CHAPTER 4

Fluoride Ion : Design and Development of Computer based Measurement System
Section 4.1

HARDWARE DEVELOPMENT

In recent years direct potentiometry has become important as an analytical technique largely because of the development of ion-selective electrodes (ISE)\(^1\). This type of electrode incorporates a special ion-sensitive membrane which may be glass, a crystalline inorganic material or an organic ion-exchanger. The membrane interacts specifically with the ion of choice, in our case fluoride, allowing the electrical potential of the half cell to be controlled predominantly by the F\(^-\) concentration. A computer based system for measurement of fluoride ion is designed and constructed in the present study. It works on the principle of an electrochemical cell, in which fluoride ion sensitive electrode\(^2\) and a silver/silver chloride electrode is used as the working and reference electrodes. The potential developed in the solution is directly proportional to the concentration of the fluoride ion in the electrolyte. 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 fluoride ion sensitive electrode is temperature dependent of the solution 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 fluoride 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 4.1. The system consists the following functional units.

1. Fluoride Ion Sensitive Electrode
2. Reference Electrode
3. Signal conditioner
4. Temperature sensing unit
5. Data acquisition system
6. Analog multiplexer
7. I/O card
Figure 4.1 Block diagram of computer based system for Measurement of Fluoride ion
8. Personal computer
9. Power supply unit

**FLUORIDE ION SENSITIVE ELECTRODE**

Any conductive crystalline material in which anions, rather than cations, (10 ref) account for current flow across the ion selective membrane can be used as the basis for a solid-state fluoride ion selective electrode\(^3\). It consists of crystalline lanthanide fluoride (LaF\(_3\)) doped with a rare earth, europium(II) (EuF\(_2\)) and cemented to a plastic tube containing an internal solution of 0.1M NaCl and 0.1M NaF. The Eu impurity sites result in fluoride holes which result in the conductivity of the crystal. In the present study a fluoride ion sensitive electrode is used as working electrode. The construction of the electrode is shown in Figure 4.2.

When the electrode is immersed in a solution which contains fluoride ions, the external ions diffuse through the membrane until equilibrium is reached between the external and internal concentrations. Thus, a potential difference is developed inside the membrane; the magnitude of the potential depends on the ratio of the fluoride ion activities between the sample and the internal solution. The potential of the electrode is measured against a saturated silver/silver chloride reference electrode with a high impedance millivolt meter or digital measuring system which measures the potential difference accurately.

The potential developed across the ion selective membrane is directly proportional to the ion activity revealed by the Nernst equation \(^4,5\) discussed earlier and the slope of the electrode can be calculated by plotting a graph between the standard solutions of concentrations \(C_1\) and \(C_2\) versus potential developed in mV of the standard solutions which is shown in Figure 4.3.

In the present study the fluoride ion sensitive electrode supplied by the pH products company, Hyderabad is used. It possesses the following specifications\(^6\).

Measuring range : \(10^{-1}\)M to \(10^{-5}\) M (1900 - 0.19 ppm)
Figure 4.2 Fluoride Ion Selective Electrode

Lanthanum trifluoride Crystal (LaF$_3$)
Membrane
Polymer body
Plastic Holder
To BNC Connector
Solid Connection

Lanthanum trifluoride Crystal (LaF$_3$) Membrane
Figure 4.3 Output Characteristics of Fluoride Ion Selective Electrode

Average Slope: -58.75 mV/decade
pH Range : 5 – 8 pH
Operating temperature range : 0 – 50 °C
Slope range : −54 to −60 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 fluoride 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 \(^7,8\) which is shown in the Figure 4.4.

The other functional blocks of the fluoride ion measuring system are discussed in chapter 2. The schematic diagram of computer based system for measurement of fluoride ion is shown in Figure 4.5.
Figure 4.4 Silver/Silver Chloride Reference Electrode
Figure 4.5 Schematic Diagram of Computer based System for Measurement of Fluoride Ion
Section 4.2
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 fluoride ion sensitive electrode, temperature sensor output into corresponding digital information for data processing to personal computer.
2. To measure the temperature of any solution with an accuracy of ± 0.5°C.
3. To calibrate the fluoride ion sensitive electrode using standard solutions by means of software to find the slope of the fluoride 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 fluoride 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
In the present study, a sub program is developed to test the hardware of the system. This program is used to test the DIOT card and analog to digital converter of the system. The software program is discussed earlier in chapter 2 at software routines.

