



A Quick and Accurate Membrane Sensor based on Bisoprolol Drug for Potentiometric Selective Determination of Thiocyanate Ion

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Abstract A novel potentiometric thiocyanate poly (vinyl chloride) membrane sensor with a newly synthesized Bisoprolol as an electroactive ion exchanger is developed. It offers attractive direct fast monitoring tool for SCN^- in the presence of many common ions. Under the manual operation, the proposed sensor displays high selectivity, wide dynamic response range down to $1.0 \times 10^{-6} \text{M}$ ($0.06 \mu\text{g ml}^{-1}$), good sensitivity, (slope $-57.8 \text{ mVdecade}^{-1}$) and rapid response (10-20s). Under hydrodynamic mode of operation, the sensor exhibits a near Nernstian slope of $51.1 \pm 0.1 \text{ mVdecade}^{-1}$ over concentration range 1.0×10^{-5} - $1.0 \times 10^{-2} \text{ M}$ SCN^- . These characteristics enable accurate measurements of as low as $0.04 \mu\text{g /ml}$ thiocyanate. The negligible response of the sensor towards CN^- and SO_3^{2-} ions makes the sensor an attractive direct and fast monitoring tool for measurement of SCN^- in the saliva and urine samples of cigarette smokers and non smokers humans.

Keywords Bisoprolol Drug, Potentiometric, Thiocyanate Ion

1. Introduction

One of the most important anions is thiocyanate SCN^- , because when wastewater-containing thiocyanate is chlorinated, highly toxic cyanogen chloride (CNCl) is formed. ISE electrodes for monitoring SCN^- ion have been suggested. Commercially available solid-state thiocyanate-selective electrodes show a large interference from I^- and S^{2-} [1].

Potentiometric sensors for assessment of various anions offer a simple unique technique with the advantages of simple design, short operation time, reasonable selectivity, fast response, applicability to colored and turbid solution, low cost and possible interfacing with automated systems [2]. The selectivity of these sensors towards a specific analyte is generally due to specific interaction of the ionophore incorporating in the sensor membrane with the test ions in solution. Many types of such interaction are based on ion exchange property, metal-ligand interactions, size-exclusion of the ionophore and ion extraction. Potentiometric thiocyanate sensors in common use are those commercially available with solid-state AgSCN membranes. The membrane of these sensors is an ionic conductor for silver ions; and hence, suffers from severe interference by species that form silver complexes or insoluble silver salts such as CN^- , I^- , Br^- , Cl^- , $\text{S}_2\text{O}_3^{2-}$ and S^{2-} . Potentiometric sensors for thiocyanate based on the use of the ion association complexes of thiocyanate with quaternary ammonium or quaternary phosphonium compounds dispersed in truly liquid or liquid polymeric membranes have been suggested. These sensors display the so called Hofmeister pattern with selectivity in the order: $\text{ClO}_4^- > \text{SCN}^- > \text{I}^- > \text{NO}_3^- > \text{Br}^- > \text{NO}_2^- > \text{Cl}^- > \text{SO}_4^{2-}$ [3-5]. A truly anion-selective electrode requires a strong interaction between the ionophore and the anion in order to successfully complex the analyte anion in a selective fashion [6].



This pattern depends on the lipophilicity and hydration energy of the anions. Sensors based on derivatives of vitamin B₁₂ or transition metal complexes of porphyrin and phthalocyanine have been suggested for thiocyanate determination. Selectivity orders of these sensors are antiHofmeister and I⁻, CN⁻, NO₂⁻, IO₄⁻, ClO₄⁻, Br⁻ and N₃⁻ ions seriously interfere [7-11].

In general many of these sensors display high detection limit [12] narrow working concentration range [13] and suffer from severe interferences by ClO₄⁻, I⁻, and IO₄⁻ [14]. Whereas electrodes based on cobyrinate ionophores (SCN⁻¹, SCN⁻²) show comparable selectivities [15].

Bisoprolol is used alone or in combination with other medications to treat high blood pressure. Bisoprolol is in a class of medications called beta blockers. It works by relaxing blood vessels and slowing heart rate to improve and decrease blood pressure [16-17].

