Journal of Chemical Reviews, 2020, Volume 2, Issue 3, Pages 148-156

Short Review Article

A Review on: Molecularly Imprinting Polymers by Ion Selective Electrodes for Determination Drugs

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Receive Date: 16 November 2019, **Revise Date:** 23 February 2020, **Accept Date:** 29 March 2020

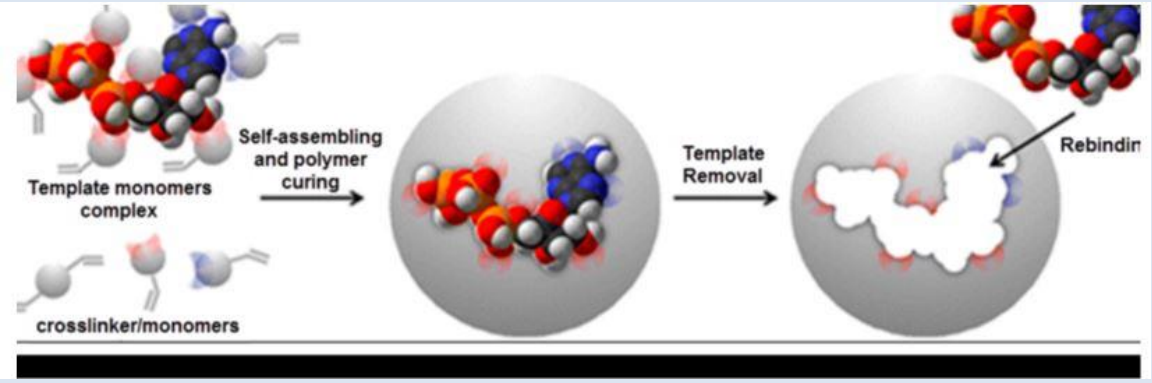
Abstract

Artificial polymer materials with several biomimetic functions with molecular identification competence, activity of catalytic and incentives-reactive functions are the definition of molecularly imprinted polymers (MIPs). Molecularly imprinting polymers can be formulated by forming complexes, the template molecule (its derivative or otherwise target molecule) and a functional monomer that also interacts non-covalently and covalently with the molecule of the template controlled by co-polymerization when a cross-linker is existent. The molecule of template is isolated, leave-taking at the back of schedule tie hollows harmonizing in shape, size, and functional set assemblage to the molecule of template, following the polymerization**.** There are several factors that should be studied in combination of the MIP as these factors may affect the properties, morphology, and usages of the polymer. In this synthesis method, the choice of chemicals influenced fabricating the effectual functional MIPs**.** The aim of this research study was to conduct a review to help preparing the molecularly imprinting polymers with ion selective electrodes for the determination of several types of drugs.

DOI: 10.33945/SAMI/JCR.2020.3.2

Keywords: Molecular Imprinting Polymers, Ion Selective Electrodes, Template, Cross linker.

Graphical Abstract:



Biography:

Amina Mohsen Abass was born in Iraq (Baghdad), in 1978. She received her B.Sc. degree from the University of Baghdad in Chemistry. She is almost done with her Master's Degree at the University of Baghdad in Analytical Chemistry. She has published 18 papers. She is working as lecturer at the Al-Nahrain University, College of Science, Baghdad. My research interests are including the ion selective electrode, sensors, and electrochemistry.

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1. Introduction

Electro analytical sensor with a membrane that shows the movement of the ion to be finding in a solution is called ion selective electrode (ISE). The membranes of ISEs contain also the glassy electrolytes, solid, liquid electrolyte solution that generally have trivial electron conductivity below the situations of measurement [1]. Devices that provide data around the conformation of a method in actual time by combination a chemically selective stratum (the identification component) to an electrochemical transducer it·s called electrochemical sensors. The first stage while a chemical sensor is use up as an analytical instrument is the selective identification of the types of importance for a given application [2]. Selectivity is the utmost main feature underneath analysis throughout the improvement of a novel sensor. While there is no seeming relative with other analytical properties, it is well-known that as soon as there is a height concentration of an interfering composite, the range of linear is decreased, and the detection limits are greater. Therefore, very much selective detection elements are requisite for the improvement of sensors. Additional features of the importance at sensor style include little response times, chemical resistance to variations of working media, and great mechanical strength. However, under critical situations multiple sensors were improved, also the biological receptors compensate for the low mechanical and chemical power of the system in antibodies or enzymes with high selectivity. Molecularly imprinted polymers (MIPs) have been conceived as artificial tailor-made receptors for molecular recognition. They combine the strong chemical strength properties and mechanical of these cross-linked substances with selectivity for the aim analyte that copycats that of the natural receptors (in the most successful cases). The work of the research group headed by K. Mosbach about twenty years ago showed the great potential of analytical methods with regard to these materials. MIPs were immediately applied to the separation field (solid-phase extraction, chromatography), with excellent results, even when the separation of chiral species was undertaken. However, the use of MIPs as artificial receptors in sensors is undergoing slower development. One explanation may lie in the intrinsic principles for building a chemical sensor. When a chromatographic column can be considered as a series of theoretical plates (equilibrium stages), the sensor response shall be controlled in a single step by the interaction between the recognition factor (i.e., the molecularly imprinting polymers) and the analyst either a surface or a bulk interaction. On the other hand, the design of a chemical sensor is more demanding as the recognition element needs to be coupled to the transducer .In the early 1990s, Mosbach and collaborators pointed out the usefulness of MIPs for chemical sensor design. The first studies of MIP-based chemical sensors used some form of electrochemical transduction, such as capacitive [3] and amperometric [4]. Initial studies on optical sensors were also published [5]. It was clear from these early works that the different transductions had different requirements for coupling the MIP to the transducer. It was also observed that the non-conducting nature of the acrylic polymers, most commonly used in the imprinting process, presented a problem for the design of devices based on dynamic electronic techniques, in which electrolysis occurs during measurements. In the effort to modify the features of these materials without compromising their chemical recognition ability, composites with electrically conductive polymers were synthesized [6].

