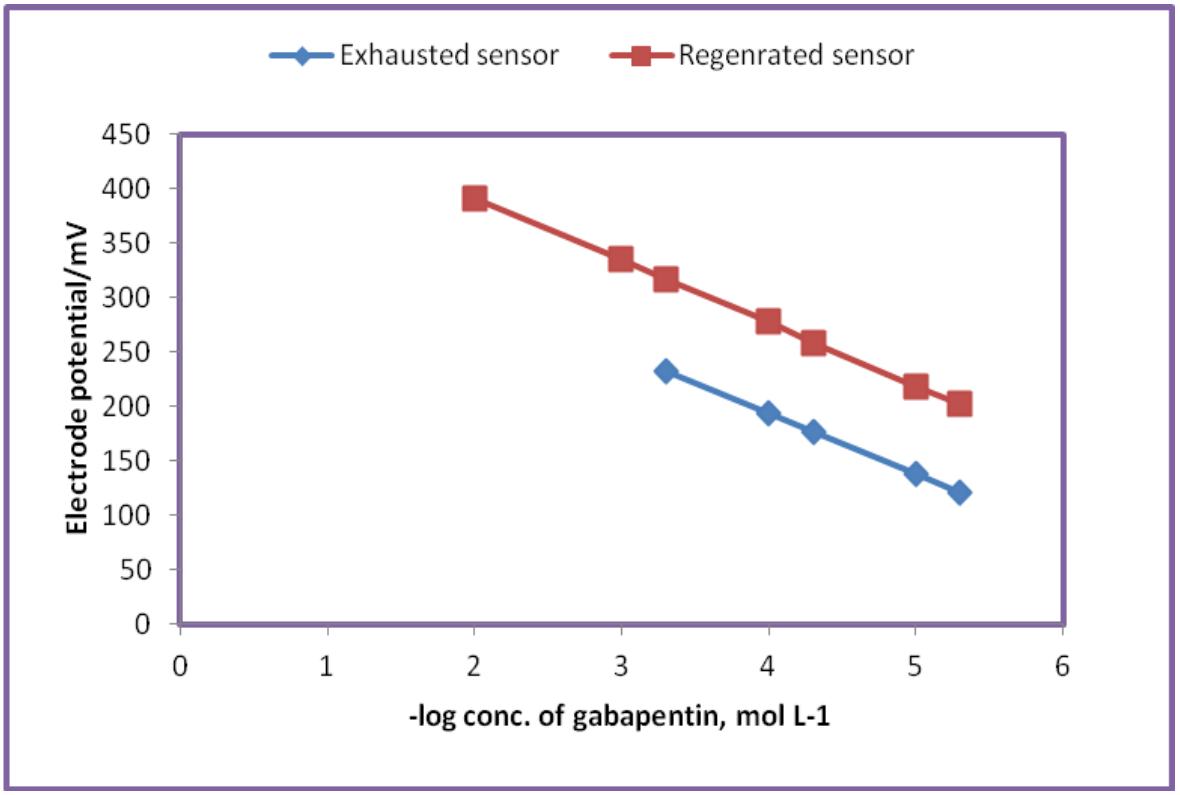

Figure 5. Regeneration of gabapentin-phosphotungstate coated wire sensor

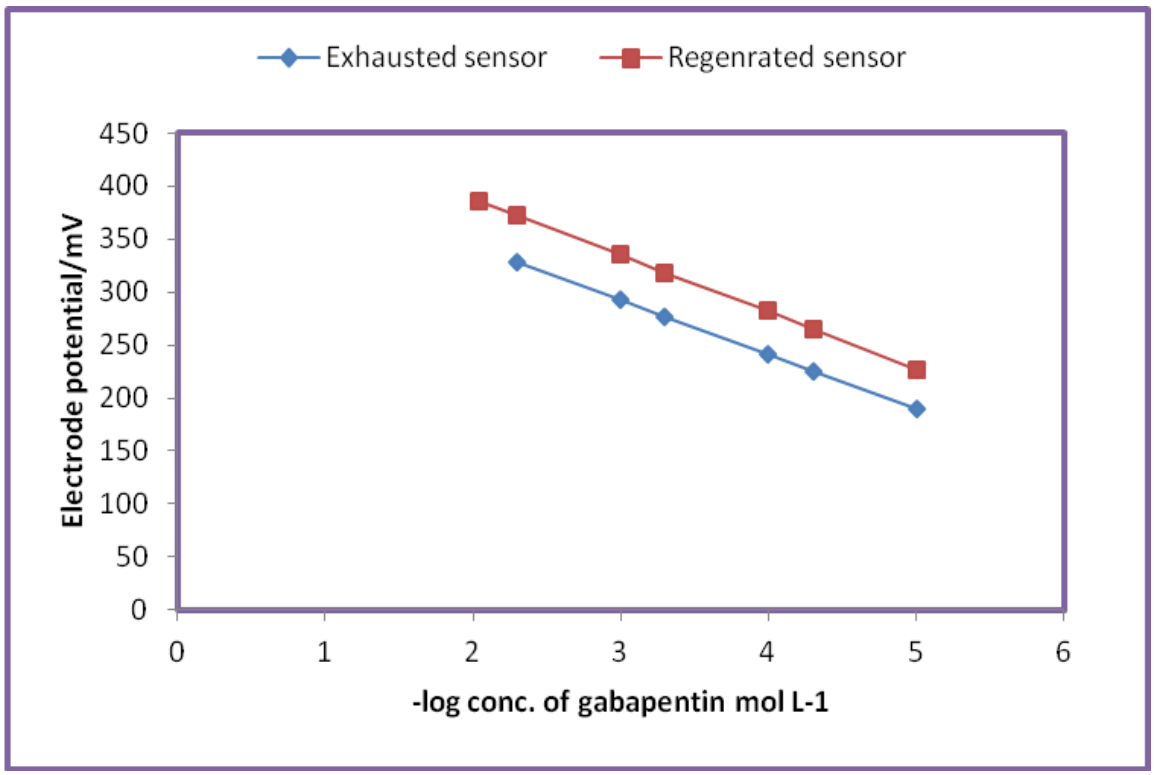

Figure 6. Regeneration of coated graphite gabapentin-phosphotungstate sensor

3.7. Effect of pH

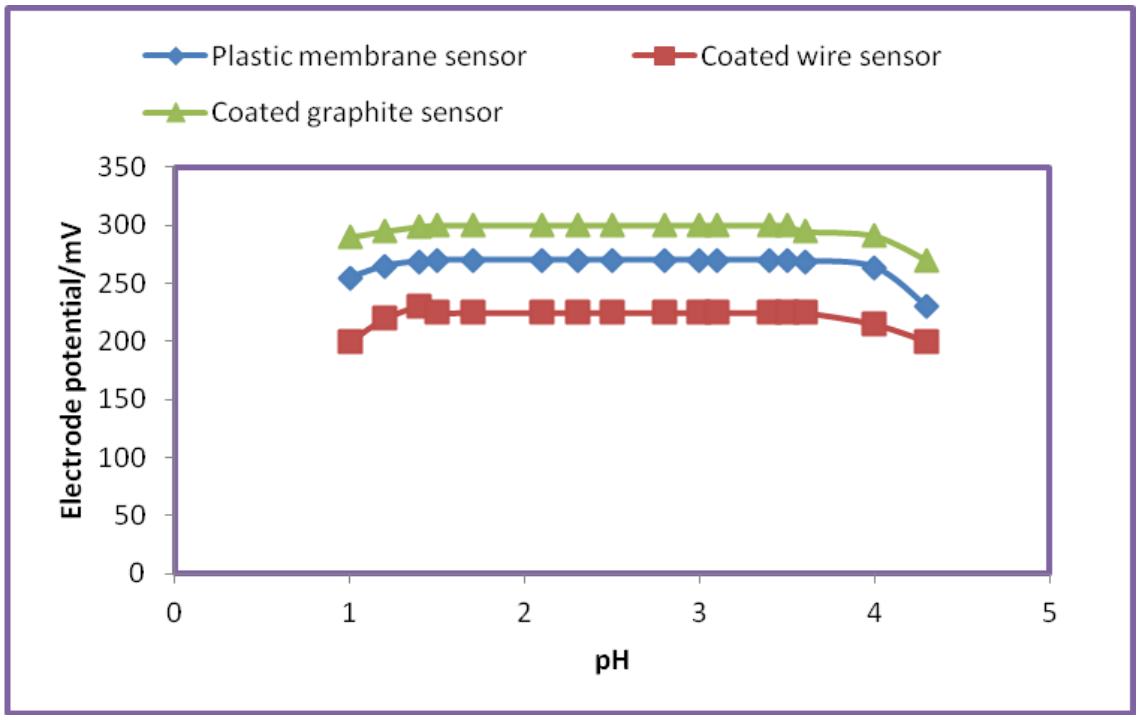

Figure 7. Effect of pH on gabapentin sensors potential using $1.0x10^{-3}$ mol L^{-1}

The pH dependence of the investigated sensors was examined using $1.0x10^{-3}$mol L^{-1} gabapentin solution. Stable response over a pH range of 1.5-3.5 was obtained, Figure 7. Adjustment of pH was performed using 0.1 mol L^{-1} hydrochloric acid and sodium hydroxide. Below pH 1.5 the potential was increased with the increase of analyte acidity which may be ascribed to extraction of H^+ ions by membrane. While at pH more than 3.5, the response decreases which may be attributed to decrease in gabapentin ion by increasing OH^- concentration.

