International Journal of Engineering, Science and Mathematics
Vol. 12 Issue 2, Feb 2023,
ISSN: 2320-0294 Impact Factor: 6.765
Journal Homepage: http://www.ijesm.co.in, Email: ijesmj@gmail.com
Double-Blind Peer Reviewed Refereed Open Access International Journal - Included in the International Serial Directories Indexed & Listed at: Ulrich's Periodicals Directory ©, U.S.A., Open J-Gage as well as in Cabell's Directories of Publishing Opportunities, U.S.A

ELECTROCHEMICAL BEHAVIOR OF GALLIC ACID AT SILVER ION SELECTIVE ELECTRODE

[1]Seema Rani

Department of Chemistry, Baba Masthnath University Asthal Bohar, Rohtak Haryana (India)

Abstract

The experimentally synthesized anion exchange membrane interface was further characterized by cyclic Voltammograms (CV) method to evaluate whether the anion exchange membrane retains its catalytic potency after being fabrication onto the working electrode. CV quantifications were performed out in an unstirred redox cell. The voltammogram of the 0.05 g/L gallic acid with potassium permanganate solution come at the modified electrode. Peaks representing a chemical change of gallic acid into semiquinone were evaluated, with a peak value of +1.2 V at cathode and the analogous two peaks value at+ 0.95 V (peak 1) and +1.2 V (peak 2) at anode, this is due to electrochemical redox movement produced by membrane action. Whereas the control runs, performed on working electrode exhibited no ionic movement at electrode. Peak current ratio of cathode over anode was nearly unity. Variation in peak value of currents with the scan rate, represent the redox reaction was a typical TDMAC surface-controlled reversible redox events.

Keywords: Gallic acid, TDMAC, voltammogram, silver ion

1. INTRODUCTION

The catalytic activities of anion exchange membrane (TDMAC) to regulate various electrochemical redox reaction processes. In electrochemical cells of redox reaction, anion exchange membrane deposit on solid surface of silver working electrode might bring change in current pattern as well as facilitate new series of reagent biosensors. The experimentally synthesized anion exchange membrane interface was further characterized

by cyclic Voltammograms (CV) method to evaluate whether the anion exchange membrane retains its catalytic potency after being fabrication onto the working electrode. CV quantifications were performed out in an unstirred redox cell [1-4]. The voltammogram of the 0.05 g/Lgallic acid with potassium permanganate solution come at the modified electrode. Peaks representing a chemical change of gallic acid into semiquinone were evaluated, with a peak value of +1.2 V at cathode and the analogous two peaks value at+ 0.95 V (peak 1) and +1.2 V (peak 2) at anode, this is due to electrochemical redox movement produced by membrane action. Whereas the control runs, performed on working electrode exhibited no ionic movement at electrode. Peak current ratio of cathode over anode was nearly unity. Variation in peak value of currents with the scan rate, represent the redox reaction was a typical TDMAC surface-controlled reversible redox events[5-7].