2. Formulation of Covalent and Non-covalent Molecular Imprinting Polymer

The primary stage in molecular imprinting polymer fabrication is to formula the functional monomer complexes-template molecule. There are two steps for complete this, which one is use cleavable covalent connecting (such as: Schiff base, amide, ester, disulfide, and the other of which is to use non-covalent connecting such as the hydrophobic reaction, p-p heaping, hydrogen bonding, van der Waals strengths and electrostatic interaction. Through non-covalent connecting -established MIPs, many tie styles are obtainable for the construction of complexes, and removal the molecules of template is largely at ease.
Alternatively, it is imperative that the formulation for these complexes is stable by polymerisation. The way to compensating for homogeneity, selectivity, solidarity and underlying in circumstances of jobs with

polymerization techniques, solvents, and temperature. Cross-linkers used for formula mediums may also interrelate with template molecules.

Consequently, the tension between the cross-linker the functional monomer(s), the template molecule, and improvement of the manufacturing condition should be examined. Covalent connecting-established molecule of template-functional monomer complexes are generally steady throughout the imprinting (polymerization) method, resultant with extra similar tie hollows, denotation the method of imprinting can be positively carried out equal underneath tough situation. Nonetheless, cleavable-covalent and pure weak bonding may be pragmatic for molecular imprinting polymers. The effect is a lack of utility and the cleavage of all covalently bound template molecules is generally difficult to reach. This results in a smaller number of tie holes compared to non-covalent binding molecular imprinted polymers, additionally needed to render with detach functional monomer-template molecule formerly conjugates to polymerization which may be too time- devouring boring. Both of the methods has its private disadvantages too benefits , thus functional monomer- molecule of template complexes established continuously also covalent bonding or non-covalent must stay carefully chosen affording for experimentation project for get in height operation MIPs.

The next stage in making the MIPs is to formula the media round the molecule of template-functional monomer complexes for stoppage them in systematic, accumulated way. These mediums must be fitted sufficient to stoppage the arrangement for the functional monomers fit for the exact tie, however they should be movable enough to radicate the template (aim) molecules. Accordingly, choice of media and modification of situations for medium construction must be prudently addressed. Although organic inorganic hybrid materials, inorganic polymers, organic polymers have each been in employment as media. Polymerization of radical methods containing controlled radical polymerization are mainly in employment used for organic polymer-established molecular imprinting polymers, for inorganic polymer-constructed molecular imprinting polymers, sol-gel methods regularly are employed.

Third stage included eliminates the molecules of template to form molecularly imprinted tie hollows able of molecular identification on the way to the molecules of template (aim), such as size, functional group arrangement, tie hollows complementary in form. It must be well-known that various binding ways can be in employment amid functional monomer conjugations -template molecule and rebinding for molecules of template (aim); to the ensuing imprinted hollows. In the molecular impression polymers, functional monomers with template molecules conjugated with easter relations will result, remains inside the imprinted hollows with the free carboxylic acid, which may bind the template molecules (aim) via non-covalent connecting types for instance hydrogen connecting and electrostatic relations; this third stage is from time to time mentioned for as semi-covalent molecular imprinting polymers. While stoichiometric non-covalent connections, which are tough sufficient for complex of stoichiometric construction, are used, the resultant molecular imprinting polymers have a benefit in excess of together covalent, non-covalent tie-established MIPs [7]. Non-covalent of stoichiometric relations obtainable for molecular imprinting polymers production are move metal synchronization complexes designed with use suitable ligands too numerous hydrogen bonding also electrostatic relations on condition that by diaminopyridines, amidines, and ureas. As these steady complexes have great empathy constants in a lesser amount of polar solvents, functional monomer- the template complexes would stay steady through the ground formation stage, also for the positive elimination for the molecules of template, solvent can easily be replaced for a extra polar solvent to deteriorate the complex relatives. It needs be seen that the non-covalent tie-established molecular imprinting polymers from time to time indicate exceptionally in height binding activity and selectivity at a small range of concentration of aim molecules. This might be due to the detail that only molecule of template-functional monomer complexes that live throughout the medium creation stage can end result in tie hollows by use this technique. For the reason that only in height empathy tie hollows derivative from greatly steady conformations of the complexes can work at little ranges of concentration while little empathy tie hollows will not work due to their height detachment constants, too however the resultant tie hollows are varied [8].