High blood pressure is a common condition and when not treated, can cause damage to the brain, heart, blood vessels, kidneys and other parts of the body. Damage to these organs may cause heart disease, a heart attack, heart failure, stroke, kidney failure, loss of vision, and other problems. In addition to taking medication, making lifestyle changes will also help to control your blood pressure. These changes include eating a diet that is low in fat and salt, maintaining a healthy weight, exercising at least 30 minutes most days, not smoking, and using alcohol in moderation [18-19].

Bisoprolol comes as a tablet to take by mouth. It is usually taken once a day. To help you remember to take bisoprolol, take it around the same time every day. Follow the directions on your prescription label carefully, and ask your doctor or pharmacist to explain any part you do not understand. Take bisoprolol exactly as directed. Do not take more or less of it or take it more often than prescribed by your doctor.

Bisoprolol controls high blood pressure but does not cure it. It may take a few weeks before you feel the full benefit of bisoprolol. Continue to take bisoprolol even if you feel well. Do not stop taking bisoprolol without talking to your doctor. Suddenly stopping bisoprolol may cause angina (chest pain), heart attack, or irregular heartbeat. Your doctor will probably decrease your dose gradually [20].

Bisoprolol also is used sometimes to treat heart failure. Talk to your doctor about the possible risks of using this medication for your condition. It is important for you to keep a written list of all of the prescription and nonprescription (over-the-counter) medicines you are taking, as well as any products such as vitamins, minerals, or other dietary supplements. You should bring this list with you each time you visit a doctor or if you are admitted to a hospital. It is also important information to carry with you in case of emergencies [21].

2. Experiment

2.1. Reagents and chemicals

All reagents used were of analytical grade and deionized water was used throughout. Poly(vinyl chloride) powder (PVC) of high relative molecular weight, *o*-nitrophenyloctyl ether (*o*-NPOE), dioctylphthalate (DOP), bis(2-ethylhexyl) sebacate (DOS), tetrahydrofuran (THF) and tridodecylmethylammonium chloride (TDMAC) were used as received from Aldrich Chemical Co. (Milwaukee, WI). High purity potassium or sodium salts of all anions were purchased from Merck Inc. (Darmstadt, Germany). A 1.0×10⁻¹M stock solution of thiocyanate was prepared by dissolving 0.8107g of sodium thiocyanate in 100 ml of water. Working solutions (1.0×10⁻² - 1.0×10⁻⁷ M) were prepared by successive dilutions with water and the pH was adjusted at pH 6 using 1.0×10⁻² M phosphate buffer solution.

2.2. Equipment

Potentiometric measurements were performed at 25 ± 1°C with an Orion digital pH/mV meter (Model SA720) using the PVC thiocyanate membrane sensors in conjunction with an Orion Ag/AgCl double junction reference electrode (Model 90-02) filled with 10% (w/v) KNO₃. A combination Ross glass-pH electrode (Orion 81-02) was used for pH measurements.

A laboratory-made flow-through tubular potentiometric cell, equipped with a Pd-complex -PVC membrane, was fabricated as described previously [22] and incorporated in a single-stream FI system. The tubing distance between



the injection valve and the detector was 5 cm. The flow injection system consisted of a Monostat cassette pump (Junior, N. Y.) and an Omnifit injection valve (Omnifit Cambridge, UK) with a sample loop of 100 μl volume. The flow cell and an Orion 90-01 Ag/AgCl double junction reference electrode were placed in a Petri dish filled with 10^{-2} M Na_2HPO_4 electrolyte carrier solution. The carrier stream was supplied from a separate reservoir through Tygon tubings (0.8 mm i.d.) and a mixing coil (15 cm). The potentiometric signals were monitored using a home made high-impedance data acquisition 8-channel box connected to a PC through the interface ADC 16 (Pico Tech., UK) and PicoLog for windows (version 5.07) software.