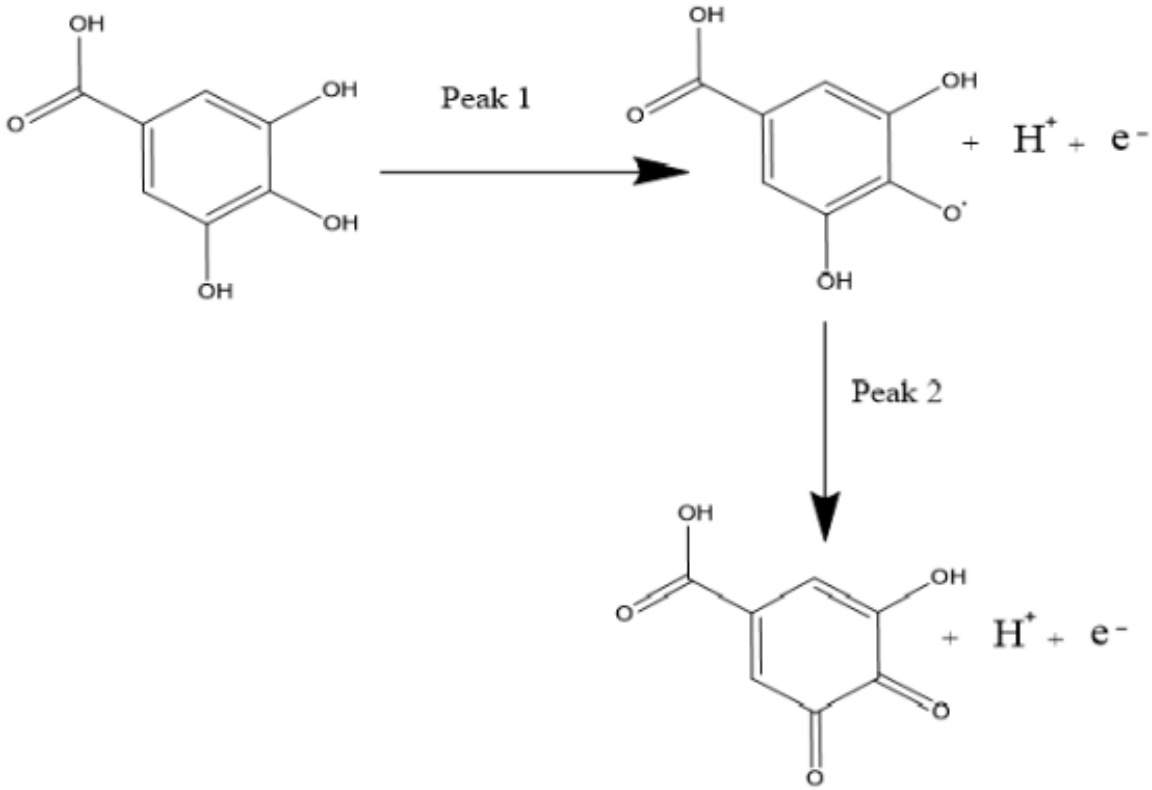

Fig: 1. Step followed by Gallic acid oxidation on the present biosensor

2. OPTIMIZATION OF THE GALLIC ACID POTENTIOMETRIC SENSOR

To progress the working presentation of the present modified biosensor at different specification such as working potential, effect of pH, effect of temperature, response of time, and the response of substrate concentration on the modified fabricated electrode biosensor were determined below.

2.1 Effect of pH:

It is well known that the pH of a solution has a significant effect on the oxidation capacity of the oxidant and reducibility of the reductant, which will certainly induce potential changes of the electrode, based on redox reaction. Considering this fact, the influence of the pH of the solution on the potential response after redox reaction between permanganate ions and gallic acid was investigated. Considering the pH values of wine at the range of 3.0–4.0, the initial pH of the model wine was about 2.52 and adjusted to this range by use of 1.0 M NaOH. The results are presented in Fig. It can be seen clearly that the potential changes remained constant in the pH range of 3.0–4.0 when the concentration of gallic acid was varied from 0.17 to 1.7 g/L. These results indicate that the redox reaction between permanganate ions and gallic acid was not significantly influenced by pH and varied at the range of 3–4. A pH value of 3.6 was chosen for consistency of the proposed sensor[8-10].

2.2 Effect of temperature

The response of present biosensor with constant increased of temperature from 10 0C to 400C was determined. It was established that the biosensor showed best response at 250C with potential in mV and after that not so much varied, almost constant valve comes of potential with increased temperature shown below. The best situation provided by support used for fabrication makes it thermally stable and balanced its chemical activity[11].

2.3 Effect of time

The response of time/s was measured from 25 s to 250 s at interval of 50 s. The response time increases with potential from 25 to 100 s and later not varied the potential with time and attains the stability. So 100s time is the best for the biosensor[12].

