A Selective Membrane Electrode for Iodide Ion based on New Ionophore and its Application to Pharmaceutical Samples

Omid Hossieni[1], Sayed Aboalfazl Maashi[2], Narges Chamkouri[1]* Zolfaghar Sabati[2], Pardis Nourbakhsh[2], Mohammad Sajedinejad[2], Avishan Gholamiyan[1]

[1]Abadan Faculty of Medical Sciences, Abadan, Iran, [2]Student Research Committee, Abadan Faculty of Medical Sciences, Abadan, Iran

Abstract

Background and Objectives: On the basis of newly synthesized i.e. imidazolidine-2tion (IMT), highly selective poly vinyl chloride (PVC) membrane electrode was utilized as a carrier for iodide selective electrode via the incorporation of membrane ingredients within the graphite electrode surface.

Method: The impact of different factors consisting of the pH, membrane arrangement and likely intervening anions were examined on the electrode's response characteristics. The created sensor displayed Nernstian responses to iodide across a concentration of 1×10^{-6} to 0.1 M with slopes of 57.8± 0.7 mV per iodide concentration decade and 7×10^{-7}M detection limit, across a pH range of 3.0-10.5.

Results: The sensor response time was 6 seconds and may be used for a minimum of 2 months with no significant divergence at potential responses.

Conclusion: The electrode was implemented with success to determine iodide within synthetic pharmaceutical samples as well as using as an indicator electrode for precipitation titration.

Keywords: *Iodide-selective electrode, potentiometric sensor, imidazolidine-2tion, coated-graphite electrode.*

Introduction

Iodide is a fundamental component of thyroid hormones which has a significant role in developing cell growth and brain function and its absence entails considerable delays in neurological development[1]. Iodine is vital to determine iodide in natural waters and biological samples in regard to environmental and biological terms[2]. Several analytical approaches have been conducted to determine iodide at low concentration levels since this bio-essential lement typically takes place at extremely low concentrations. The majority of these approaches need costly instruments, complex techniques, inadequate sensitivity and are time consuming e.g. classical spectrophotometry or titrimetry, and/or sample pretreatments namely in a complex matrix such as wastewater. A simple approach i.e. potentiometric detection on the basis of an ion-selective electrode has numerous advantages such as a speedy process, straightforward preparation, simple instrumentation, expeditious response, extensive dynamic range, appropriate selectivity and is cost-effective. Such properties have unavoidably produced sensors for numerous species with the available electrodes list expanding significantly over the past few years [2]. Different types of electrodes have been recommended to determine the analyst ion. In addition to traditionally produced electrodes, the coated wire electrode has gained attention due to its simple manipulation and fabrication, great dynamic range, low detection limit and improved miniaturization potential. Thus, there has been growing interest in developing and applying potentiometric sensors. The majority of lately reported potentiometric sensors are carrier based ion-selective electrodes (ISEs) that likely act on chemical recognition principles. Numerous recognition elements types have been used in selecting or synthesizing appropriate carriers to construct ISE's such as the utilization of adequate sized

---

Corresponding Author:
Narges Chamkouri
Abadan Faculty of Medical Sciences, Abadan, Iran

carriers and particular metal-ligand interactions [3, 4]. A selective interaction among the ionophores and anions is needed in ion selective electrodes for the purpose of successfully complex anions within a selective manner. The attraction between active sites used in anions and membranes may be separated into two categories; a quaternary ammonium and phosphonium salts by the ion exchange procedure and generates a selectivity pattern named the Hofmeister pattern [4]. In this study, the selectivity for various ions and the impact of the membrane matrix, ionophore concentration, additives and the pH on potentiometric response characteristics regarding the suggested electrodes is examined.

Experimental

Coated-graphite electrodes were prepared based on a prior method [5]. The spectroscopic grade graphite was used to prepare the graphite rods of 3mm diameter and 10 mm length. A silver loaded epoxy resin was used to glue a shielded copper wire to one of the ends of the graphite rod. The rod was then placed into the end of the PVC tube. A polishing cloth was used to polish the electrode. Water and methanol were used to rinse the electrode before being left to dry. A concoction of the membrane additive, MTOAC, PVC, plasticizer with an overall mass of 100mg was disintegrated in approximately 3 ml of THF. The electro active material imidazolidine-2tion was added to the mixture prior to being mixed. By repeatedly dipping the polished graphite electrodes into the membrane solution, the electrodes were coated. On the graphite surface, a membrane was created which was left to set overnight. Water was used to rinse the electrodes prior to being conditioned for 14 hour and 18 hour time periods in a 0.05 M potassium iodide solution for the imidazolidine-2tion. If the coating solutions are preserved in a refrigerator, they can remain stable and may be used to construct new membranes.