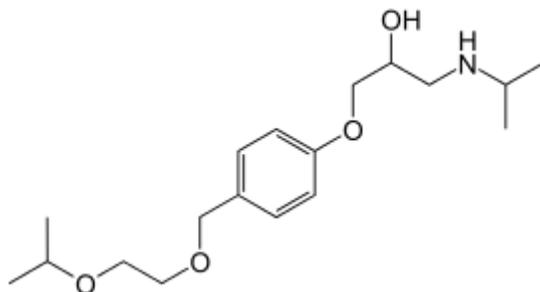


Figure 2.1: structure formula of Bisoprolol drug

2.3. Membrane preparation and sensor construction

A thiocyanate responsive membrane sensor was prepared as described previously [23] by mixing 1.5 wt. % Bisoprolol (3 mg), 64.5 wt. % *o*-NPOE plasticizer (129 mg) and 34 wt. % PVC (68 mg). The mixture was dissolved in 5 ml THF in a glass Petri dish (~3 cm diameter), covered with a filter paper and left to stand overnight to allow slow evaporation of the solvent at room temperature. Disks (0.7 mm o.d) were cut out from the parent membrane and mounted in the PVC electrode body (0.6 mm i.d) using THF. A mixed solution consisting of equal volumes of 10^{-3} M NaSCN and 10^{-3} M KCl was used as an internal reference solution and Ag/AgCl coated wire (3 mm diameter) was employed as an internal reference electrode. The sensor was conditioned by soaking over night in a solution of 10^{-2} M NaSCN and stored in the same solution when not in use.

The tubular sensor used as a detector in the flow injection measurements was constructed as described previously [24]. A coating solutions were prepared by dissolving 68 mg of PVC in 5 ml THF followed by addition of 129 mg of *o*-NPOE and 3 mg of Bisoprolol. This solution was deposited 3-4 times directly in a hole wall of Tygon tube window of 1 cm length and 2 mm i.d using a dropper. After each addition, the THF was allowed to evaporate slowly at room temperature to give a thin film with suitable thickness (approximately 0.1 mm). The sensor was conditioning by soaking in 1.0×10^{-2} M SCN^- for 24 hours. This sensor was closed fitted in the tube at distance of 5 cm from the injection valve. The end of the tube sensor was placed in a Petri dish with a double junction Ag/AgCl reference electrode.

2.4. Manual potentiometric determination of thiocyanate

Thiocyanate membrane sensors based on Bisoprolol ion exchanger and Ag/AgCl double junction reference electrode were immersed in a 25 ml beaker containing 9.0 ml of 10^{-2} M potassium phosphate buffer of pH 6. Portions (1.0 ml) of 1.0×10^{-6} to 1.0×10^{-1} M standard thiocyanate solutions were successively added and the potential response of the sensor was measured after stabilization (± 0.2 mV). A calibration graph was constructed by plotting the potential change against the logarithm of the thiocyanate ion concentration. The plot was used for subsequent determination of unknown thiocyanate solutions.

2.5. Potentiometric determination of thiocyanate in saliva and urine

Samples of saliva and urine were collected from non smokers and cigarette smokers into plastic tubes. The samples were immediately centrifuged, stored at 4°C and analysed for thiocyanate within 6 hours. Portions (5.0 ml) of the samples were diluted 10 times with 1.0×10^{-2} M phosphate buffer of pH 6. The solutions were used for both batch



and flow injection measurements. For batch assessment, the thiocyanate sensor and double junction Ag/AgCl reference electrode were immersed in the solution, and the potential readings were recorded after reaching the equilibrium response (10-20 s). A blank experiment was made under identical conditions. The concentration of thiocyanate was calculated using a calibration graph.

2.6. Sensor selectivity

Potentiometric selectivity coefficients were evaluated using the separate solutions method (SSM) [25-26] using equation (2.1):

$$\log K_{A,B}^{pot} = \frac{(E_B - E_A)Z_A F}{2.303RT} + (1 - Z_A/Z_B) \log a_A \quad \dots\dots\dots (2.1)$$

The potentials of a cell comprising the membrane sensor and the reference electrode were measured in two separate solutions, one containing the thiocyanate ion (A) at the activity a_A (but no B), the other containing the interfering ion (B) at the same activity $a_A = a_B$ (but no A) and E_A and E_B are measured values, respectively. Different interfering anions at a concentration of 10^{-3} M were used and the results were obtained using the above equation.