2.4 Effect of substrate (gallic acid) concentration

Biosensor response correlated with gallic acid content between 0.05 and 3.5 g/L. After 3.0 g/L, the reaction reached a steady state. When compared to other published potentiometric gallic acid biosensors, the present study's working range of 0.05-3.0 g/L is more impressive[13].

2.5 Effect of membrane composition

The anion exchange membrane TDMAC plays an important role for extracting the ion from the sample solution. It is semi permeable in nature and passes through them only special ion. After adding gallic acid to the mixture, various mass percentages of TDMAC were tested to see what would happen, and any unexpected results were investigated. Gallic acid biosensors with TDMAC membranes of varying compositions were dipped into sample solutions containing gallic acid. Then found that the potential of the membrane sensor increase according to different composition of membrane. This shows that the increase no of membrane particles done more redox reaction with gallic acid molecules and increase the potential, but after the 1.7 g/L concentration of gallic acid and the composition of membrane 9.0% not increased the potential of the potentiometric sensor[14-17] .

2.6 Effect of inner filling solution

$KMno_4$'s potentiometric response is heavily influenced by the solution used to fill its interior. The detection sensitivity was studied in relation to the presence of permanganate ions. We found that as the concentration of permanganate ions in the inner filling solution was increased from 103 to 101 M, while the concentration of gallic acid was held constant at 1.7 g/L, the sensor's potential, measured in millivolts, rose proportionally. This is because the potential of the system shifts when additional ions congregate at the membrane's boundary and galic acid is also provided at the membrane's surface through redox reactions. The maximum change in potential is 18 mV at a concentration of 10-1 in the inner filling. As can be seen in the picture below, the potentiometric sensor used to ascertain the gallic acid and total phenolic content of wine samples functions more reliably at this concentration[18-20].

3. EVALUATION OF GALLIC ACID SENSOR

Using a functioning TDMAC anion exchange membrane that was built on the Ag working electrode, a new method was devised for the potentiometric detection of gallic acid in wine samples. This method makes use of the samples. The oxidation of gallic acid using permanganate ions that came from the inner filling solution and went through the anion exchange membrane was the method that was used. The potentiometric biosensor worked by measuring the voltage response of gallic acid using a digital potentiometer. This voltage response was produced through the oxidation of gallic acid. The gallic acid content of the wine samples was shown to have a direct and proportional relationship to the potential that was measured. The benefit of the current system is that it is straightforward, sensitive, and easy to manipulate. Additionally, it is more particular and quick to respond. After some period of time, the electrodes that are used in the procedure become more stable and can be reused. The linear concentration range of the present biosensor is lower than that of the reference methods, which are immobilization of tyrosinase or laccase on the surface of GCE modified with GO-**111** MWCNT hybrid (1-2.6 g/L) and ITO/LAC/Tyr electrode (1.6-8.3), respectively. The linear concentration range of the present biosensor is between 0.05 and 3.0 g/L. The analytical performance of the current gallic acid biosensor, which makes use of the TDMAC anion exchange Ag working electrode, was evaluated based on the following criteria, which were researched and investigated[21-23].

3.1 Linear range

“There was a relationship between potential(mV) and gallic acid concentration (g/L) of the present gallic acid biosensor ranging from 0.05- 3.0g/L), response was constant after 3.0 g/L which is better than previous reported potentiometric gallic acid biosensors based on chitosan membrane(0.0016-0.1g/L), ZnO-NPs-CPE by the CV, and DPV in the red wine (1 × 10-6 to 6.5 × 10-5, SiO2-NPs -GrO nanocolloids-GCE by the CV, and DPV in red and white wine(6.25 × 10-6 to 1 × 10-3), Amorphous Zirconia-CPE by the CV, DPV in red and white wine 1 × 10-6 to 6–1 × 10-3, ZrO2/Co3O4/rGO-FTO by CV, DPV in the Fruit juice[24-26].