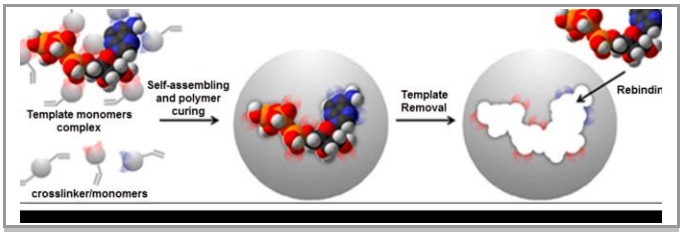

Figure 1. Crystal structures of TiO_2: (**a**) Rutile; (**b**) Anatase; (**c**) Brookite; and (**d**) TiO_2(B), red spheres represent Ti atoms, and the grey spheres represent O atoms [37].

3. MIP-Based Potentiometric Sensors

There is a change of mixtures of appreciation signal transducers and elements. Potentiometric sensors, in which an electrode is used as the transduction element for checking the voltage at zero current, epitomize an essential subclass of electrochemical sensors. The

immobilization of molecular imprinting polymers on the transducer surface is an important feature in the design of MIP-depended on potentiometric sensors.

4. Plasticized PVC Membrane Sensors

Entrapment of MIP particles into PVC membranes has often been used for electrochemical transducers. These formed substances are applied onto the transducer surface. In a typical manner, the sensing membrane was prepared by mixing PVC powder and template polymer particles with a plasticizer. The admixture was moved till the PVC was fine soaked, and later the admixture was isolated in THF. The resultant admixture was sufficiently mixed using a magnetic stirrer with the flow on top of the plate of glass, and solvent was evaporated little by little at temperature of room till a formed of solid membrane with about 0.3 mm thickness. A wanted part of the membrane was cut later was connected to the tip of a Pyrex tube by a sticky solution of THF with PVC as a paste [10-12]. Resultant sensor was later full with an analyst as an internal solution and conditioned for a correct period of time Fig. 2 for a schematic diagram. Mosbach's group was prepared the first imprinted polymer ISEs for calcium and magnesium ions [13].

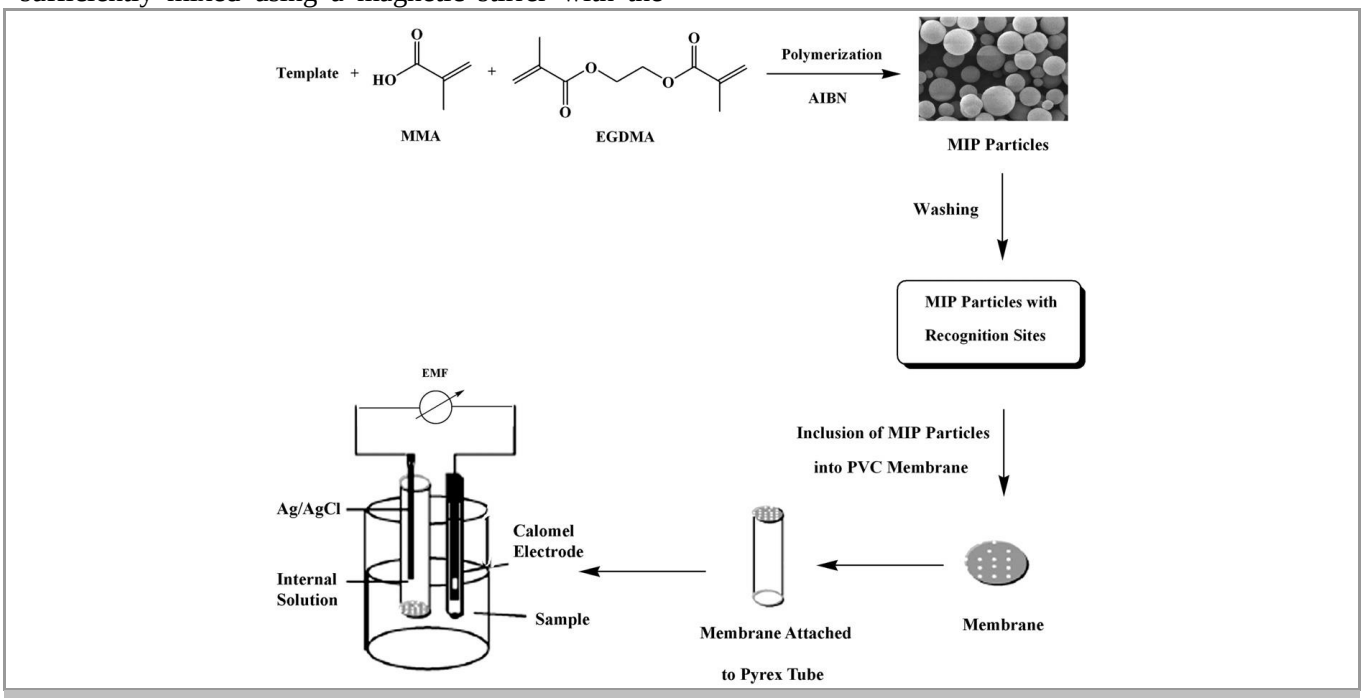

Figure 2. Schematic diagram for fabrication of a MIP-based PVC membrane sensor [14].

