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1. Introduction

1-1. History of ion selective electrodes : -

Progress in ion-selective electrodes (ISE) development has occurred rapidly in the past 40 years, with promising innovations still on the horizon [1].

During the period (1900-1930), four aspects of electrochemistry arose, grew, and matured. First the design of electrodes (half cell), of the zeroeth (inert metal|redox couple), first ($M|M^+$), second (M|MX|X), and third orders ($M|MX|NX|N^+$) were explored. (M is metal, M^+ and N^+ are cations, X represents anions, and MX and NX are barely soluble salts of the respective cations and anions). Second, the use of these cells without electrolyte junctions to calculate thermodynamic properties captured the interest of scientists.

The third topic was perturbation of cell with small current. Transport studies were formulated using dc or ac through regions of uniform electrolyte, which were well isolated from the working electrodes, and transfer numbers were determined. The fourth and most important electrochemical lesson learned was connection between the space charge, and capacitance of the phase boundary between solid conductors and electrolyte solutions [2].

The history starts with the observations of Cremer[3] in 1906 and the more detailed investigations of Haber and Klemensiewicz[4], which showed that a hydrogen ion-sensing glass electrode responded to hydrogen ions according to the Nernst equation.

The first attempts to make ion-selective electrodes in the 1930s that from materials other than glass were made by Tendeloo et al. [5-7]. In 1934 Lengyel and Blum[8] showed that an electrode made from a glass containing Al_2O_3 or B_2O_3 could give a Nernstain response to sodium ions.

In 1937 Kolthoff and Sanders[7] made the first silver halide disk electrodes.

In 1949, Perley[9] published an article on the relationship of glass composition to pH function. In the late 1950s Tendeloo and Krips[10,11] produce a calcium-sensing electrode from a membrane of paraffin impregnated with calcium oxalate. Ross and Frant[12] of Orion Researchers founding fathers of ion-selective electrodes. The calcium and fluoride ion selective electrodes are developed in the mid 1960 and the big bang that started a new era in potentiometric analysis. The silver and halide ion-selective electrodes became commercially available in Hungary in 1960s[13].

The idea to incorporate all membrane ingredients into a PVC matrix and control site density came from the work of Bloch and Shatkay in 1967 [14]. The most important procedure for compounding , casting, drying and mounting PVC sensor membranes was developed by Thomas and Moody in 1970 [15].

The newly formed Orion Research Inc was producing calcium electrodes for use in blood gas analyzers. Since then numerous probes have been developed for the analysis of samples containing many different ions[9].

1-2. *Principle of ion-selective electrode (ISE):-*

An electrochemical sensor, based on a thin selective membrane or film as recognition element and is an electrochemical half-cell equivalent to other half-cells of the zeroth (inert metal in a redox electrolyte)[16]. Ion selective electrodes (ISE) are membrane electrodes that respond selectivity to ions in the presence of other. These include probes that measure specific ions and gasses in solution. The most commonly used

ISE is the pH probe. Other ions that can be measured include elements (Fluoride, Bromide, Cadmium, and Cupric to name a few) and gasses in solution such as ammonia, carbon dioxide, nitrogen oxide, and oxygen[17]. The potential difference response(i.e., that of ISE versus outer reference electrode potentials) as its principal component, of the Gibbs energy change associated with perm-selective mass transfer of ions (e.g., by ion-exchange, solvent extraction or some other mechanism) across a phase boundary. The ISE must be used in conjuction with reference electrode (i.e., "outer" or "external" reference electrode) to form a complete electrochemical cell. The measured potential differences (ISE versus outer reference electrode potentials) are linearity dependent on the logarithm of activity of a given ion in solution[16].

Ion selective electrodes are used in industry, process control, physiological measurements, environmental monitoring, biochemical research, and biophysical research, where measurements of ionic concentration in an aqueous solution are required, usually on a real time basis[18]. The term "ion-specific electrode" is not recommended. The term "specific" implies that the electrode does not respond to additional ions. Since no electrode is truly specific for one ion, the term "ion-selective" is recommended as more appropriate. "selective ion-sensitive electrode" is rarely used term to describe an ion-selective electrode. "Principal" or "primary" ions are those for determination of which an electrode is designed. It is certain that the ISE is more sensitive to the "principal" ion than to interferences, e.g., nitrate ISEs[16].

1-2-1. *Classification of ion-selective membranes:*

There are four types of ion-selective membranes used in ion-selective electrodes[19]:

1-2-1-1. Glass membranes:

Glass membranes are made from an ion-exchange type of glass (silicate of chalcogenide). This type of ISE has good selectivity, but only for several single-charged cations; mainly H^+, Na^+, and Ag^+. Chalcogenide glass also has selectivity for double-charged metal ions, such as Pb^{2+}, and Cd^{2+}. The glass membrane has excellent chemical durability and can work in very aggressive media. A very common example of this type of electrode is the pH glass electrode.

1-2-1-2. Crystalline membranes:

Crystalline membranes are made from mono- or polycrystallites of a single substance. They have good selectivity, because only ions which can introduce themselves into the crystal structure can interfere with the electrode response. Selectivity of crystalline membranes can be for both cation and anion of the membrane-forming substance such as LaF_3 for F^-.

1-2-1-3.PVC-Membrane electrode:

The considerable interest in ion-selective electrode boosted the development of liquid ion-exchanger membrane and soon led to a new range of PVC matrix membrane electrodes. This kind of membrane is usually supported PVC matrix containing the ion exchanger dissolved in a suitable solvent mediator[20]. Plasticizers lower the glass transition temperature of PVC and produce homogenous and flexible films with good mechanical stability[21].

A general 'rule' of thumb is that PVC-based polymer membranes for potentiometric sensors should contain about 70% by weight plasticizer and 30% PVC. The amount of ionophore needed is only about 1% and is included in the amount of plasticizer [15].

The main component of electroactive membrane is neutral or charged compounds, which is able to complex ions reversibly and to transfer them

through an organic membrane by carrier translocation. This compound is called as an ionophore or an ion carrier. There are two kinds of ionophores : charged one and neutral carriers. They are mobile in both free and complex forms, so the mobility of all species are part of the selectivity coefficient together with ion-exchange equilibrium. The mobile binding sites are dissolved in a suitable solvent and usually trapped in a matrix of organic polymer (gel)[22].

An appropriate plasticizer is added to a membrane in order to ensure the mobility of the free and complex ionophore. It determines the membrane polarity and provides suitable mechanical properties of membrane. Although other polymers like: polisiloxane, polystyrene, polyamide or polyimide can be used a membrane matrix, PVC is the most widely used matrix due to simplicity of membrane preparation. Examples of such ion-selective electrodes(ISEs) are Ca^{2+} and NO_3^- [23-25].

The choice of plasticizers according to these influences the response, slope, curve linearity, and selectivity of PVC membrane electrodes[26]. The solvent mediator used to dissolve the ion-exchange sensor plays supplementary roles[27] by adjusting:

- Ultimate relative permittivity of the final organic phase.
- Mobility of the ion-exchange sites according to the viscosity of the mediator.
- Site density by variation of the concentration of the ion exchanger[28,29] .

These adjustments can influence the extent of synergistic enhancement of the partition coefficient for the ion with consequent effect on electrode selectivity[30].

1-2-1-4. Enzyme electrodes:

Enzyme electrodes definitely are not true ion-selective electrodes but usually are considered within the ion-specific electrode topic. Such an electrode has a "double reaction" mechanism – an enzyme reacts with a specific substance, and the product of this reaction (usually ammonia or carbon dioxide) is detected by a true ion-selective electrode, such as a pH-selective electrodes. All these reactions occur inside a special membrane which covers the true ion-selective electrode, which is why enzyme electrodes sometimes are considered as ion-selective. An example is glucose selective electrodes[19].

1-2-2. Reference electrodes :

In order to measure the change in potential difference across the ion-selective membrane as the ionic concentration changes, it is necessary to include in the circuit a stable reference voltage which acts as a half-cell from which to measure the relative deviations[31].

1- The most common and simplest reference system is the Ag / AgCl and Hg/ Hg_2Cl_2 single junction reference electrodes. The Ag/ AgCl single junction reference electrode generally consists of a cylindrical glass tube containing a 4 M solution of KCl saturated with AgCl. The lower end is sealed with a porous ceramic frit which allows the slow passage of the internal filling solution and forms the liquid junction with the external test solution. Dipping into the filling solution is a silver wire coated with a layer of silver chloride (it is chloridised) which is joined to a low-noise cable which connects to the measuring system.

In electrochemical terms, the half-cell can be represented by:

$Ag / AgCl_{(Satd)}, KCL_{(Satd)}$

and the electrode reaction is:

$AgCl\ (s) + e^- = Ag\ (s) + Cl^-$

The electrode potential for this half-cell is + 0.2046 V relative to the Standard Hydrogen Electrode at 25°C

2- One problem with reference electrodes is that, in order to ensure a stable voltage, it is necessary to maintain a steady flow of electrolyte through the porous frit. Thus there is a gradual contamination of the test solution with electrolyte ions. This can cause problems when trying to measure low levels of K^+, Cl^-, or Ag^+, or when using other ISEs with which these elements may cause interference problem. In order to overcome this difficulty the double junction reference electrode was developed. In this case the silver / silver chloride cell described above forms the inner element and this is inserted into an outer tube containing a different electrolyte which is then in contact with the outer test solution through a second porous frit. The outer filling solution is said to form a "salt bridge" between the inner reference system and the test solution and is chosen so that it does not contaminate the test solution with any ions which would effect the analysis.

Commonly used outer filling solutions are:

potassium nitrate - for Br, Cd, Cl, Cu, CN, I, Pb, Hg, Ag, S, SCN.

sodium chloride - for K,

ammonium sulphate - for $N0_3$,

magnesium sulphate - for NH_4,

Note that double junction reference electrodes are named after their outer filling solutions.

One disadvantage with double junction reference electrodes is that they introduce an extra interface between two electrolytes and thus give the opportunity for an extra liquid junction potential to develope.

1-2-3. Cell design of ion-selective electrode:

An ion-selective electrode in conjunction with a reference electrode is an ion-selective electrode cell. Generally, the cell contains two reference electrodes, "internal" and "external", and a selective thin film or membrane as the recognition/ transduction element. However, besides this conventional type of the cell with solution contact on both sides of the membrane there are ISE cell arrangements with wire contact to one side of the membrane (all solid state and coated wire types)[16].
Conventional notation of the cell is:

Outer ref. electrode | test solution| membrane| internal ref. electrode

The PVC membrane electrode cell is similar to the above cell of ISE. The potential of the electrode is registered with respect to reference electrode such as saturated calomel electrode (SCE). The cell [32] consists of:

Ag/AgCl| internal filling solution | ion-selective membrane| sample solution | KCl (sat.), Hg_2Cl_2, Hg

Cell design according to the basic rule of designing of electrolytical cells, with a condition that the current passed through the electrolytical cell equals zero, as showed in figure (1-1) [33] .

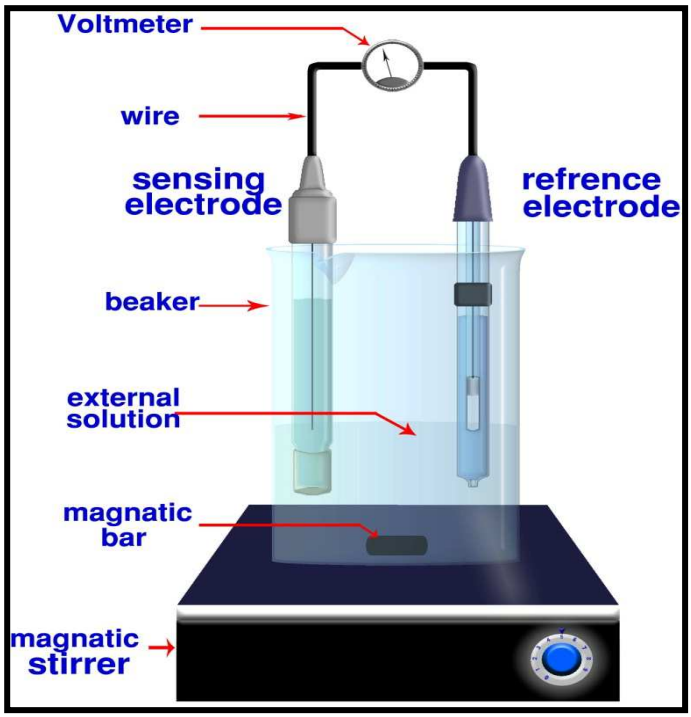
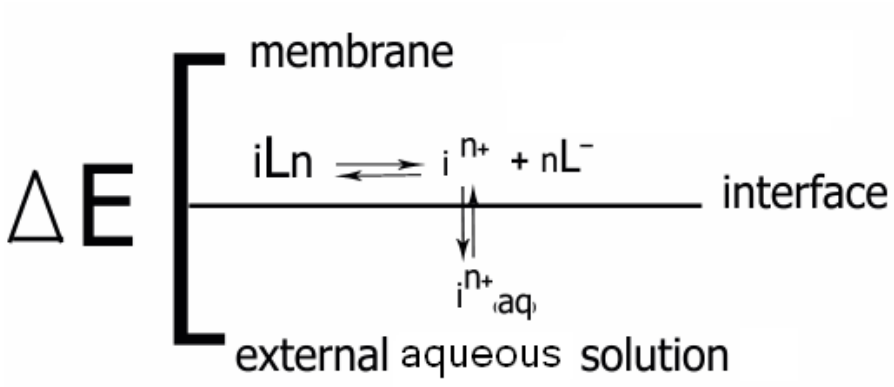


Figure (1-1): Basic component of ion-selective electrode cell

The exchange that happened between the internal and external solution across the membrane depends on ionic exchange and the active ionophore which used in the membrane. The mechanism below shows the ionic exchange process to a cation through a membrane[34]:



1-2-4. Membrane of ion-selective electrode (ISE):

This general term refers to a continuous layer, usually consisting of a semi-permeable (solid or liquid) material, with controlled permeability. The membrane separate the internal components of the ion-selective electrode(ISE) from the test solution. It covers solid electric conductor, such as carbon or an inert metal, or separate two electrolyte solutions. This latter case is the most typical for an ISE. The membrane of an ion selective electrode is responsible for the e.m.f. response and selectivity of the ISE.

Membranes of sensor electrodes are thought to be practically homogeneous, but an actual membrane may contain inhomogeneous regions, often at surfaces, depending on the materials and preparation methods used. Inhomogeneous regions may include polymer regions with low and high local density of charged sites. Surface regions of plasticized liquid membranes often are low in charged sites and high in plasticizer or exuded impurities [16].

1-2-4-1.Liquid Junction Potentials.

It must be noted that the standard voltage given by a reference electrode is only correct if there is no additional voltage supplied by a liquid junction potential formed at the porous plug between the filling solution and the external test solution. Liquid junction potentials can appear whenever two different electrolytes come into contact. At this junction, a potential difference will develope as a result of the tendency of the smaller and faster ions to move across the boundary more quickly than those of lower mobility. These potentials are difficult to reproduce, tend to be unstable, and are seldom known with any accuracy; so steps must be taken to minimize them. Using 4 M KCl as the inner filling solution has the advantage that the K^+ and Cl^- ions have nearly equal

mobility and hence form an equi-transferrent solution. Also, in the single junction electrodes, the electrolyte concentration is much higher than that of the sample solution thus ensuring that the major portion of the current is carried by these ions. A third factor in minimizing the junction potential is the fact that there is a small but constant flow of electrolyte out from the electrode thus inhibiting any back-diffusion of sample ions - although this is less important with modern gel electrolytes[31].

1-2-4-2. *Membrane potential* [35] :

Potentiometry is the field of electroanalytical chemistry in which potential is measured under the conditions of no current flow. The measured potential may then be used to determine the analytical quantity of interest, generally the concentration of some component of the analyte solution.

Membrane potential developes across a membrane which is permeable to ions. Ion-selective membranes are here of particular interest; these membrane are permeable only to one kind of ions.
In this case[36]:

$$E_A = K - [RT/(Z_iF)] \ln a_{i,A} \qquad (1\text{-}1)$$

$$E_B = K - [RT/(Z_iF)] \ln a_{i,B} \qquad (1\text{-}2)$$

$$\Delta E = [RT/(Z_iF)] \ln (a_{i,A} / a_{i,B}) \qquad (1\text{-}3)$$

- Where : Z_i is charge of the ion, $\mathbf{a_{i,A}}$ and $\mathbf{a_{i,B}}$ are activities of the ion (i), on both sides (A,B) of the membrane, K is constant, (RT/ZF) is the ***Nernst*** factor with a value of 59.16 mV at 25^oC for monovalent ion.

Physical phenomena which do not involve explicit redox reactions, but whose initial conditions have a non-zero free energy, also will generate a potential. An example of this would be ion concentration gradients across a semi-permeable membrane. This can also be a potentiometric phenomena, and is the basis of measurements that use ***ion-selective electrodes.***

$$\mathbf{E_{mem.} = (constant\ ) - [RT/(Z_iF)]\ ln\ (a_i)} \qquad \mathbf{(1\text{-}4)}$$

Electrode membranes have the property of rapidly establishing ion-exchange equilibrium across the membrane/solution interface. Conducting through the membrane may be ionic and /or electronic process [35].

Membrane potential may be regarded as combinations of interfacial potential terms with inter diffusional terms arising from the different mobilities of the ion in the membrane. Practically, the membrane potential is obtained from the measurement of the electromotive force of a complete electrochemical cell.

The response of ISE, E, to determine certain ion (X) is represented by the ***Nernst*** equation which gives the electromotive force of the cell [37]

$$\mathbf{E = Constant \pm 2.303\ (RT/zF)\ log\ a_x} \qquad \mathbf{(1\text{-}5)}$$

Where

- E is the potential developed by the cell.

  The constant term depends on the junction potentials of the cell except that of membrane, the standard potential corresponding to E_M and the reference electrode system used including the liquid-liquid junction potential E_J.
- 2.303 (RT/ZF) is the ***Nernst*** factor with a value of 59.16 mV at 25^oC for monovalent ion.

- a_X is the activity of the ion X in the sample solution.
- z is the ion charge including sign format being positive for cation and negative for anion.

It is clear that the functional potential of any ISE depends on a number of factors including potential activity, responses selectivity in the presence of various interferants, operative pH range, response time, temperature and operative life. The ideal membrane would sense one species only. All made up membranes are not ideal showing only a higher selectivity toward one ion over the other [37].

For ion-selective electrodes, the membrane internal diffusion potential is zero if no ion concentration gradients occur. This is often the case for membrane that shows a Nernstian response. For the sake of simplicity, diffusion potential are treated as secondary effects, in other cases are neglected, therefore it can be postulated

$$\mathbf{E_M = E_{Const} + E_{PB}} \qquad \mathbf{(1\text{-}6)}$$

Where E_{PB} is the phase boundary potential at the membrane-sample interface, which can be derived from basic thermodynamical considerations.

As shown in figure (1-2); a classification of such selective legands based on their charge type. Since the widely used uncharged carriers are neutral when uncomplexed and the complexes have the same charge as the analyte ion, the respective membrane require the additional incorporation of lipophilic ions of the opposite charge to ensure premselectivity .

Since poly (vinyl chloride) as membrane matrix already contains ionic impurities with cation-exchanger properties, neutral carrier-based cation-selective membranes are usually functional without the incorporation of anionic sites [38]. However, their selectivity and lifetime behavior is often not optimal. To a second important group of ionophores belong

compounds that are electrically charged when uncomplexed and neutral when it legated to the analyte ion (figure 1-2); with charged carriers perm-selectivity can be achieved without the incorporation of additional ionic sites[39].

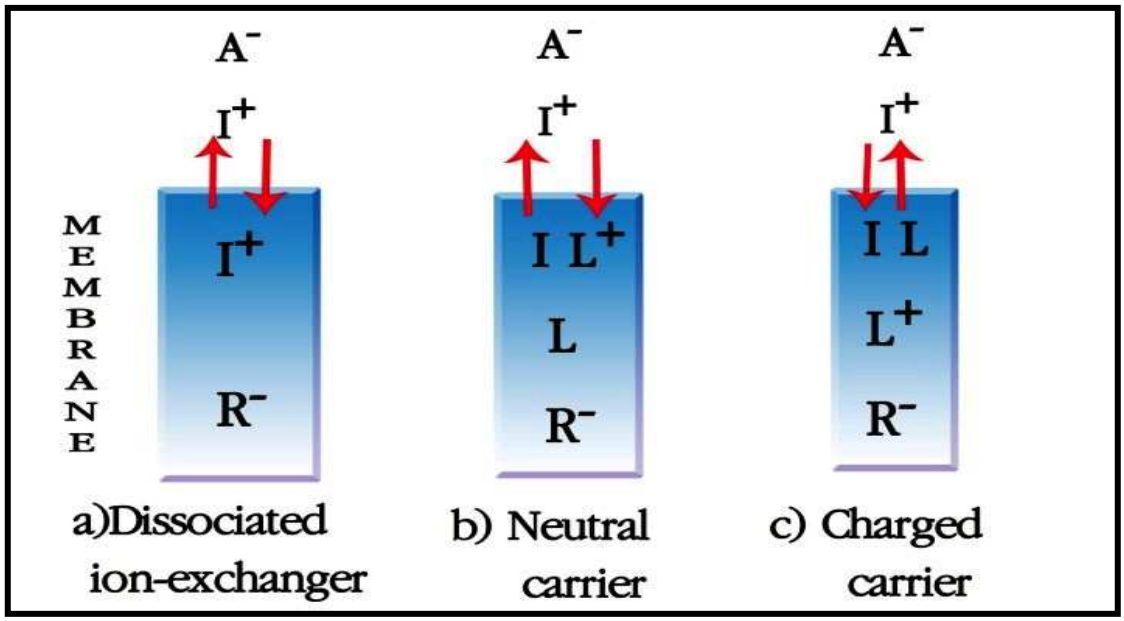


Figure (1-2): Classification of ion-selective membrane (for cationic analyses).

1-2-5. Selectivity of an ISEs

Selectivity is the one of the most important characteristics of an electrode[22]. No ion-selective electrodes are completely ion-specific; all are sensitive to other ions having similar physical properties, to an extent which depends on the degree of similarity[19]. The electrode may actually be much more sensitive to the interfering ion than to the desired ion and that affects on the measured potential of the cell when interfering ions are founding in the test sample[40].

The degree of selectivity of the electrode for the primary ion, A, with respect to an interferent, B, is expressed by the potentiometric selectivity coefficient according to the Nicolsky-Eisenman equation as[41]

$$E=E^{0}+[RT/(Z_A F)]\ln[a_A+\sum K_{A,B}(a_B)^{ZA/ZB}] \quad (1\text{-}7)$$

Where z_A and z_B are the charges of ion A and B, respectively.

E^o is the standard potential of the electrode.

This selectivity coefficient can be determined using either separate solutions or match solutions method, containing both the analyte A, and the interfering B ions [42].

1. ***Separate solution methods:***

When ($a_A = a_B$)

The potential of a cell comprising an ion-selective electrode and a reference electrode is measured with two separate solutions, one containing the ion A at the activity a_A (but no B), the other one containing the ion B at the same activity $a_A=a_B$ (but no A). when measured values of E_A and E_B, respectively, the value of $K_{A,B}$ is calculated by the equation[43]:

$$\text{Log } K_{A,B}=[(E_B-E_A)\,Z_A F/(RT)\ln 10]+(1-Z_A/Z_B)\log a_A \quad (1\text{-}8)$$

Which is equivalent to

$$K_{A,B}^{pot} = a_A^{(1-Z_A/Z_B)}\, e^{(E_B-E_A)\,Z_A F/(RT)} \quad (1\text{-}9)$$

When ($E_A = E_B$)

Therefore, the potential of an ISE for the primary and interfering ions are obtained independently. Then, the activities that correspond to the same electrode potential value are used to determine the $K_{A,B}$ value and it equal:

$$K_{A,B}^{pot.} = \frac{a_A}{a_B^{(z_A/z_B)}} \quad (1\text{-}10)$$

2. Match solutions methods:

The match potential method was first proposed in 1984 by Gadzekpo and Christian[44] as a practical and empirical method being independent of the Nickolsky- Eisenman equation.

In this method , the potentiometric selectivity coefficient is defined as the activity ratio of the primary and interfering ions that give the same potential change under identical conditions. At first, a known activity (a_A`) of the primary ion solution is added into a reference solution that contains a fixed activity (a_A) of primary ions, and the corresponding potential change (ΔE) is recorded next, a solution of an interfering ion is added to the reference solution until the same potential change (ΔE) is recorded. The change in potential produced at the constant background of the primary ion must be the same in both cases.

$$K_{A,B} = (a_A` - a_A)/a_B \qquad (1\text{-}11)$$

Where a_A is initial back ground activity of ion A; and a_B is activity of ion B.

The matched potential method, MPM, was recommended in 1995 by IUPAC [45] .The procedure was expected to report selectivity coefficients relevant for practical applications. The characteristics of the MPM are

1.The charge number of the primary and interfering ions does not need to be taken into account.

2. Contrast to the SSM and FIM.

Nernstian portions of the responses of the primary or interfering ions are not required. These characteristic features lead to the this advantages:

1. The power-term problem for ions with unequal charge disappears.
2. This method is widely applicable, even to non-Nernstian interfering ions.

Such advantages of the MPM allow delivering analytically more meaningful results than those obtained by the two methods, SSM and FIM.

3.Mixed solution methods: They are common and rapid methods, and $K_{A,B}$ can be evaluated by[43] :

3-1 *Fixed interference method (FIM):* The electromotive force (e.m.f) of a cell comprising an ion-selective electrode and a reference electrode (ISE cell) is measured for solutions of constant activity of the interfering ion; a_B, and varying activity of the primary ion, a_A . The e.m.f. values obtained are plotted vs. the logarithm of the activity of the primary ion. The intersection of the extrapolated linear portions of this plot indicates the value of a_A that is to be used to calculate $K_{A,B}$ from the equation(1-10) where both Z_A and Z_B have the same signs, positive or negative.

3-2. *Fixed primary ion method (FPM):* The e.m.f of the cell comprising an a ion-selective electrode and reference electrode (ISE cell) is measured for solutions of constant activity of the primary ion, a_A and a varying activity of the interfering ion, a_B. The e.m.f. values obtained are plotted vs. the logarithm of the activity of the interfering ion. The intersection of the extrapolated linear portions of this plot indicates the value of a_B that is to be used to calculate $K_{A,B}$ from the equation(1-10).

1-2-6.*Characterization of an ISEs:*

The properties of an ion-selective electrode are characterized by parameters like:

***1-2-6-1.Slope*:** The slope is the linear part of the measurement calibration curve of the electrode. The theoretical value according to the

Nernst equation is: 59.16 [mV/log (ax)] at 298K for a single charge ion or 59.16/2 = 29.58 [mV/decade] (25-30 [mV per decade] for double charged ion)[21]. Measured slopes generally lie in the rang 59±5 for single charge ion and 29±3 for double charge ion however, in certain applications the value of the electrode slope is not critical and its value dose not exclude its usefulness. The slope of an electrode can be determined by measuring the mV response in two standard solutions with concentrations (activity) a_1 and a_2 (drawn calibration graph of mV (E) against the log of concentration)[46].

1-2-6-2.Detection limit: According to the IUPAC recommendation the detection limit is, that concentration at which the measured potential differs from that predicted by the linear regression by more than $\Delta E = 18/n$ mV (where n is charge of ion)[46].The detection limit is defined by the cross-section of the two extrapolated linear parts of the ion-selective calibration curve. In practice, detection limit on the order of 10^{-4}-10^{-6}M is reported for most of ion selective electrodes. The observed detection limit is often governed by the presence of other interfering ions or impurities [47].

1-2-6-3.Range of linear response: The measuring range of ISEs is defined as the activity ratio of upper and lower detection limit and approximately corresponds to the Nernst equation[48]. Or simply, at the part of the calibration curve , through which a linear regression would demonstrate that the data point does not deviate from linearity by more ±2 mV[46].

1-2-6-4.Response time and stability: The response time is a very important characteristic of ISEs. It is defined by IUPAC recommendations as the time taken for the potential of the cell containing the electrode to reach a value ±1mV for the final equilibrium potential

after a supposedly instantaneous change in determined activity[49],electrode response varies according to the electrode type. Generally electrodes with liquid ion-exchanger membrane have longer response time than solid membrane electrode[50]. interfering usually increase response time and the "poisoning" of the electrode by various non ionic materials also increase the response time[51,52]. The factors which influence the response time include type of membrane, (concentration change, total volume of the test solution, rate of stirring, temperature, interfering species), the stability and reproducibility of electrode depend practically, on the same factors as the response time.

1-2-7. General applications of ISEs:

Ion-selective electrodes are used in a wide variety of applications for determining the concentrations of various ions in aqueous solutions. The following is a list of some of the main are as in which ISEs have been used[53].

1- Pollution Monitoring: CN^-, F^-, S^{2-}, Cl^-, NO_3^- etc., in effluents, and natural waters
2- Agriculture: NO_3^-, Cl^-, NH_4^+, K^+, Ca^{2+}, I^-, CN^- in soils, plant material, fertilisers and feedstuffs.
3- Food Processing: NO_3^-, NO_2^- in meat preservatives.
4- Salt content of meat, fish, dairy products, fruit juices, brewing solutions.
5- F^- in drinking water and other drinks.
6- Ca^{2+} in dairy products and beer.
7- K^+ in fruit juices and wine making.
8- Corrosive effect of NO_3^- in canned foods.
9- Detergent Manufacture: Ca^{2+}, Ba^{2+}, F^- for studying effects on water quality.

10- Paper Manufacture: S^{-2} and Cl^- in pulping and recovery-cycle liquors.

11- Explosives: F^-, Cl^-, NO_3^- in explosive materials and combustion products.

12- Electroplating: F^- and Cl^- in etching baths; S in anodizing baths.

13- Biomedical Laboratories: Ca^{2+}, K^+, Cl^- in body fluids (blood,plasma, serum, sweat).

14- F^- in skeletal and dental studies.

1-2-8. Potential techniques:

Many potential techniques based on ion selective electrodes have been described[54]. The characterization of ion-selective electrodes for a particular application has been based on the study of many parameters such as the composition of the samples, the required precision and accuracy and the time available to perform such analysis. The most important and widely used techniques for such studies are ; direct, standard and titration methods [55].

1-2-8-1. Direct method: is the simplest, and most widely used methods of obtaining quantitative results using ion selective electrodes[56]. After preparation a calibration curve with standard activities or concentrations, the ion selective electrode and reference electrode can be placed in the sample solution and measuring the (e.m.f) of an electrode chemically. The direct potentiometry is the most straight forward technique and it is usually extremely rapid enabling measurements to be completed in just two or three minutes[55]. This method is suitable for the analyses of all samples in which the analyte of interest is present in the free uncomplexed states[21].

1-2-8-2. Standard addition method:

1-2-8-2 a. Standard addition (single point):

This method is generally more accurate than direct method for concentration measuring in the sample, but it is more time-consuming because of the calibration involved[56].The electrode potential of a known volume of unknown concentration solution is measured[21]. A small volume of a known concentration solution is added to the first volume and the electrode potential re-measured, from which the potential difference (ΔE) is found. By solving the following equation the unknown concentration can be obtained:[56]

$$C_U = C_s / 10^{\Delta E/S} [1+ V_U/V_S] - (V_U /V_S) \qquad (1\text{-}12)$$

Where :

C_U: the concentration of unknown solution

C_S: the concentration of standard solution

V_U: the volume of unknown solution

V_S: the volume of standard solution

S: the slope of electrode

1-2-8-2 b. Multiple standard addition:

In this method several addition of standard solution to the same sample to be measured in order to increase the accuracy and decreases the errors. It is an extension of standard method. The response of ion-selective electrode to certain analyte A in solution free from interfering ions can be represented by Nernstain equation

$$E = E^0 + S \log (c+ x V_S/V_U) \qquad (1\text{-}13)$$

Where:

S :slope

V_S: volume of added standard

V_U: volume of unknown

C: concentration of unknown

X: concentration of added standard

X is usually set to be hundred times more concentrated than C. Rearranging of equation and taking the antilog gives:

$$\textbf{Antilog (E/S) = constant (c +x } V_S/V_U\textbf{)} \qquad \textbf{(1-14)}$$

Where antilog (E^0/S) is constant thus the antilog (E/S) is proportional to V_S. A plot of antilog (E/S) against V_S, a straight line is obtained, the intercept of which with the volume axis denote the end point of the unknown concentration in an addition method [56].

Gran's plot was devised by Gran[57] in 1952 as a away of linearizing the data obtained in potentiometric titration and thus easily and precisely locating the equivalence points of titrations. The plots are used in work with ion-selective electrode, for this original purpose and also for linearizing data from multiple standard addition procedures. The technique may be applied to both complexometric and precipitation titrations[55].

1-2-8-3. Potentiometric titration:

Potentiometry is generally valuable as a technique for detecting the end-point of titrations where there is often a drastic change in the concentration of the reactants and thus a big shift in the electrode potential. These end point determinations can often be made more precisely than other ISE methods because they depend on the accuracy of the volumetric measurements rather than the measurement of the electrode potential. This method can also be used to extend the range of ions measurable by ISEs [56].

1-2-9. Sources of Error [58]:

1- Diffusion - Orion Research corporation LTD points out that differences in the rates of diffusion of ions based on size can lead to some error. In the example of sodium iodide, sodium diffuses across the junction at a given rate. Iodide moves much slower due to its larger size. This difference creates an additional potential resulting in error. To compensate for this type of error it is important that a positive flow of filling solution move through the junction and that the juction not become clogged or fouled.

2- Sample Ionic Strength – Covington[17] points out that the total ionic strength of a sample affects the activity coefficient and that it is important in which this factor stay constant. In order accomplish this, the addition of an ionic strength adjuster is used. This adjustment is large, compared to the ionic strength of the sample, such that variation between samples becomes small and the potential for error is reduced.

3- Temperature - It is important that temperature be controlled as variation in this parameter can lead to significant measurement errors. A single degree (C) change in sample temperature can lead to measurement errors greater than 4%.

4- pH - Some samples may require conversion of the analyte to one form by adjusting the pH of the solution (e.g. ammonia). Failure to adjust the pH in these instances can lead to significant measurement errors.

5- Interferences - The background matrix can effect the accuracy of measurements taken using ISEs. Covington points out that

some interferences may be eliminated by reacting the interfering ions prior to analysis

1-3. Promethazine Hydrochloride:

Promethazine Hydrochloride, (2RS) – N,N - dimethyl – 1 – (10*H*–phenothazin–10–yl) propane-2-amine hydrochloride, $C_{17}H_{20}N_2S,HCl$ (Figure 1-3), is a white or faintly yellowish crystalline powder with molecular weight of 320.9, it melts at about (222^0C),with decomposition. It is very soluble in water ; freely soluble in alcohol and in methylene chloride.

Promethazine is Histamine H_1 – receptor antagonist [59], promethazine is used commonly to relieve itchy, red, irritated, watery eyes; runny nose; sneezing; and itchy skin caused by hay fever and allergies. It also is used for motion sickness, before and after surgery as a sedative to relieve apprehension, and prevent and treat nausea and vomiting[60].

Phenergan, an promethazine hydrochloride tablet, promethazine hydrochloride 10 mg and 25 mg tablets; 5 mg/5 ml elixir.Phenergan tablets are blue, film-coated, biconvex, containing 10 mg or 25 mg promethazine hydrochloride. The tablet diameters are approximately 6.1 mm and 8.5 mm respectively. Phenergan 10 mg and 25 mg tablets contain lactose[61]. Phenergan elixir is a very light brown or yellow solution and contains promethazine hydrochloride 5 mg each 5 ml.Phenergan action is a potent histaminic H_1 antagonist with additional anti-emetic and sedative/calming properties. Its duration of action is 4-6 hours.

Promethazine is well absorbed after oral dosing and slowly excreted via urine and bile. It is distributed widely in the body. It enters

then brain and crosses the placenta. phenothiazines pass into breast milk at low concentrations.

Phenergan is manufactured locally by the state company for Drug Industries and medical Appliance (Samara-IRAQ-SDI)[62].

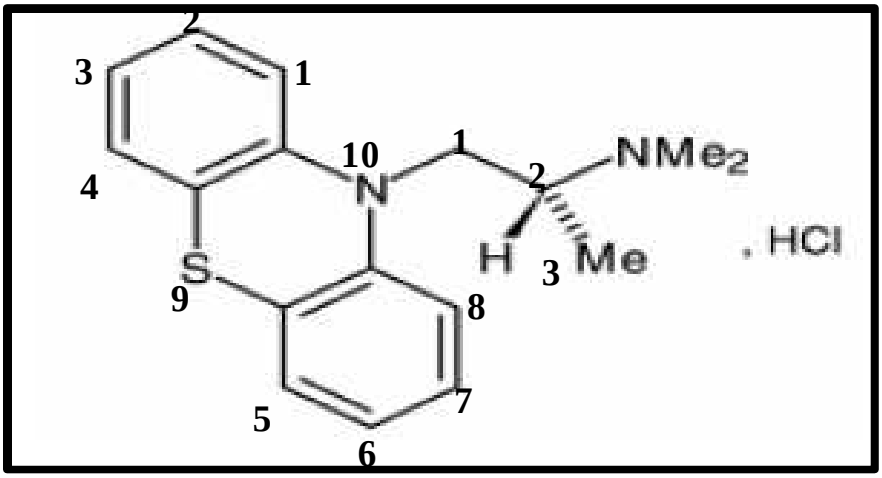


Figure (1-3): Structure formula of promethazine hydrochloride.

1-3-1.*Methods of promethazine hydrochloride determination:*

Simple spectrophotometric method for the determination of promethazine hydrochloride in bulk powder and in its dosage forms. The Lambert-Beer's law is obeyed in the concentration range of 10-80 µg of promethazine hydrochloride per ml or reaction mixture by using spectrophotometry[63].

The use of derivative UV-spectrophotometry is proposed for the simultaneous quantification of promazine hydrochloride in the presence of sulfoxide. The determination of promazine was made using the first-order derivative (deltalambda = 10 nm, second polynomial degree) at 268 nm. An elaborated method was successfully used to determine analytes in commercial promazine pharmaceuticals[64].

Novel methods for the rapid spectrophotometric determination of dapsone**,** rapid, sensitive and simple spectrophotometric methods for the determination of dapsone are described. Absorbances of the resulting violet and green products are measured at 570 nm and 610 nm respectively and are stable for 24 h and 50 min at 27°C respectively. Beer's law is obeyed in the concentration range of 0.1–2.5 μg mL^{-1} of DAP (for IDB) and 0.5–5.0 μg mL^{-1} of DAP (for NBS) at 570 nm and 610 nm respectively. The methods are successfully employed for the determination of dapsone in pharmaceutical preparation and common excipients used as additives in pharmaceuticals. The methods offer the advantages of rapidity, sensitivity and simplicity without the need for extraction or heating. Reaction sequences are described for the formation of products in both the methods[65].

Three simple methods using visual titrimetric, potentiometric and spectrophotometric techniques are described for the determination of promethazine hydrochloride (PMH) in pure form and in dosage forms.
Both titrimetric procedures are applicable over the (1-10) mg range of PMH and the titration reaction follows a 1:1 stoichiometry. In the spectrophotometric method, Beer's law is obeyed over the (10-120) $\mu g.ml^{-1}$ concentration range with an apparent molar absorptivity of 1.28×10^{-3} $mol^{-1}cm^{-1}$ and a Sandell sensitivity of 251 $ng.cm^{-2}$. The limits of detection and quantification were calculated to be 5.77 and 19.26 $\mu g.ml^{-1}$, respectively. The methods were successfully applied to the determination of PMH in tablet, injection and elixir formulations and the results were as accurate as those, obtained by the reference method. The reliability of the methods was further ascertained by the recovery experiments via standard-addition technique[66].

Determination of five phenothiazines in pure and pharmaceutical preparations using vanadium pentoxide as a chromogenic reagent. Also the resolution of the binary mixtures of compounds can be determined by a very simple, sensitive, and accurate spectrophotometric procedure. The reaction is selective for these phenothiazine drugs with 0.05 mg/10 mL as visual limit of quantitation and thus provides a basis for a new spectrophotometric determination. The color reaction obeys Beer's Law from 0.05 mg/10 mL to 2 mg/10 mL for all five phenothiazines with a relative standard deviation from 0.63 to 0.80%. The quantitative assessments of tolerable amounts of other drugs were also studied. The results compare favorably with those of the official methods[67].

Determination of bromethalin in commercial rodenticides found in consumer product samples by HPLC–MS, a small amount of green particulate material is encountered in a consumer complaint sample. The selective and sensitive nature of the MS detector makes it possible to determine bromethalin without extensive sample cleanup and preconcentration. The estimated detection limit with the UV–Vis detector is 500 pg of bromethalin injected into the column. The extensive fragmentation of the bromethalin molecule under APCI conditions provides sufficient structural information for positive identification[68].

Determination of thiazinamium, promazine and promethazine in pharmaceutical formulations using a CZE method, a developed method (HPLC) using capillary zone electrophoresis (CZE) for quantitative analysis of three phenothiazines: thiazinamium methylsulphate (TMS), promazine hydrochloride (PZH) and promethazine hydrochloride (PMH) in pharmaceutical formulations. The method allows the separation of the phenothiazines in 5.0 min at optimized conditions: 100mM tris(hydroxymethyl)-amino methane (Tris) buffer at a pH 8.0, 15%

acetonitrile, capillary with 58.5 cm in length at 25 °C and a voltage of 30 kV. Detection occurred at 254 nm, acceptable precision (relative standard deviation (R.S.D.) 5.3%) and linearity were achieved using the internal standard (IS) method. The limits of detection (LODs) were 2.8 $\mu g ml^{-1}$ for TMS and 3.3 $\mu g ml^{-1}$ for PZH and PMH. The method has been successfully applied in the analysis of pharmaceutical formulations[69].

High-performance liquid chromatographic simultaneous determination of commonly used tricyclic antidepressants, a method for simultaneous measurement of five commonly used tricyclic antidepressant drugs (doxepin, desipramine, nortriptyline, imipramine, andamitriptyline) in serum by paired-ion high-performance liquid chromatography, with use of are reversed-phase column and ultraviolet detection at 254 nm. Linear response is observed for drug concentrations up to 1500 µg/Iiter and the detection limit is 2-3 µg/liter. Within-run precision ranges from 1.4 to 2.9% and day to-day precision from 1.7 to 7%, depending on the specific drug. The entire procedure can be completed within 45 min and is well adapted to the routine clinical laboratory. 48 common basic and several neutral drugs tested for possible interferences, only three benzodiazepines, three phenothiazines and three antihistamines interfere with the assay of doxepin, desipramine and nortriptyline, respectively[70].

Oxidation of desmethylpromethazine catalyzed by pig liver flavin-containing monooxygenase number and nature of metabolites. The products, identified with the aid of chemically synthesized reference compounds, All other metabolites detected are formed by further oxidation of the latter product. In addition, sulfoxidation of desmethylpromethazine is the first demonstration that flavin-containing monooxygenase can catalyze sulfoxidation of a phenothiazine drug bearing a basic side-chain nitrogen[71].

Separation, conformation in solution and absolute configuration of ethopropazine enantiomers, enantiomers of ethopropazine . Enantiomeric purity for (m)-enantiomer was 99.1% and for (+)-enantiomer 97.9%. Combined data from NMR and CD spectra of both enantiomers, along with previously reported X-ray structure analyses of racemic ethopropazine, revealed skewed conformation of tricyclic system in solution, and (*S*)-configuration on the stereogenic center for (m)-enantiomer, and (*R*)-configuration for (+)-enantiomer[72].

Degradation products of the promethazine radical cation, The degradation products of the promethazine radical cation, generated from promethazine with horseradish peroxidase/H_2O_2, have been investigated. The main product (approx. 90%) was identified as 10-formyl-5-oxophenothiazine. The likely structure of three minor products was also elucidated. The degradation of the promethazine radical cation is different from that of radical cations derived from the propanamine side chain containing phenothiazine drugs[73].

A gas chromatography procedure was used to stabilize of a combination of meperidine hydrochloride 50 mg, promethazine hydrochloride 25 mg, and atropine sulfate 0.4 mg in plastic syringes per ml at room temperature. Atropine was separated from the mixture and assayed alone for greater accuracy. Drug concentrations in the plastic syringes were not significantly different from controls at any of the test times. A mixture of meperidine hydrochloride, promethazine hydrochloride, and atropine sulfate in dosages commonly administered as a preoperative medication was stable for 24 hours in plastic syringes[74].

Gas chromatographic determination of 1,4-Dioxane at low parts-per-million levels in glycols; 1,4-Dioxane is a flammable liquid and tends to

form explosive peroxides. GC analysis may be carried out using a flame ionization detector. Results show that 1,4-dioxane can be comfortably determined down to 2 ppm in glycols and benzene[75].

Optimum TLC system for identification of phenothiazines and tri- and tetracyclic antidepressants, the TLC separation of twelve drugs from three pharmaceutical groups: phenothiazines and tri and tetracyclic antidepressants is presented. The experimental data obtained during optimization were interpreted using a matrix presentation. In the optimal conditions the differences between positions of the spots enable identification of ten of the examined drugs, but two remained unresolved[76].

Silica gel thin-layer chromatography plates impregnated with macrocyclic antibiotic as chiral selector were prepared and used for the resolution of promethazine hydrochloride. The spots were detected with iodine vapors and the detection limit was found to be 0.074 µg of each enantiomers[77].

A liquid chromatographic method for the simultaneous determination of promethazine and three of its metabolites in plasma using electrochemical and UV detectors. The limit of detection level for PMZ is 1.0 ng/mL when a 0.2-mL specimen of plasma is assayed. A validation study is also conducted for evaluating the recovery, precision, linearity of response, sensitivity, and selectivity of the method[78].

1-3-2. Applications of ISEs in pharmaceutical drugs:

Characterization of bulk drugs has become increasingly important in the pharmaceutical industry. The ion-selective membrane are widely used for pharmaceutical analysis with advantages of determining sample

directly, rapidly and simple. Analytical techniques are employed for this purpose were[79]: amoxicillin trihydrate[80], cephalexin monohydrate[80] and atenolol[21] are PVC membrane electrodes, that was based on ion-pair with phosotungstic acid. But promethazine hydrochloride[81], methacycline hydrochloride[82], anisodamine, n-butylscopolamine and homatropine[83], chloropromazine[84], methacholine chloride[85], chlorpheniramine maleate[86],procaine[87], clobutinol hydrochloride[88], aromatic amines[89], chlorprothixene[90]and metoclopramide[91] were PVC membrane electrodes based on ion-pair with tetraphenylborate. Another drugs such as chlorpyramine[92]and disopyraminde[93] are based on ion-pair complexes with tetrakis(4-chlorophenyl)borate but ketotifen cation[94] based on ion-pair with [3,5-bis(trifluoromethyl)phenyl], determination of quaternary ammonium salts[89] in pharmaceutical preparation by ion association with sodium tetrakis(4-fluorophenly)borate. Ion selective electrode with a pseudoliquid membrane phase used for determination of cephalothin[95] by reacting with quaternary ammonium salts to form association complex. Pethidine hydrochloride[96] was determined by ion selective electrode based on ion-associate with silicotungstic acid. Liquid membrane electrode for the direct determination of ephedrine[97] based on the use of the ephedrine-5-nitrobarbiturate ion-pair complex in pharmaceutical preparations. A novel triiodide ion-selective electrode based on clotrimazole-triiodide[98] ion pair as a membrane carrier for determination of clotrimazole in pharmaceutical preparations. salicylate[99] liquid membrane electrode with anitron-saliicylate as ion-pair complex, the construction of either PVC membrane (lidocaine[100]-selective electrode) with lidocaine-dinonylnaphthalenesulphonate as ion-pair complex, Potentiometric determination of dopamine[101] in pharmaceutical preparations by modified-PVC membrane sensors, diphenhyramine hydrochloride[102],

this electrode was based on diphenhydramine-dipicrylamine as ion-association complex.

Naproxen[103] , a naproxenate-selective electrode with a liquid membrane consisting of a tetraheptylammonium-naproxenate ion-pair complex, determination of thiamine [104] (vitamin B_1) in pharmaceutical preparations by liquid membrane electrode based on the formation of an ion-pair between the thiamine and reineckate. Determination of the phenobarbitone sodium [105] by phenobarbitone electrode (coated-wire)was based on the ion-pair complex between phenobarbitone and tricaprylylmethylammonium form, simultaneous determination of ascorbic acid and paracetamol[106] in drug formulations by differential-pulse voltammetry using a glassy carbon electrode. Novel membrane potentiometric sulfate ion sensor based on zinc-phthalocyanine for the quick determination of trace amounts of sulfate in phthalocyanine[107], thiopyrilium[108] ,novel imidazole PVC-Based sensor based on a thiopyrilium compound. Triiodide [109],a new PVC membrane electrode for the triiodide ion based on a charge-transfer complex of iodine with 7,16-dibenzyl-1,4,10,13-tetraoxa-7,16-diazacyclooctadecane as a membrane carrier. Ibuprofen[110], novel ibuprofen potentiometric membrane sensors based on tetraphenylporphyrinato indium (III). Comparative study of the response of membrane electrodes based on calix[6]arene and calix[8]arene derivatives to organic ammonium ions, octahydroxycalix[4]arene derivative[111]**.** Silver(I)-selective coated-wire electrode based on an octahydroxycalix[4]arene derivative[112]. A selective iodide PVC membrane electrode was used for determination of tetrakis(4-*N*,*N*dimethylaminobenzene) porphyrinate by using a novel carrier [Tetrakis (4-*N*,*N*dimethylaminobenzene)porphyrinato]manganese (III) acetate for a selective iodide PVC membrane electrode[113].

Potassium-selective membrane electrodes based on macrocyclic metacyclophanes analogous to calixarenes[114]. New cadmium(II)-selective electrode based on a tetraazacyclohexadeca-macrocyclic ionophore[115]. Potentiometric determination of silver(I) by selective membrane electrode based on derivative of porphyrin[116]. A silver ion-selective electrode was prepared with a polymeric membrane incorporating 2,6-bis-methylsulfanyl-[1,3,5]thiadiazine-4-thione as an ionophore[117]. New plastic membrane and carbon paste ion selective electrodes for the determination of triprolidine[118]. New conventional coated-wire ion-selective electrodes for flow-injection potentiometric determination of chlordiazepoxide[119].

1-4. *Aim of the work:*

This project was aimed to construct and characterize several ion-selective electrodes for the potentiometric determination of promethazine hydrochloride. These electrodes utilize the solvent mediators or plasticizers, Di-butylphthalate (DBPH), Di-butylphosphate (DBP), Tri-butyl phosphate (TBP) and o-nitrophenyloctylether (ONPOE). The constructed electrodes characteristic parameters that include slope, linear range, detection limit, lifetime , selectivity , and working pH range will be investigated. The best combination of promethazine hydrochloride (ionophore), solvent mediator, and PVC matrix will be chosen. Potentiometric measurements including direct method, standard addition method and titration method will be studied.

3.Results and Discussion

3-1. Influence of membrane composition:

It is well known that the selectivity, linear dynamic range and sensitivity obtained for a given ionophore depend significantly on the membrane composition and the nature of the solvent mediator and additives used. Thus , the influence of some important features of PVC membrane such as the membrane composition, nature and amount of plasticizer. It is expected to play an important role in determining the characteristics of the ion selective electrode[123].

Different ratios of membrane composition were employed to evaluate their effect on the response characteristics of membrane electrode. The results revealed that the best composition of membrane was
ion-pair : PVC : plasticizer = to have 1% : 29% : 70% (weight ratio)[124] .

The complex found to have neutral charge by measuring the conductivity of this complex ,it was equal to 0.2 µS/cm and the electrode was immersed in distilled water that conductivity is equal to 2 µS/cm. The complex is obtained by conversion promethazine hydrochloride into promethazine hydrochloride phosphotungastate (PMH-PT) gray precipitate which was characterized by it's FTIR spectrum as shown in Fig (3-1 a, b).

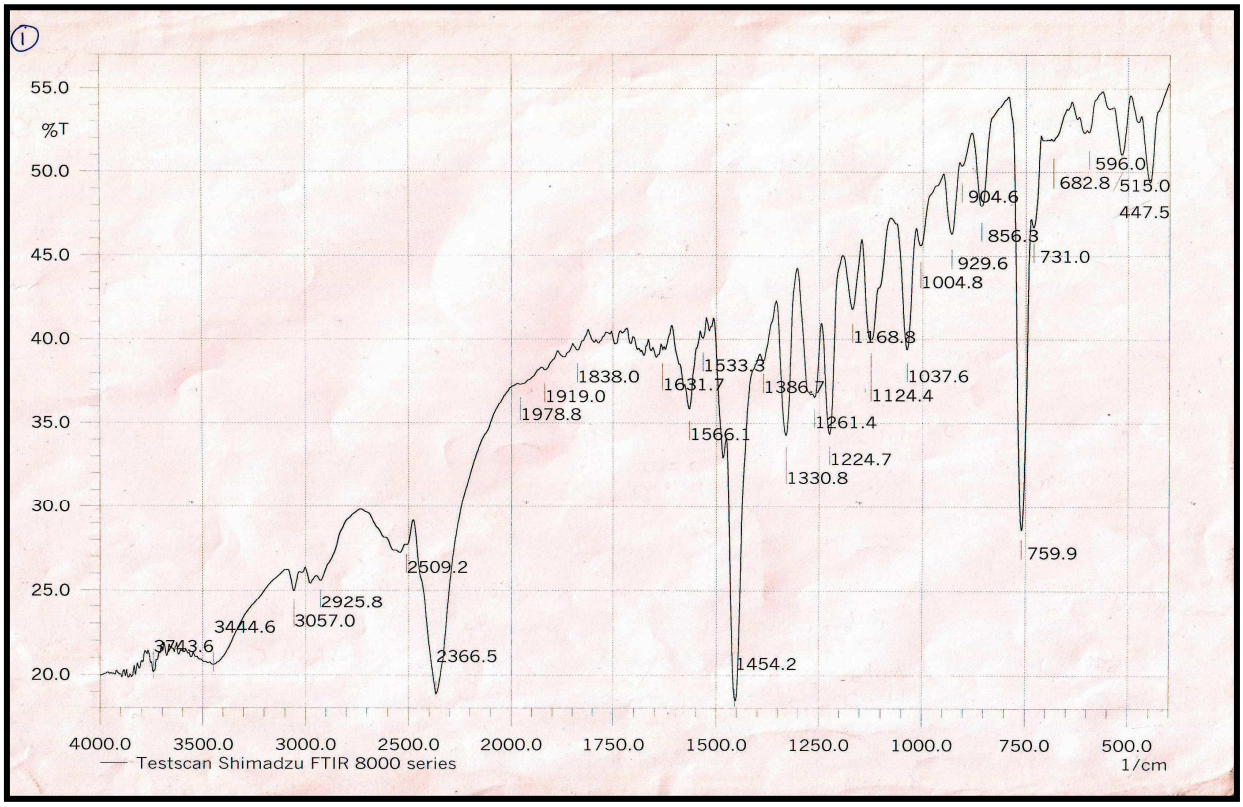
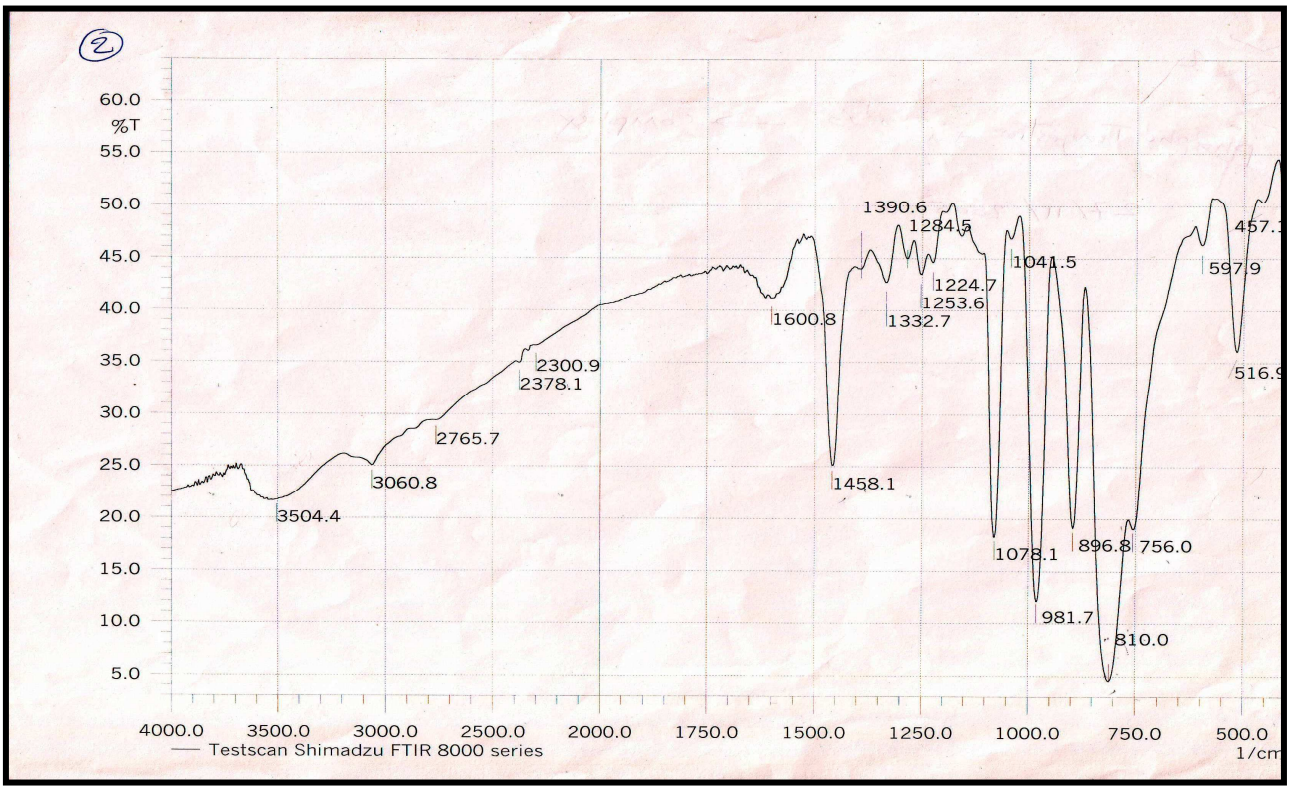


Figure (3-1a): FTIR spectrum of standard promethazine hydrochloride.



Figure(3-1b): FTIR spectrum of (PMH-PT) electro-active substance.

The IR spectra indicate and improved the formation of the complex PMH-PT. The functional groups for both promethazine hydrochloride and the complex are listed in table (3-1). The suggestion is that the connection between the promethazine hydrochloride and phosphotungstic acid was through by nitrogen atom of the ($N(CH_3)_2$) moiety.

Table (3-1): The functional groups obtained from the spectrum for each promethazine hydrochloride and promethazine hydrochloride- phosphotungstic acid.

Functional group	Promethazine hydrochloride(PMH)	Complex (PMH-PT)
ν(C-H) aromatic	3057	3060
ν (C-H) aliphatic	2925	-
ν (R_3NH^+) Cl^-	2366	-
ν (C=C) aromatic	1631	1600
ν (C-H) bend	1454	1458.1
ν ($N(CH_3)_2$	1224	1253.6
ν (C-N) STR	1124	-
Ortho disub. Benzene	1037	1078.1
ν (C-S-C)	759	756
ν (M-N)	-	516

Promethazine hydrochloride- phosphotungstate is a stable ion-pair complex which is water insoluble but readily soluble in an organic solvent such as tetrahydrofuran (THF).The obtained complex was incorporated into a PVC membrane with the following plasticizers: DBP (Di n-butyl phosphate), electrode A; TBP (Tri n-butyl phosphate),

electrode B; ONPOE (ortho nitro phenyl octyl ether), electrode C; DBPH (Di n-butyl phthalate), electrode D. The physical properties for these membranes were studied and listed in table (3-2).

Table(3-2): Physical properties of the four membranes.

No. of membrane	Color of membrane	Nature of membrane	Transparency
A	colorless	Flexible and clear	Transparent
B	colorless	Flexible and clear	Transparent
C	Light yellow	Very Flexible and clear	Transparent
D	Light blushful	Very Flexible and clear	Transparent

The working characteristics for the investigated A, B, C, D electrodes were assessed on the basis of the calibration curves which were obtained by measuring of the e.m.f. values of the set of promethazine hydrochloride solutions ranged ($10^{-1} – 10^{-5}$) M.

The membranes of the electrodes were conditioned by soaking into 1×10^{-1} M of promethazine hydrochloride solution for 2 hours before applying for potential measurements. When not in use ,the electrode was stored in air.

These electrodes show sub-Nernstain response to the promethazine hydrochloride activity in different concentration ranges depending on the properties of the plasticizers and ion-pair complex. Each electrode was calibrated every two days to determine the change in electrodes parameters such as slope, detection limit and electrode drift.

3-1-1. Electrode A (using Di-butyl phosphate):

For this electrode di-butyl phosphate (DBP) was used as a plasticizer, the calibration curve is shown in figure (3-2):

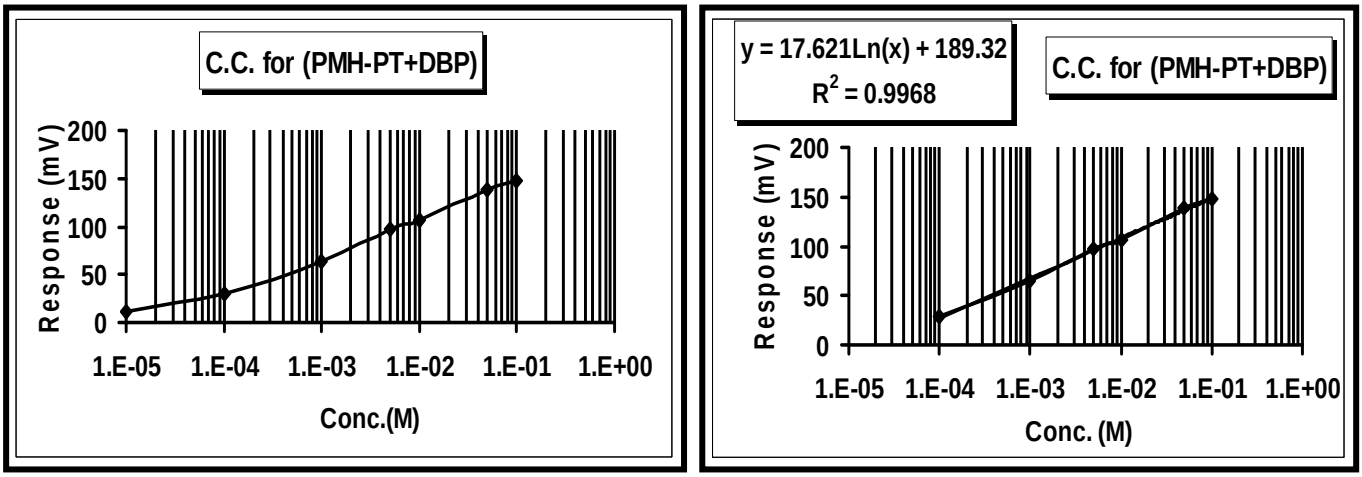


Figure (3-2):Calibration curve of promethazine hydrochloride selective electrode using (DBP) as a plasticizer.

From the calibration curve obtained by plotting potential at different concentrations of promethazine hydrochloride displayed the slope 40.58 mV/decade, correlation coefficient equal 0.9984 with linear concentration range (1×10^{-1}-1×10^{-4}) M. The limit of detection was 3.5×10^{-5} M and the life time was about 29 days.

Non-Nernstain slope 40.58 mV/decade was obtained from the calibration curve of electrode A. This low value may be attributed to high viscosity of the plasticizer which decrease the ion-exchange process between ion-pair complex (PMH-PT) in membrane and the external solution of promethazine hydrochloride as shown in table (3-3), or may be attributed to the steric factor of the alkyl group of plasticizers (DBP) ,which decrease the bond strength with ion-pair complex (PMH-PT) that lead to decrease the slope values of electrode.