Fluoride 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 fluoride signal channel by sending 01H data to Port C of 8255 (Use PC0, PC1&PC2)
5. Read the fluoride signal from the fluoride ion sensitive electrode through ADC and store the value.
6. Compute the temperature and fluoride values of the solution in terms of °C and M/ppm units respectively.
7. Store and display the temperature and fluoride ion concentration of the solution
8. Repeat the steps from 2 to 8. The flow chart diagram for fluoride ion measurement is shown in Figure 4.6.

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 (NaF) of 0.1M, 0.01M, 0.001M & 0.0001M concentrations
2. Dip the electrodes in 0.0001M standard NaF solution and read the corresponding voltage developed in the cell.
3. Dip the electrodes in 0.001M standard NaF 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 NaF solution and read the corresponding voltage developed in the cell and calculate the slope of the electrode for the second and third solutions.
5. Finally dip the electrodes in 0.1M standard NaF 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 4.7.
Figure 4.6 Flow Chart Diagram for Fluoride Ion Measurement

1. Start
2. Select Temperature Channel
3. Read ADC output corresponding to the existing temperature
4. Compute and store the Temperature value
5. Store and display the Temperature value
6. Select fluoride channel
7. Read ADC output corresponding to the fluoride ion concentration
8. Compute and store the fluoride ion concentration
Figure 4.7 Flow Chart Diagram for Calibration of the System

1. Start
2. Dip the Electrodes in standard NaF solution of 0.0001M concentration
3. Read ADC output corresponding to the sodium ions and store its value
4. Dip the Electrodes in standard NaF solution of 0.001M concentration
5. Read ADC output corresponding to the sodium ions. Compute and store slope value for 1st and 2nd solutions
6. Dip the Electrodes in standard NaF solution of 0.01M concentration
7. Read ADC output corresponding to the sodium ions. Compute and store slope value for 2nd and 3rd solutions
8. Dip the Electrodes in standard NaF solution of 0.1M concentration
9. Read ADC output corresponding to the sodium ions. Compute and store slope value for 3rd and 4th solutions
10. Compute and store the average value of slope
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 4.8.

The detailed software program of the present system developed in C language is as follows.
Figure 4.8 Overall Flow Chart Diagram for Fluoride Ion Measuring System

1. Hardware Testing
2. Fluoride Measurement
3. Temperature Measurement
4. Calibration
5. Quit

START

1. Hardware Testing
   - Tests the DIO T card and ADC Module

2. Fluoride Measurement
   - Measures the fluoride ion concentration and the temperature, stores the values

3. Temperature Measurement
   - Reads temperature from LM35 sensor through ADC and displays the temperature in °C

4. Calibration
   - Calibrates the system by using a known standard solution and stores the slope of the electrode

5. Quit
   - Comes out of the program execution

STOP

Return to Main Menu
PROGRAM IN DETAIL

/* Software Program for Computer Based System for Measurement of Fluoride Ion */

#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 = 0xdfa0, pb = 0xdfa1, pc = 0xdfa2, cr = 0xdfa3, cw = 0x92;
float c1_vol,slope,con;
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)
    {
        flod();
        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 SUBROTINE

int menu( )
{
    int opt;
    clrscr( );
gotoxy(20,3);
printf("COMPUTER BASED FLUORIDE ION MEASUREMENT");
gotoxy(23,6);
printf("1. ANOLOG TO DIGITAL CONVERTER TEST");
gotoxy(23,7);
printf("2. FLUORIDE 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);
}

// FLUORIDE ION MEASUREMENT ROUTINE

flod( )
{
    float samp_vol,delta;
    float ppm;
    double frac_analog;
    clrscr( );
gotoxy(31,3);
printf("FLUORIDE ION MEASUREMENT");