5. MIP-Based Sensors for Determination of Drugs in Pharmaceutical Samples

Tablets or capsules taken orally remain one of the most effective means of treatment available. Before any potentiometric analysis with an MIP-based sensor, it is necessary to convert these formulations into a solution that is free from any particle. For this procedure, usually in a small dish, ten capsules or tablets are weighed. Then weighed exactly portion of the powder, equal to one capsule or tablet , is dissolved in solutions at pH in acidic range and filtered .Then completed the solutions to the mark with suitable buffer. An aliquot of both solutions is transported to a 50-mL beaker, and the drug sensor in combination with a duple junction reference electrode is submerged and compared with the calibration curve [15].

6. Characterizations of Potentiometric Sensors with Molecular Imprinting Polymer

The use of potentiometric sensors has come a well-founded routine analytical performance in various fields, counting environmental and clinical analysis, process control and physiology. At two decade ago, imprinted polymers have fascinated wide attention as of scientists selected in electrochemical sensor expansion [15-17]. This interest can be explained by the actual potential improvements by use molecularly imprinted polymers (MIPs) in place of enzymes and natural receptors for example their high selectivity, low cost, easy preparation ,and better stability. As well, MIPs are greatly stable towards organic solvents, high temperature, pressure and pH than their biological complements. Additionally, the materials can be kept in the dry formal in the temperature of room for long times of time because of low cost of these materials. Molecular imprinting, including: exceedingly highly cross-linked polymers can be making the most of two structure three-dimensional hollows with tie places, copycatting the specificity of biological particles,

within a flow in which functional monomers, for example: methacrylic acid (MA), and cross-linkers for instance, ethylene glycol dimethacrylate (EGDMA) or trimethylolpropane trimethacrylate (TRIM) dare copolymerized in the attendance of the chosen analyte as typical. Afterward end the method of polymerization and to provide tie places matching to the structure of typical (template) ,then the template is take out. These polymers are a lot denoted to as synthetic antibodies. MIPs method a in height potential by way of synthetic receptors in applications of numerous for example solid phase extraction [18-21], liquid chromatography [22] sensor technology and assays [23-26], and drug supply methods [27,28]. New studies have been devoted to the appliance of MIPs in the sensor growth [16-18, 24, 25, 29-31].Biomimetic sensors with MIPs deal with several stimulating benefits to characteristic biological-depended on sensors, for example those by use enzymes or antibodies. The technique of molecular imprinting is a commanding method for formulating synthetic appreciation places with fixed selectivity for a widespread range of aim molecules. Compared to the increase in the quantity of MIP information on electrochemical sensors with an electrochemical capacitive transduction ,voltammetric ,amperommetric and conductometric.It is shocking that in the malice of the relatively easy transduction of the potientiometric signal, only a very small amount of MIP-dependent sensors were mentioned using a potientiometric transducer [32,33]. Table 1 represents some drugs determined by using the molecularly imprinting polymer MIP.

Table 1. Molecular imprinting polymer for determination some drugs with using ISE method.

Entry	Name of MIP	Template	Cross Linker	Monomer Functional	Solvent	Results	Ref.
1	Molecularly Imprinted Polymer Based PVC-Membrane-Coated Graphite Electrode	Metoprolol	Methacrylic acid	Ethylene glycol dimethacrylate	$CHCl_3$	**Slope**= 55.4±1 mV/decade **Conc. Range**= 2.0×10^{-7}-8.0×10^{-3}M **Detection Limit**= 1.26×10^{-7}M **Response time**=14sec **Life time**=6 months **PH range**= 3.5-10.5	[34]
2	Molecularly imprinted polymers acting as ionophores	Trimethoprim	trimethylolpropane trimethacrylate	Methacrylic acid and 2-vinyl pyridine as	$CHCl_3$	**Slope**= 59.7mV/decade **Conc. Range**= 2.0×10^{-7}-8.0×10^{-3} **Detection Limit**= 4.01×10^{-7} M **PH range**= 2-6	[35]
3	Molecularly Imprinted Polymer Membrane for the Potentiometric Determination of Sertraline	Sertraline hydrochloride	Ethylene glycol dimethacrylate	Methacrylic acid	$CHCl_3$	**Slope**= 57.7mV/decade **Conc. Range**= 1.0 μmol L^{-1} - 10 mmol L^{-1} **Detection Limit=** 0.8 μmol L^{-1} **PH range**= 2-6	[36]
4	Ciprofloxacin-imprinted polymeric receptors	Ciprofloxacin	Ethylene glycol dimethacrylate	Methacrylic acid or 2-vinyl pyridine	–	**Slope**=26.8 to 50.0 mV/decade **Detection Limit=** 1.0×10^{-5} to 2.7×10^{-5} mol L^{-1}	[37]
5	Screening Phenylalanine in Blood Serum Based on Molecularly Imprinted Polymer	Phenylalanine	Ethylene glycol dimethacrylate	Azo-bis-iso-butyronitrile	–	**Slope**=29.73 ± 1.0 mV/decade **Conc. Range**=1×10^{-5}-1×10-4 M **Detection Limit=5×10^{-9}M** 5×10^{-9}M **PH range**= 4.0-7.5 **Response time =** ~ 20 sec	[38]
6	Molecularly imprinted potentiometric sensor on electrosynthesized polyaniline	Sodium dodecylsufate	–	Aniline	–	**Slope**= 45.54□6 mV/decade **Conc. Range**= 3□10^{-6} to 1□10^{-2} M **Detection Limit**= 1□10^{-5} M	[39]
7	A Molecularly Imprinted Polymer of Clarithromycin	Clarithromycin	Ethylene glycol dimethyl acrylate	Methacrylic acid	$CHCl_3$	**Slope**=50.8±1.0 mV/decade **Conc. Range**= 1.0×10^{-6} to 5.0×10^{-3} **Detection Limit**= 8.0×10^{-7}M **Response time**=15sec **Life time**=45 days **PH range**= 3.5-10.5	[40]