Table (3-3): Viscosity of plasticizers used in this work

Plasticizers	Viscosity (cSt)
DBP	112.89
TBP	3.11
ONPOE	11.44
DBPH	14.44

3-1-2. Electrode B (using Tri-butyl pholsphate):

The second electrode was based on tri-butyl phosphate (TBP) as a plasticizer, the calibration curve is shown in figure (3-3):

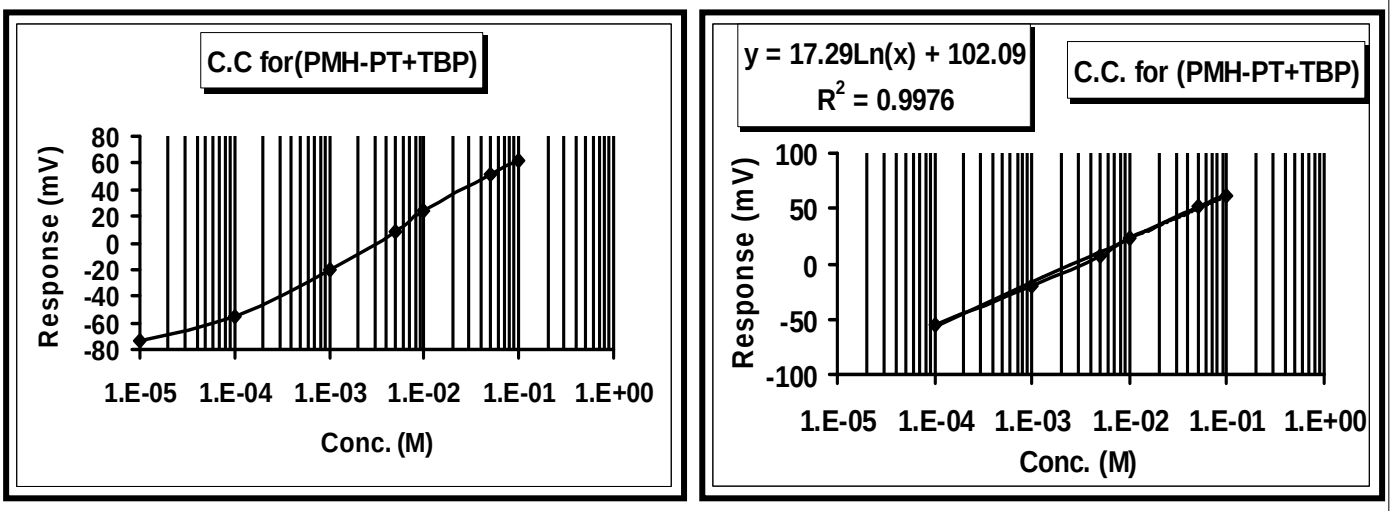


Figure (3-3): Calibration curve of promethazine hydrochloride selective electrode using (TBP) as a plasticizer.

The calibration curve figure, (3-3) gave a slope of 39.82 mV/decade, correlation coefficient equal 0.9988 with linear concentration range (1×10^{-1}- 1×10^{-4}) M. Limit of detection was 5×10^{-5} M and the life time was about 23 days.

Also the non-Nernstain slope 39.82 mV/decade was obtained. This may be attributed to the low viscosity of TBP (3.11) and lead to leaching of the complex from the membrane to the external solution as well as decrease ion-exchange process between ion-pair complex (PMH-PT) in membrane and the external solution of promethazine hydrochloride, or may be attributed to the steric factor as in electrode A.

3-1-3. Electrode C(using of O-Nitro phenyl octyl ether):

The third electrode prepared by using o-nitro phenyl octyl ether (ONPOE) as a plasticizer, the calibration curve is shown in figure (3-4):

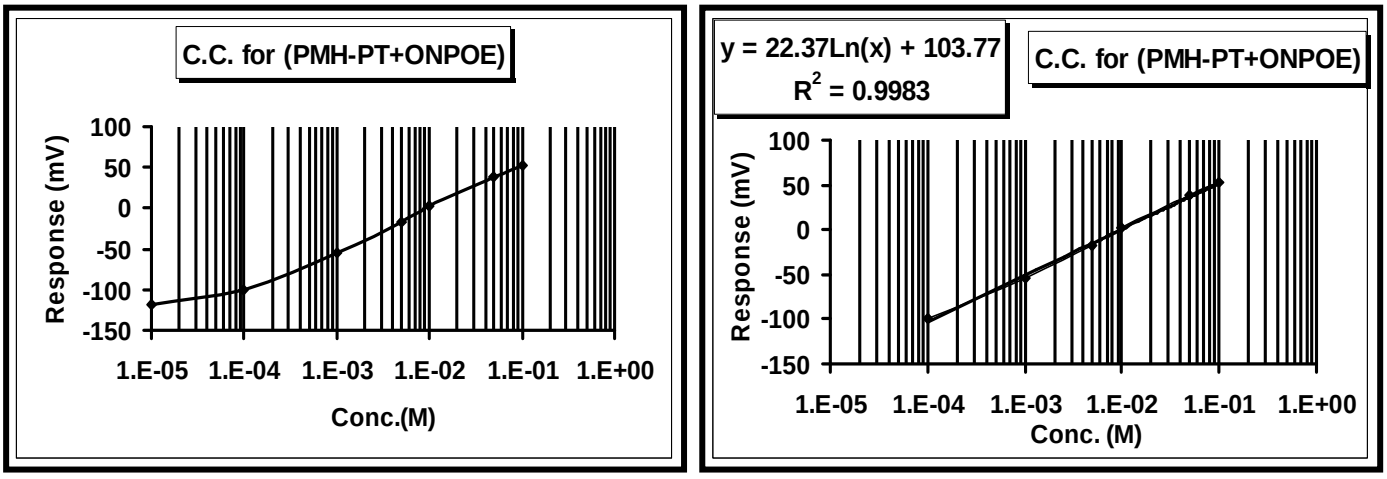


Figure (3-4): Calibration curve of promethazine Hydrochloride selective electrode using (ONPOE) as a plasticizer.

From figure (3-4) was found that the calibration curve gave a slope of 51.52 mV/decade, correlation coefficient equal 0.9991 with linear concentration range (1×10^{-1}- 1×10^{-4}) M. The limit of detection was 5.5×10^{-5} M and the life time was about 2 days.

A good parameters were obtained with a Nernstain slope 51.52 mV/decade except the life time was 2 days. This may be due to high quantity of the plasticizer used which makes the mobility of the complex inside the membrane to increase and cause easy leaching of the complex

from the membrane to the external solution. In this case a low quantity of the plasticizer may be used.

3-1-4. Electrode D (using of Di-butyl phthalate):

The fourth electrode used di-butyl phthalate (DBPH) as a plasticizer, the calibration curve is shown in figure (3-5):

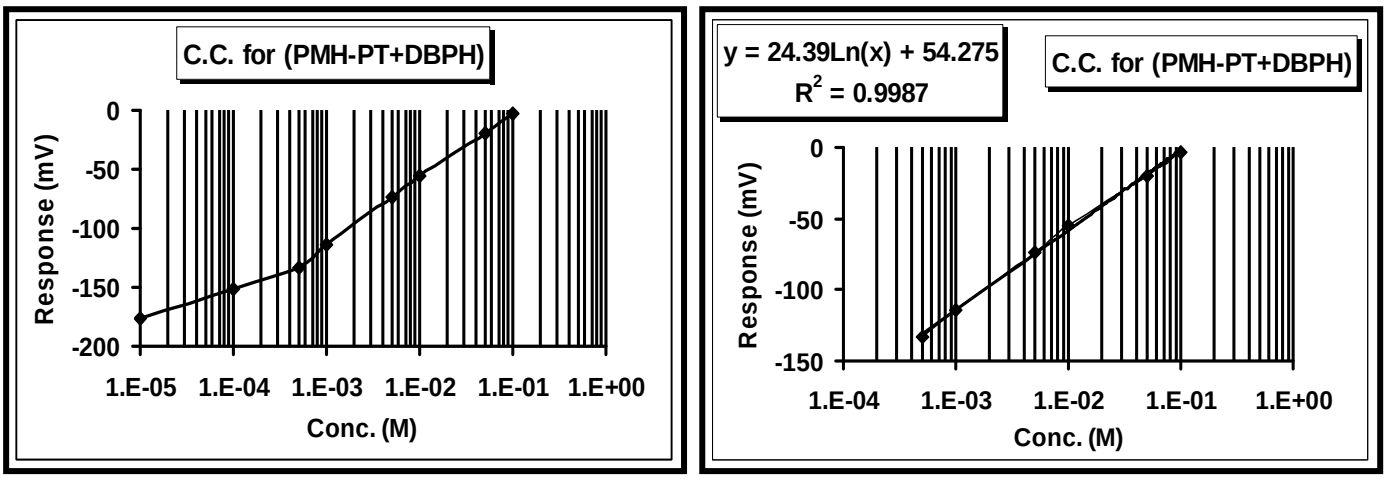


Figure (3-5): Calibration curve of promethazine Hydrochloride selective electrode using (DBPH) as a plasticizer.

From figure (3-5) was found that the calibration curve of promethazine hydrochloride displayed which gave a slope 56.17 mV/decade ,correlation coefficient equal was 0.9993 with linear concentration range (1×10^{-1}-5×10^{-4}) M. The limit of detection was 2×10^{-4} M and the life time was about 72 days.

Excellent electrode parameters were obtained for this electrode which gave a good response and stability in comparison with the other electrodes, that may be due to the compatibility of the plasticizer used to the electro-active compound in both structure and composition.

The stability of the four electrodes was monitored continuously at 1×10^{-3} M of promethazine hydrochloride solution and evaluated for period of 1 day; the standard deviation of potential drift obtained for 6

replicated measurements were =(±3, ±4, ±9 and ±1) mV/day for membrane Nos., (A,B,C and D) respectively as listed in table (3-4).

The precision reproducibility of the potential response of the electrode D based on (DBPH) was relatively good and the response properties of the proposed electrode did not changed obviously after the use of electrode D for about 72 days.

Table (3-4): Standard deviation of potential drift of the electrodes.

Membrane number	Std. deviation of slope drift (mV/days)
A	±3
B	±4
C	±9
D	±1

Deviation from linearity at concentrations below (1×10^{-4} M) was obtained, which may be attributed to the dissociation of complex to the external solution. This phenomenon has also been reported in the literature for liquid membrane electrodes [125].

Response characteristics of promethazine hydrochloride selective electrode, were determined and the results are listed in table (3-5).

Table (3-5): Response characterizes of promethazine hydrochloride selective electrodes.

Parameter	Electrode number			
	A	B	C	D
Plasticizer	**DBP**	**TBP**	**ONPOE**	**DBPH**
Slop mV/decade	**40.58**	**39.82**	**51.52**	**56.17**
Correlation coefficient	**0.9984**	**0.9988**	**0.9991**	**0.9993**
Linearity range(M)	1×10^{-1}-1×10^{-4}	1×10^{-1}-1×10^{-4}	1×10^{-1}-1×10^{-4}	1×10^{-1}-5×10^{-4}
Detection limit(M)	3.5×10^{-5}	5×10^{-5}	5.5×10^{-5}	2×10^{-4}
Potential drift (mV/day)	**3**	**4**	**9**	**1**
%RSD	**0.662**	**0.802**	**0.414**	**0.287**
Life time	**~29**	**~23**	**~2**	**~72**
F test	-	-	**0.375**	**0.375**

The relative standard deviations (RSD%) were obtained from the calibration curves for all the electrodes at concentration 10^{-2} M and the RSD% was calculated for multiple concentrations (n=5). The results for RSD [table (3-5)] for electrode D based on (DBPH) gave the lowest value among other electrodes which means more stability and reproducibility. Also the F test was calculated for electrode D (PMH-PT+DBPH) and electrode C (PMH-PT+ONPOE) to compare the accuracy for the two electrodes [table (3-5)] which can be noted that the value calculated of F

test is less than the value tabulated of F test (that is value 6.26 in table) for the confidence limit 95%, at free degree (n-1), this indicated that the two electrodes are equivalent in the same accuracy and can be used for determination of promethazine hydrochloride but in the same time the value of the slope of electrode C (PMH-PT+ONPOE) was lower when compared with electrode D (PMH-PT+DBPH), so that it was better to use electrode D (PMH-PT+DBPH). Also the electrode C based on (ONPOE) can be used for determination of promethazine hydrochloride as well as electrode D because the slope of these electrodes were near to Nernstain slope and the correlation coefficients were near to one, but the life time of electrode D was relatively longer than life time of electrode C as discussed previously.

For electrode based on TBP as a plasticizer, we noticed that the plasticizer can be leached to the external solution in which the colour of the external solution was leached due to low viscosity of TBP.

This mean the electrode D based on DBPH can be used for about 72 days, after this time the electrode D becomes less sensitive toward promethazine hydrochloride, may be due to gradually leaching the sensor from the membranes to the external solution.

Three synthetic drug concentrations (10^{-3}, 5×10^{-3} , 5×10^{-2}) M were taken for measuring recovery%, relative error%, mean relative error, confidence limit for concentration at 95% and confidence limit for potential at 95% respectively, these parameters were calculated by using all the electrodes. These calculated values are listed in tables (3-6) to (3-9).

Parameter	Electrode A

A mount of PMH taken (M)	10^{-3}	5×10^{-3}	5×10^{-2}
A mount of PMH found (M)	9.94×10^{-4}	5.01×10^{-3}	4.99×10^{-2}
%RC.	99.4	100.2	99.8
%RE.	-0.6	0.2	-0.2
Mean % RE	-0.2	-	-
Regre. Eq. Y=m X + b	Y = 17.621 ln(X)+189.32		
Conf. limit. Pot. (mV) 95% C.I	136.48 ± 0.4762		

Table(3-6): Statistical treatments for drug concentrations of electrode A (PMH-PT+DBP).

Table(3-7): Statistical treatments for drug concentrations of electrode B (PMH-PT+TBP).

Parameter	**Electrode B**		
A mount of PMH taken (M)	10^{-3}	5×10^{-3}	5×10^{-2}
A mount of PMH found (M)	9.91×10^{-4}	5.01×10^{-3}	4.91×10^{-2}
%RC	99.1	100.2	98.2
%RE	-0.9	0.2	-1.8
Mean % RE	-0.83	-	-
Regre. Eq. Y=m X + b	Y= 17.29 ln(X) + 102.09		
Conf. limit. Pot. (mV) 95% C.I	10.5 ± 0.1963		

Table(3-8): Statistical treatments for drug concentrations of electrode C (PMH-PT+ONPOE).

Parameter	Electrode C		
A mount of PMH taken (M)	10^{-3}	5×10^{-3}	5×10^{-2}
A mount of PMH found (M)	1.015×10^{-3}	4.95×10^{-3}	5.05×10^{-2}
%RC	101.5	99	101
%RE	1.5	-1	1
Mean % RE	0.5	-	-
Regre. Eq. Y=m X + b	Y= 22.37 ln X + 103.77		
Conf. limit. Pot. (mV) 95% C.I	-15 ± 0.1962		

Table(3-9): Statistical treatments for drug concentrations of electrode D (PMH-PT+DBPH).

Parameter	Electrode D		
A mount of PMH taken (M)	10^{-3}	5×10^{-3}	5×10^{-2}
A mount of PMH found (M)	1.01×10^{-3}	4.99×10^{-3}	4.95×10^{-2}
%Rec.	101	99.8	99
$\%E_{rel.}$	1	-0.2	-1
Mean % $E_{rel.}$	-0.067	-	-
Regre. Eq. Y=m X + b	Y = 24.39 ln (X)+ 54.275		
Conf. limit . Pot. (mV) 95% C.I	75 ± 0.196		

3-2.Effect of pH:

The effect of pH on the electrode potentials for promethazine hydrochloride selective membrane electrodes was examined by measuring the e.m.f. of the cell in promethazine hydrochloride solutions at two different concentration (10^{-3},10^{-2}) M in which the pH measured from 1.0-11.5. The pH adjusted by adding appropriate amounts of hydrochloric acid and/or sodium hydroxide solution and the results are

shown in figures (3-6) to (3-9).

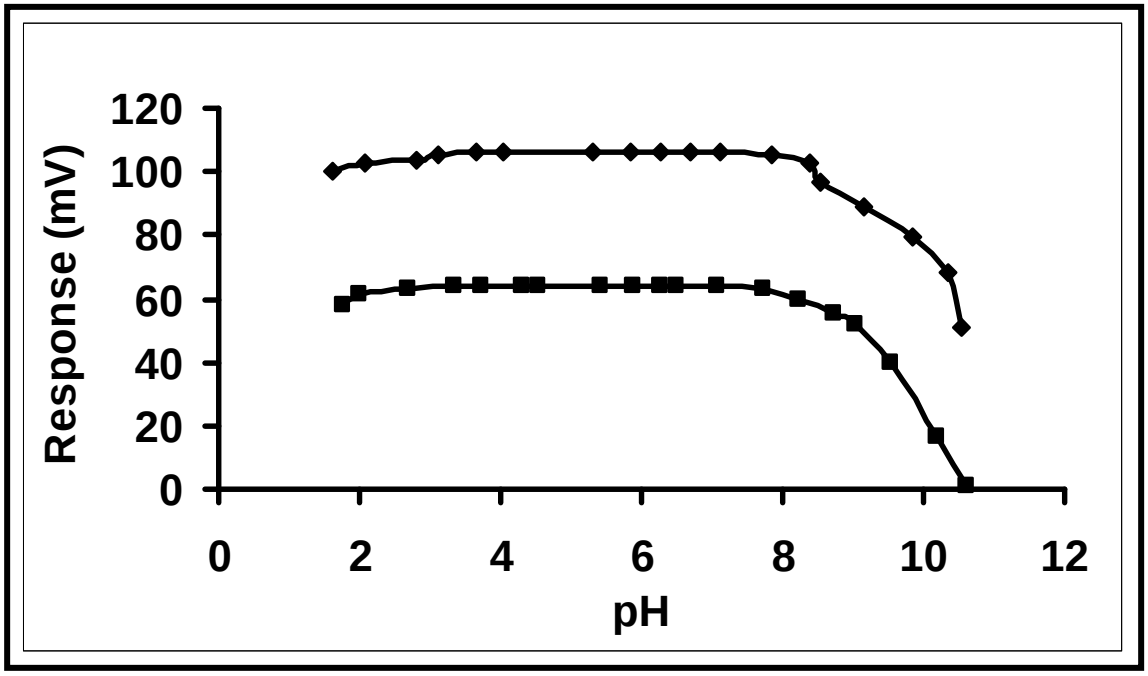


Figure (3-6): Effect of pH on the potential of the electrode A (PMH-PT+DBP).(♦=10^{-2}, ■=10^{-3}) M promethazine hydrochloride.

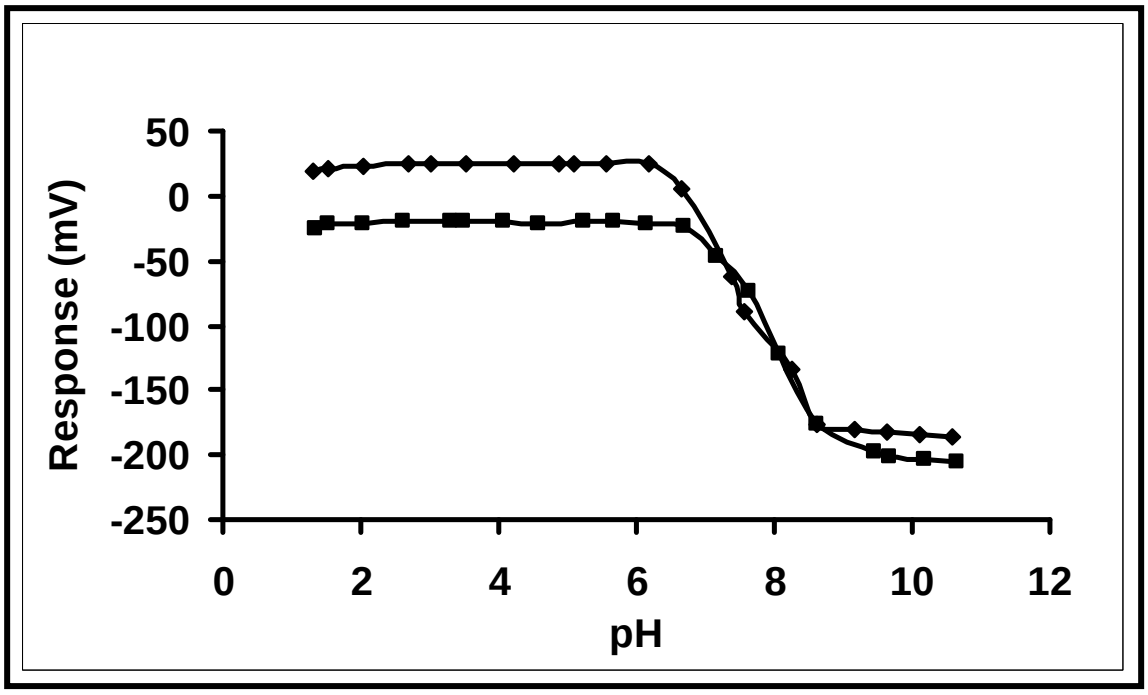


Figure (3-7): Effect of pH on the potential of the electrode B (PMH-PH+TBP).(♦=10^{-2}, ■=10^{-3}) M promethazine hydrochloride.

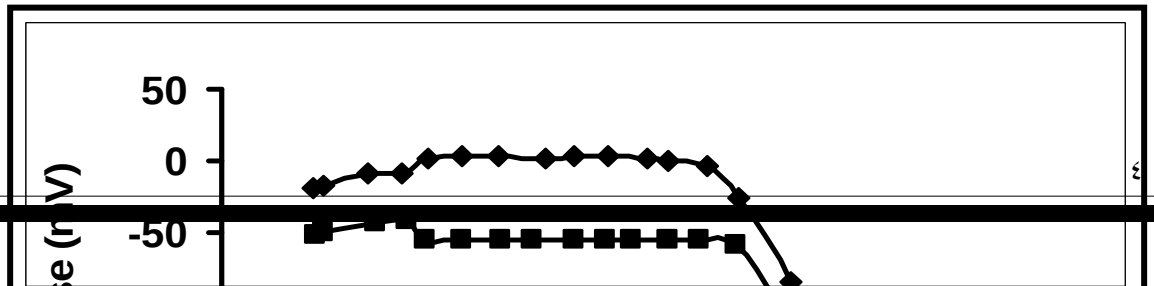


Figure (3-8): Effect of pH on the potential of the electrode C (PMH-PT+ONPOE).(♦=10^{-2},■=10^{-3}) M promethazine hydrochloride.

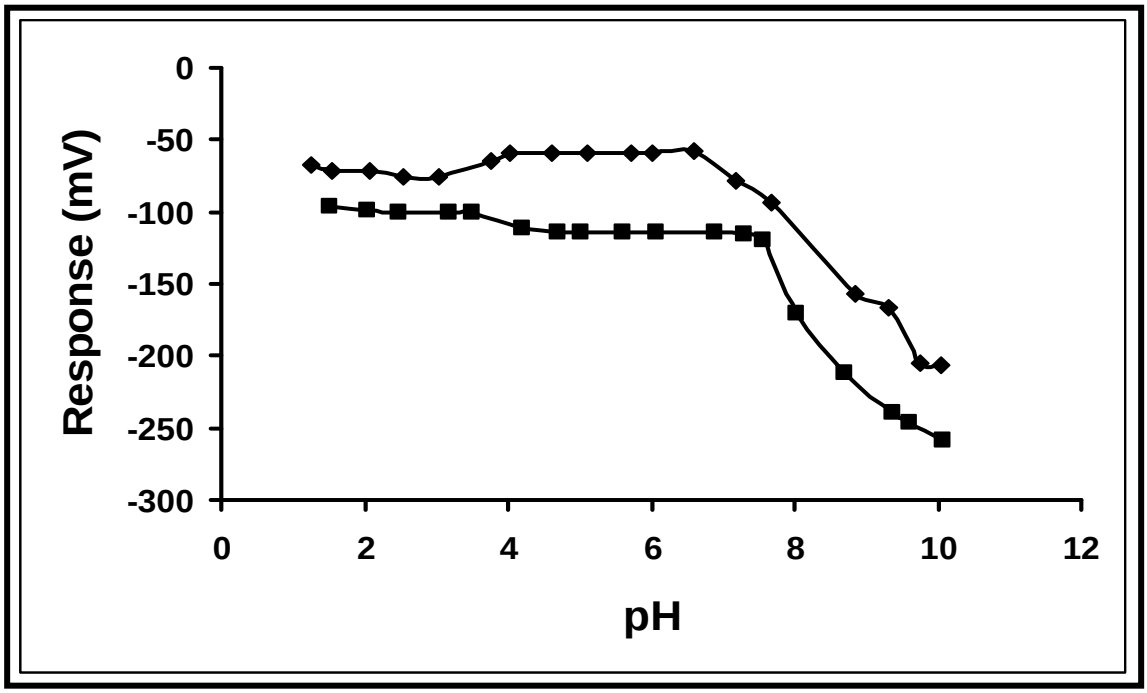


Figure (3-9): Effect of pH on the potential of the electrode D (PMH-PT+DBPH).(♦=10^{-2}, ■=10^{-3}) M promethazine hydrochloride.

It can be seen; that the potential for the four electrodes were remained nearly constant nearly at 2-7 pH range. This represented that the proposed

electrodes can be used to measure a wide range of promethazine hydrochloride solutions without pH adjustment.

Non Nernstain calibration curve was obtained by buffering each solution (10^{-1}-10^{-5}) M at pH=4 (using buffer potassium hydrogen phthalate). The calibration curve is shown in figure (3-10), in which there is a deviation from the calibration curve in which slope became 27.32 mV/decade and correlation coefficient (R) =0.9650.

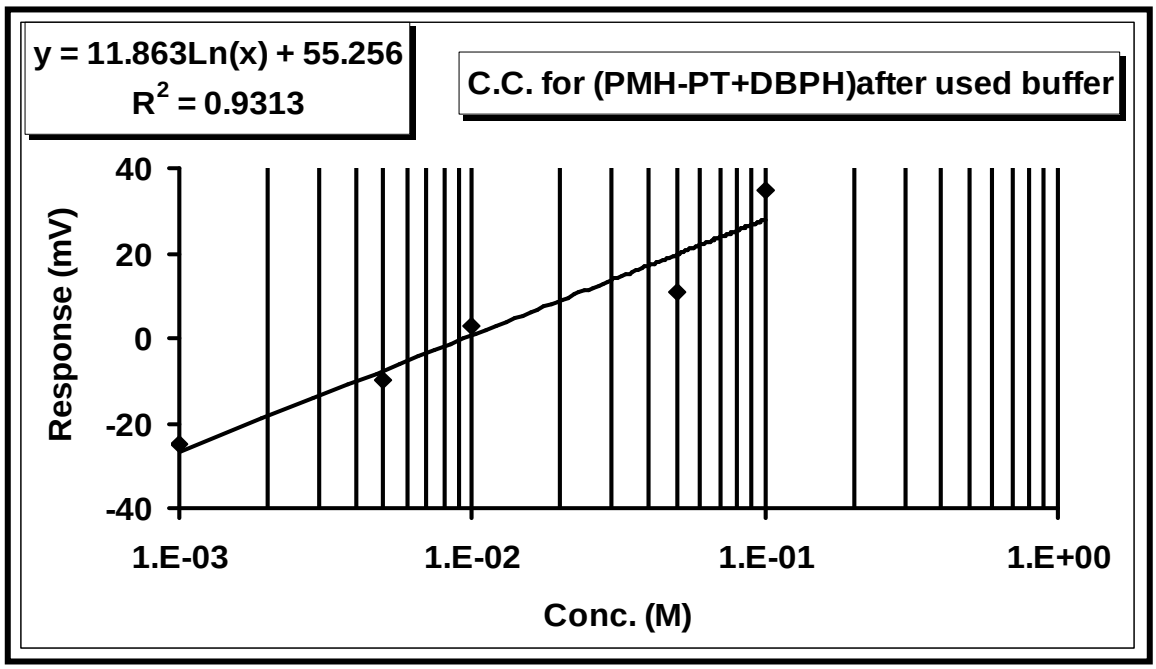


Figure (3-10): Calibration curve for electrode D (PMH-PT+DBPH) after used buffer at pH =4

At pH values lower than 1.0 or in very high acidity, the electrodes responses has been increased rather irregularly. This may be due to that the electrodes responses to H^+ activities as well as analyte ions . A drift in potential was noticed at pH > 8. This attributed to the poisoning of the membrane by formation a white precipitated tungsten oxides or sodium phosphotungastate.

The results of working pH ranges for the electrodes (A,B,C and D) are listed in table (3-10).

Table (3-10): Working pH ranges for electrodes (A,B,C and D).

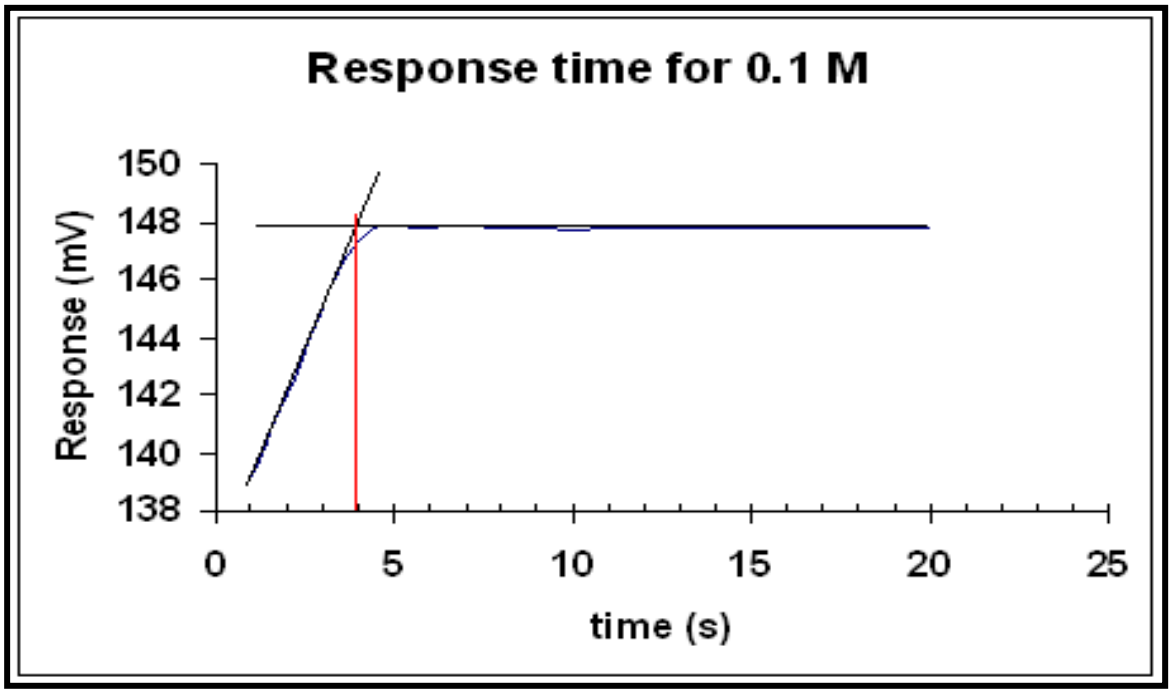
Membrane No.	Plasticizer	pH range
A	DBP	2.4- 8.4
B	TBP	1.5-6.4
C	ONPOE	3.0-7.3
D	DBPH	4.1-6.8

3-3. Response time:

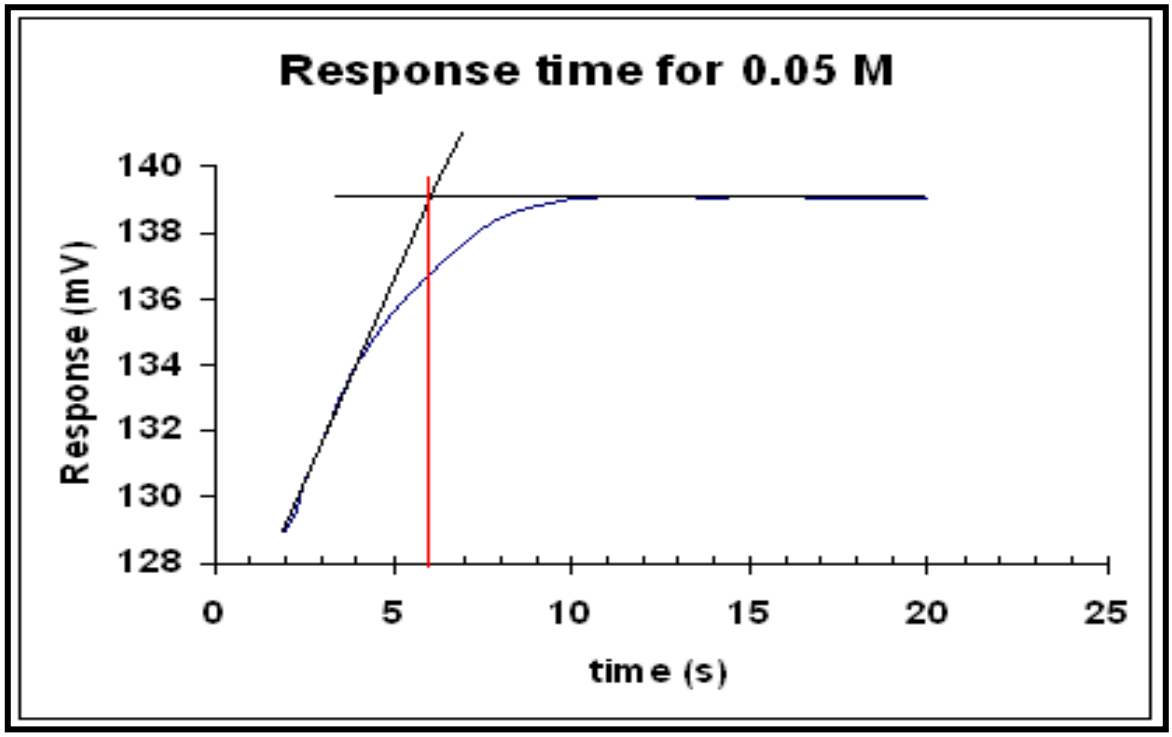
The response time for four electrodes (A,B,C and D) to reach a stable potential within ±1 mV of the final equilibrium value was determined.

3-3-1. Response time for electrode A:

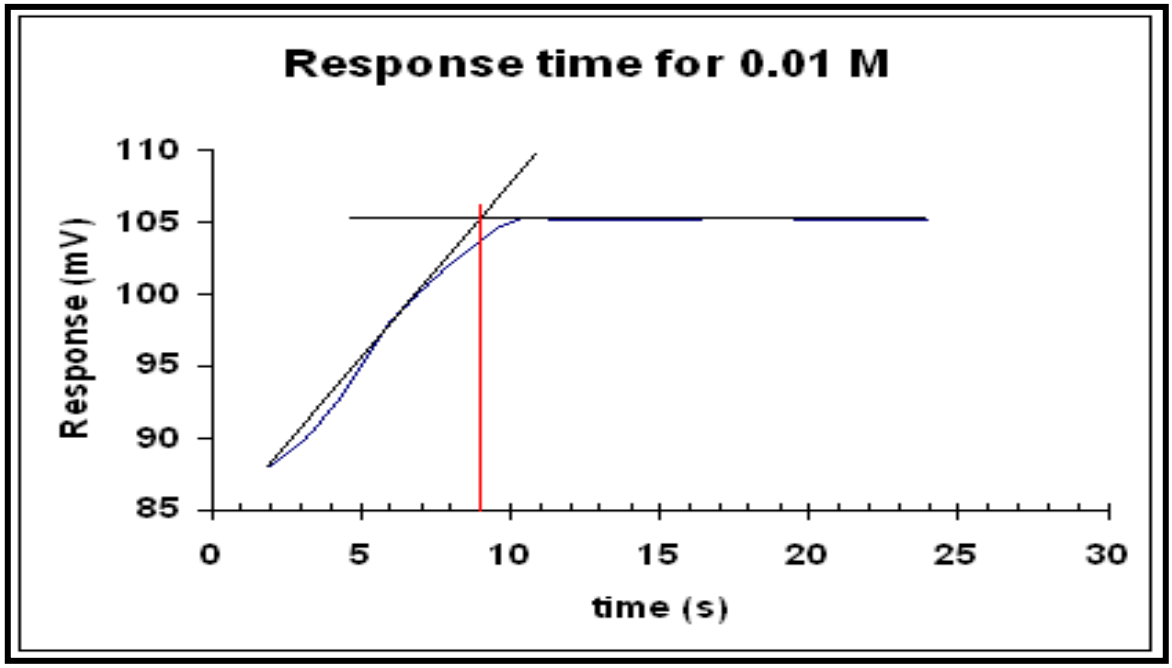
The response time for electrode A based on DBP as a plasticizer for concentration range (10^{-1}-10^{-5}) M is shown in the following figures.



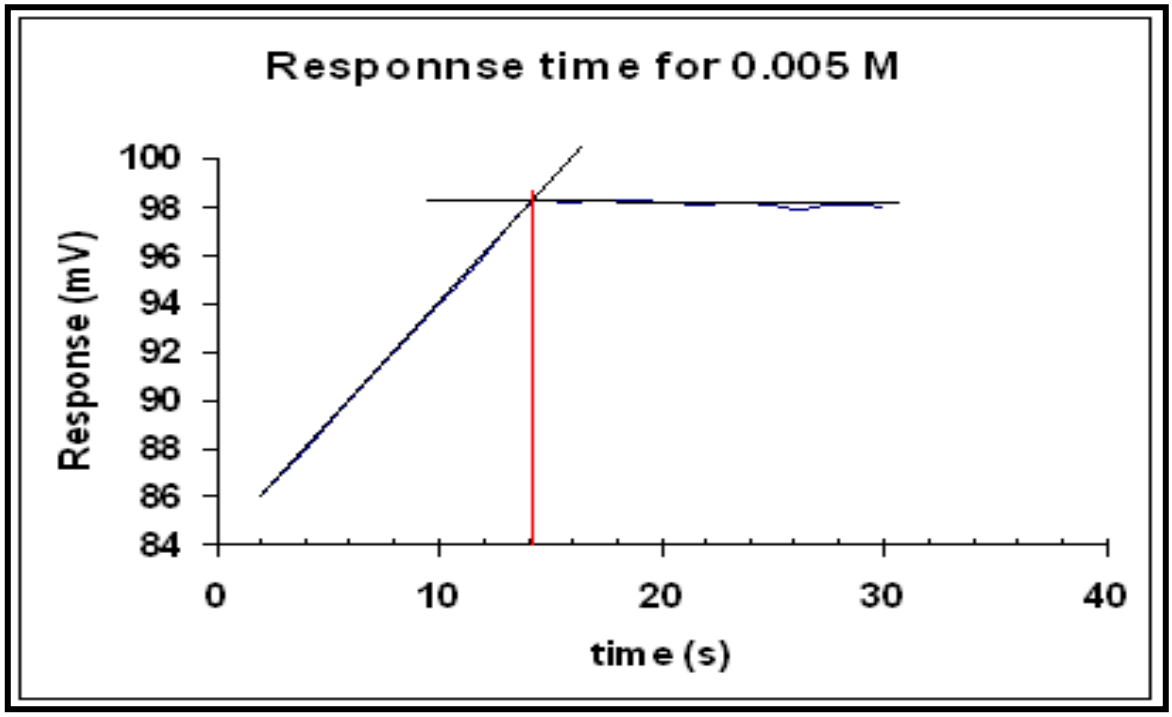
Figure(3-11): Response time of electrode A based on DBP for 0.1 M promethazine hydrochloride.



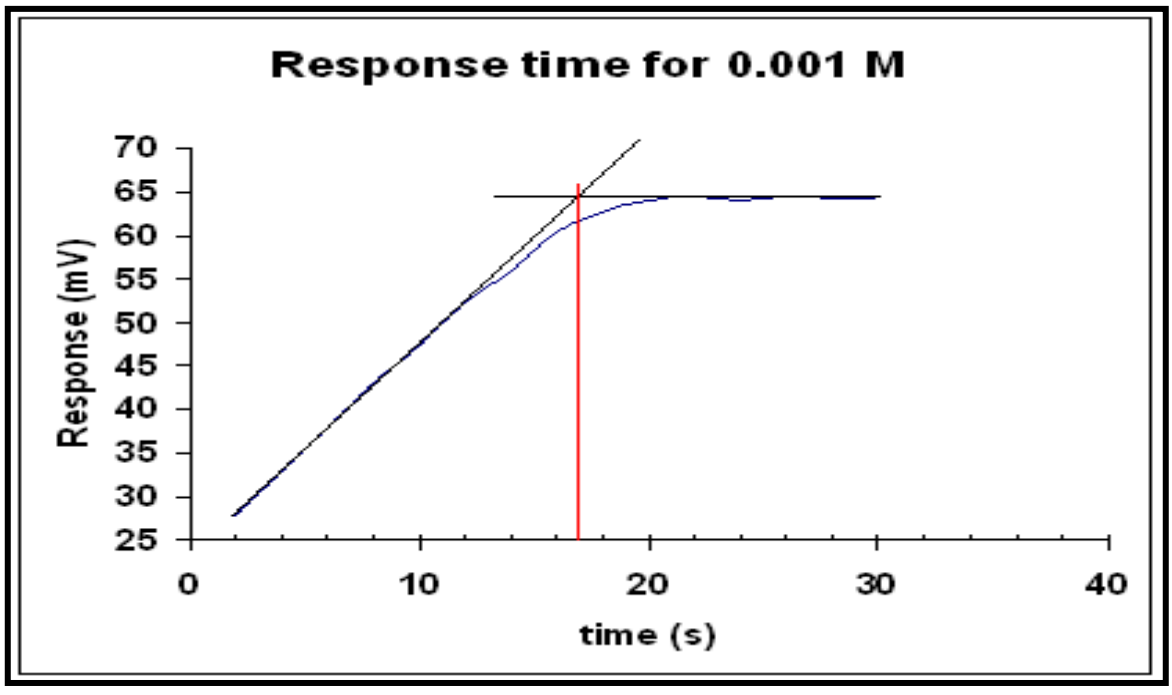
Figure(3-12): Response time of electrode A based on DBP for 0.05 M promethazine hydrochloride.



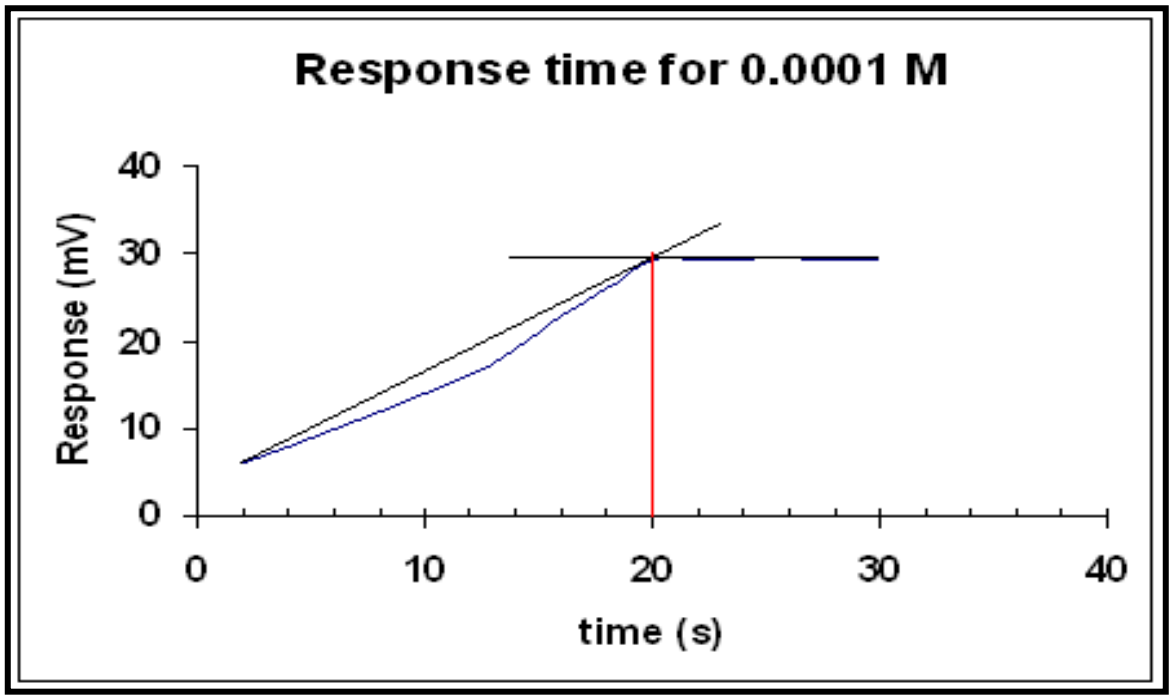
Figure(3-13): Response time of electrode A based on DBP for 0.01 M promethazine hydrochloride.



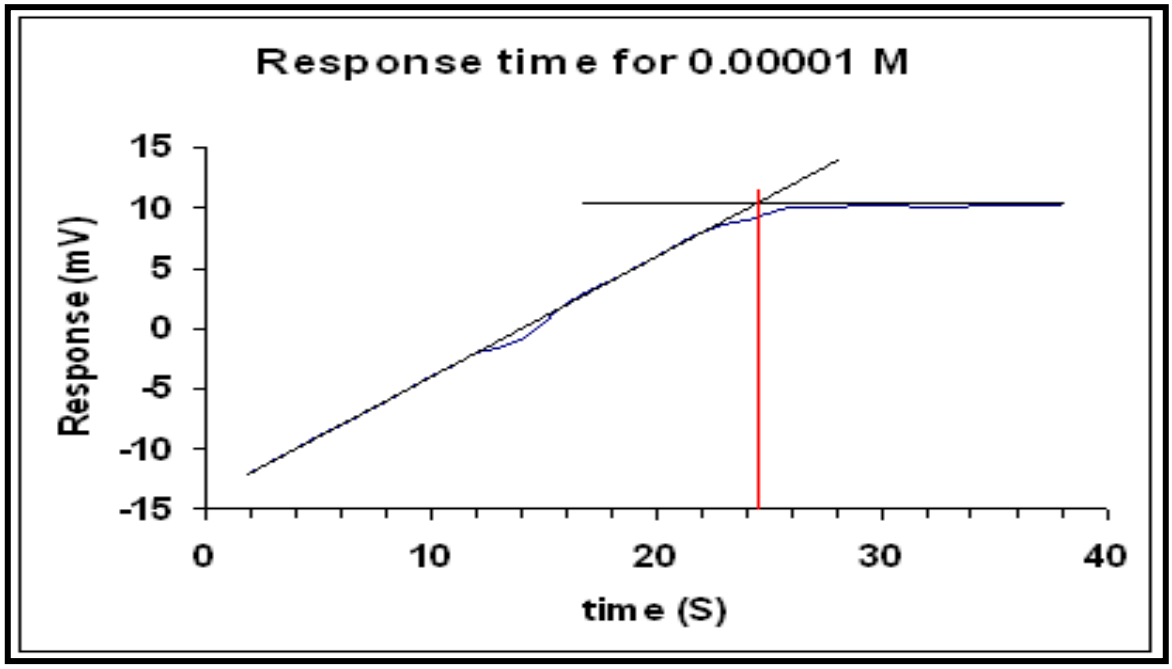
Figure(3-14): Response time of electrode A based on DBP for 0.005 M promethazine hydrochloride.



Figure(3-15): Response time of electrode A based on DBP for 0.001 M promethazine hydrochloride.



Figure(3-16): Response time of electrode A based on DBP for 0.0001 M promethazine hydrochloride.



Figure(3-17): Response time of electrode A based on DBP for 0.00001 M promethazine hydrochloride.

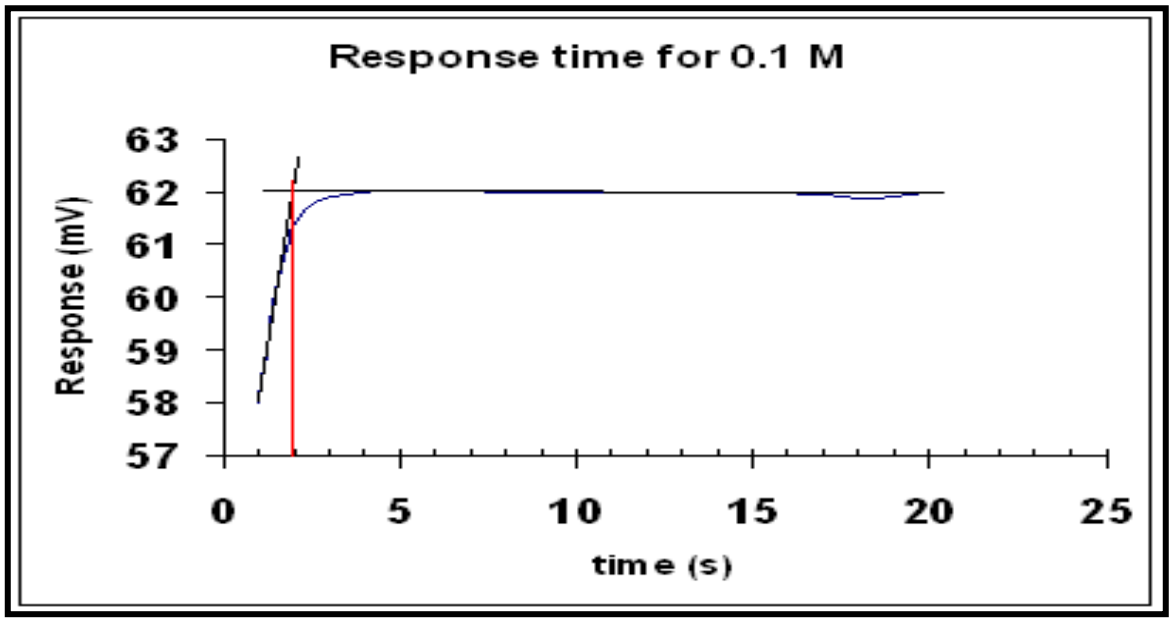
The values of response times for four electrodes (A,B,C and D) were calculated and the results for electrode A based on DBP are listed in table (3-11). As we noticed from the table that the values of response time increase as the concentration decrease. This is attributed to the more time to reach the equilibrium between the complex in the membrane and the external solution when the concentration of external solution is too low.

Table(3-11): Response time at $t_{95\%}$ for electrode A based on DBP.

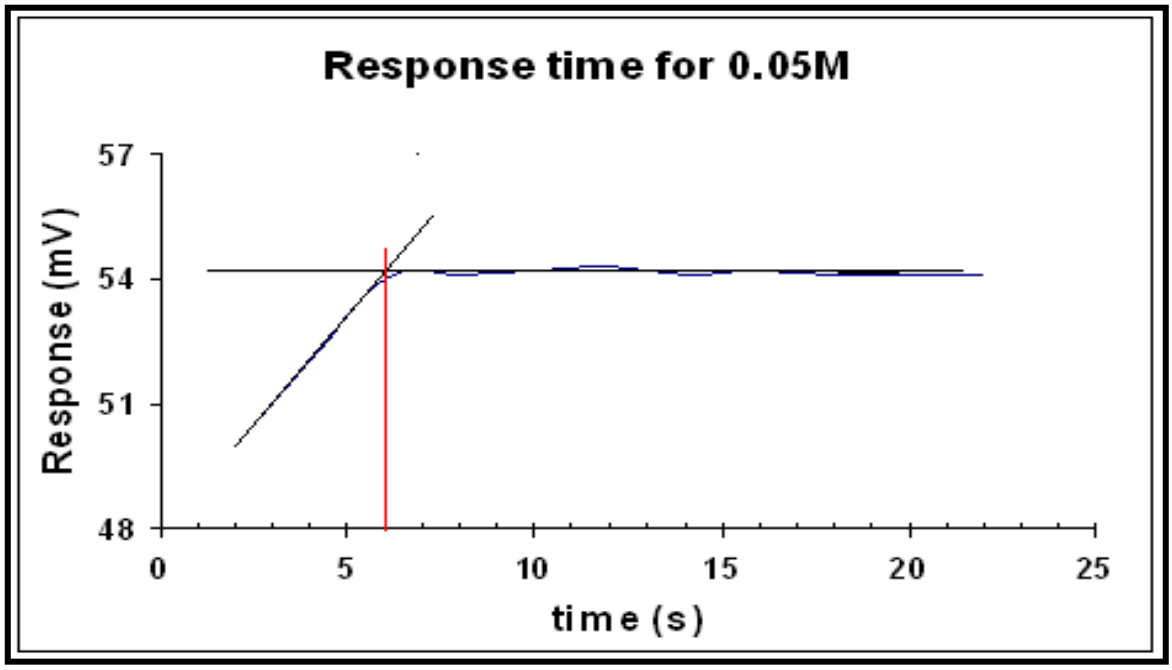
Concentration(M)	Potential (mV) at $t_{100\%}$	Response time	
		Time (s) at 100%	Time(s) at 95%
0.1	147.9	4.0	1.5
0.05	139.0	6.0	3.3
0.01	105.3	9.0	6.9
0.005	98.0	14.0	9.5
0.001	64.5	17.0	16.4
0.0001	29.5	20.0	18.9
0.00001	10.5	24.6	25.4

3-3-2. Response time for electrode B:

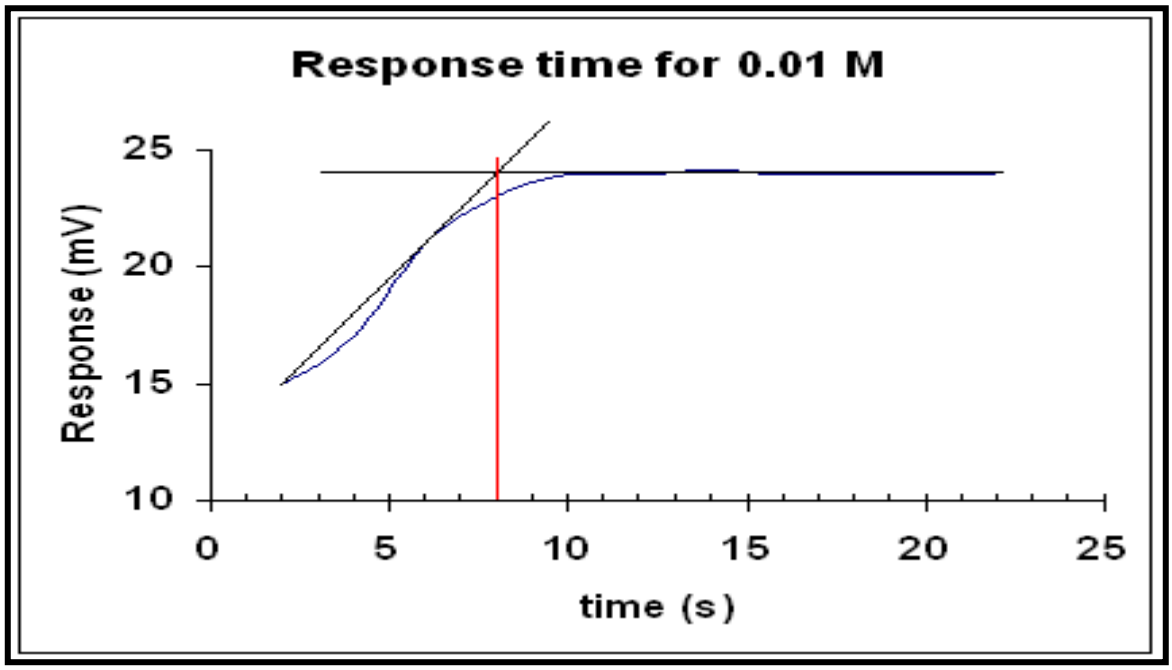
The working response time for electrode B based on TBP as a plasticizer for concentration range (10^{-1}-10^{-5}) M as shown in the following figures.



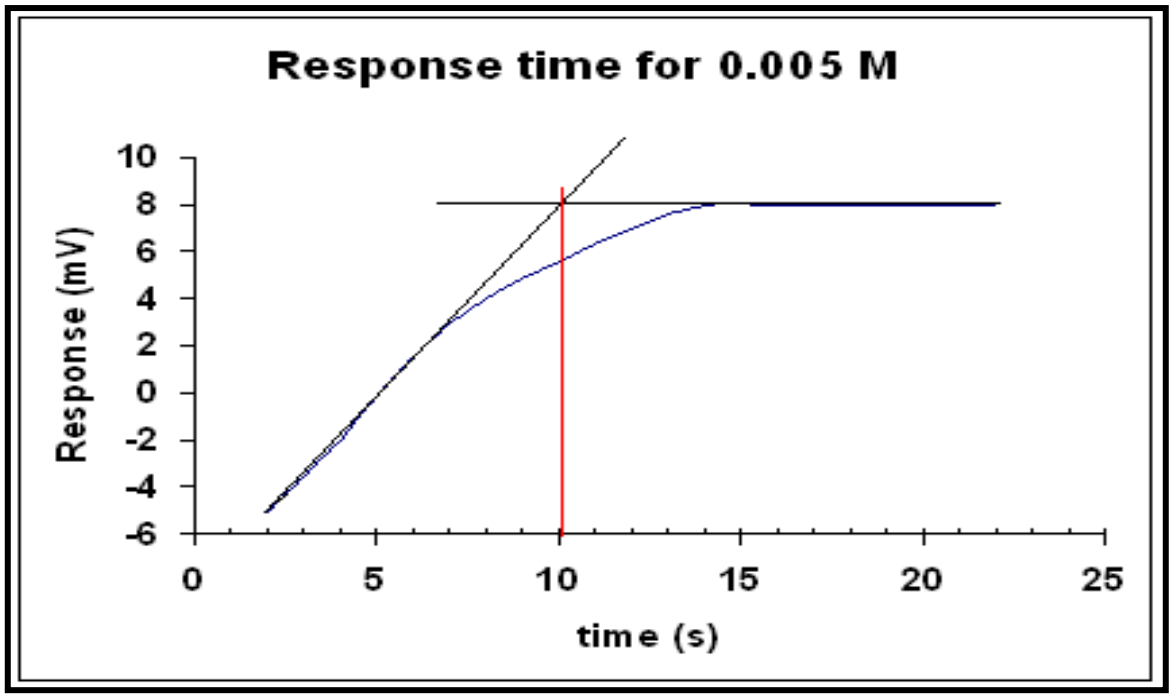
Figure(3-18): Response time of electrode B based on TBP for 0.1 M promethazine hydrochloride.



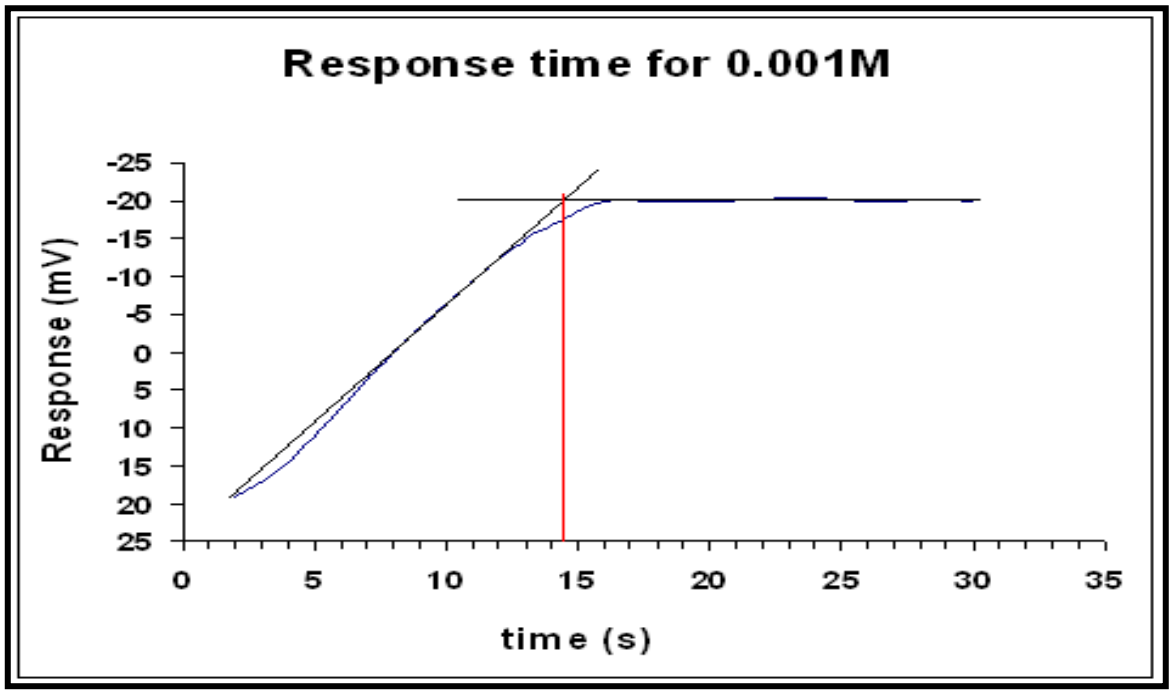
Figure(3-19): Response time of electrode B based on TBP for 0.05 M promethazine hydrochloride.



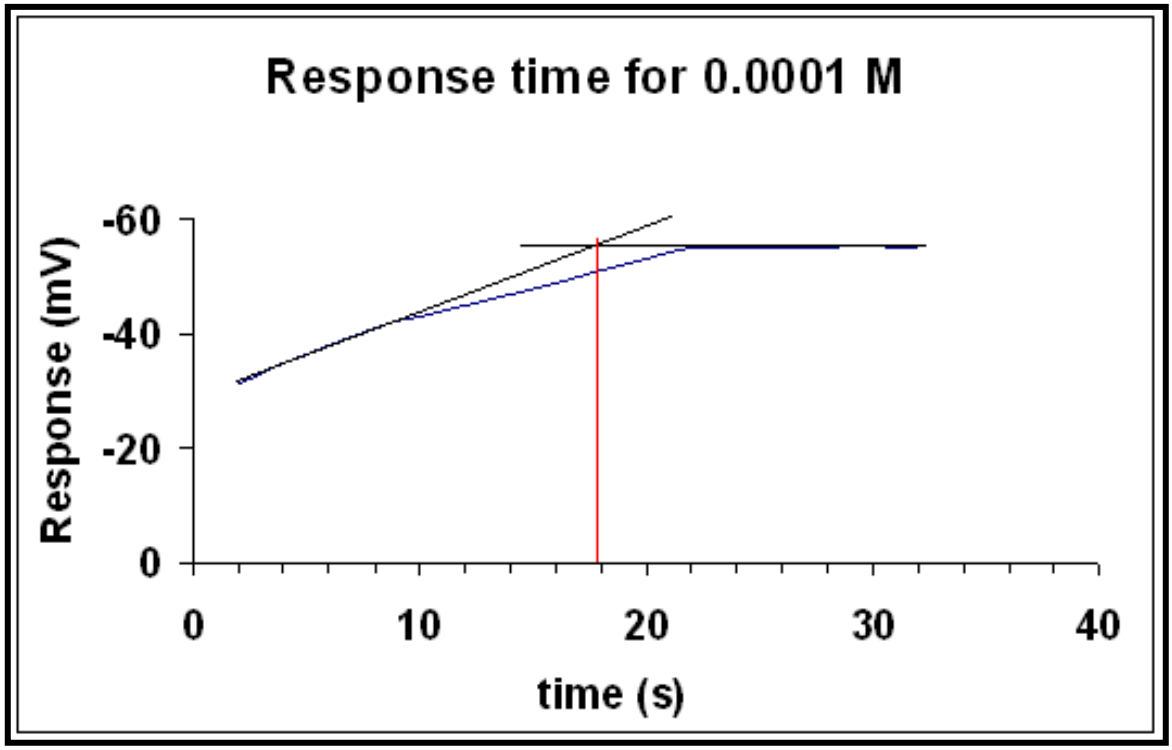
Figure(3-20): Response time of electrode B based on TBP for 0.01 M promethazine hydrochloride.



