CHAPTER – 1

INTRODUCTION
Section 1.1

INTRODUCTION TO SODIUM, FLUORIDE, CHLORIDE, IODIDE AND HYDROGEN IONS

Modern measuring instruments are the fruits of science and technology. New discoveries in science provided new instruments for the study of Nature; and these studies, in turn, produced new discoveries. The precise and accurate measurement of physical and chemical parameters plays an important role in unraveling the mysteries of Nature.

The estimation of sodium, fluoride, chloride, iodide and hydrogen ion concentrations in agriculture, chemical, biomedical and environmental fields gives valuable information to agriculturists, chemists, biochemists, ecologists etc. The excess or deficiency of these elements causes severe health disorders in humans and plants. It is necessary to analyze these ions and to take necessary precautions. The measurement of concentration of these ions in aqueous solutions is very essential to warn and educate the people on its beneficial and toxic effects in the corresponding fields.

SODIUM

Sodium is an alkali metal element, found in Group Ia of the periodic table. It was first discovered by Sir Humphry Davy in 1807AD by the electrolysis of fused caustic soda\textsuperscript{1,2}. It is an abundant metallic element which is widely disseminated in nature constituting 2.75\% of known terrestrial matter\textsuperscript{3}. However, because of its high reactivity it is not found naturally in its elemental state. It is found in many rocks and minerals. It is abundant in rock salt and other saline residues, in ocean water and salt lakes, and is present in nearly all natural waters.

Sodium is a silver-white metallic element which is soft and malleable\textsuperscript{4}. It is one of the important minerals which is essential to human, animals and plant lives. In humans and animals it is needed to maintain a proper water balance of the body\textsuperscript{5}. In biological field it is the major cation found in the extra-cellular fluid\textsuperscript{6-8}. It plays a central role in the maintenance of the normal distribution of water and the osmotic pressure in the various fluid compartments. The main source of body sodium is sodium chloride contained in
ingested foods. Only about one-third of the total body's sodium is contained in the skeleton since most of it is contained in the extra-cellular body fluids.

It is an electrolyte in the body which is required to manufacture hydrochloric acid in the stomach, which protects the body from any infections that may be present in food. In humans, sodium is required for nerve impulse transmission and muscular cell contraction. It is also important for regulating plasma volume and balancing fluids in general. Sodium is also involved in acid/base balance and plays an important role in glucose transport from the intestine to the blood.

In agriculture sodium is absorbed by the plant in the Na⁺ ion form. It seems to encourage yields and in specific cases it acts as an antidoting agent against various toxic salts. It may act as a partial substitute for potassium deficiencies in maintaining cell turgidity. Excess sodium (100 ppm or more) may cause plant toxicity or induce deficiencies of other elements. There are no deficiency symptoms of sodium since sodium is abundant in alkaline soils.

Deficiency of sodium is rare, but can easily happen with diarrhea which causes "low salt syndrome," which is characterized by weakness, laziness, anorexia and vomiting, mental confusion, abdominal cramps, skeletal muscle aches. Deficiency can also cause plasma volume reduction. Sodium deficiencies can be caused by chronic wasting illness (cancer, liver disease), major surgery or trauma, excessive sweating, or ingestion of drugs that inhibit sodium absorption.

An increase in the concentrations of sodium in the bloodstream can be toxic. The normal concentration of sodium in the blood plasma is 136-145 mM, while levels over 152 mM can result in seizures and death. Increased plasma sodium, which is called hypernatremia, causes various cells of the body, including those of the brain, to shrink. Shrinkage of the brain cells results in confusion, coma, paralysis of the lung muscles, and death. Death has occurred where table salt (sodium chloride) was accidentally used, instead of sugar, for feeding infants. Death due to sodium toxicity has also resulted when baking soda (sodium bicarbonate) was used during attempted therapy of excessive
diarrhea or vomiting. Although a variety of processed foods contain high levels of sodium chloride, the levels used are not enough to result in sodium toxicity.

**FLUORIDE**

Fluorine is the first element among the members of halogen family and elementally it is in gaseous form. Its name is derived from the Latin word ‘Fleure’ meaning to flow. It was isolated by Henri Moissan in 1886 in Paris, France. Fluorine is the most chemically reactive and electronegative of all the elements that is available in nature only in the chemically combined form and hence, it got the name ‘Super Halogen’.

Fluorine is extensively distributed throughout nature. It ranks thirteen in the order of abundance of elements in the earth’s crust constituting about 0.065% . It has been detected in such diverse substances as water, rocks and minerals, fossils, teeth, foodstuffs and many biological specimens. Interests in the fluorine content of these materials arises chiefly from the toxic effects of prolonged ingestion of small amounts of fluorine (Fluorosis), together with detrimental results of sub-optimum levels in the diet. Therefore, there is a need for the determination of trace amounts of fluorine, which is applicable to a wide variety of substances.

This element is essential to both plant and animal life at low concentrations, but is toxic at higher concentrations. It is also equally important because of its widespread use of its compounds in industries like aluminum, plastic, atomic energy, electrolytic plating, insecticides, rubber, petroleum, refrigeration etc.

Fluoride is one of several trace elements in coal receiving stations owing to its possible harmful ecological effects. The potential toxicity of fluorine has been classified as “high” for terrestrial life and “low” for aquatic life. Although fluorine is present in very small amounts in coal, its high volatility and increasing world consumption may result in quantitatively significant emissions.

The effect of fluoride on both humans and animals has a dual role - as an essential element and at high levels as a toxic substance. Excess fluoride ion results in
fluorosis and renal, gastrointestinal and immunological toxicity \(^{22}\). Also, plants and fruits such as apricots, plums, grapes, tulips, iris and sweet corn are sensitive to fluoride \(^{23}\).

Hydrogen fluoride is often found in rainwater \(^{24}\) as a result of various industrial processes, such as phosphate fertilizer production, aluminium production and metal smelting. Therefore, an accurate and rapid method for the determination of fluoride in rainwater samples is important for assessment of air and water quality.

In agriculture field, plants are the receptors of fluoride from sources in their environment viz., soil, water and air. Their fluoride content may vary from place to place and from species to species. Plants grown in soils treated with lime materials and soluble phosphate free of fluorides were found to absorb less fluoride \(^{25}\). Almost every known food contains trace amounts of fluoride owing to its abundance in earth’s crust. Some food materials contain relatively high concentrations of fluoride.

In biological field, fluoride is known to have its adverse physiological effects on both the human beings and animals. It enters the body through various food items, depending on the fluoride content of water and soil that varies from location to location.

Fluoride has not only notable chemical quantities but also physiological properties of great importance for hum and stock health. Even at very low concentration the fluoride ion can inhibit or stimulated enzymatic process. Fluoride was found to affect the proper function of the thyroid \(^{26}\). On the other hand, it is found useful even in trace amounts in the normal process of mineralisation of hard tissues viz., bones. Fluoride, present in drinking water in amounts up to 1.0 ppm, is beneficial to the health of the children as it develops caries resistant dental enamel. However, apart from the beneficial effects, fluoride in drinking water above 1.0 ppm is proved to be toxic to human and animal physiology. The toxic effect of teeth involves the development of chalky white patches and pitting with chipped-off edges followed by their premature loss. Concentrations exceeding 2-3 ppm give rise to skeletal abnormalities and pain in joints. Prolonged ingestion of the ion causes increasing stiffness of the spine and kyphosis.
Besides human beings, cattle are also affected by the ingestion of fluoride ion. The presence of chemical substance such as fluoride in water in excess of permissible concentration can be toxic or injurious to health and render the water unfit for use for various domestic purposes.

