CHAPTER 5

Chloride Ion: Design and Development of Computer based Measurement System
Section 5.1
HARDWARE DEVELOPMENT

In the present study a computer based instrumentation system is developed for the measurement of chloride ion. It works on the principle of an electrochemical cell which consists of a chloride ion sensitive electrode as the working electrode and a silver/silver chloride electrode as reference electrode and the solution whose chloride ion concentration is to be estimated. The cell produces an emf proportional to the concentration of the chloride ion. The emf produced is of the order of a few millivolts and it is generally of the order of 59.16 millivolts/decade at 25 °C. The potential of the chloride ion sensitive electrode slightly depends on the temperature of the solution also, which is to be compensated.

The emf generated in the electrochemical cell is given to a high input impedance amplifier and the analog output of the amplifier is converted into digital form using an analog to digital converter. The digital information corresponding to concentration of chloride ion is stored and displayed with the help of a computer using appropriate interfacing devices. The necessary software to operate the system is developed in C language. The block diagram of the system is shown in Figure 5.1.

The system designed in the present study, consists the following functional blocks.

1. Chloride ion sensitive electrode
2. Reference electrode
3. Signal conditioner
4. Temperature sensing unit
5. Data acquisition system
6. Analog multiplexer
7. I/O card
8. Personal computer
9. Power supply unit
Figure 5.1 Block diagram of computer based system for Measurement of Chloride Ion

DAS: Data Acquisition System
DIOT: Digital Input Output Timer Card

Reference Electrode
Temperature Sensor
Chloride ISE
Electrolyte

Signal Conditioner
Signal Conditioner
Analog Mux
ADC
DAS

Power Supply
Personal Computer

Figure 5.1 Block diagram of computer based system for Measurement of Chloride Ion
WORKING ELECTRODE

The chloride ion selective electrode is made up of a selective membrane which allows only chloride ions to penetrate to the electrode. A potential drop is developed between the two sides of the sensing membrane. This potential is proportional to the logarithm of the concentration of the chloride ion according with the Nemst equation described earlier in chapter 2. A chloride ion selective electrode is used in the present study as working electrode. The sensing membrane of chloride ion is sealed on to one end of a heavy-walled polymer tube fixed into a polymer body. The construction of the electrode is shown in Figure 5.2.

When the electrode is immersed in an aqueous solution containing chloride ions the external ions disseminate through the membrane until an equilibrium position is reached between the external and internal concentrations. Thus a charge is build up at the membrane which is proportional to the number of chloride ions in the external solution. At equilibrium position there is a little current flow in the solution. So, the potential difference developed at the electrode is measured with the help of a stable reference system which should be inert to the solution. A high impedance millivolt meter or digital measuring system should be used to measure the potential difference accurately.

The potential developed across the ion selective membrane is directly proportional to the ion activity revealed by the Nemst equation and the slope of the electrode can be calculated by plotting a graph between the standard solutions of concentrations C1 and C2 versus potential developed in mV of the standard solutions which is shown in Figure 5.3.

In the present study the chloride ion sensitive electrode supplied by the pH products company, Hyderabad is used. It possesses the following specifications.

- Measuring range: $10^{-1} \text{M} \text{ to } 10^{-4} \text{M} (3550 - 3.55 \text{ ppm})$
- pH Range: 2.5 - 9 pH
- Operating temperature range: 0 - 80 °C
- Slope range: -54 to -60 mV
Figure 5.2 Chloride Ion Selective Electrode
Chloride Ion Selective Membrane
->
Internal Filling Solution
Polymer body
Plastic Holder
To BNC Connector
Figure 5.3 Output Characteristics of Chloride Ion Selective Electrode

Average Slope: -58 mV/decade

Concentration of Standard Solutions (pCl⁻) (M/L) vs. E (mV)
REFERENCE ELECTRODE

A stable reference voltage should be included in the circuit which acts as half-cell in the electrochemical cell to measure the change in potential difference across the chloride ion selective membrane as the ionic concentration changes. A stable reference voltage should be included in the circuit which acts as half-cell in the electrochemical cell. In the present system a silver / silver chloride electrode is used as reference electrode\textsuperscript{6,7} which is shown in the Figure 5.4.