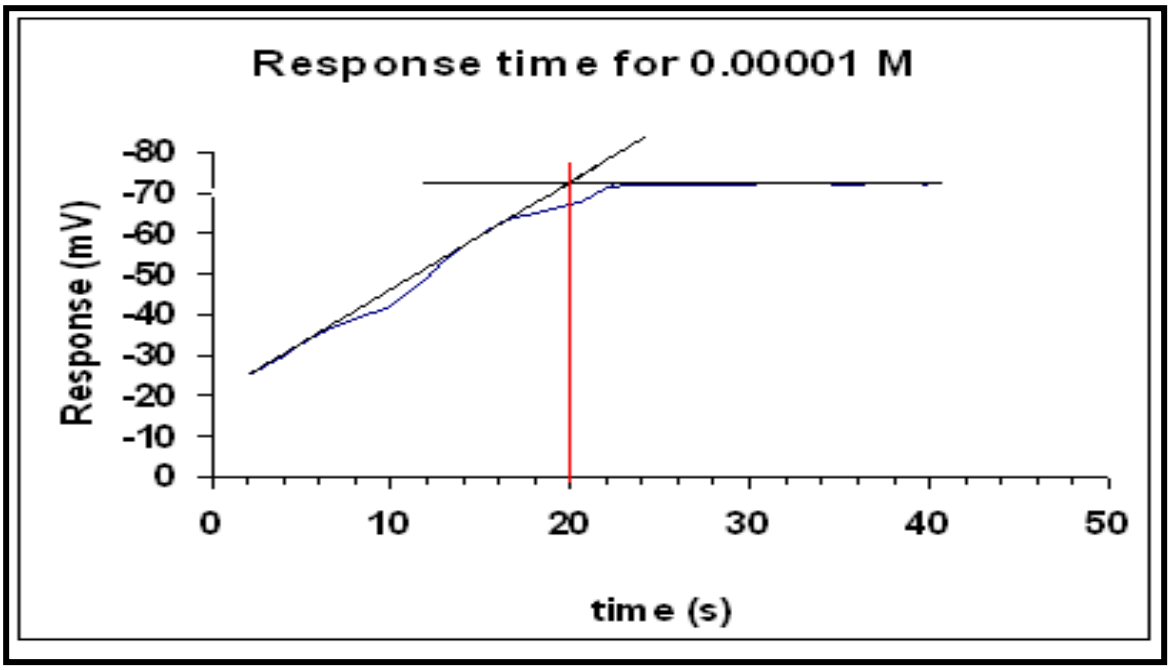
Figure(3-21): Response time of electrode B based on TBP for 0.005 M promethazine hydrochloride.



Figure(3-22): Response time of electrode B based on TBP for 0.001 M promethazine hydrochloride.



Figure(3-23): Response time of electrode B based on TBP for 0.0001 M promethazine hydrochloride.



Figure(3-24): Response time of electrode B based on TBP for 0.00001 M promethazine hydrochloride.

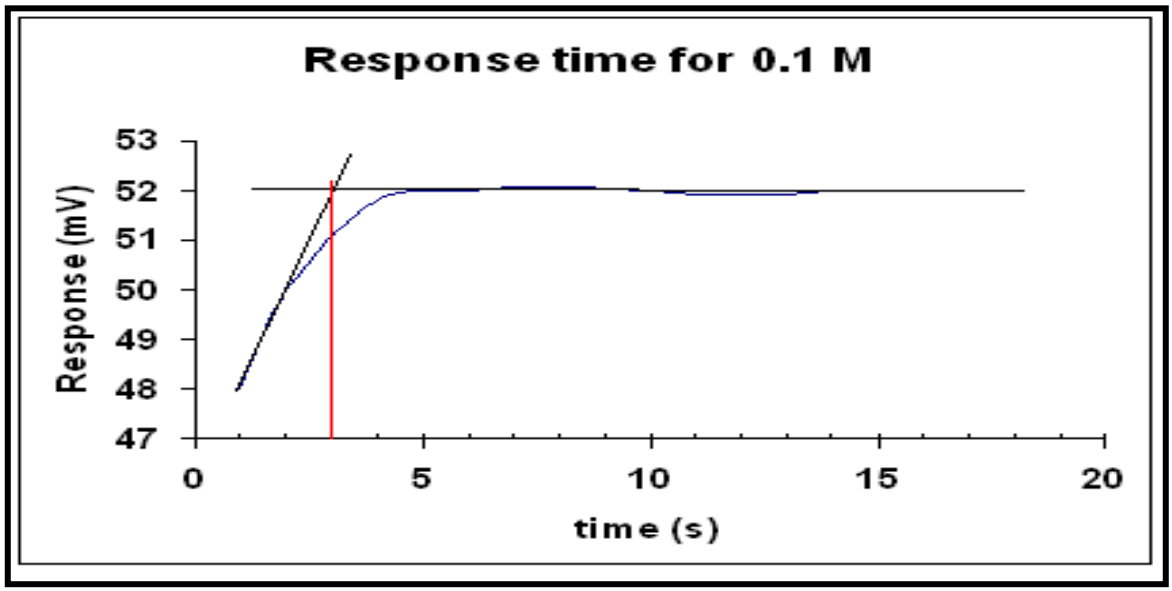
The response time for electrode B is less than electrode A because the low viscosity for electrode B as shown in table (3-5), that was high mobility of complex inside the membrane matrix so that increase the ion exchange process between the complex inside the membrane and the external solution.

Table(3-12): Response time at $t_{95\%}$ for electrode B based on TBP.

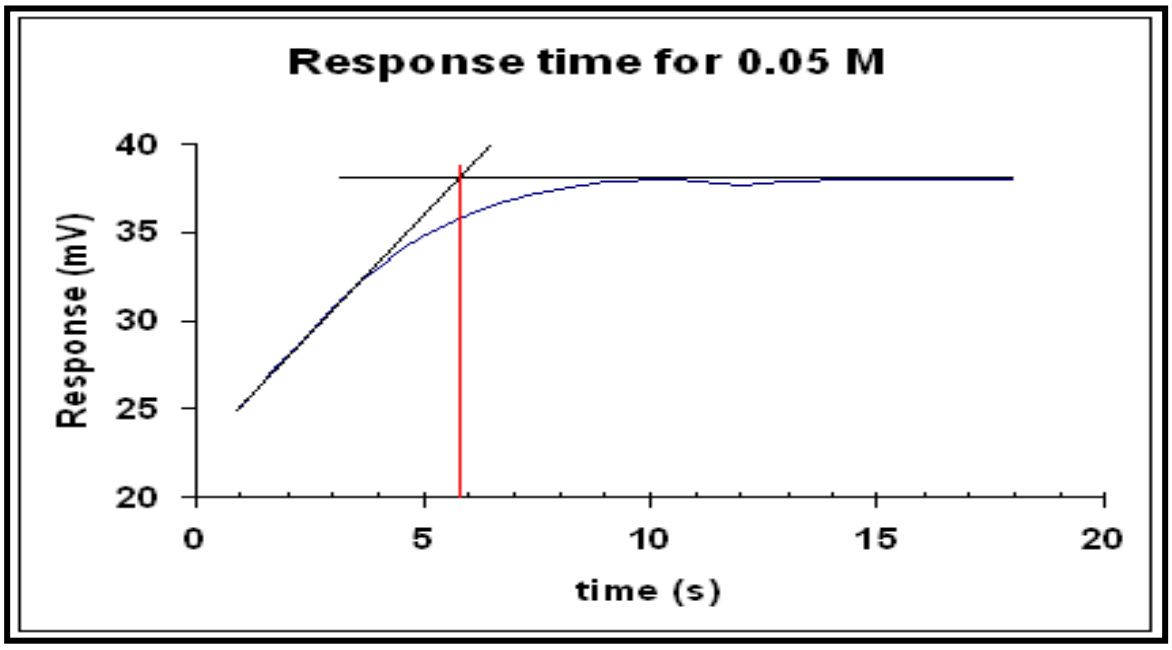
Concentration(M)	Potential (mV) at $t_{100\%}$	Response time	
		Time (s) at 100%	Time (s) at 95%
0.1	62.1	2.0	1.2
0.05	54.3	6.0	3.7
0.01	24.0	8.0	7.2
0.005	8.0	10.0	13.0
0.001	-20.0	14.5	15.3
0.0001	-55.0	17.9	18.9
0.00001	-74.0	20.0	21.5

3-3-3. Response time for electrode C:

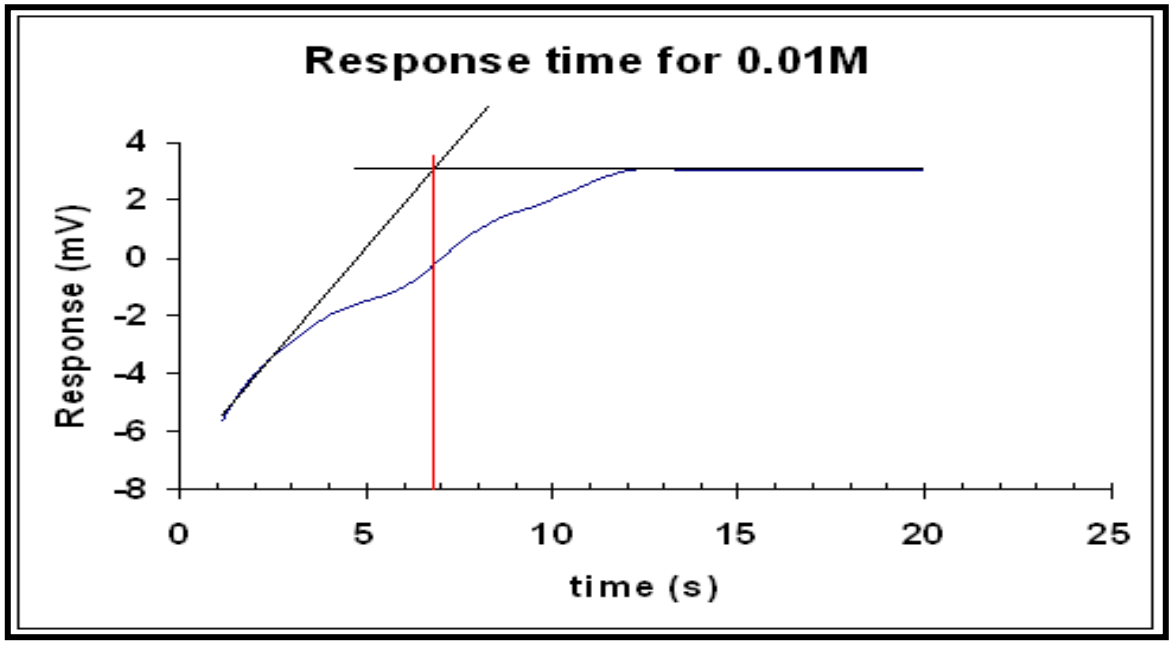
The working response time for electrode C based on ONPOE as a plasticizer for concentration range (10^{-1}-10^{-5}) M as shown in the following figures.



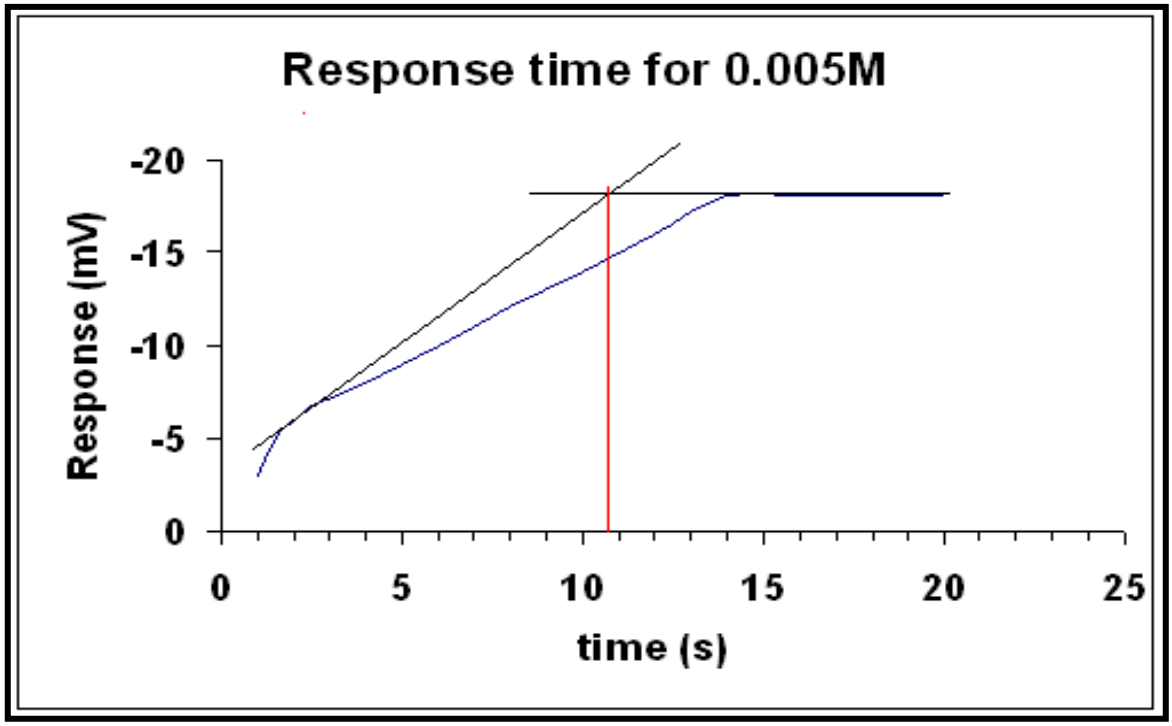
Figure(3-25): Response time of electrode C based on ONPOE for 0.1 M promethazine hydrochloride.



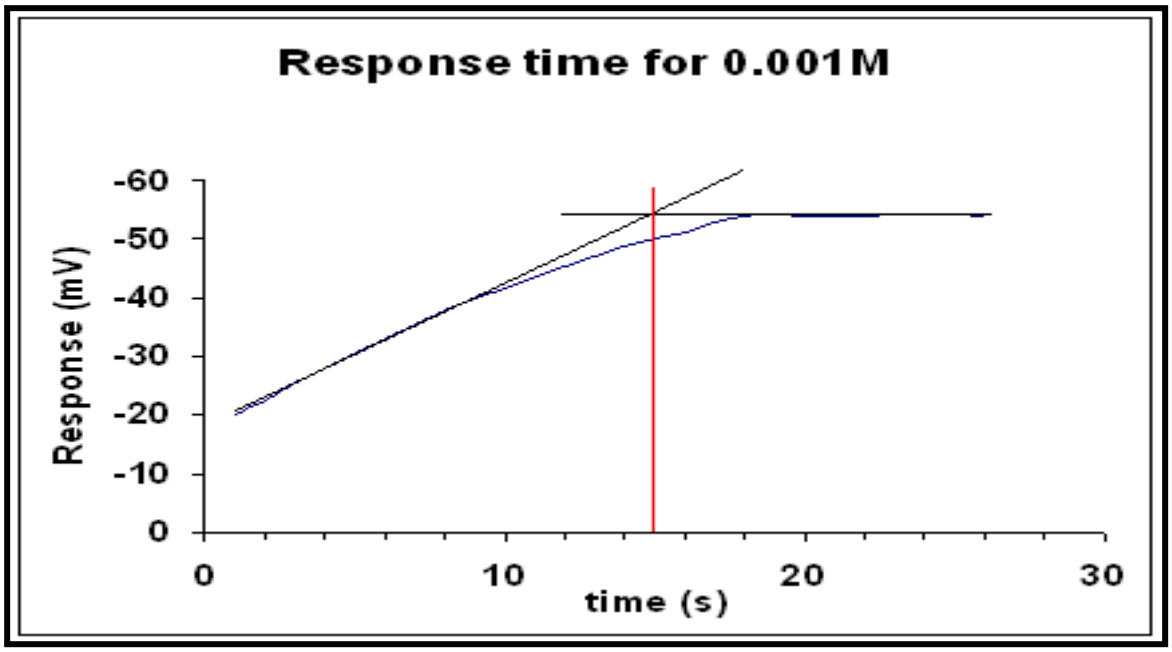
Figure(3-26): Response time of electrode C based on ONPOE for 0.05 M promethazine hydrochloride.



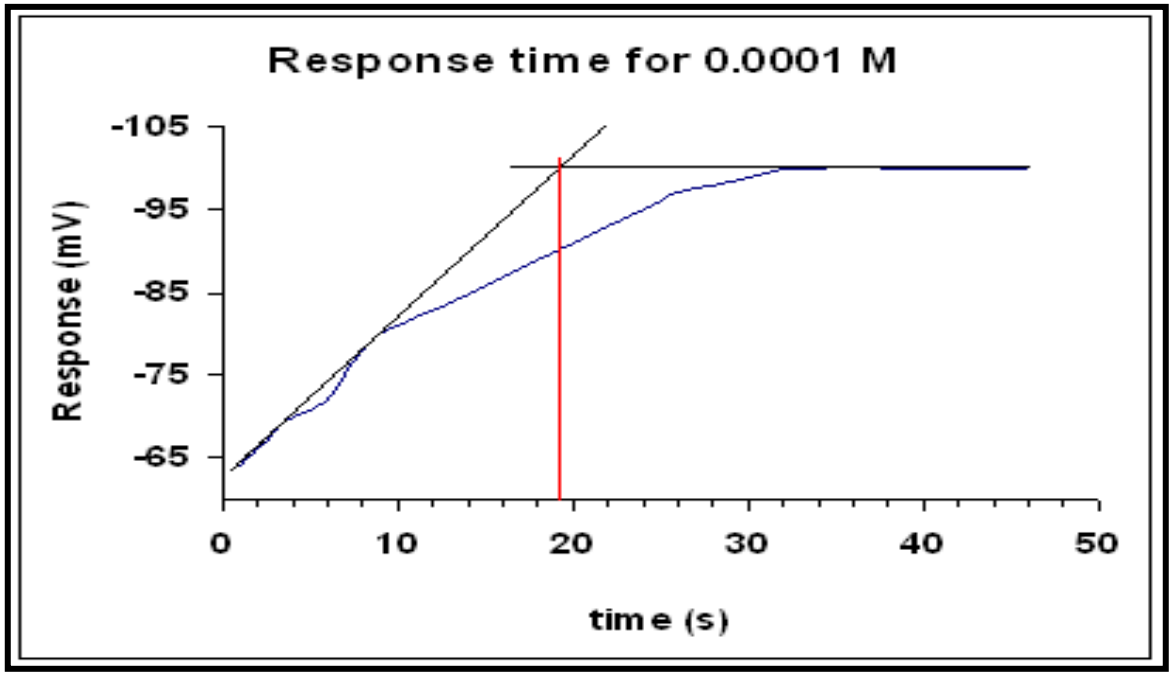
Figure(3-27): Response time of electrode C based on ONPOE for 0.01 M promethazine hydrochloride.



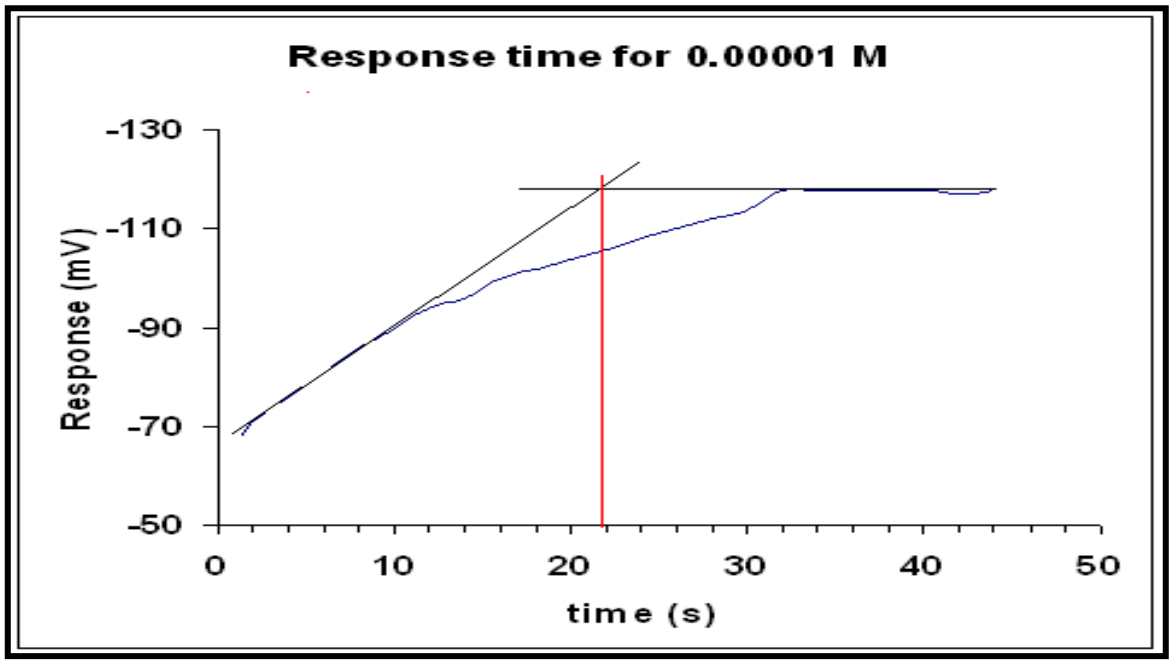
Figure(3-28): Response time of electrode C based on ONPOE for 0.005 M promethazine hydrochloride.



Figure(3-29): Response time of electrode C based on ONPOE for 0.001 M promethazine hydrochloride.



Figure(3-30): Response time of electrode C based on ONPOE for 0.0001 M promethazine hydrochloride.



Figure(3-31): Response time of electrode C based on ONPOE for 0.00001 M promethazine hydrochloride.

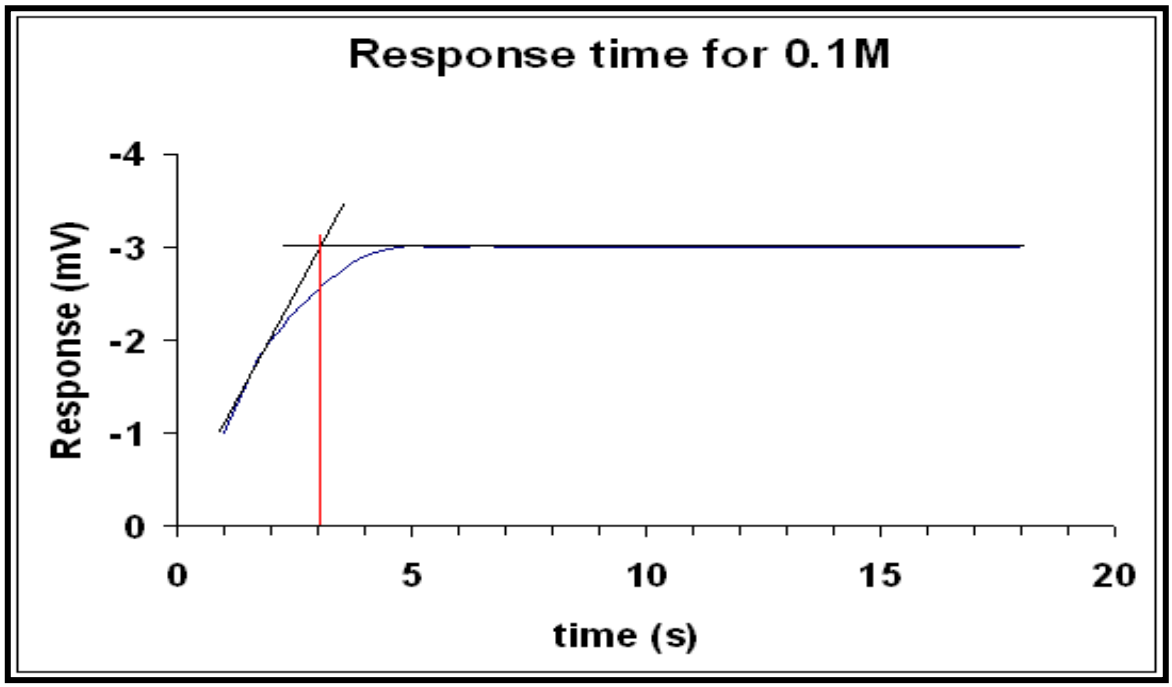
It was measured the response time for electrode C at 95% and it was listed in table (3-13).

Table(3-13): Response time at $t_{95\%}$ for electrode C based on ONPOE.

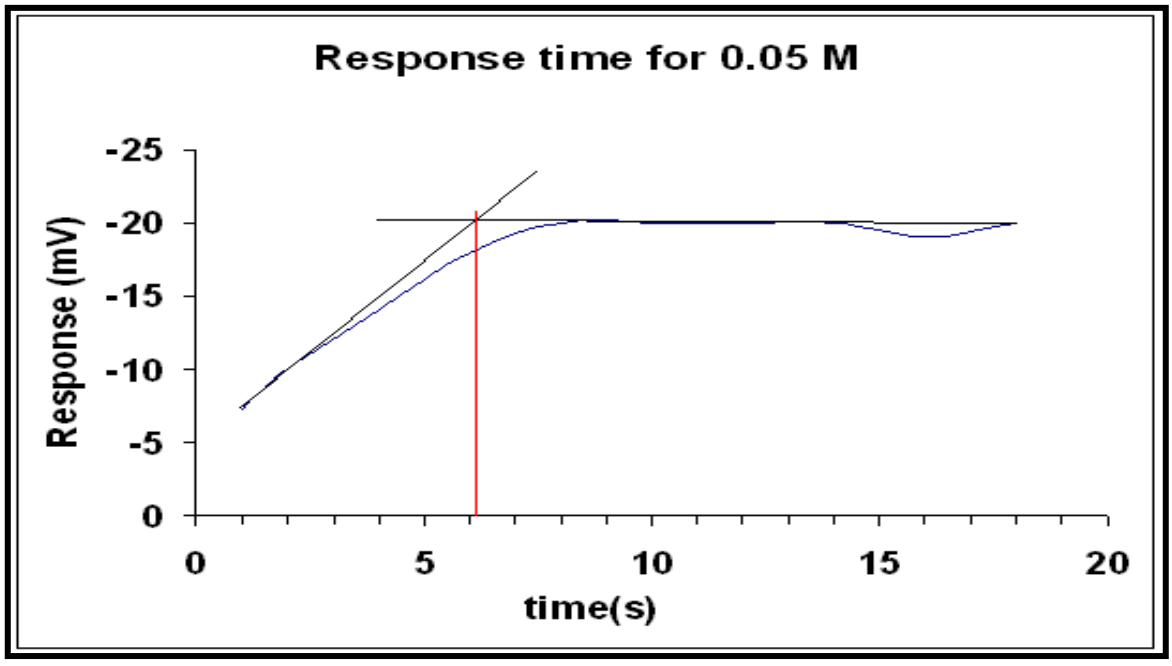
Concentration(M)	Potential (mV) at $t_{100\%}$	Response time	
		Time (s) at 100%	Time (s) at 95%
0.1	52.1	3.0	1.8
0.05	38.0	5.8	6.6
0.01	3.0	6.8	11.2
0.005	-18.0	10.8	12.9
0.001	-54.0	15.0	15.9
0.0001	-100.0	19.2	23.9
0.00001	-118.0	21.9	25.0

3-3-4. Response time for electrode D:

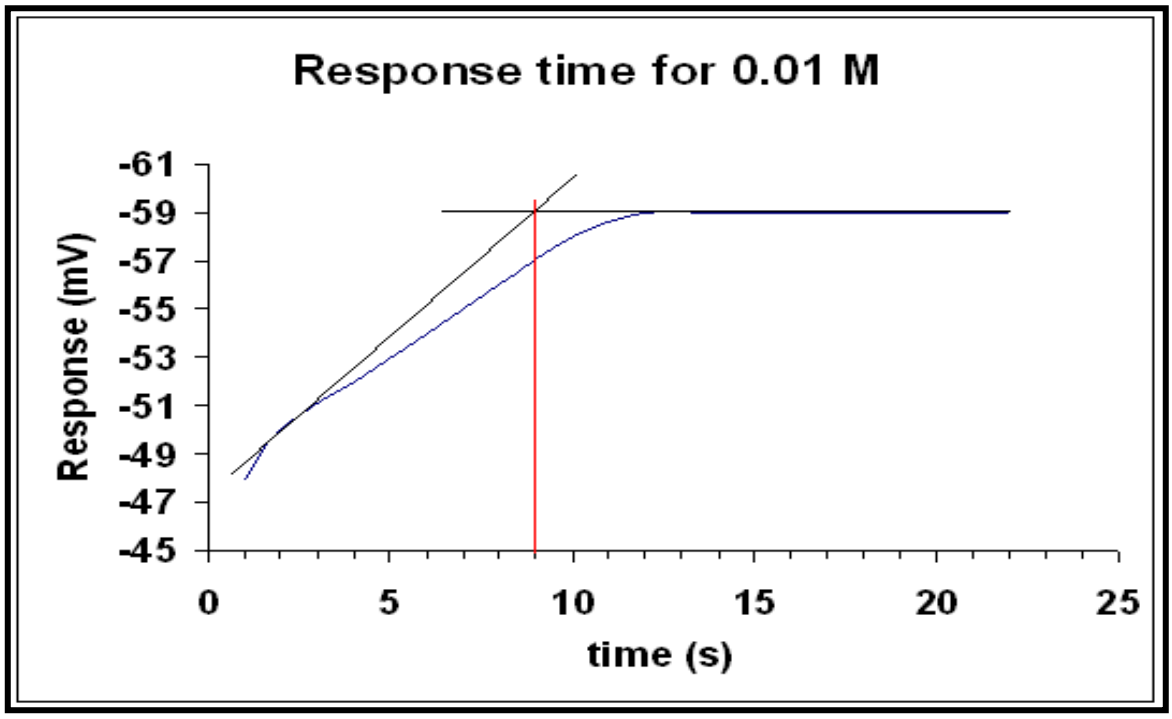
The working response time for electrode D based on DBPH as a plasticizer for concentration range (10^{-1}-10^{-5}) M as shown in the following figures.



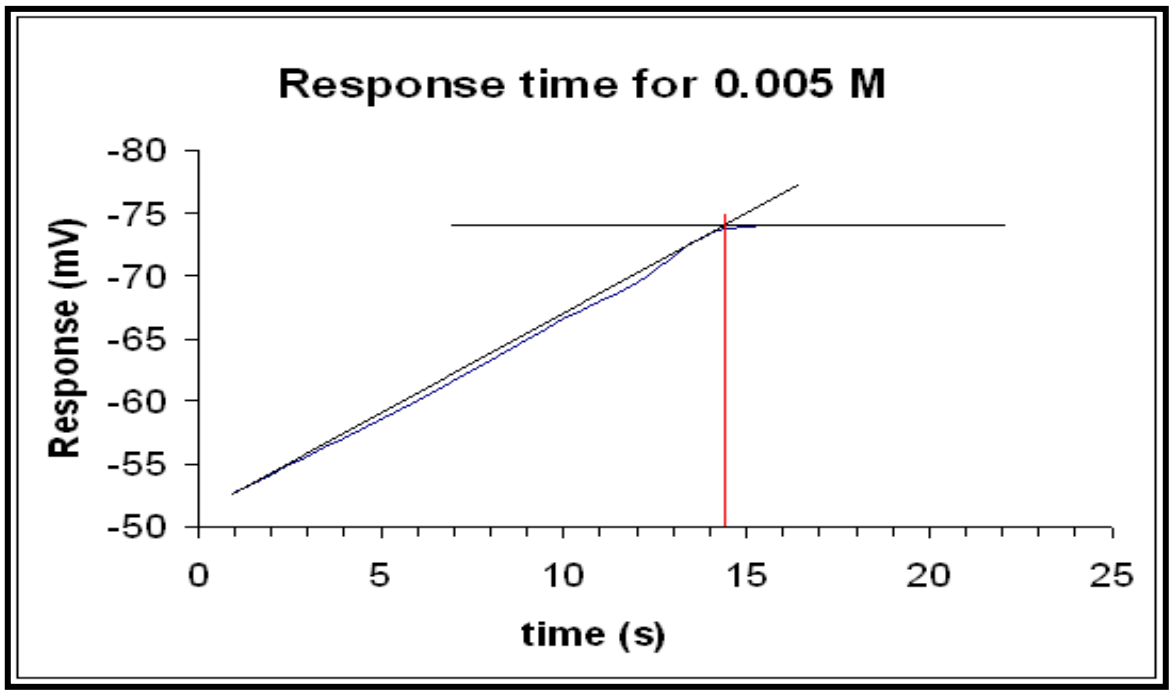
Figure(3-32): Response time of electrode D based on DBPH for 0.1 M promethazine hydrochloride.



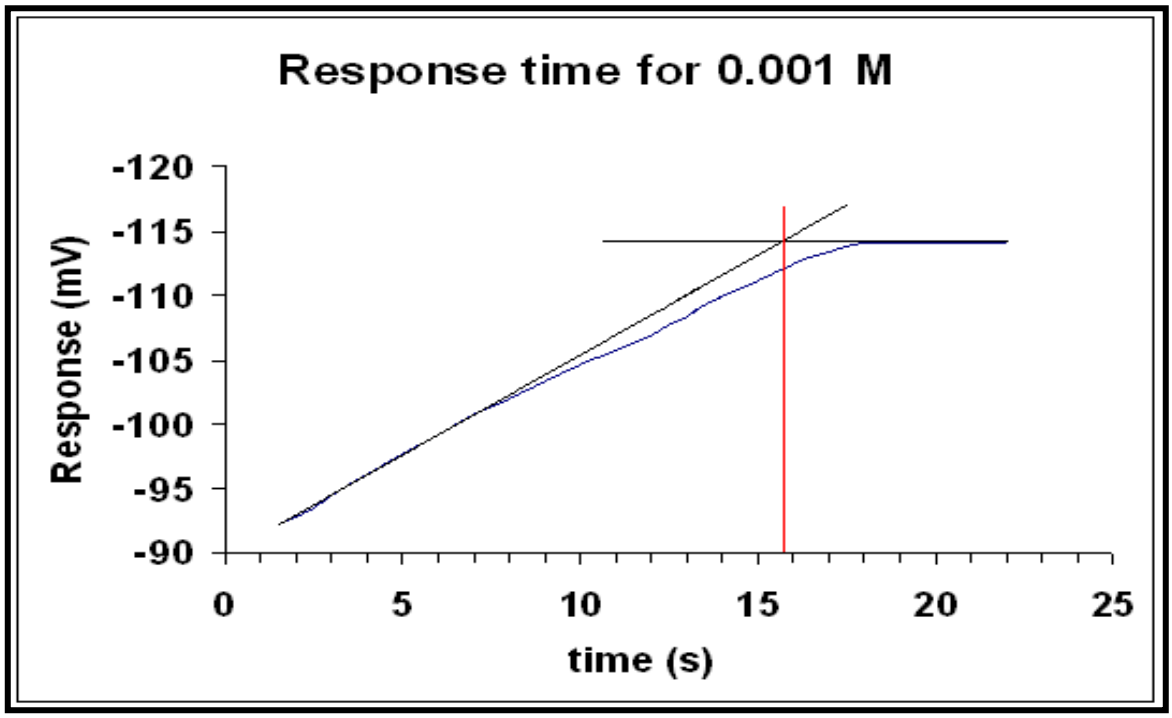
Figure(3-33): Response time of electrode D based on DBPH for 0.05 M promethazine hydrochloride.



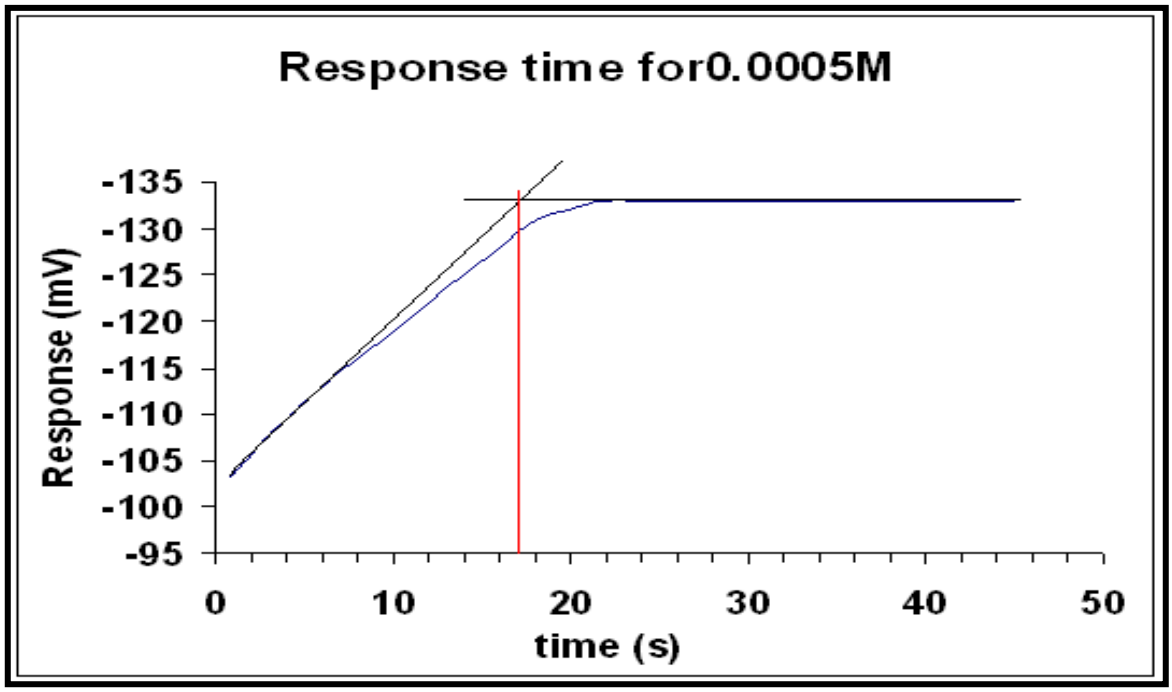
Figure(3-34): Response time of electrode D based on DBPH for 0.01 M promethazine hydrochloride.



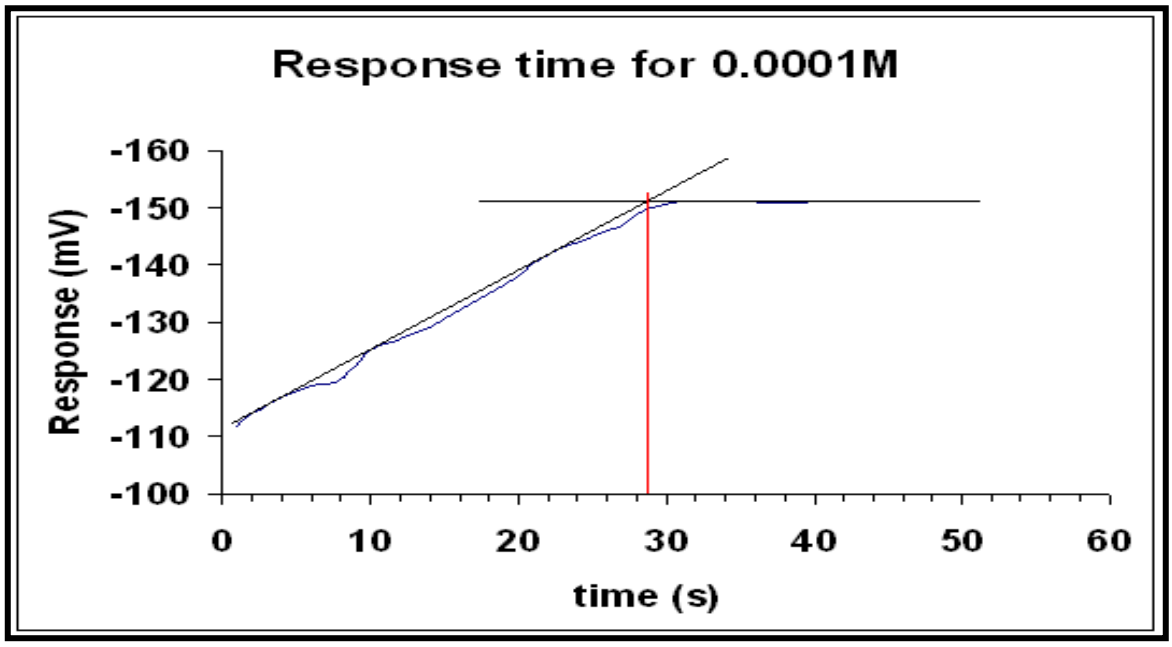
Figure(3-35): Response time of electrode D based on DBPH for 0.005 M promethazine hydrochloride.



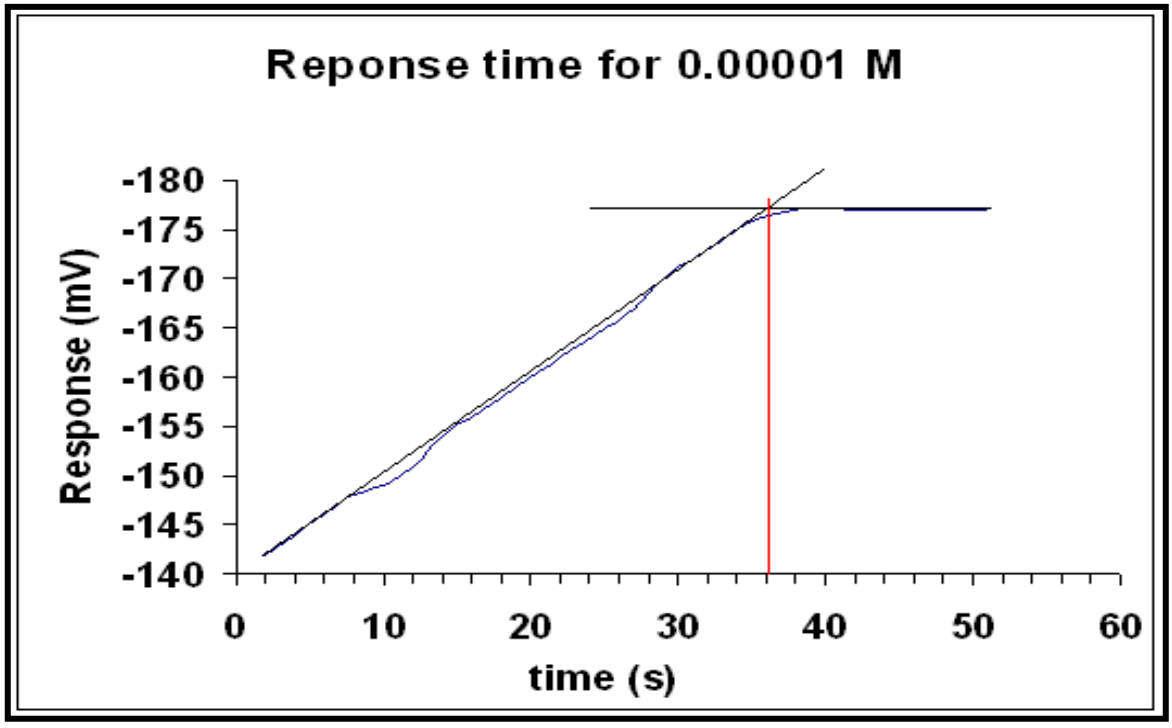
Figure(3-36): Response time of electrode D based on DBPH for 0.001 M promethazine hydrochloride.



Figure(3-37): Response time of electrode D based on DBPH for 0.0005 M promethazine hydrochloride.



Figure(3-38): Response time of electrode D based on DBPH for 0.0001 M promethazine hydrochloride.



Figure(3-39): Response time of electrode D based on DBPH for 0.00001 M promethazine hydrochloride.

It was measured the response time for electrode D, it was noticed the response time for electrode C is less than that of electrode D that for the several factor may be due to life time of the electrode C, so that decrease the response time for electrode C. Which , it was can be measured the response time in 95%, it was listed in table (3-9).

Table(3-14): Response time at $t_{95\%}$ for electrode D based on DBPH.

Concentration(M)	Potential (mV) at $t_{100\%}$	Response time	
		Time (s) at 100%	Time (s) at 95%
0.1	-3.0	3.1	3.9
0.05	-20.1	6.2	7.0
0.01	-59.0	9.0	8.4
0.005	-74.0	14.5	12.4
0.001	-114.0	15.0	13.5
0.0005	-133.0	17.0	14.9
0.0001	-151.0	28.9	23.5
0.00001	-177.1	36.1	28.0

3-4. Selectivity of the four electrodes:

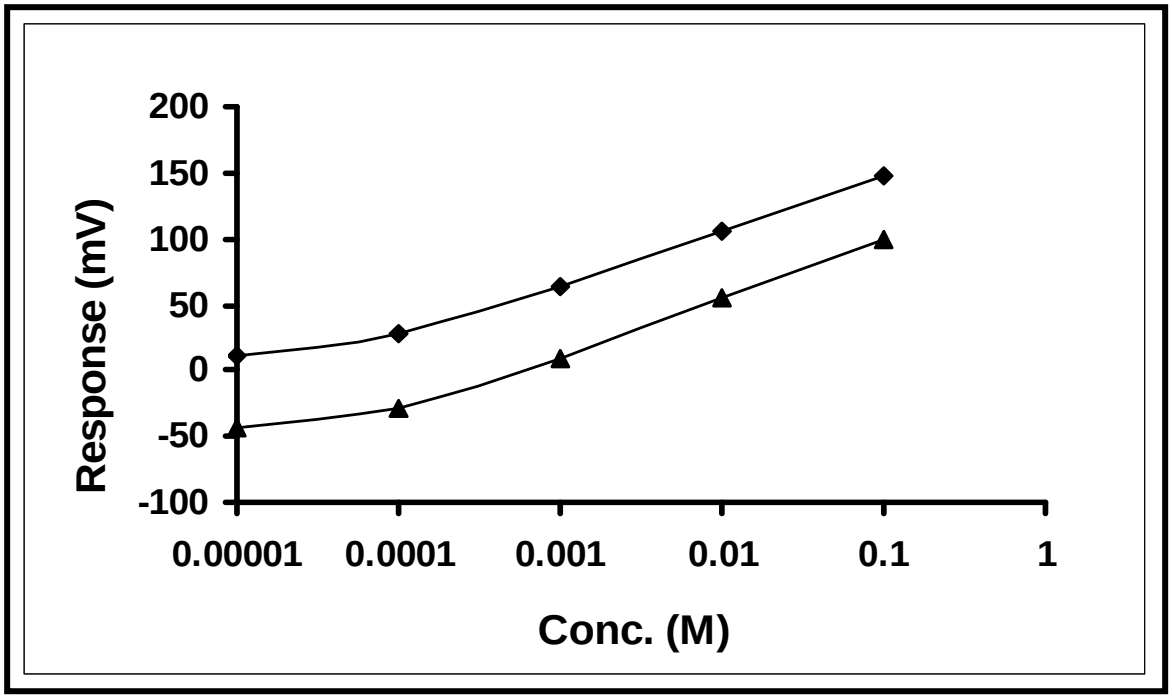
The influence of some inorganic cations such as (Li^+,Na^+,K^+,Mg^{+2},Ca^{+2},Zn^{+2},Al^{+3},Fe^{+3},Cr^{+3}) on these four electrodes was also studied. The selectivities of the four electrodes (A,B,C and D) were measured by separate solution method for concentrations range (10^{-1}-10^{-5}) M of the promethazine hydrochloride solutions and concentrations for each cation were ranged from 10^{-1} to 10^{-5} M and the potentiometric selective coefficients were calculated by using equation(1-8). Also the match method was used for measuring the selectivity coefficients, in which this method can be used when the non – Nerstain behavior was obtained for the electrode. This method is including to prepare one standard solution of promethazine hydrochloride with concentration 10^{-3}

M in 25 ml then added 0.1 ml of 0.1 M from standard solution of promethazine hydrochloride which has concentration 100 times more than that of sample, and measured the potential of standard solution 10^{-3} M before and after each addition of standard solution. 0.1 ml of 0.1 M of interfering ion (Li^{+}, Na^{+}, K^{+}, Ca^{2+}, Mg^{2+}, Zn^{2+}, Al^{3+}, Fe^{3+}, Cr^{3+}) was added to the same concentration 10^{-3} M of promethazine hydrochloride and measured potential before and after each addition of interfering ions, the potentiometric selectivity coefficients, which were calculated by using equation (1-11).

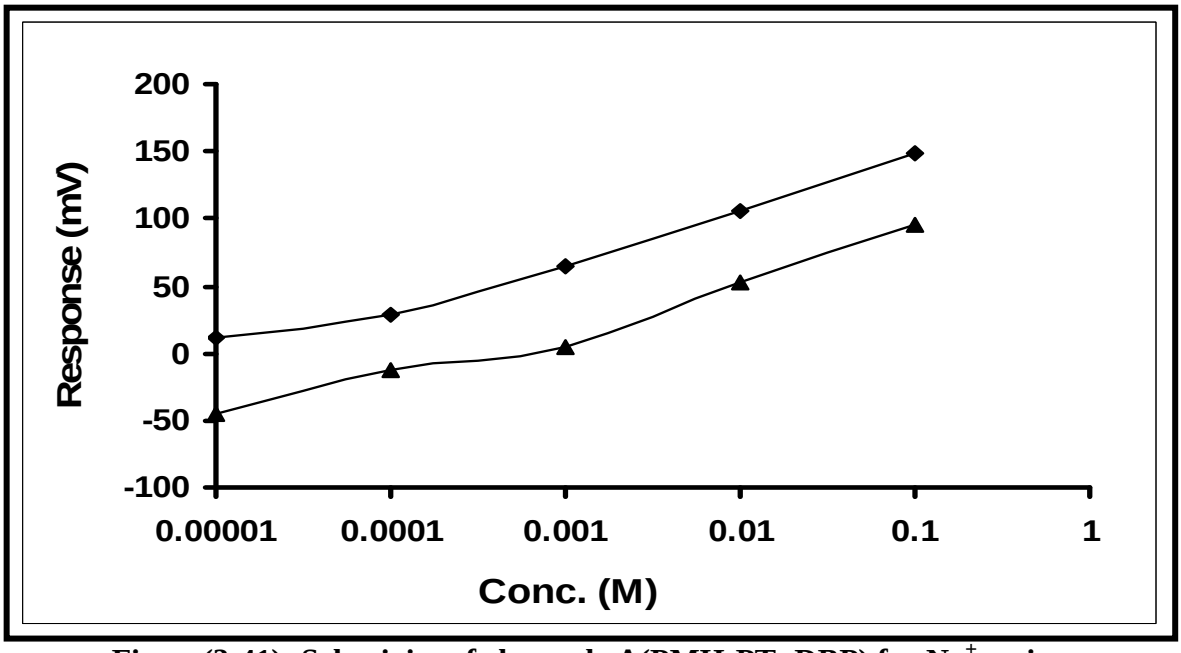
3-4-1. Selectivity by separation method:

3-4-1-1.Selectivityof the electrode A:

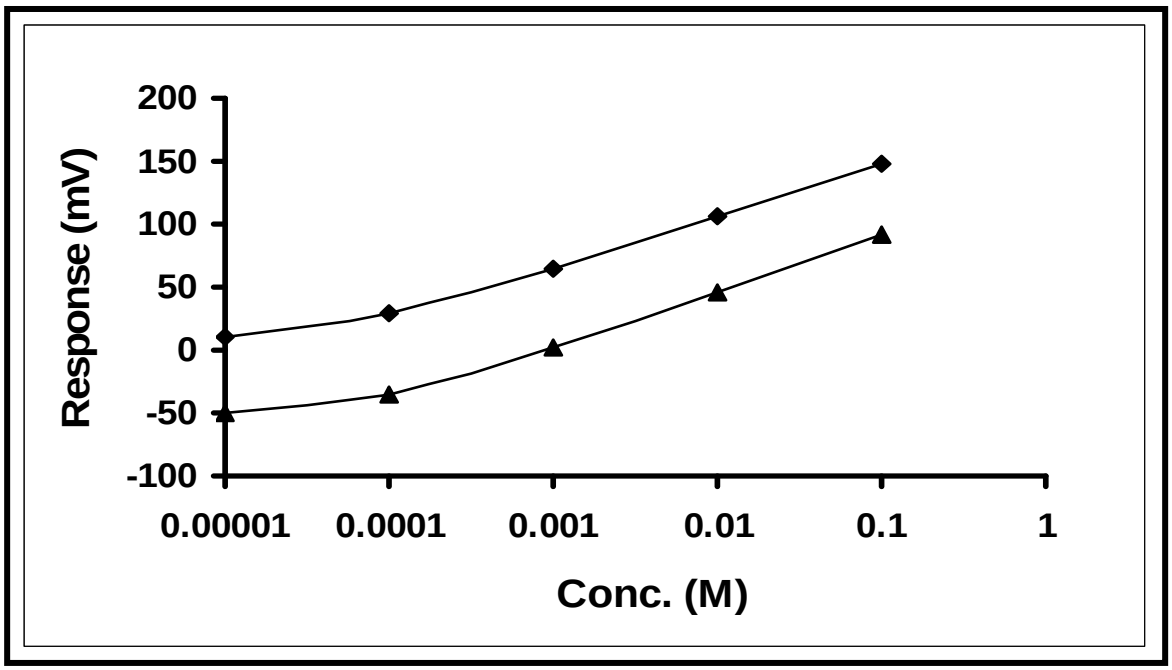
The influence of some inorganic cations such as (Li^{+},Na^{+},K^{+},Mg^{+2},Ca^{+2},Zn^{+2},Al^{+3},Fe^{+3},Cr^{+3}) for electrode A was measured. The selectivity of electrode A (PMH-PT+DBP) can be measured by separation solution method for concentrations range (10^{-5}-10^{-1}) M of promethazine hydrochloride solutions in presence of cations solutions, the potentiometric selectivity coefficients were calculated by using equation(1-8), and the results are shown in figures (3-40) to (3-48).



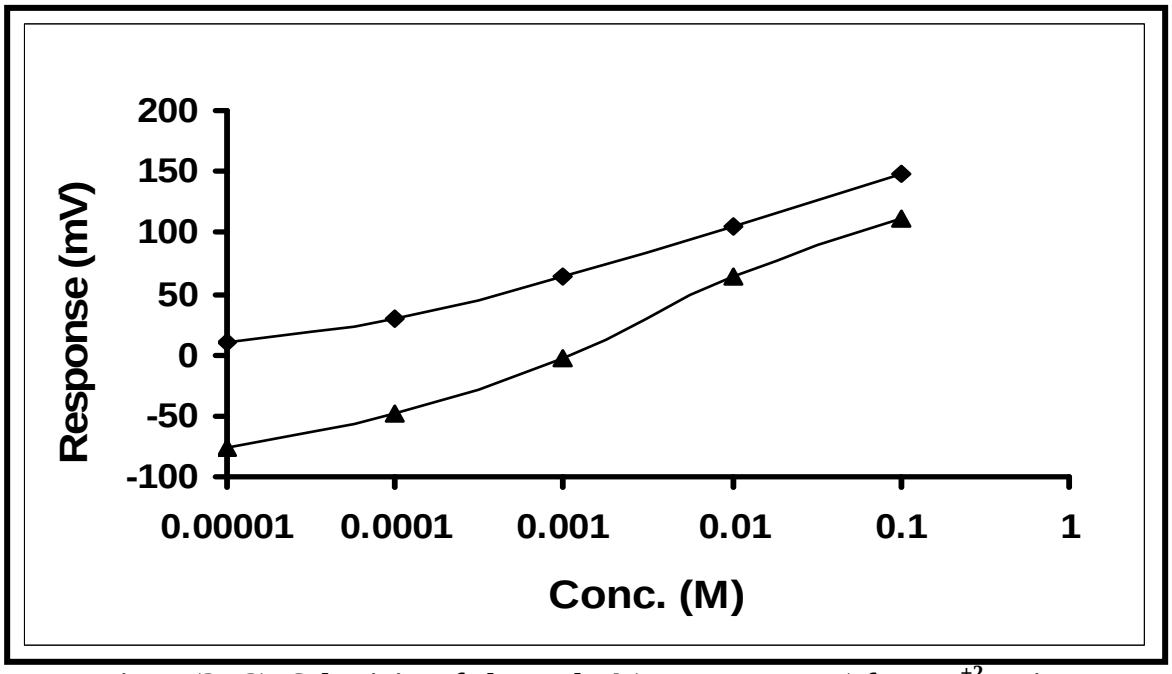
Figure(3-40): Selectivity of electrode A(PMH-PT+DBP) for Li^+ cation interfering by separation method,♦ promethazine hydrochloride solutions, ▲ solutions of lithium cation interfering.



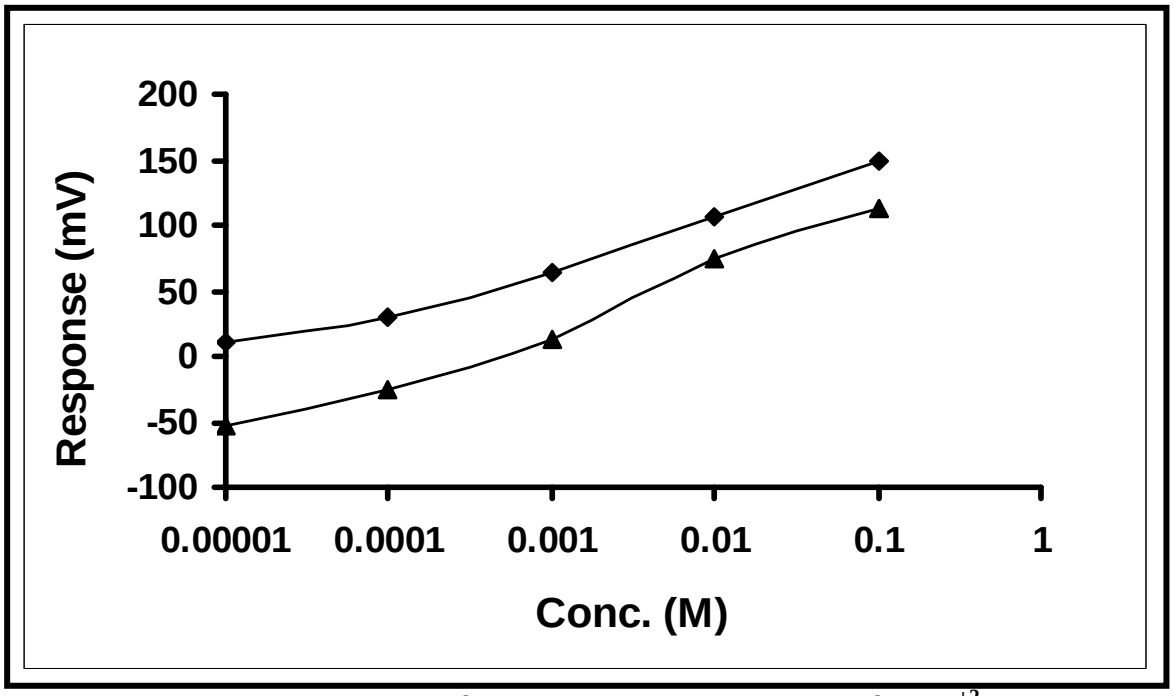
Figure(3-41): Selectivity of electrode A(PMH-PT+DBP) for Na^+ cation interfering by separation method,♦ promethazine hydrochloride solutions, ▲solutions of potassium cation interfering.



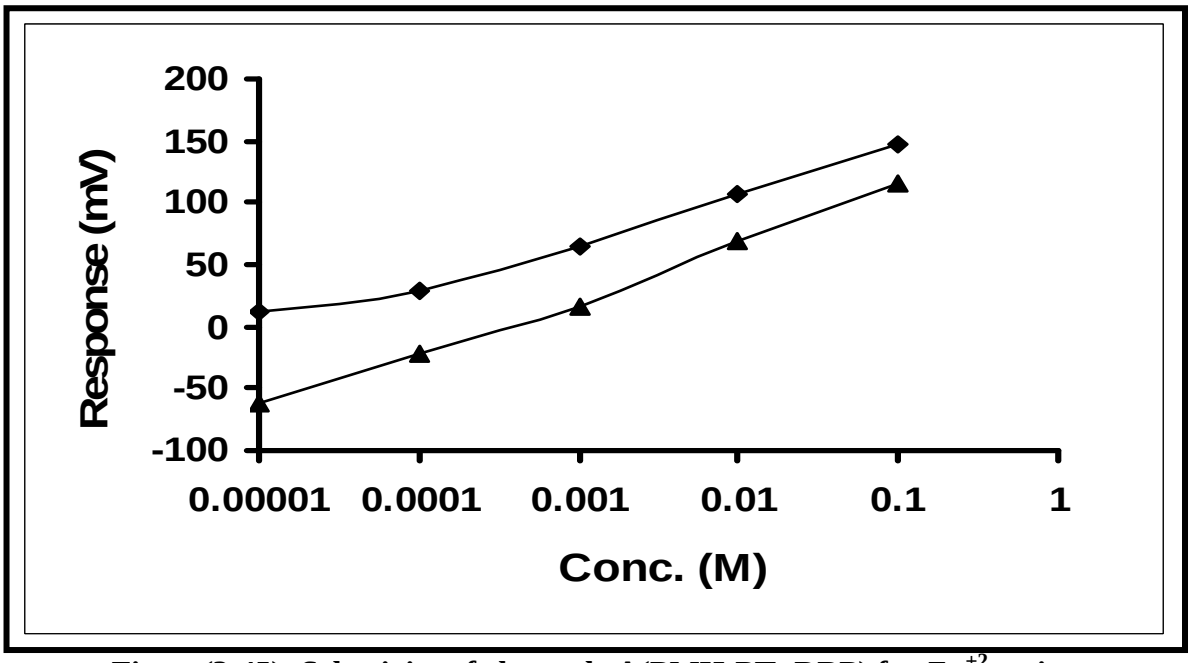
Figure(3-42): Selectivity of electrode A(PMH-PT+DBP) for K^+ cation interfering by separation method,♦ promethazine hydrochloride solutions, ▲ solutions of sodium cation interfering.



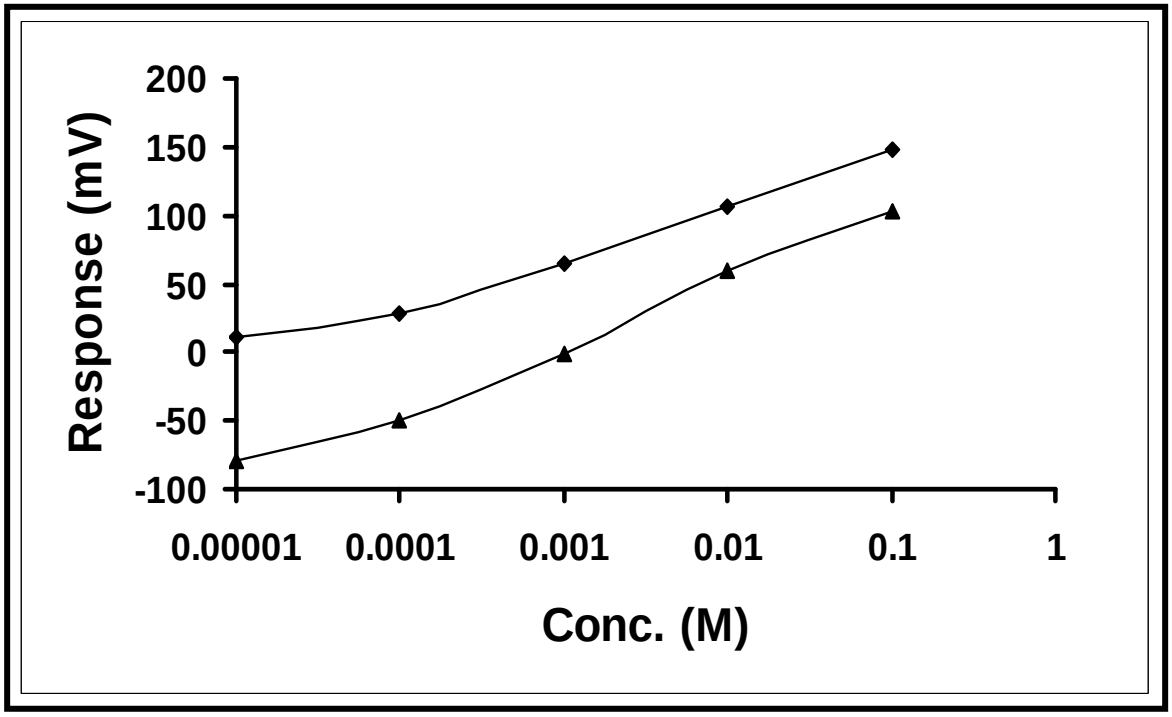
Figure(3-43): Selectivity of electrode A(PMH-PT+DBP) for Mg^{+2} cation interfering by separation method,♦ promethazine hydrochloride solutions,▲solutions of magnesium cation interfering.