**CHLORIDE**

Chlorine is one of the elements that belongs to halogen family. It was first isolated and discovered by Carl W Scheele in 1774 in Uppsala, Sweden. Its name is derived from the Greek word ‘chloros’, meaning pale green. It is yellowy-green dense gas with choking smell. It is very poisonous and was used as a weapon during the First World War.

Chlorine is widely distributed in nature and is used extensively in its various oxidation states. For example aqueous chlorine (Cl$_2$) and hypochlorite (OCl$^{-}$) are employed as bleaching agents and a disinfectants to prevent the wide spread of waterborne diseases. Because of the reactivity of the higher oxidation states of chlorine, the element occurs in nature primarily as the chloride ion (Cl$^{-}$) and is one of the major inorganic constituents of surface waters, ground waters and wastewaters. Clinical measurement of the chloride ion is essential for monitoring of electrolyte balance of patients, as it plays a major role in maintaining water balance between cells, plasma and interstitial fluid in combination with sodium and potassium and in the confirmation of the diagnosis of Cystic Fibrosis.

Chloride is used in the manufacture of bleach and PVC plastic. It is used to purify drinking water and to disinfect swimming pools. It is has very wide applications in pharmaceutical, food processing; brewing and wine production, petroleum and oil production and cement manufacture industries, photography, veterinary etc.

In agriculture, it is one of the essential plant nutrients, which is involved in the evolution of oxygen in the photosynthesis process and as a disease resistant. Chlorine raises the cell osmotic pressure, affects stomatal regulation and increases the hydration of...
plant tissue. Plants with chlorine deficiencies will be pale and suffer wilting\textsuperscript{34}. Excesses will cause burning of tips and margins and bronzing and abscission of the leaves.

Chlorine exists in the form of a salt (chloride) in the human body. It comprises about 0.15% of the human body weight\textsuperscript{35}. It is mainly found in cerebrospinal fluid and gastrointestinal secretions. In plasma and interstitial fluid, it helps maintain osmotic pressure and electrolytic balance. It is necessary for the manufacture of glandular hormone secretions and prevents the building of excessive fat and auto-intoxication. It regulates the alkali-acid balance in the blood and it is essential for the production of hydrochloric acid in the stomach, which is needed for proper protein digestion.

Deficiency of chloride can occur when sodium chloride is restricted during the active phase of general oedema or hypertension. Deficiency may lead to loss of hair and teeth\textsuperscript{36}. It may also result in impaired digestion of foods and derangement of fluid levels in the body. It also causes symptoms like loss of appetite, lethargy and muscle weakness. Excessive loss of salt from the body due to perspiration can result in heat cramps. However, excess amount of chlorine in the body may cause high blood pressure, anemia, hives and shingles\textsuperscript{37}.

**IODIDE**

Iodine, a halogen, is widely distributed in the biosphere and usually classified among the rarer elements. It is ranked 62nd in abundance with an average crustal concentration of 0.46 ppm\textsuperscript{38-40}. It occurs in sea water at a concentration of 0.05 ppm. It is also present in some algae\textsuperscript{41}. The name iodine was derived from the Greek word ‘iodes’ meaning violet\textsuperscript{42}. It was first discovered by Barnard Courtois in 1811 in Paris, France.

Iodine comes as black, shiny crystals. It is an essential trace element in animal and human lives and is a component of the thyroid hormones\textsuperscript{43,44} because iodine-containing hormones produced in thyroid gland play a very important role in mental development, growth, and basic metabolism\textsuperscript{45}. Natural sources of iodine are mainly marine animals and plants.
Iodine dissolved in alcohol is used as an antiseptic solution. Its salts (iodides) are used in dyes, industrial catalysts and in the manufacture of pharmaceuticals. It is used in the manufacture of germicides in analytical chemistry, chemical industry and in photography. Artificial isotopes of iodine are used in medical, biological and biochemical research. Iodine is essential for thyroid hormone synthesis and, accordingly, it is required for normal development, growth, and metabolism. Lack of thyroid hormone for the first years of life may permanently harm brain function. Worldwide, iodine deficiency is a main cause of preventable brain damage and mental retardation.

Iodine deficiency during pregnancy results in cretinism in the newborn. Cretinism involves mental retardation, a large tongue, and sometimes deafness, muteness, and lameness. A dietary lack of iodine may lead to anaemia, fatigue, lethargy, loss of interest in sex, a slow pulse, low blood pressure, and a tendency towards obesity. A serious deficiency may result in high blood cholesterol and heart disease. Iodine and thyroxine are critically important in the prevention of hypothyroidism (under active thyroid) and hyperthyroidism (over active thyroid).

Iodine also has a multitude of secondary, but very important, functions in our body. These include supercharging the white blood cells microbe-killing capabilities; ensuring healthy overall body development, particularly skin and hair; maintaining acute mental function; control of bodily energy generation; and preventing surplus mucous buildup in the body (especially important to those suffering from lung diseases).

HYDROGEN (pH)

pH is one of the most common laboratory measurements because many chemical and biological processes are dependent on pH. The speed or rate of chemical reactions can often be significantly altered by changing the pH of the solution. The solubility of many chemicals in solution, and their bioavailability is dependent on pH. The physiological chemistry of living organisms usually has very specific pH boundaries. In our modern lives, virtually everything we use has been tested for pH at one time; from the tap water; we brush our teeth with, the paper we write on, the food we eat, to the medicines we take, at some point a pH measurement was performed. Controlling the pH
of solutions is very important in order to optimize the desired reaction and to prevent unwanted reaction.

**Basic pH Theory**

The term pH is derived from "p", the mathematical symbol of the negative logarithm, and "H", the chemical symbol of Hydrogen.

**Definition of pH**

pH is a measure of the hydrogen ion activity of a solution, which defines the degree of acidity or alkalinity of the solution at a given temperature. Therefore, pH is the unit of measure for acidity, as pounds are for weight. P.L. Sorensen, a Danish chemist who developed the pH scale in 1909, defined pH as the negative logarithm of the hydrogen ion concentration, which he later changed to hydrogen ion activity represented by the equation given below:

$$\text{pH} = -\log a_{H^+}$$

The term activity is used because pH reflects the amount of available hydrogen ions, not the concentration of hydrogen ions.

pH is one of the important parameters frequently measured in soils and probably the most useful single indicator for soil functioning and processes. pH of soil plays an important role in plant growth and influences many facets of crop production and soil chemistry, including availabilities of nutrients and toxic substances, activities and nature of microbial populations, solubility of heavy metals and activities of certain pesticides. In an archaeological context pH is a key parameter for the preservation of archaeological remains of several different materials e.g. bone, shells, iron, bronze and even flint. pH measurements are therefore normally included in monitoring programs at archaeological sites preserved in situ and in reburial experiments.
The measurement of pH is common to all industries that use water. The proper pH of a solution can assure product quality, optimize the yield, increase the rate of reaction, or in general terms, just improve the process. It is essential for control of chemical reactions carried out in nearly all industries that deal with water: from the drinking water, the food and the drugs to the paper, plastics, semiconductors, cements, glass or textiles.
Determination of the molecular forms (speciation) in which an element exists becomes one of the basic requirements in many chemical investigations nowadays. This information is particularly useful in studies related to chemical, industrial, agricultural, environmental, toxicological and physiological investigations etc. Most speciation schemes rely on element-specific detection. Speciation analysis refers to the determination of chemical forms of metals and metalloids including metalloorganic compounds.