8	Molecularly imprinted polymer membrane of sertraline	Sertraline Hydrochloride	Ethylene glycol dimethacrylate	Methacrylic acid	$CHCl_3$	**Slope**= 57.7mV/decade **Conc. Range**= 1.0 µmol L^{-1} to 10 mmol L^{-1} **Detection Limit**= 0.8 µmol L^{-1} **Response time**=15sec **Life time**=45 days **PH range**= 3.5-10.5	[41]
9	Carbon Paste Electrode Based on Molecular Imprinted Polymer (MIP) of Clonazepam	Clonazepam	Ethylene glycol dimethacrylate	methacrylic acid	MeOH	**Slope**=29.66 ± 1.0 mV/decade **Conc. Range**= 1.0×10^{-7} to 1.0×10^{-1} M **Detection Limit**= 7.3×10^{-7}**M** **Response time**= less than 15sec **PH value**= 6	[42]
10	Molecularly Imprinted Polymer of Risperidone	Risperidone	Ethylene glycol dimethacrylate	Acrylic acid and Acrylamide	MeOH	**Slope**=55.2±0.1 and 59.0±0.2 mV/decade **Conc. Range**= 1.0×10^{-6} - 1.0×10^{-2} M and 5.0 x 10^{-7} to 1.0 x 10^{-2} **Response time**= less than 30sec **Life time=** 7and13 weeks **PH range**= 4-8	[43]
11	Molecularly imprinted polymer of Tiemonium methylsulphate	Tiemonium methylsulphate	Divinylbenzene	Acrylamide	CH_3CN	**Slope**= 56.4, 56.1and 57.5 mV/decade **Conc. Range**= 1×10^{-4}-1×10^{-2} M 1×10^{-5}-1×10^{-2} M **Life time**=5 weeks and 65 days **PH range**= 2–7	[44]
12	Molecularly imprinted materials of Amoxicillin	Amoxicillin	Ethylene glycol dimethacrylic acid	Methacrylic acid (MAA), 2-acrylamido-2-methyl-1-propanesulfonic acid (AAMPSO) and vinyl pyridine (VPY)dimethacrylic acid	–	**Slope**= 60.7mV/decade **Detection Limit** =2.9×10^{-5} M **PH range**= 4–5	[45]
13	Molecularly Imprinted Polymers for of Clenbuterol in	Clenbuterol in	Methacrylic acid methyl methacrylate	Trimethylolpropane Trimethacrylate Divinylbenzene 80	MeOH	**Slope**= 55.7 mV/decade **Conc. Range**=1×10^{-7}-1×10^{-4} M **Detection Limit=**7.0×10^{-8}M **Response time =** less than 3 min	[46]
14	Molecular Imprinting Polymer for Metoprolol	Metoprolol	Methacrylic acid	Ethylene glycol dimethacrylate	$CHCl_3$	**Slope**= 55.4 ± 1 mV/decade 1.0×10-1M Conc. Range= 1.0×10^{-6} **Detection Limit**= 7.0×10^{-7} M **Response time**=14sec **Life time**= at least 6 months **PH range**= 3.5-10.5	[47]
15	Molecularly imprinted polymer for of hydroxyzine	Hydroxyzine	Methacrylic	Ethylene glycol dimethacryl	–	**Slope**= 29.4 ± 1.0 mV/decade **Conc. Range**= 2.0×10^{-7}-8.0×10^{-3}M **Detection Limit**= 1.3×10^{-7} M **Response time**= ~15sec **Life time**= more than 5 months	[48]
16	Molecularly Imprinted Polymers for Glibenclamide	Glibenclamide	Ethylene glycol dimethacrylate	acrylic acid and acrylamide	$CHCl_3$	**Slope**= -51.5±0.5and -57.8±0.1 mV/decade **Conc. Range**= 1.0×10^{-4}- 1.0×10^{-2} and 1.0×10^{-5}- 1.0×10^{-3} M **Detection Limit**= 1.0×10^{-4} and 1.0×10^{-5}M **Response time**= less than 30 sec **Life time**= 1 and 6 weeks PH range= 2-4	[49]

17	Sensor for Dimethylamine Assessment Using A Molecularly Imprinted Polymer	Dimethylamine	acrylamide and ethylene glycol dimethacrylate	acrylamide	CH_3CN, CH3COOH, MeOH	**Slope**= 51.3 ± 0.3 and 50.1 ± 0.7mV/decade **Conc. Range**= 5.0×10^{-5} - 1.0×10^{-2} and 8.0×10^{-5} - 1.0×10^{-2}M **Detection Limit**= 4.6×10^{-6} and 1.0×10^{-5}M **Response time**= 10 and 60sec **Life time**= 8 weeks PH range= 2.8-9.7 and 2.8-9.7	[50]
18	Carbon paste electrodes modified by molecularly imprinted polymer as potentiometry sensors	uric acid	ethylene glycol dimethacrylate	methyl methacrylate	–	**Slope**= 30.19mV/decade **Conc. Range**= 10^{-6}-10^{-3}M **Detection Limit**= 3.03×10^{-6} M	[51]