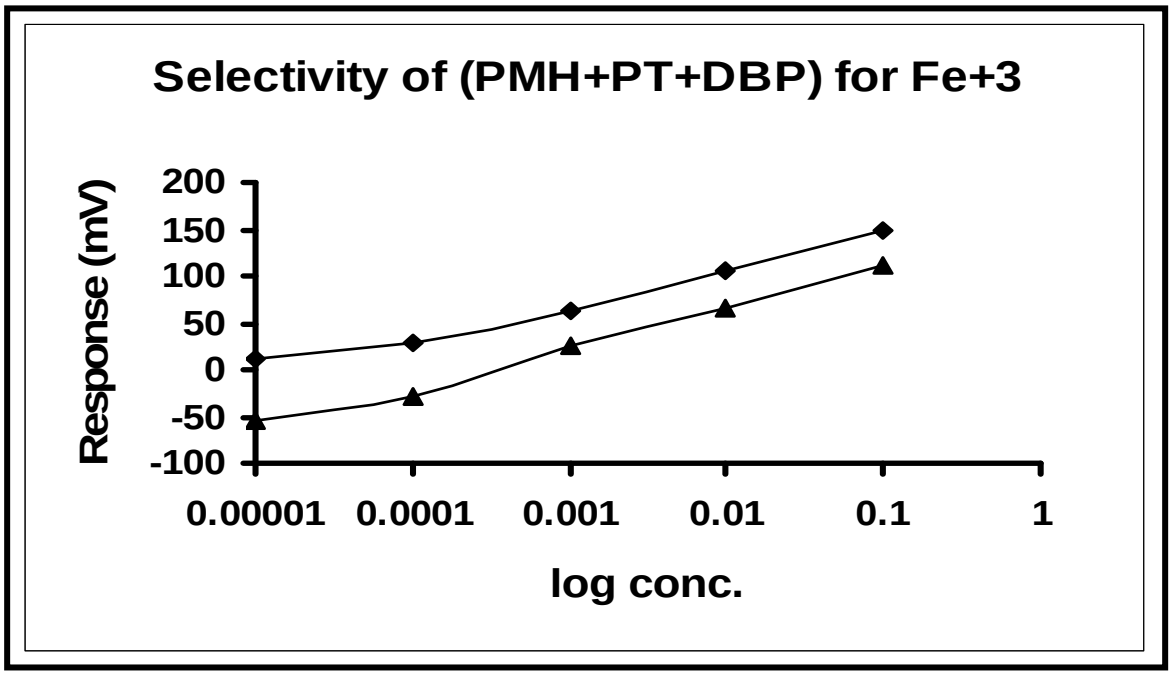
Figure(3-44): Selectivity of electrode A(PMH-PT+DBP) for Ca^{+2} cation interfering by separation method,♦ promethazine hydrochloride solutions, ▲solutions of calcium cation interfering.



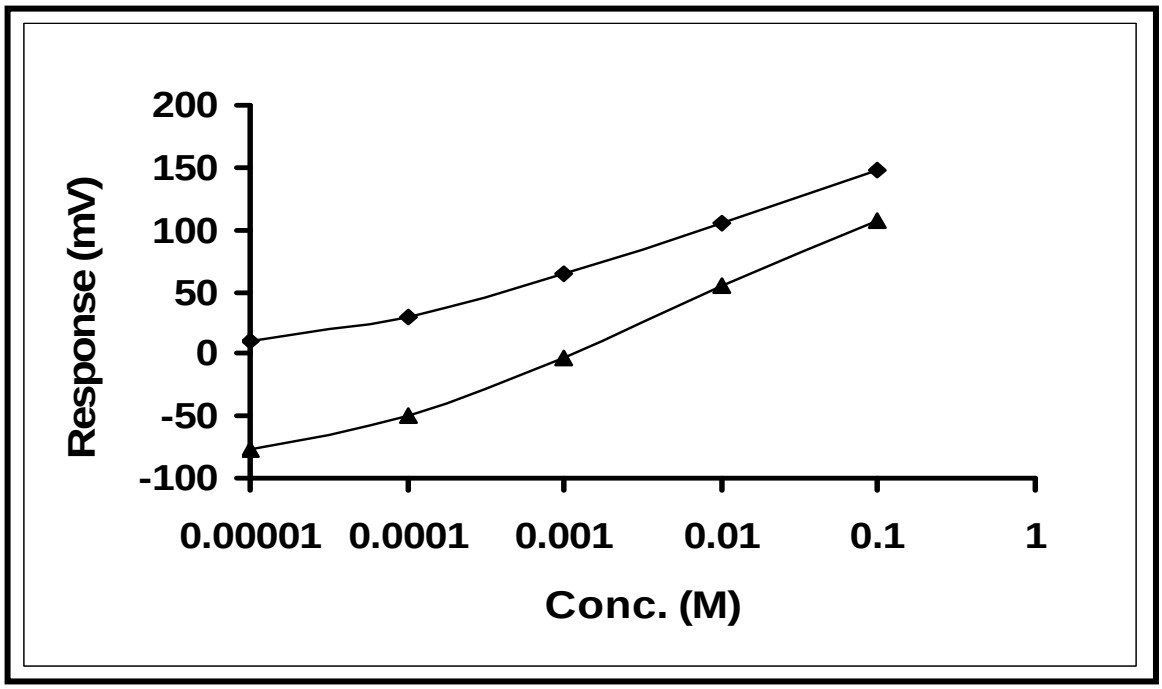
Figure(3-45): Selectivity of electrode A(PMH-PT+DBP) for Zn^{+2} cation interfering by separation method,♦ promethazine hydrochloride solutions, ▲solutions of zinc cation interfering.



Figure(3-46): Selectivity of electrode A(PMH-PT+DBP) for Al^{+3} cation interfering by separation method,♦ promethazine hydrochloride solutions, ▲ solutions of aluminum cation interfering.



Figure(3-47): Selectivity of electrode A(PMH-PT+DBP) for Fe^{+3} cation interfering by separation method,♦ promethazine hydrochloride solutions, ▲solutions of ferric cation interfering.



Figure(3-48): Selectivity of electrode A(PMH-PT+DBP) forCr^{+3} cation interfering by separation method,♦ promethazine hydrochloride solutions, ▲ solutions of chromic cation interfering.

From these figures ,it can be measured the selectivity coefficient ($K_{A,B}$) for cation interfering of electrode A (PMH-PT+DBP). The results of the selectivity coefficient are listed in table (3-15).

Table (3-15): Selectivity coefficient values for electrode A (PMH-PT+DBP) at different concentrations in the presences of some cations.

ng-	Concentrations								
	10^{-1}		10^{-2}		10^{-3}		10^{-4}		10
	E_B(mV)	**$K_{A,B}$**	**E_B(mV)**	**$K_{A,B}$**	**E_B (mV)**	**$K_{A,B}$**	**E_B(mV)**	**$K_{A,B}$**	**E_B(mV)**
	99	6.2×10^{-2}	56	5.9×10^{-2}	١٠	4.7×10^{-2}	-28	3.9×10^{-2}	-44
	95	4.9×10^{-2}	52	4.7×10^{-2}	5	3.5×10^{-2}	-13	9.2×10^{-2}	-46
	92	4.2×10^{-2}	45	3.1×10^{-2}	2	3.0×10^{-2}	-35	2.6×10^{-2}	-50
	111	3.9×10^{-2}	63	9.0×10^{-3}	-2	7.0×10^{-4}	-49	1.2×10^{-4}	-76
	113	4.3×10^{-2}	75	1.7×10^{-2}	12	1.7×10^{-3}	-26	4.4×10^{-4}	-54
	115	4.9×10^{-2}	68	1.1×10^{-2}	16	2.1×10^{-3}	-22	5.5×10^{-4}	-62
	102	1.6×10^{-2}	59	3.0×10^{-3}	-1	2.5×10^{-4}	-50	2.4×10^{-5}	-79
	112	2.8×10^{-2}	67	5.0×10^{-3}	27	1.2×10^{-3}	-28	8.5×10^{-5}	-53
	107	2.1×10^{-2}	55	3.0×10^{-3}	-4	2.0×10^{-4}	-53	2.0×10^{-5}	-77

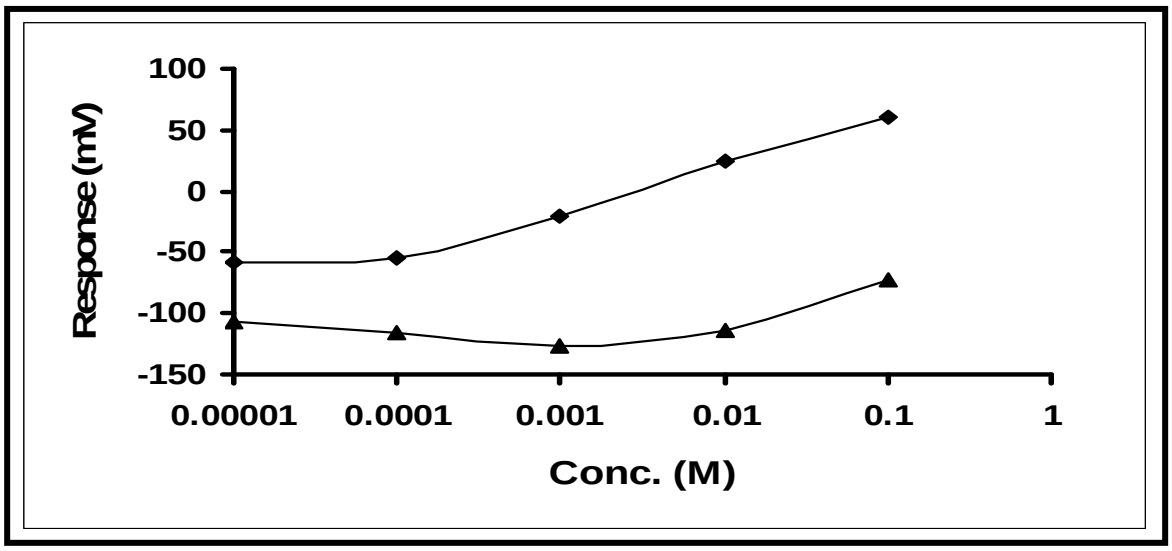
we noticed from table (3-15) the selectivity coefficient values for mono valent cations is higher than the values from di and tri valents cations interfering, that may be due to differences in ionic size, mobility and permeability and the order of selectivity is:

mono valent > di valent > tri valent.

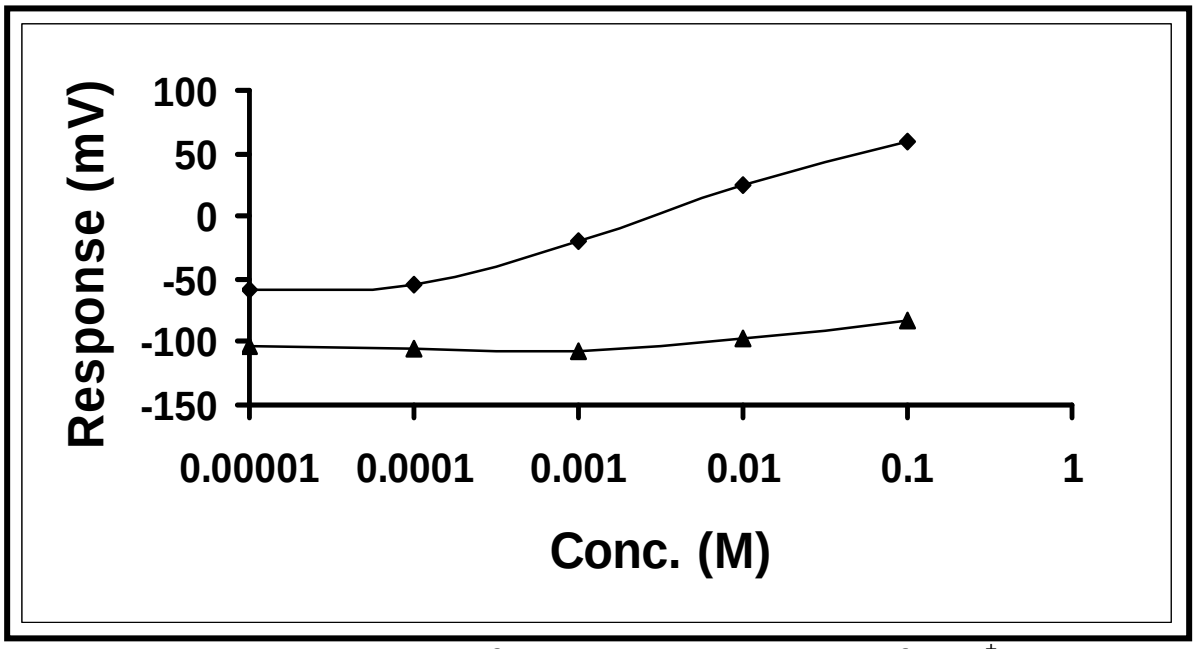
In the same time the selectivity coefficient values for concentration 10^{-5} M is very low because 10^{-5} M is in the non linear region of the calibration curve.

3-4-1-2.Selectivityof the electrode B:

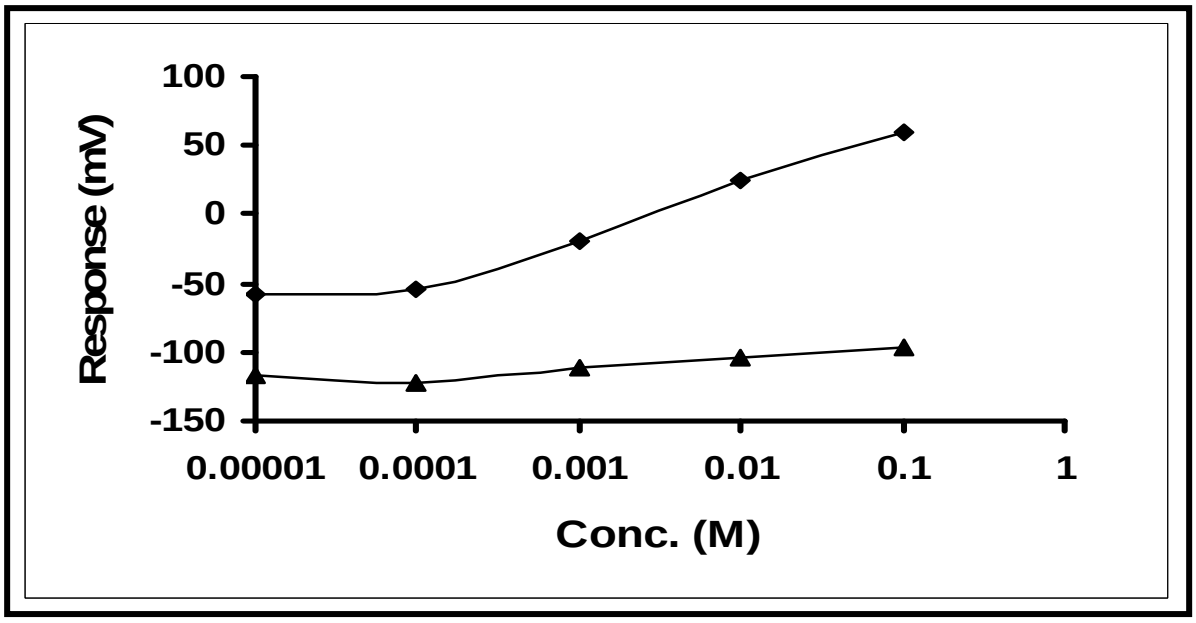
The influence of some inorganic cations such as (Li^{+},Na^{+},K^{+},Mg^{+2},Ca^{+2},Zn^{+2},Al^{+3},Fe^{+3},Cr^{+3}) for electrode B was studied. The selectivity of electrode B (PMH-PT+TBP) can be measured by separation solution method at concentrations range (10^{-5}-10^{-1}) M of promethazine hydrochloride solutions in presence of cations solutions, the potentiometric selectivity coefficients were calculated by using equation(1-8), and the results are shown in figures (3-49) to (3-57). The values of selectivity coefficients are listed in table (3-16).



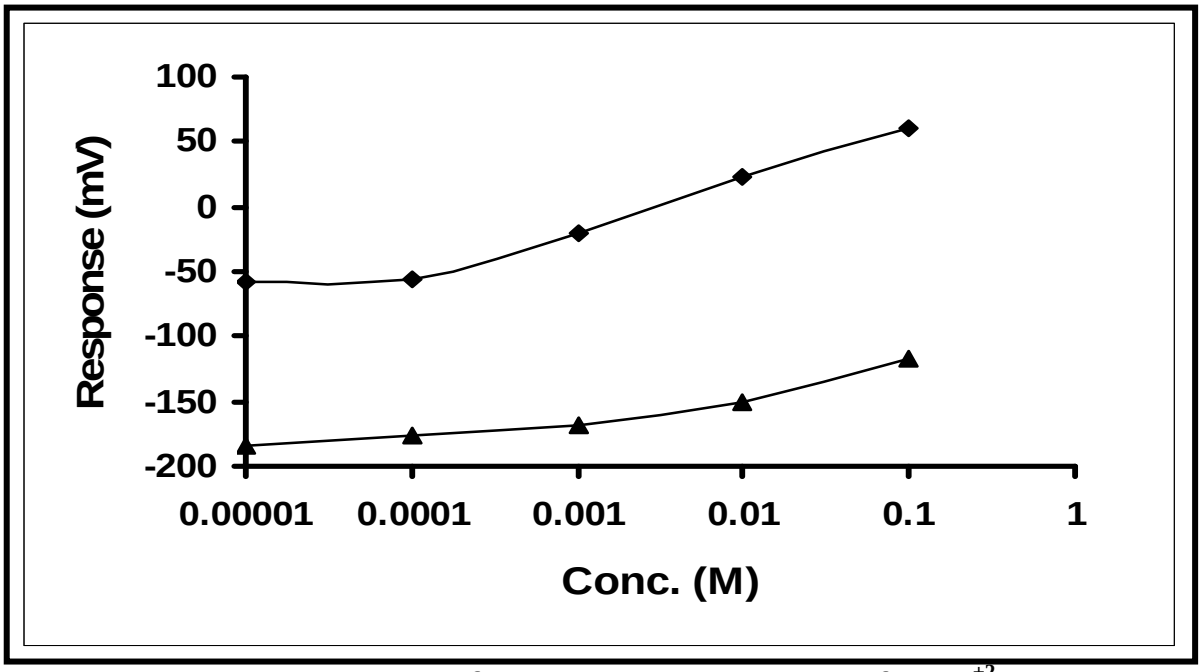
Figure(3-49): Selectivity of electrode B(PMH-PMT+TBP) for Li^+ cation interfering by separation method,♦ promethazine hydrochloride solutions, ▲ solutions of lithium cation interfering.



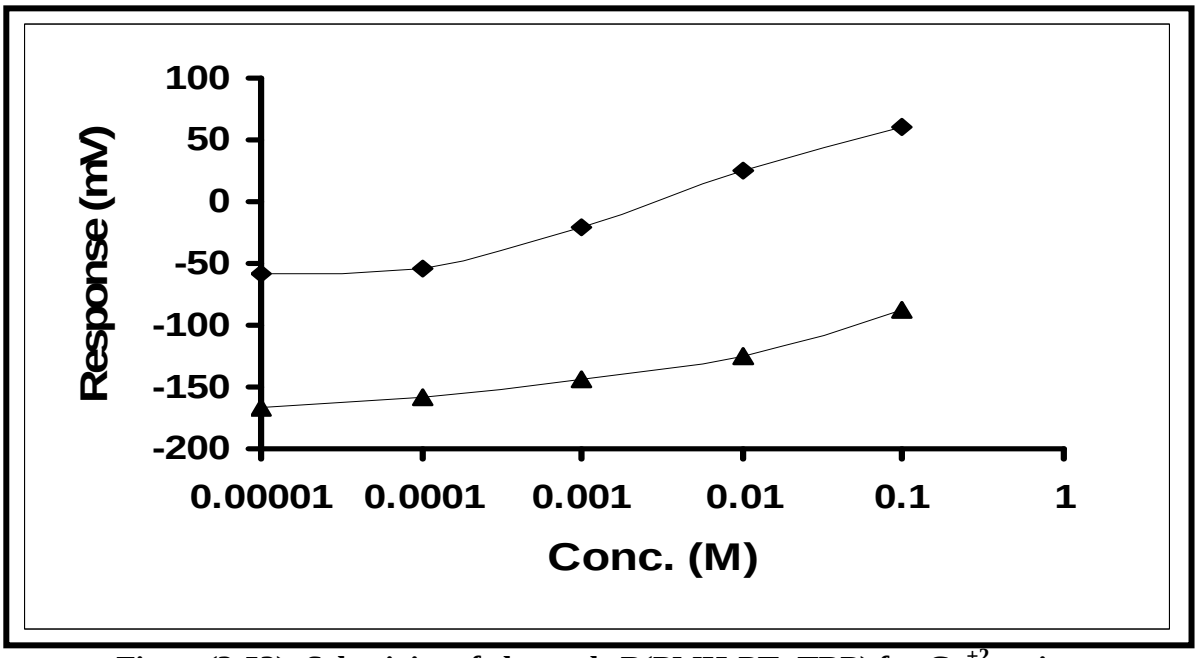
Figure(3-50): Selectivity of electrode B(PMH-PT+TBP) for Na^+ cation interfering by separation method,♦ promethazine hydrochloride solutions, ▲solutions of sodium cation interfering.



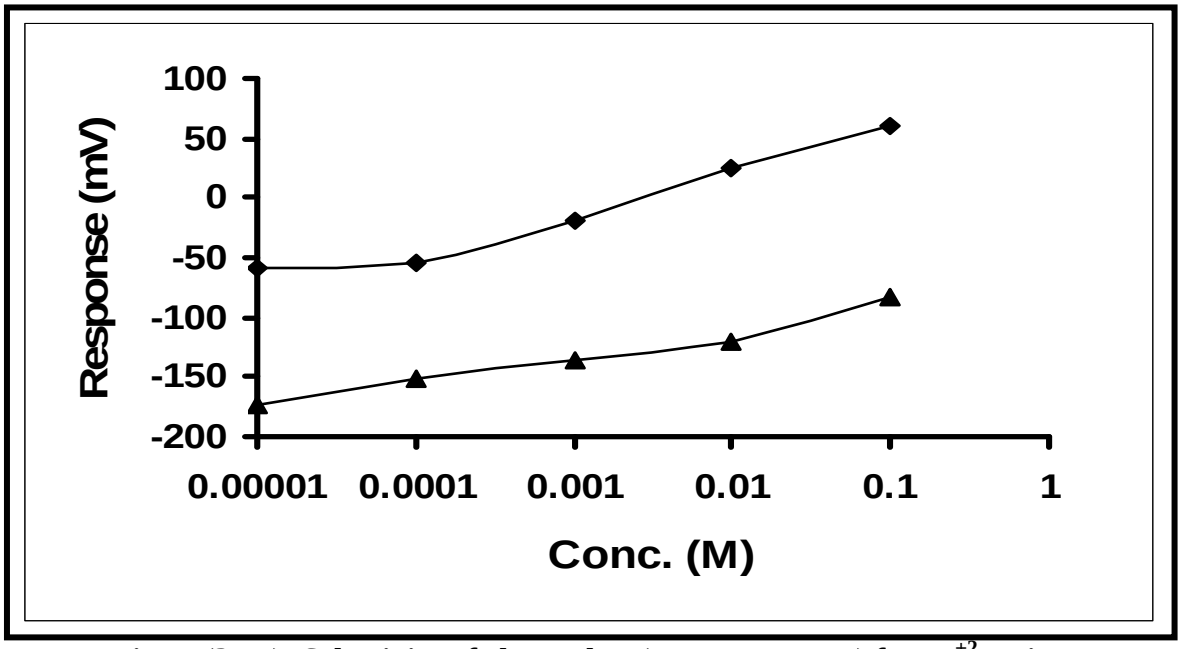
Figure(3-51): Selectivity of electrode B(PMH-PT+TBP) for K^+ cation interfering by separation method,♦ promethazine hydrochloride solutions, ▲ solutions of potasium cation interfering.



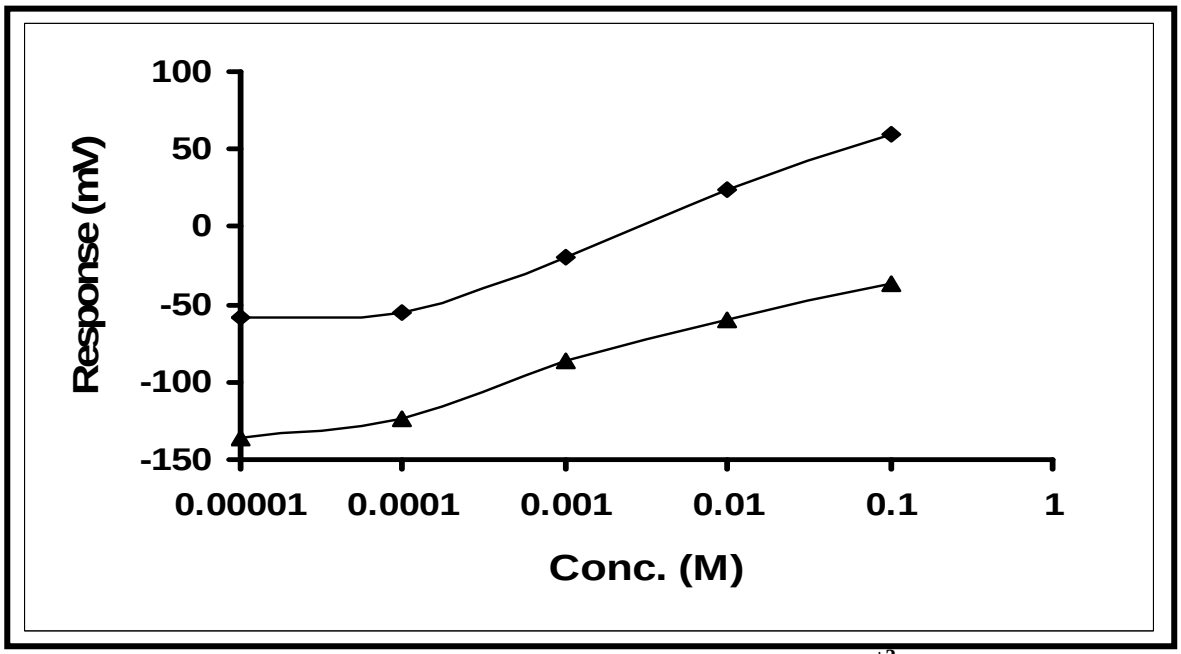
Figure(3-52): Selectivity of electrode B(PMH-PT+TBP) for Mg^{+2} cation interfering by separation method,♦ promethazine hydrochloride solutions, ▲ solutions of magnesium cation interfering.



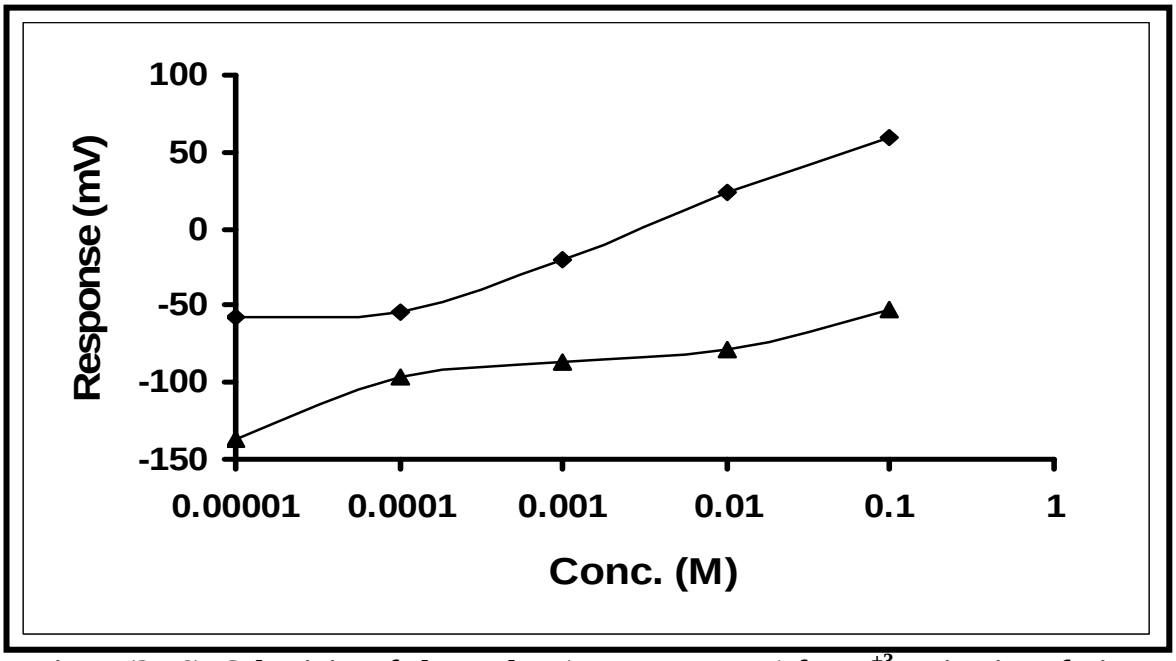
Figure(3-53): Selectivity of electrode B(PMH-PT+TBP) for Ca^{+2} cation interfering by separation method,♦ promethazine hydrochloride solutions, ▲solutions of calcium cation interfering.



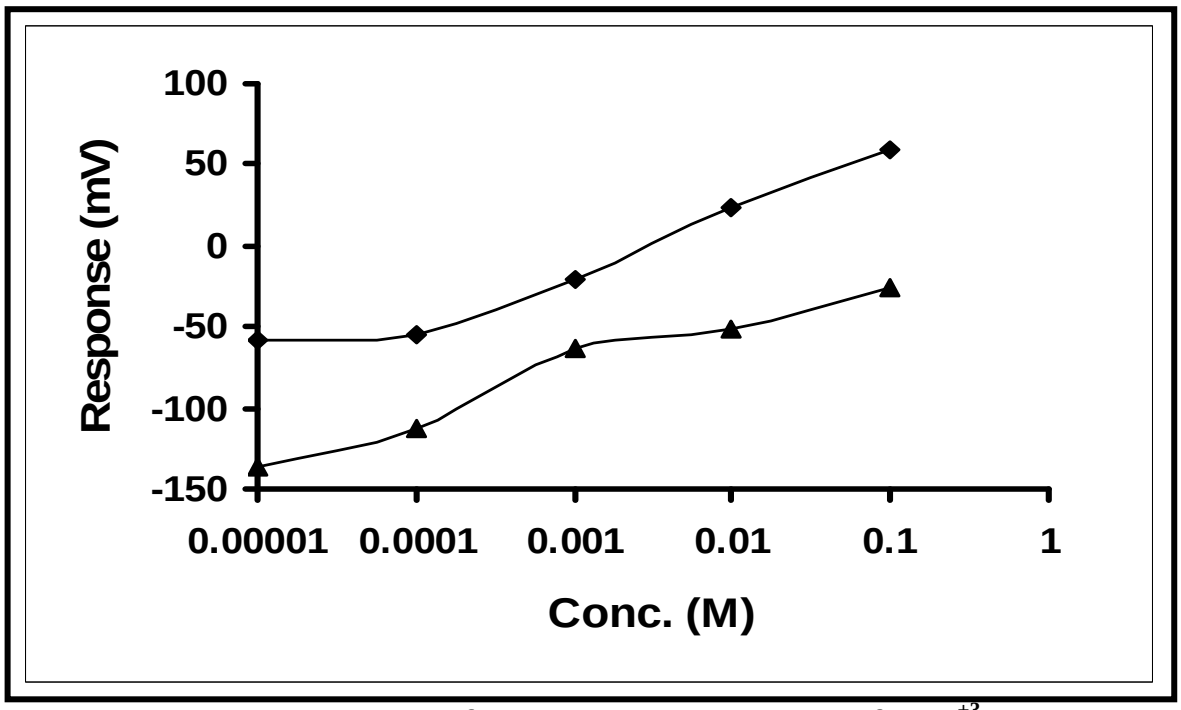
Figure(3-54): Selectivity of electrode B(PMH-PT+TBP) forZn^{+2} cation interfering by separation method,♦ promethazine hydrochloride solutions, ▲solutions of zinc cation interfering.



Figure(3-55): Selectivity of electrode B(PMH-PT+TBP) forAl^{+3} cation interfering by separation method,♦ promethazine hydrochloride solutions, ▲solutions of aluminum cation interfering.



Figure(3-56): Selectivity of electrode B(PMH-PT+TBP) forFe^{+3} cation interfering by separation method,♦ promethazine hydrochloride solutions, ▲ solutions of ferric cation interfering.



Figure(3-57): Selectivity of electrode B(PMH-PT+TBP) for Cr^{+3} cation interfering by separation method,♦ promethazine hydrochloride solutions, ▲solutions of chromic cation interfering.

Table (3-1٦): Selectivity coefficient values for electrode B (PMH-PT+TBP) at different concentrations in the presences of some cations.

ng-	Concentrations								
	10^{-1}		10^{-2}		10^{-3}		10^{-4}		10
	E_B(mV)	**$K_{A,B}$**	**E_B(mV)**	**$K_{A,B}$**	**E_B (mV)**	**$K_{A,B}$**	**E_B(mV)**	**$K_{A,B}$**	**E_B(mV)**
	-72	4.3×10^{-4}	-114	3.4×10^{-4}	-126	2.2×10^{-4}	-115	3.1×10^{-2}	-106
	-82	2.4×10^{-4}	-98	8.6×10^{-4}	-107	6.5×10^{-3}	-106	5.2×10^{-2}	-103
	-97	1.0×10^{-4}	-104	6.1×10^{-4}	-112	4.9×10^{-3}	-122	2.1×10^{-2}	-117
	-117	1.0×10^{-5}	-151	4.0×10^{-6}	-169	5.7×10^{-6}	-177	8.6×10^{-6}	-164
	-88	5.4×10^{-5}	-124	1.9×10^{-5}	-144	2.4×10^{-5}	-159	2.4×10^{-5}	-167
	-83	7.2×10^{-5}	-120	2.4×10^{-5}	-136	3.9×10^{-5}	-151	3.9×10^{-5}	-154
	-37	7.0×10^{-4}	-60	3.6×10^{-4}	-84	2.5×10^{-4}	-124	4.0×10^{-5}	-136
	-53	2.8×10^{-4}	-79	1.2×10^{-4}	-86	2.2×10^{-4}	-96	2.0×10^{-4}	-127
	-26	1.3×10^{-3}	-52	5.7×10^{-4}	-64	7.8×10^{-4}	-112	8.0×10^{-5}	-128

we noticed from table (3-16) the selectivity coefficient values for mono valent cations is higher than the values from di and tri valents cations interferings, that may be due to differences in ionic size, mobility and permeability, the order of the selectivity is:

mono valent > di valent > tri valent.

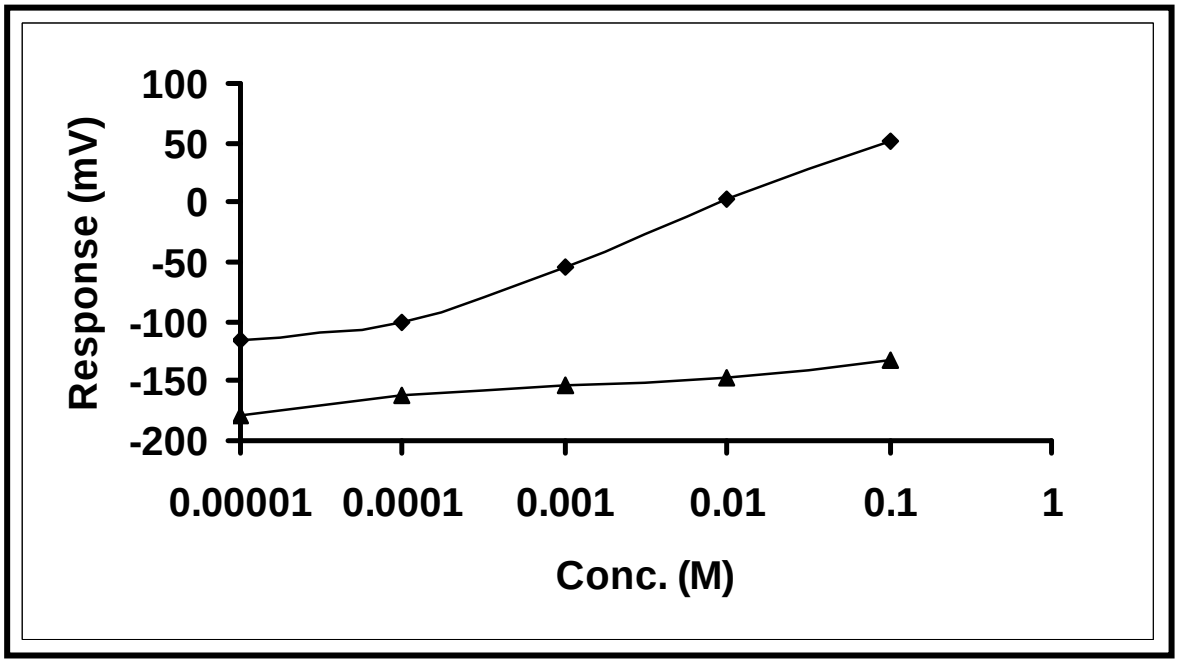
But at 0.1 M concentration, the selectivity coefficient values for tri valent cations is higher than the values from mono and di valents cations interfering, the order of the selectivity is:

tri valent > mono valent > di valent.

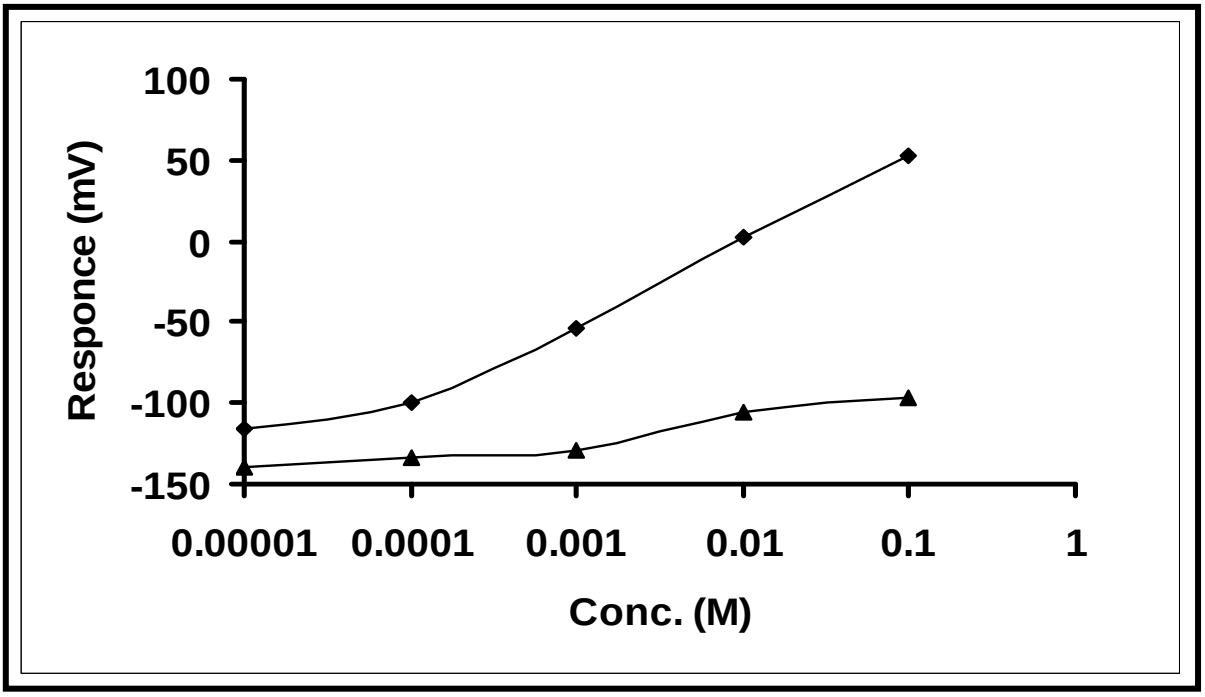
The selectivity coefficient values for electrode A (PMH-PT+DBP) is higher values than selectivity coefficient values for electrode B(PMH+PT+TBP) to may be attributed to the steric factor by along alkyl group of plasticizers (TBP) than plasticizer of (DBP) ,which decrease the bond strength with ion-pair complex (PMH-PT) that leads to increase the ion-interfering occupation the drug position in the membrane.

3-4-1-3.Selectivityof the electrode C:

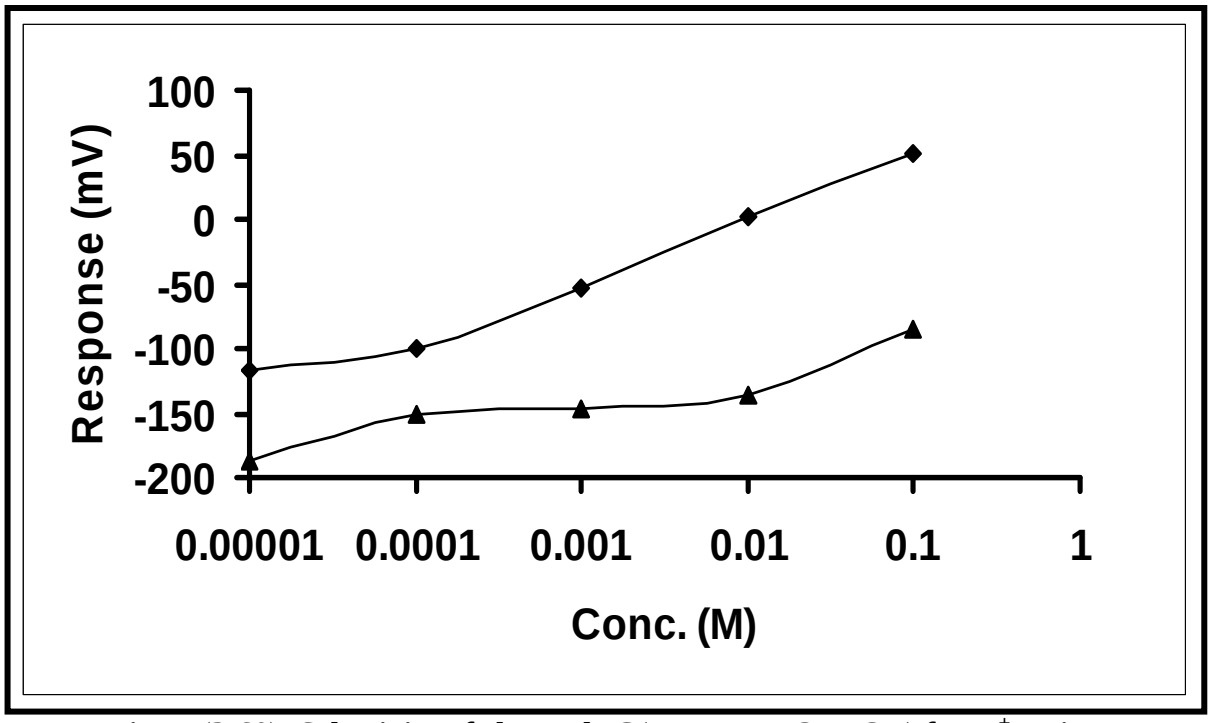
The influence of some inorganic cations such as (Li^{+},Na^{+},K^{+},Mg^{+2},Ca^{+2},Zn^{+2},Al^{+3},Fe^{+3},Cr^{+3}) for electrode C was measured. The selectivity of electrode C (PMH-PT+ONPOE) can be measured by separation solution method for concentrations range (10^{-5}-10^{-1}) M of promethazine hydrochloride solutions in presence of cations solutions, the potentiometric selectivity coefficients were calculated by using equation(1-8), figures (3-58) to (3-66). The results of selectivity coefficients values are listed in table (3-17).



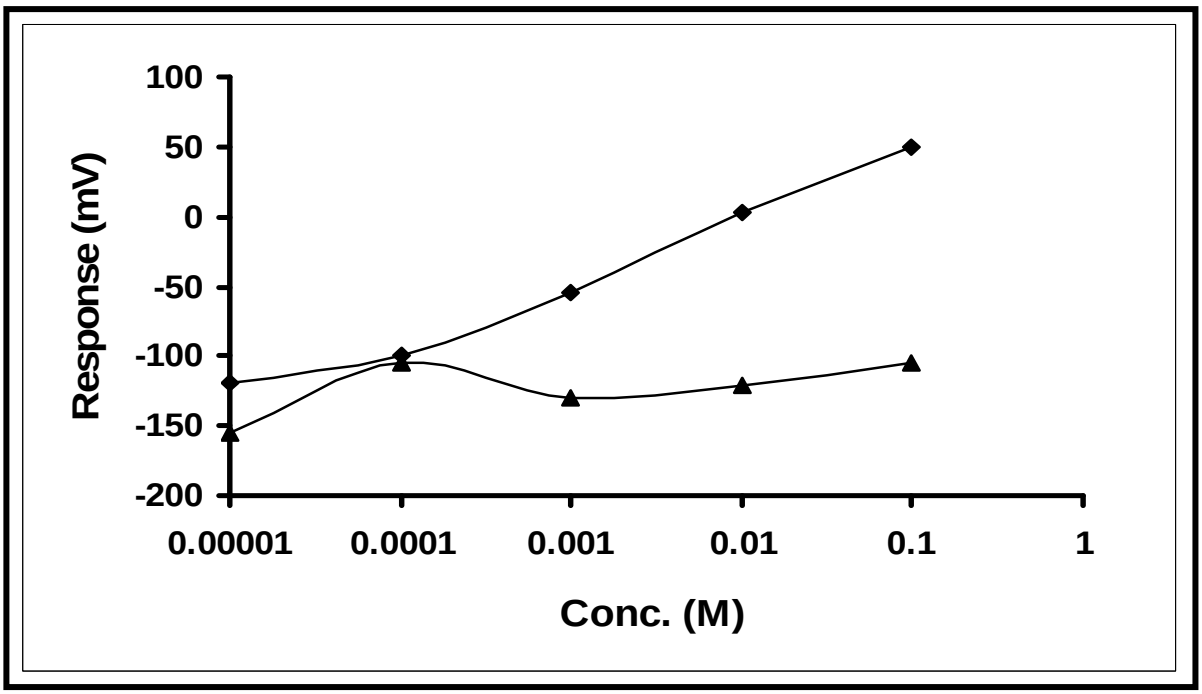
Figure(3-58): Selectivity of electrode C(PMH-PT+ONPOE) for Li^+ cation interfering by separation method,♦ promethazine hydrochloride solutions, ▲ solutions of lithium cation interfering.



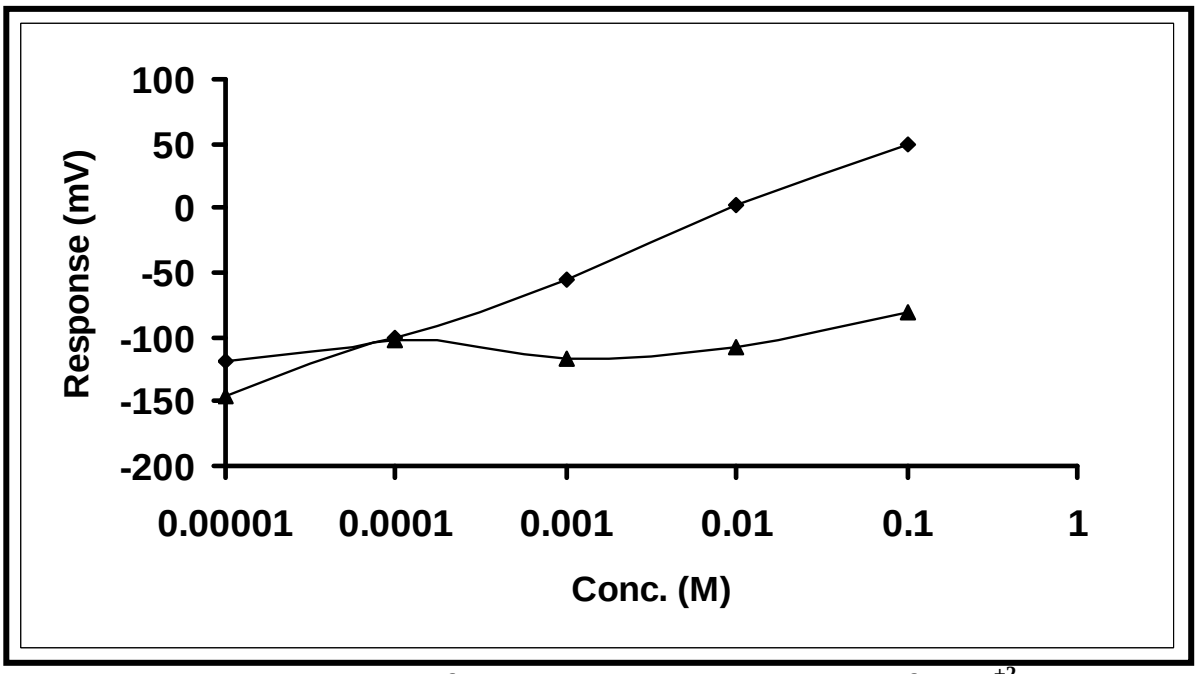
Figure(3-59): Selectivity of electrode C(PMH-PT+ONPOE) for Na^+ cation interfering by separation method,♦ promethazine hydrochloride solutions, ▲solutions of sodium cation interfering.



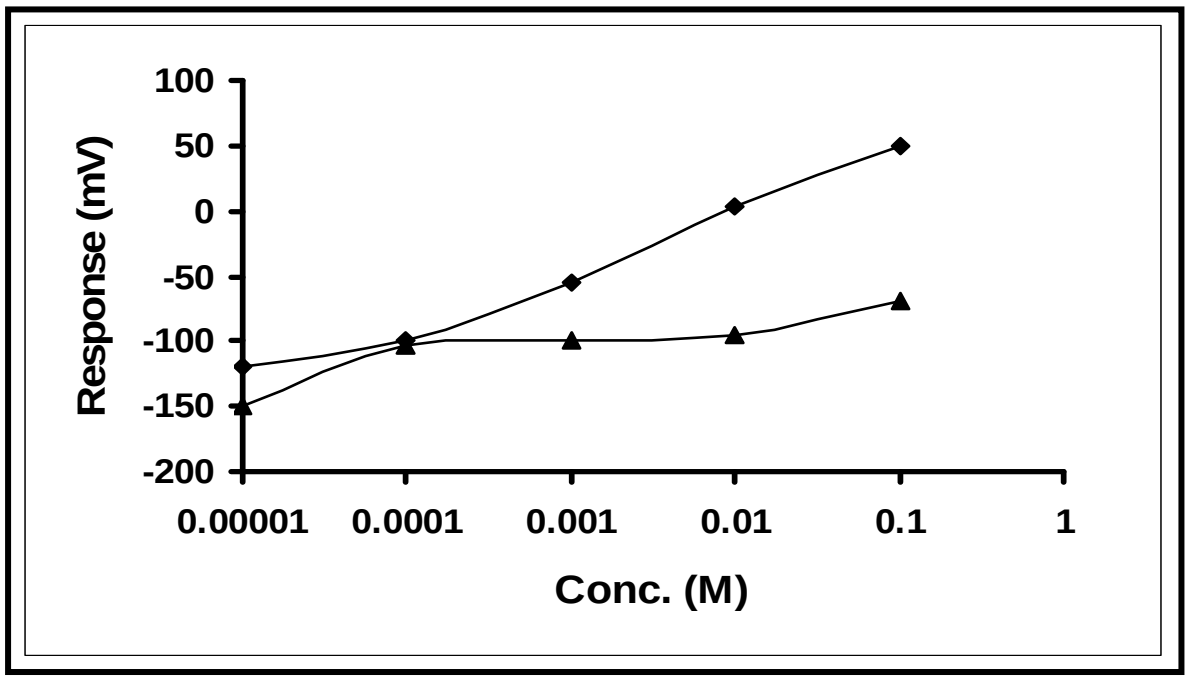
Figure(3-60): Selectivity of electrode C(PMH-PT+ONPOE) for K^+ cation interfering by separation method,♦ promethazine hydrochloride solutions, ▲solutions of potassium cation interfering.



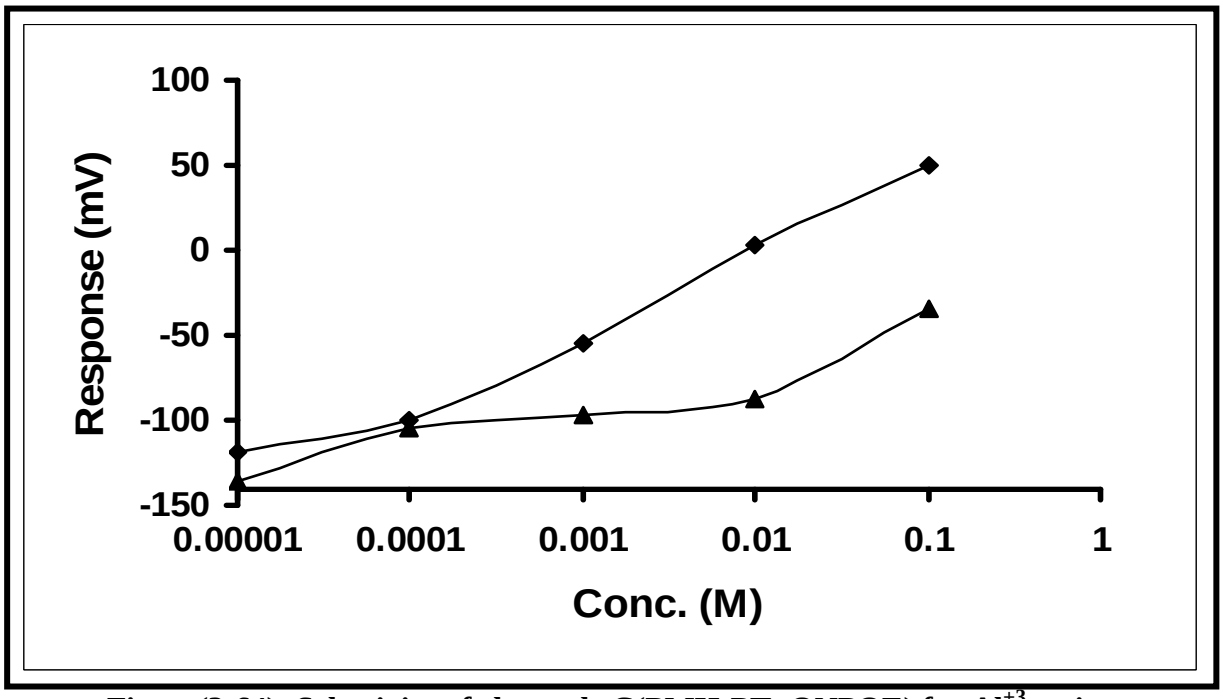
Figure(3-61): Selectivity of electrode C(PMH-PT+ONPOE) for Mg^{+2} cation interfering by separation method,♦ promethazine hydrochloride solutions, ▲ solutions of magnesium cation interfering.



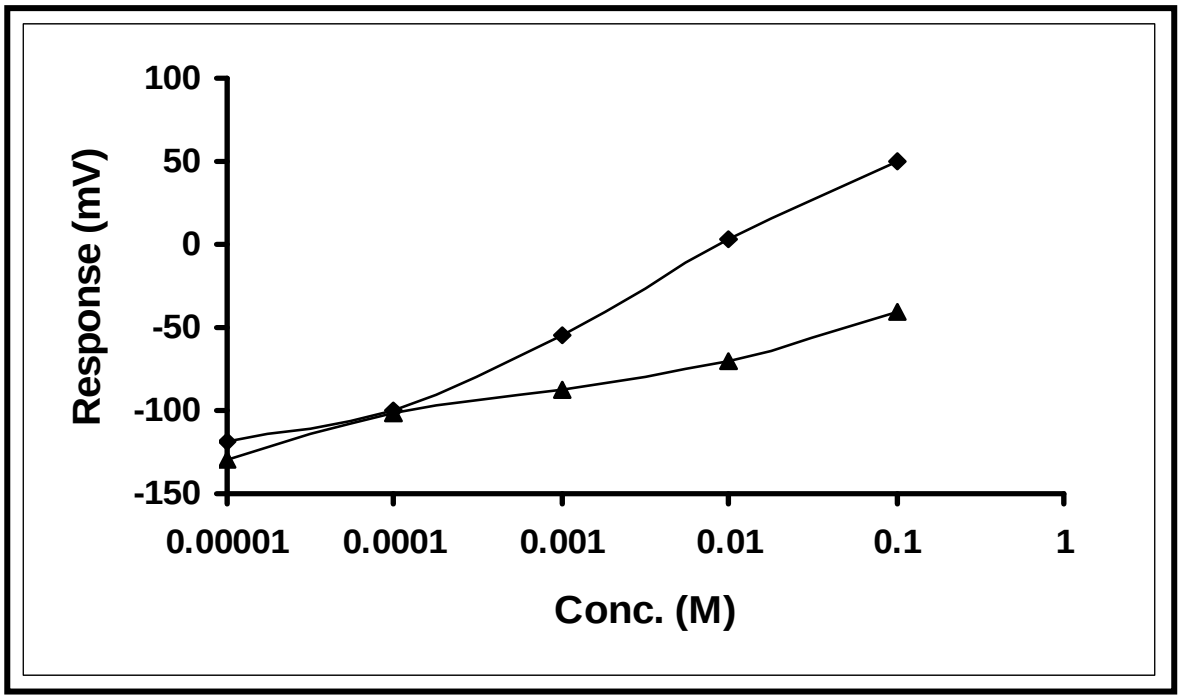
Figure(3-62): Selectivity of electrode C(PMH-PT+ONPOE) for Ca^{+2} cation interfering by separation method,♦ promethazine hydrochloride solutions, ▲solutions of magnesium cation interfering.



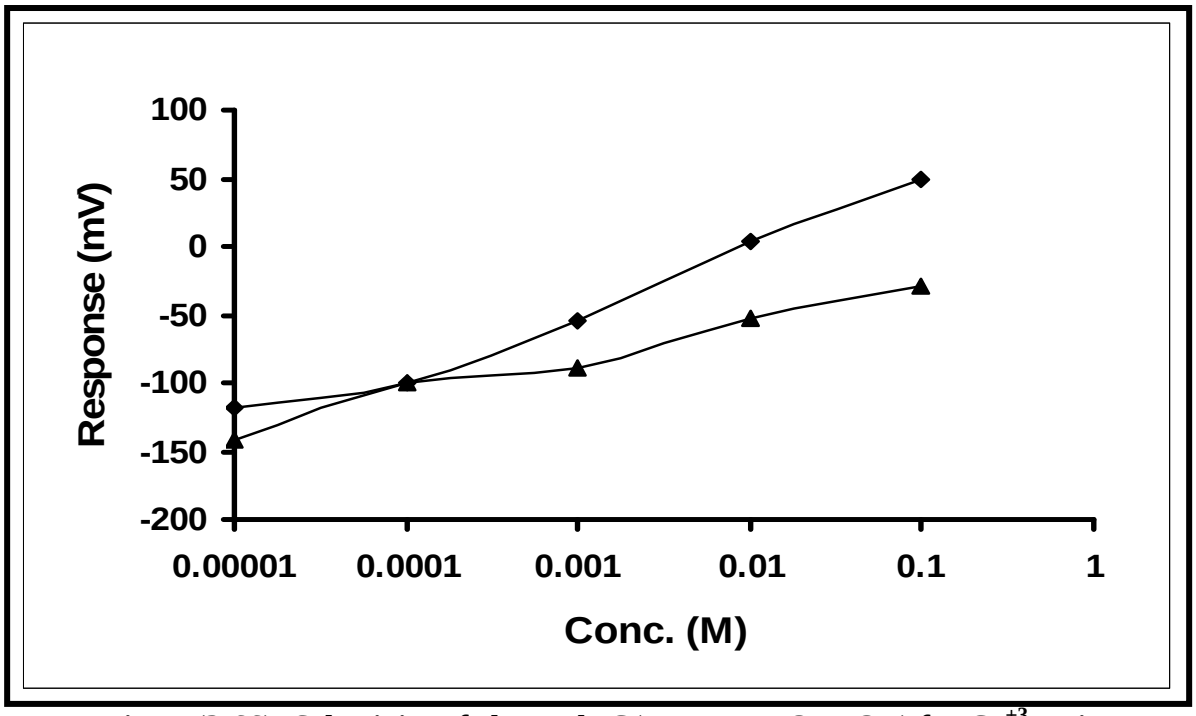
Figure(3-63): Selectivity of electrode C(PMH-PT+ONPOE) for Zn^{+2} cation interfering by separation method,♦ promethazine hydrochloride solutions, ▲ solutions of zinc cation interfering.



Figure(3-64): Selectivity of electrode C(PMH-PT+ONPOE) for Al^{+3} cation interfering by separation method,♦ promethazine hydrochloride solutions, ▲solutions of aluminum cation interfering.



Figure(3-65): Selectivity of electrode C(PMH-PT+ONPOE) for Fe^{+3} cation interfering by separation method,♦ promethazine hydrochloride solutions, ▲solutions of ferric cation interfering.



Figure(3-66): Selectivity of electrode C(PMH-PT+ONPOE) for Cr^{+3} cation interfering by separation method,♦ promethazine hydrochloride solutions, ▲solutions of chromic cation interfering.