3.2 Detection limit & sensitivity

The lower detection limit (LOD) of the present biosensor was 6.6mg/L which was better than earlier reported potentiometric gallic acid biosensors. “The detection limit of the

present gallic acid sensor was 6.6 mg/Lwith a sensitivity of present improved gallic acid biosensor 18mV/decade which was better than earlier reported potentiometric gallic acid biosensor based on ZnO-NPs-CPE by the CV, and DPV in the red wine 1.86 × 10-7 mol/L(LOD) , SiO2-NPs -GrO nanocolloids-GCE by the CV, and DPV in red and white wine 2.09 × 10-6 mol/L (LOD), Amorphous Zirconia-CPE by the CV, DPV in red and white wine 1.24 × 10-7 mol/L (LOD) [27-28].

3.3 Analytical recovery

To check the accuracy of the present gallic acid biosensor method, the analytical recovery of added gallic acid in wine samples was determined. The average analytical recoveries of gallic acid added to wine sample (at levels of 5.0 g/L,10g/L and 15g/L) were varied from 96.8%,99.2% and 98.74.

CONCLUSION

Worldwide, wine consumption decreases the risk of cardiovascular disease and some cancers. There is evidence that the presence of different phenolic substances, specifically those richly present in wine, might contribute to these biological effects on human health and disease prevention. Aside from the well-recognized activity, phenolic compounds also contribute to sensorial characteristics of wines and the total phenolic content is also a worldwide standardized indicator to estimate the state of the quality of wine, therefore, rapid and accurate determination of total phenolic content in wine is of great importance for controlling sensory attributes and market value or quality. Classical determination methods for total phenolic content in the laboratory rely on the Folin–Ciocalteu (FC) method, based on spectral detection. While this is a convenient and simple analytical technique for the total phenolic content in wine, it suffers from the limitations of not having an environmentally friendly reagent and a long processing time. Currently, a series of analytical methodologies based on infrared spectroscopy (IR), a chemiluminescence system and nuclear magnetic resonance (NMR) spectral have been developed for total phenolic content detection in a variety of samples. Obviously, these tests cannot be performed easily worldwide due to their high cost. Mass spectrometric platforms targeting total phenols represent a burgeoning technology that facilitate the method development of qualitative and quantitative analysis with higher accuracy and a lower detection limit, however, these mass spectrometry-based platforms also have significant limitations, including a requirement for tedious sample pretreatment and sophisticated instruments,

creating a high cost per sample[29]. To compare, electrochemical sensors have been used as particularly attractive tools for total phenolic content analysis due to their high sensitivity, low manufacturing cost, fast response and ease of operation. Electrochemical biosensors, based on the immobilization of laccase coupled with voltammetry, have been constructed successfully for rapid detection of total

Phenols for example, Immobilization of enzymes, such as laccase, on electrodes requires complicated procedures, however, and is still a key challenge for operators. An alternative and highly successful approach, ion selective electrode-based potentiometry, has shown to be promising for trace-level measurements in food samples. A potentiometric methodology was fabricated for the determination of mono-phenols based on molecularly imprinted nanobeads as ionophores. Unfortunately, the developed potentiometric strategies were not suitable for the determination of total phenol content. Recently, a label-free potentiometric biosensor based on solid-contact was fabricated for the determination of total phenols in honey and propolis, and the transducer-containing two layers was manufactured using the covalent bond method. Obviously, this platform also has significant limitations, including a requirement for tedious and complicated procedures and a high manufacturing cost.