Findings

Membrane composition effect

As with prior reports, a plasticizer: PVC ratio, 2:1 was maintained as constant in the optimization of the suggested iodide ion-selective electrode ingredients. Because of the plasticizer effect and its quantity on the dielectric constant regarding the ligands mobility and membrane phase, it is assumed to have a significant role in detection limit control[6] and sensitivity/selectivity of the electrode[7]. Since membranes possess 60–70 wt.% of a plasticizer, it is predicted that the dielectric constant values of the liquid membranes are identical to the values resulting from the pure liquid plasticizer. The binding of synchronizing anions namely the thiocyanate and iodide with the complexes' metal centers is predicted to be strengthened while the polarity of the solvents is decreased. The membrane solvent that is less polar is more appropriate for the anti-Hofmeister actions of a provided anion ionophore. Hence, at plasticizer: PVC ratio of ≈ 2 the impact of the plasticizer type concerning the response properties of the iodide ion-selective electrode was examined using 6 plasticizers with various polarities that included BA, NPOE, DMS, DOP and DBP. From 5 various implemented plasticizers, the membrane was prepared using DOP (ε=5.1) had the most favorable characteristic response. When DOP (ε= 5.1) was replaced with DBP (ε= 6.4), BA (ε= 5.0), or DBS (ε= 5.4), the electrode's slope was reduced. For the polar membranes based on o-NPOE (ε= 23.9), the detection limit was higher. The o-NPOE polarity is higher than the polarity of DOP but they are of similar lipophilicity. This may be because of the synergism among the polarity and lipophilicity where the most beneficial results were acquired when these properties achieved an intermediate value. The electrode with DBP and DOP with low polarity compounds between the plasticizers were examined and presented useful circumstances to incorporate highly lipophile iodide ion within the membrane before coordinating it with soft mercury ion within the complex. This is in accordance with the literature that proves sensors for iodide ion-selective electrodes with comparatively non-polar membrane material may enhance iodide responses. The responses of the electrode prepared using various IMT amounts was examined. The electrode response sensitivity and working range were enhanced when IMT concentrations were increased to 9.7. Adding more ionophores concentrations deteriorated the electrode response which was likely because of membrane saturation or membrane non-uniformity [5, 8]. It is established that lipophilic salts improve the response behavior and selectivity whilst reducing sample anion interference in addition to reducing membrane resistance [9-12]. Neutral carrier based anion selective electrodes need lipophilic cathionic sites. However, concerning charged carrier-based ISEs, the ionic sites should hold the same charge as analyte ion [13]. The effect of the membrane additives concentration and type were examined by integrating NaTPB or MTOAC into the membranes. The carrier-based membranes potentiometric response significantly enhanced the existence of lipophilic cationic additive, MTOAC in comparison to the membranes with no additive. However, no responses were seen when NaTPB was integrated into the membranes. The MTOAC concentration influence on the membranes was examined at numerous additive/carrier mole ratios. The electrode with MTOAC/carrier mole with 0.42 ratio exhibited close-Nernstian response within an extensive iodide concentration range.