7. Conclusion

Molecular impression may explain how synthetic polymers are used for bio-copied molecular recognition capability for specific templates, where the template shows the way the structural components are directed by a cross-linking agent. It was found that, the molecular imprinting polymer for the drugs are including the nernstain response, a wide range of concentration, low detection limit, good response time, wide range of PH with a suitable life time of ion selective electrodes prepared. That might be due to selecting a suitable solvent and the functional monomers toughly interrelate with a template for polymerization. The solution construction of the resulting assemblages probably described the consequently made binding sides. By steadying the monomer-template assemblages it is probable to raise the number of imprinted places. In addition, it is imperative that the formation of membrane potential amid inner filling solutions and sample do not involve the template to be taken out from the membrane. This is a benefit because removal of the template in order to leave absence recognition places standing for binding is a reason for improbability at the sensitivity limiting factor or determination. Alternative exclusive feature of the potentiometry is that the types do not distribute throughout the membrane, therefore, there is not any size limit for the template composite.

Acknowledgment

The authors would like to appreciate the Al-Nahrain University and University of Anbar for their support.

Disclosure statement

No potential conflict of interest was reported by the authors.

References

[1] Peper, S., & Gonczy, C. (**2011**). Potentiometric Response Characteristics of Membrane-Based Cs. *International Journal of Electrochemistry*, *2011*, 276896.

[2] Janata, J. (**2010**). *Principles of chemical sensors*. Springer Science & Business Media.

[3] Canfarotta, F.,Czulak, J.,Guerreiro, A.,Cruz, A.G.,Piletsky, S.,Bergdahl, G.F.,HedstrÖm, M., & Mattiasson, B., (**2018**). A novel capacitive sensor based on molecularly imprinted nanoparticles as recognition elements. *Biosensors and Bioelectronics*,*120*,108-114.

[4] Takeda, Sh.,Yagi, H.,Mizuguchi, S.,Funahashi, H.,Shiigi, H.,Nagaoka, T.,(**2008**). A Highly Sensitive Amperometric Adenosine Triphosphate Sensor Based on Molecularly Imprinted Overoxidized Polypyrrole. *J. Flow Injection Anal*. *25*(1),77–79.

[5] Drusová, S., Bakx, W., Wexler, A. D., & Offerhaus, H. L. (**2019**). Possibilities for Groundwater Flow Sensing with Fiber Bragg Grating Sensors. *Sensors*, *19*(7), 1730.

[6] Huang, Y., Kormakov, S., He, X., Gao, X., Zheng, X., Liu, Y., ... & Wu, D. (2019). Conductive polymer composites from renewable resources: an overview of preparation, properties, and applications. *Polymers*, *11*(2), 187.

[7] Wloch, M., & Datta, J.,(**2019**). Chapter Two - Synthesis and polymerisation techniques of molecularly imprinted polymers. *Comprehensive Analytical Chemistry*.*86*, 17-40.

[8] Takeuchi T., Sunayama H. (**2014**) *Molecularly Imprinted Polymers. In: Kobayashi S., Müllen K.* (eds) Encyclopedia of Polymeric Nanomaterials. Springer, Berlin, Heidelberg.

[9] Abass, A. M., & Ahmed, A. (**2017**). Synthesis and Application of Trimethoprim Selective Electrodes. *RJLBPCS*, *3*(2), 146-156.

[10] Abass, A. M. (**2017**). Synthesis New Liquid Selective Electrodes of Ciprofloxacin Hydrochloride for Determination Ciprofloxacin in Pure form and Pharmaceuticals Preparation. *Baghdad Science Journal*, *14*(4), 787-792.

[11] Abass, A. M. (**2018**). Preparation and Application of Tetracycline Hydrochloride Liquid membrane Electrodes. *Al-Nahrain Journal of Science*, *21*(2), 73-80.

[12] Gao, R., Kong, X., Wang, X., He, X., Chen, L.,

& Zhang, Y. (**2011**). Preparation and characterization of uniformly sized molecularly imprinted polymers functionalized with core–shell magnetic nanoparticles for the recognition and enrichment of protein. *Journal of Materials Chemistry*, *21*(44), 17863-17871.

[13] Yoshikawa, M., Tharpa, K., & Dima, S. O. (**2016**). Molecularly imprinted membranes: Past, present, and future. *Chemical reviews*, *116*(19), 11500-11528.

[14] Li, S., Ge, Y., Piletsky, S. A., & Lunec, J. (Eds.). (**2012**). *Molecularly imprinted sensors: overview and applications*. Elsevier.

[15] Guo, Z., Florea, A., Jiang, M., Mei, Y., Zhang, W., Zhang, A., ... & Jaffrezic-Renault, N. (**2016**). Molecularly imprinted polymer/metal organic framework based chemical sensors. *Coatings*, *6*(4), 42.