Recently, a promising potentiometric detection approach based on ion fluxes across ion-selective electrode membranes has been found useful analytically for measuring some organic analytes which can decrease the concentrations of the indicator ions released at the membrane boundary via redox, complexing or enzyme-catalyzed reactions. Currently, the potential change of the electrode is related to the concentration of the measured substance. Potentiometric analytical methods based on a permanganate release system, for example, have been developed for potentiometric detection of reductants such as dopamine and ascorbate. Nevertheless, intense research efforts still focus on their new applications and, herein, ions for the evaluation of the total phenolic content in wine is the emphasis. Analysis conditions such as membrane composition, inner filling solution and pH are optimized. The results are compared with the data measured by the Folin–Ciocalteu (FC) method. Therefore, in order to determine the amount of gallic acid present in the wine samples, which has been successfully proposed, we offered a potentiometric sensor that was both straightforward and reliable. In order to construct this sensor, we initially fabricated the anion exchange membrane TDMAC using a variety of chemicals and a range of weight percentages. The details of this process may be found in the thesis work. To facilitate the formation of a membrane electrode system, TDMAC contributes a binding

capacity that facilitates the covalent connection of the membrane onto the exposed surface of the silver electrode, after that put into 0.1 M sodium chloride solution so that it could become more durable. The voltammogram of the solution that has been altered to contain potassium permanganate and gallic acid at a concentration of 0.05 g/L has arrived at the electrode that has been modified. Analyses were performed on peaks that indicated a chemical change from gallic acid to semiquinone. One peak had a value of +1.2 V at the cathode, while the comparable two peaks at the anode had values of + 0.95 V (peak 1) and +1.2 V (peak 2). This is because electrochemical redox movement is produced by membrane action, and it was discovered that the highest value at the cathode was +1.2 V. This leads to the conclusion that membrane action is responsible for producing electrochemical redox movement. On the other hand, the control runs that were performed on the working electrode revealed no indication of ionic mobility at the electrode. The values of the peak currents produced at the anode and cathode by the action of membrane particles were measured, when the scan rate was set to 100 mV. The ratio of peak current from the cathode to that of the anode was very near to being equal to one. The redox reaction was an example of a surface-controlled reversible event that was measured using TDMAC. The change in peak value of the currents as a function of scan rate is reflective of the redox reaction. After that, the circumstances of the potentiometric sensor should be optimised by taking into account the influence of factors such as pH, temperature, time, and substrate concentration. An analysis of the potentiometric sensor is going to be carried out as soon as this method has been finished. This method of quantitative analysis is based on the potential changes of the TDMAC-based silver working electrode that are generated by the redox action between the permanganate ion, which comes from the inner filling solution through the polymeric membrane, and phenols such as gallic acid in the sample solution. The potential changes of the TDMAC-based silver working electrode are generated when the permanganate ion reacts with the phenols in the sample solution. To be more specific, the permanganate ion is utilised in this procedure for the purpose of determining the amount of phenols present in the sample solution. The degree to which there is a shift in potential is directly proportional to the amount of permanganate ion that is present in the solution. This is because the amount of change in potential is proportional to the number of ions that enter the solution and react with the gallic acid. It is a simple and robust potentiometric approach for determining the total phenolic content has been successfully proposed. The quantitative analysis method is based on the potential changes induced by redox action between permanganate ion fluxes across the polymeric membrane

and phenols such as gallic acid in the sample solution. Additionally, these also exhibit a fast response time, an acceptable reproducibility and long-term stability. Note that, although the total phenolic content assessed by the proposed potentiometric sensor was higher compared to the data obtained by the Folin–Ciocalteu method, pave the way to detect and quantify total phenolic content in other food analysis applications. It has been demonstrated that the proposed electrodes exhibit a linear response to the concentration of gallic acid over the range of 0.05 g/L to 3.0 g/L, with a detection limit of 6.6 mg/L. This response is valid over the whole range of concentrations. In addition to this, they have a short response time, a repeatability that is sufficient, and stability over the course of a lengthy period of time. It is important to note that although though the total phenolic content that was measured by the suggested potentiometric sensor was found to be higher compared to the data that was obtained by the Folin-Ciocalteu method, the values that were obtained by the two methods correlate very highly with one another.