3.8. Selectivity of the electrode

Table 3 showed that the proposed gabapentin-phosphotungstate membrane electrode(s) was highly selective toward gabapentin. The electrode(s) exhibited no response to a number of potentially interfering ionic and non ionic excepients usually used in the manufacturing of the pharmaceutical preparations. Also some amino acids and related drugs were found to be non-interfering with the proposed method.

Table 3. Selectivity coefficients of the gabapentin-phosphotungstate sensors calculated by the separate solution method ($1.0x10^{-3}$ mol L^{-1} of both gabapentin and the interferent) at 25 °C

Interfernt	Plastic membrane sensor	Coated wire sensor	Coated graphite sensor
Na+	$4.9x10^{-4}$	$4.5x10^{-3}$	$1.5x10^{-3}$
K+	$5.9x10^{-3}$	$3.1x10^{-3}$	$8.7x10^{-3}$
NH4+	$8.1x10^{-3}$	$2.9x10^{-3}$	$6.3x10^{-3}$
Mg2+	$1.1x10^{-3}$	$1.4x10^{-3}$	$4.0x10^{-3}$
Ca2+	$1.5x10^{-3}$	$1.3x10^{-3}$	$1.9x10^{-3}$
L-cystin	$9.1x10^{-4}$	$2.5x10^{-4}$	$8.2x10^{-4}$
L-luecin	$2.2x10^{-4}$	$7.1x10^{-4}$	$3.0x10^{-4}$
Starch	$1.9x10^{-5}$	$1.7x10^{-4}$	$8.9x10^{-4}$
Glucose	$3.3x10^{-5}$	$5.6x10^{-4}$	$1.1x10^{-3}$
Lactose	$2.1x10^{-4}$	$2.7x10^{-4}$	$3.6x10^{-3}$
Sucrose	$4.9x10^{-4}$	$9.1x10^{-4}$	$1.8x10^{-4}$
Urea	$2.5x10^{-3}$	$8.2x10^{-4}$	$3.3x10^{-3}$
Quinidine	$2.8x10^{-5}$	$9.3x10^{-4}$	$9.4x10^{-3}$
Pseudoephedrine HCl	$6.5x10^{-4}$	$3.8x10^{-4}$	$5.1x10^{-4}$
Caffeine	$6.9x10^{-5}$	$5.4x10^{-3}$	$7.5x10^{-3}$
Phenytoin sodium	$2.1x10^{-3}$	$4.1x10^{-3}$	$7.1x10^{-3}$
Paroxetine- HCl	$3.2x10^{-4}$	$5.4x10^{-4}$	$9.4x10^{-4}$

3.9. Quantification of gabapentin

Determination of gabapentin in pure form using gabapentin-phosphotungstate sensors was performed and calculated from the calibration curves. The average percentage recoveries were 99.36±0.662, 99.64±0.612 and 99.38±0.468 for plastic membrane, coated wire and coated graphite

electrodes, respectively. No significant difference between these results and those of reported method [11] were showed, Table 4.

Table 4. Determination of gabapentin in pure form in comparison with reference method using gabapentin-phosphotungstate sensors

Statistical parameter	Reference Method [11]	Calibration method	Standard addition method
Plastic membrane sensor			
Mean±SD	99.69±0.492	99.36±0.662	99.11±0.931
t-test		0.980(2.228)*	1.349(2.228)*
F-test		1.81(5.05)*	3.58(5.05)*
Coated wire sensor			
Mean±SD	99.54±0.468	99.64±0.612	99.24±0.365
t-test		0.334(2.201)*	0.747(2.228)*
F-test		1.71(4.39)*	3.42(5.05)*
Coated graphite sensor			
Mean±SD	99.52±0.287	99.38±0.468	99.14±0.379
t-test		0.625(2.228)*	1.957(2.228)*
F-test		2.67(5.05)*	1.76(5.05)*

*****The figures between parentheses are the theoretical values of " t" and "F" at P=0.05

3.10. Method validation

Good correlation (r^2 = 0.8897-0.9999) were obtained between potential response and – log [drug] in concentration range of $1.0x10^{-6}$-$1.0x10^{-2}$ mol L^{-1} gabapentin. Table 2 showed regression parameters together with other response characteristics.