Response Characteristics and Selectivity of the Electrode

The results shown in Fig. 1, the potential response of the electrode based on carrier is independent of pH over the range 3.0–10.5. Dynamic response time is an important factor for an iodide sensitive electrode. In this study, the practical response time was recorded by changing solution with different low-to-high I^- concentrations. The actual potential versus time traces is shown in Fig. 2. As can be seen, in whole the concentration range, the electrode reaches the equilibrium response in a very short time (approx.6 s). To evaluate the reversibility of the electrode, a similar procedure at the opposite direction was adopted. This time, measurements were performed in the sequence of high-to-low sample concentrations and the results are shown in Fig. 2, which shows that the potentiometric response of the sensor was reversible, although the time needed to reach equilibrium values were somewhat longer than that of the low-to-high order of sample concentration. Optimum conditioning time for the membrane sensor in a 5.0×10^{-2} M potassium iodide solution is 14 h in 0.05 M potassium iodide. It then generates stable potentials when placed in contact with I^-solutions. The long-term stability of the electrode were studied by direct periodically recalibrating in standard solutions (KI and air and distilled water) and calculating the response slope over the range of 1.0×10^{-5} to 1.0×10^{-1} iodide ion. The slopes of the lectrode responses were reproducible to within 1.0 mV/decade over a period of 2 months, but life time studies for more than this period have not been done. Therefore, the membrane electrode can be used for at least 2 months, without a considerable change in the response characteristics towards iodide ion. The electrode was stored in solution when not in use. The potentiometric response of the electrode was examined in the concentration range 1.0×10^{-7}–1.0×10^{-1} M. The calibration plots for iodide selective electrode are shown in Fig. 3, which show linearity over the concentration range of 1.0×10^{-6}–1.0×10^{-1} M and with a detection limit of $\approx 7.0 \times 10^{-7}$ M and sensitivity of 55.2 ±0.9 mV/ decade of iodide concentration (n=6). The reproducibility and stability of the coated graphite electrode were evaluated by repeated calibration of the electrode in potassium iodide solutions. Repeated monitoring of potentials and calibration, using the same electrode for each carrier, over several days gave good slope reproducibility; the standard deviation of slope was 1.0 mV/decade. Repeated monitoring of potentials and calibration, using the same electrode for each carrier, over several days gave good slope reproducibility; the standard deviation of slope was 1.0 mV/decade, as given in Table 1. The standard deviation of 10 replicate measurements at 1.0×10^{-2} and 1.0×10^{-3} M iodide concentrations were between ±0.6 to±0.9 mV. Life time study was based on monitoring the change in electrode slope and linear response range with time.

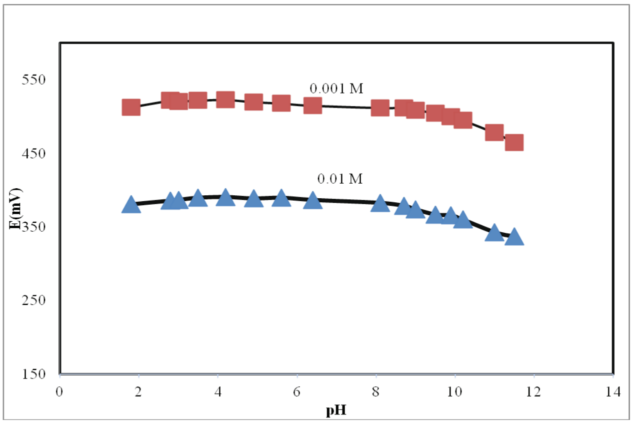

Figure 1. Effect of pH on response of iodide selective electrode

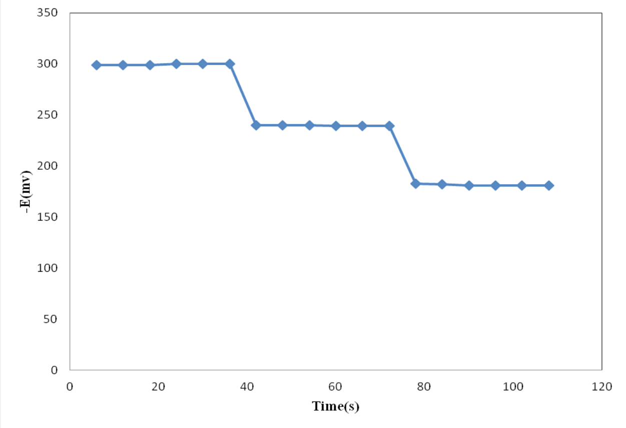

Figure 2. Typical potential-time recorder trace of the electrode

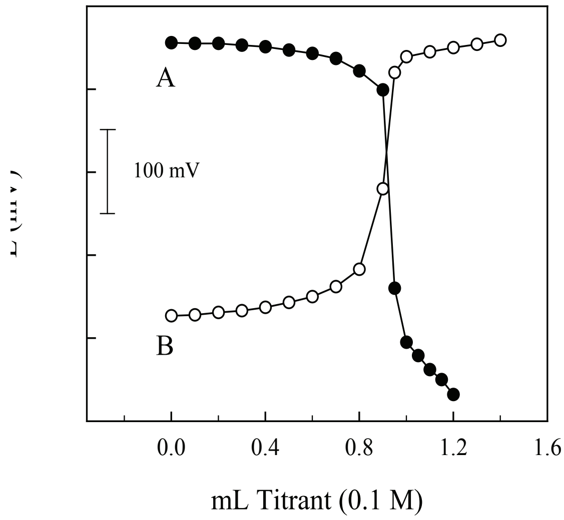

Figure 3. Application of the electrode based on IMT for potentiometric titration

of (A) 100 ml 1 ×10^{-3} M Ag^+ with 0.1 M I^- and (B) 100 ml 1 ×10^{-3} M I^- with