Where $\log K_{SCN^-,J}^{pot}$ is the potentiometric selectivity coefficient, S the slope of the calibration plot, a_A the activity of thiocyanate and Z_A and Z_B are the charges of SCN^- and the interfering anions, respectively.

3. Results and Discussion

During a course of preparation of some new organometallic compounds to be used as anion exchangers or ionophores in potentiometric sensors, it was found that the newly synthesized Bisoprolol has a high exchange capacity towards thiocyanate ion. Selectivity of the complex for thiocyanate over several other common inorganic and organic anions is due to interaction of the strong SCN^- nucleophile with the complex and displacement of the chloride ion. The infrared spectrum of the complex after shaking with thiocyanate solution, thorough washing with water and drying, shows a new characteristic absorption band at 2069 cm^{-1} due to the presence of ν_{SCN} group confirming the exchange process.

3.1. Performance characteristics of the sensor

In preliminary experiments plasticized PVC-based membrane sensors with and without Bisoprolol were prepared and used for determining thiocyanate ion. Sensor with membrane containing no Bisoprolol displayed no significant response for thiocyanate and other common anions. Sensor with membrane containing the complex demonstrated strong Nernstian response towards SCN^- ions. Influence of the Bisoprolol, plasticizer and additives on the optimal response of the sensors were investigated. Solvent mediators with different polarities (e.g dioctylphthalate, DOP, dioctylsebacate, DOS, and *o*-nitrophenyloctyl ether, *o*-NPOE, were tested. The results reveal that best performance was obtained with 60- 67 wt % *o*-NPOE as membrane plasticizer. Cationic excluders (e.g TDMAC) in the membrane have no significant effect on the performance of the sensor confirming that the response of the sensor is based on an ion exchange and not ion carrier mechanism.

A sensor with membrane consisting of 1.5 wt. % ionophore, 64.5 wt. % *o*-NPOE plasticizer and 34 wt. % PVC exhibited a linear response over the concentration range of 1.0×10^{-6} - 1.0×10^{-2} M SCN^- with a slope of -57.0 mV per decade. Sensors with membrane incorporating DOS and DOP solvent mediator exhibited narrow response range (3.1×10^{-5} - 1.0×10^{-2} and 6.3×10^{-5} - 1.0×10^{-2} M) and sub-Nernstian slopes (-41.5, and -37.6 mV per decade), respectively Fig. 3.1. Stable and reproducible potentials at relatively short response time were obtained by sensor conditioning in a 1.0×10^{-2} M KSCN for 24 h after preparation. The sensor was stored in the same solution when not in use. The results are summarized in Table 3.1.



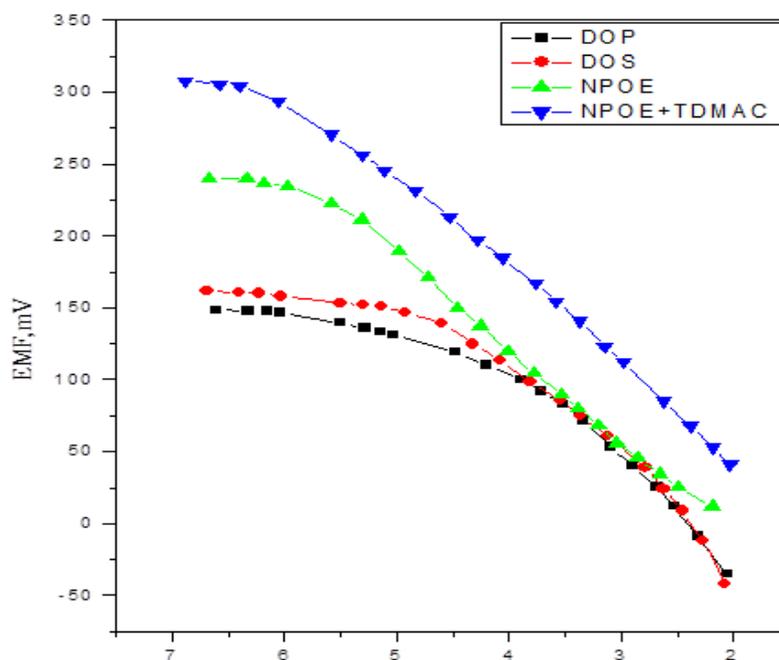


Figure 3.1: Potentiometric response curves of thiocyanate ion membrane sensor using different plasticizers