The other functional units of the present system are described in chapter 2. The schematic diagram of computer based system for measurement of chloride ion is shown in Figure 5.5.
Figure 5.4 Double Junction Silver/Silver Chloride Reference Electrode
Figure 5.5 Schematic Diagram of Computer based System for Measurement of Chloride Ion
Section 5.2
SOFTWARE DEVELOPMENT

The main role of the software in the present study is to govern the following activities.
1. To make the data acquisition system to convert the analog signal of the chloride ion sensitive electrode, temperature sensor output into corresponding digital information for data processing to personal computer.
2. To measure the temperature of any solution at an accuracy of ± 0.5°C.
3. To calibrate the chloride ion sensitive electrode using standard solutions by means of software to find the slope of the chloride ion sensitive electrode and to store the slope value.
4. To make the different functional units of system work in a systematic and sequential manner.
5. To compute, display and storage of chloride ion concentration and temperature values.
6. To indicate the hardware defects if any.

The necessary software in the present study is developed in C language to implement these tasks for effective functioning of the system.

SOFTWARE ROUTINES

The software program developed in the present study is divided into five parts using functions. Each routine is described below.

Hardware Testing
A sub program is developed in the present study to test the hardware of the system. This program is used to check the DIOT card and analog to digital converter of the system which is described in chapter 2.
Chloride ion measurement routine

1. Initialize the I/O card
2. Select the temperature channel by sending 00H data to Port C of 8255 (Use PC0, PC1&PC2).
3. Read the temperature signal from LM335 through ADC and store the value.
4. Select the chloride signal channel by sending 01H data to Port C of 8255 (Use PC0, PC1&PC2)
5. Read the chloride signal from the chloride ion sensitive electrode through ADC and store the value.
6. Compute the temperature and chloride values of the solution in terms of °C and M/ppm units respectively.
7. Store and display the temperature and chloride ion concentration of the solution
8. Repeat the steps from 2 to 8. The flow chart diagram for chloride ion measurement is shown in Figure 5.6.

Temperature measurement routine

The measurement of temperature for compensation of temperature error in the electrochemical cell is discussed earlier in chapter 2 at software routines section.

Calibration of the system routine

1. Prepare four concentrations of standard solutions (KCl) of 0.1M, 0.01M, 0.001M & 0.0001M concentrations.
2. Dip the electrodes in 0.0001M standard KCl solution and read the corresponding voltage developed in the cell.
3. Dip the electrodes in 0.001M standard KCl solution and read the corresponding voltage developed in the cell and calculate the slope of the electrode for the first two solutions.
4. Dip the electrodes in 0.01M standard KCl solution and read the corresponding voltage developed in the cell and calculate the slope of the electrode for the second and third solutions.
Figure 5.6 Flow Chart Diagram for Chloride Ion Measurement
5. Finally dip the electrodes in 0.1M standard KCl solution and read the corresponding voltage developed in the cell and calculate the slope of the electrode for the third and fourth solutions.

6. Compute and store the average slope of the electrode

The flowchart for the calibration of the system is shown in Figure 5.7.

**Quit routine**

Press key No. 5 on the keyboard to quit from the program. The overall flow chart of the system is presented in Figure 5.8.

The detailed software program of the present system developed in C language is as follows.
Figure 5.7 Flow Chart Diagram for Calibration of the System
Figure 5.8 Overall Flow Chart Diagram for Chloride Ion Measuring System
#include<stdio.h>
#include<conio.h>
#include<dos.h>
#include<math.h>
#include<stdlib.h>
#include<graphics.h>
#define cl 0.1
#define c2 0.01
#define c3 0.001
#define c4 0.0001

float adc_value,t;
int pa = Oxdfa0, pb = Oxdfal, pc = 0xdfa2, cr = 0xdfa3, cw = 0x92;
float c1_vol,slope,cone;
FILE *slp,*res;

// MAIN PROGRAM//

void main() 
{
    int opt;
    outportb(cr,cw);
    clrscr();

    again: opt=menu( );
    if(opt==1)
    {
        system("hardtest.exe");
        goto again;
    }
    else if(opt==2)
    {
        chlor( );
        goto again;
    }
    else if(opt==3)
    {
        temperature( );
        goto again;
    }
}
else if(opt==4)
{
    calibrate( );
    goto again;
}
else if(opt==5)
{
    quit();
}
else
{
    goto again;
}
}