A variety of methods have been employed for the analysis of inorganic anions and cations. Traditional methods for the analysis of anion are ion-exchange chromatography, spectroscopic techniques such as colorimetry; wet chemical methods such as gravimetric analysis, turbidimetry, and titrimetry; and electrochemical techniques such as use of an ion selective electrode (ISE) and amperometric titrations. Many of these methods suffer from interferences and limited sensitivity. They can be labor intensive and are often difficult to automate. The use of flow injection analysis (FIA) enables the automation of certain colorimetric and ISE methods of analysis, although still only for one analyte at a time. Multiple analytes can be determined by adding additional channels to an FIA system. However, this adds complexity and cost to the instrument.

The analysis of cations in different samples is quite different in the case of anions. Many rapid and sensitive spectroscopic methods such as AAS (atomic absorption spectroscopy), ICPAES (inductively coupled plasma atomic emission spectroscopy), and electrochemical methods such as polarography, ion selective electrodes and anodic stripping voltammetry are available for cation analysis. Many of these are multi-element techniques. Regulatory methods for cation (metal) analysis in environmental samples tend to be based primarily upon AAS and ICP (inductively coupled plasma) instrumentation. However, ion chromatography does offer an advantage over spectroscopic techniques for cation analysis in the area of metal speciation.
The determination of ions is a very difficult task despite the appearance of new methods. The following are the different methods that are in use for the estimation of sodium, fluoride, chloride, iodide and other ions.

a. Flame photometry
b. Atomic absorbance spectroscopy
c. Colorimeter
d. Spectrophotometer
e. Ion spectroscopy
f. Ion chromatography
g. Electrochemical methods etc.

FLAME PHOTOMETRY
A traditional and simple method for determining sodium and potassium in agricultural and biological fluids involves the technique of emission flame photometry. This relies on the principle that an alkali metal salt drawn into a non-luminous flame will ionise, absorb energy from the flame and then emit light of a characteristic wavelength as the excited atoms decay to the unexcited ground state. The intensity of emission is proportional to the concentration of the element in the solution. A photocell detects the emitted light and converts it to a voltage which can be recorded. Since Na\(^+\) and K\(^+\) emit light of different wavelengths (colours) using the appropriate colour filters, the emission due to Na\(^+\) and K\(^+\) (and hence their concentrations) can be specifically measured in the same sample. One drawback of flame photometers is that they respond linearly to ion concentrations over a narrow concentration range. Hence, suitable dilutions are to be prepared.

Flame photometry is also named as flame emission spectroscopy because of the use of a flame to provide the energy of excitation to atoms introduced into the flame. It provides high sensitivity and high reliability for the determination of elements in the first two columns of the periodic table. Among these elements are sodium, potassium, lithium, calcium, magnesium, strontium, and barium. And also it is successful in determining the transition elements such as copper, iron and manganese. By making a wavelength scan of
The emission spectrum, it is also possible to do qualitative analysis by employing flame photometer. This method is less reliable than atomic absorption spectroscopy. It cannot provide information about the molecular structure of compound present in the sample solution. Non-radiating elements such as carbon, hydrogen and halides cannot be detected.

**ATOMIC ABSORBANCE SPECTROSCOPY**

Atomic absorption spectroscopy is an analytical technique based on the absorption of radiant energy by atoms. In this method when a dispersion of the atoms of a sample is produced in a flame, some of these atoms get thermally excited and emit characteristic radiation as they return to the ground level. Most of them, however, remain in the ground state. When a beam of light is made to pass through the flame, a portion of it will be absorbed by dispersed atoms. It is possible to find a series of absorption bands corresponding to the energy levels of the atoms sprayed into the flame. The wavelength of the bands is characteristic of the atoms of the element concerned and the absorbance of the band proportional to the concentration of the atoms in the flame.

In atomic absorption spectroscopy both ionization and chemical interferences may occur. These interferences are caused by other ions in the sample and result in reduction of the number of neutral atoms in the flame. Ionization is a problem with the technique because ions have inherently different electron band structures than unionized atoms of the same element. Therefore, ions do not absorb light of the same characteristic frequencies. This leads to artificially low absorbance and concentration data. The ability to measure very low elemental concentrations is also hindered by ionization. Alkali elements such as potassium are especially prone to ionization when they enter the flame. This method is expensive and time-consuming.

**COLORIMETER**

Instrument used for measuring absorption in the visible region is generally called colorimetry. The term colorimeter designates an instrument for absorption measurements in which the human eye serves as the detector. One or more color comparison standards are required. It is the simplest form, where human eye acts as a measuring
instrument. This involves comparison by visual means of the colour of an unknown solution, with the colour produced by a single standard or a series of standards. The comparison is made by obtaining a match between colour of the unknown and that of a particular standard by comparison with a series of standards.

In earlier days, visual methods were commonly employed for all colorimetric measurements, but now photoelectric methods have largely replaced them and are used almost exclusively for quantitative colorimetric measurements. Any method involving measurement of colour in the visual region of the electromagnetic spectrum (400-700 μm) is referred to as the colorimetric method.

This method is simple in construction and operation. They are used for a great deal of analytical work where high accuracy is not required. The disadvantage is that a range of filters is required to cover different wavelength regions. Also the spectral bandwidth of these filters is large in comparison with that of the absorption band being measured and also the inability of the eye to compare light intensities.

**SPECTROPHOTOMETER**

A spectrophotometer is an instrument which isolates monochromatic radiation in a more efficient and versatile manner than colour filters used in filter photometers. In these instruments, light from the source is made into a parallel beam and passed to a prism or diffraction grating, where the light source is made into a parallel beam and passed to a prism or diffraction grating, where the light of different wavelengths is dispersed at different angles. The diffracted light is passed through the sample. The amount of light reaching the detector of the spectrophotometer is generally very smaller than that available for a colorimeter. The detector current is amplified electronically and displayed directly on an indicating meter or in digital form. These instruments have the advantage in speed of measurement. This technique is used to measure absorbance, concentration, percent transmission and differential absorbance reading. The light sources in the spectroscopy will differ according to the sample absorbance wavelength region. And named according the source wave length like visual spectrophotometer for visible region
and infrared spectrophotometer for infrared region etc. This method has two types of errors categorized as instrument errors and non-instrument errors.