References

1. Lo Presti, R.; Carollo, C.; Caimi, G. Wine consumption and renal diseases: New perspectives. Nutrition 2007, 23, 598–602.

2. Nunes, C.; Freitas, V.; Almeida, L.; Laranjinha, J. Red wine extract preserves tight junctions in intestinal epithelial cells under inflammatory conditions: Implications for intestinal inflammation. Food Funct. 2019, 10, 1364–1374

3. Gambacorta, G.; Trani, A.; Fasciano, C.; Paradiso, V.M.; Faccia, M. E_ects of prefermentative cold soak on polyphenols and volatiles of Aglianico, Primitivo and Nero di Troia red wines. Food Sci. Nutr. 2019, 7, 483–491.

4. Cravero, M.C. Organic and biodynamic wines quality and characteristics: A review. Food Chem. 2019, 295,

334–340.

5. Nerantzaki, A.A.; Tsiafoulis, C.C.; Charisiadis, P.; Kontogianni, V.G.; Gerothanassis, I.P. Novel determination of the total phenolic content in crude plant extracts by the use of 1H NMR of the OH spectral region. Anal. Chim. Acta 2011, 688, 54–60.

6. Maria Toledo-Martin, E.; del Carmen Garcia-Garcia, M.; Font, R.; Manuel Moreno-Rojas, J.;

Salinas-Navarro, M.; Gomez, P.; del Rio-Celestino, M. Quantification of total phenolic and carotenoid content in blackberries (rubus fructicosus L.) using near infrared spectroscopy (NIRS) and multivariate analysis. Molecules 2018, 23, 3191.

7. Al Mughairy, B.; Al-Lawati, H.A.J.; Suliman, F.O. Characterization and application of nanocolloidal Mn(IV) in a chemiluminescence system for estimating the total phenolic content in pomegranate juices using a nanodroplet microfluidics platform. Sens. Actuators B Chem. 2018, 277, 517–525.

8. Cascant, M.M.; Sisouane, M.; Tahiri, S.; El Krati, M.; Cervera, M.L.; Garrigues, S.; de la Guardia, M. Determination of total phenolic compounds in compost by infrared spectroscopy. Talanta 2016, 153, 360–365.

9. Önder, F.C.; Ay, M.; Sarker, S.D. Comparative study of antioxidant properties and total phenolic content of the extracts of humulus lupulus L. and quantification of bioactive components by LC–MS/MS and GC–MS. J. Agric. Food Chem. 2013, 61, 10498–10506.

10. Leitao, S.G.; Leitao, G.G.; Vicco, D.K.T.; Pereira, J.P.B.; Simao, G.D.; Oliveira, D.R.; Celano, R.; Campone, L.; Piccinelli, A.L.; Rastrelli, L. Counter-current chromatography with o_-line detection by ultra high performance,liquid chromatography/high resolution mass spectrometry in the study of the phenolic profile of Lippia origanoides. J. Chromatogr. A 2017, 1520, 83–90. [CrossRef] [PubMed]

11. Draghi, P.F.; Fernandes, J.C.B. Label-free potentiometric biosensor based on solid-contact for determinationmof total phenols in honey and propolis. Talanta 2017, 164, 413–417.

12. Merkyte, V.; Morozova, K.; Boselli, E.; Scampicchio, M. Fast and simultaneous determination of antioxidant activity, total phenols and bitterness of red wines by a multichannel amperometric electronic tongue. Electroanalysis 2018, 30, 314–319.

13. Sekretaryova, A.N.; Volkov, A.V.; Zozoulenko, I.V.; Turner, A.P.F.; Vagin, M.Y.; Eriksson, M. Total phenol analysis of weakly supported water using a laccase-based microband biosensor. Anal. Chim. Acta 2016, 907,

45–53.