// SUB ROUTINES //
// MENU SUBROUTINE //

int menu( )
{
    int opt;
    clrscr( );
    gotoxy(20,3);
    printf("COMPUTER BASED CHLORIDE ION MEASUREMENT");
    gotoxy(23,6);
    printf("1. ANALOG TO DIGITAL CONVERTER TEST");
    gotoxy(23,7);
    printf("2. CHLORIDE ION MEASUREMENT");
    gotoxy(23,8);
    printf("3. TEMPERATURE MEASUREMENT");
    gotoxy(23,9);
    printf("4. CALIBRATION OF THE SYSTEM");
    gotoxy(23,10);
    printf("5. QUIT");
    gotoxy(23,15);
    printf("SELECT YOUR CHOICE? = ");
    scanf("%d",&opt);
    return(opt);
}

// CHLORIDE ION MEASUREMENT ROUTINE

chlor( )
{
    float samp_vol,delta;
    float ppm;
    double frac,anlog;
    clear: clrscr( );
    gotoxy(31,3);
    printf("CHLORIDE ION MEASUREMENT");

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gotoxy(20,4);
printf("PLACE THE ELECTRODES IN THE SAMPLE SOLUTION");
do
{
    temp();
    outportb(pc,0x00); //Chloride channel
    delay(500);
    adc(); // Cx = C2 * antilog(Δ/S)
    adc();
    samp_vol = adc_value * 1000.0; // Δ = delta = Ex - high E
    slp = fopen("chld7135.dat","r");
    fscanf(slp,"%f %f",&slope,&c1_vol);
    delta = samp_vol - c1_vol;
    fclose(slp);
    frac = delta/slope;
    anlog = pow(10,frac);
    conc = (c1 * anlog) - (0.0002 * t);
    ppm = conc * 35500;
    if (conc > 1)
        goto clear;
    res = fopen("chldres.dat","w");
    fprintf(res,"Clconc : %fClppm : %f",conc,ppm);
    fclose(res);
    gotoxy(20,7);
    printf("The Chloride ion Conc. : %.5f",conc);
    gotoxy(20,8);
    printf("The Chloride ion Conc. in ppm : %.2f",ppm);
    gotoxy(20,9);
    printf("Temperature in Degree Celcius : %.2f",t);
    gotoxy(20,10);
    printf("The Slope of the Electrode : %.2f",slope);
    gotoxy(20,13);
    printf("Press any key to stop");
}
while(!kbhit ());
getch ();
return;
}

// TEMPERATURE MEASUREMENT SUBROUTINE

temperature()
{
    clrscr( );
do
    {
        gotoxy(23,5);
        printf("TEMPERATURE MEASUREMENT");
        temperature();
    }
}
temp();
gotoxy(20,8);
printf("Temperature in Degree Celcius : %3.2f",t);
gotoxy(20,10);
printf("Press any key to stop");
}
while(!kbhit());
getch();
return;

// CALIBRATION OF THE SYSTEM

calibrate()
{
float c2_vol,c3_vol,c4_vol;
float s1,s2,s3,dif_1,dif_2,dif_3;
cirscr();
do
{

gotoxy(27,5);
printf("CALIBRATION OF THE SYSTEM ");
gotoxy(14,6);
printf("FOR CALIBRATION PREPARE 4 STANDARDS OF KCI SOLUTIONS");
gotoxy(18,7);
printf("OF CONCENTRATIONS 0.1M,0.01M,0.001 & 0.0001M ");
gotoxy(12,8);
printf("DIP THE ELECTRODES IN 0.0001M CONCENTRATION KCI SOLUTION");
}
while(!kbhit());
getch();
cirscr();
do
{

gotoxy(20,6);
printf("DIP THE ELECTRODES IN 0.0001M CONCENTRATION KCI SOLUTION");
temp();
outportb(pc,0x00);  //Chloride channel
delay(500);
adc();
adc();
c4_vol = adc_value * 1000.0;
gotoxy(20,12);
printf("The voltage developed in 0.0001 M KCl SOLN : %3.2f",c4_vol);
gotoxy(20,13);
printf("Temperature in Degree Celcius : %3.2f",t);
gotoxy(20,15);
printf("Press any key to continue...");
}
while(!kbhit( ));
getch( );
clrscr( );
do {