ION SPECTROSCOPY

Ion spectroscopy is a powerful technique applied to surface characterization. The two techniques usually adopted are ion-scattering spectroscopy (ISS) and secondary-ion mass spectroscopy. Ions are formed by bombarding gas atoms with electrons. The positive ions are accelerated and focused on the sample at an angle of 45°. Ions are scattered in all directions. However, only those electrons which are in a selected small solid angle are received in the 127° electrostatic analyzer. The detector can be a channel electron multiplier or a solid state silicon device. To obtain the spectra, the back-scattered primary ions are sampled by the cylindrical mirror analyzer and their kinetic energies are measured.

The ion-scattering spectroscopy is sensitive to every element heavier than helium, since the lightest isotope used as a primary ion is \(^3\)He and the scattering element must be heavier than the scattering gas. The specificity (ability to separate two particular elements) will vary depending on the scattering gas used. The detection limit of ISS is probably of the order of \(10^{-3}\) % of a monolayer. This method is expensive and time-consuming.

ION CHROMATOGRAPHY

Ion chromatography is a useful technique for the measurement of various ionic species in solution. It is based on the principles of chromatography separation, and detection methods, the most common method uses conductivity suppression. The conductometric application of ion chromatography can be applied to cations, it is well suited for the detection of inorganic anions, as other methods during its time of development were insensitive and time consuming.
The ion chromatography is suited for the analysis of a variety of inorganic and organic anions and cations. The most important fields of application of ion chromatography are the environmental analysis, for the determination of anions and cations in all kinds of water, including sea, continental and waste water.

Conductometric suppression of analyte has been a remarkable improvement of the method. It allows more sensitive detection of the conductivity difference between an anions and the mobile phase eluent. Since the concentration of eluent is very high relative to that of the anions, it is often difficult to detect the slight drops in highly conductive eluent as less conductive anions pass through the detection cell. Since its development, conductometric detection has become a common means of detecting anions, such as the seawater component, sulfate and others. Sodium, potassium, magnesium, and calcium can be analysed with ion chromatography in precipitation. Ion chromatography has no special advantage concerning sensitivity, precision and accuracy over the spectroscopic methods. And also this method is expensive.

ELECTROCHEMICAL INSTRUMENTS
The determination of an ion or molecule by direct potentiometric measurement is rapid and simple. The comparison of the potential developed by the indicator electrode in the test solution and the potential when immersed in one or more standard solutions of the analyte. Because most indicator electrodes are selective, preliminary separations steps are seldom required. In addition, direct potentiometric measurements are rapid and readily adapted to the continuous and automatic monitoring of ion activities. There are many instruments based on the electrochemical cell theory such as conductivity meters, voltammetry, polar graphs, coulometers etc.

In voltammetry and polarography, the measurement is carried out via a current produced from prior electrolytic process, handled under controlled conditions of mass transport at appropriately small polarizable electrodes. In these methods the concentration is related with the intensity when definite voltage functions are applied. The qualitative information is obtained from the peak potential and the quantitative information from the diffusion-current. Polarography with microscopic microelectrodes is used to study the
chemical process going on inside organs of living species such as mammal brains. Voltammetry and polarography techniques are excellent methods for trace and ultra-trace analysis of inorganic and organic substances and compounds due to their low detection in ppb/ppt range with high accuracy and high precision as well as the possibility of multi-element detection.

Chemical sensors are miniaturized analytical devices which can deliver real-time and on-line information on the presence of specific compounds or ions in complex samples. Usually an analyte recognition process takes place followed by the conversion of chemical information into an electrical or optical signal. Among various classes of chemical sensors, ion-selective electrodes (ISE) are one of the most frequently used potentiometric sensors that are used in laboratory analysis as well as in industry, process control, physiological measurements, and environmental monitoring. The principle of ion-selective electrodes operation is quite well investigated and understood.

An ion-selective membrane is the key component of all potentiometric ion sensors. It establishes the preference with which the sensor responds to the analyte in the presence of various interfering ions from the sample. If ions can penetrate the boundary between two phases, then an electrochemical equilibrium will be reached, in which different potentials in the two phases are formed. If only one type of an ion can be exchanged between the two phases, then the potential difference formed between the phases is governed only by the activities of this target ion in these phases. When the membrane separates two solutions of different ionic activities \((a_1\) and \(a_2\)) and provided the membrane is only permeable to this single type of ion the potential difference \((E)\) across the membrane is described by the Nernst equation:

\[
E = \frac{RT}{zF} \ln \left(\frac{a_2}{a_1}\right)
\]

If the activity of the target ion in phase 1 is kept constant, the unknown activity in phase 2 \((a_1 = a_x)\) is related to \((E)\) by:

\[
E = \frac{RT}{z_x F} \ln \left(\frac{a_x}{a_1}\right) = \text{const} + S \cdot \log(a_x)
\]

where \(S = 59.16/z\) [mV] at 298 K and \(z_x\) - the charge of the analyte. The potential difference can be measured between two identical reference electrodes placed in the two phases. In practice the potential difference i.e. the electromotive force is measured
between an ion selective electrode and a reference electrode, placed in the sample solution. It is important to note that this is a measurement at zero current i.e. under equilibrium conditions. Equilibrium means that the transfer of ions from the membrane into solution is equal to the transfer from the solution to the membrane. The measured signal is the sum of different potentials generated at all solid-solid, solid-liquid and liquid-liquid interfaces.

The common methods applied for speciation of organometals are separation of the species by chromatography, followed by detection and determination of the element with a specific detector such as atomic absorption spectrometry or mass spectrometry. These methods are expensive and time-consuming. Electroanalytical methods have much more to offer in terms of species-selective detection than spectroscopic methods. Potentiometry with ion-selective electrodes is in principle well suited to speciation studies because of its selective response to free ions in aqueous solutions. The selectivity of these electrodes is based on interface molecular recognition process.

During last three decades, a number of ion-selective electrodes with polymeric membranes have been reported. Among the various ligands available for ion-selective electrodes such as crowns, podands, cryptands and spherands, the calixarenes met many of the requirements that an ionophore should satisfy for the use in ion-selective electrodes. A number of calixarene derivatives containing pendant ether, amide, ketonic and ester groups have been incorporated as neutral carriers into ion-selective electrodes sensitive to sodium, potassium and cesium ions.

Advantages of ion selective electrode are simple to operate, inexpensive, rapid, rugged and selective. And also it has some disadvantages. They are not really an identification tool, more of a quantification tool, not as selective as some voltammetric techniques and not a tool to study electron transfer rxns. When compared to many other analytical techniques, ISEs are one of the best methods unlike the flame photometer which offer a linear response over a wide concentration range. However, they require attention if good results are to be obtained.
Many of them are not entirely ion-specific. For example, the sodium electrode also responds to potassium ions, of course with less sensitivity. This means that \( \text{Na}^+ \) will be overestimated if a high concentration of \( \text{K}^+ \) is present. Mathematical techniques have been devised to compensate for this. They underestimate high concentrations because of "crowding" of the ions at the membrane. The activity coefficient is a measure of activity equals concentration at low values, but it is less than concentration at high values.

