International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 3 Issue 9, September- 2014

Investigation of Some Electronic Properties of Combined pH Electrode

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***Abstract*— Some electronic properties of combined pH electrode have been investigated with the help of electronic circuits. Electrode-electrolyte resistance has been measured by half deflection method and its value depends on the thickness of glass. The bulk resistance of test solution, internal solution of glass and reference electrodes have been measured by AC Wheatstone's bridge and they are dependent on ionic concentration. The capacitance of glass electrode has been measured by de Sauty's bridge. The impedance of double screened co-axial cable has measured by LCR meter. The measured values of resistance and capacitance are matching with the desired values. Present study is useful to the electronic engineers for designing of preamplifier section of pH meter.**

Keywords—combined pH electrode, electrode-electrolyte resistance, AC Wheatstone's bridge, de Sauty's bridge.

I. INTRODUCTION

pH measurement is generally done with the use of a combination electrode. The combination electrode is an electrode system formed by a glass half-cell which works as measuring electrode and reference half- cell. A potential develops on the membrane surface when a pH electrode comes in contact with a sample and its value varies with the pH of the sample [1]. The voltage signal produced by the pH electrode is a very small, high impedance signal. Due to this reason, the voltmeter is not directly connected to the pH electrode. An interface of amplifier with high input impedance is required between the electrode and voltmeter. With the age of glass electrode, its resistance changes. Generally it increases due to chemical deposition and deformation due to thermal effect. This resistance change alters the electrode potential. For this cause, electrode should be calibrated regularly. The resistance of electrode depends on the type of material used for making the glass balloon.

The balloon of pH electrode is made from a special glass composed of alkali metal ions [2-4]. The alkali metal ions of the glass and the hydrogen ions in solution undergo an ion exchange reaction generating a potential difference. Electronically, the ion exchange is equivalent to the leakage of charge through the glass membrane. The glass membrane forms the solid dielectric medium of non-polar capacitor. The internal ionic buffer solution and the external test solution form the plates of capacitor. The value of capacitance depends on the thickness of glass membrane and the ionic concentration of solutions. The response time of pH measurement depends on the capacitance.

The potential of the reference portion is produced by the internal element in contact with the reference fill solution. The potential at glass electrode is measured with reference to the potential of reference electrode. In order to measure the correct potential due to test solution, the potential of reference electrode should be constant [5]. For this reason, the fill solution should contain constant number of ions. The saturated solution of salt, such as KCl, has more ions and less resistance of the order of 2000 Ω.

The present work deals with the measurement of resistance and capacitance of combined pH electrode. The resistance of glass and solution were measured by half deflection method and AC Wheatstone's bridge respectively. The capacitance of glass was measured by the de Sauty's bridge method. The rest of article is organized as follows: in section II electrical equivalent circuit of combined pH electrode is discussed. The design of electronic circuits, their description and results are discussed in section III. Finally, the conclusion and the future scope of present work are discussed in section IV.

II. METHOD

In the present work, electronic parameters of combined electrode have been measured by designing the electronic circuits. Figure 1 shows the combined electrode and it also shows the corresponding equivalent electronic components. The balloon of glass electrode forms the electrode-electrolyte interface and it is equivalent to the parallel combination of resistor (R_g) of glass and capacitor (C_g) with glass as dielectric. The internal and external ionic solutions form the plates of parallel plate capacitor. The resistance of internal solution (R_{int}) is in series with R_g and Ag/AgCl wire. The R_g and C_g are given by [6],

$$R_g = \frac{\rho \times d}{B}, \qquad C_g = \frac{\varepsilon_0 \times k \times A}{d}$$

Where, ρ=specific resistance, d= thickness, B= cross-sectional area, ε_0= permittivity of free space, k=dielectric constant, A=surface area of balloon.

The resistance of glass and ionic solutions cannot be measured by electronic ohm meter. This is due to non-conducting behavior of glass and the nature of charge transport in the ionic solution. Special methods are required to measure them and they are discussed in the next section.

Fig.1 shows the electrical equivalent circuits of glass electrode, reference electrode, test solution and the co-axial cable. The reference electrode is filled with saturated solution with resistance (R_r). The resistance of liquid junction is ignored because it is negligible as compared to R_r.

The potential produced by the electrode is very small. The amplifier with low bias current is required to increase the strength of electrode signal. The signal carrying wire should have minimum resistance (R_{wi}). The screen of co-axial cable is used to carry the return signal. This outer layer should have less resistance (R_{wo}). The insulating PVC cover of the inner wire forms the dielectric of cylindrical capacitor (C_{ins}). There is possibility of leakage of charge through the insulating coating of wire. The capacitance due to insulation should be minimum, and it is possible by use of thick insulating cover.

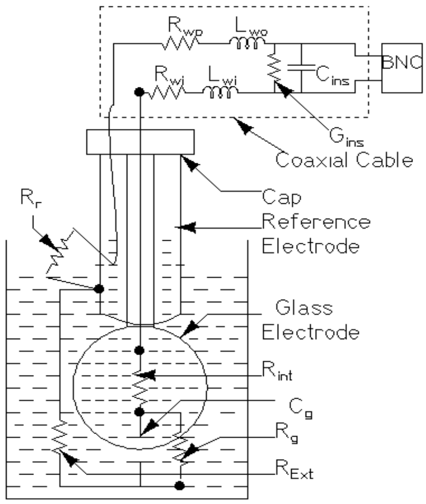

Fig.1: Electrical equivalent circuit of combined pH electrode

III. ELECTRONIC CIRCUIT DESIGN AND RESULTS

A. Measurements of Resistance

1) Measurement of R_g: It is the resistance due to charge transferred through glass medium and it cannot be measured by dc Ohm-meter. The charge transferred through glass is negligible and due to this, Ohm-meter is not suitable for the measurement of R_g. In the present work we have used the half deflection method which is based on the measurement of potential difference (PD).