Table 3.1: Potentiometric response characteristics of Bisoprolol sensor with different plasticizers

Parameter	DOP	DOS	NPOE	NPOE+0.5%
	Sensor I	Sensor II	Sensor III	TDMAC Sensor IV
Slope, (mVdecade ⁻¹)	37.4 ± 0.1	41.5 ± 0.1	57.8 ± 0.2	57.8 ± 0.2
Correlation coefficient, (r ²)	0.9748	0.9936	0.9859	0.9929
Intercept, (mV)	58	67	112	58
Linear range, M	6.3x10 ⁻⁵ -1x 10 ⁻²	3.1x10 ⁻⁵ -1x 10 ⁻²	1x10 ⁻⁶ -1x 10 ⁻²	1.3x10 ⁻⁶ -1x 10 ⁻²
Detection limit M	3.1x10 ⁻⁵	1.2 x10 ⁻⁵	6.3x10 ⁻⁷	6.3x10 ⁻⁷
Working range, pH	2-10	2-10	2-10	2-10
Response time, (s)	≤30	≤30	≤20	≤20
Precision, %	97	97.3	98	98
Within-day-reproducibility, mV	0.5	0.5	0.3	0.3
Between-day variability, mV	0.8	0.8	0.6	0.6
Accuracy, %	97.0	97.5	98.0	98.1
Standard deviation, %	0.4	0.4	0.3	0.3

The dynamic response time of the sensor to reach 95% of the equilibrium potential response is 20-30 s for 1.0×10⁻⁶-1.0×10⁻² M SCN⁻ solutions (Fig. 3.2).

The response functions do not change over a period of three weeks when the sensors are stored in 1.0×10⁻² M SCN⁻ solution at pH 6. Day to-day reproducibility of the sensors responses is ± 0.6 mV. The standard deviations of the mV readings for four consecutive 1.0×10⁻⁵ and 1.0×10⁻³ M SCN⁻ concentrations are ±1.5 mV and ± 1.0 mV, respectively.

3.2. Effect of pH

The pH dependence of the potential of the sensor for 1.0×10⁻⁵-1.0×10⁻⁴ M thiocyanate was tested over the pH range 2-10. The solutions were adjusted by addition of HCl and /or NaOH. The results show a working pH range of 4-10 (Fig. 3.3).

The potential response of the sensor was practically pH independent over this range. Calibration plots obtained using 1.0×10⁻² M phosphate buffers of pH 6-8, and 1.0×10⁻² M acetate buffer of pH 4-6 were found to be almost identical



in terms of detection limit and linear range. Phosphate buffer 1.0×10^{-2} M, pH 6 was used for all subsequent measurements.