**pH METHODS**

The measurement of pH is the most widely employed test for biochemical, chemical, industrial and other labs. New methods and techniques have broadened the scope of the pH detection since from the first use of glass electrode to detect pH. New materials and technology have widened the development and application of pH sensors from day to day innovation for the development of pH measurement. Some of the techniques such as metal/metal oxide, ion sensitive field-effect transistors (ISFET), fibre-optical techniques, nano-techniques and polymer techniques have been extensively developed.

**COMMON DETECTION METHODS**

In tradition, the measuring methods for pH values fall roughly into four categories: indicator reagents, pH test strips, metal electrode methods (hydrogen electrode, quinhydrone electrode and antimony electrode method) and glass electrode methods. Indicator dyes, such as methyl orange or phenolphthalein, are organic compounds with absorbance in the visible range. They shift their conformation with the activity of hydrogen ions, which causes a change in the absorbance maximum of the compound and hence a change in color. pH strips are strips of paper or other material fixed with indicators. Immersed in the test liquid, they show a particular color corresponding to the pH of the solution. A standard color is compared to give the rude pH value. This method is simple but it is impossible to expect a high accuracy due to the errors from high salt concentration, the temperature or the organic substances in the test liquid. The hydrogen electrode method is a golden standard for all methods of pH measure. The activity of the hydrogen ions is determined by potentiometric measurement using a standard hydrogen electrode and a reference electrode. The standard hydrogen electrode consists of a platinum electrode in a solution of 1.00 M hydrogen ion. In order to ensure a saturated
layer of hydrogen adsorbed at the platinum surface, hydrogen gas is continuously 
bubbled around the platinum electrode. However, this method is not suitable for daily use 
due to the inconvenience of handling hydrogen gas.

The quinhydrone electrode can be used for the potentiometric determination of 
\( \text{pH} \) and was used prior to the introduction of the glass electrode. Quinhydrone is an 
equimolar mixture of quinone and hydroxyquinone. When dissolved in water, 
quinhydrone forms a \( \text{pH} \) dependent oxidation-reduction couple. The redox-potential of 
the resulting equilibrium is proportional to the \( \text{pH} \) of the solution. A platinum electrode 
is used to measure this redox-potential. The quinhydrone electrode is often used to 
check whether an ORP meter works well by quinhydrone solution in a certain \( \text{pH} \) or to 
calibrate other reference electrodes\(^{121}\). This method is now quite limited due to its poor 
reproducibility. Similar to the quinhydrone electrode, the results from antimony 
electrode method are quietly dependent on the degree of polishing and so the low 
reproducibility limits its application \(^{122}\). This method is now only used in cases where 
the sample solution contains \( \text{F}^- \) and where no high accuracy is needed. Because of the 
above-mentioned difficulty in the use of hydrogen electrode and the metal electrode, 
the glass electrode commonly is used and considered to be the standard measuring 
method. It is composed of a bulb of glass membrane, which selectively permits the 
passage of hydrogen ions, and a fixed concentration of \( \text{HCl} \) or a buffered chloride 
solution inside in contact with an internal reference electrode. When a new electrode is 
immersed in the solution, the outer bulb surface becomes hydrated and exchanges 
sodium ions for hydrogen ions to build up a surface layer of hydrogen ions. The build 
up of charges on the inside of the membrane is proportional to the amount of hydrogen 
ions in the external solution. The potential difference across the membrane is 
proportional to the logarithm of the ionic concentration in the external solution, as 
shown in the following Nernst equation\(^{123}\):

\[
E_{\text{cell}} = E_0 + \frac{2.303 \, RT}{nF} \log aH^+ 
\]

where \( E \) is the electrode potential, \( E_0 \) is the standard potential of the electrode, \( R \) is the 
universal gas constant (8.31441 \( J \, K^{-1} \, mol^{-1} \)), \( T \) is the absolute temperature, \( n \) is 
valency (\( n = 1 \) for Hydrogen ions), \( F \) is the Faraday constant and \( aH^+ \) activity of 
hydrogen ions.

The glass electrode is most widely used for \( \text{pH} \) measurement due to ideal 
Nernstian response independent of redox interferences, short balancing time of electrical
potential, high reproducibility and long lifetime. However, glass electrode has several drawbacks for many industrial applications. Firstly, they are unstable in alkaline or HF solutions or at temperatures higher than 100 °C. Also, they exhibit a sluggish response and are difficult to miniaturize. Moreover, they cannot be used in food or in vivo applications due to their brittle nature. There is an increasing need for alternative pH electrodes.

NEW TECHNIQUES FOR pH DETECTION

Optical-fibre-based pH sensors
Optical methods offer many advantages over the common glass electrode or other electrochemical devices for pH measurement. Organic dye molecules with pH dependent spectral properties have recently been used as indicators to develop optical fibre probe for pH measurement. A novel optical-fibre-based pH sensor was reported \(^{124,125}\). It is based upon surfacic adsorption of methylene blue dye, producing absorption in the evanescent field surrounding the sensing fibre. The linear range of operation is between pH 3 and 9 and its response time is considerably shorter than indicator-based probes, which measure spectral changes of pH-sensitive chemicals. Effects of ionic strength are shown to be negligible, which is a further advantage of this sensor over other pH sensors.

Fibre optic probes for pH monitoring were coupled with Ocean Optics spectrometers to measure pH by monitoring color changes in indicator dyes. The pH-sensitive films used in the Ocean Optics pH sensor are reversible, solid-state versions of common dissolved-pH indicators. Each dye responds to over a 3 – 4 pH unit range, centered at the pK of the immobilized material. The precision of the system is ± 0.001 pH units near the pK. It is reported that they are especially useful for monitoring low conductivity samples, such as boiler water, where potentiometric devices fail; or for turbid, fouling environments where particulate matter, slurries and other media can coat or destroy electrodes.

Mass-sensitive pH sensor
A pH sensor is described based on a reversible, mass-changing pH-responsive hydrogel \(^{126}\). The hydrogel is coupled with a magneto-elastic sensor whose resonance
frequency corresponds with applied mass load. The poly(acrylic acid-co-isooctyl acrylate) hydrogel, with an acrylic acid and N,N-ethylenbis(acrylamide) cross linker, was synthesized by free radical polymerization. The pH responsive hydrogel is adhered to the ribbon-like magneto-elastic sensor by pre-coating the sensor with a layer of polyurethane and adding 1-(3-dimethylaminopropyl)-3-ethylcarbodiimide (EDC) into the hydrogel solution. The pH sensor response is accurately fit with the equation $f_r = 49.891 - 1.04 \text{ pH} + 0.048 \text{ pH}^2$. The average change in sensor resonance frequency is 506 Hz/pH, approximately 1%/pH of the resonance frequency value, from pH 4.4 to 8.5, where the measurement resolution is 0.02 pH units, corresponding to a resonance frequency measurement error (standard deviation) of 2.9 Hz.

**Metal oxide pH sensors**

Metal oxide could be used to develop a pH electrode with wide application at high temperature and pressure. pH sensors have been constructed from the materials of Pt/PtO$_2$, W/W$_2$O$_3$, Pb/PbO$_2$, Ru/RuO$_2$, and Sb/Sb$_2$O$_3$. Iridium oxide (IrO$_x$)-based potentiometric pH electrodes have proven to be very attractive candidates because they show good stability over a wide pH range, even at high temperature, high pressure, and in aggressive environments, and exhibit fast response even in non-aqueous solutions. A solid-state pH sensor was developed by a “carbonate-melt-oxidation” technique. The electrodes of this type show an ideal Nernstian response with fast response and drift free behavior. The presented electrode is very promising for pH sensing and, in many applications, could replace glass electrodes or other metal oxide-based pH electrodes.