Half deflection method: R_g can be measured in following three steps.

a) Voltage across R_g is measured and it is called full deflection (V_{fd}) as shown in figure 2(a).

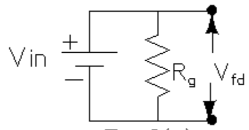

Fig.2(a)

b) A known variable resistor (R_k) is connected in series with R_g and by varying R_k, the voltage across R_g is reduced to ½ V_{fd}, as shown in fig 2(b).

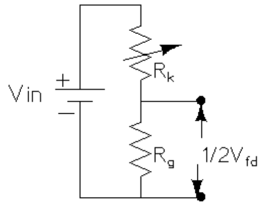

Fig.2(b)

The voltage across R_g can be calculated by using potential divider formula,

$$v_{R_g} = \frac{v_{fd}}{2} = \left(\frac{R_g}{R_g + R_k}\right) v_{in}$$

Further, value of R_g can be obtained as,

$$R_g = \frac{v_{fd} \times R_k}{2v_{in} - v_{fd}}$$

c) At half deflection position, resistance R_k equals to R_g. The value of R_k can be obtained by using Ohm-meter.

Above method has been used to measure the resistance Rg of glass electrode. The measured Rg of new and old glass electrodes are 400 MΩ and 420 MΩ respectively.

B. Measurement of Bulk Resistance (R_{ext}) of Solution and Resistance (R_{int}) of Internal Buffer Solution

These resistances are due to the ionic charge transport in solution. They can be measured with the use of AC Wheatstone's bridge as shown in fig. 3.

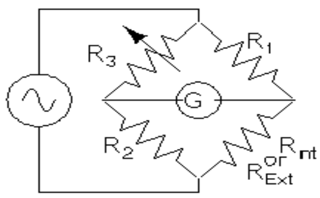

Fig.3

The resistor R_3 is varied to balance the bridge. The resistances R_{int} or R_{Ext} can be obtained from bridge balance condition,

$$R_{int} = \frac{R_1 \times R_2}{R_3}$$

Where R_1 and R_2 are fixed resistors and R_3 is variable resistor used for balancing the bridge.

Above method has been used to measure the resistance of test (R_{Ext}) and internal buffer (R_{int}) solutions. The R_{Ext} of 0.05 M Potassium Hydrogen Pthalate and R_{int} of 0.1M HCl are 9 KΩ and 5 KΩ respectively.

C. Measurement of Capacitance (C_g)

The balloon of glass forms the dielectrics of capacitor glass and it is measured by de Sauty's bridge method as shown in figure 4.

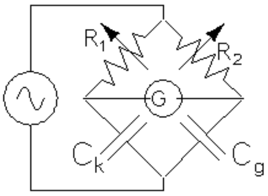

Fig.4

If bridge is balanced then C_g is given by,

$$C_g = \frac{R_2 \times C_k}{R_1}$$

Above method has been used to measure the capacitance C_g of glass. The C_g of new and used combined electrodes are 60pF and 58 pF respectively. The results of measurements of electrical properties of combined pH electrode are summarized in Table I.

TABLE I. Electrical properties of combined pH electrode

Sr. No.	Property	Combined pH electrode	
		New	Old
1	Resistance of glass (R_g)	400MΩ	420MΩ
2	Capacitance due to glass balloon (C_g)	60pF	58pF
3	Resistance of 0.1 M HCl (R_{int})	5KΩ	5.4KΩ
4	Resistance of saturated KCl (R_r)	2KΩ	2.2KΩ
5	Resistance of pH 4 solution (R_{ext})	9KΩ	9.8KΩ
6	Resistance of inner conductor of coaxial cable (R_{wi})	0.1Ω /m	0.11Ω /m
7	Resistance of screen of coaxial cable (R_{wo})	0.12Ω /m	0.13Ω /m

IV. CONCLUSIONS AND FUTURE SCOPE

Resistance and capacitance of combined electrode play significant role in the measurement of potential. The value of resistance is very high and it changes due to the chemical deposition. The glass electrode is more sensitive to pH measurement, if its resistance is low. Capacitance of glass electrode depends upon thickness of glass and its composition. For better sensitivity capacitance value should be high and it can be achieved by use of thin glass. The measurement of resistance and capacitance values of combined pH electrodes are necessary for the design of an amplifier circuit of pH meter.

In the present work, prototype electronic circuits were designed using ordinary readily available components. They are manually operated circuits and give good estimate of the parameters of pH electrode. In future, our plan is to develop automatic system using special components for the measurement of parameters.

REFERENCES

[1] G. R. Chatwal, S. K. Anand, "Instrumental methods of chemical analysis," Himalaya publishing house, 5th Edn, 2008.

[2] R.A. Weeks, "The structure of glass: past, present, and prescient," Volume 73, Issues 1–3, Pages 273–284, August 1985.

[3] F.G. K. Baucke, "The glass electrode-applied electrochemistry of glass surfaces," Journal of Non-Crystalline Solids Volume 73, Issues 1–3, Pages 215–231, August 1985.

[4] M.M. Shultz, "Chemistry of glass," Journal of Non-Crystalline Solids Volume 73, Issues 1–3, Pages 91–101, August 1985.

[5] Skoog, D. M. West, F. J. Holler & S. R. Crouch, "Fundamentals of Analytical Chemistry," 8th Edn, Thomson-Brooks/Cole, 2004

[6] Paul Horowitz and Winfield Hill, "The art of Electronics," 2nd Edn., Cambridge University Press, 1989.

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