Table (3-17): Selectivity coefficient values for electrode C (PMH-PT+ONPOE) at different concentrations in the presences of some cations.

ng-	Concentrations								
	10^{-1}		10^{-2}		10^{-3}		10^{-4}		1(
	E_B(mV)	**$K_{A,B}$**	**E_B(mV)**	**$K_{A,B}$**	**E_B (mV)**	**$K_{A,B}$**	**E_B(mV)**	**$K_{A,B}$**	**E_B(mV)**
	-122	4.2×10^{-4}	-125	3.3×10^{-3}	-126	4.2×10^{-2}	-136	0.2	-1.8
	-99	1.2×10^{-3}	-103	8.8×10^{-3}	-120	5.5×10^{-2}	-127	0.299	-1.2
	-96	1.3×10^{-3}	-114	5.4×10^{-3}	-117	6.3×10^{-2}	-120	0.409	-1.4
	-104	3.0×10^{-4}	-121	3.9×10^{-4}	-130	1.1×10^{-3}	-104	8.4×10^{-3}	-1.5
	-80	8.7×10^{-4}	-107	7.3×10^{-4}	-116	2.1×10^{-3}	-102	9.1×10^{-3}	-1.5
	-70	1.4×10^{-3}	-95	1.3×10^{-3}	-99	4.4×10^{-3}	-103	8.8×10^{-3}	-1.9
	-34	4.6×10^{-3}	-88	7.9×10^{-4}	-97	1.5×10^{-3}	-105	1.7×10^{-3}	-1.6
	-40	3.5×10^{-3}	-70	1.8×10^{-3}	-88	2.3×10^{-3}	-101	2.1×10^{-3}	-1.0
	-29	5.8×10^{-3}	-53	3.8×10^{-3}	-90	2.1×10^{-3}	-100	2.2×10^{-3}	-1.2

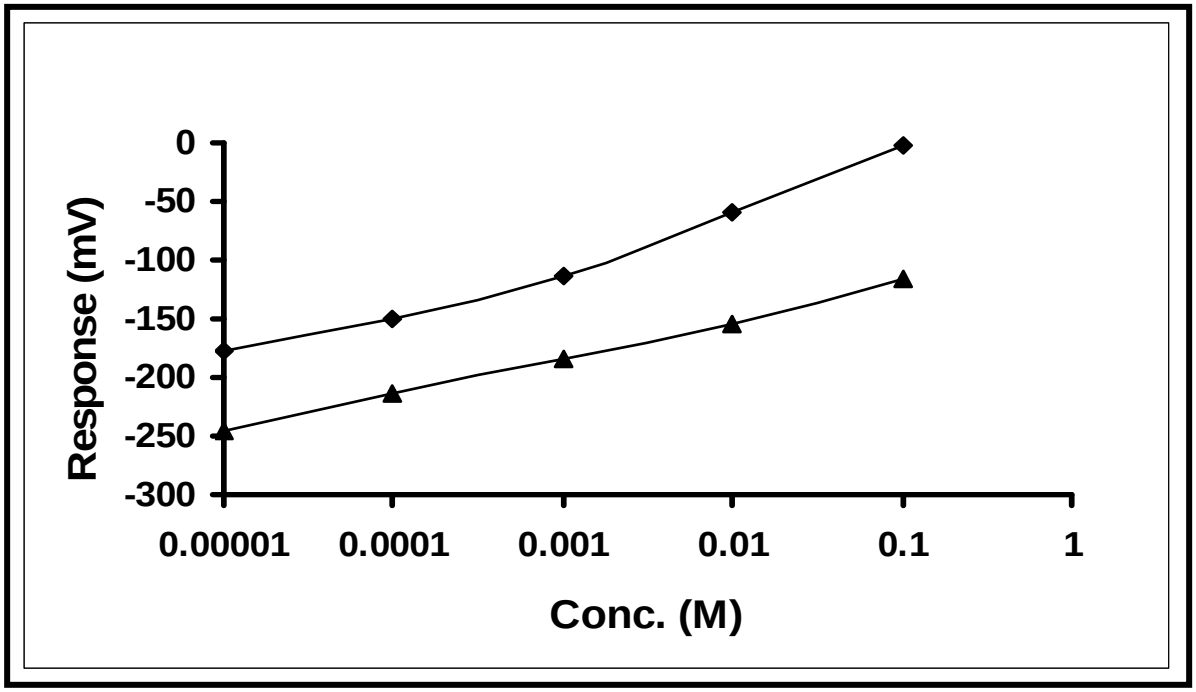
From the results show that the selectivity coefficients values are very low. This means no interference of these cations on electrode response. We noticed from table (3-17) the selectivity coefficient values for mono valent cations is higher than the values for di and tri valents cations interfering, that may be due to differences in ionic size, mobility and permeability, so that the mono valent interfere with the electrode response than the di and tri valents cations.

As we noticed from the values of the selectivity coefficient of the mono-di valent and tri valent cations at concentrations 10^{-4} and 10^{-5} M can be interfere with electrode response more than the cations of concentrations 10^{-1}-10^{-3} M. The higher interference of cations at concentration 10^{-5} M is due to the electrode can not be response to the drug at low concentrations. In this case the drug start to leach from the membrane to the external solutions which contain the interfering cations and the cations can be exchange the drug of the complex in the membrane. Therefore, the interference of the cations on electrode response can be increased.

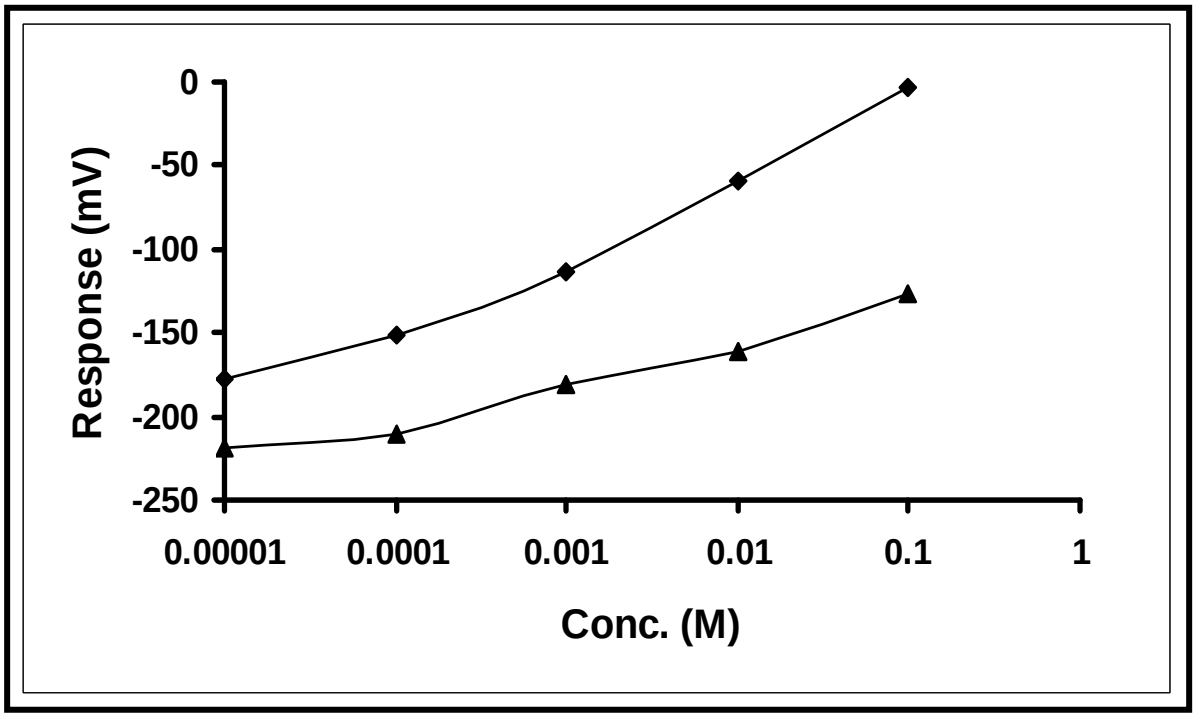
3-4-1-4.Selectivityof the electrode D:

The influence of some inorganic cations such as (Li^{+},Na^{+},K^{+},Mg^{+2},Ca^{+2},Zn^{+2},Al^{+3},Fe^{+3},Cr^{+3}) on electrode D was also studied. The selectivity of electrode D(PMH-PT+DBPH) can be measured by separation solution method for concentrations range(10^{-5}-10^{-1}) M for promethazine hydrochloride solutions and interferences cations solutions respectively, the potentiometric selectivity coefficient were calculated by using equation(1-8). The figures for separation method of

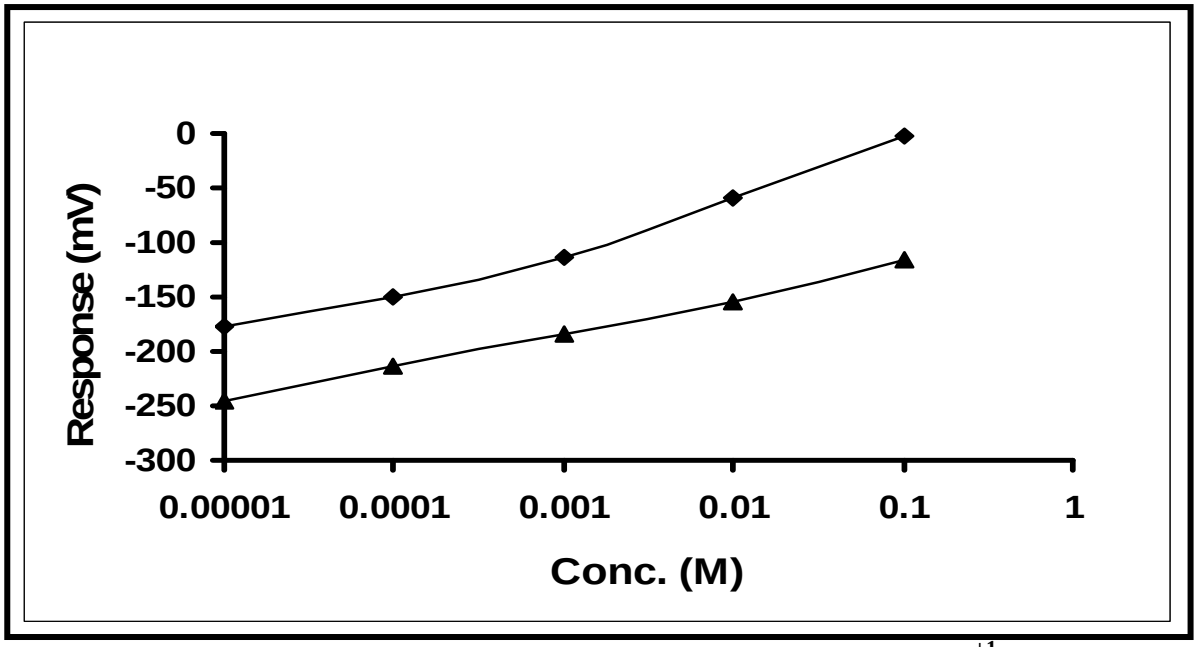
these ion interfering such as (Li^{+},Na^{+},K^{+},Mg^{+2},Ca^{+2},Zn^{+2},Al^{+3},Fe^{+3},Cr^{+3}) are shown in figures (3-67) to (3-75). The values of selectivity coefficients are listed in table (3-18).



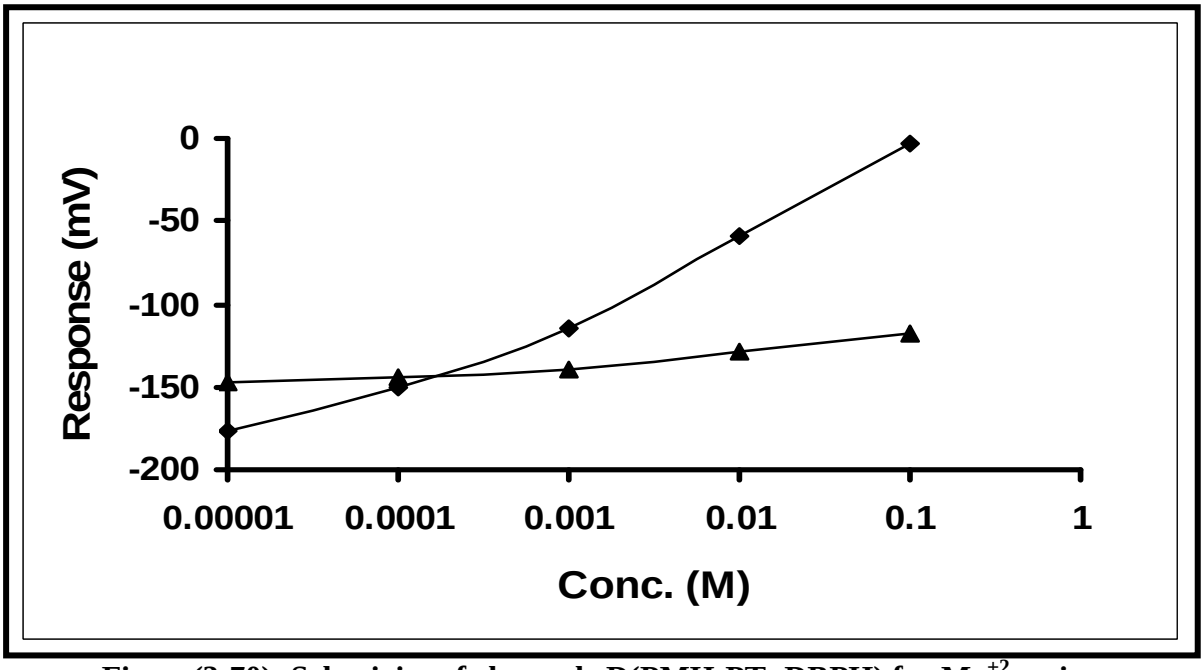
Figure(3-67): Selectivity of electrode D(PMH-PT+DBPH) for Li^{+1} cation interfering by separation method,♦ promethazine hydrochloride solutions, ▲solutions of lithium cation interfering.



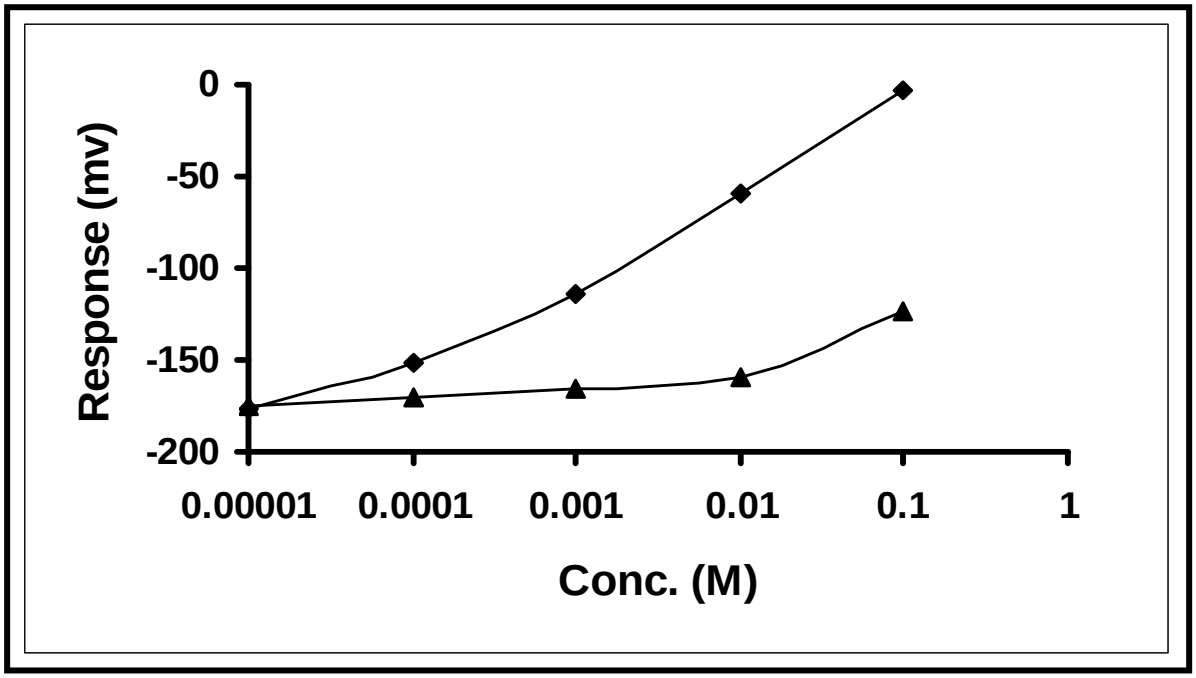
Figure(3-68): Selectivity of electrode D(PMH-PT+DBPH) for Na^{+1} cation interfering by separation method,♦ promethazine hydrochloride solutions, ▲ solutions of sodium cation interfering.



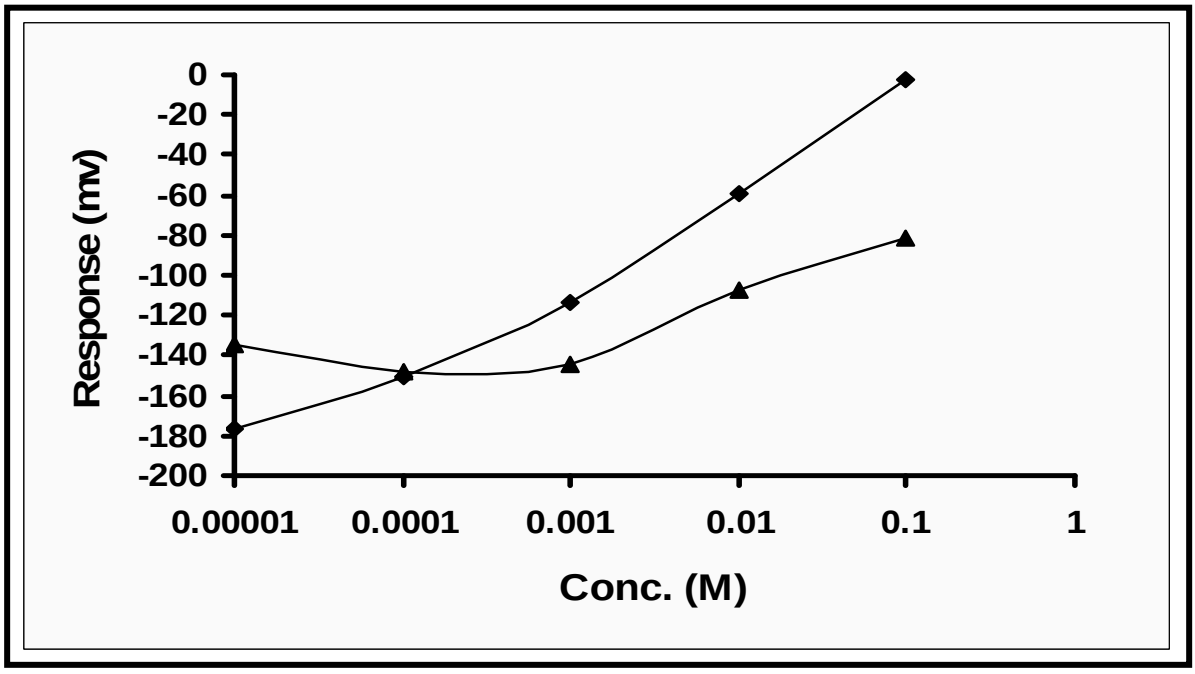
Figure(3-69): Selectivity of electrode D(PMH-PT+DBPH) for K^{+1} cation interfering by separation method,♦ promethazine hydrochloride solutions, ▲solutions of potassium cation interfering.



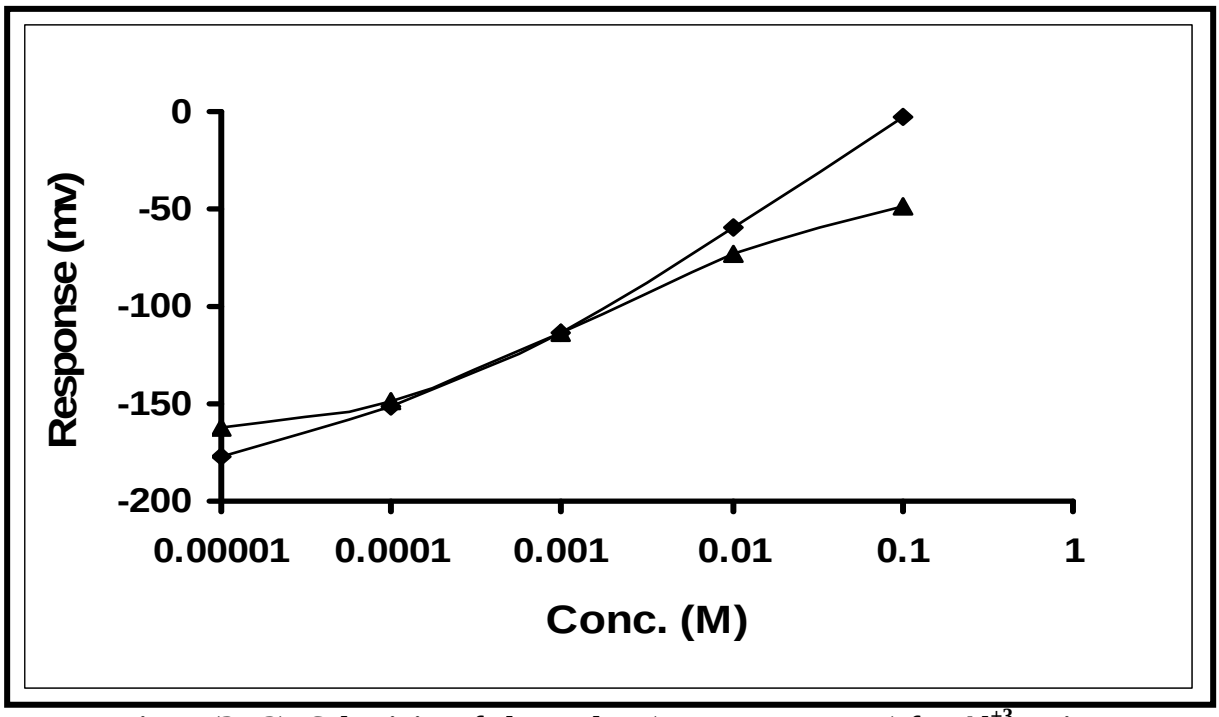
Figure(3-70): Selectivity of electrode D(PMH-PT+DBPH) for Mg^{+2} cation interfering by separation method,♦ promethazine hydrochloride solutions, ▲solutions of magnesium cation interfering.



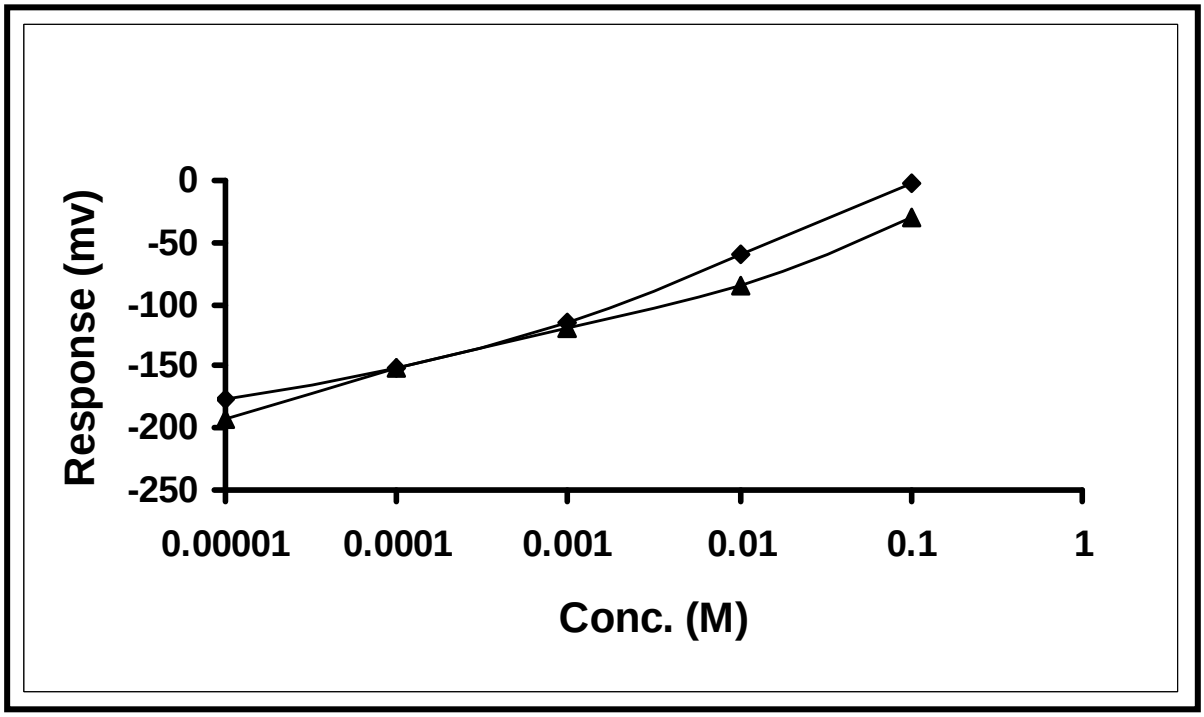
Figure(3-71): Selectivity of electrode D(PMH-PT+DBPH) for Ca^{+2} cation interfering by separation method,♦ promethazine hydrochloride solutions, ▲ solutions of calcium cation interfering.



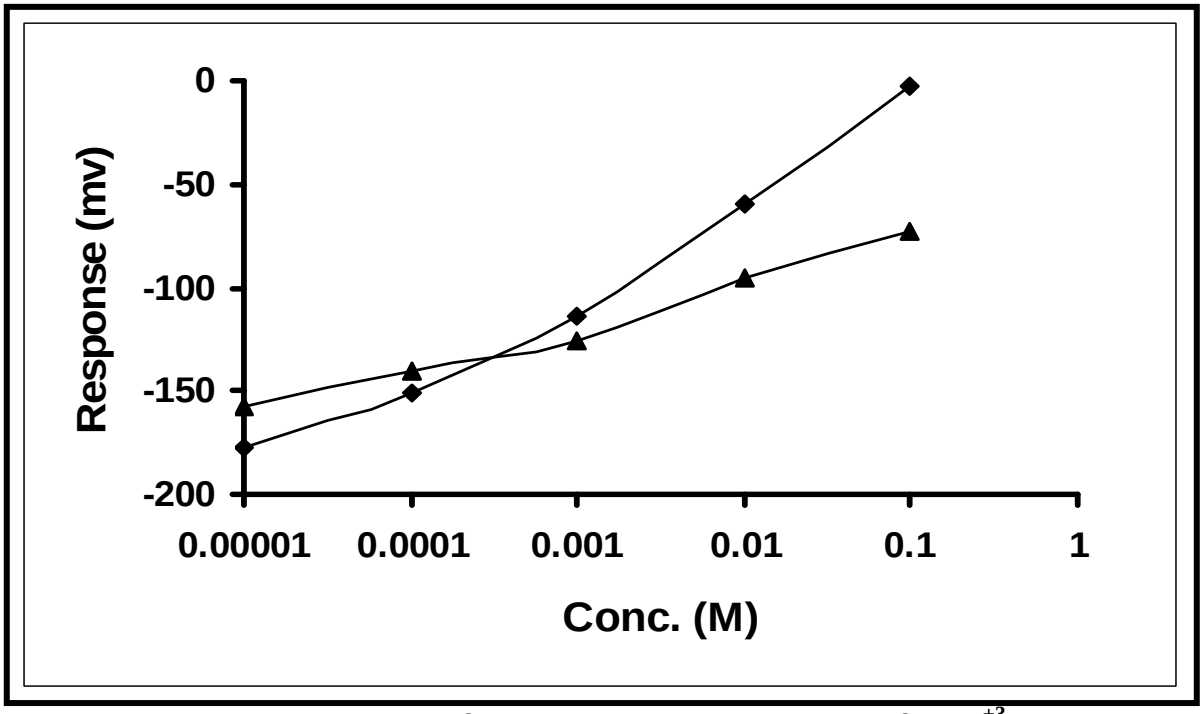
Figure(3-72): Selectivity of electrode D(PMH-PT+DBPH) for Zn^{+2} cation interfering by separation method,♦ promethazine hydrochloride solutions, ▲solutions of zinc cation interfering.



Figure(3-73): Selectivity of electrode D(PMH-PT+DBPH) for Al^{+3} cation interfering by separation method,♦ promethazine hydrochloride solutions, ▲ solutions of aluminum cation interfering.



Figure(3-74): Selectivity of electrode D(PMH-PT+DBPH) for Fe^{+3} cation interfering by separation method,♦ promethazine hydrochloride solutions, ▲ solutions of ferric cation interfering.



Figure(3-75): Selectivity of electrode D(PMH-PT+DBPH) for Cr^{+3} cation interfering by separation method,♦ promethazine hydrochloride solutions, ▲solutions of chromic cation interfering.

Table (3-18): Selectivity coefficient values for electrode D (PMH-PT+DBPH) at different concentrations in the presences of some cations.

fering on	Concentrations											
	10^{-1}		10^{-2}		10^{-3}		5×10^{-4}		10^{-4}			10
	E_B (mV)	$K_{A,B}$	E_B (mV)	$K_{A,B}$	E_B (mV)	$K_{A,B}$	E_B (mV)	$K_{A,B}$	E_B (mV)	$K_{A,B}$	E_B (mV)	
i^+	-146	2.8×10^{-3}	-174	9.0×10^{-3}	-204	2.5×10^{-2}	-212	3.9×10^{-2}	-224	5.0×10^{-2}	-23	
a^+	-126	6.5×10^{-3}	-161	1.5×10^{-2}	-181	6.4×10^{-2}	-192	8.9×10^{-2}	-210	8.9×10^{-2}	-21	
$^+$	-116	9.7×10^{-3}	-155	1.9×10^{-2}	-184	5.7×10^{-2}	-199	6.7×10^{-2}	-214	7.6×10^{-2}	-24	5
g^{+2}	-118	2.8×10^{-3}	-129	5.7×10^{-3}	-139	1.1×10^{-2}	-140	1.7×10^{-2}	-149	1.1×10^{-2}	-18	2
$^{+2}$	-124	2.2×10^{-3}	-159	1.7×10^{-3}	-166	3.8×10^{-3}	-170	4.9×10^{-3}	-170	4.6×10^{-3}	-17	3
$^{+2}$	-81	1.3×10^{-2}	-108	1.3×10^{-2}	-144	9.2×10^{-3}	-148	1.2×10^{-2}	-150	1.0×10^{-2}	-19	1
$^{+3}$	-48	3.4×10^{-2}	-73	2.6×10^{-2}	-113	1.0×10^{-2}	-131	6.8×10^{-3}	-152	2.1×10^{-3}	-18	2
$^{+3}$	-29	7.4×10^{-2}	-85	1.6×10^{-2}	-119	8.2×10^{-3}	-133	6.3×10^{-3}	-151	2.2×10^{-3}	-19	2
$^{+3}$	-73	1.2×10^{-2}	-95	1.1×10^{-2}	-126	6.1×10^{-3}	-132	6.6×10^{-3}	-153	1.9×10^{-3}	-19	2

Low values of selectivity coefficients were obtained which means low interfering of these cations on electrode response.

Generally, the values of selectivity coefficient in the above tables indicated that the interference was increased as the concentration of the drug decrease. Also the higher interference was noticed for mono valent cations than di and tri-valent cations. The higher interference of cations at concentration 10^{-5} M is due to the electrode can not be response to the drug at low concentrations. In this case the drug start to leach from the membrane to the external solutions which contain the interfering cations and the cations can be exchange the drug of the complex in the membrane. Therefore, the interference of the cations on electrode response can be increased.

3-4-2. Selectivity by Match method:

The match method was used for measuring the selectivity coefficients. The study was carried out for all the electrodes at different concentrations of promethazine hydrochloride and various concentrations of interfering cations. The results are shown in figures (3-76) to (3-115).

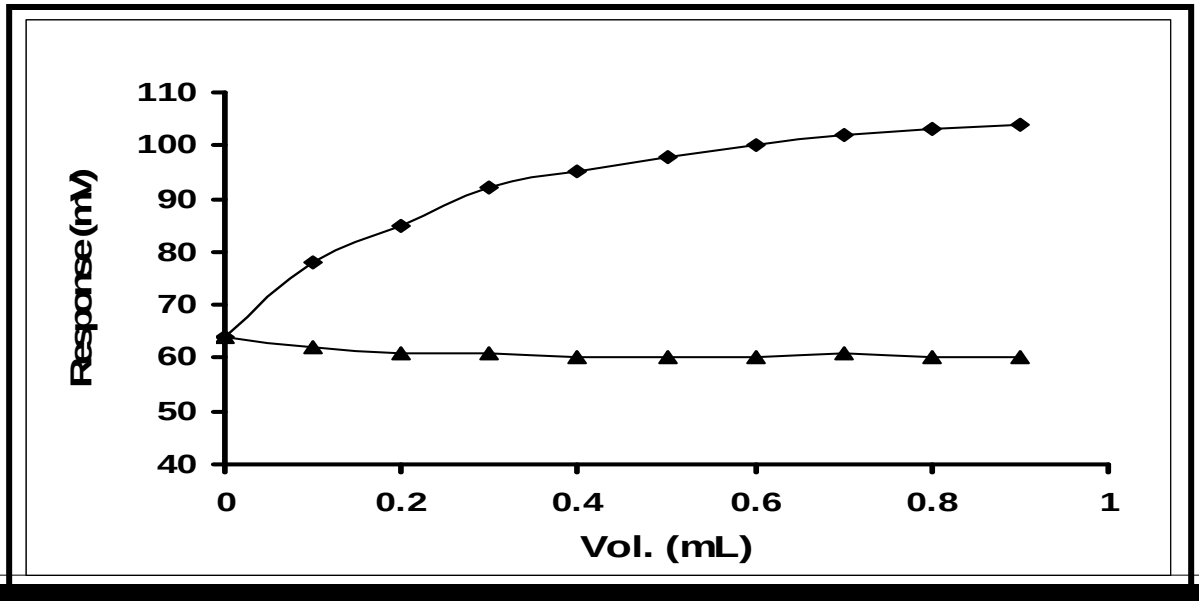


Figure (3-76): Selectivity of electrode A(PMH-PT+DBP) at concentration (10^{-3}) M for Li^{+1} cation interfering by Match method,♦ promethazine hydrochloride solutions, ▲ solutions of lithium cation interfering.

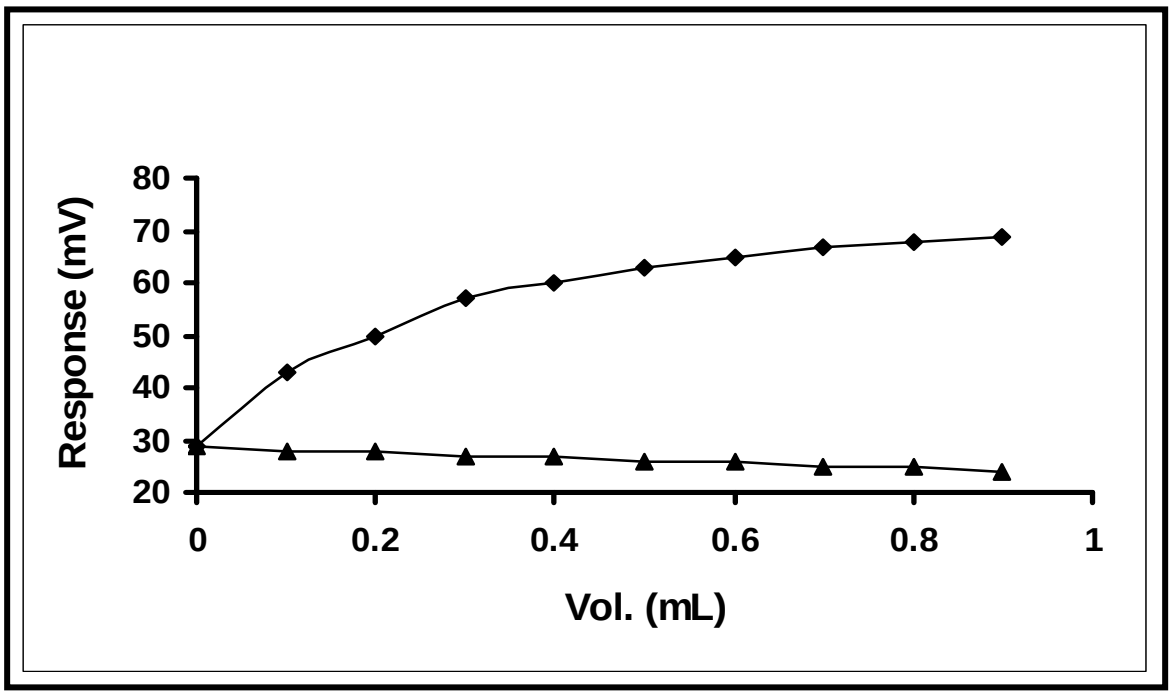


Figure (3-77): Selectivity of electrode A(PMH-PT+DBP) at concentration (10^{-4}) M for Li^{+1} cation interfering by Match method,♦ promethazine hydrochloride solutions, ▲ solutions of lithium cation interfering.

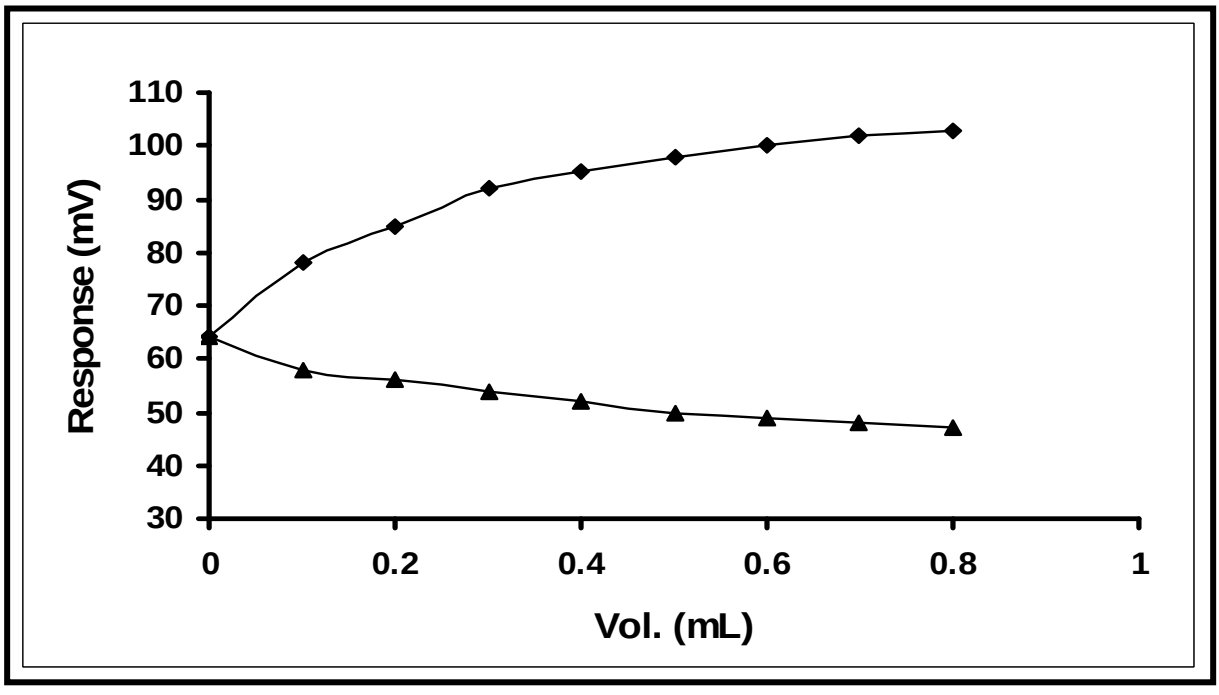


Figure (3-78): Selectivity of electrode A(PMH-PT+DBP) at concentration (10^{-3}) M for Na^{+1} cation interfering by Match method,♦ promethazine hydrochloride solutions, ▲ solutions of sodium cation interfering.

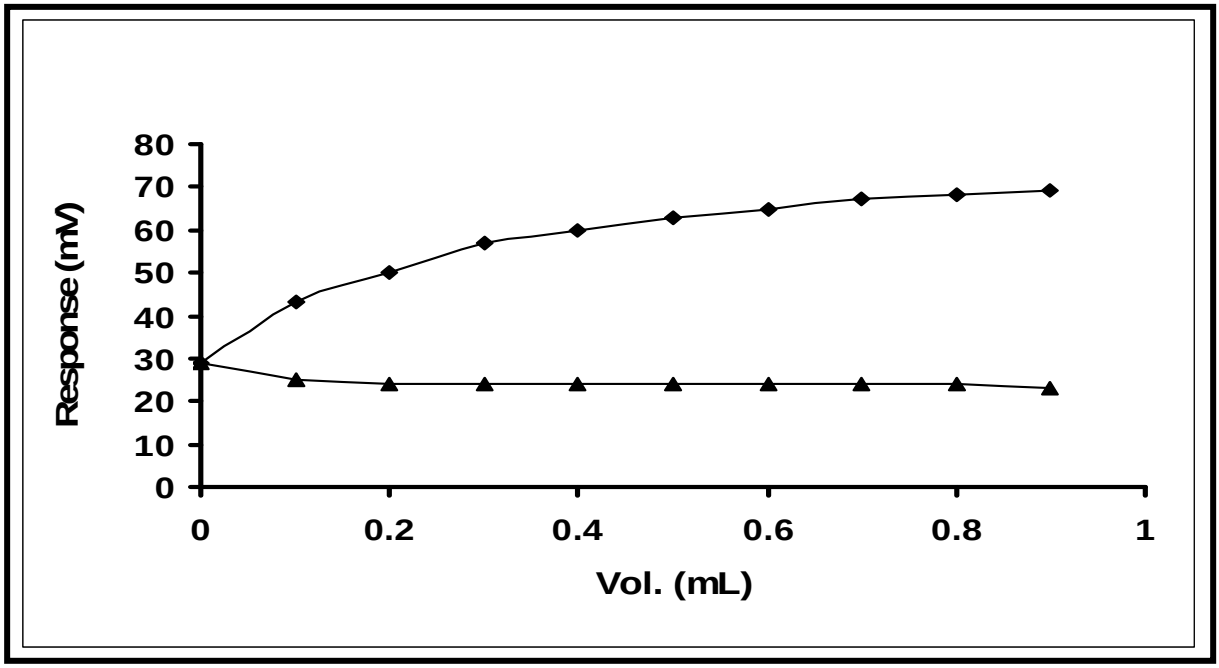


Figure (3-79): Selectivity of electrode A(PMH-PT+DBP) at concentration (10^{-4}) M for Na^{+1} cation interfering by Match method,♦ promethazine hydrochloride solutions, ▲ solutions of sodium cation interfering.

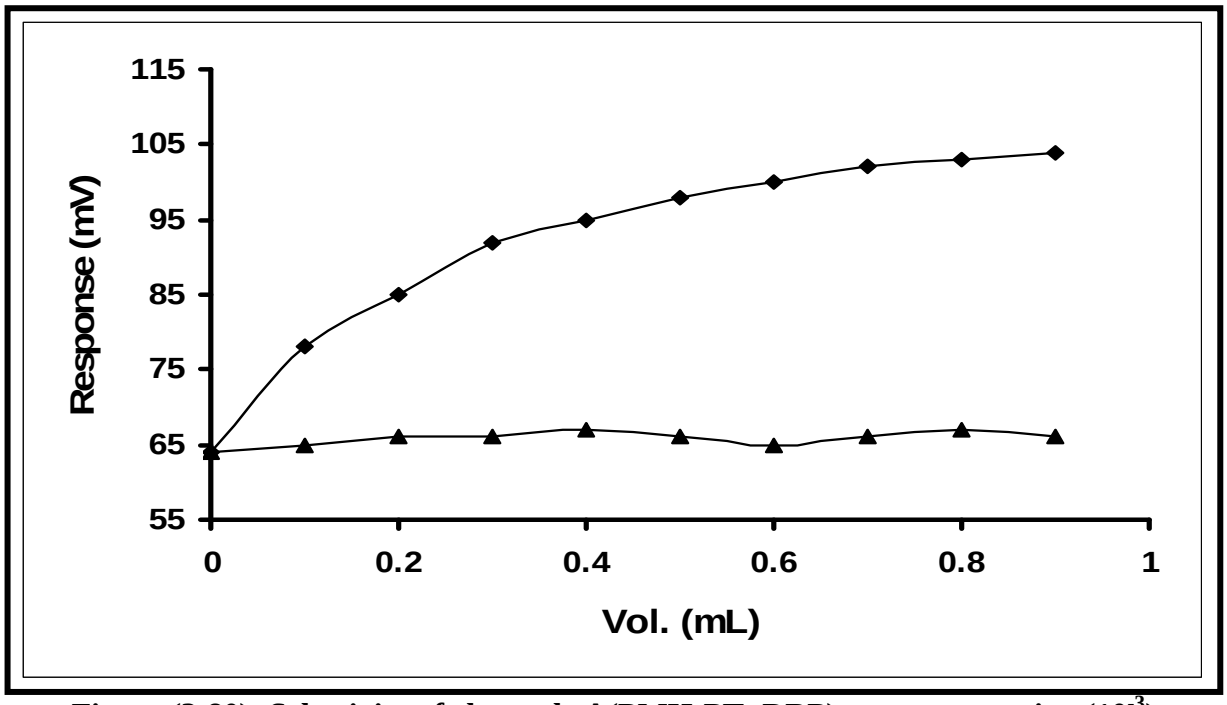


Figure (3-80): Selectivity of electrode A(PMH-PT+DBP) at concentration (10^{-3}) M for K^{+1} cation interfering by Match method,♦ promethazine hydrochloride solutions, ▲ solutions of potassium cation interfering.

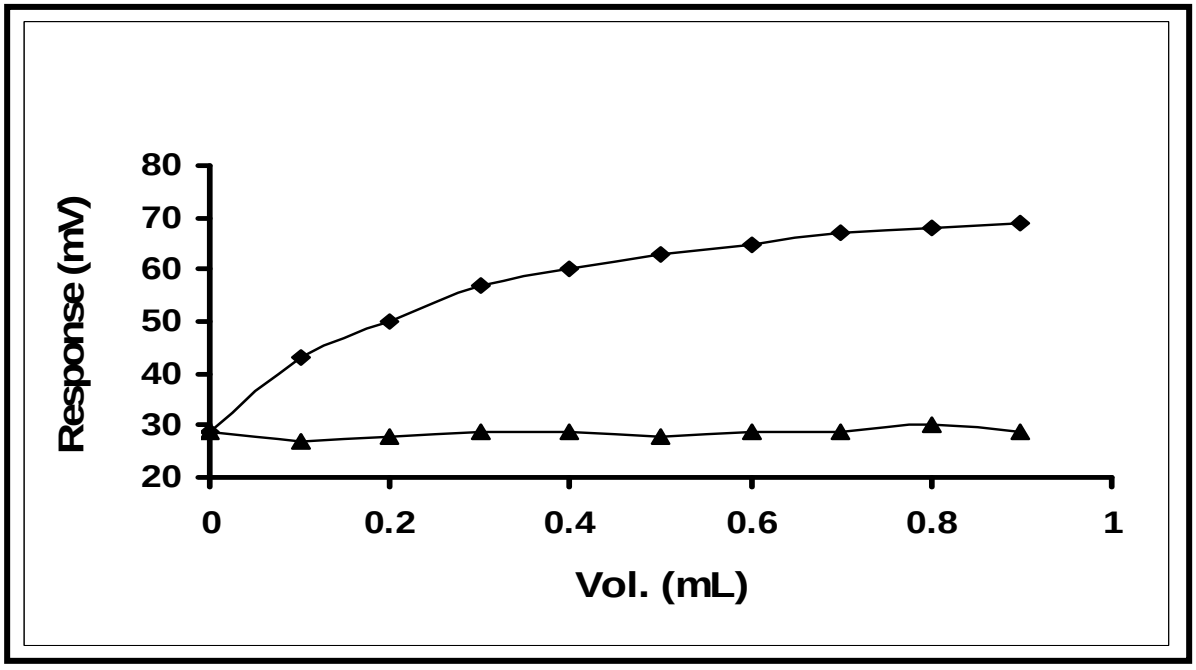


Figure (3-81): Selectivity of electrode A(PMH-PT+DBP) at concentration (10^{-4}) M for K^{+1} cation interfering by Match method,♦ promethazine hydrochloride solutions, ▲ solutions of potassium cation interfering.

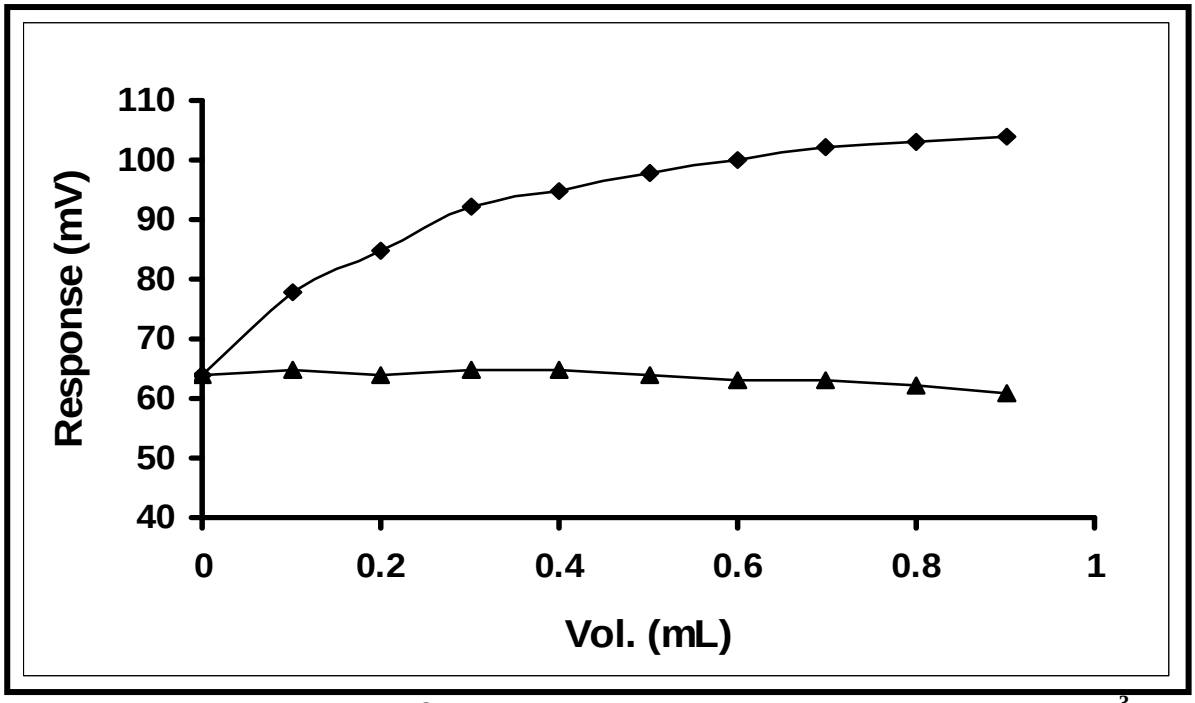


Figure (3-82): Selectivity of electrode A(PMH-PT+DBP) at concentration (10^{-3}) M for Mg^{+2} cation interfering by Match method,♦ promethazine hydrochloride solutions, ▲ solutions of magnesium cation interfering.

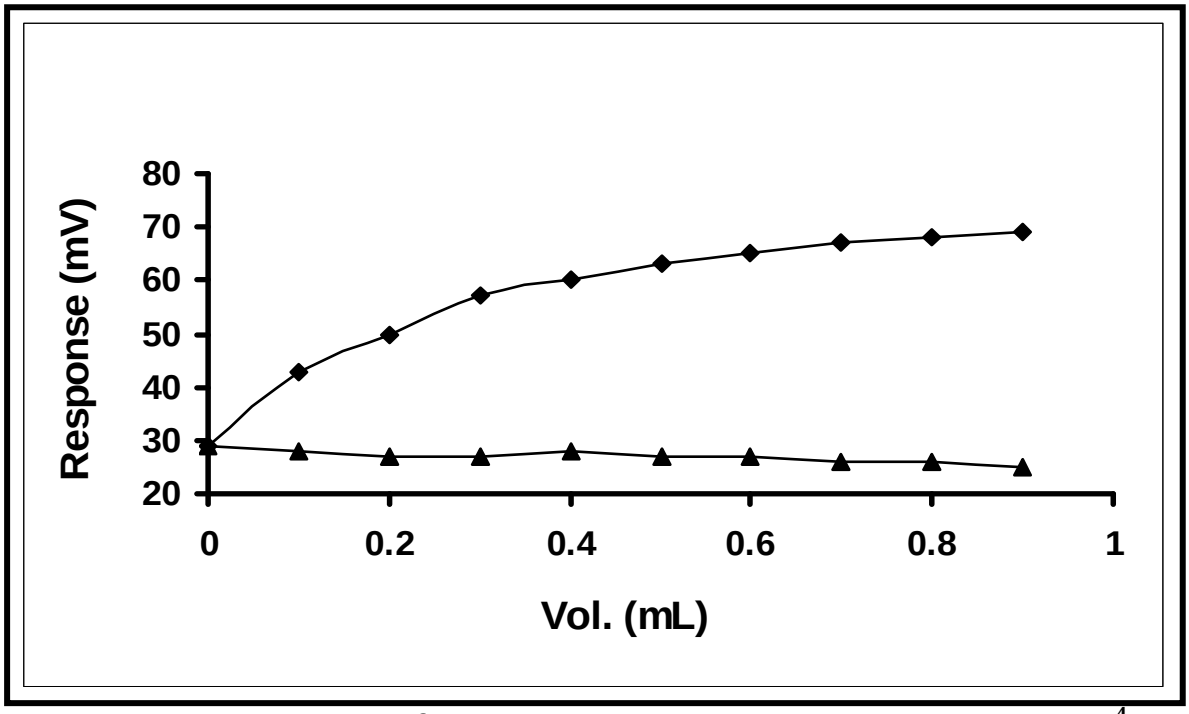


Figure (3-83): Selectivity of electrode A(PMH-PT+DBP) at concentration (10^{-4}) M for Mg^{+2} cation interfering by Match method,♦ promethazine hydrochloride solutions, ▲ solutions of magnesium cation interfering.

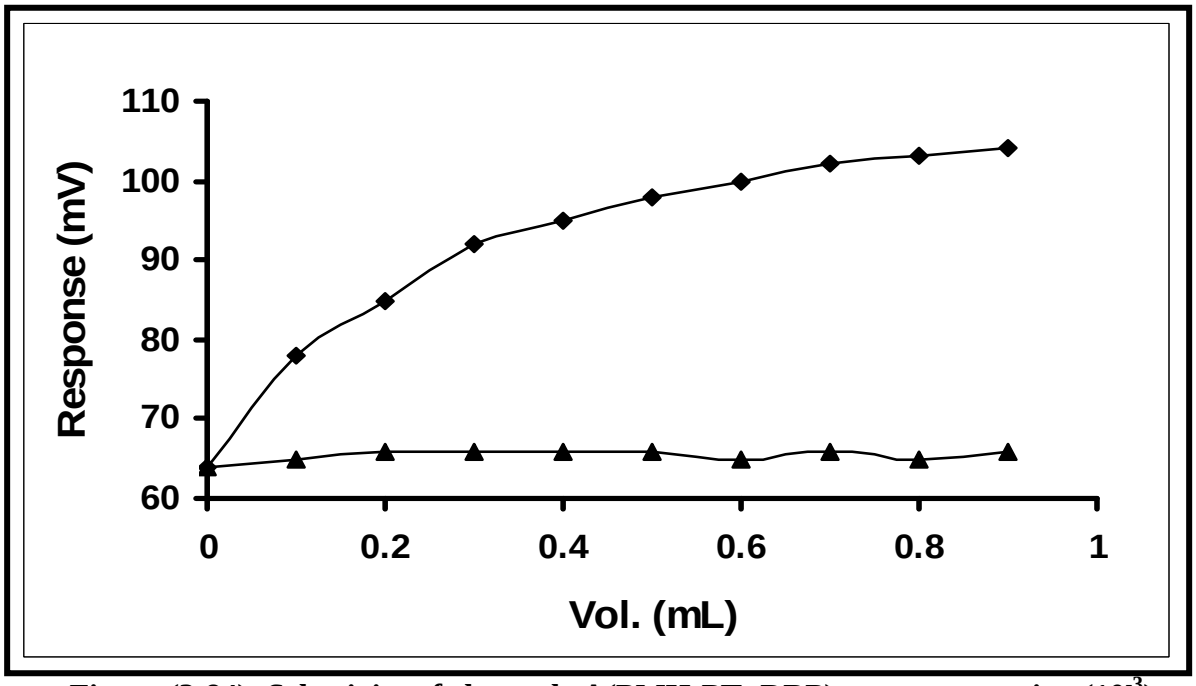
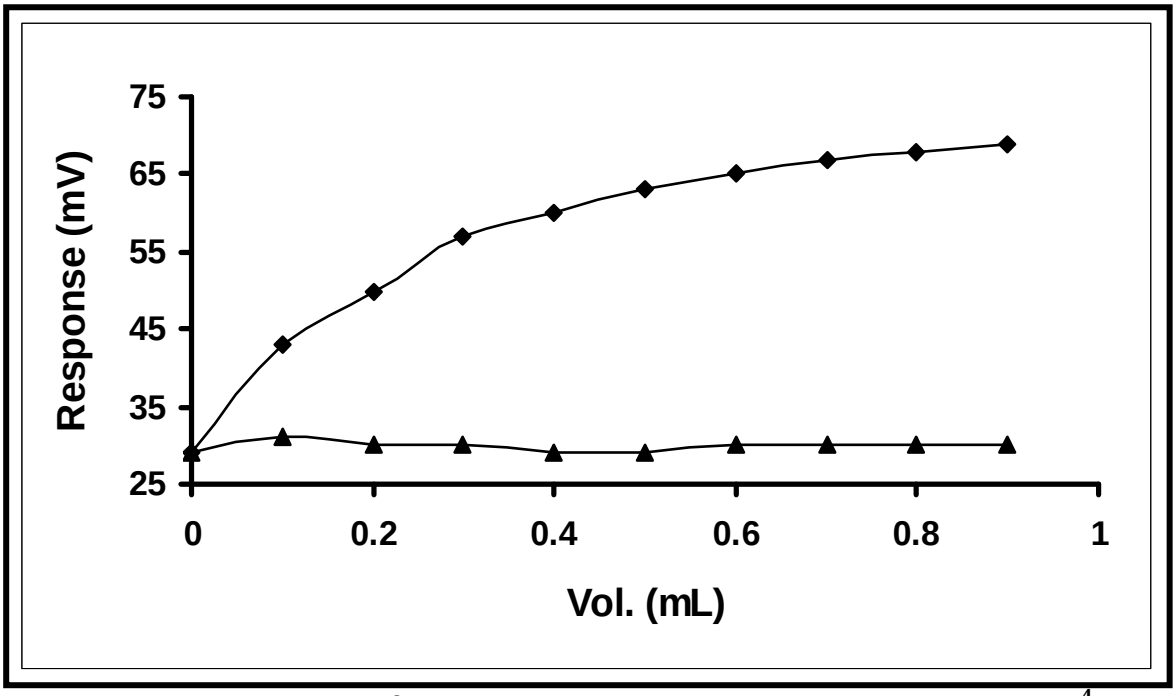
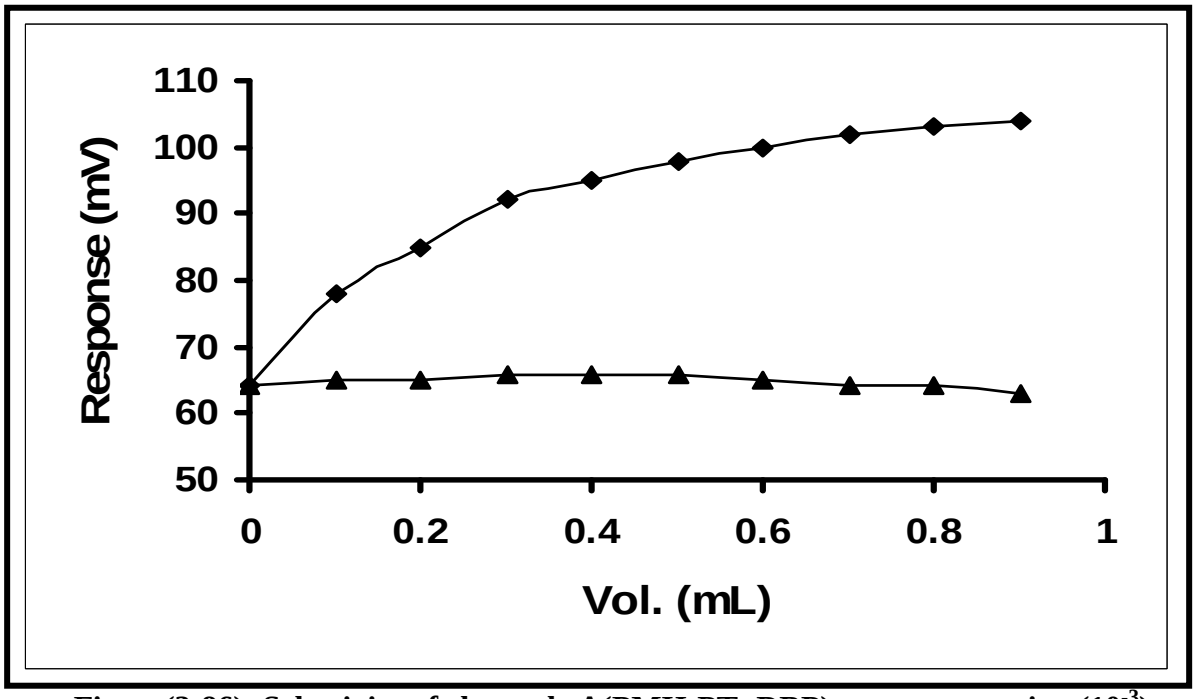


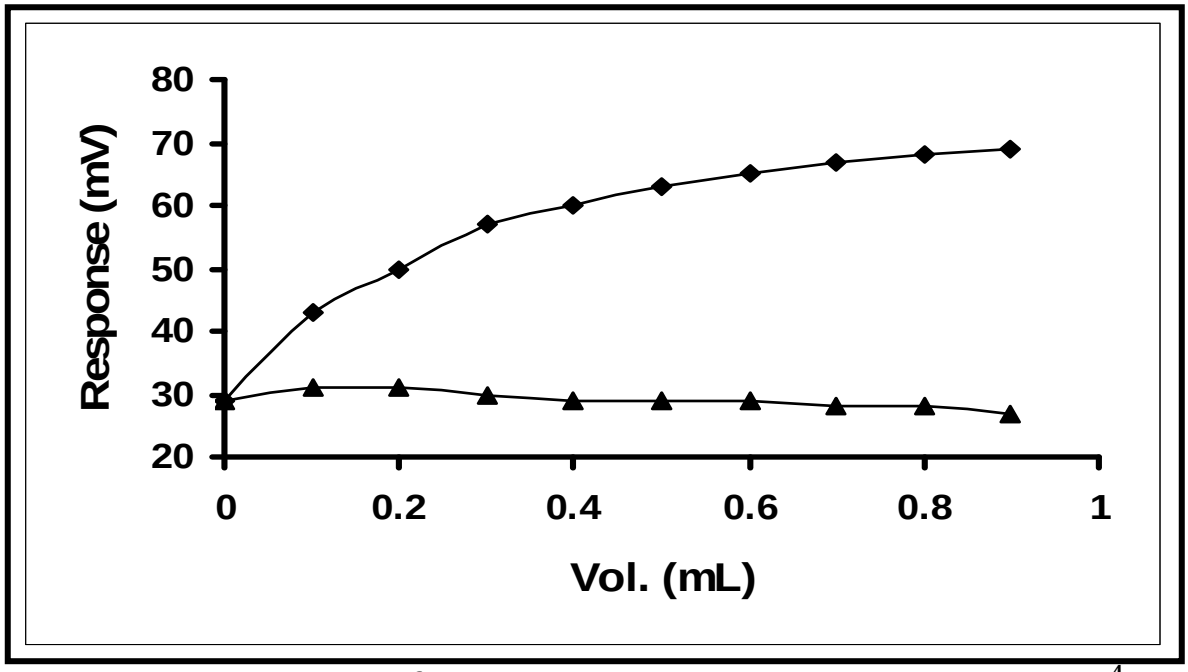
Figure (3-84): Selectivity of electrode A(PMH-PT+DBP) at concentration (10^{-3}) M for Ca^{+2} cation interfering by Match method,♦ promethazine hydrochloride solutions, ▲ solutions of calcium cation interfering.



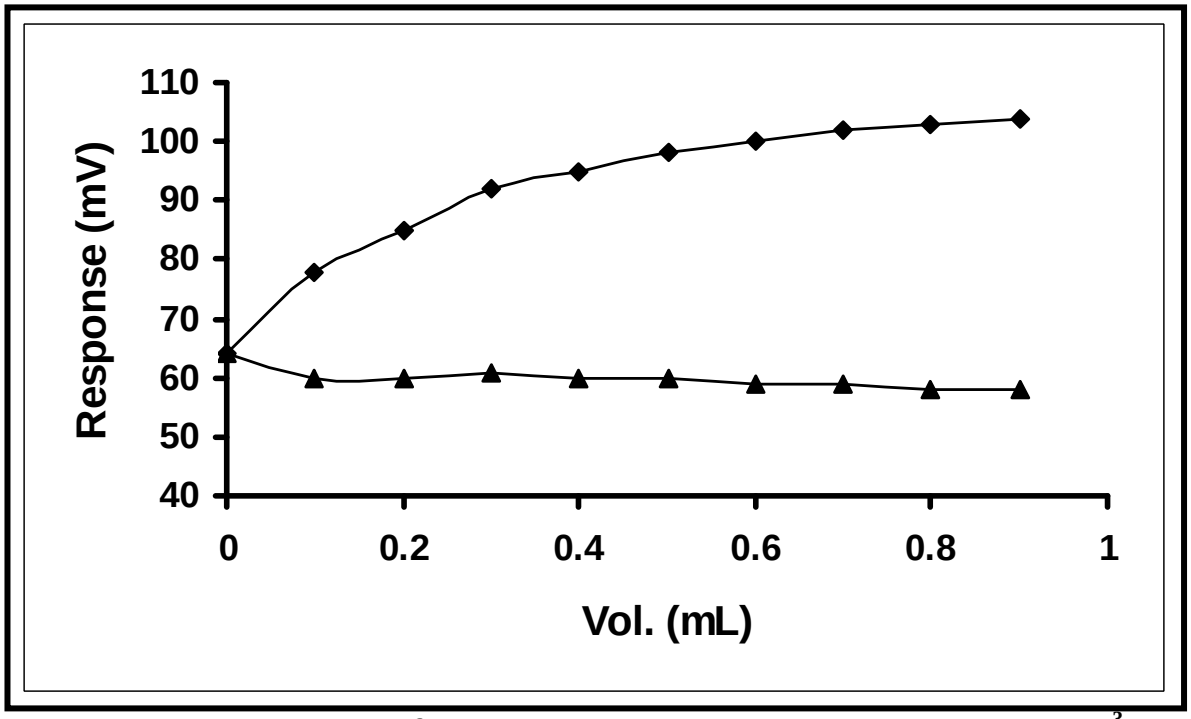
Figure(3-85): Selectivity of electrode A(PMH-PT+DBP) at concentration (10^{-4}) M for Ca^{+2} cation interfering by Match method,♦ promethazine hydrochloride solutions, ▲ solutions of calcium cation interfering.