**Conducting polymer pH sensors**

Many research discussed the pH sensitivity of conducting polymers including polypyrrole, polyaniline, etc., which is useful to develop all-solid-state pH sensors. Han et al. reported a polyaniline-based pH sensor with the Nernstian slope of 52.1 mV/pH and the linear dynamic range between 3.50 to 11.94. A poly-m-phenylenediamine modified electrode (PPME) was prepared as pH sensor by electropolymerization of the m-phenylenediamine on the surface of a platinum electrode. There was not obvious influence of the temperature on pH determination up to 46 °C. The sensor gave a linear response from pH 1.5 to 13.0 and a slope of 56.7 mV/pH. Fairly good potential stability and reproducibility were obtained. It is possible that the ortho-position or para-position of a –NH$_2$ on the m-phenylenediamine is easy to
polymerize with another m-phenylenediamine. Therefore, the polymerizing positions provided for m-phenylenediamine would be more than the other derivatives of aniline and so poly-m-phenylenediamine modified membrane could get more H+ than other derivatives of aniline, and it extended the pH response range. The pH response mechanism of membrane may be represented by the following formula:

\[ -NH_2 + H^+ \leftrightarrow NH_3^+ \]

\[ -NH_3^+ + OH^- \leftrightarrow -NH_2 + H_2O \]

**Nano-constructed cantilever-based pH sensors**

A micro cantilever structure was reported as an ultra sensitive pH sensor. Silicon-on-insulator wafers were used to fabricate cantilevers on which a polymer consisting of poly(methacrylic acid)(PMAA) with poly(ethylene glycol) dimethacrylate was patterned. As the pH increased above the pKa of PMAA, the polymer network expanded and resulted in a reversible change in surface stress causing the micro cantilever to bend. The sensitivity would be $5 \times 10^{-5}$ pH for a 1nm nm bending deflection resolution, which is among the highest reported for any micro-scale pH detector.

IBM also reported a cantilever-based pH sensor. Two cantilevers are functionalized with mercaptohexadecanoic acid (MHA) and hexadecanethiol (HDT), respectively. Owing to the differing functionalization of the cantilever surfaces, changes in the interfacial stress between thiol-covered cantilevers and buffer solutions of various pH values occur. The difference in responses (MHA minus HDT) shows a net signal that can be correlated with pH value. The main advantage of such devices is their extremely small size ($< 0.1 \text{ mm}^2$) which allows cheap mass-produced fabrication using integrated circuit technology.

**ISFET-based pH sensors**

A relatively recent development in pH measurement is the introduction of ion-sensitive field effect transistors (ISFET) technology as an alternative to the glass electrode. The glass-less and small-sized sensor has led to the development of inexpensive, battery-powered, pocket-sized pH measurement system. Many reviews have been given to introduce ISFET-based pH sensors.
**pH-image sensor**

A novel pH-imaging sensor based on photocurrent characteristics of semiconductor silicon was reported for the surface analysis of carious dentin from extracted human teeth. The acid or base distributions on the dentin surface was detected as pH value and concerted as pH images. The sensor functions as an array of multiple sensing parts, which is based on light addressable potentiometric sensor made up of a Si$_3$N$_4$/SiO$_2$/Si structure. The proton-sensitive surface is contacted with an electrolyte and a light beam is illuminated from the Si side with a bias voltage between the electrolyte and the Si side. The spatial resolution and the pH resolution of the sensor are 100 µm and 0.1 pH, respectively.
Section 1.3

ROLE OF COMPUTERS IN INSTRUMENTATION

Instrumentation has its origin in the attempts to measure, monitor or record various physical, chemical, biological or engineering phenomena. Historically, instrumentation had its roots in mechanical and hydraulic systems, but rapidly moved to electrical and electronic devices\textsuperscript{139}.

The art of measurement is a wide discipline in both engineering and science, encompassing the areas of detection, acquisition, control and analysis of data\textsuperscript{140}. It involves the precise measurement and recording of a physical, chemical, mechanical, optical and electrical parameters. Measurement plays a vital role in every branch of scientific research and industrial processes interacting basically with control systems, material sciences, and other branches of science and technology which resulted in the development of many sophisticated and high precision measuring devices and systems, catering to varied measurement problems in disciplines such as aeronautics, science and technology, space, medicine, oceanography, and industry in general\textsuperscript{141}.

With the invention of the microprocessor and microcomputers, the measurement of any parameter became possible by interfacing the system with microcomputer. Such a system measures, stores and displays the data read from the system. And also it is used to control the parameter.

Computer plays a pivotal role in instrumentation. Computer interactions with analytical instruments are of two types - passive and active. In passive applications, the computer does not participate in the control of experiment but is used only for data handling, processing, storing, file searching and display. In active interaction, the output from the computer controls sequence of steps required for operation of the instrument. The part of the time is devoted to data collection, the rest of the time being utilized for data processing and control. Thus active applications are real-time operations.
Not only instrumentation and measurement are playing an increasingly important role in technological society but also computers are playing an increasingly important role in instrumentation. The reason for this is that most physical quantities can be converted into electrical signals by means of transducers and these signals are processed and converted into digital form for automatic analysis and storage. The interfacing of instruments with computers has vastly increased our ability to measure and thereby our ability to find nature's answers to new questions.

There are many advantages for a computer-based instrument. The computer based measurement offers CRT text read-out, updating measurement readings, scale factors, general calculations, waveform scaling, time-frequency conversion, scale factor calculation, controlling and coordinating modules within an instrument etc. Another useful feature is auto or self calibration. Self-calibration can also be extended to complete waveforms in waveforms processing instruments. These instruments have the provision to store and print the data. Processing and analysis of data is another important feature of these instruments. There is a provision for real time measurements.

Another important advantage in using computers is their self-test ability. A computer with appropriate software can easily locate the failure in the board level, or perhaps the section or chip level and also it helps in rectifying the faults. Automated instruments offer a major economic advantage because of their savings in labour costs. The major advantage of automated instruments is their speed, which is significantly greater than that of manual devices. Another advantage of automation is that a well-designed analyzer can usually produce more reproducible results over a long period of time than can an operator employing a manual instrument.

We are living in the world that can do nothing without computers. So, completely we are dominated by that term and the major nations of the world would shut down without it.
Section 1.4

PERSONAL COMPUTERS - AN OVERVIEW

The evolution of computers from the ENIAC to the present day supercomputers marks an era of the development of the computer technology within a span of hardly 50 years. Today, there is more computing power in the desktop computer than there was in the ENIAC, which weighed 30 tonnes and took up about 14 square meters of floor space\(^{142}\). Broadly speaking, the computer industry evolved through three distinct phases. The first, really started by IBM, gave the mainframe computers of the 1960s. The second phase introduced the minicomputers of the 1970's, launched by companies such as Digital Equipment, Wang Laboratories and Data General.