gotoxy(20,4);
printf("DIP THE ELECTRODES IN 0.001 M CONCENTRATION KCl SOLUTION");
gotoxy(20,14);
printf("Press any key to continue...");
}
while(!kbhit( ));
getch( );
clrscr( );
do {

temp( );
outportb(pc,0x00);       //Chloride channel
delay(500);
adc( );
adc( );
c3_vol = adc_value * 1000.0;
dif_l = c4_vol - c3_vol;
s1 = dif_l/(log10(c4) - log10(c3));
gotoxy(20,3);
printf("DIP THE ELECTRODES IN 0.001 M CONCENTRATION KCl SOLUTION");
gotoxy(20,7);
printf("Voltage developed in 0.001 M KCI SOLN : %3.2f",c3_vol);
gotoxy(20,8);
printf("Temperature in Degree Celcius : %3.2f",t);
gotoxy(20,9);
printf("SLOPE OF THE ELECTRODE : %2.2f",s1);
gotoxy(20,13);
printf("Press any key to continue...");
}
while(!kbhit( ));
getch( );
clrscr( );
do {

gotoxy(20,4);
printf("DIP THE ELECTRODES IN 0.01 M CONCENTRATION KCl SOLUTION");
gotoxy(20,14);
printf("Press any key to continue...");
while(!kbhit( ));
getch( );
crscr( );
do
{
    temp( );
    outportb(pc,0x00);       //Chloride channel
delay(500);
    adc( );
    adc( );
c2_vol = adc_value * 1000.0;
dif_2 = c3_vol - c2_vol;
s2 = dif_2/(log10(c3) - log10(c2));
gotoxy(20,3);
    printf("DIP THE ELECTRODES IN 0.01M CONCENTRATION KCl SOLUTION");
gotoxy(20,7);
    printf("VoItage developed in 0.01 MKCl SOLUTION : %3.2f",c2_vol);
gotoxy(20,9);
    printf("Temperature in Degree Celcius : %3.2f",t);
gotoxy(20,13);
    printf("SLOPE OF THE ELECTRODE : %2.2f",s2);
}
}
while(!kbhit( ));
getch( );
crscr( );
do
{
    gotoxy(20,4);
    printf("DIP THE ELECTRODES IN 0.1M CONCENTRATION KCl SOLUTION");
gotoxy(20,14);
    printf("Press any key to continue...");
}
while(!kbhit( ));
getch( );
crscr( );
do
{
    temp( );
    outportb(pc,0x00);       //Chloride channel
delay(500);
    adc( );
    adc( );
c1_vol = adc_value * 1000.0;
dif_3 = c2_vol - c1_vol;
\[ s_3 = \frac{\text{d}_{f3}}{\log_{10}(c_2) - \log_{10}(c_1)}; \]
\[ \text{slope} = \frac{(s_1 + s_2 + s_3)/3.0 - (0.0002 \times t)}{3}; \]
\[ \text{gotoxy}(20,3); \]
\[ \text{printf}(\text{"DIP THE ELECTRODES IN 0.1M CONCENTRATION KCl SOLUTION"}); \]
\[ \text{gotoxy}(20,7); \]
\[ \text{printf}(\text{"Voltage developed in 0.1 M KCl SOLN : %3.2f', c1_vol}); \]
\[ \text{gotoxy}(20,8); \]
\[ \text{printf}(\text{"Temperature in Degree Celcius : %3.2f', t}); \]
\[ \text{gotoxy}(20,9); \]
\[ \text{printf}(\text{"Slope of the Electrode : %2.2f', s3}); \]
\[ \text{gotoxy}(20,10); \]
\[ \text{printf}(\text{"AVERAGE SLOPE OF THE ELECTRODE : %2.2f', slope}); \]
\[ \text{gotoxy}(20,15); \]
\[ \text{printf}(\text{"Press any key to continue..."}); \]
\[ \text{slp} = \text{fopen}(\text{"chld7135.dat"}, \text{"w");} \]
\[ \text{fprintf}(\text{slp}, \text{"%f %f', slope, c1_vol}); \]
\[ \text{fclose}(\text{slp}); \]
\[ \text{while}(!	ext{kbhit}()); \]
\[ \text{getch}(); \]
\[ \text{return}(\text{slope}); \]

// QUIT ROUTINE
quit() {
    \text{return};
}

// temp function
temp() {
    \text{outportb}(\text{pc}, 0x01); \quad \text{//temperature channel}
    \text{delay}(500);
    \text{adc( );}
    \text{adc( );}
    \text{t} = ((\text{adc_value} \times 100); \quad \text{return}(t); \]

// adc function
adc( ) function program is presented in chapter 3 at software development section

*****
Section 5.3
CALIBRATION AND MEASUREMENT PROCEDURES

The individual blocks of the computer based system for measurement of chloride ion are designed and constructed. The necessary software is developed in C language. These details are already discussed in earlier chapters.