0.1 M Ag^+.

Table 1. Specification of iodide selective electrodes

Parameter	Value
Electrode type	Coated–graphite electrode
MTOAC /Carrier ratio	0.42
pH range	3 –10.5
`Conditioning time	At least 18 h in 0.05 M KI
Linear range (I-, M)	1×10-6 - 1×10-1
Slope (mV/decade)	55.2
Detection limit (M)	~6×10-7
Standard deviation of slope (mV/decade)	± 0.9
Standard deviation of measurement	± 0.4 at 1×10-2 M ± 0.8 at 1×10-3 M
Response time (s)	≤ 6
Life time of the electrode	At least 3 months

Selectivity of the Electrode

The selectivity behavior is obviously one of the most important characteristics of an ion-selective electrode, determining whether a reliable measurement in the target sample is possible. In order to assess the selectivity of the proposed iodide ion selective electrode over other anions the method of fix interference method [FIM] and separate solution method [SSM] was employed.[14,15] According to this method, the potentiometric selectivity coefficients, Kpot I, can be evaluated from the potential measurements on solutions containing a fixed concentration (0.01 M or 0.001 M) of interfering ion (respective potassium or sodium salts) and varying concentration of iodide ion in FIM and in SSM potential of different solution containing same amount of iodide or interfering ion (0.01 M). As can be seen, the electrode based on carrier has not shown the tendency toward the highly lipophilic anions such as ClO_4^-, N_3^-,Br^-, NO_3^-, and NO_2^-.

Indirect Determination of Iodine-containing Drug

The proposed electrode was applied for the indirect determination of iodine containing drugs including iodiquinol (Jalinous Pharmaceutical Co, Tehran, Iran) and Levothyroxin (Iran Hormon Co, Tehran, Iran) as follow: 2 g of sodium were placed into an alkaline fusion tube and heated until all of the sodium was fused. Then an appropriate and accurately weighed amount of finely powder tablet (i.e., 0.1 g of 4 mixture tablet) was added to hot tube, and the resulting mixture was completely burned. The hot tube was immediately transferred into a beaker containing 25 ml distilled water. After cooling the reaction mixture was filtered and washed with water and diluted to mark in a 50 ml calibrated volumetric flask. The iodide released from the decomposition of drug was determined by potentiometric titration method using standardized silver nitrate, the proposed electrode as indicator electrode.

Direct Determination of Iodide-containing Drug

The resulting electrodes were applied to determine iodide in a drug preparation (Meglumine Compound Injection, from Darou Pakhsh Pharmaceutical Co., Iran; is an iodide containing drug used for protection from light and secondary X-rays). The sample was prepared by refluxing 1.0 ml of the drug preparation in concentrated sodium hydroxide solution in the presence of zinc powder for 30 min.[16] After cooling, the reaction mixture was filtered and washed with water three times. The filtrate was acidified with H_2SO_4 and diluted to 1 with water. The iodide content of the resulting solution was determined potentiometrically by the standard addition method.

Conclusions

This iodide selective electrode based on IMT as new carrier can be used for determination of iodide in polluted and industrial samples. Due to the high mechanical resistance and durability of the coated-wire electrode, and low solubility of the carrier used, the proposed electrode can be used in flowing streams. The characteristics and the typical applications presented in this paper, make the electrode suitable for measuring the iodide content in a wide variety of samples, without a significant interaction from concomitant anionic species. The results show that there was a coordination interaction between iodide and the proposed carrier, which played an important role in the response characteristics and selectivity of the electrode.

Acknowledgment: The authors would like to acknowledge the support of Abadan School of Medical Sciences for financial support of this work (Project ID: 95U-1018 and code of ethics:IR.AbADANUMS.RES.1395.151).