Today, the industry is firmly entrenched in the third phase, the era of the personal computers. The personal computer has appeared around 1976 and within a span of 30 years it has grown in computing power, speed, portability and performance un-dreamt of during the first phase.

Birth of Personal Computer

In 1976, Steve Jobs, brought out a model of personal computer, which became famous for its performance. It was named “Apple” in a moment of pure nostalgia for a summer in an Oregon orchard. Prior to Apple, home computers from Atari, Tandy and Commodore were popular and mainly used for games. In 1977, Apple II was launched with advanced features. It was the first console style personal computer with a built-in keyboard, with user-accessible RAM of 4K, empty sockets for increasing RAM memory up to 44K, 8K of ROM and 6K of Apple's version of BASIC. With 12K of RAM, Apple II could generate a high resolution graphic display up to four colours. In this mode the video screen is divided into 280 X 192 display points. Apple II was popular and found its use in schools and offices alike. The sales of these computers soared from 2.7 million to 200 million dollars in 1980. Smelling gold, a galaxy of aggressive competitors such as Atari, Tandy and Xerox entered the Apple-seeded PC market. The last to enter was IBM in 1981, which marked the beginning of the development of the personal computer industry.
IBM Success

IBM broke a long-standing tradition by going to external sources for supporting hardware and software. With little software available and with limited hardware capability, the personal computer was an instant success for two reasons. First, IBM's name and company's reputation; secondly, the personal computer was an "open" machine enabling dependent vendors to offer supporting products. Literally hundreds of companies provided thousands of products to support the personal computer, ranging from expansion boards to every kind of software imaginable. IBM's strategy was to make the technical specifications of machine known, effectively inviting outside vendors to design new hardware and develop software. This gave a rise to an almost endless array of additional products for the IBM's personal computer, which helped it to become the world standard in the personal computer field.

Development of the PC

From the university-built machines to mainframes, the size of computers diminished, prices dropped and the performance increased dramatically. The demand for more computing power and graphics has driven PC technology along a development path parallel to that of workstations. Over 1000 million PCs are in use around the world. Today, throughout the industry, sophisticated mainframe techniques are migrating down to personal computers. The challenge for all the PC silicon suppliers is to adopt mainframe techniques and recast them into fast and inexpensive chips. The success of the PC is due to the fact that manufacturers have managed to push performance to high levels, at the same time reducing the costs.

From the simple machines used for elementary data processing, PCs have grown in sophistication, capable of performance comparable to that of minicomputers and workstations. In fact we now have a new breed of PCs known as personal workstations. PCs have gone through several development stages. They are packaged as towers portables, laptops and now even palm top computers, the size of a pocket book.
Applications
Apart from the basic data/word processing jobs of which we all are familiar, specialized fields of application like neural networking, 3-D graphics, multitasking, distributed processing CAD, document image processing, voice recognition, desktop publishing etc. have proved the capability of the PC. Tasks that once required minicomputers and workstations can be performed by the PC. The PCs have helped us to reach new frontiers in the world of computing.

Digital signal processing (DSP) has been around for at least 20 years, mostly in high-end military or industrial applications and in research. The availability of single-chip DSPs and the affordability of single-chip DSPs and the affordable cost is expanding its use in numerous applications—particularly on PCs and it is one of the fastest growing areas in digital technology today. As PCs have grown in size and capability, they have begun to encroach upon the province of workstations, while the latter have acquired added features that make them more accessible and user-friendly, beginning to reach into the areas of the PCs. As a result, we now have a new breed of computers with the capabilities of a workstation and the accessibility of a PC—the personal workstation.

The appearance of laptops has bridged the gap. Modern portables offer fast CPUs, plenty of RAM, big hard disk drives and enough options for almost any computing situation. Nickel cadmium cells power these portables. Displays for high-end portables are LCD or gas plasma/electro luminescent displays. One can travel from place to place and plug into the office computer mainframe via modems, obtaining vital information instantly and enabling decisions to be taken on the spot.

Selecting a Personal Computer
Personal computers that a few years ago were available mainly to professionals in science, engineering and business, are now available to millions of users all over the world. Buying a computer is relatively simple, but buying one that is right for a particular requirement is not so easy. There is an enormous range of products on offer, with a confusing array of variations in packaging and terminology. Some reasons for obtaining a computer are given here.
1. To understand computing and programming.
2. To use it for home entertainment.
3. To maintain files of relatively slow moving information (such as name and address).
4. To maintain primary accounts for a business.
5. To handle on-line transactions from multiple users.
6. To control a process, such as a heating or lighting system.
7. To communicate with a database stored remotely on a mainframe or minicomputer.

**Software**

Software refers to programs that can be run by a computer. It is generally distributed on media such as floppy discs or magnetic cassette or cartridge for use on various computer systems and is available from your dealer or software vendor or the manufacturer. Software can also be user-written for specific applications.

The performance of any computer system depends on the quality of the programs controlling it. Good software has to perform as many of your required tasks as possible. It executes major functions quickly and correctly, cutting the time you spend waiting. It provides on-screen help such as user-friendly menus, or multiple choices prompts to guide you through problems without constant reference to the manual.

Good software should also accept all possible input errors and notify you without crashing (stopping suddenly), in which case data can be lost. It should be able to guide you out of trouble with on-screen commands and resume program execution with all data intact. In other words, a good software writer will anticipate potential problems and provide routines to cope with them.

Another point about good software is that it should be thoroughly tested and debugged by the software author. In many cases the software author is not the manufacturer of the computer you are using. Many manufacturers provide their own tested applications software for their personal computers, designed to utilise their expanded capabilities such as screen-labeled soft keys.
Reading, wRiting and aRithmetic are called the three Rs of learning. Now one more subject has been added to the three Rs - the computer science. Next to arithmetic, computer study is the most useful and practical of all subjects. Computers are no longer the monopoly or the prerogative of specialists or the common man\[143\].

Computer study has now become part and parcel of general education or liberal education. This is why, the policy makers have thought fit to introduce them in all schools. It is only the computer knowledge that will give completeness to the human personality and so it is imperative that every one should acquire this powerful knowledge. Just like humans computers are also multilingual. Several computer languages like FORTRAN, COBOL, BASIC, PASCAL, C etc. have been developed to communicate with these inanimate machines. All the computer languages have the same underlying philosophy that of communicating the formula and the data to the computer.

Since computers solve problems by obeying the procedures or the instructions given by the humans, any such instruction must come within the realm of computer capabilities. The following are the procedural instructions which the machine can obey.

1. Read, Write and Storage instructions.
2. Arithmetic logic instructions.
3. Testing signs of arithmetical expressions and testing the true or false values of logical expressions, and
4. Branching instructions.

So the procedural instructions or the program given to the computer for solving it use the above set of operational instructions. This means that man has to learn a lot about the problem, before he commands or order a computer to solve them. It is worth taking all the trouble, since there is still a huge saving of mundane tasks for him. A man has to develop two skills before he can attempt to write a computer program for solving a problem. Firstly, he must learn to analyse the problem and convert it into procedures
which come within the realm of machine capabilities. Secondly, he must learn the
language, in which he has to write instructions or the program.