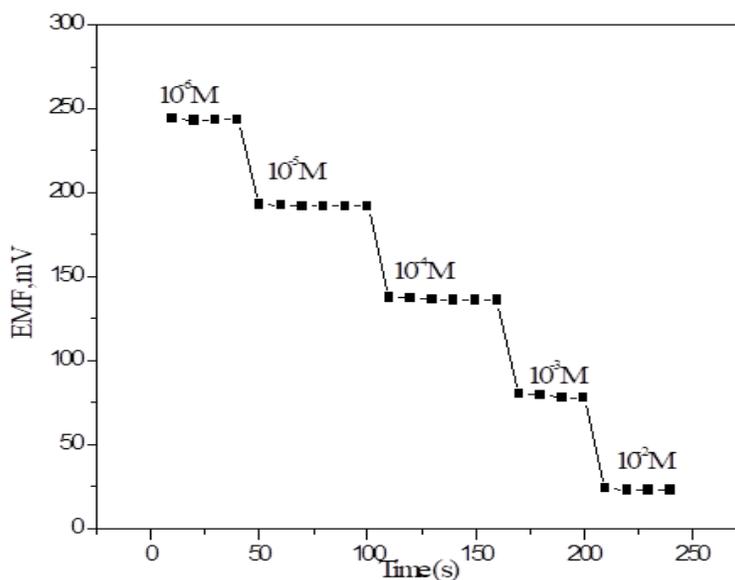


Figure 3.2: Dynamic response time of thiocyanate ion membrane sensor

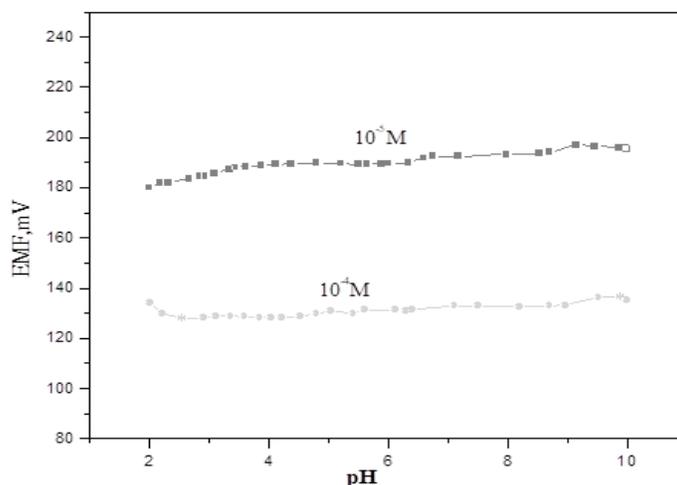


Figure 3.3: Effect of pH on thiocyanate PVC membrane sensor based on Bisoprolol

3.3. Sensor Selectivity

Using the optimized membrane composition and measurement conditions described above, tests were conducted to determine the response of the sensors towards different anions. The selectivity coefficients of Bisoprolol based membrane sensor for various ions were evaluated using the separate solutions method [27-28]. The results obtained are summarized in Table 3.2. The proposed sensor displayed high selectivity towards thiocyanate in the presence of many common ions such as CN^- , F^- , I^- , Br^- , Cl^- , NO_3^- , NO_2^- , SO_4^{2-} , $\text{S}_2\text{O}_3^{2-}$, PO_4^{3-} , citrate, acetate and oxalate. It has been reported that many thiocyanate sensors based on different membrane compositions suffer from severe interference by CN^- , NO_3^- , I^- , and IO_4^- . The solid state Ag/AgSCN sensor displays significant interference from S^{2-} , CN^- , halides and pseudo halides.

The proposed sensor, however, is not only has a superior selectivity behavior over many of the previously suggested sensors but also better linear response range [24] and lower detection limit [29-30]. Cyanide ion which is a serious



interferent with thiocyanate in many instrumental techniques [31-32] has no effect with the present method. Table 3.3 summarizes the main performance characteristics of some previously suggested sensors.

Table 3.2: Potentiometric selectivity coefficients of Bisoprolol based thiocyanate PVC membrane sensor with o-NPOE plasticizer

Interferent, B	$K_{SCN^-,J}^{POT}$	$K_{SCN^-,J}^{POT}$
	Without additive	With 30% NaTBP
Cl ⁻	2.4×10^{-4}	4.6×10^{-5}
I ⁻	3.3×10^{-3}	5.3×10^{-4}
F ⁻	7.1×10^{-4}	8.8×10^{-5}
NO ₃ ⁻	1.4×10^{-3}	3.9×10^{-4}
NO ₂ ⁻	8.7×10^{-4}	6.3×10^{-5}
CN ⁻	4.2×10^{-3}	6.7×10^{-4}
SO ₄ ²⁻	6.5×10^{-4}	7.8×10^{-5}
S ₂ O ₃ ²⁻	4.9×10^{-4}	6.9×10^{-5}
SO ₃ ²⁻	5.6×10^{-4}	7.6×10^{-5}
PO ₄ ³⁻	1.6×10^{-4}	3.8×10^{-5}
ClO ₄ ⁻	1.0×10^{-2}	1.2×10^{-3}
(citrate) ³⁻	5.4×10^{-4}	6.5×10^{-5}
Acetate) ⁻	2.3×10^{-4}	$\times 10^{-5}$ 14.
(Oxalate) ²⁻	1.9×10^{-4}	3.6×10^{-5}