Before using the system, the electrodes must be calibrated by measuring a series of known standard solutions, made by serial dilution of the 0.1M KCl standard solution. In the present study, the system is calibrated at four concentrations of standard KCl solutions - 0.1M, 0.01M, 0.001M and 0.0001M.

Preparation of the standard solutions:
To prepare the standard solutions, primarily, make a stock solution of 0.1M KCl which is prepared by dissolving 584.4 milli grams of chloride chloride salt in 100 ml of distilled water.

To prepare 0.01M KCl solution take 10 ml of 0.1M KCl solution and dilute it to 100 ml with distilled water. For 0.001M KCl solution take 10 ml of 0.01M KCl solution and dilute it to 100 ml with distilled water. Similarly for 0.0001M KCl solution take 10 ml of 0.001M KCl solution and dilute it to 100 ml with distilled water. 2 ml of 2.5 Molar KCl buffer solution (ISAB) should be added to each 100 ml standard and mix thoroughly to compensate for different activity coefficients between samples and standards. The standard solutions are prepared in the laboratory in accordance with the accepted principles of analytical chemistry\textsuperscript{10,11}.

After preparing the standard solutions, run the software program of the system for calibration. When the execution of the program starts, a user menu is displayed on the CRT screen of the computer as shown below.
Main Menu

1. Hardware Testing
2. Chloride Measurement
3. Temperature Measurement
4. Calibration of the system
5. Quit

Select the option ‘4’ for calibration of the system by pressing key number 4 on the keyboard and press ‘Enter key’. Now the system is ready to calibrate the system. The calibration menu itself guides the user to calibrate the system which is shown below (which appears on the monitor of the PC).

CALIBRATION OF THE SYSTEM

FOR CALIBRATION PREPARE 4 STANDARDS OF KCl SOLUTIONS OF CONCENTRATIONS 0.1M, 0.01M, 0.001M & 0.0001M

(Rinse the electrodes with distilled water thoroughly and blot dry with tissue paper before dipping the electrodes in the solutions every time)

**DIP THE ELECTRODES IN 0.0001M KCl STANDARD SOLUTION**
After a stable reading press any key on the keyboard to continue to next step.

**DIP THE ELECTRODES IN 0.001M KCl STANDARD SOLUTION**
After stable reading we can see the slope of the electrode in milli volts/decade for the first and second standard solutions. Press any key on the keyboard to continue to next step.

**DIP THE ELECTRODES IN 0.01M KCl STANDARD SOLUTION**
After stable reading we can see the slope of the electrode in milli volts/decade for the second and third standard solutions. Press any key on the keyboard to continue to next step.
DIP THE ELECTRODES IN 0.1M KCL STANDARD SOLUTION

The average slope of the chloride ion sensitive electrode is computed and displayed on the screen. And it automatically switches to main menu after pressing the enter key on the keyboard.

Now the calibration of the system is completed and the system is ready to measure the chloride ion concentration of the sample. The slope of the electrode tells the sensitivity and linearity of the chloride ion sensitive electrode.

After making the appropriate adjustments both in the hardware and software and also following the calibration procedure as mentioned earlier, the instrument is tested with the standard solutions of chloride. The outputs of the chloride ion measuring system are presented in Figure 5.9 to Figure 5.13. The results of measurements are presented in Table 5.1. The measurements made are compared with an Ion Analyzer of Elico Make (Model No. L1126) and the results are presented in the same table. The results of the present study are in good agreement with those obtained from the Ion analyzer. The system is reasonably good in the measurement of chloride ion. The results of some more samples are presented in chapter 9.
### TABLE 5.1