[16] Blanco-López, M. C., Lobo-Castanon, M. J., Miranda-Ordieres, A. J., & Tunon-Blanco, P. (**2004**). Electrochemical sensors based on molecularly imprinted polymers. *TrAC Trends in Analytical Chemistry*, *23*(1), 36-48.

[17] Piletsky, S. A., & Turner, A. P. (**2002**). Electrochemical sensors based on molecularly imprinted polymers. *Electroanalysis: An International Journal Devoted to Fundamental and Practical Aspects of Electroanalysis*, *14*(5), 317-323.

[18] Zhang, H., Yao, R., Wang, N., Liang, R., & Qin, W. (**2018**). Soluble molecularly imprinted polymer-based potentiometric sensor for determination of bisphenol AF. *Analytical chemistry*, *90*(1), 657-662.

[19] Olcer, Y. A., Demirkurt, M., Demir, M. M., & Eroglu, A. E. (**2017**). Development of molecularly imprinted polymers (MIPs) as a solid phase extraction (SPE) sorbent for the determination of ibuprofen in water. *RSC advances*, *7*(50), 31441-31447.

[20] Chen, L., Wang, X., Lu, W., Wu, X., & Li, J. (**2016**). Molecular imprinting: perspectives and applications. *Chemical Society Reviews*, *45*(8), 2137-2211.

[21] Refaat, D., Aggour, M. G., Farghali, A. A., Mahajan, R., Wiklander, J. G., Nicholls, I. A., & Piletsky, S. A. (**2019**). Strategies for Molecular Imprinting and the Evolution of MIP Nanoparticles as Plastic Antibodies-Synthesis and Applications. *International Journal of Molecular Sciences*, *20*(24), 6304.

[22] Boysen, R. I., Schwarz, L. J., Nicolau, D. V., & Hearn, M. T. (**2017**). Molecularly imprinted polymer membranes and thin films for the separation and sensing of biomacromolecules. *Journal of separation science*, *40*(1), 314-335.

[23] Gärtner, C., Ungerböck, B., Schulz, I., Jahn, T., Mosig, A., Mayr, T., & Becker, H. (**2015**, May). Sensor enhanced microfluidic devices for cell based assays and organs on chip. In *Smart Biomedical and Physiological Sensor Technology XII* (Vol. 9487, p. 948704). International Society for Optics and Photonics.

[24] Correia, R., James, S., Lee, S. W., Morgan, S. P., & Korposh, S. (**2018**). Biomedical application of optical fibre sensors. *Journal of Optics*, *20*(7), 073003.

[25] Giouroudi, I., & Hristoforou, E. (**2018**). Perspective: Magnetoresistive sensors for biomedicine. *Journal of Applied Physics*, *124*(3), 030902.

[26] Cinti, S., Moscone, D., & Arduini, F. (**2019**). Preparation of paper-based devices for reagentless electrochemical (bio) sensor strips. *Nature protocols*, *14*(8), 2437-2451.

[27] Zaidi, S. A. (**2020**). Molecular imprinting: A useful approach for drug delivery. *Materials Science for Energy Technologies*, *3*, 72-77.

[28] Kamel, A. H., Mohammad, S. G., Awwad, N. S., & Mohammed, Y. Y. (**2019**). Survey on the Integration of Molecularly Imprinted Polymers as Artificial Receptors in Potentiometric Transducers for pharmaceutical Drugs. *Int. J. Electrochem. Sci*, *14*, 2085-2124.

[29] Ahmad, O. S., Bedwell, T. S., Esen, C., Garcia-Cruz, A., & Piletsky, S. A. (**2019**). Molecularly imprinted polymers in electrochemical and optical sensors. *Trends in biotechnology*, *37*(3), 294-309.

[30] Moro, G., Cristofori, D., Bottari, F., Cattaruzza, E., De Wael, K., & Moretto, L. M. (**2019**). Redesigning an Electrochemical MIP Sensor for PFOS: Practicalities and Pitfalls. *Sensors*, *19*(20), 4433.

[31] Adumitrăchioaie, A., Tertiș, M., Cernat, A., Săndulescu, R., & Cristea, C. (**2018**). Electrochemical methods based on molecularly imprinted polymers for drug detection. A review. *Int. J. Electrochem. Sci*, *13*, 2556-2576.

[32] Mahmoudi S., Rashedi H.,Faridbod F.,(**2018**). A Molecularly Imprinted Polymer (MIP)-based Biomimetic Potentiometric sensing device for the analysis of Clarithromycin. *Anal. Bioanal. Electrochem.*,*10*(12), 1654-1667.

[33] Selvolini, G., & Marrazza, G. (**2017**). MIP-based sensors: Promising new tools for cancer biomarker determination. *Sensors*, *17*(4), 718.

[34] Al-Mustafa, J. I., Abu-Dalo, M. A., & Nassory, N. S. (**2014**). Liquid selective electrodes for dextromethorphan hydrobromide based on a molecularly imprinted polymer in PVC matrix membrane. *Int. J. Electrochem. Sci*, *9*(1), 292-303.