Table 3.3: General performance characteristics of some potentiometric SCN⁻ sensors

Ionophore	Slope, mV/decade	Linear Range, (M)	Limit of detection, (M)	Interference	Ref.
AgX/SCN solid state	-58.5	1×10^{-6} - 1×10^{-1}	-	I ⁻ , S ₂ ²⁻ , X ⁻	[1]
Di,tetra and hexaimideopyridine derivative	-55.6-58.3	9×10^{-6} - 1×10^{-2}	5×10^{-6}	IO ₄ ⁻	[23]
Cadmium -schiff's complex	-59 ± 0.2	1×10^{-6} - 1×10^{-1}	7×10^{-7}	Salicylate, I ⁻ , MnO ₄ ⁻	[27]
Mn(II) complex of N,N-bis-(4phenylazosalicilidene) o-phenylene diamine	-57	7×10^{-6} - 1×10^{-1}	-	I ⁻ , ClO ₄ ⁻ , salicylate	[7]
Bis [N-(2 hydroxyethyl) salicyldiaminino] copper (II)	-59	6×10^{-6} - 1×10^{-1}	2×10^{-6}	Salicylate, I ⁻ , ClO ₄ ⁻	[14]
Urea -functionalized porphyrin	-58	5×10^{-5} - 1×10^{-2}	4×10^{-5}	NO ₃ ⁻ , NO ₂ ⁻ , I ⁻ , Cl ⁻ , Br ⁻ , ClO ₄ ⁻	[33]
Cobalt and Mn phthalocyanine	-57.5	1×10^{-6} - 1×10^{-1}	3×10^{-6}	Salicylate, I ⁻ and N ₃	[31]
Butane -2,3-dione bis salicylhydrazonate zinc	-56 ± 0.1	1×10^{-6} - 1×10^{-1}	6.3×10^{-7}	--	[35]
Dibenzyl-hexaazacyclotetradecane Ni(II)perchlorate	-58 ± 0.4	3.3×10^{-6} - 1×10^{-1}	3.0×10^{-6}	I ⁻ , S ₂ O ₃ ²⁻ , CrO ₄ ²⁻ , MnO ₄ ⁻	[36]
Manganese porphyrin derivative	-59.5	1×10^{-7} - 1×10^{-1}	5×10^{-8}	N ₃ ⁻ , CN ⁻ , ClO ₄ ⁻	[30]
Bis (2- mercaptobezoxazolato)mercury	-60.6 ± 0.8	1×10^{-6} -0.1	6×10^{-7}	I ⁻	[32]
Pd-complex	-57.8 ± 0.2	10^{-6} - 10^{-1}	6.3×10^{-7}	-	Present work

3.4. Manual determination of thiocyanate

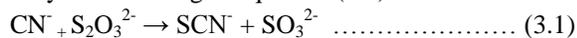
The assay method of thiocyanate was validated by determining the performance characteristics of the procedure using the quality control-quality assurance standards [33]. Five batches (five determination each) covering the



concentration range 1.0×10^{-6} - 1.0×10^{-2} M thiocyanate were used for determining the accuracy, trueness, precision, range, lower detection limit, repeatability (CV_w) and between-day variability (CV_b). The results obtained are presented in Table 3.1. A statistical evaluation of the results indicates that the student's test t at 95% confidence level shows no statistical difference between the calculated ($t = 2.015$) and theoretical values ($t = 0.780$).