gotoxy(20,4);
printf("PLACE THE ELECTRODES IN THE SAMPLE SOLUTION");
do
{

temp();
outportb(pc,0x00); // Fluoride channel
delay(500);
adc(); // Cx = C2 * antilog(Δ/S)
adc();
samp_vol = adc_value * 1000.0; // Δ = delta = Ex - high E
slp = fopen("flod7135.dat","r");
ftscanf(slp,"%f %f",&slope,&c1_vol);
delta = samp_vol - c1_vol;
close(slp);
frac = delta/slope;
anlog = pow(10,frac);
conc = c1 * anlog;
ppm = conc * 19000;
if (conc > 1)
goto clear;
res = fopen("flodres.dat","w");
fprintf(res,"flconc : %ffppm : %f",conc,ppm);
close(res);
gotoxy(20,7);
printf("The Fluoride ion Conc. : %.7f",conc);
gotoxy(20,8);
printf("The Fluoride 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");
}
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_voI,c4_vol;
    float s1,s2,s3,dif_1,dif_2,dif_3;
    clrscr();
do
{
    gotoxy(27,5);
    printf("CALIBRATION OF THE SYSTEM ");
    gotoxy(14,6);
    printf("FOR CALIBRATION PREPARE 4 STANDARDS OF NaF 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 NaF SOLUTION");
}
while(!kbhit());
getch();
clrscr();
do
{
    gotoxy(20,6);
    printf("DIP THE ELECTRODES IN 0.0001M CONCENTRATION NaF SOLUTION");
    temp();
    outportb(pc,0x00);       //Fluoride channel
delay(500);
    adc();
    adc();
c4_vol = adc_value * 1000.0;
gotoxy(20,12);
    printf("The voltage developed in 0.0001 M NaF 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 0.001M CONCENTRATION NaF SOLUTION");
gotoxy(20,14);
printf("Press any key to continue...");
}
while(!kbhit( ));
getch( );
clrscr( );
do
{

temp( );
outportb(pc,0x00); //Fluoride channel
delay(500);
adc( );
adc( );
c3_vol = adc_value * 1000.0;
dif_1 = c4_vol - c3_vol;
s1 = dif_1/(log10(c4) - log10(c3));
gotoxy(20,3);
printf("DIP THE ELECTRODES IN 0.001M CONCENTRATION NaF SOLUTION");
gotoxy(20,7);
printf("Voltage developed in 0.001 M NaF 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 0.01M CONCENTRATION NaF SOLUTION");
gotoxy(20,14);
printf("Press any key to continue...");
}
Chapter 4

while(!kbhit( ));
getch();
c1rsr( );
do{
    temp( );
    outportb(pc,0x00);   //Fluoride 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 NaF SOLUTION");
gotoxy(20,7);
printf("Voltage developed in 0.01 M NaF SOLN : %3.2f",c2_vol);
gotoxy(20,8);
printf("Temperature in degree celcius : %3.2f",t);
gotoxy(20,9);
printf("SLOPE OF THE ELECTRODE : %2.2f",s2);
gotoxy(20,13);
printf("Press any key to continue...");
}
while(!kbhit( ));
getch();
c1rsr( );
do{
    gotoxy(20,4);
    printf("DIP THE ELECTRODES IN 0.1M CONCENTRATION NaF SOLUTION");
gotoxy(20,14);
    printf("Press any key to continue...");
}
while(!kbhit( ));
getch();
c1rsr( );
do{
    temp( );
    outportb(pc,0x00);   //Fluoride channel
delay(500);
    adc( );
    adc( );
c1_vol = adc_value * 1000.0;
dif_3 = c2_vol - c1_vol;
s3 = dif_3/(log10(c2) - log10(c1));
slope = (s1+s2+s3)/3.0;
gotoxy(20,3);
printf("DIP THE ELECTRODES IN 0.1M CONCENTRATION NaF SOLUTION");
gotoxy(20,7);
printf("Voltage developed in 0.1 M NaF SOLN : %3.2f",c1_vol);
gotoxy(20,8);
printf("Temperature in degree celcius : %3.2f",t);
gotoxy(20,9);
printf("Slope of the Electrode : %2.2f",s3);
gotoxy(20,10);
printf("AVERAGE SLOPE OF THE ELECTRODE : %2.2f",slope);
gotoxy(20,15);
printf("Press any key to continue...");
slp = fopen("flod7135.dat","w");
fprintf(slp,"%f %f",slope,c1_vol);
fclose(slp);
}
while(!kbhit( ));
getch( );
return(slope);
}

// QUIT ROUTINE
quit( )
{
  return;
}

// temp function
temp( )
{
  outportb(pc,0x01); //temperature channel
delay(500);
adc( );
adc( );
t = ((adc_value) * 100);
return(t);
}

// adc function
adc( ) function program is presented in chapter 3

*****
Section 4.3

CALIBRATION AND MEASUREMENT PROCEDURES

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

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 NaF standard solution. In the present study, the system is calibrated at four concentrations of standard NaF 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 NaF which is prepared by dissolving 584.4 milli grams of fluoride chloride salt in 100 ml of distilled water.

To prepare 0.01M NaF solution take 10 ml of 0.1M NaF solution and dilute it to 100 ml with distilled water. For 0.001M NaF solution take 10 ml of 0.01M NaF solution and dilute it to 100 ml with distilled water. Similarly for 0.0001M NaF solution take 10 ml of 0.001M NaF solution and dilute it to 100 ml with distilled water. 2 ml of 2.5 Molar NaF 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.