[35] Rebelo, T. S., Almeida, S. A., Guerreiro, J. R. L., Montenegro, M. C. B., & Sales, M. G. F. (**2011**). Trimethoprim-selective electrodes with molecularly imprinted polymers acting as ionophores and potentiometric transduction on graphite solid-contact. *Microchemical*

Journal, *98*(1), 21-28.

[36] Arvand, M., & Hashemi, M.,(**2012**). Synthesis by Precipitation Polymerization of a Molecularly Imprinted Polymer Membrane for the Potentiometric Determination of Sertraline in Tablets and Biological Fluids. *J. Braz. Chem. Soc*.,*23*(3), 392-402.

[37] Oliveira, H. M., Moreira, F. T., & Sales, M. G. F. (**2011**). Ciprofloxacin-imprinted polymeric receptors as ionophores for potentiometric transduction. *Electrochimica Acta*, *56*(5), 2017-2023.

[38] Bangaleh, Z., Sadeghi, H.B., Ebrahimi, S.A., &Najafizadeh, P., (**2019**). A New Potentiometric Sensor for Determination and Screening Phenylalanine in Blood Serum Based on Molecularly Imprinted Polymer. *Iranian Journal of Pharmaceutical Research 18*(1), 61-71.

[39] Biñas, F. G., & Sevilla, F. (**2014**). Molecularly imprinted potentiometric sensor for surfactant based on electrosynthesized polyaniline. *Acta Manilana*, *62*, 61-67.

[40] Radi, A. E., Wahdan, T., & El-Basiony, A. (**2019**). Electrochemical Sensors Based on Molecularly Imprinted Polymers for Pharmaceuticals Analysis. *Current Analytical Chemistry*, *15*(3), 219-239.

[41] Mirzajani, R., & Arefiyan, E. (**2019**). Construction and Evaluation of a Graphene Oxide Functionalized Aminopropyltriethoxy Silane Surface Molecularly Imprinted Polymer Potentiometric Sensor for Dipyridamole Detection in Urine and Pharmaceutical Samples. *Journal of the Brazilian Chemical Society*, *30*(9), 1874-1886.

[42] Babanejad, M ., Tehrani, M. S., Mafakheri, M., & Sardari, S.,(**2016**). Potentiometric Determination of Clonazepam Using Carbon Paste Electrode Based on Molecular Imprinted Polymer (MIP) in Solution and in a Biological Fluid Model. *Pharm Anal Acta* , 7(*7*), 2.

[43] Abdulla, N. I., & Yaseen, H. M. (**2015**). Potentiometric Transducers for the Selective Recognition of Risperidone Based on Molecularly Imprinted Polymer. *Iraqi Journal of Pharmaceutical Sciences*, *24*(2), 30-40.

[44] Hussein, L. A. (**2017**). Application of membrane-selective electrodes for the determination of Tiemonium methylsulphate. *Bulletin of Faculty of Pharmacy, Cairo University*, *55*(1), 141-146.

[45] Guerreiro, J. R. L., Sales, M. G. F., Moreira, F. T., & Rebelo, T. S. (**2011**). Selective recognition in potentiometric transduction of amoxicillin by molecularly imprinted materials. *European Food Research and Technology*, *232*(1), 39-50.

[46] Rong-Ning, L., Qi, G., & Wei,Q.,(**2012**). Potentiometric Sensor Based on Molecularly Imprinted Polymers for Rapid Determination of Clenbuterol in Pig Urine. *Chin J Anal Chem.40* (3),354–358.

[47] Tehrani, M.S., Vardini, M.T., Azar, P.A., & Husain, S.W.,(**2010**). Molecularly Imprinted Polymer Based PVC-Membrane-Coated Graphite Electrode for the Determination of Metoprolol.Int. *J. Electrochem. Sci.,5* , 88 – 104.

[48] Javanbakht, M., Fard, S. E., Mohammadi, A., Abdouss, M., Ganjali, M. R., Norouzi, P., & Safaraliee, L. (**2008**). Molecularly imprinted polymer based potentiometric sensor for the determination of hydroxyzine in tablets and biological fluids. *Analytica chimica acta*, *612*(1), 65-74.

[49] Yassen, H. M., & Abdulla, N. I. (**2016**). PVC Polymeric Membranes Coated Graphite Electrodes Based on Molecularly Imprinted Polymers for the Selective Determination of Glibenclamide. *Ibn AL-Haitham Journal For Pure and Applied Science*, *29*(1), 133-149.

[50] SM Hassan, S., Amr, E., El-Galil, A., Abd El-Naby, H., A Al-Omar, M., H Kamel, A., & Khalifa, N. M. (**2019**). Potentiometric PVC-Membrane-Based Sensor for Dimethylamine Assessment Using A Molecularly Imprinted Polymer as A Sensory Recognition Element. *Polymers*, *11*(10), 1695.

[51] Darmokoesoemo H., N. Widayanti N., Khasanah M., Kusuma H.S.,(**2017**). Analysis of Uric Acid using carbon paste electrodes modified by molecularly imprinted polymer as potentiometry sensor.*RASÀYAN J.Chem.10*(1), 54-58.

How to cite this manuscript: Amina M. Abass, Jamal M. Rzaij, A Review on: Molecularly Imprinting Polymers by Ion Selective Electrodes for Determination Drugs, *Journal of Chemical Reviews*, **2020**, 2(3), 148-156.