Conflict of Interest: Authors have declared that no competing interests exist.

Ethical Clearance: Ethical clearance taken from ethical committee of Abadan Faculty of Medical Sciences.

References

[1] Jakmunee J, Grudpan K. Flow injection amperometry for the determination of iodate in iodized table salt. Analytica chimica acta. 2001 3;438(1-2):299-304.

[2] Daunert S, Wallace S, Florido A, Bachas LG. Anion-selective electrodes based on electropolymerized porphyrin films. Analytical Chemistry. 1991 ;63(17):1676-9.

[3] Daunert S, Florido A, Bricker J, Dunaway W, Bachas LG, Valiente M. Iodide-selective electrodes based on a mercury-triisobutylphosphine sulfide complex. Electroanalysis. 1993;5(9-10):839-43.

[4] Bricker J, Daunert S, Bachas LG, Valiente M. Selective electrodes for silver and anions based on polymeric membranes containing complexes of triisobutylphosphine sulfide with silver. Analytical Chemistry. 1991;63(15):1585-9.

[5] Ghaedi M, Shojaie AF, Montazerozohori M, Karami B, Gharaghani S. Iodide-Selective Electrodes Based on Bis [N (2-methyl-phenyl) 4-Nitro-thiobenzamidato] mercury (II) and Bis [N-phenyl 3, 5-Dinitro-thiobenzamidato] mercury (II) Carriers. Electroanalysis: An International Journal Devoted to Fundamental and Practical Aspects of Electroanalysis. 2005;17(19):1746-54.

[6] Amini M, Ghaedi M, Rafi A, Habibi M, Zohory M. Iodide Selective Electrodes Based on Bis (2-mercaptobenzothiazolato) Mercury (II) and Bis (4-chlorothiophenolato) Mercury (II) Carriers. Sensors. 2003;3(11):509-23.

[7] Eugster R, Rosatzin T, Rusterholz B, Aebersold B, Pedrazza U, Rüegg D, Schmid A, Spichiger UE, Simon W. Plasticizers for liquid polymeric membranes of ion-selective chemical sensors. Analytica chimica acta. 1994;289(1):1-3.

[8] Shamsipur M, Sadeghi S, Naeimi HO, Sharghi H. Iodide ion-selective PVC membrane electrode based on a recently synthesized salen-Mn (II) complex. Polish Journal of Chemistry. 2000;74(2):231-8.

[9] Huser M, Gehrig PM, Morf WE, Simon W, Lindner E, Jeney J, Toth K, Pungor E. Membrane technology and dynamic response of ion-selective liquid-membrane electrodes. Analytical chemistry. 1991 Jul 1;63(14):1380-6.

[10] Yajima S, Tohda K, Bühlmann P, Umezawa Y. Donnan exclusion failure of neutral ionophore-based ion-selective electrodes studied by optical second-harmonic generation. Analytical Chemistry. 1997 May 15;69(10):1919-24.

[11] Akhond M, Ghaedi M, Tashkhourian J. Development of a new copper (II) ion-selective poly (vinyl chloride) membrane electrode based on 2-mercaptobenzoxazole. Bulletin of the Korean Chemical Society. 2005;26(6):882-6.

[12] Bakker E, Malinowska E, Schiller RD, Meyerhoff ME. Anion-selective membrane electrodes based on metalloporphyrins: The influence of lipophilic anionic and cationic sites on potentiometric selectivity. Talanta. 1994 Jun 1;41(6):881-90.

[13] Amemiya S, Bühlmann P, Pretsch E, Rusterholz B, Umezawa Y. Cationic or anionic sites? Selectivity optimization of ion-selective electrodes based on charged ionophores. Analytical chemistry. 2000

Apr 1;72(7):1618-31.

[14] Pungor E, Toth K, Hrabeczy-Pall A. Selectivity coefficients of ion-selective electrodes. Pure Appl. Chem. 1979;51:1913-80.

[15] Neda AN, Fahimeh S, Tahereh ZK, Leila F, Zahra N, Bahman C, Narges CK. Lead level in umbilical cord blood and its effects on newborns anthropometry. Journal of Clinical and Diagnostic Research: JCDR. 2017;11(6): 01-04.

[16] Bakker E, Pretsch E, Bühlmann P. Selectivity of potentiometric ion sensors. Analytical chemistry. 2000 Mar 15;72(6):1127-33.