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. Fluoride 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 NaF 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 CONCENTRATION CL SOLUTION
After a stable reading press any key on the keyboard to continue to next step.

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

DIP THE ELECTRODES IN 0.01M NAF 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 NAF STANDARD SOLUTION

The average slope of the fluoride 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.

After calibration, the system is ready to measure the fluoride ion concentration of the sample. The slope of the electrode tells the sensitivity and linearity of the fluoride 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 fluoride. The outputs of the fluoride ion measuring system are presented in Figure 4.9 to Figure 4.13. The results of measurements are presented in Table 4.1. The measurements made are compared with an Ion Analyzer of Elico Make (Model No. LI126) 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 quite successful in the measurement of fluoride ion. The results of some other samples are presented in chapter 9.


### TABLE 4.1

**FLUORIDE ION MEASUREMENT IN STANDARD SOLUTIONS**

<table>
<thead>
<tr>
<th>Molarity (M)</th>
<th>ppm</th>
<th>Present study</th>
<th>Ion Analyzer</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1M (NaF)</td>
<td>1900.00</td>
<td>0.1000000/1900.00</td>
<td>1902.03</td>
</tr>
<tr>
<td>0.01M (NaF)</td>
<td>190.00</td>
<td>0.0100020/190.05</td>
<td>189.01</td>
</tr>
<tr>
<td>0.001M (NaF)</td>
<td>19.00</td>
<td>0.0009910/18.83</td>
<td>19.23</td>
</tr>
<tr>
<td>0.0001M (NaF)</td>
<td>1.90</td>
<td>0.0001010/1.92</td>
<td>1.99</td>
</tr>
<tr>
<td>0.00001M(NaF)</td>
<td>0.19</td>
<td>0.0000100/0.19</td>
<td>0.25</td>
</tr>
</tbody>
</table>
Computer Based Fluoride Ion Measurement

1. Hardware Testing
2. Fluoride Ion Measurement
3. Temperature Measurement
4. Calibration of the System
5. Quit

Select your choice? : 1

Figure 4.9: Main menu of Fluoride 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 4.10 : 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 4.10a : 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 : 0.124

Press any key to stop

Figure 4.10b : Data acquisition system testing

FLUORIDE ION MEASUREMENT
PLACE THE ELECTRODES IN THE SAMPLE SOLUTION

The Fluoride ion Conc. in M : 0.0001010
The Fluoride ion Conc. in ppm : 1.92
Temperature in degree celcius : 29.01
The Slope of the Electrode : 59.00 mV/decade

Press any key to stop

Figure 4.11 : Fluoride ion measurement
TEMPERATURE MEASUREMENT

Temperature in degree celcius : 30.21

Press any key to stop

Figure 4.12 : Temperature measurement

CALIBRATION OF THE SYSTEM

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

DIP THE ELECTRODES IN 0.0001M CONCENTRATION NaF SOLUTION

Press any key to continue...

Figure 4.13 : Calibration of Fluoride ion Measuring System
DIP THE ELECTRODES IN 0.0001M CONCENTRATION NaF SOLUTION

The voltage developed in 0.0001 M NaF SOLN : 609.00 mV
Temperature in degree celcius : 30.21

Press any key to continue...

Figure 4.13a : Voltage developed in 0.0001M NaF Solution

DIP THE ELECTRODES IN 0.001M CONCENTRATION NaF SOLUTION

The voltage developed in 0.001 M NaF SOLN : 549.00 mV
Temperature in degree celcius : 29.99
SLOPE OF THE ELECTRODE : 60 mV

Press any key to continue...

Figure 4.13b : Voltage developed in 0.001M NaF Solution
DIP THE ELECTRODES IN 0.01M CONCENTRATION NaF SOLUTION

The voltage developed in 0.01 M NaF SOLN : 490.00 mV
Temperature in degree celcius : 30.02
SLOPE OF THE ELECTRODE : 59.00 mV

Press any key to continue...

Figure 4.13c : Voltage developed in 0.01M NaF Solution

DIP THE ELECTRODES IN 0.1M CONCENTRATION NaF SOLUTION

The voltage developed in 0.1 M NaF SOLN : 432.00 mV
Temperature in degree celcius : 29.99
SLOPE OF THE ELECTRODE : 58.00 mV
AVERAGE SLOPE OF THE ELECTRODE : 59.00 mV

Press any key to continue...

Figure 4.13d : Voltage developed in 0.1M NaF Solution
REFERENCES

7. Material on Ion-selective Electrodes prepared by Wojciech Wroblewski in the web site, with address www.ch.pv.cdo.pl/dybko/csrg/tutorials/ise/ion selective electrodes.htm