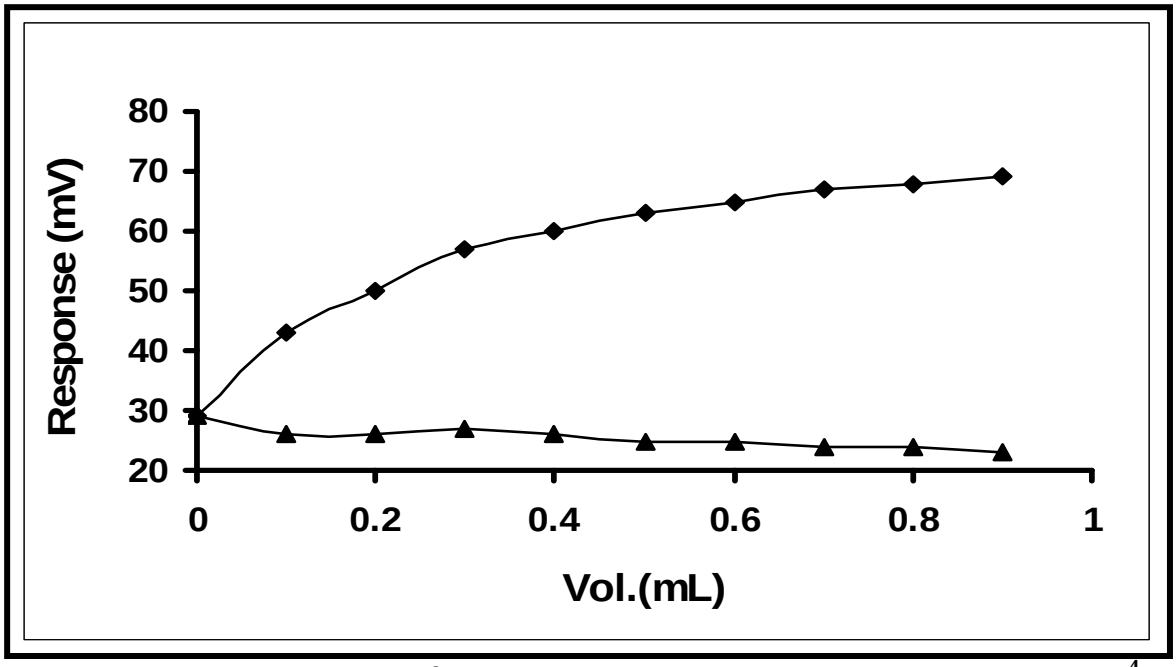
Figure(3-86): Selectivity of electrode A(PMH-PT+DBP) at concentration (10^{-3}) M for Zn^{+2} cation interfering by Match method,♦ promethazine hydrochloride solutions, ▲ solutions of zinc cation interfering.



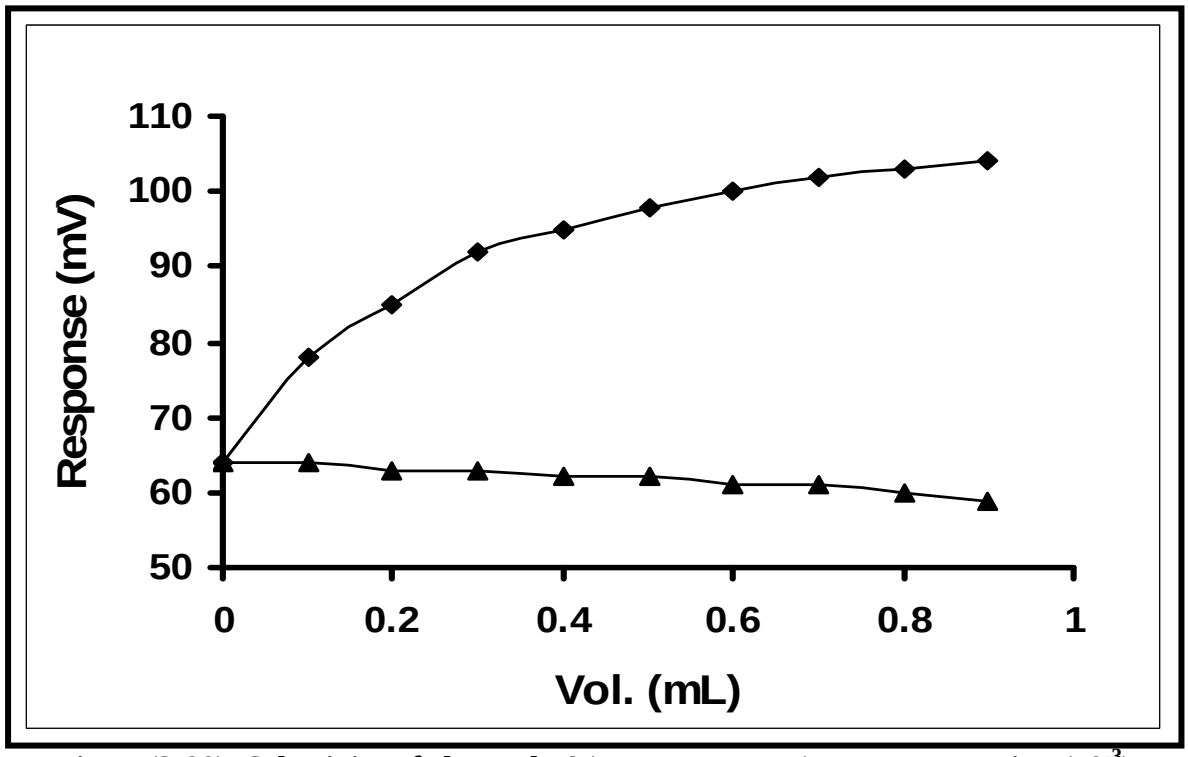
Figure(3-87): Selectivity of electrode A(PMH-PT+DBP) at concentration (10^{-4}) M for Zn^{+2} cation interfering by Match method,♦ promethazine hydrochloride solutions, ▲ solutions of zinc cation interfering.



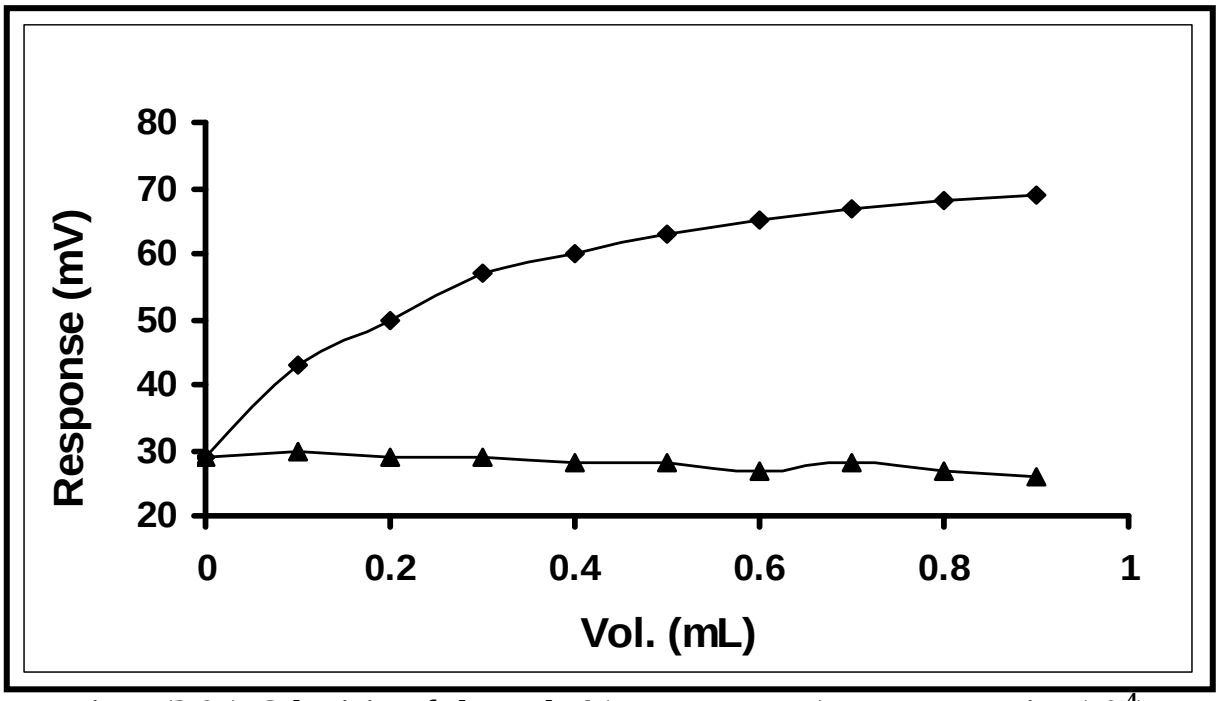
Figure(3-88): Selectivity of electrode A(PMH-PT+DBP) at concentration (10^{-3}) M for Al^{+3} cation interfering by Match method,♦ promethazine hydrochloride solutions, ▲ solutions of aluminum cation interfering.



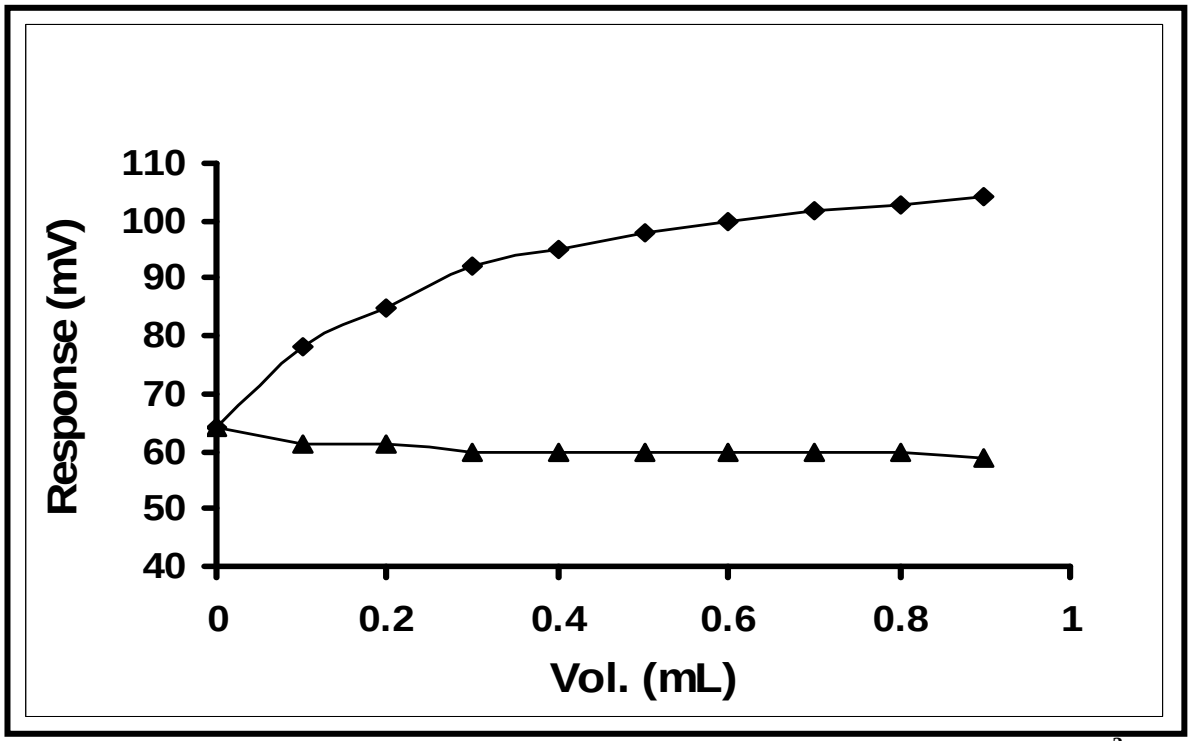
Figure(3-89): Selectivity of electrode A(PMH-PT+DBP) at concentration (10^{-4}) M for Al^{+3} cation interfering by Match method,♦ promethazine hydrochloride solutions, ▲ solutions of aluminum cation interfering.



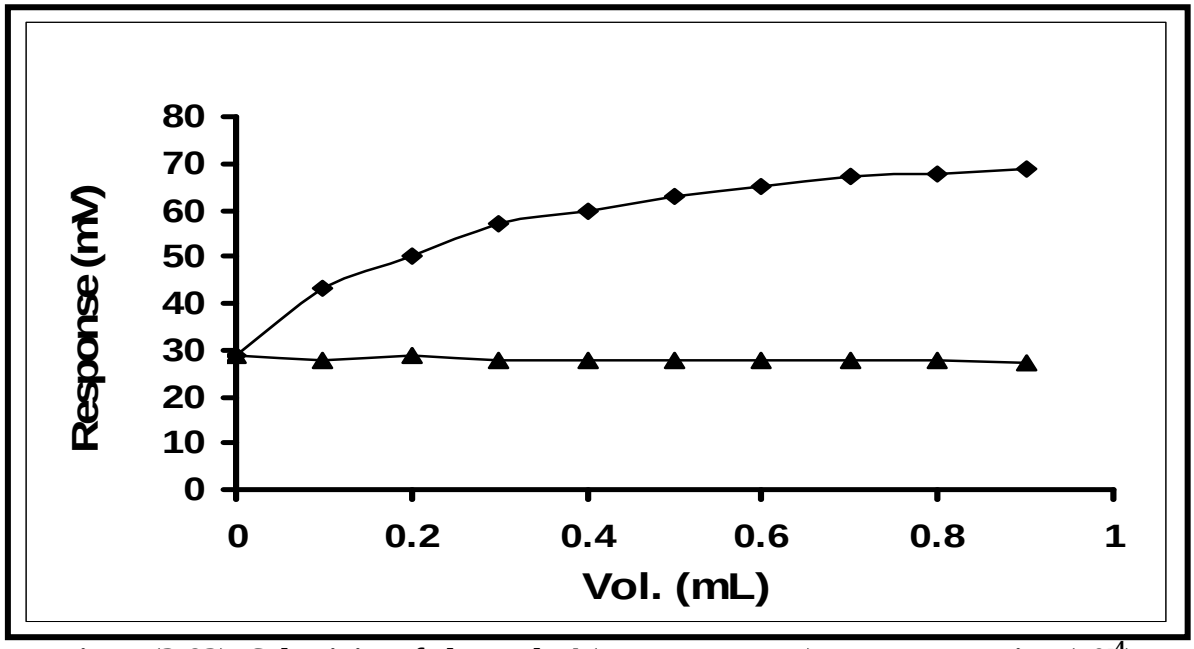
Figure(3-90): Selectivity of electrode A(PMH-PT+DBP) at concentration (10^{-3}) M for Fe^{+3} cation interfering by Match method,♦ promethazine hydrochloride solutions, ▲ solutions of ferric cation interfering.



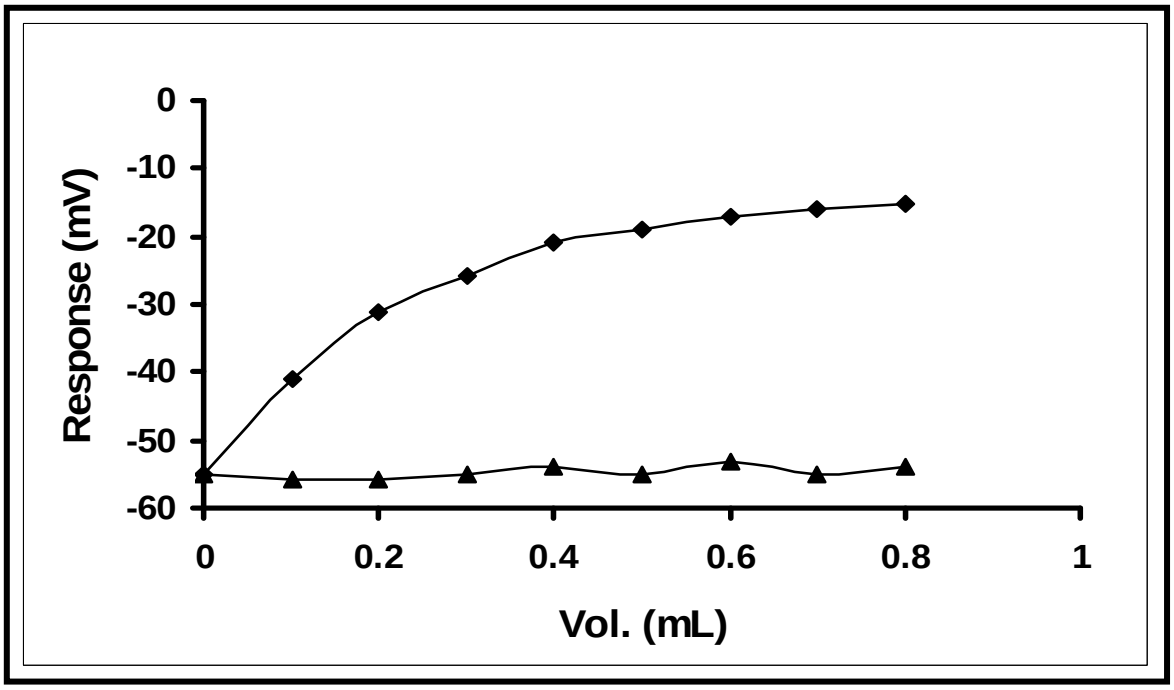
Figure(3-91): Selectivity of electrode A(PMH-PT+DBP) at concentration (10^{-4}) M for Fe^{+3} cation interfering by Match method,♦ promethazine hydrochloride solutions, ▲ solutions of ferric cation interfering.



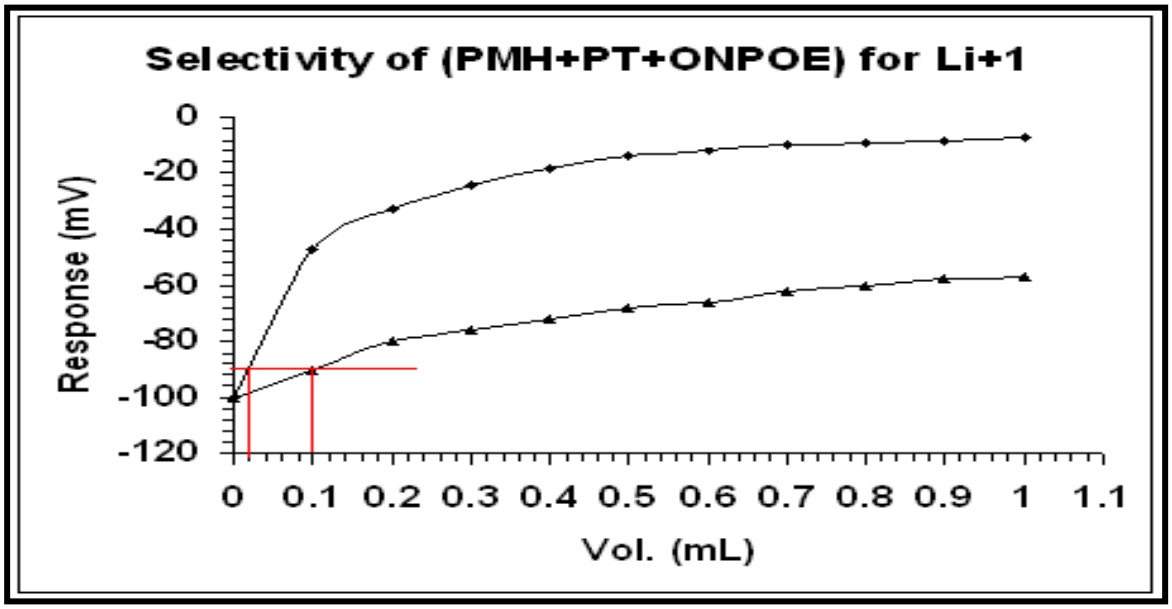
Figure(3-92): Selectivity of electrode A(PMH-PT+DBP) at concentration (10^{-3}) M for Cr^{+3} cation interfering by Match method,♦ promethazine hydrochloride solutions, ▲ solutions of chromic cation interfering.



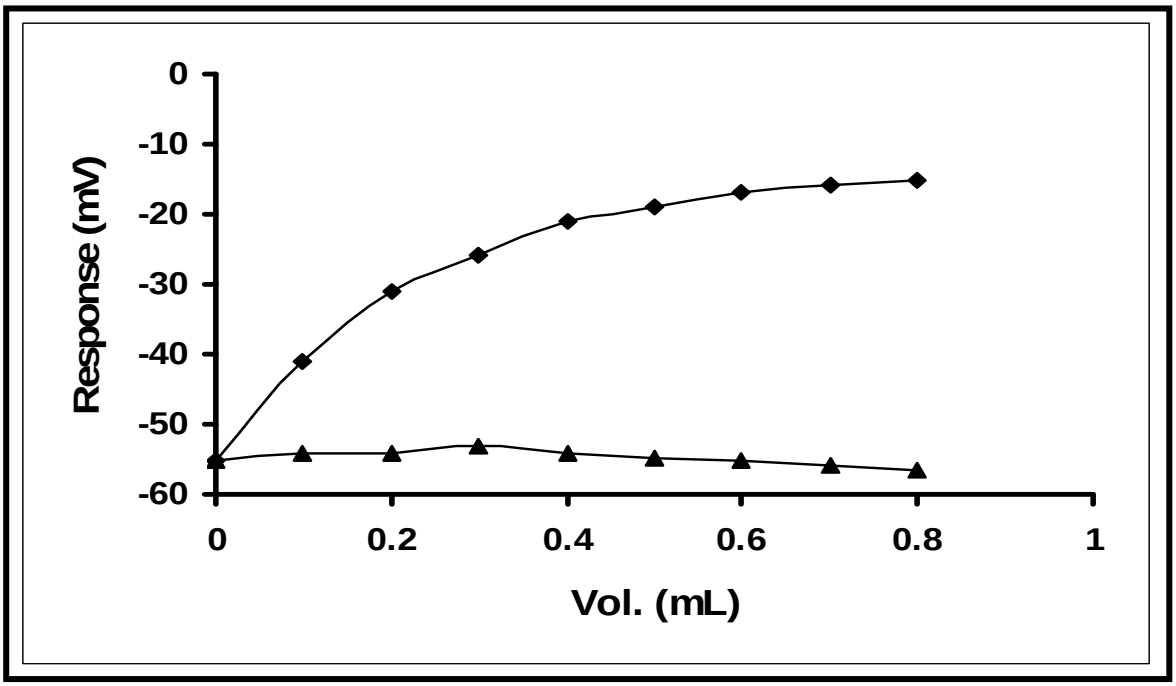
Figure(3-93): Selectivity of electrode A(PMH-PT+DBP) at concentration (10^{-4}) M for Cr^{+3} cation interfering by Match method,♦ promethazine hydrochloride solutions, ▲ solutions of chromic cation interfering.



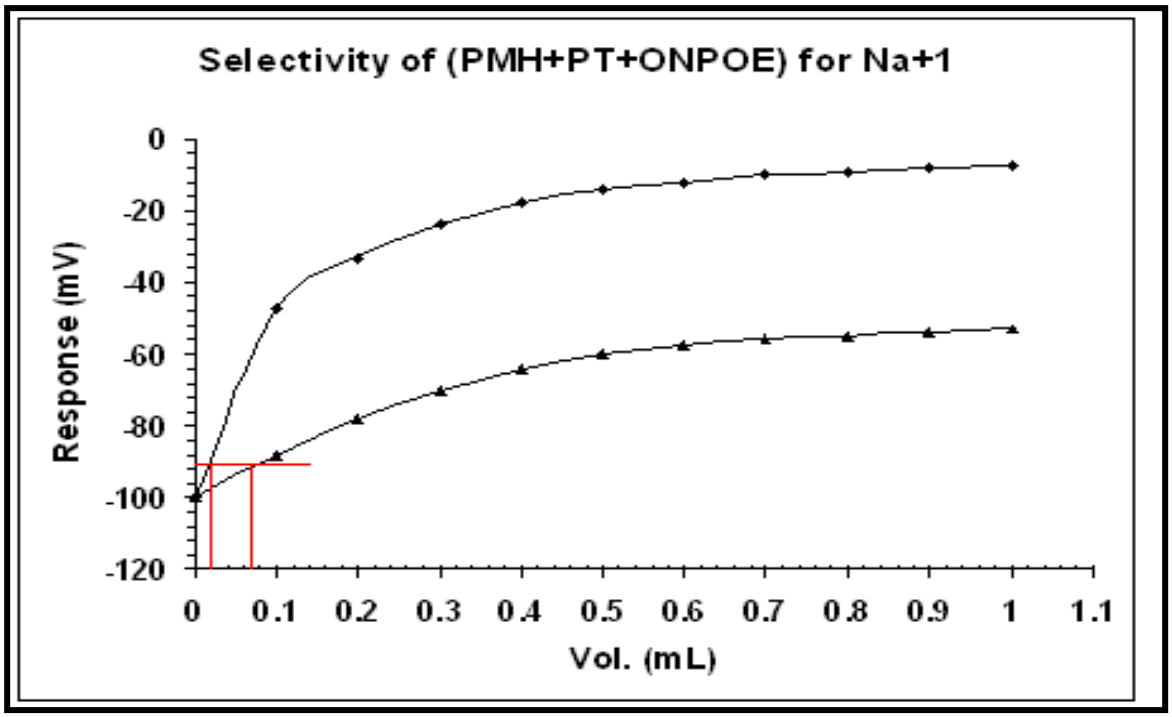
Figure(3-94): Selectivity of electrode C(PMH-PT+ONPOE) at concentration (10^{-3}) M for Li^{+1} cation interfering by Match method,♦ promethazine hydrochloride solutions, ▲ solutions of lithium cation interfering.



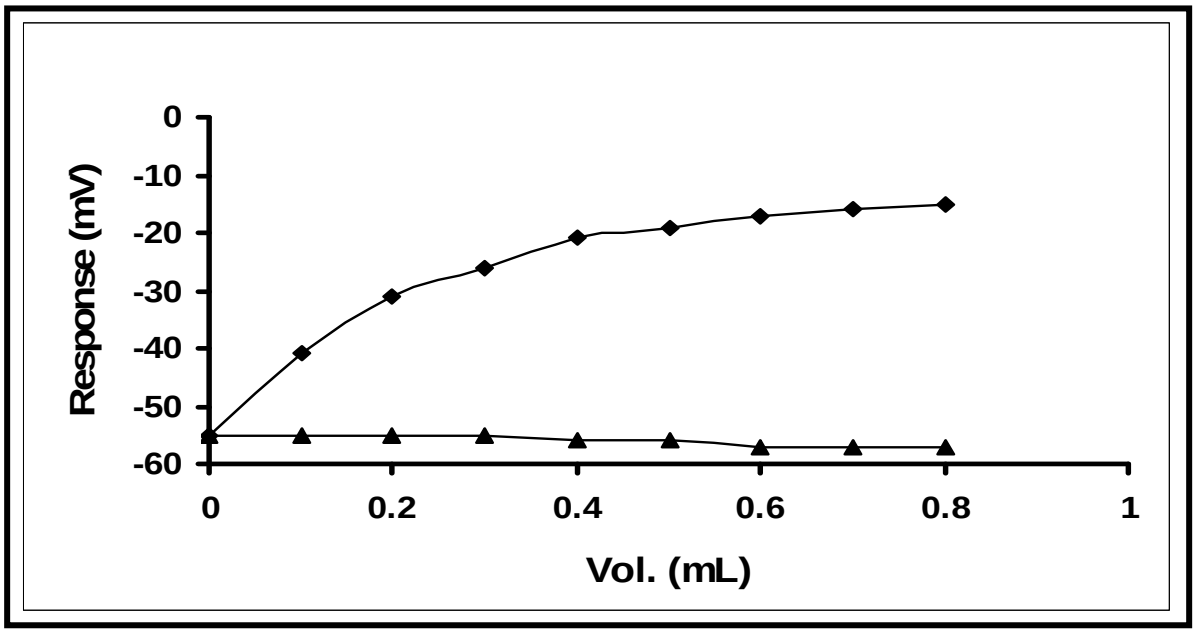
Figure(3-95): Selectivity of electrode C(PMH-PT+ONPOE) at concentration (10^{-4}) M for Li^{+1} cation interfering by Match method,♦ promethazine hydrochloride solutions, ▲ solutions of lithium cation interfering.



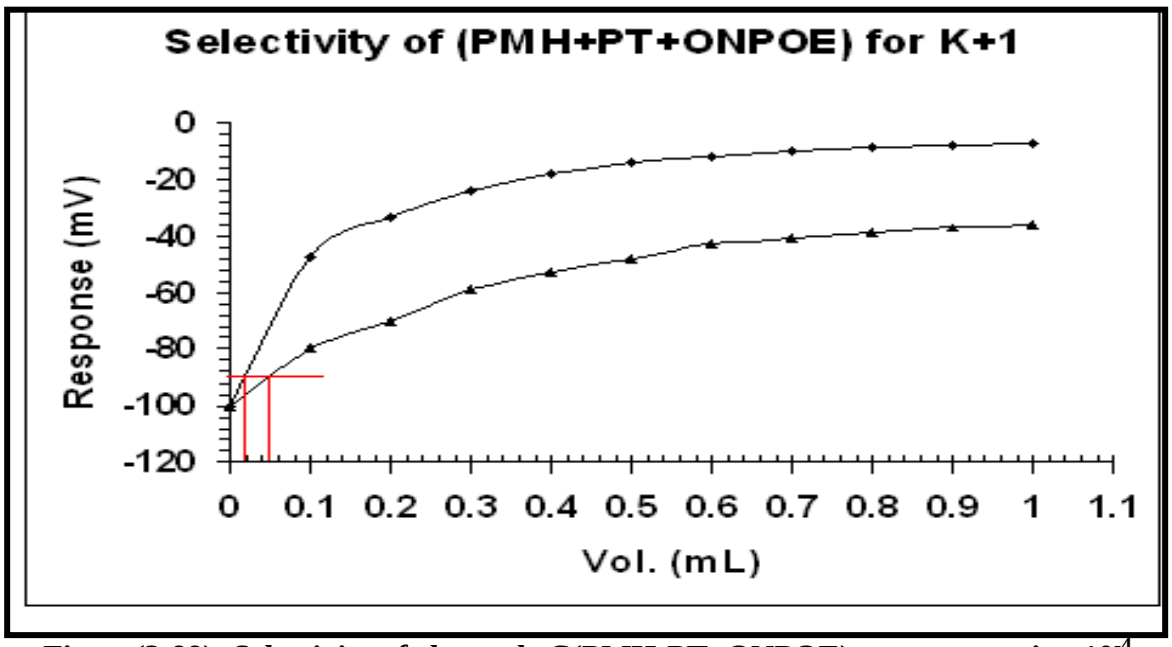
Figure(3-96): Selectivity of electrode C(PMH-PT+ONPOE) at concentration (10^{-3}) M for Na^{+1} cation interfering by Match method,♦ promethazine hydrochloride solutions, ▲ solutions of sodium cation interfering.



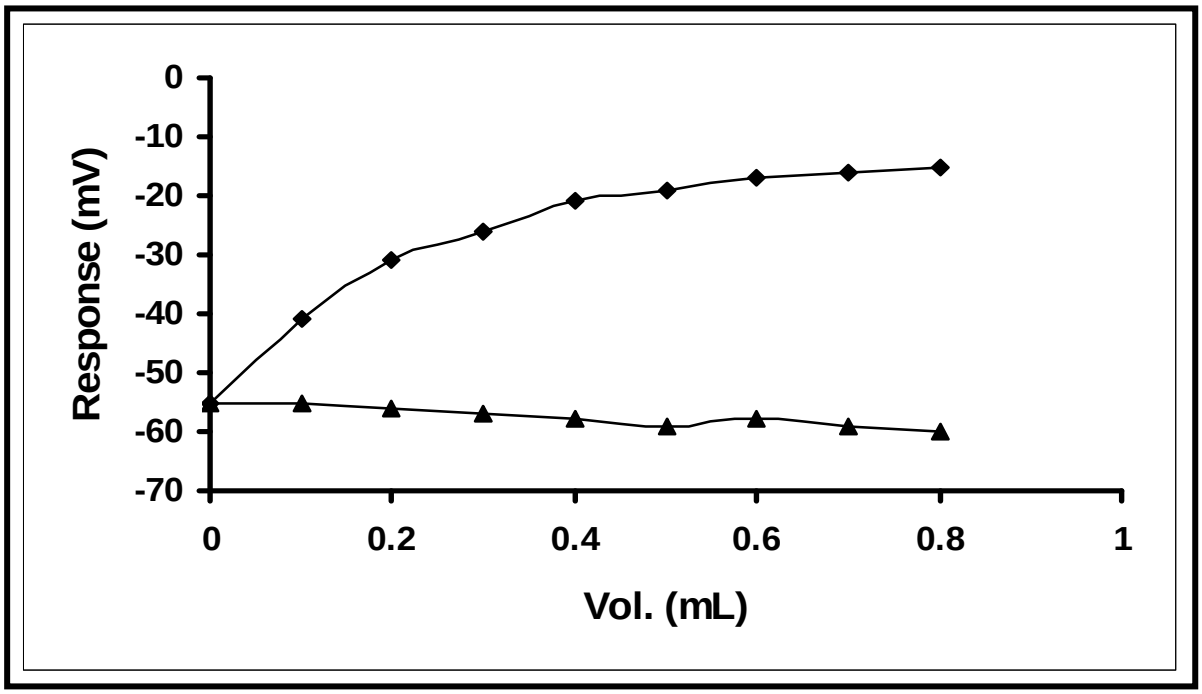
Figure(3-97): Selectivity of electrode C(PMH-PT+ONPOE) at concentration (10^{-4}) M for Na^{+1} cation interfering by Match method,♦ promethazine hydrochloride solutions, ▲ solutions of sodium cation interfering.



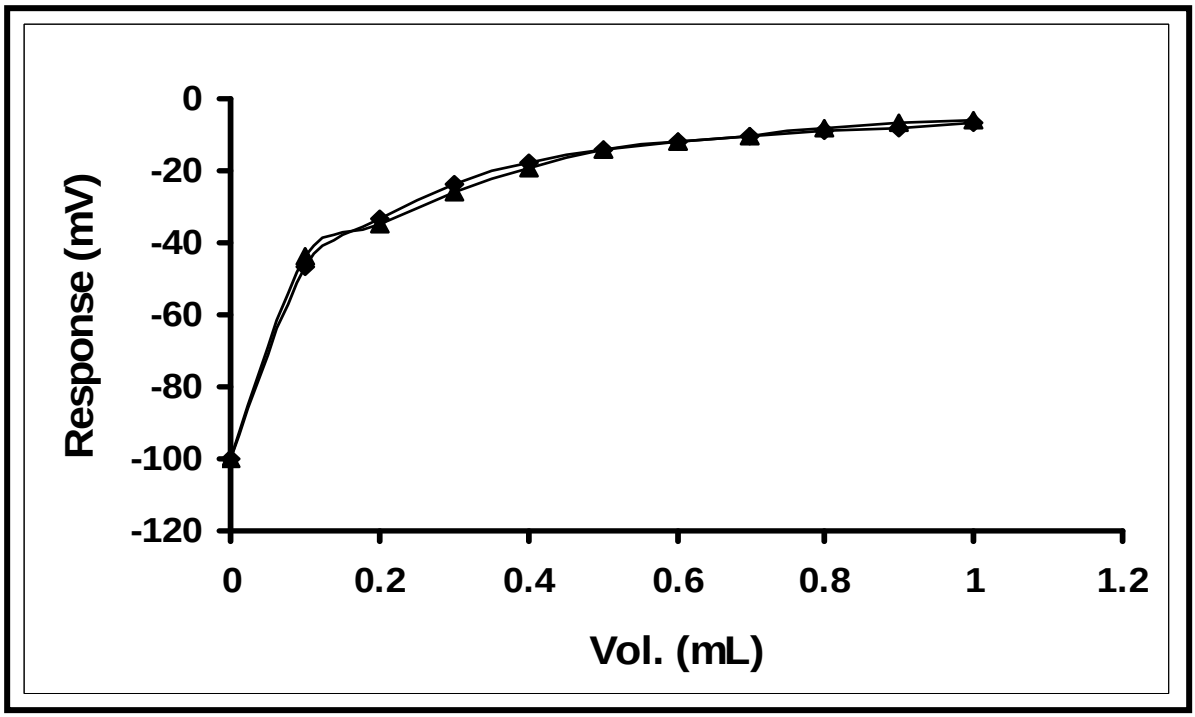
Figure(3-98): Selectivity of electrode C(PMH-PT+ONPOE) at concentration (10^{-3}) M for K^{+1} cation interfering by Match method,♦ promethazine hydrochloride solutions, ▲ solutions of potassium cation interfering.



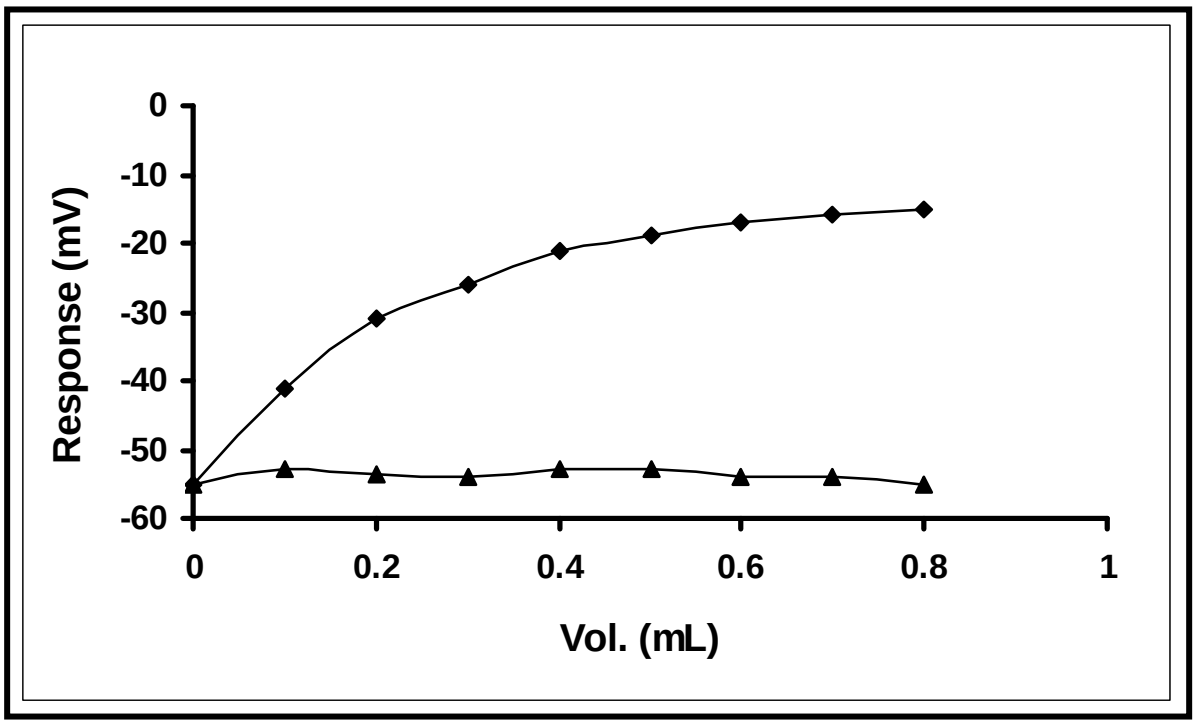
Figure(3-99): Selectivity of electrode C(PMH-PT+ONPOE)at concentration 10^{-4} M for K^{+1} cation interfering by Match method,♦ promethazine hydrochloride solutions, ▲ solutions of potassium cation interfering.



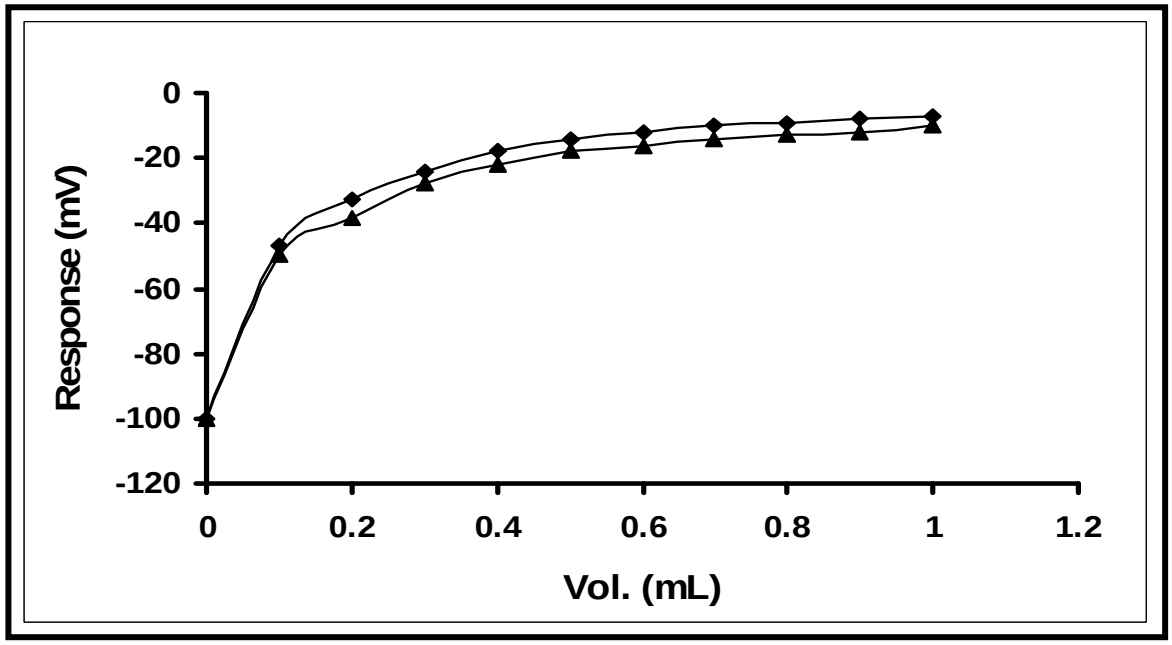
Figure(3-100): Selectivity of electrode C(PMH-PT+ONPOE) at concentration (10^{-3}) M for Mg^{+2} cation interfering by Match method,♦ promethazine hydrochloride solutions, ▲ solutions of magnesium cation interfering.



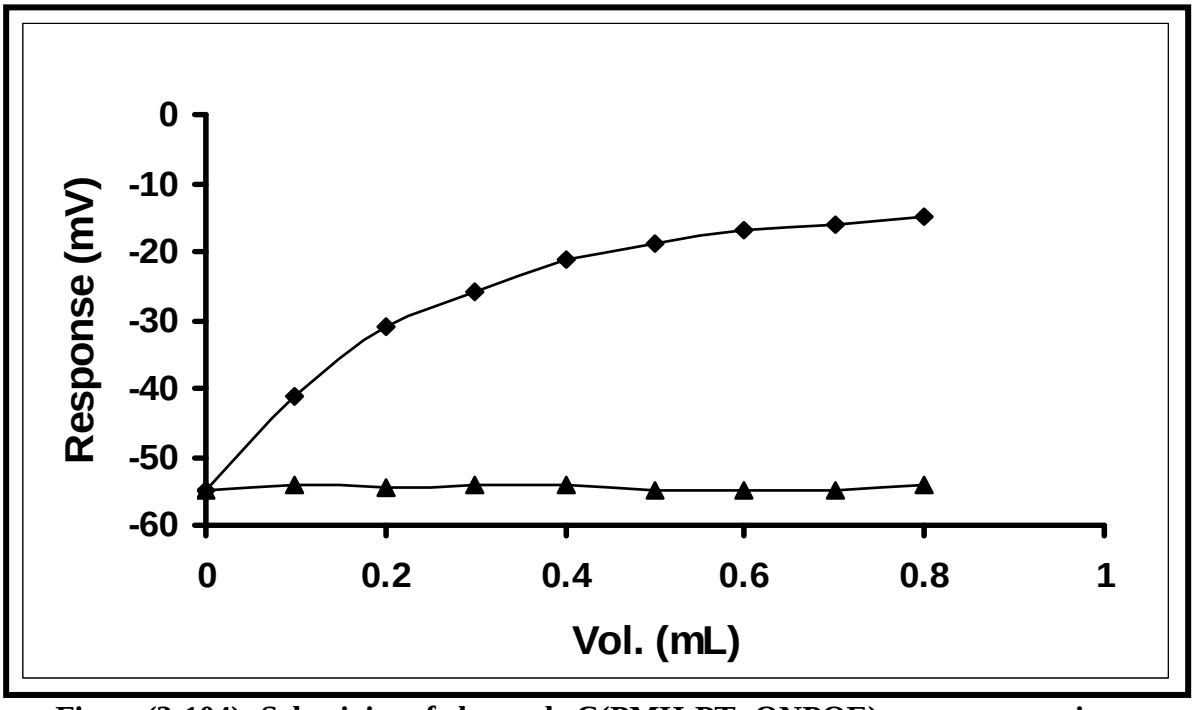
Figure(3-101): Selectivity of electrode C(PMH-PT+ONPOE) at concentration (10^{-4}) M for Mg^{+2} cation interfering by Match method,♦ promethazine hydrochloride solutions, ▲ solutions of magnesium cation interfering.



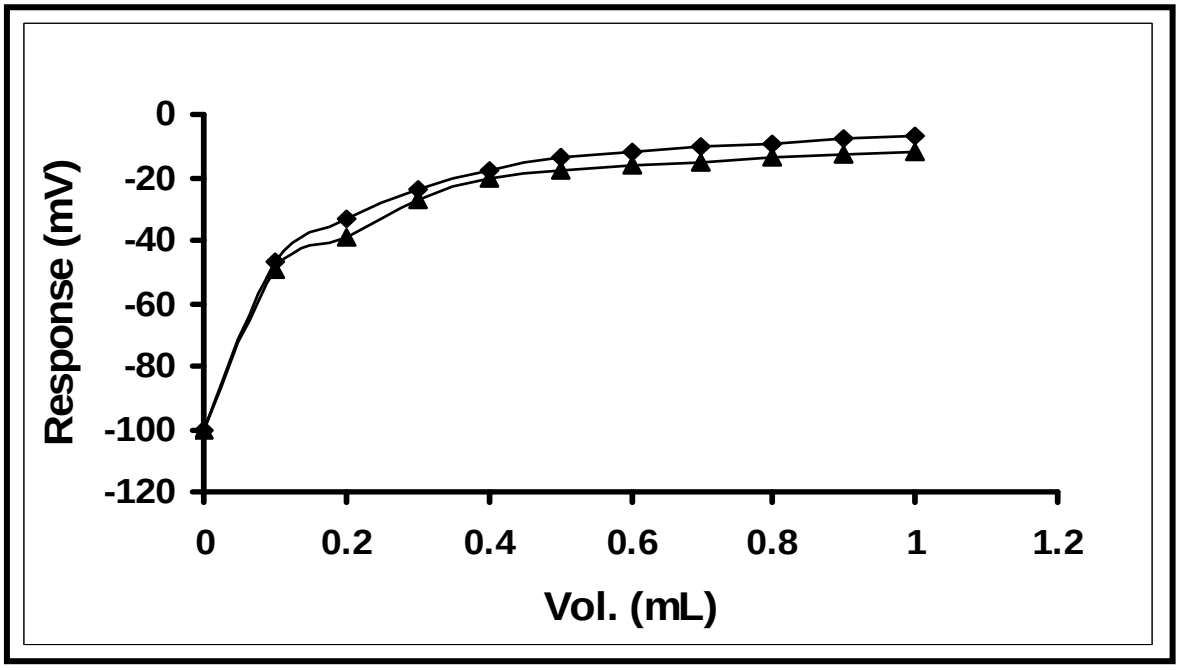
Figure(3-102): Selectivity of electrode C(PMH-PT+ONPOE) at concentration (10^{-3}) M for Ca^{+2} cation interfering by Match method,♦ promethazine hydrochloride solutions, ▲ solutions of calcium cation interfering.



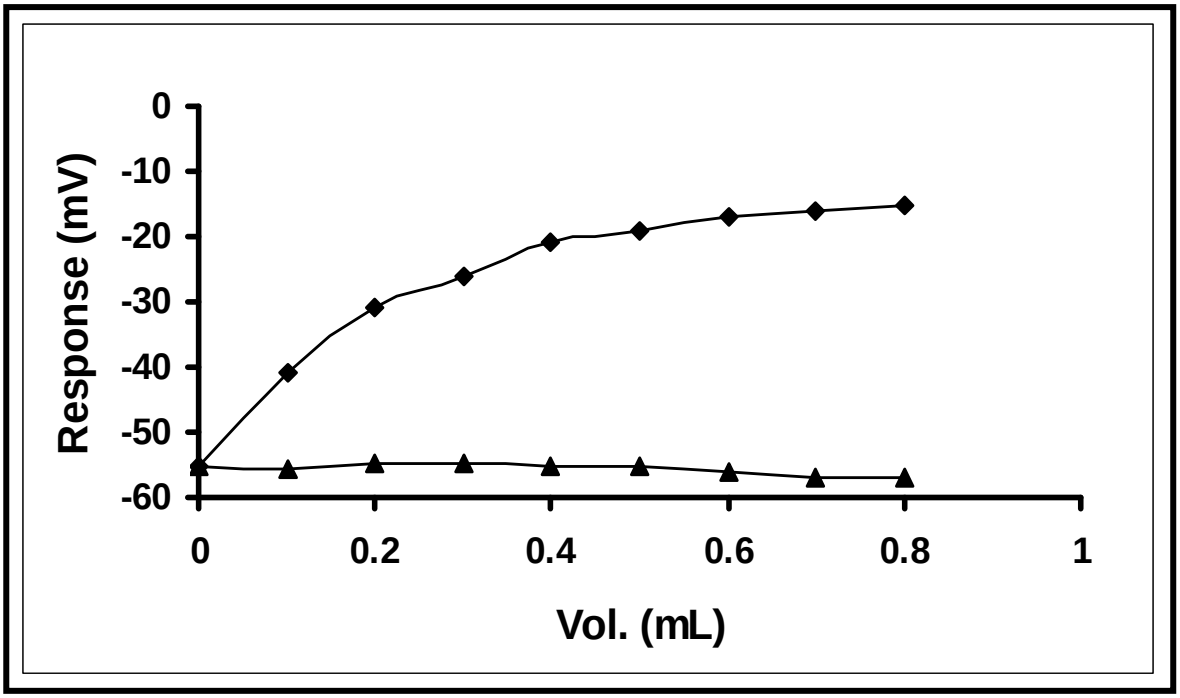
Figure(3-103): Selectivity of electrode C(PMH-PT+ONPOE) at concentration (10^{-4}) M for Ca^{+2} cation interfering by Match method,♦ promethazine hydrochloride solutions, ▲ solutions of calcium cation interfering.



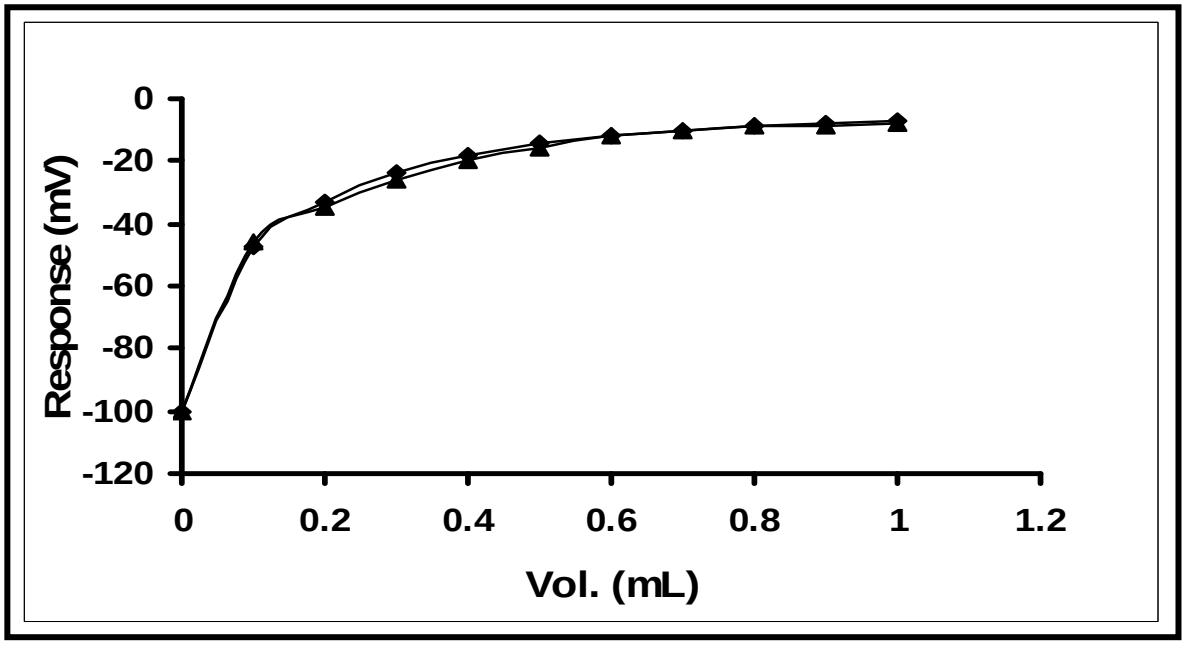
Figure(3-104): Selectivity of electrode C(PMH-PT+ONPOE) at concentration (10^{-3}) M for Zn^{+2} cation interfering by Match method,♦ promethazine hydrochloride solutions, ▲ solutions of znic cation interfering.



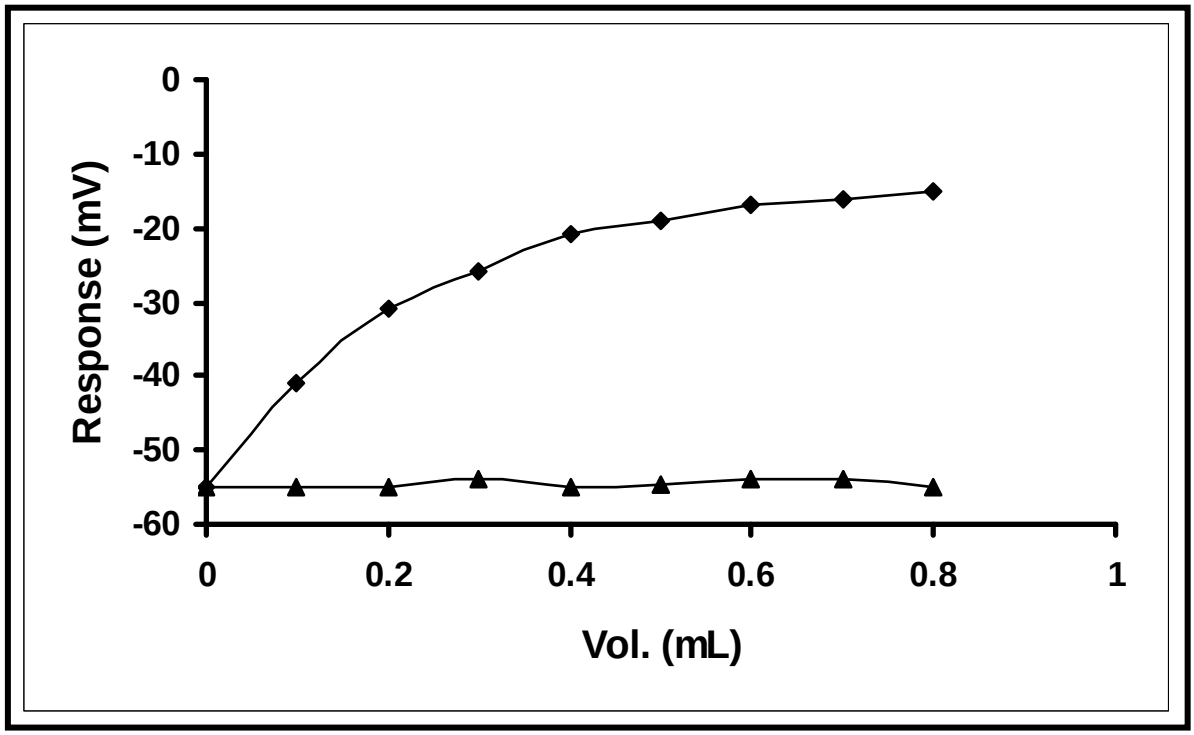
Figure(3-105): Selectivity of electrode C(PMH-PT+ONPOE) at concentration (10^{-4}) M for Zn^{+2} cation interfering by Match method,♦ promethazine hydrochloride solutions, ▲ solutions of znic cation interfering.



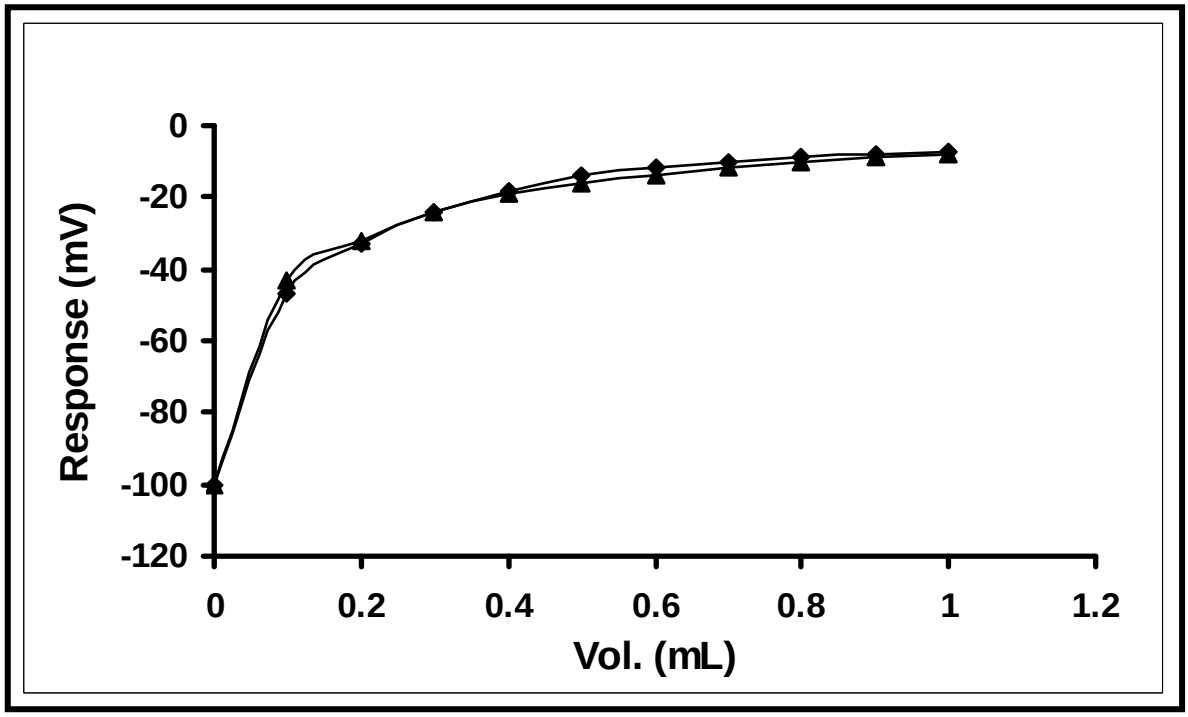
Figure(3-106): Selectivity of electrode C(PMH-PT+ONPOE) at concentration (10^{-3}) M for Al^{+3} cation interfering by Match method,♦ promethazine hydrochloride solutions, ▲ solutions of aluminum cation interfering.



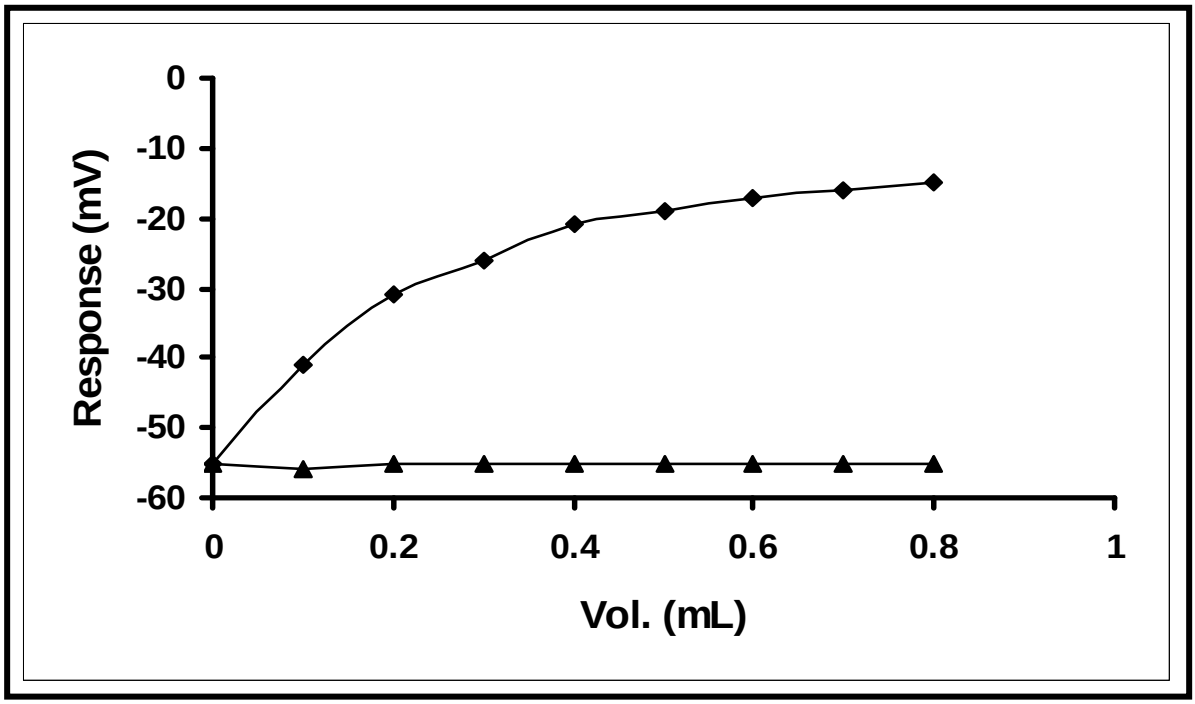
Figure(3-107): Selectivity of electrode C(PMH-PT+ONPOE) at concentration (10^{-4}) M for Al^{+3} cation interfering by Match method,♦ promethazine hydrochloride solutions, ▲ solutions of aluminum cation interfering.