The calculated LOD ranged between $2.5x10^{-6}$ and $5.0x10^{-6}$ mol L^{-1} gabapentin highly detectable method.

The robustness of the proposed method was tested by adjusting sample to pH 3 using phosphate buffer instead of 0.1 mol L^{-1} hydrochloric acid. The results presented in Table 2 indicated more or less similar recoveries ± SD (100.0±0.116, 99.97±0.819 and 99.96±0.227) for the three mentioned sensors, respectively. Furthermore, upon using two different pH-meters for measuring the potential, the results were in accordance with each other indicating rugged method, Table 2.

The suggested procedure was applied for the analysis of gabapentin in spiked placebo samples of lactose. The results clarified that the percentage recoveries ranged between 98.82-99.16 % indicating good accuracy and validity of the proposed method for the three gabapentin investigated sensors.

The %RSD values for the repeated determinations were 0.383%, 0.624% and 0.832% for determination of gabapentin in Conventin® 100 mg/ Cap and 0.549%, 0.435% and 0.663% in Neurontin® 400 mg/Cap for the three mentioned sensors, respectively.

3.11. Analytical applications of the proposed method

3.11.1. Gabapentin capsules:

Good recoveries of 98.20-99.48% or 98.60-99.64% for Conventin® or Neurontin® capsules, respectively. Statistical analysis of these results with those of a reported method revealed non-significant differences with respect to precision and accuracy, Table 5.

Table 5. Determination of gabapentin in its pharmaceutical formulations in comparison with reference method using gabapentin-phosphotungstate sensors

Statistical parameter	Reference Method [11]	Conventin ® 100 mg /Cap	Neurontin® 400 mg/Cap
Plastic membrane sensor			
Mean±SD	99.12±0.434	98.70±0.379	99.13±0.578
t-test		1.785(2.228)*	0.869(2.201)*
F-test		1.31(5.05)*	1.16(4.39)*
Coated wire sensor			
Mean±SD	99.10±0.721	99.01±0.459	99.59±0.549
t-test		0.272(2.201)*	0.197(2.201)*
F-test		2.46(4.39)*	2.98(4.39)*
Coated graphite sensor			
Mean±SD	99.00±0.483	98.20±0.825	98.60±0.781
t-test		2.049(2.228)*	1.579(2.228)*
F-test		2.92(5.05)*	2.15(5.05)*

*****The figures between parentheses are the theoretical values of " t" and "F" at P=0.05

3.11.2. Content uniformity assay of gabapentin capsules

The content uniformity assay by the proposed method showed mean±SD of 99.64± 0.569, 100.09±0.615 and 99.28±0.360 for plastic membrane, coated wire and coated graphite sensors, respectively.

3.11.3. Application to serum and urine

Successful application of the proposed potentiometric method to biological fluids was proved by good mean recoveries of 98.15-99.37% for serum samples and 98.32-98.98% for urine samples, Table 6.

Table 6. Determination of gabapentin in human serum and urine using gabapentin-phosphotungstate sensors

Statistical parameter	Plastic membrane sensor		Coated wire sensor		Coated graphite sensor	
	Calibration method	Standard addition method	Calibration method	Standard addition method	Calibration method	Standard addition method
Serum Sample						
Mean±SD	98.99±0.837	99.30±0.720	98.15±0.445	98.79±0.642	98.88±0.896	99.37±0.571
n	6	5	5	5	6	6
Variance	0.701	0.518	0.198	0.412	0.803	0.326
SE	0.342	0.322	0.199	0.287	0.366	0.233
RSD	0.846	0.725	0.453	0.650	0.906	0.575
Urine Sample						
Mean±SD	98.36±0.822	98.37±0.797	98.98±0.781	98.32±0.870	98.88±0.886	98.51±0.832
n	6	6	5	5	6	6
Variance	0.676	0.635	0.610	0.757	0.785	0.692
SE	0.336	0.325	0.319	0.389	0.362	0.340
RSD	0.836	0.810	0.789	0.885	0.896	0.845

4. CONCLUSION

The newly developed gabapentin sensors based on the incorporation with phosphotungstic acid were constructed and validated for determining gabapentin in pure form, pharmaceutical preparations and biological fluids. Developed sensors have shown good performance characteristics with time stability, sensitive and accurate to be privileges for applications in quality control laboratories.

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