14. Mel, L.P.; Feng, J.J.; Wu, L.; Zhou, J.Y.; Chen, J.R.; Wang, A.J. Novel phenol biosensor based on laccase immobilized on reduced graphene oxide supported palladium-copper alloyed nanocages. Biosens. Bioelectron. 2015, 74, 347–352.

15. Zhang, H.; Yao, R.;Wang, N.; Liang, R.; Qin,W. Soluble Molecularly imprinted polymer-based potentiometric sensor for determination of bisphenol AF. Anal. Chem. 2018, 90, 657–662.

16. Kamel, A.H.; Jiang, X.; Li, P.; Liang, R. A paper-based potentiometric sensing platform based on molecularly imprinted nanobeads for determination of bisphenol A. Anal. Methods 2018, 10, 3890–3895.

17. Elbehery, N.H.A.; Amr, A.E.-G.E.; Kamel, A.H.; Elsayed, E.A.; Hassan, S.S.M. Novel potentiometric 2,6-dichlorophenolindo-phenolate (dcpip) membrane-based sensors: Assessment of their input in the determination of total phenolics and ascorbic acid in beverages. Sensors 2019, 19, 2058.

18. Afshar, M.G.; Crespo, G.A.; Xie, X.; Bakker, E. Direct alkalinity detection with ion-selective

chronopotentiometry. Anal. Chem. 2014, 86, 6461–6470. 19. Ding, J.; Qin, W. Current-driven ion fluxes of polymeric membrane ion-selective electrode for potentiometric biosensing. J. Am. Chem. Soc. 2009, 131, 14640–14641.

20. Bakker, E. Membrane response model for ion-selective electrodes operated by controlled-potential thin-layer coulometry. Anal. Chem. 2011, 83, 486–493.

21. Song, W.J.; Ding, J.W.; Liang, R.N.; Qin, W. Potentiometric flow injection system for determination of reductants using a polymeric membrane permanganate ion-selective electrode based on current-controlled reagent delivery. Anal. Chim. Acta 2011, 704, 68–72.

22. Guo, H.M.; Yin, T.J.; Su, Q.M.; Qin,W. Potentiometric measurement of ascorbate by using a solvent polymeric membrane electrode. Talanta 2008, 75, 851–855. [CrossRef] [PubMed]

23. Tompa, K.; Birbaum, K.; Malon, A.; Vigassy, T.; Bakker, E.; Pretsch, E. Ion-selective supported liquid membranes placed under steady-state di_usion control. Anal. Chem. 2005, 77, 7801–7809.

24. Lv, E.; Ding, J.; Qin, W. Potentiometric aptasensing of small molecules based on surface charge change. Sens. Actuators B Chem. 2018, 259, 463–466.

25. Langmaier, J.; Samcova, E.; Samec, Z. Potentiometric sensor for heparin polyion: Transient behavior and response mechanism. Anal. Chem. 2007, 79, 2892–2900.

26. Telting-Diaz, M.; Bakker, E. E_ect of lipophilic ion-exchanger leaching on the detection limit of carrier-based ion-selective electrodes. Anal. Chem. 2001, 73, 5582–5589.

27. Gyurcsanyi, R.E.; Pergel, E.; Nagy, R.; Kapui, I.; Lan, B.T.T.; Toth, K.; Bitter, I.; Lindner, E. Direct evidence of ionic fluxes across ion selective membranes: A scanning electrochemical microscopic and potentiometric study. Anal. Chem. 2001, 73, 2104–2111.

28. Zhen, X.V.; Rousseau, C.R.; Buhlmann, P. Redox bu_er capacity of ion-selective electrode solid contacts doped with organometallic complexes. Anal. Chem. 2018, 90, 11000–11007.

29. Shrivastava, A.; Gupta, V.B. Methods for the determination of limit of detection and limit of quantitation of the analytical methods. Chron. Young Sci. 2011, 2, 21–25.