**Evolution of computer languages:**
The development of computer languages started with the discovery of the computer in
1948. The earliest computer language developed for the machine is called the machine
language. A machine language program is a set of instructions written for implementation
by the machine using only two digits - 1 and 0.

Every instruction or data is coded by a suitable combination of 1s and 0s. Just as a
combination of dots and dashes is used to send messages by telegraph, a suitable
combination of 1s and 0s is used to establish communication with the machines. So a
machine language program consists of a coded string of 1s and 0s, each string code is
having some specific meaning for the computer. The next development is the discovery
of the assembly language, in which the binary codes are replaced by alphabetic codes.
Though the alphabetic codes are somewhat meaningful than the number codes, they are
difficult to learn, since they are not akin to spoken languages.

One set of words must mean only one thing. Hence, any computer language must
satisfy the following requirements.
1. The language must be contest free.
2. The language must be unambiguous.
3. The language must be both semantically and syntactically exact.

Then comes the discovery of high level languages which are more akin to spoken
languages. FORTRAN, COBOL, BASIC, PL/1, PASCAL, C, C++, LISP, SNOBOL,
FORTH, ALGOL, PROLOG, Visual BASIC, Visual C++ etc., fall in the category of high
level languages. They are easy to learn because they are very much similar to the spoken
English language.

BASIC  (Beginners All-purpose Symbolic Instruction Code), was written to
enable more people to operate and program computers through simple statements derived
from common English. The standard and enhanced versions of BASIC onboard certain personal computers contain extra built-in commands that transform sequences of steps into one-step operations. FORTRAN (FORmula TRANslation) is a high level programming language often used in scientific applications. COBOL (COmmon Business Oriented Language) is designed to handle large amounts of data and it was written for use in business environments. FORTH is a complex, very effective programming language that enables the user to compile a dictionary of routines that comprise program "kernels". PASCAL and C are English-oriented languages compatible on many computer systems and to encourage more logical programming practices. Excellent programs can be written in any of the high level languages described here.

Requirements of high level languages
Earlier it was mentioned that the ordinary spoken languages like English are not suitable for communication with the computers. It is because these languages do not have unambiguous meanings for a particular set of words. Computers being machines cannot distinguish ambiguities in meanings. The computer requires to be exactly told in an unambiguous language as to what is to be done.

THE C LANGUAGE
The C language was developed in the early 1970's by Dennis Ritchie at Bell Telephone Laboratories. The ancestry of C can be traced through a design lineage that started with Algol and includes Pascal and PL/I. C was developed to be a programmer's language for use on the new UNIX operating system. UNIX had been written in assembly language on the PDP-7 and ported to the PDP-11. C was influenced by its predecessor, B, which was written by Ken Thompson and descended from BCPL. BCPL written in 1969 by Martin Richards, was an outgrowth of the Combined Programming Language project from London and Cambridge Universities. UNIX was rewritten in C, and it was first distributed outside of the Bell Laboratories environment, giving credibility to the nation that an operating system can be successfully written in a language other than assembly language.
C language characteristics
C is a language of functions, data types, assignments, and flow control. To program in C, one must call a function, and most functions return values. The value returned from a function, the value of data variable, or the value of constant can be used in an assignment statement to change the value of another variable. With the addition of flow control - if, while, for do, switch - the C language takes on the structure of high-level language, enabling and promoting good programming style.

C has a small set of data types: integers, floating point numbers, characters, bit fields, and enumerated types. In C one can declare a pointer variable that points to any data type. The address arithmetic of C is sensitive to the properties of the pointer being adjusted. Pointers to functions are also supported. The data types can be extended by building structures that are hierarchies of members, each member being one of the data types or an earlier-declared structure. Unions resemble structures but define a different kind of hierarchy in which all data types occupy common memory. Arrays of data types can be declared. An array consists of any data type, including a structure or union. Arrays can have multiple dimensions.

C functions are recursive by default; you can code a function that does not work in a recursive operation, but the language naturally tends to support recursion and requires little recursion programming effort. The code in a C function is grouped into blocks; each block can have its own local variables. Blocks can be executed as the result of a single flow control operator. Block can be nested within blocks. Variables and functions can be global to the program, global to the source module, or local to the block in which they are declared. Local variables can be declared so they retain their value through all invocations of their block (static), or they can be considered as new entities for each invocation (automatic).
C allows you to develop a program in multiple source files that are independently compiled. The re-locatable object modules of individual source files are linked into a single executable program. This feature allows a compiler to support object libraries or reusable functions as well as large programs made up of many small source code components.

The C language has no input/output operations. The compiler compiles a language of functions, and input and output is done with functions. Because of this feature, a standard library of functions has evolved, and this standard is what gives C its most endearing quality - C language code can be portable. There can be no question of the overwhelming acceptance of C as the language of choice among software developers. The management of software development companies like C, for the apparent independence it gives them from specific hardware and operating system environments. Today's managers, many of whom are yesterday's programmers, are sensitive to both advantages. C is the development language for most of the world's best-selling PC software packages. Hence, in the present study, C language is chosen for software development.
Modern measuring instruments are the fruits of science and technology. New discoveries in science provided new instruments for the study of Nature; and these studies, in turn, produced new discoveries. The precise and accurate measurement of physical and chemical parameters plays an important role in unraveling the mysteries of Nature.

The estimation of sodium, fluoride, chloride, iodide and hydrogen ion concentrations in agriculture, chemical, biomedical and environmental fields gives valuable information to agriculturists, chemists, biochemists, ecologists etc. The excess or deficiency of these elements causes severe health disorders in humans and plants. It is necessary to analyze these ions and to take necessary precautions. The measurement of concentration of these ions in aqueous solutions are very essential to warn and educate the people on its beneficial and toxic effects in the corresponding fields.

Amongst the various analytical techniques available, the use of ion-selective membrane electrodes is a well-established analytical technique\textsuperscript{147}. Good ion-selective electrodes possess many advantages over the traditional methods of analysis as they provide accurate, reproducible, fast and often selective determination of various ionic species. And also the ion-selective electrodes allow non-destructive, on line monitoring of particular ion in small volume of sample without any pretreatment. Hence, the use of ISEs is increasing day by day in medicinal, environmental, agricultural and industrial fields.

The automation of the analytical instruments such as ion measurement systems with computers delivers a great advantage in measuring the different parameters without manual attention\textsuperscript{148-152}. It also provides to control the system and it is capable to store data. The stored data can be used to analyze the properties of the liquid under investigation at any time you want. The display helps us in selecting user-friendly menu options. And also it indicates the improper circuits actions due to the faulty adjustments.
No doubt, several investigators developed the techniques for the measurement of different ion concentrations in different samples and several manufacturers are producing a variety of instruments for different ion estimation. But these are conventional and suffer from many disadvantages. But the attempts to design and develop the computer based systems for the measurement of ions are rather scarce particularly in India though they offer many advantages. Hence, in the present study, an attempt is made to design and fabricate the computer based systems for measurement of different ion concentrations (potassium, sodium, fluoride, chloride, iodide and hydrogen) individually and a multi channel system to allow simultaneous measurement of these ions in liquid samples.
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