3.5. Potentiometric determination of thiocyanate in saliva and urine

It was reported that high concentrations of HCN are present in cigarette smoke [34] Thiocyanate, on the other hand, is the end product of the detoxification of HCN present in cigarette smoke through a reaction catalyzed by rhodanase enzyme according to equation (3.1):



Thus, excretion of thiocyanate in urine, saliva and sweat provides a useful marker for cigarette smoking exposure in smokers and non smokers [35]. Consequently selective determination of thiocyanate in the presence of high levels of cyanide and sulfite is highly demanded. The high selectivity exhibited by the proposed Pd-complex based membrane sensor especially in the presence of CN^- and SO_3^{2-} supported the use of the proposed sensor for such monitoring.

The feasibility of using the proposed sensor to measure thiocyanate concentration in human urine and saliva samples was examined with samples collected from donors of ages ranged from 30 to 55 years. Five donor groups: nonsmokers (group I), smokers (1-5 cigarettes per day) (group II), smokers (6-10 cigarettes per day) (group III), smokers (11-20 cigarettes per day) (group IV) and smokers (more than 20 cigarettes per day) (group V) were tested. The samples were diluted 1: 10 and adjusted to pH 6 with 1.0×10^{-2} M phosphate buffer followed by manual and FI potentiometric measurements. A spectrophotometric procedure for the assay of thiocyanate was also used in parallel as a reference method [37]. The results (Table 3.4) indicate that the concentrations of saliva- SCN^- and urine- SCN^- in non cigarette smokers are $6.6 - 7.6 \times 10^{-5}$ and $4.1 - 4.8 \times 10^{-5}$ M, respectively. In cigarette smokers, saliva- SCN^- and urine- SCN^- concentrations are 2.7×10^{-4} - 4.6×10^{-3} and 1.7×10^{-4} - 4.5×10^{-3} M, respectively. These results fairly agree with data obtained by other authors using spectrophotometric technique [36] and are in a good agreement with the results obtained by the reference spectrophotometric method. An F - test shows no significant difference at 95% confidence level between means and variances of the potentiometric and spectrophotometric sets of results. The calculated F - values were found to be in the range 0.7- 4.2 which are lower than the tabulated value (6.39 at 95% confidence limit, $n = 5$).

Table 3.4: Potentiometric determination of thiocyanate in some biological samples using thiocyanate PVC membrane sensor and spectrophotometry

No of smoked cigarette/ day	Age	Potentiometry*		Spectrophotometry* [37]	
		[Urine- SCN^-]M	[Saliva- SCN^-]M	[Urine- SCN^-] M ¹	[Saliva- SCN^-]M
0	30-33	$(6.8 - 7.6 \pm 0.3) \times 10^{-5}$	$(4.3 - 4.8 \pm 0.1) \times 10^{-5}$	$(6.6 - 7.5 \pm 0.2) \times 10^{-5}$	$(4.1 - 4.7 \pm 0.1) \times 10^{-5}$
1-5	30-42	$(2.7 - 3.8 \pm 0.1) \times 10^{-4}$	$(1.7 - 2.7 \pm 0.1) \times 10^{-4}$	$(2.8 - 3.7 \pm 0.1) \times 10^{-4}$	$(1.7 - 2.5 \pm 0.1) \times 10^{-4}$
6-10	38-42	$(4.2 - 6.2 \pm 0.2) \times 10^{-4}$	$(2.8 - 3.6 \pm 0.1) \times 10^{-4}$	$(4.1 - 6.1 \pm 0.2) \times 10^{-4}$	$(2.6 - 3.5 \pm 0.1) \times 10^{-4}$
11-20	36-45	$(2.9 - 3.8 \pm 0.1) \times 10^{-3}$	$(1.8 - 2.6 \pm 0.1) \times 10^{-3}$	$(2.8 - 3.7 \pm 0.1) \times 10^{-3}$	$(1.7 - 2.5 \pm 0.1) \times 10^{-3}$
>20	46-54	$(4.6 - 5.5 \pm 0.1) \times 10^{-3}$	$(2.5 - 3.5 \pm 0.1) \times 10^{-3}$	$(4.5 - 5.4 \pm 0.1) \times 10^{-3}$	$(2.4 - 3.4 \pm 0.1) \times 10^{-3}$

*Average of five measurements

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