**CHLORIDE ION MEASUREMENT IN STANDARD SOLUTIONS**

<table>
<thead>
<tr>
<th>Standard values</th>
<th>Present study</th>
<th>Ion Analyzer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molarity (M)</td>
<td>ppm</td>
<td>M/ppm</td>
</tr>
<tr>
<td>0.1M (KCl)</td>
<td>3550.00</td>
<td>0.10000/3550.00</td>
</tr>
<tr>
<td>0.01M (KCl)</td>
<td>355.00</td>
<td>0.01010/356.44</td>
</tr>
<tr>
<td>0.001M (KCl)</td>
<td>35.50</td>
<td>0.00102/36.42</td>
</tr>
<tr>
<td>0.0001M (KCl)</td>
<td>3.5</td>
<td>0.00010/3.56</td>
</tr>
</tbody>
</table>
COMPUTER BASED CHLORIDE ION MEASUREMENT

1. HARDWARE TESTING
2. CHLORIDE ION MEASUREMENT
3. TEMPERATURE MEASUREMENT
4. CALIBRATION OF THE SYSTEM
5. QUIT

SELECT YOUR CHOICE? : 1

Figure 5.9 : Main menu of Chloride Ion measurement system
HARDWARE TESTING

1. TESTING OF DIGITAL INPUT OUTPUT CARD
2. TESTING OF DATA ACQUISITION SYSTEM
3. QUIT

SELECT YOUR CHOICE? : 1

Figure 5.10: Main menu of hardware testing of the system

TESTING OF DIGITAL INPUT OUTPUT CARD

Connect the test module to the I/O card connector

Press any key when ready

Observe the test module for ON and OFF of the LED's

Press any key to stop

Figure 5.10a: Digital Input Output Timer card testing
TESTING OF DATA ACQUISITION SYSTEM

Apply Known DC voltage (+/-1.5V) to channel 0 or 1

Enter the channel No. : 1

The Voltage in V : 0.925

Press any key to stop

Figure 5.10b : Data acquisition system testing

CHLORIDE ION MEASUREMENT
PLACE THE ELECTRODES IN THE SAMPLE SOLUTION

The Chloride ion Conc. in M : 0.00102
The Chloride ion Conc.in ppm : 36.42
Temperature in degree celsius : 29.51
The Slope of the Electrode : 58.00 mV/decade

Press any key to stop

Figure 5.11 : Chloride ion measurement
TEMPERATURE MEASUREMENT

Temperature in degree celcius : 29.52

Press any key to stop

Figure 5.12 : Temperature measurement

CALIBRATION OF THE SYSTEM

FOR CALIBRATION PREPARE 4 STANDARDS OF KCl SOLUTIONS OF CONCENTRATIONS 0.1M, 0.01M, 0.001 & 0.0001M

DIP THE ELECTRODES IN 0.0001M CONCENTRATION KCl SOLUTION

Press any key to continue...

Figure 5.13 : Calibration of Chloride ion Measuring System
DIP THE ELECTRODES IN 0.0001M CONCENTRATION KCl SOLUTION

The voltage developed in 0.0001 M KCl SOLN : 260.50 mV
Temperature in degree celcius : 29.51

Press any key to continue...

Figure 5.13a : Voltage developed in 0.0001M KCl Solution

DIP THE ELECTRODES IN 0.001M CONCENTRATION KCl SOLUTION

The voltage developed in 0.001 M KCl SOLN : 201.50 mV
Temperature in degree celcius : 29.50
SLOPE OF THE ELECTRODE : 59 mV

Press any key to continue...

Figure 5.13b : Voltage developed in 0.001M KCl Solution
**DIP THE ELECTRODES IN 0.01M CONCENTRATION KCl SOLUTION**

The voltage developed in 0.01 M KCl SOLN: 144.50 mV
Temperature in degree celsius: 29.51
SLOPE OF THE ELECTRODE: 59.00 mV

Press any key to continue...

*Figure 5.13c: Voltage developed in 0.01M KCl Solution*

**DIP THE ELECTRODES IN 0.1M CONCENTRATION KCl SOLUTION**

The voltage developed in 0.1 M KCl SOLN: 86.50 mV
Temperature in degree celsius: 29.52
SLOPE OF THE ELECTRODE: 58.00 mV
AVERAGE SLOPE OF THE ELECTRODE: 58.00 mV

Press any key to continue...

*Figure 5.13d: Voltage developed in 0.1M KCl Solution*
REFERENCES