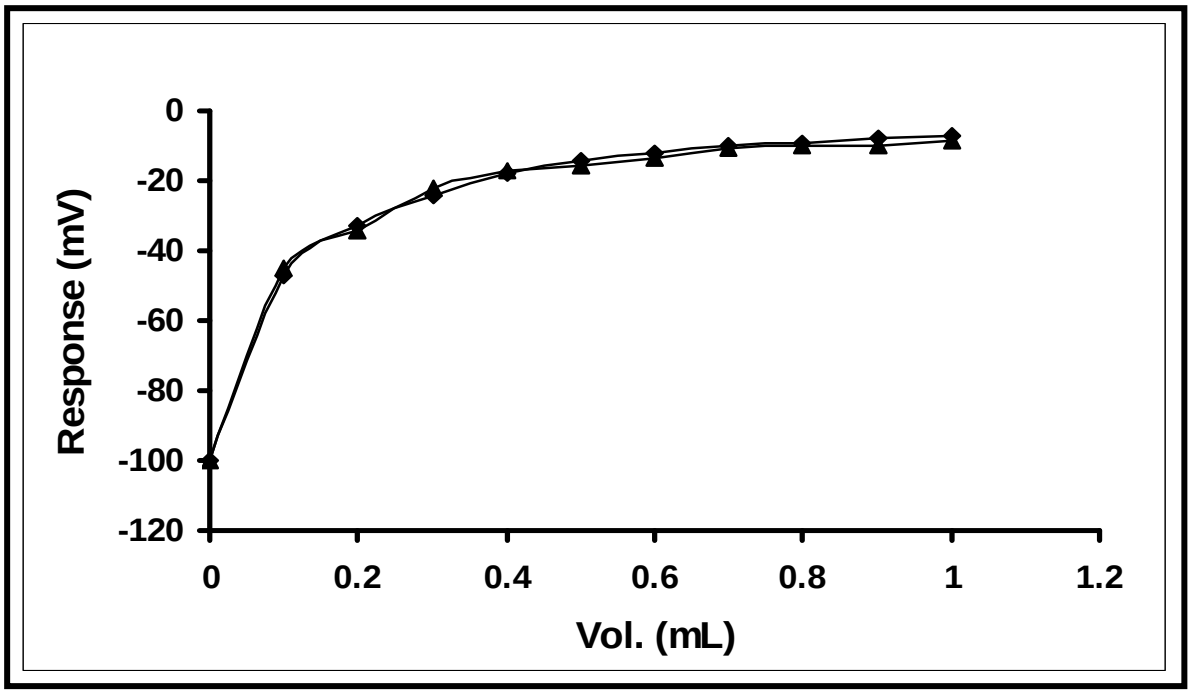
Figure(3-108): Selectivity of electrode C(PMH-PT+ONPOE) at concentration (10^{-3}) M for Fe^{+3} cation interfering by Match method,♦ promethazine hydrochloride solutions, ▲ solutions of ferric cation interfering.



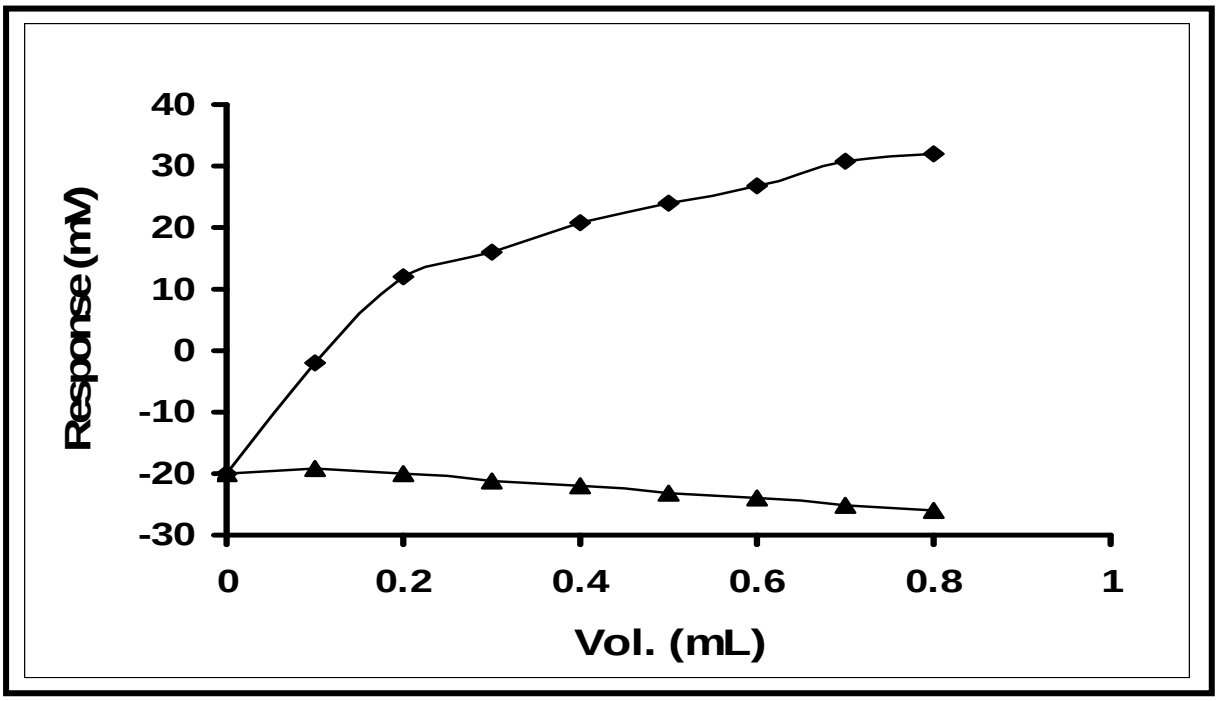
Figure(3-109): Selectivity of electrode C(PMH-PT+ONPOE) at concentration (10^{-4}) M for Fe^{+3} cation interfering by Match method,♦ promethazine hydrochloride solutions, ▲ solutions of ferric cation interfering.



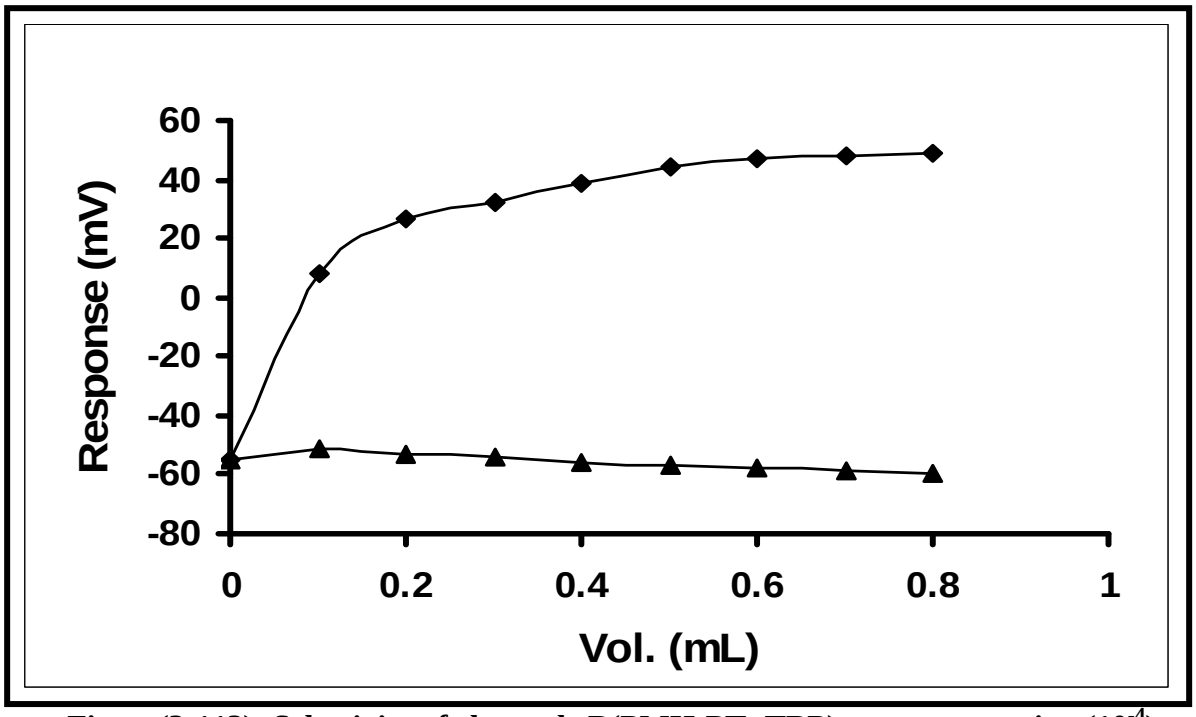
Figure(3-110): Selectivity of electrode C(PMH-PT+ONPOE) at concentration (10^{-3}) M for Cr^{+3} cation interfering by Match method,♦ promethazine hydrochloride solutions, ▲ solutions of chromic cation interfering.



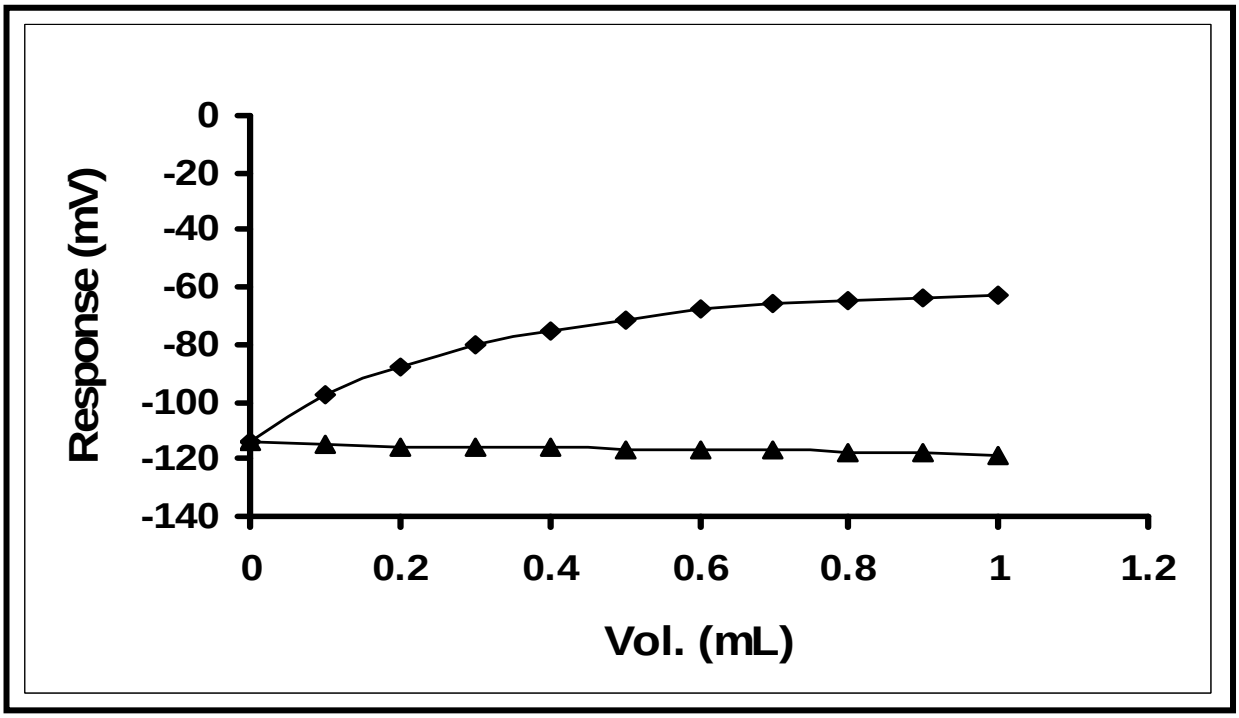
Figure(3-111): Selectivity of electrode C(PMH-PT+ONPOE) at concentration (10^{-4}) M for Cr^{+3} cation interfering by Match method,♦ promethazine hydrochloride solutions, ▲ solutions of chromic cation interfering.



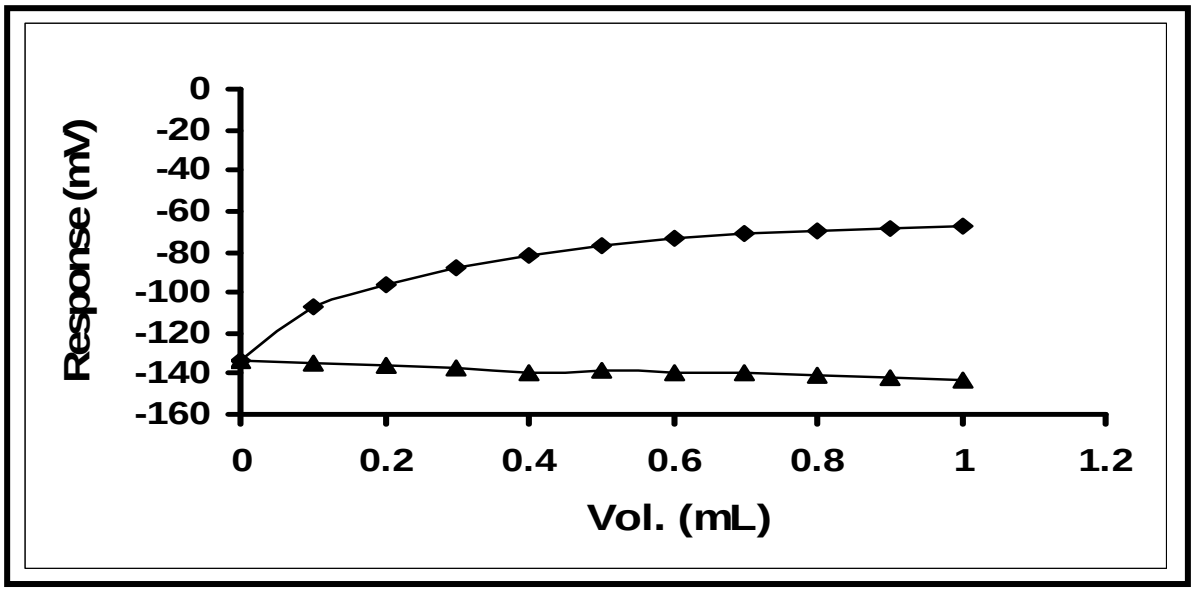
Figure(3-112): Selectivity of electrode B(PMH-PT+TBP) at concentration (10^{-3}) M for Li^{+1} cation interfering by Match method,♦ promethazine hydrochloride solutions, ▲ solutions of lithium cation interfering.



Figure(3-113): Selectivity of electrode B(PMH-PT+TBP) at concentration (10^{-4}) M for Li^{+1} cation interfering by Match method,♦ promethazine hydrochloride solutions, ▲ solutions of lithium cation interfering.



Figure(3-114): Selectivity of electrode D(PMH-PT+DBPH) at concentration (10^{-3}) M for Li^{+1} cation interfering by Match method,♦ promethazine hydrochloride solutions, ▲ solutions of lithium cation interfering.



Figure(3-115): Selectivity of electrode D(PMH-PT+DBPH) at concentration (5×10^{-4}) M for Li^{+1} cation interfering by Match method,♦ promethazine hydrochloride solutions, ▲ solutions of lithium cation interfering.

From the above figures [(3-76) – (3-111)] shows no interferences of the cations on promethazine hydrochloride at concentrations 10^{-3} and 10^{-4} M by using electrodes A and C. Therefore, the selectivity coefficients can not be determine because there is no different in potential between the drug solution and interfering cation even at 5 mV or 10 mV. For the electrode C, figure (3-94)- (3-99), the selectivity coefficients can be measured at 10^{-4} M promethazine hydrochloride in presence of Li^{+1}, Na^{+1}, K^{+1} when the difference in potential was 10 mV and the selectivity calculated are 0.2, 0.298, 0.41 respectively. Also the difficulty for measuring the selectivity coefficient for di and tri-valent cations (Mg^{+2}, Ca^{+2},…) because there is no difference in potential between the drug and interfering cations at 10 mV or 5 mV. Also the difficulty of the match method to apply for the electrode D at concentrations 5×10^{-4} and 10^{-3} M of drug solution. As we conclude that match method can not be used for measuring the selectivity coefficient at these concentrations 10^{-3} and 10^{-4} M. Therefore, the concentration of the promethazine hydrochloride should be less than 10^{-4} M, but the problem in this case the prepared

electrodes of promethazine can not be response for low concentrations of promethazine hydrochloride. The match method was applied for electrode B and electrode D as shown in figures (3-112) to (3-115), also we noticed that the selectivity coefficient can not be determine as well as for electrodes A and C.

3-5. Sample analyses:

The concentration of promethazine in prepared standard solutions were determined using electrodes based on (PMH-PT) ionophore with DBPH, ONPOE as plasticizers. Five potentiometric techniques were used for determination of promethazine hydrochloride including , direct, standard addition, multi standard addition, Gran's plots, and titration method. Three samples were prepared for promethazine hydrochloride with comparable concentrations and the average for these values were used to calculate the relative error (RE%) and relative standard deviation(RSD%) for each method.

3-5-1. Direct method:

This is the simplest method of obtaining quantitative results using ISEs. The calibration curve was constructed and the concentration of the unknown was calculated by linear equation of the calibration curve and the results are listed in table (3-32).

3-5-2. Standard addition method (SAM):

In this method, the concentration of standard solution of promethazine hydrochloride was ≈100 times higher than the concentration of the sample to eliminate the dilution effect. It carried by a procedure that 0.1 mL of 1×10^{-1} M promethazine hydrochloride as standard was added to sample as unknown. The results of calculation using SAM method for the two promethazine hydrochloride electrodes;

(PMH-PT+ONPOE) and (PMH-PT+DBPH) using equation (1-12) are listed in tables (3-19) to (3-24) respectively, and the results of determination promethazine hydrochloride, relative error and relative standard deviation for five addition of promethazine hydrochloride are listed in table (3-32).

Table (3-19): Calculation for five additions promethazine hydrochloride standard using (SA) method for electrode C(PMH-PT+ONPOE) at concentration10^{-3} M.

V_S mL added	E/mV	ΔE	Antilog(ΔE/S)	(V_U/V_S)	C_U(M)
0	-55	0	1	-	-
0.1	-40	15	1.955	100	1.026×10^{-3}
0.2	-31	24	2.923	50	1.009×10^{-3}
0.3	-25	30	3.822	33.33	1.021×10^{-3}
0.4	-19	36	4.998	25	9.529×10^{-4}
0.5	-16	39	5.715	20	9.999×10^{-4}

Table (3-20): Calculation for five additions promethazine hydrochloride

V_S mL added	E/mV	ΔE	Antilog(ΔE/S)	(V_U/V_S)	C_U(M)
0	-100	0	1	-	-
0.1	-47	53	10.684	100	1.021×10^{-4}
0.2	-33	67	19.974	50	1.032×10^{-4}
0.3	-24	76	29.8645	33.33	1.008×10^{-4}
0.4	-18	82	39.049	25	1.0098×10^{-4}
0.5	-12	88	51.059	20	0.9503×10^{-4}

standard using (SA) method for electrode C(PMH-PT+ONPOE) at concentration10^{-4} M.

Table (3-21): Calculation for five additions promethazine hydrochloride standard using (SA) method for electrode C(PMH-PT+ONPOE) at concentration10^{-5} M.

V_S mL added	E/mV	ΔE	Antilog(ΔE/S)	(V_U/V_S)	C_U(M)
0	-118	0	1	-	-
0.1	-28	90	55.83	100	1.805×10^{-5}
0.2	-12	106	114.14	50	1.733×10^{-5}
0.3	-2	116	178.46	33.33	1.641×10^{-5}

0.4	10	128	305.12	25	1.2645×10^{-5}
0.5	16	134	398.96	20	1.196×10^{-5}

V_S mL added	E/mV	ΔE	Antilog(ΔE/S)	(V_U/V_S)	C_U(M)
0	-115	0	1	-	-
0.1	-99	16	1.927	100	1.057×10^{-3}
0.2	-89	26	2.903	50	1.0197×10^{-3}
0.3	-82	33	3.868	33.33	1.005×10^{-3}
0.4	-76	39	4.947	25	0.965×10^{-3}
0.5	-72	43	5.828	20	0.9766×10^{-3}

Table (3-22): Calculation for five additions promethazine hydrochloride standard using (SA) method for electrode D(PMH-PT+DBPH) at concentration10^{-3} M.

Table (3-23): Calculation for five additions promethazine hydrochloride standard using (SA) method for electrode D(PMH-PT+DBPH) at concentration 5×10^{-4} M.

V_S mL added	E/mV	ΔE	Antilog(ΔE/S)	(V_U/V_S)	C_U(M)
0	-133	0	1	-	-
0.1	-106.5	26.5	2.963	100	5.018×10^{-4}
0.2	-94.5	38.5	4.846	50	5.072×10^{-4}
0.3	-86.5	46.5	6.727	33.33	5.059×10^{-4}
0.4	-80.5	52.5	8.603	25M	5.033×10^{-4}
0.5	-75	58	10.779	20	4.846×10^{-4}

Table (3-24): Calculation for five additions promethazine hydrochloride standard using (SA) method for electrode D(PMH-PT+DBPH) at concentration10^{-4} M.

V_S mL added	E/mV	ΔE	Antilog(ΔE/S)	(V_U/V_S)	C_U(M)
0	-151	0	1	-	-
0.1	-100	51	8.090	100	1.394×10^{-4}
0.2	-85	66	14.963	50	1.402×10^{-4}
0.3	-76	75	21.639	33.33	1.409×10^{-4}
0.4	-71	80	26.56	25	1.502×10^{-4}
0.5	-67	84	31.294	20	1.569×10^{-4}

Excellent results were obtained for electrode C at concentrations 10^{-3} and 10^{-4} M, but the results start to deviate at low concentration < 10^{-4}. At 10^{-5} M of promethazine hydrochloride the error was to high about 6%. For electrode D the error becomes very high when the concentration of promethazine hydrochloride become less than 10^{-4} M. These concentrations are not included in the linear range of electrode response.

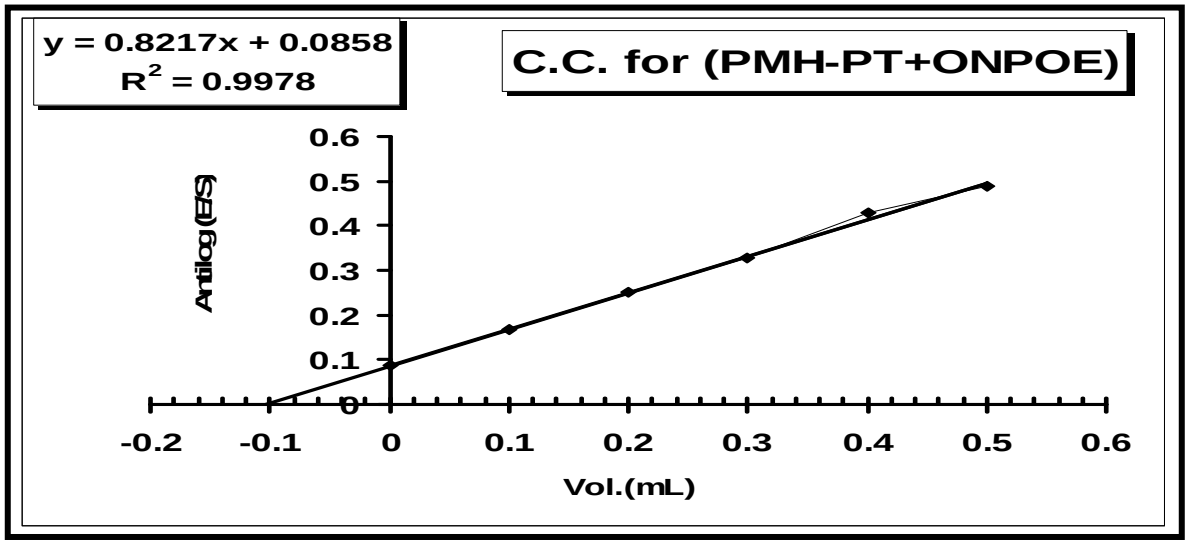
3-5-3. Multi standard addition method (MSA):

In this method, the applied procedure was, 0.1 mL of 1×10^{-1} M promethazine hydrochloride as standard was added to sample as unknown. The results of calculation using MSA method for the two promethazine hydrochloride electrodes; (PMH-PT+ONPOE) and (PMH-PT+DBPH) using equation (1-14) are listed in tables (3-25) to (3-30) respectively,and the results of determination promethazine hydrochloride, relative error and relative recovery for five addition of promethazine hydrochloride are listed in table(3-32).The plot of antilog(E/S) versus the volume of the five addition for promethazine hydrochloride electrodes are shown in figures (3-116) to (3-121) for the two electrodes, (PMH-PT+ONPOE) electrode and (PMH-PT+DBPH)electrode. From the equations of the calibration curves, the volume(V) ml at intercept with X axis for each curve was calculate. The volume(V) at intercept with X axis and (C_U) were listed in table (3-32).

V(ml)	E/mV	Antilog (E/S)
0	-55	0.0856

Table(3-25): Reading of (MSA) method for electrode C (PMH-PT+ONPOE) at concentration 10^{-3} M.

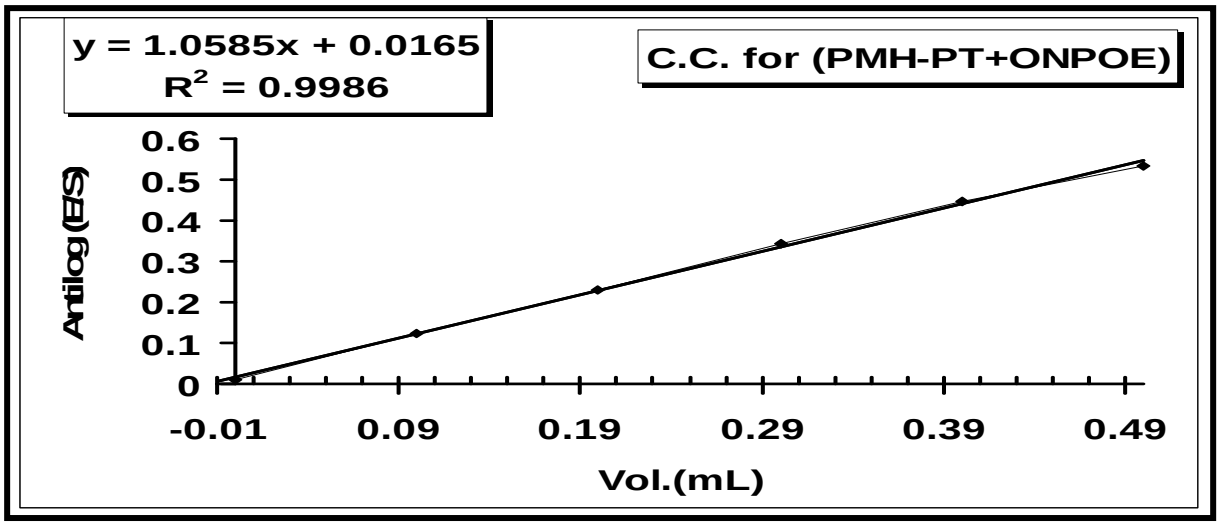
0.1	-40	0.1673
0.2	-31	0.2502
0.3	-25	0.3271
0.4	-19	0.4278
0.5	-16	0.4891



Figure(3-116): Calibration curve of antilog (E/S) versus the volume added of standard (0.1 M) for determination of promethazine hydrochloride solution (10^{-3} M) by (MSA) of electrode C (PMH-PT+ONPOE).

Table (3-26): Reading of (MSA) method for electrode C (PMH-PT+ONPOE) at concentration 10^{-4} M.

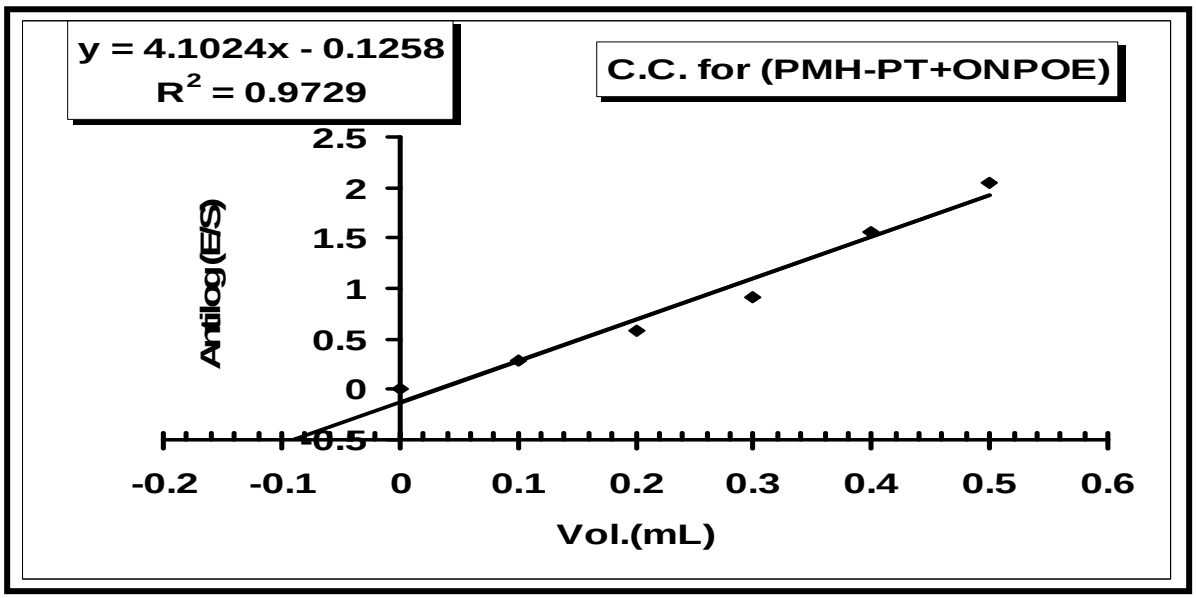
V(ml)	E/mV	Antilog (E/S)
0	-100	0.01145
0.1	-47	0.1224
0.2	-33	0.2288
0.3	-24	0.3421
0.4	-18	0.4473
0.5	-12	0.5848



Figure(3-117): Calibration curve of antilog (E/S) versus the volume added of standard(0.1 M) for determination of promethazine hydrochloride solution (10^{-4} M) by (MSA) of electrode C (PMH+PT+ONPOE).

Table(3-27): Reading of (MSA) method for electrode C (PMH+PT+ONPOE) at concentration 10^{-5} M.

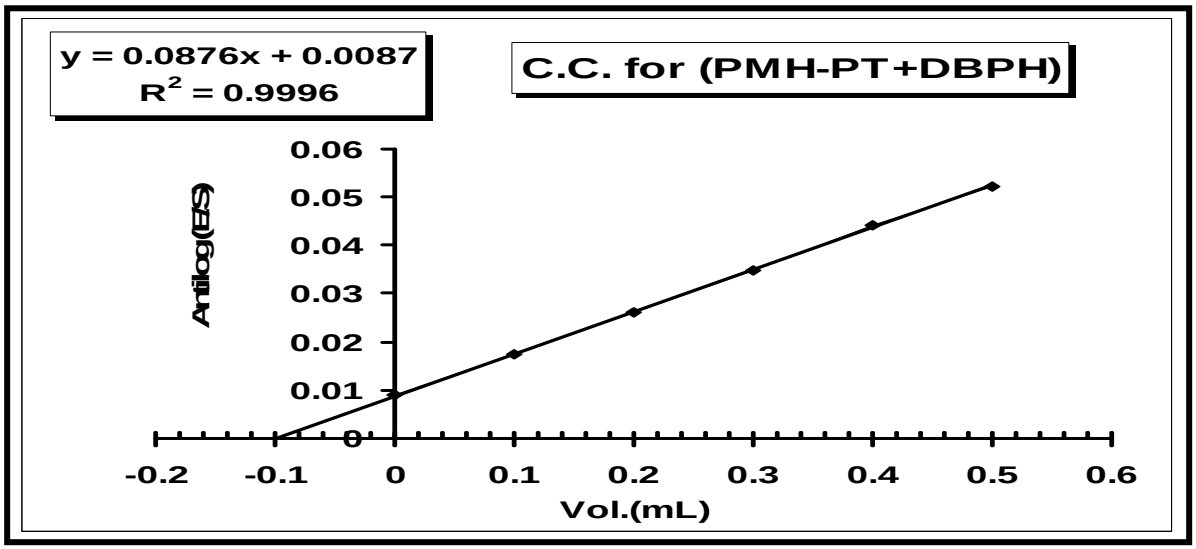
V(ml)	E/mV	Antilog (E/S)
0	-118	0.0051
0.1	-28	0.2861
0.2	-12	0.5849
0.3	-2	0.9145
0.4	10	1.5635
0.5	16	2.0444



Figure(3-118): Calibration curve of antilog (E/S) versus the volume added of standard (0.1 M) for determination of promethazine hydrochloride solution (10^{-5} M) by (MSA) of electrode C (PMH+PT+ONPOE).

Table(3-28): Reading of (MSA) method for electrode D (PMH-PT+DBPH) at concentration (10^{-3}) M.

V(ml)	E/mV	antilog (E/S)
0	-115	0.0089
0.1	-99	0.0173
0.2	-89	0.0260
0.3	-82	0.0347
0.4	-76	0.0443
0.5	-72	0.0523

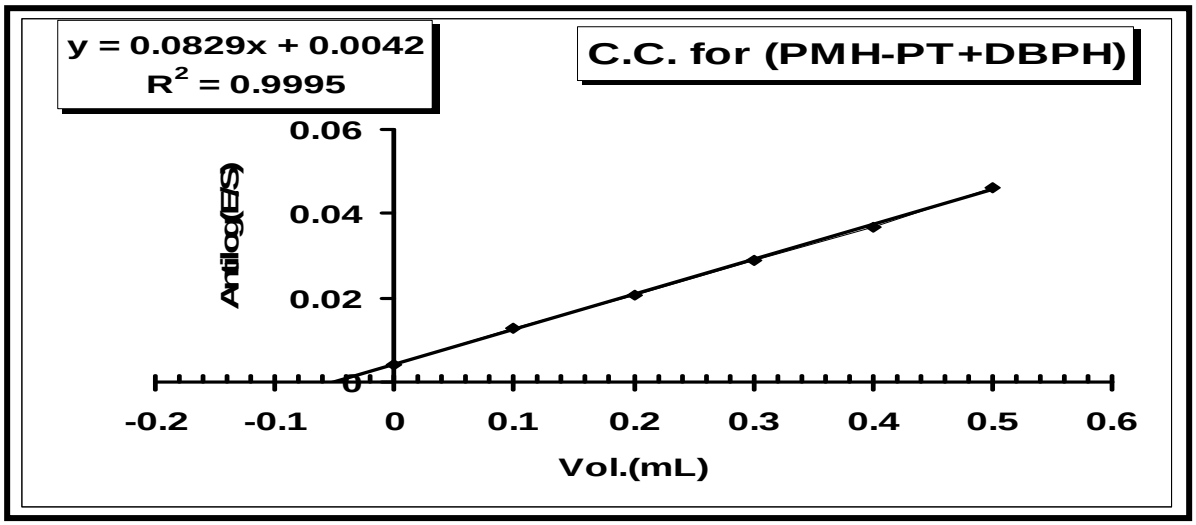


Figure(3-119): Calibration curve of antilog (E/S) versus the volume added of standard(0.1 M) for determination of promethazine hydrochloride solution (10^{-3} M) by (MSA) of electrode D (PMH-PT+DBPH).

Table(3-٢٩): Reading of (MSA) method for electrode D (PMH-PT+DBPH) at concentration 5×10^{-4} M.

V(ml)	E/mV	Antilog (E/S)
0	-133	0.0043
0.1	-106.5	0.0127
0.2	-94.5	0.0208
0.3	-86.5	0.0288

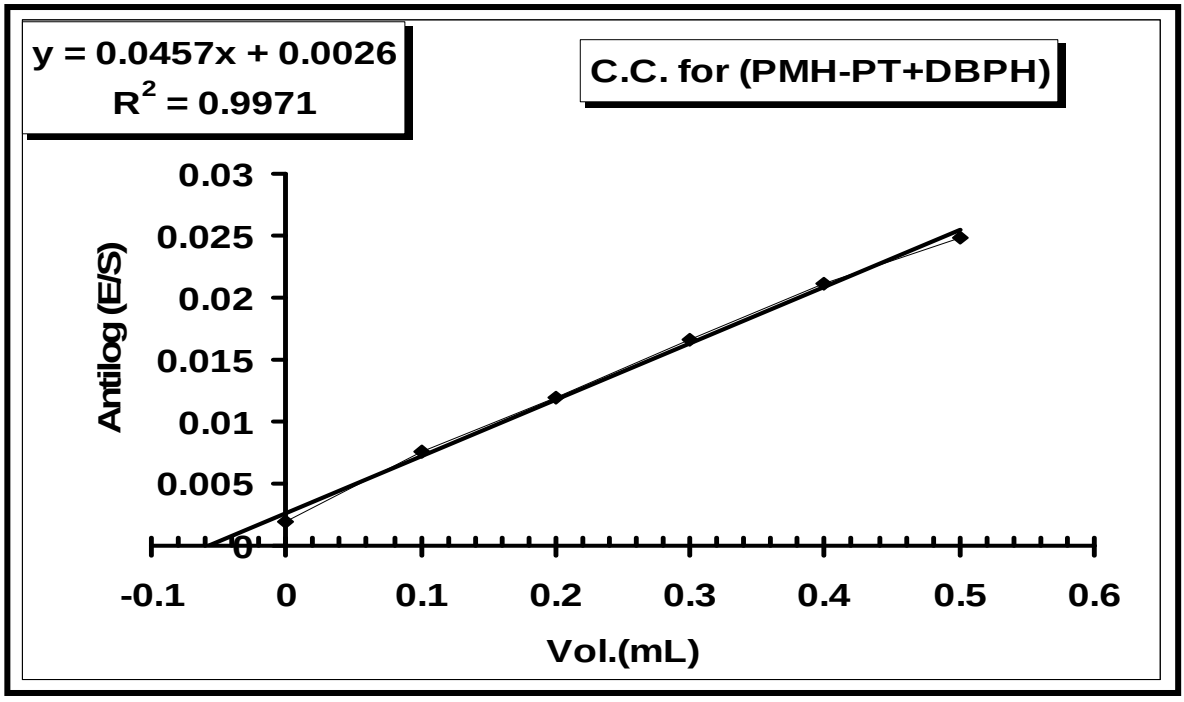
0.4	-80.5	0.0369
0.5	-75	0.0462



gure(3-120): Calibration curve of antilog (E/S) versus the volume added of standard(0.1 M) for determination of promethazine hydrochloride solution (5×10^{-4} M) by (MSA) of electrode D (PMH-PT+DBPH).

Table(3-30): Reading of (MSA) method for electrode D (PMH-PT+DBPH) at concentration 10^{-4} M.

V(ml)	E/mV	Antilog(E/S)
0	-151	0.002
0.1	-119	0.0076
0.2	-108	0.0119
0.3	-100	0.0166
0.4	-94	0.0212
0.5	-90	0.0249



Figure(3-121): Calibration curve of antilog (E/S) versus the volume added of standard(0.1 M) for determination of promethazine hydrochloride solution (10^{-4} M) by (MSA) of electrode D (PMH-PT+DBPH).

Table (3-31): Volume at intercept with X axis and calculation the concentration C_U(M) for electrode C and D by (MSA) method.

Electrode No.	Conc.(M)	V(ml)at intercept	C_U(M)
C(PMH+PT+ONPOE)	1×10^{-3}	0.0990	0.99×10^{-3}
	1×10^{-4}	0.0098	0.98×10^{-4}
	1×10^{-5}	0.0910	0.91×10^{-3}
D(PMH+PT+DBPH)	1×10^{-3}	0.0990	0.99×10^{-3}
	5×10^{-4}	0.0501	5.01×10^{-4}
	1×10^{-4}	0.0580	5.80×10^{-4}

The results in table (3-31) indicate that good results were obtained for electrode C at concentrations 10^{-3} and 10^{-4} M of promethazine hydrochloride, but relative error becomes high (52.79%) for a concentration 10^{-5} M promethazine hydrochloride solution of SAM. As well as for electrode D the error increased when the concentration of promethazine hydrochloride were at 10^{-4} M in which the error was about (45.52%) of SAM.

3-5-4. Gran ś Plot:

Gran ś Plot paper with 10% volume correction paper was used to calculate the volume(V) mL of equivalent point for sample at the intercept with (X) axis for MSA and titration methods by plotting potential versus the added volume. Figure (3-122) to (3-125) show the titration curve for electrodes C and D . the results of determination promethazine hydrochloride samples, relative error and relative recovery were listed in table(3-32).

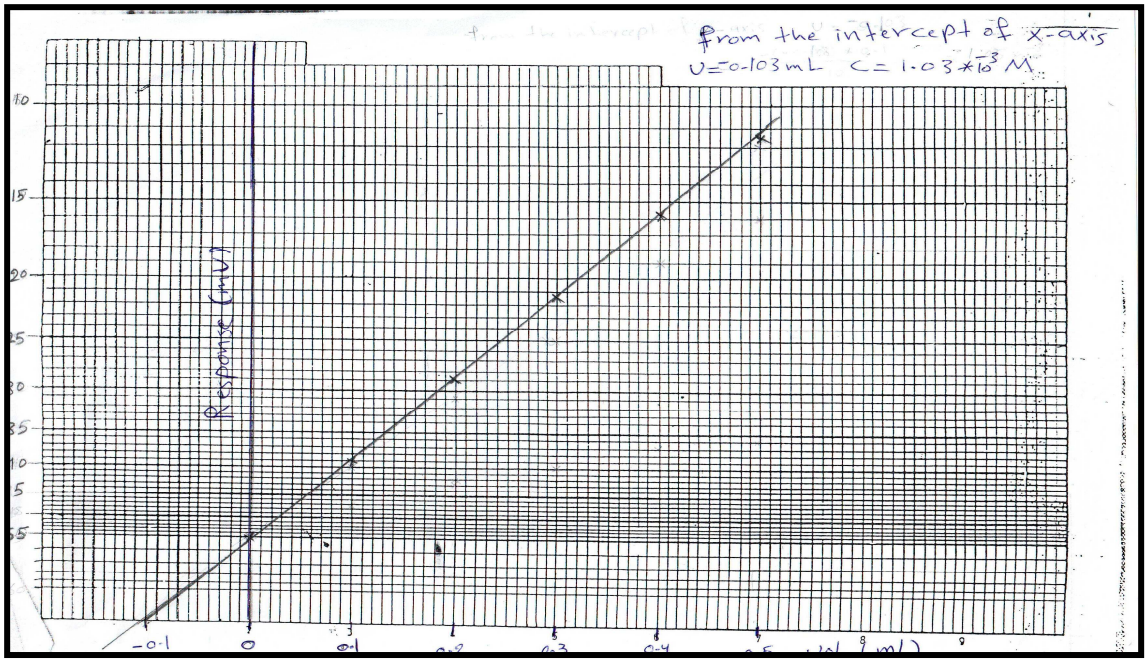


Figure (3-122):Gran plot of response (mV) versus volume (mL) of the added stander for the determination of 0.001 M promethazine hydrochloride for electrode C(PMH-PT+ONPOE).

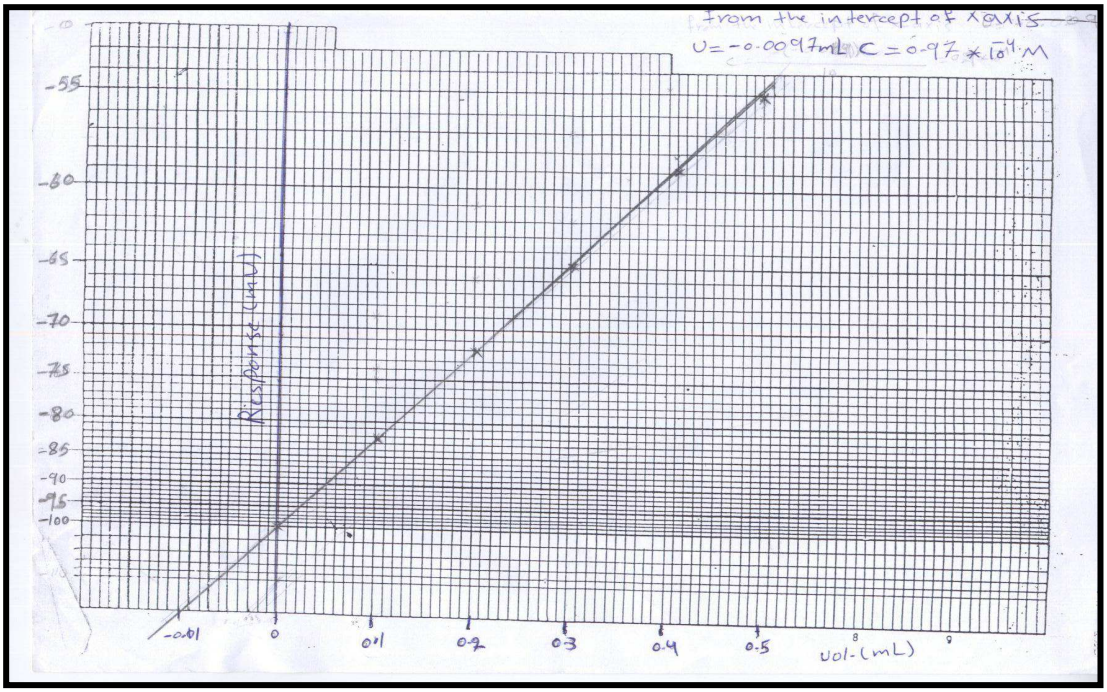


Figure (3-123):Gran plot of response (mV) versus volume (mL) of the added stander for the determination of 0.0001 M promethazine hydrochloride for electrode C(PMH-PT+ONPOE).

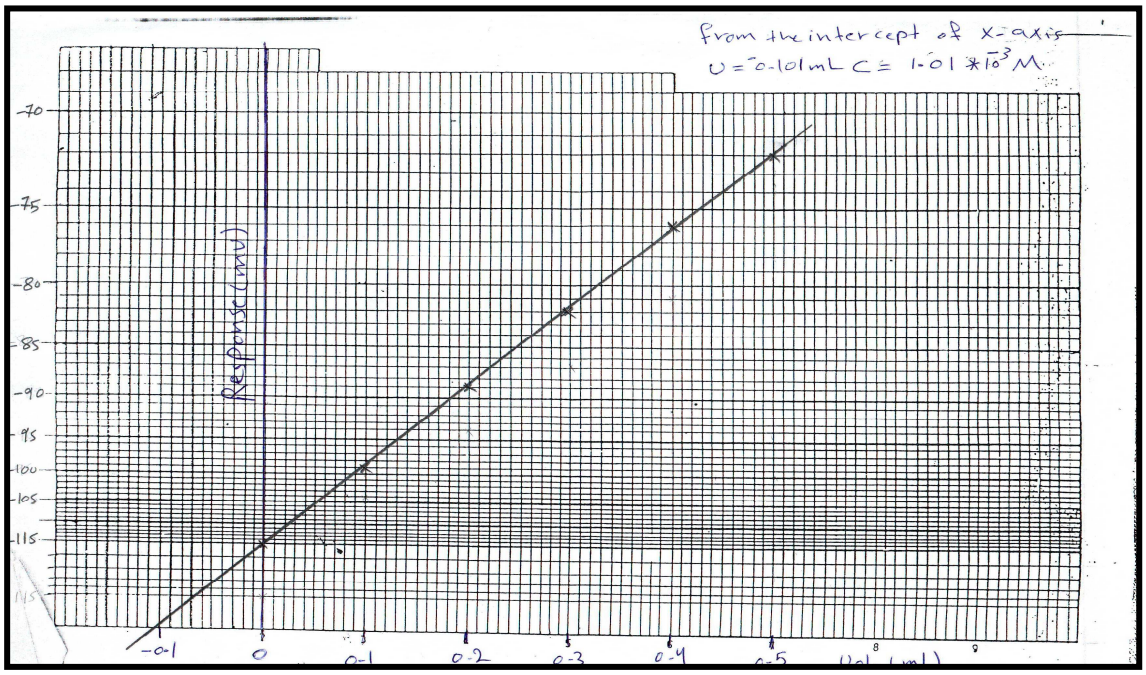


Figure (3-124): Gran plot of response (mV) versus volume (mL) of the added stander for the determination of 0.001 M promethazine hydrochloride for electrode D(PMH-PT+DBPH).

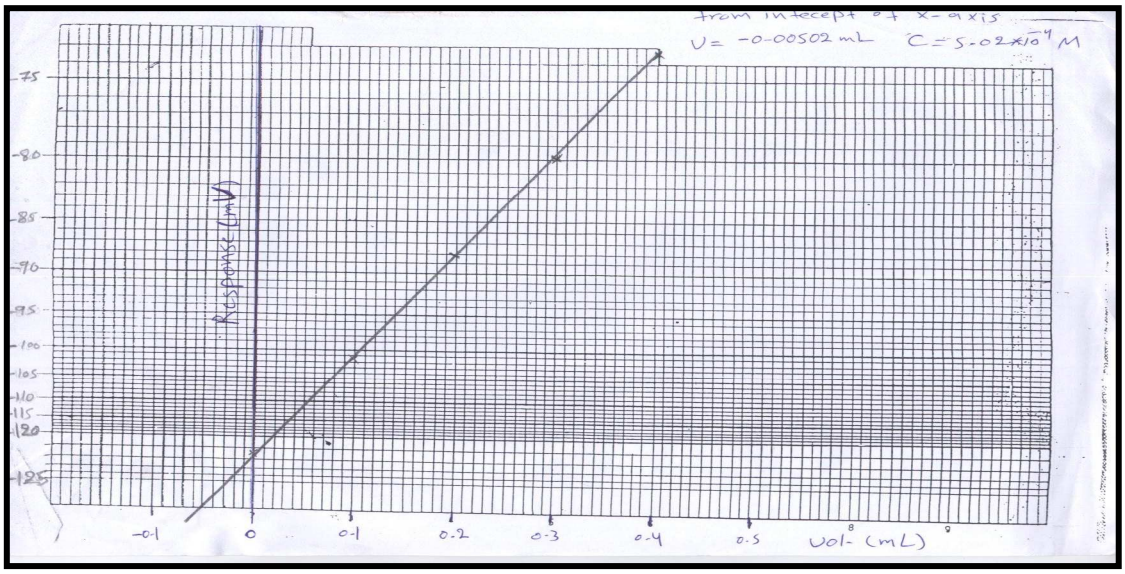


Figure (3-125): Gran plot of response (mV) versus volume (mL) of the added stander for the determination of 0.0005 M promethazine hydrochloride for electrode D(PMH-PT+DBPH).

Table (3-32):Promethazine hydrochloride sample analyses by using potentiometric methods for electrode C (PMH-PT+ONPOE) and electrode D(PMH-PT+DBPH).

Electrode No.	Concentrations (M)				
	Sample	Measurements using potentiometric methods			
		Direct	SA	MSA	Gran's Plot
Electrode C (PMH+PT+ ONPOE)	1×10^{-3}	1.014×10^{-3}	1.002×10^{-3}	0.99×10^{-3}	1.03×10^{-3}
	RSD%	0.197*	1.8042*	-	-
	RC%	101.4	100.2	99	100.3
	RE%	1.4	0.2	-1	3
	1×10^{-4}	1.021×10^{-4}	1.004×10^{-4}	0.98×10^{-4}	0.97×10^{-4}
	RSD%	0.294*	2.0359*	-	-
	RC%	102.1	100.4	98	97
	RE%	2.1	0.4	-2	-3
Electrode D (PMH+PT+ DBPH)	1×10^{-3}	1.008×10^{-3}	1.005×10^{-3}	0.99×10^{-3}	1.01×10^{-3}
	RSD%	0.0992*	0.1863*	-	-
	RC%	100.8	100.5	99	99
	RE%	0.8	0.5	-1	-1
	5×10^{-4}	4.99×10^{-4}	5.006×10^{-4}	5.01×10^{-4}	5.02×10^{-4}
	RSD%	0.8104*	0.4509*	-	-
	RC%	99.8	100.12	100.2	100.4
	RE%	-0.2	0.12	0.2	0.4

*** Each measurement was repeated three times**

From the results in table (3-32) shows that, the electrode D (PMH-PT+DBPH) is the best than the electrode C (PMH-PT+ONPOE) because the relative standard deviation (RSD%) for concentrations 10^{-3} M and 5×10^{-4} M are 0.0992 and 0.8104 respectively, this mean the precision of the electrode D (PMH-PT+DBPH) by using direct method is better than the electrode C (PMH-PT+ONPOE), it may be the low slope of electrode (PMH-PT+ONPOE),also the relative standard deviation(RSD%) for concentration 10^{-3} M and 5×10^{-4} M by using SA method are 0.1863% and 0.4509% respectively. The values of relative standard deviation for concentration 10^{-3} M was much lower than the relative standard for 5×10^{-4} M. The relative error obtained from SA and MSA methods at concentrations 10^{-3} M and 5×10^{-4} M for electrode D(PMH-PT+DBPH) are 0.5, 0.12 respectively and for MSA are -1, 0.2 respectively. this consistent with the properties of standard addition method which the influence of the interferences to be eliminated.

3-5-5.Titration method:

This method was used for potentiometric titration of promethazine hydrochloride solution with 1×10^{-2} M and 1×10^{-3} M of phosphotungistic acid as titrant solution. The results are listed in table (3-33).

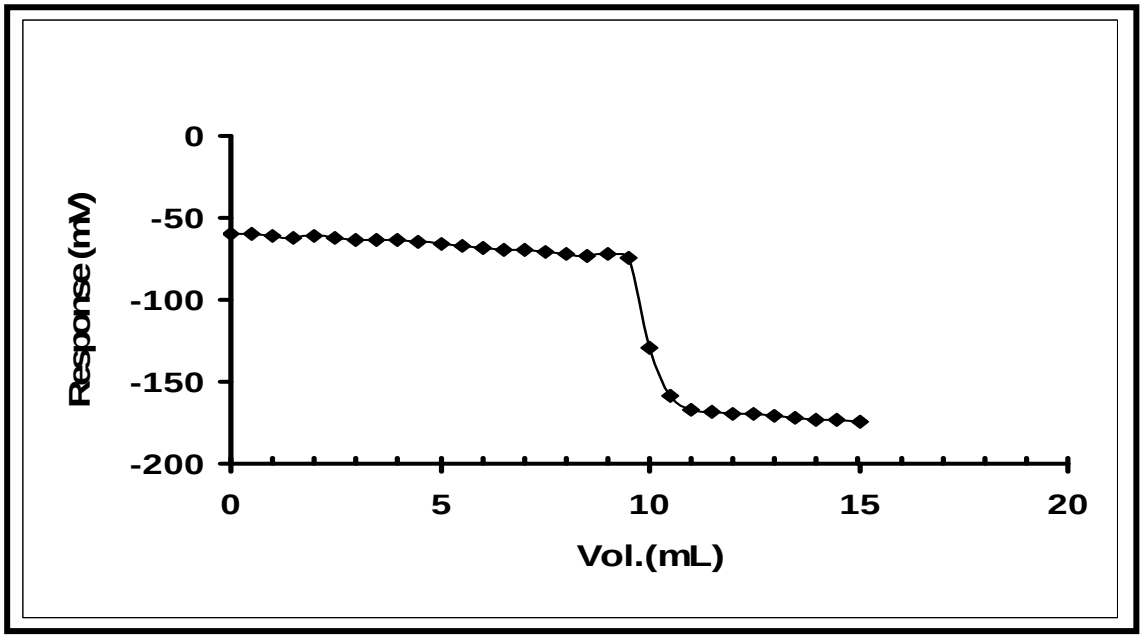


Figure (3-126): Titration curve of electrode C(PMH-PT+ONPOE) for sample solution containing 0.01 M promethazine hydrochloride with 10.2 ml of 0.01 M of pt as a titrant solution at pH 5.08.

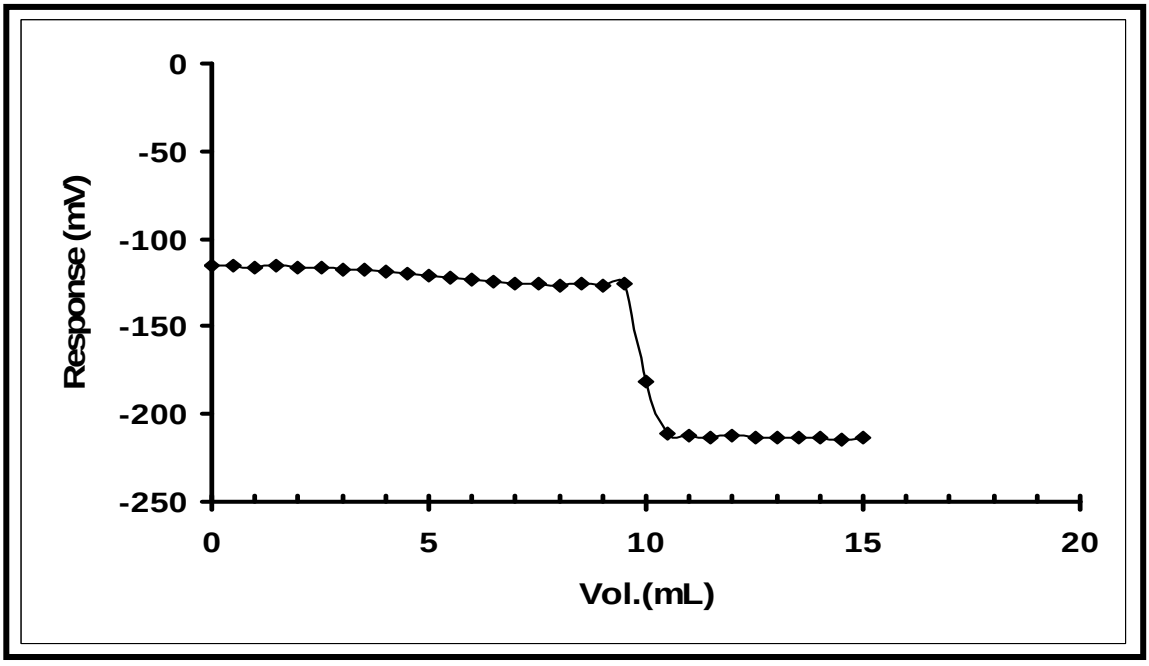


Figure (3-127): Titration curve of electrode C(PMH-PT+ONPOE) for sample solution containing 0.001 M promethazine hydrochloride with 10.1 ml of 0.001 M of pt as a titrant solution at pH 5.67.

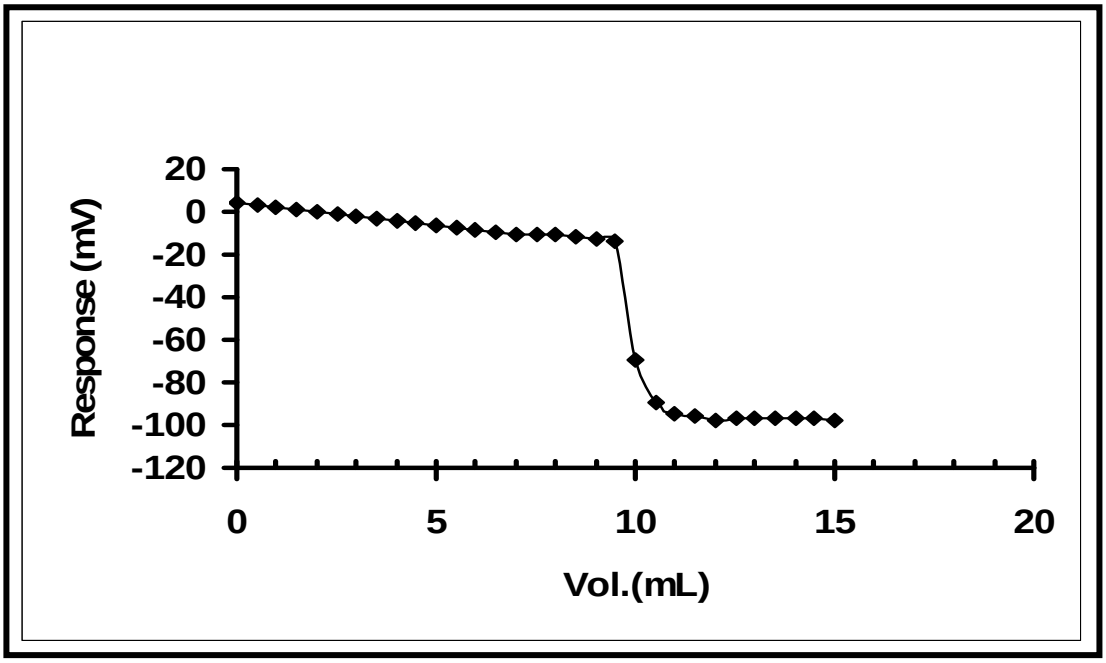


Figure (3-128): Titration curve of electrode D(PMH-PT+DBPH) for sample solution containing 0.01 M promethazine hydrochloride with 9.8 ml of 0.01 M of ptas a titrant solution at pH 5.08.

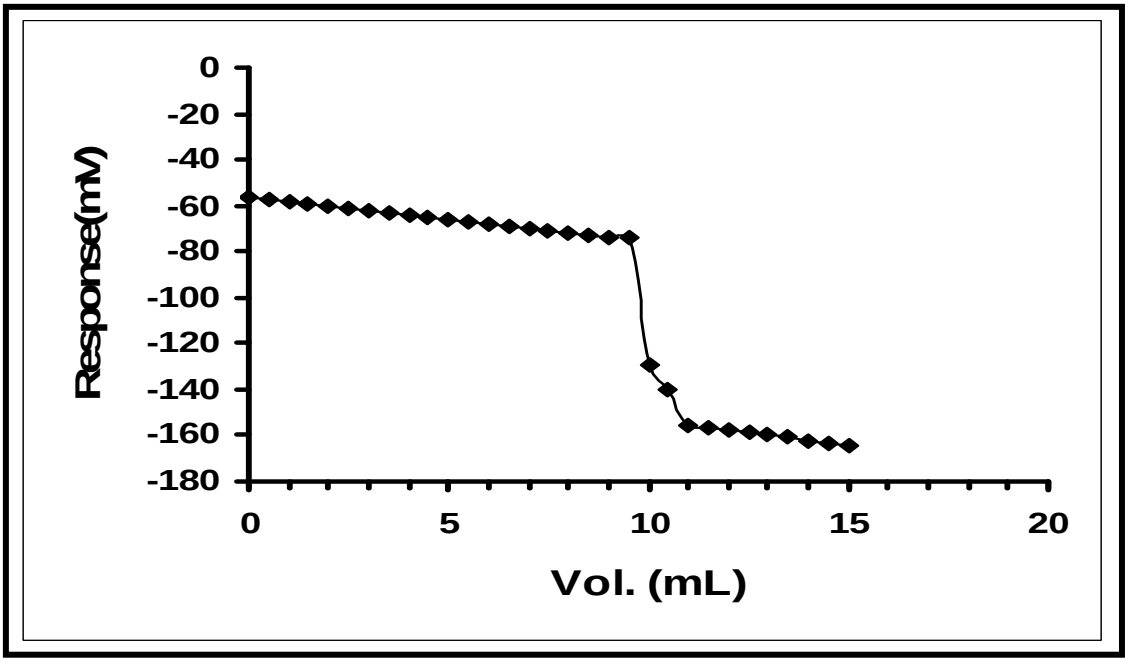


Figure (3-129): Titration curve of electrode D(PMH-PT+DBPH) for sample solution containing 0.001 M promethazine hydrochloride with 9.9 ml of 0.001 M of pt as a titrant solution at pH 5.67.

Table (3-33): Promethazine hydrochloride sample analyses by using titration method for electrode C(PMH-PT+ONPOE) and electrode D(PMH-PT+DBPH).

Electrode No.	Concentration (M)	
	Sample	**Measured using titration potentiometric methods**
Electrode C (PMH-PT+ONPOE)	1×10^{-2}	1.02×10^{-2}
	RSD%	5.882*
	RC%	102
	RE%	2
	1×10^{-3}	1.01×10^{-3}
	RSD%	3.96*
	RC%	101
	RE%	1
Electrode D (PMH-PT+DBPH)	1×10^{-2}	0.98×10^{-2}
	RSD%	4.082*
	RC%	98
	RE%	-2
	1×10^{-3}	0.99×10^{-3}
	RSD%	2.535*
	RC%	99
	RE%	-1

*** Each measurement was repeated three times**

The relative standard deviation (RSD%) for electrode D(PMH-PT+DBPH) is best than electrode C (PMH-PT+ONPOE) ,this may be to the low slope of electrode C(PMH-PT+ONPOE). The calculated RSD% using titration method is relatively large in comparison with the other methods used; this may be attributed to precipitation of (PMH-PT) complex on the surface of the membrane and poisoning the membrane. Figures from (3-126) to (3-129) show titration curve of promethazine hydrochloride samples with phosphotungistic acid as a titrant solution. Also the titration was carried out at concentrations 10^{-2} and 10^{-3} M but in neutral and basic medium of promethazine hydrochloride sample with phosphotungistic acid as a titrant solution and the results are shown in figures (3-130) to (3-137).

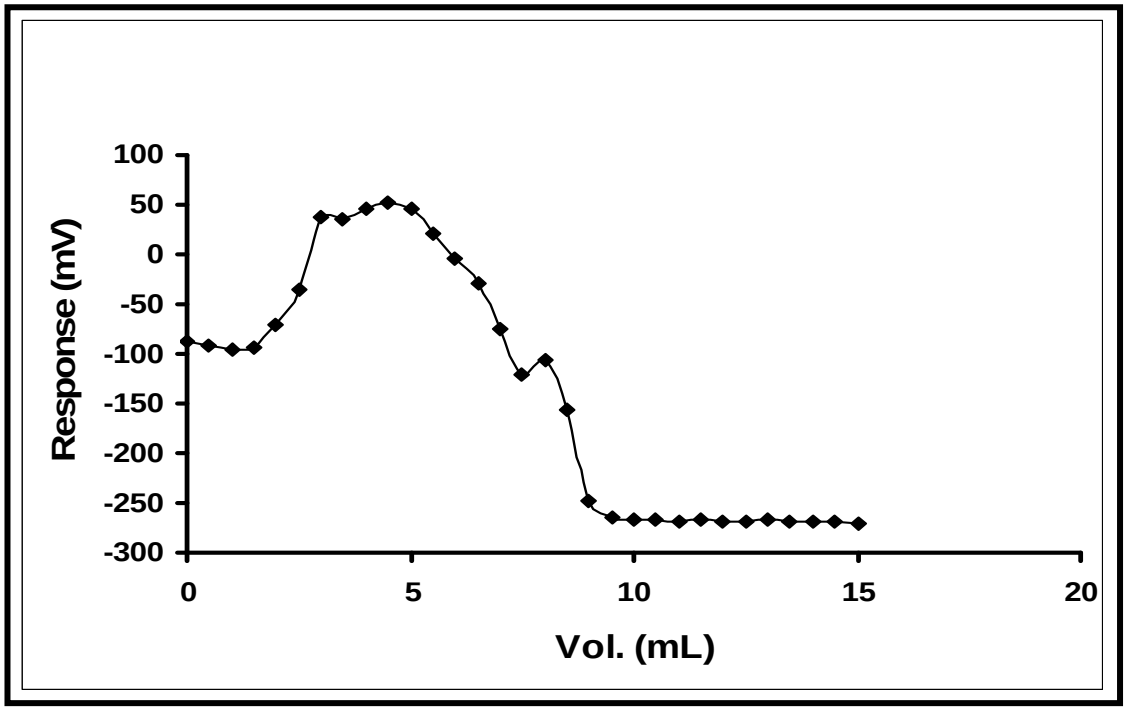


Figure (3-130): Titration curve of electrode D(PMH-PT+ONPOE) for sample solution containing 0.001 M promethazine hydrochloride of 0.001 M of pt as a titrant solution at pH 7.39.

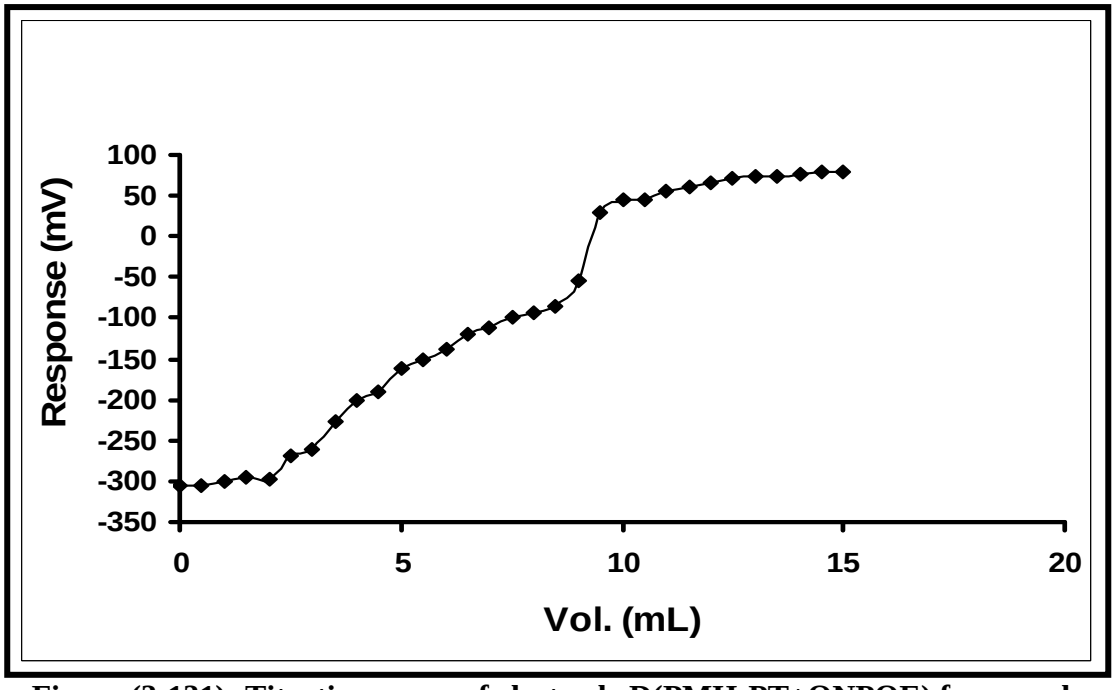


Figure (3-131): Titration curve of electrode D(PMH-PT+ONPOE) for sample solution containing 0.001 M promethazine hydrochloride with 0.001 M of pt as a titrant solution at pH 9.98.

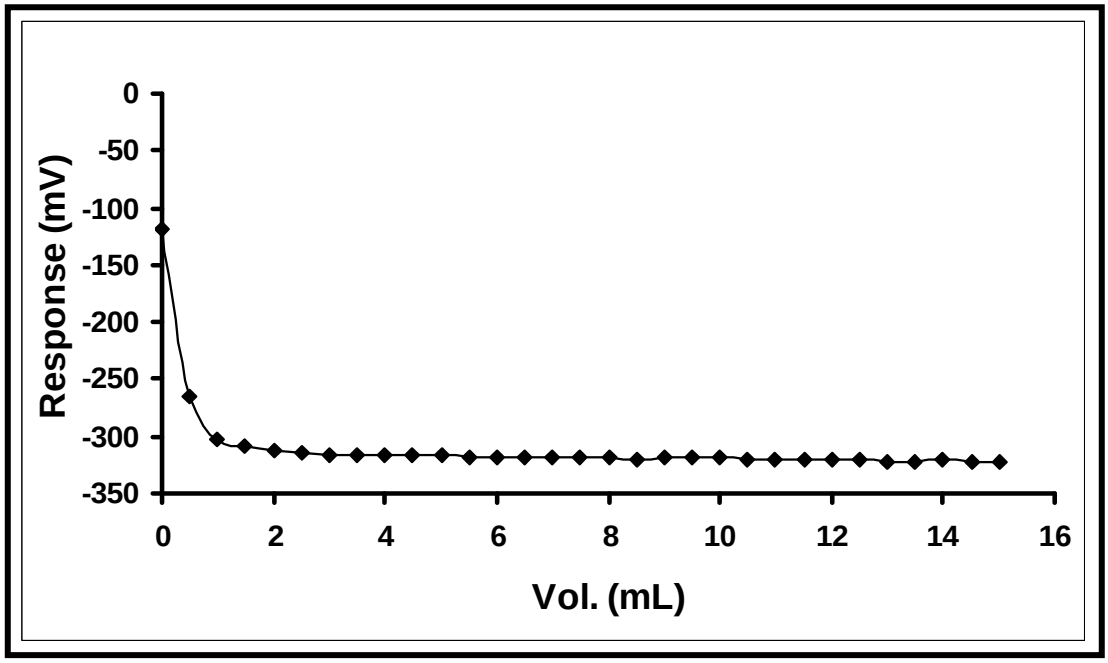


Figure (3-132): Titration curve of electrode C(PMH-PT+ONPOE) for sample solution containing 0.01 M promethazine hydrochloride with 0.01 M of pt as a titrant solution at pH 7.20.

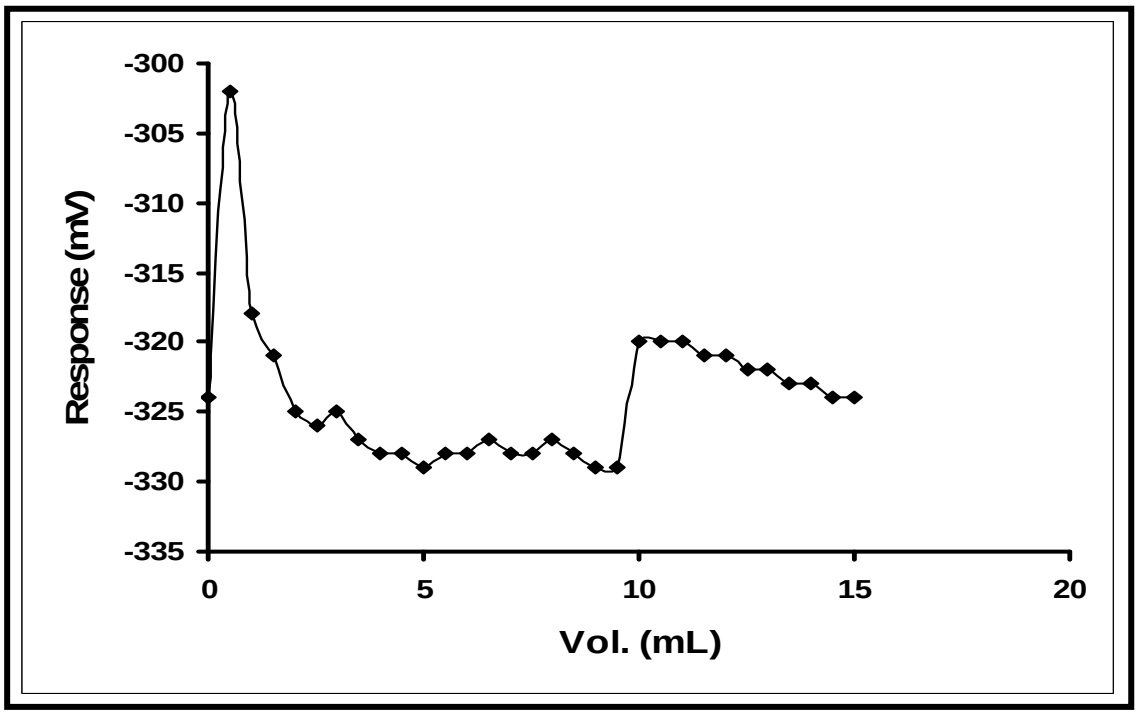


Figure (3-133): Titration curve of electrode C(PMH-PT+ONPOE) for sample solution containing 0.01 M promethazine hydrochloride with 0.01 M of pt as a titrant solution at pH 9.68.

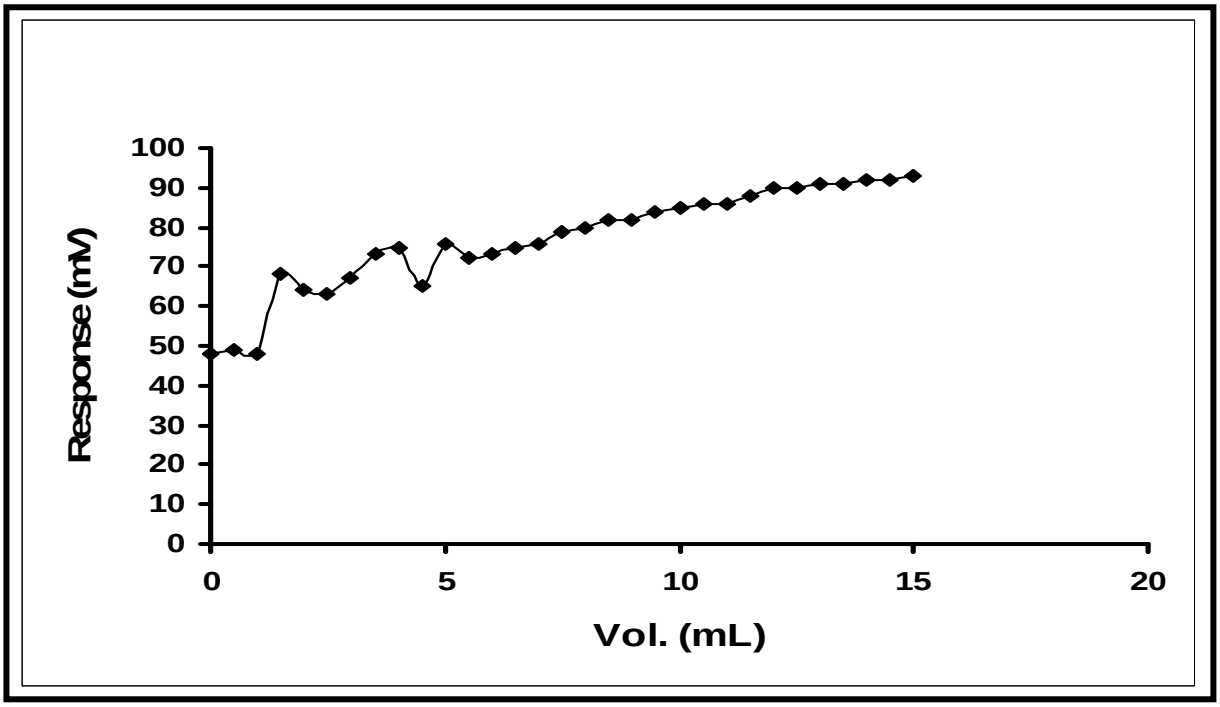


Figure (3-134): Titration curve of electrode D(PMH-PT+DBPH) for sample solution containing 0.01 M promethazine hydrochloride with 0.01 M of pt as a titrant solution at pH 7.03.

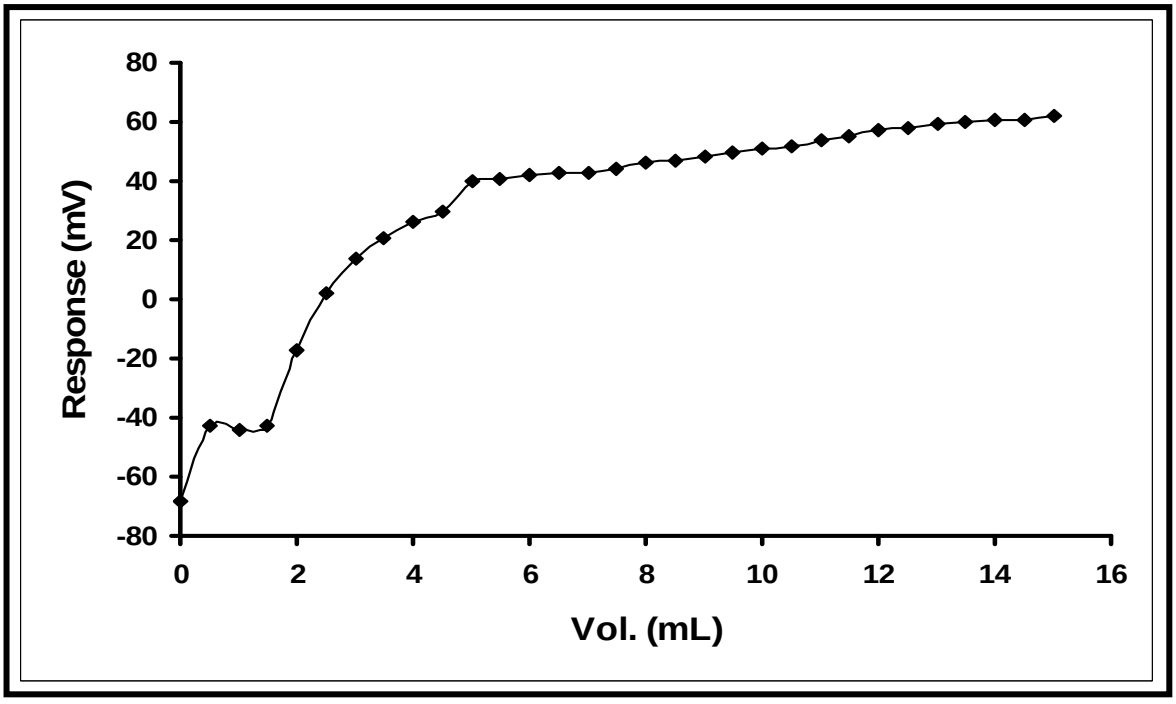


Figure (3-135): Titration curve of electrode D(PMH-PT+DBPH) for sample solution containing 0.01 M promethazine hydrochloride with 0.01 M of ptas a titrant solution at pH 10.1.

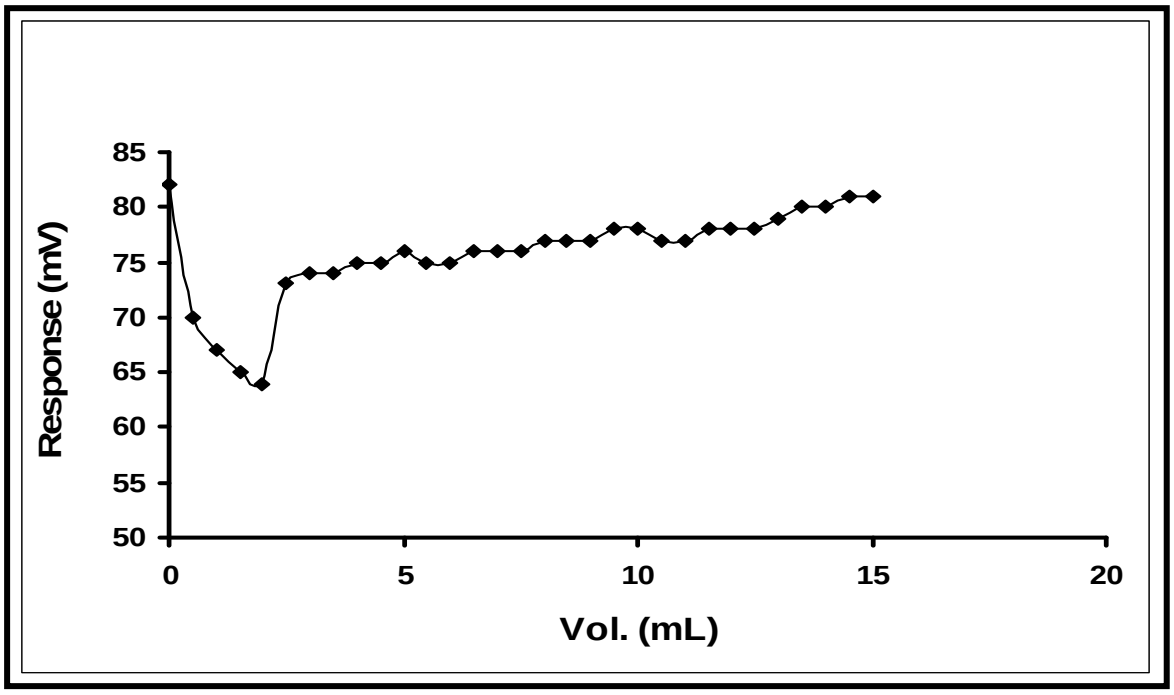


Figure (3-136): Titration curve of electrode D(PMH-PT+DBPH) for sample solution containing 0.001 M promethazine hydrochloride with 0.001 M of pt as a titrant solution at pH 6.55.

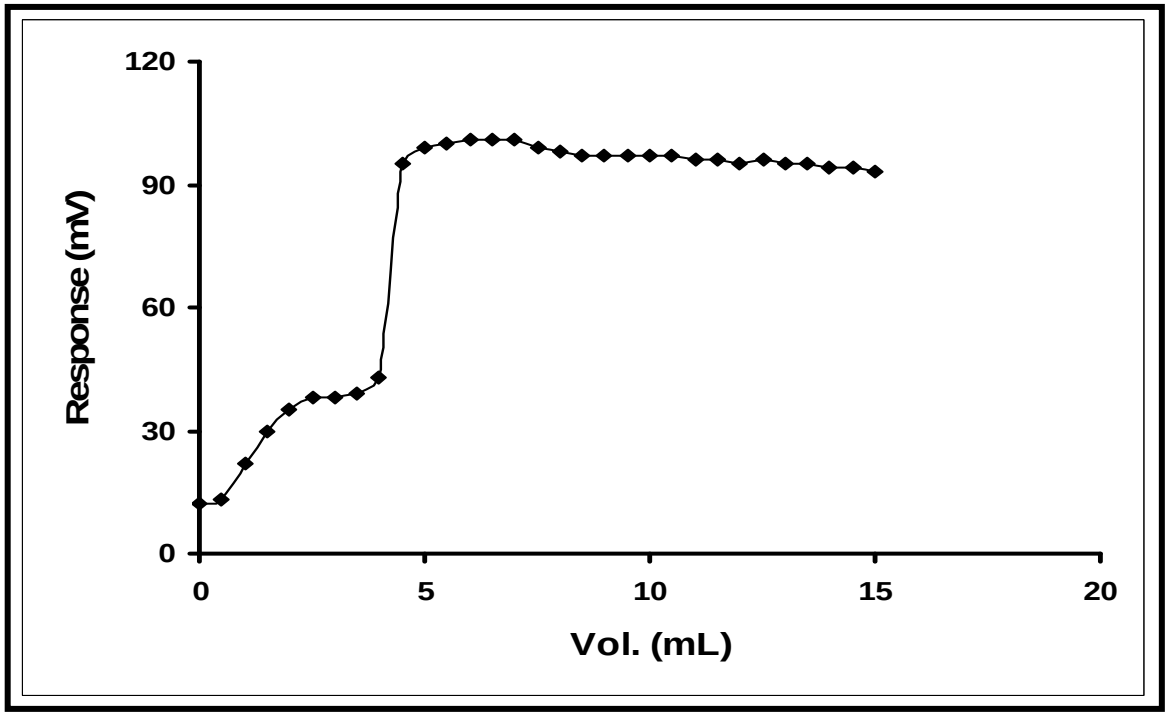


Figure (3-137): Titration curve of electrode D(PMH-PT+DBPH) for sample solution containing 0.001 M promethazine hydrochloride with 0.001 M of pt as a titrant solution at pH 9.73.

From these figures we noticed there is not any response for electrode C (PMH-PT+ONPOE) and electrode D (PMH-PT+DBPH) in neutral and base medium for concentrations 10^{-2} M and 10^{-3} M. This means the electrode responsed in acid medium (2-7) of drug. The working titration curve with hydroquinone standard solution as oxidation reagent at concentration 10^{-3} M of promethazine hydrochloride solution is shown in figure (3-138).

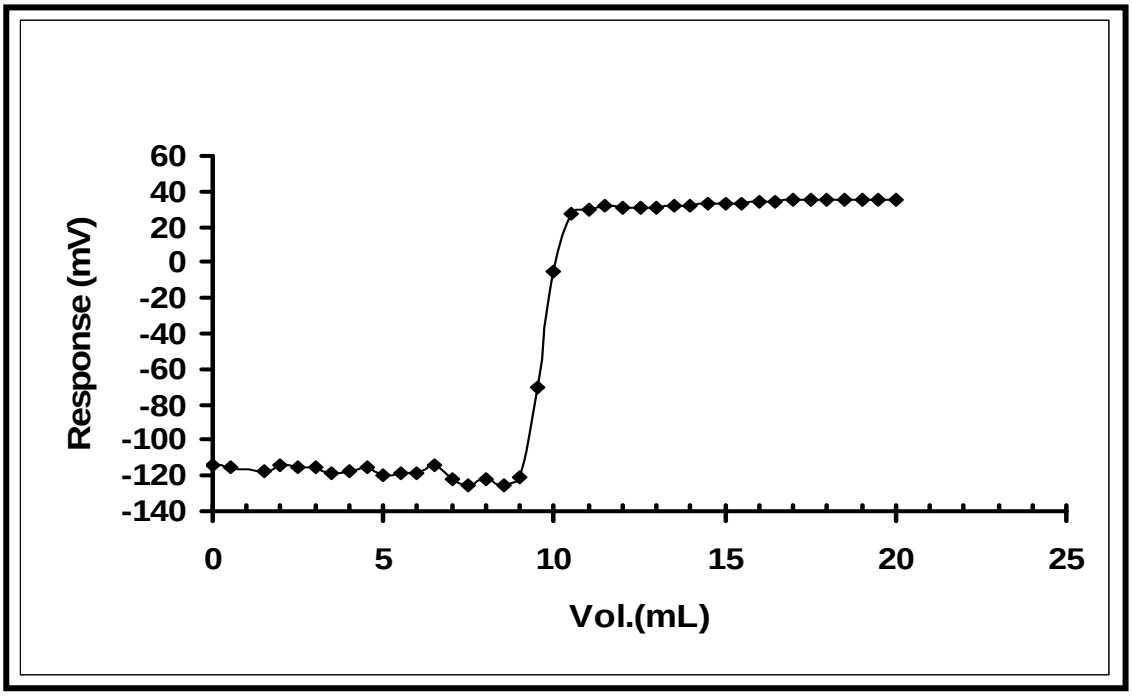


Figure (3-138): Titration curve of electrode D(PMH-PT+DBPH) for sample solution containing 0.001 M promethazine hydrochloride with 0.001 M of hydroquinone as a titrant solution at pH 5.68.

3-6. Analytical application of the selected electrode:

The electrode D(PMH-PT+DBPH) and electrode C(PMH-PT+ONPOE) were proved to be useful in the potentiometric determination of promethazine hydrochloride in pharmaceutical preparations by direct potentiometric, standard addition method, multi addition method and potentiometric titration method. The data obtained for standard addition method, multi addition method and potentiometric titration are listed in tables (3-34) to (3-38), which indicates the average

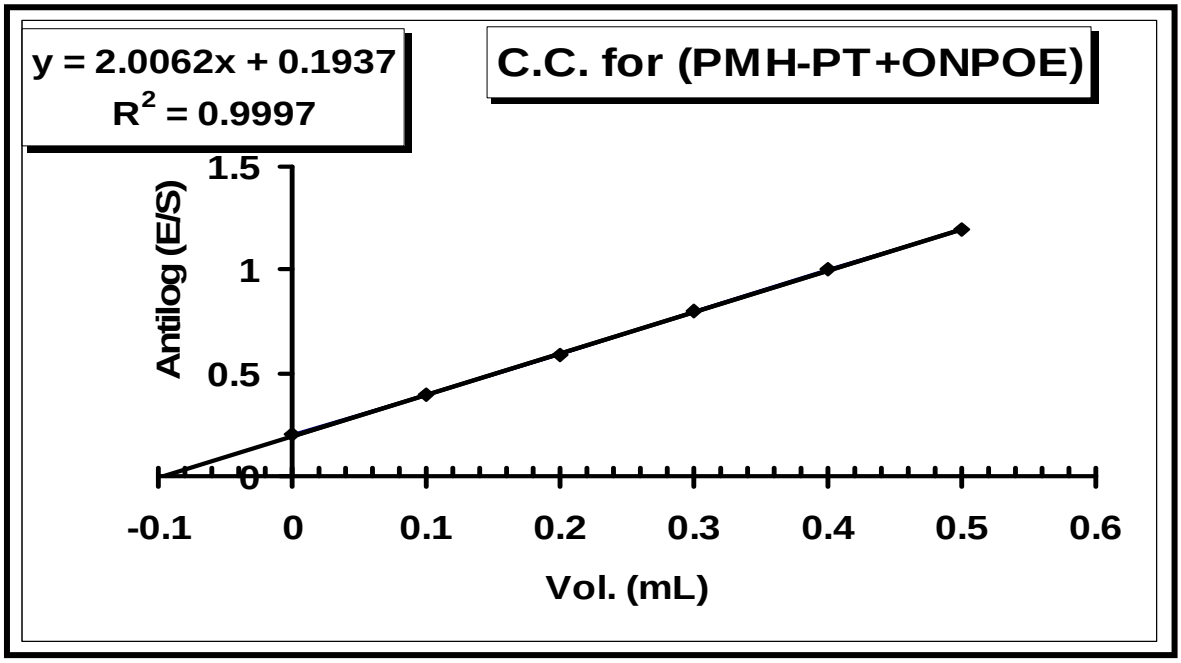
recovery and standard deviation to be 99.53%, 0.7142 % for electrode C (PMH-PT+ONPOE) and 100.77%, 0.4475% for electrode D (PMH-PT+DBPH). The values of standard deviation and recovery are proved that the electrode D is very successful than the electrode C for the determination of promethazine hydrochloride either in standard solution or pharmaceutical preparations.

Table (3-34): Calculation for five additions promethazine hydrochloride using (SA) method for electrode C(PMH-PT+ONPOE) of drug at concentration 10^{-3} M.

V_S mL added	E/mV	ΔE	Antilog(ΔE/S)	(V_U/V_S)	C_U(M)
0	-36	0	1	-	-
0.1	-21	15	1.9545	100	1.03×10^{-3}
0.2	-12	24	2.922	50	1.01×10^{-3}
0.3	-5	31	3.995	33.33	0.963×10^{-3}
0.4	0	36	4.994	25	0.954×10^{-3}
0.5	**4**	**39**	**5.711**	**20**	**1.001×10^{-3}**

Table(3-35): Reading of (MSA) method for electrode C(PMH-PT+ONPOE) of drug at concentration (10^{-3}) M.

V(ml)	E(mV)	Antilog(E/S)
0	-36	0.200
0.1	-21	0.391
0.2	-12	0.585
0.3	-5	0.7998
0.4	0	1
0.5	4	1.196



Figure(3-139): Calibration curve of antilog (E/S) versus the volume added of standard(0.1 M) for determination of promethazine hydrochloride drug(10^{-3} M) by (MSA) of electrode C(PMH-PT+ONPOE).

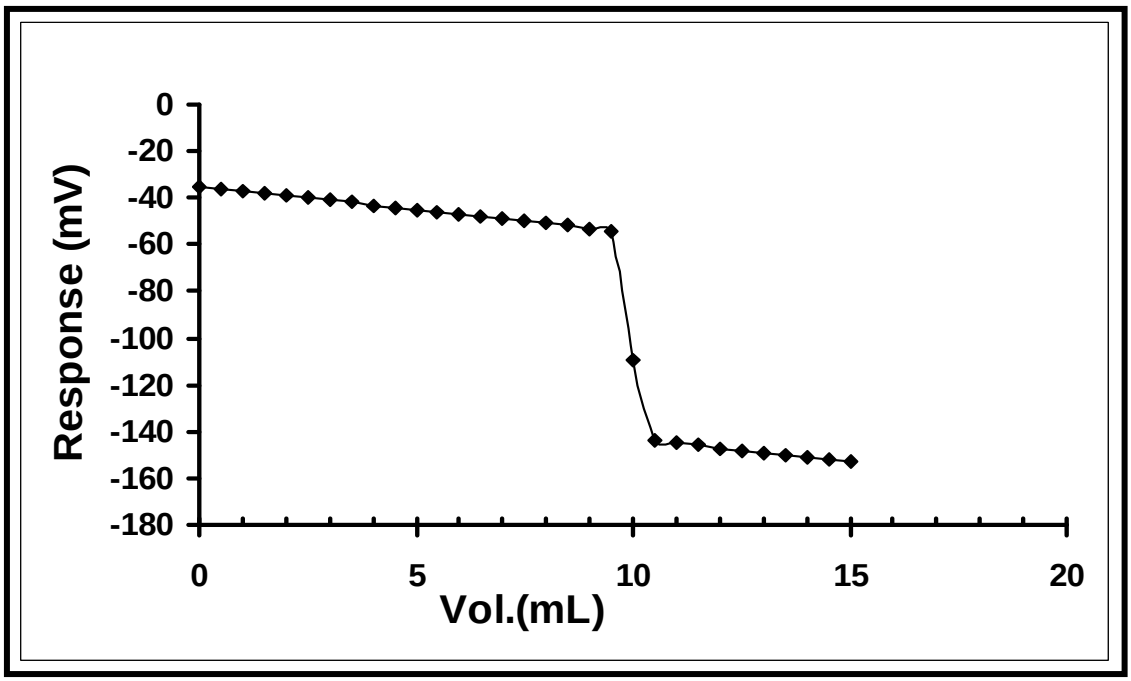


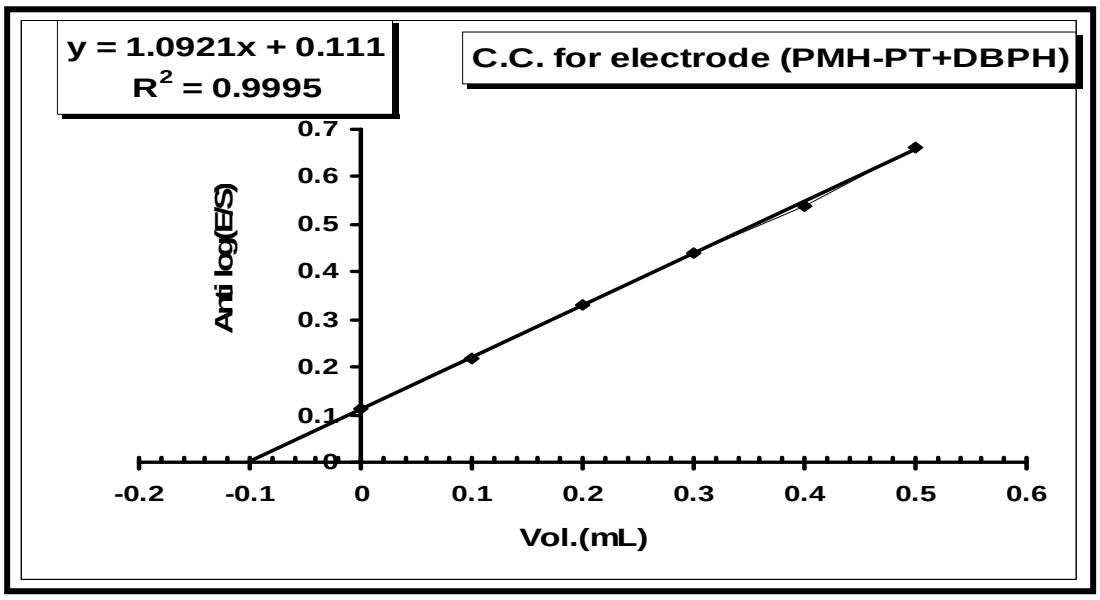
Figure (3-140): Titration curve of electrode C(PMH-PT+ONPOE) for Drug solution containing 0.001 M promethazine hydrochloride with 0.001 M of pt as a titrant solution.

Table (3-36): Calculation for five additions promethazine hydrochloride using (SA) method for electrode D(PMH-PT+DBPH) of drug at concentration 10^{-3} M.

V_S mL added	E/mV	ΔE	Antilog(ΔE/S)	(V_U/V_S)	C_U(M)
0	-53	0	1	-	-
0.1	-36.5	16.5	1.97	100	1.010×10^{-3}
0.2	-27	26	2.911	50	1.016×10^{-3}
0.3	-20	33	3.881	33.33	1.008×10^{-3}
0.4	-15	38	4.767	25	1.011×10^{-3}
0.5	-10	43	5.854	20	0.972×10^{-3}

Table(3-37): Reading of (MSA) method for electrode D(PMH-PT+DBPH) of drug at concentration (10^{-3}) M.

V(ml)	E(mV)	Antilog(E/S)
0	-53	0.1133
0.1	-36.5	0.223
0.2	-27	0.3297
0.3	-20	0.4396
0.4	-15	0.5399
0.5	-10	0.663



Figure(3-141): Calibration curve of antilog (E/S) versus the volume added of standard(0.1 M) for determination of promethazine hydrochloride drug(10^{-3} M) by (MSA) of electrode D(PMH-PT+DBPH).

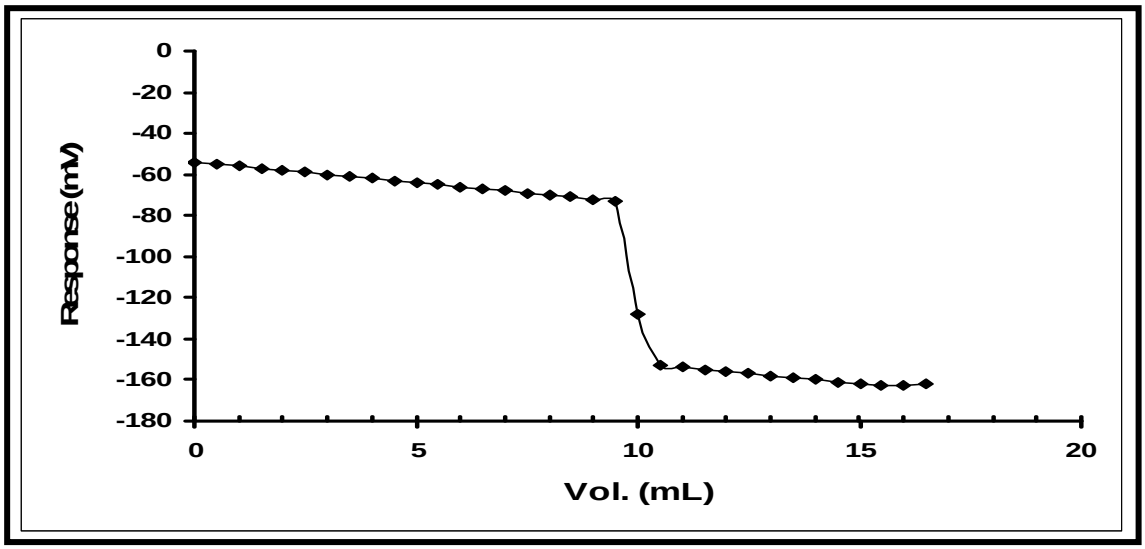


Figure (3-142): Titration curve of electrode C(PMH-PT+DBPH) for Drug solution containing 0.001 M promethazine hydrochloride with 0.001 M of PT as a titrant solution.

Table (3-38): Volume at intercept with X axis and Calculation the concentration C_U(M) of electrode C and D by (MAM) method for drug solution.

Electrode No.	Conc.(M)	V(ml)at intercept	C_U(M)
C(PMH-PT+ONPOE)	1×10^{-3}	0.096	0.96×10^{-3}
D(PMH-PT+DBPH)	1×10^{-3}	0.099	0.99×10^{-3}

Table (3-39): Promethazine hydrochloride tablets analyses by using potentiometric methods for electrode C(PMH-PT+ONPOE) and electrode D(PMH-PT+DBPH).

Electrode No.	Concentration(M)			
	Sample	Measured using potentiometric methods		
		SA	MSA	Titration
C(PMH-PT+ONPOE)	1×10^{-3}	0.992×10^{-3}	0.96×10^{-3}	0.98×10^{-3}
	RSD%	1.290*	-	3.273*
	RC%	99.2	96	98
	RE%	-0.8	-4	-2
D(PMH-PT+DBPH)	1×10^{-3}	1.003×10^{-3}	0.99×10^{-3}	1.01×10^{-3}
	RSD%	0.351*	-	2.683*
	RC%	100.3	99	101
	RE%	0.3	-1	1

*** Each measurement was repeated three times**

Table (3-40): Promethazine hydrochloride tablets analyses for electrode C(PMH-PT+ONPOE) and electrode D(PMH-PT+DBPH).

Electrode No.	Parameter	Phenergan		
Electrode C (PMH-PT+ONPOE)	Concentration(M)	1×10^{-3}	1×10^{-3}	1×10^{-3}
	Founded(M)	1.003×10^{-3}	0.989×10^{-3}	0.994×10^{-3}
	RSD%	0.7142*		
	RC%	100.3	98.9	99.4
	RE%	0.3	-1.1	-0.6
Electrode D (PMH-PT+DBPH)	Concentration(M)	1×10^{-3}	1×10^{-3}	1×10^{-3}
	Founded(M)	1.008×10^{-3}	1.012×10^{-3}	1.003×10^{-3}
	RSD%	0.4475*		
	RC%	100.8	101.2	100.3
	RE%	0.8	1.2	0.3

* **Each measurement was repeated three times**

The electrode D (PMH-PT+DBPH) gave good results than electrode C (PMH-PT+ONPOE) in the analyses the tablets of promethazine hydrochloride in Phenergan drug because the electrode D(PMH-PT+DBPH) have RSD% about o.4475 , that means have a good precision than electrode C (PMH-PT+ONPOE) in which RSD% equal 0.7142 . The relative error (RE%) for SA, MAM and titration methods are -0.8,-4 and -2 respectively for electrode C but for electrode D are 0.3,-1 and 1 respectively which are good results for Phenergan drug compared with electrode C because the electrode C was low slope than electrode D as shown in table (3-39).

2. Experimental part

2-1.Instruments and equipment:

1- Expandable ion analyzer, ORION, model EA 940 with calomel reference and Silver- Silver Chloride (Ag/AgCl) electrodes.

2- FTIR-8300 Fourier transform infrared spectrophotometer SHIMADZU.

3- WTW model pH 522, made in Germany.

4- Clear PVC tubing (6 mm o.d.).

5- Magnetic stirrer.

6- Ultra pure water manufacturing devise, TORAYPURE, Model LV-08 (Mihama, Japan).

2-2.Chemicals:

Promethazine hydrochloride was a gift from the State Company of Drug Industries and Medical Appliances(Samara- IRAQ-SDI). Phenergan tablets (25 mg promethazine hydrochloride) (Bristol-Myeres sequibb company, USA), were purchased from local market.

The following plasticizers were used:

1- Di-butylphosphate (DBP) ($C_8H_{19}O_4P$), purity(98.9%)

2- Tri-butylphosphate (TBP) ($C_{12}H_{27}O_4P$), purity (97%)

3- O-nitrophenyloctylether (ONPOE) ($C_{14}H_{21}NO_3$), purity (98%)

4- Di-butylphthalate (DBPH) ($C_{16}H_{22}O_4$), purity (99%)

Were obtained from Fluka AG, (Switzerland). Other chemicals and reagents of analytical grade reagent were obtained from Fluka, BDH and Aldrich companies.

2-3.Preparation of standard solution:

All solutions were prepared in doubly distilled deionized water. Stock solutions of 0.1 M of LiCl, NaCl, KCl, $CaCl_2$,$MgCl_2$,$ZnCl_2$, $FeCl_3$, $AlCl_3$ and $CrCl_3$ were prepared. More diluted solutions were prepared by subsequently dilution of the stock solutions.

A standard solution of 0.1 M promethazine hydrochloride was prepared by dissolving 0.8023 g of standard promethazine hydrochloride and completing the solution up to 25 ml. The other promethazine hydrochloride standard solutions were prepared by subsequent dilution of the stock solution.

0.05M- Potassium hydrogen phthalate buffer (pH=4.01) was prepare by dissolving 10.21 g of the solid (potassium hydrogen phthalate) and diluted to 1 liter[120].

2-4.Preparation of Ion-pair Compound:

The promethazine hydrochloride ion-selective electrode is prepared based on the use of ion-pair compound promethazine hydrochloride-phosphotungastate (PMH-PT) as the electro-active substance[121].

The preparation of ion-pair of (PMH-PT) was performed by mixing 50 ml of 0.01 M solution of promethazine hydrochloride (PMT) with 50 ml of 0.01 M phosphotungastate with stirring. The resulting precipitate was filtered off, washed with water, dried at ~60^{o}C. The composition of the ion-pair compound, (PMH-PT), was confirmed using FTIR.

2-5. Casting the membrane:

The method of immobilizing the promethazine hydrochloride into the PVC matrix membrane was made as described by Davis et al. [122]. A 0.040 g of (PMH-PT) matrix was mixed with 0.360 g of plasticizer and 0.17 g of PVC powder, after that (6.0 or 7.0) ml of THF was added with stirring until the formation of viscous solution. The above solution poured

into a glass casting ring about 30 mm length and 35 mm in diameter. It consists of two pieces; one of them is the glass cylinder and the other is glass plate. The two pieces was pasted together by using (PVC-THF) viscous mixture (to make sure no loss in the membrane mixture) figure (2-1). The top side of the cylinder was covered with a pad of filter paper on which a heavy weight (~200 g) was placed. The assembly was left for 2-3 days to allow graduate evaporation of the solvent.

2-6. Assembling the ion-selective electrode:

The glass ring with adhering membrane was carefully removed from the glass plates as shown in figure (2-1) (3rd step). The membrane was then detached away from the edge of the ring. A disc of the membrane was cut equal to the external diameter of a PVC tube, step 4.One of sides of PVC tubing was flatted and smoothed by placing it on glass plate moistured with THF with aid of vertical rotation. The disc then mounted with a forceps on the polished end, the outer edge of the disc membrane was carefully sealed to the end of the PVC tube, step (5). Next step is connection into a glass tube, step (6). The other side of the glass tube was assembled with plastic cover in which Ag/AgCl wire was inserted through it, the tube was filled 3/4 with 0.1M promethazine hydrochloride solution before fixing the cover, step (7). The electrode was then conditioned by placing it in 0.1M solution containing the ion to be measured (at least 2 hour's) before using.

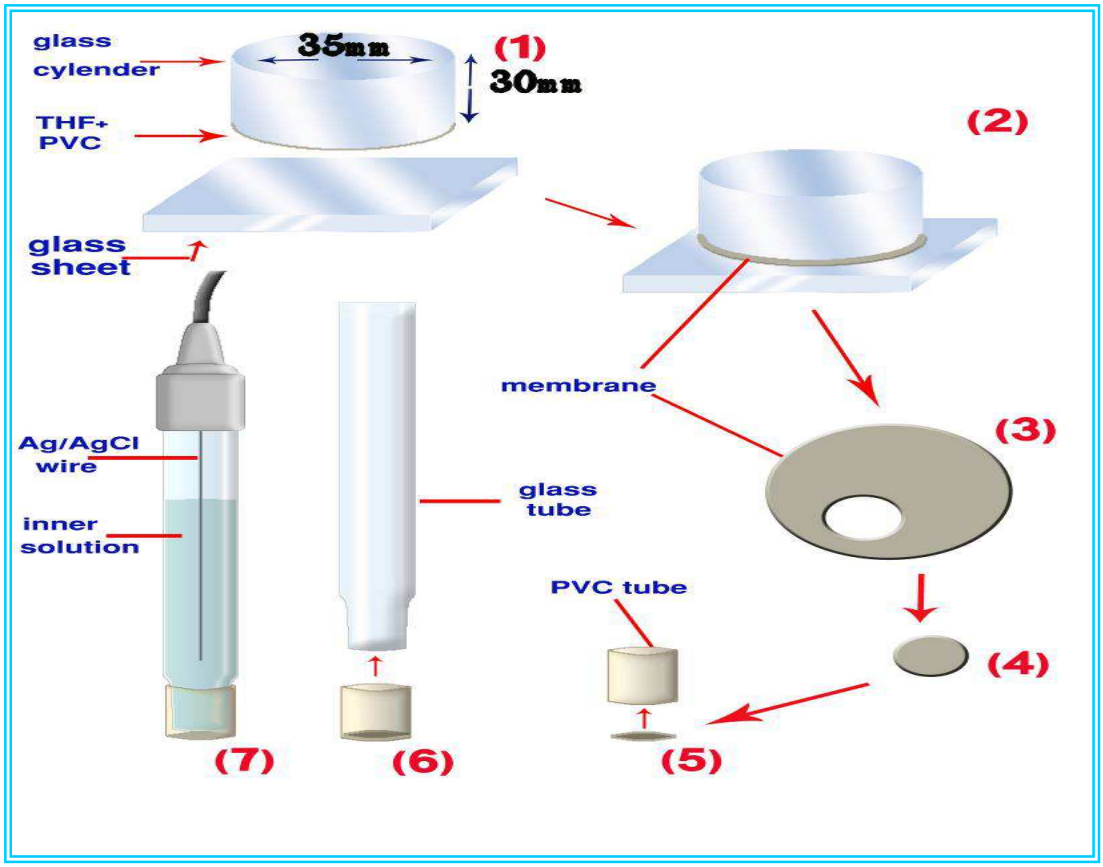


Figure (2-1): Assembling the Ion-selective Electrode.

2-7.Potential measurement:

A promethazine hydrochloride selective electrode and saturated calomel electrode (SCE) were used as indicating electrode and the reference electrode, respectively. The e.m.f. measurements were carried out at room temperature using the following cell:

Ag/AgCl | internal sol. of PMH (0.1 M) | membrane (PMH+PT)| external sol. of (PMH) (X M) | SCE

A calibration curve was constructed for each ISE using several standard solutions ranged from 10^{-1} M to 10^{-5} M promethazine hydrochloride. The test solutions were constantly stirred with magnetic stirrer. The activity coefficients of the above standards were calculated using Deby-Hükle equation [37] (2-1):

$$\mathbf{Log}\ f = Az^2\ \sqrt{\mu}/(1+0.329\ R\ \sqrt{\mu}) \quad \ldots\ldots\ldots\ldots\ (2\text{-}1)$$

Where

f :is the activity coefficient.

z :is the charge of the analyte ion.

μ: is the ionic strength of the solution.

A :is constant which depend on temperature and solvent

(A= 0.511 for water at 25^{o}C).

R: is the effective ionic radius of actual ion (R was taken as 6A^{o}).[37]

Calibration curves were then prepared by plotting the potential versus the activity on Orion semi-log graph paper.

From the calibration curve all statistical facts including slope; correlation coefficient, concentration range and detection limit, which characterize the manufactured electrodes were evaluated.

The effect of pH on the response of membrane was examined by measuring the potential of the standard solutions with concentrations (10^{-3}, 10^{-2}) M at different pH ranged from 1-12; where the pH values were adjusted with sodium hydroxide and HCL solutions. The life time of each membrane was calculated; that is the decrease in Nernstian response with the time after first measurement.

2-8. Selectivity measurements:

The selectivity of the electrode has been measured by two methods.

1- The separate solution method [30]. In this method, standard solutions (10^{-1}-10^{-5}) M promethazine hydrochloride were prepared and there potentials were measured. At the same time the potential for interfering ions (Li^{+}, Na^{+}, K^{+}, Ca^{2+}, Mg^{2+}, Zn^{2+}, Al^{3+}, Fe^{3+}, Cr^{3+}) which were selective due to their biological importance at

concentrations range from (10^{-1}- 10^{-5}) M were measured. From equation (1-8) the selectivity coefficient can be calculated.

2- match method. This method is including to prepare one standard solution of promethazine hydrochloride of concentration 10^{-3} M and 10 mL of the standard can be used for measurement. The potential of the standard promethazine hydrochloride 0.1 M was remeasurement after addition of 0.1 mL of 0.1 M standard solution. At the same time the potential was measured after addition 0.1mL of 0.1 M interfering ions (Li^{+}, Na^{+}, K^{+}, Ca^{2+}, Mg^{2+}, Zn^{2+}, Al^{3+}, Fe^{3+}, Cr^{3+}) which were selective due to their biological importance. From equation (1-11) the selectivity coefficient can be calculated.

2-9. Sample analysis:

Three synthetic samples of the different concentration were prepared. The concentration of these samples were calculated using direct, standard addition (SA) and titration method using Gran plot (except for direct method).

In the direct method the e.m.f. of sample is measured directly using promethazine hydrochloride indicator electrode see figure (1-1). The concentration was then calculated using calibration curve of standard promethazine hydrochloride.

In the standard addition method the sample of 10 mL with concentration of $1x10^{-3}$ M is introduced followed by addition of 0.1 mL of 0.1 M increments. The e.m.f. is calculated before and after each addition. The concentration of the sample is calculated [20] using equation (1-12) for a single point increment.

These methods depend on the fact that the plot of electrode potential (mV) against concentration (M) is a logarithmic curve. Thus any particular ratio of the amount of increase in mV in response to a particular increase in concentration (i.e. the slope of the curve) will only fit in one unique part of the curve and thus the concentration before and after addition can be determined. The multi addition method was plotted between antilog $[(E_2-E_1)]/S$ and volume addition of standard solution.

A SA Gran's plot was also prepared on semi-antilog graph paper by plotting the cell potential versus the added volume of standard. The concentration of each sample was then calculated (MSA method) by extrapolating the x-axis of the calibration line[9].

A precipitation titration was then performed on the samples under study after the addition of phosphotungistic acid solution, and the precipitation titration was studied in the different media(acid, base, and neutral). The titration is then followed potentiometrically using the prepared ISE. A titration curve using Gran's plot was then constructed for each sample. The titration method was included titrate hydroquinone solution with analyte sample and measured the potential after addition hydroquinone.

2-10. Preparation of pharmaceutical formulation:

Three phenergan tablets were crushed, mixed in a mortar and weighted of three tablets accurately, then taken average weight of tablets. Preparation of concentration 10^{-3} M by weighted from the average weight and dissolved in 50 ml with stirring to prepare this concentration.

Conclusion:

Promethazine-selective PVC membrane electrodes based on ion pair compound (complex) of PMH-PT and (DBP,TBP,ONPOE,DBPH) as plasticizers were constructed, and used as a method for potentiometric determination. The electrodes can be used for drug determination in pharmaceutical formulation.

The best electrode for PMH was based on (DBPH) which gives excellent electrode parameters as well as good result in determination of PMH. Also there is no interference for some cations (Li^{+1}, Na^{+1}, K^{+1}, Mg^{+2}, Ca^{+2}, Zn^{+2}, Al^{+3}, Fe^{+3}, Cr^{+3}), it was also that the working pH was in the range (2-7). The practical utility of the electrode has been demonstrated by use it as indicator electrode in potentiometric precipitation titration of PMH solution with phosphotungistic acid solution. Standard addition method and multi standard addition method have been also successfully applied and presenting an excellent results.

The proposed electrode was successfully applied to the determination of promethazine hydrochloride in pharmaceutical preparation (Phenergan). The analytical method proposed proved to be simple , rapid and of good accuracy.

Contents

Examining Committee's Certification

We, the Examining Committee, certify that we have read this thesis and examined the student (Bashaer Abbas Khudhair) in its contents, and that in our opinion it is adequate with (**Excellent**) standing as a thesis for the Degree of **Master of Science,** in **Chemistry.**

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Supervisor Certification

We certify that this thesis was prepared under our supervision at the Department of Chemistry, College of Science, AL- Nahrain University as partial requirements for the **Degree of Master of Science in Chemistry.**

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In View of the available recommendations, I forward this thesis for debate by the Examining Committee.

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Future work:

Based on the above study, future work can be conducted on the other ISE ́s which can be fabricated using:

1. Preparation electrodes for drugs and amines.

2. To extend our work by using another plasticizers to find excellent electrode parameters.

3. Using another matrices instead of PVC in order to compare with PVC matrix.

4. Other amount and percent of components proportions in membrane, through fixing one of the components and changing the others.

List of figures

List of tables

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Preparation and Potentiometric Study for Promethazine Hydrochloride Selective Electrodes and their Use in Determination of some Drugs

A Thesis submitted to the College of Science Al-Nahrain University in partial fulfillment of the requirements for the Degree of Master of Science in Chemistry

By
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Summary

Electrodes for the determination of promethazine hydrochloride based on PVC membrane were prepared based on the use of ion pair (promethazine-phosphotungstic acid) with the following plasticizers: Di-butyl phosphate (DBP), Tri-butyl phosphate (TBP), O-nitrophenyloctyl ether (ONPOE), and Di-butyl phthalate (DBPH). The properties of these electrodes were studied, including: slope, correlation coefficient, concentration range, detection limit, pH effect, and life time. The statistical treatments were applied for the results that include: relative standard deviation (RSD), relative error (RE), mean error, confidence limit for concentration, and confidence limit for potential.

The electrodes (A,B and C) based on DBP, TBP and ONPOE respectively, gave a same linear range from $1x10^{-1}$ to $1x10^{-4}$ M but for electrode D based on DBPH gave the linear range from $1x10^{-1}$ to $5x10^{-4}$ M. The slopes are (40.58, 39.82, 51.52 and 56.17) mV/decade, with the correlation coefficients are (0.9984, 0.9988, 0.9991 and 0.9993), and the limit of detection $3.5x10^{-5}$, $5x10^{-5}$, $5.5x10^{-4}$ and $2x10^{-4}$ M respectively. The pH range was (2.4-8.4), (1.5-6.4), (3.0-7.3) and (4.1-6.8) respectively, and the lifetime were about (~29 days, ~23 days, ~2 days and ~72 days) respectively. The relative standard deviation (RSD%) was (0.662, 0.802, 0.414 and 0.287) respectively.

The stability of the four electrodes was monitored continuously and evaluated; the standard deviation of potential drift obtained = (±3, ±4, ±9 and ±1) mV/day for membranes (A, B, C and D) respectively. The influence of inorganic cations such as (Li^{+}, Na^{+}, K^{+}, Mg^{+2}, Ca^{+2}, Zn^{+2}, Al^{+3}, Fe^{+3}, Cr^{+3}) for the electrodes (A, B, C, and D) was studied by using separation and match methods to determine the selectivity potential

coefficient $\mathbf{K^{pot}_{A,B}}$. It was found that the electrodes (D) based on DBPH plasticizer gave excellent results; so, it has been chosen as the best combination of plasticizer and electro-active compound.

The practical utility of the electrode has been demonstrated by using it's as indicator electrode in potentiometric precipitation titration of promethazine hydrochloride solution with phosphotungistic acid solution and with hydroquinone solution. Standard addition method and multi standard addition method have been also successfully applied and presenting an excellent results.

The proposed electrode was successfully applied to the determination of promethazine hydrochloride in pharmaceutical preparation (Phenergan). The analytical method proposed proved to be a simple, rapid and good accuracy.

الخلاصه

تم تصنيع عدة أقطاب بوليمريه في مادة PVC حساسة للهيدروكلورايد بروميثازين بالاعتماد على المعقد المحضر (promethazine-phosphotungistic acid) كمادة فعالة. هذه المادة الفعالة تكون مذابة في عدة مواد ملدنه منها :

Di-butylphosphate(DBP),Tri-butyl phosphate (TBP), O-

nitrophenyloctylether (ONPOE), Di-butylphthalate(DBPH),

وقد تم دراسة خواص هذه الأقطاب و التي شملت(ميل منحني المعايرة و معامل الارتباط و مدى التراكيز و حد التحسس و عمر القطب وتأثير إل pH) و تطبيق المعالجة الاحصائيه على هذه النتائج والتي تشمل (نسبة الانحراف القياسي ونسبة الخطأ و معدل الأخطاء وحد الثقة بالنسبة للجهد. ومن خلال الدراسة وجد إن الأقطاب المتكونة من (DBP,TBP and) ONPOE كمواد ملدنه تمتلك مدى متساوي من التراكيز التي تتحسسه هذه الأقطاب يتراوح من 1×10^{-4} M إلى 1×10^{-1} M, لكن المعتمدة على (DBPH) كمادة ملدنة تعطي مدى التركيز يتراوح من 5×10^{-4} M إلى 1×10^{-1} M, و تعطي ميل منحني معايرة (40.58, 39.82, 51.52 and 56.17) (mV/decade) مع معامل ارتباط (0.9984, 0.9988, 0.9991 and 0.9993) بالتعاقب . و كان حد التحسس لهذه الأقطاب يساوي(3.5×10^{-5}, 5×10^{-5}, 5.5×10^{-5} and 2×10^{-4}) و مدى إل pH بحدود (1.5-6.4), (3.0-7.3) and (6.8-4.1), (2.4-8.4), وكان عمر هذه الأقطاب تقريبا بحدود (29, 23, 2 and 72) يوم بالتعاقب. إما نسبة الانحراف القياسي كانت تساوي (0.662, 0.802, 0.414 and 0.287) بالتعاقب. إن استقرارية الأقطاب الأربعة تقاس بشكل مستمر و حصلنا على الانحراف القياسي لانحراف الجهد لهذه الأقطاب بمقدار (±1 and ±9, ±4، ±3) بالتعاقب.أيضاً تم دراسة تداخلات بعض الأيونات الموجبة مع الأقطاب بوساطة طريقة المحاليل المنفصلة وطريقة تناسب الجهد لتعين معامل الانتقائية $K^{pot}_{A,B}$ لهذه الأيونات، وتبين إن تداخلات الأيونات الأحادية تكون أكبر من تداخلات الأيونات الثنائية والثلاثية بالاعتماد على حجم وشحنة ونفاذية الايونات . ووجدنا ان القطب الرابع المعتمد على (DBPH) كمادة ملدنة يعطي أفضل النتائج لذلك تم اختياره كأفضل اتحاد بين

المادة الملدنة و المادة الفعالة . لدراسة الخواص ألعمليه في محاليل قياسيه محضره مختبرياً وكذلك في نماذج دوائية، تم استخدام القطب كقطب كاشف في عملية التسحيح الترسيبي واستخدمت أيضاً طريقة الإضافات القياسية وطريقة المتعددة الإضافات وطبقت بنجاح وأعطت نتائج ممتازة.

وان القطب المقترح طبق بنجاح في تحديد المادة الدوائية في المستحضرات الصيدلانية (Phenergan). وان الطرق التحليلية أثبتت أنها طريقة سريعة وبسيطة وتعطي نتائج جيدة.

الاهداء

إلى من يحفر الصخر ليشق لنا درب الحياة ومن لا يكل أو يبخل لنا بأي نصيحة ومساعدة. إلى من عانى لكي أصبح...
إلى الشمعة التي أذابها التعب ...
إلى من دفع دمه في سبيل العلم لإنارة درب المستقبل...
إلى الأستاذ الفاضل و والدي العزيز...

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إلى من تحت أقدامها السبع الجنان...

والدتي العزيزة
إلى سندي في الحياة ...

إخوتي وأخواتي
إلى الذين شاطروني أفراحي وإحزاني وكانوا موضع ثقتي ...

صديقتي مريم

بشائر

بسم الله الرحمن الرحيم

نرفع درجات من نشاء وفوق كل ذي علم عليم

صدق الله العظيم

جمهورية العراق
وزارة التعليم العالي والبحث العلمي
جامعة النهرين/كلية العلوم
قسم الكيمياء

تحضير ودراسة جهديه لأقطاب البروميثازين الانتقائية واستخدامها في تعيين المواد الدوائية

رسالة
مقدمة إلى كلية العلوم- جامعة النهرين
وهي جزء من متطلبات نيل درجة الماجستير في الكيمياء

من قبل
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Abbreviations

C.C.	Calibration curve
cm	Centimeter
CZE	Capillary zone electrophoresis
DBP	Dibutylphosphate
DBPH	Dibutylphthalate
e.m.f.	Electromotive force
FTIR	Fourier transform infrared spectroscopy
FIM	Fixed interference method
FPM	Fixed primary ion method
GC	Gas chromatography
HPLC	High performance liquid chromatography
HQ	Hydroquinone
ISE	Ion-selective electrode
LC	Liquid chromatography
mg	Milligram
ml	Milliliter
mm	Millimeter
MPM	Match potential method
µg	Microgram
µl	Micro liter
M	Molarity

MSA	Multi standard addition
mV	Millivolt
MS	Mass spectrophotometry
ONPOE	Ortho nitro phenyl octyl ether
PVC	Poly vinyl chloride
PMH	Promethazine hydrochloride
PT	Phosphotungastic acid
Ref.	Reference
RSD	Relative standard deviation
RE	Relative error
RC	Recovery
SCE	Saturated calomel electrode
SSM	separate solution method
SDI	State company for drug industries
Std.	Standard
SA	Standard addition
s	Second
THF	Tetrahydrofuran
TBP	Tributylphosphate
$t_{95\%}$	Time at 95%
TLC	Thin layer chromatography
UV	Ultraviolet
Vis	visible
Vol.	Volume